Fundamentals of Health and Physical Activity

Fundamentals of Health and Physical Activity

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Rate Your Risk[footnote]Sexually Transmitted Infections. Government of Canada. https://www.canada.ca/en/public-health/services/infectious-diseases/sexual-health-sexually-transmitted-infections/reports-publications/infections.html#t2. Updated on June 1, 2015. Accessed on February 2, 2020.[/footnote] 848

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1. UNESCO. "Open Educational Resources (OER)". Accessed January 1, 2020. https://en.unesco.org/themes/building-knowledge-societies/oer

1.1. MANAGING HEALTHY BEHAVIOURS

1.1.1. Wellness: Nine Dimensions

Why Study Wellness?

As most college students do, you have probably set goals. Obviously, your individual goals differ from those of your fellow classmates, but everyone's goals share one common attribute: their intention to improve individual wellbeing. However, there are as many ideas about how to do that as there are individuals. Do your goals involve making more money, achieving better health, improving your relationships? Holistic wellness involves all those aspects of life and more. This chapter explains the importance of overall wellness, which is about more than being physically and mentally healthy, free from illness and disease. In fact, the study of wellness incorporates all aspects of life. Achieving overall wellness means living actively and fully. People in this state exude confidence, optimism, and self-efficacy; they have the energy reserves to do what needs to be done today and to plan for a better tomorrow. The most effective and transformative goals are those designed to achieve the highest level of personal wellness.

Dimensions of Wellness

Wellness is a familiar term, but what is its true definition? Is it simply the absence of disease? This chapter will define all the components of holistic wellness and describe the factors that contribute to **not only a person's physical and mental health, but**

also their ability to develop, thrive, succeed, enjoy life, and meet challenges head on with confidence and resolve. To achieve this type of overall wellness, a person must be healthy in nine interconnected dimensions of wellness: physical, emotional, intellectual, spiritual, social, environmental, occupational, financial, and cultural. A description of each dimension follows.

The Nine Dimensions of Wellness

Physical Wellness. People who are physically well actively make healthy decisions on a daily basis. They eat a nutritionally balanced diet; they try to get an adequate amount of sleep, and they visit the doctor routinely. They make a habit of exercising three to five times per week; they have the ability to identify their personal needs and are aware of their body's limitations. They maintain positive interpersonal relationships and make healthy sexual decisions that are consistent with their personal values and beliefs.

Emotional Wellness. An emotionally well person successfully expresses and manages an entire range of feelings, including anger, doubt, hope, joy, desire, fear, and many others. People who are emotionally well maintain a high level of self-esteem. They have a positive body-image and the ability to regulate their feelings. They know where to seek support and help regarding their mental health, including but not limited to, seeking professional counseling services.

Intellectual Wellness. Those who enjoy intellectual wellness engage in lifelong learning. They seek knowledge and activities that further develop their critical thinking and heighten global awareness. They engage in activities associated with the arts, philosophy, and reasoning.

Spiritual Wellness. People who can be described as spiritually well have identified a core set of beliefs that guide their decision making, and other faith-based endeavors. While firm in their spiritual beliefs, they understand others may have a distinctly different set of guiding principles. They recognize the relationship between spirituality and identity in all individuals.

Social Wellness. A socially well person builds healthy relationships based on interdependence, trust, and respect. Those who are socially well have a keen awareness of the feelings of others. They develop a network of friends and co-workers who share a common purpose, and who provide support and validation.

Environmental Wellness. An environmentally well person appreciates the external cues and stimuli that an environment can provide. People who have achieved environmental wellness recognize the limits to controlling an environment and seek to understand the role an individual plays in the environment.

Occupational Wellness. An occupationally well person enjoys the pursuit of a career which is fulfilling on a variety of levels. This person finds satisfaction and enrichment in work, while always in pursuit of opportunities to reach the next level of professional success.

Financial Wellness. Those who are financially well are fully aware of their current financial state. They set long- and short-term goals regarding finances that will allow them to reach their personal goals and achieve self-defined financial success.

Cultural Wellness. Culturally well people are aware of their own cultural background, as well as the diversity and richness present in other cultural backgrounds. Cultural wellness implies understanding, awareness, and intrinsic respect for aspects of diversity. A culturally well person acknowledges and accepts the impact of these aspects of diversity on sexual orientation, religion, gender, racial and ethnic backgrounds, age groups, and disabilities.

For more information on the nine dimensions of wellness, click on the link below:

Nine Dimensions of Wellness

To watch a video about the nine dimensions of wellness, click on the following link:

Video on the Nine Dimensions of Wellness

1.1.2. Improving Health Issues

Health Problems

What are the factors that account for these health problems that have arisen over the past 100 years? Most health problems faced by people in North America are chronic diseases that are preventable and caused by poor everyday choices and unhealthy lifestyles.

The links below provides more information about the leading causes of death in Canada and the United States. Using these links you can also find information on the leading causes of death for specific age groups.

Leading Causes of Death in Canada

To see a 2014 chart that shows the leading cause of death by age group, click on the link below:

Leading Cause of Death by Age Group in America

In the video linked below, you will learn about the determinants of health as outlined by Healthy People 2020. Healthy People 2020 is a federal advisory committee comprised of non-federal, independent subject matter experts who gather data and provide advice on how to promote health and prevent disease in America.

Healthy People 2020 and Determinants of Health

The link below is to the Canadian version of Healthy People 2020, The Canadian Public Health Association. By following the link you can find information on their policies and missions.

The Canadian Public Health Association

Behaviours That Promote Wellness

There are several lifestyle behaviours that can be modified to improve health and quality of life. Bad habits are hard to break, but choosing healthier lifestyle behaviours provides benefits that go far beyond a more ideal body weight and shape.

Engage in Physical Activity. Being physically fit can stave off many of the diseases and medical conditions discussed in the previous section, including heart disease, the number 1 killer in America and 2nd leading killer in Canada. Exercise has shown to reduce stress and ease depression. Healthier employees are also more productive. Being physically fit nurtures the mind, body, and spirit and is the cornerstone of wellness.

> The following video illustrates how 30 minutes of physical activity a day can make drastic improvements to your overall health.
>
> Video: 23 and 1/2 hours
>
> The following link provides a daily activity log for you to determine how much time each day you spend being physical active.
>
> Physical Activity Journal

Choose a Healthy Diet. Choosing to eat healthy by eating the appropriate number of calories and consuming the recommended number of fruits and vegetables, minimizing processed foods, and eating a diet high in whole grains in fibre can help prevent obesity and several other diseases such as heart disease, stroke, and type 2 diabetes.

Manage Stress Effectively. Stress not only has a negative effect on cardiovascular health but in addition, people often cope with stress by binge eating, smoking, or drinking alcohol, all of which are detrimental to health. Finding effective ways to cope with stress such as meditation or exercise can greatly improve health.

Avoid Smoking, Drugs and Excessive Alcohol. Substance abuse is directly linked to a number of health conditions such as cancer, heart disease, and stroke. In Canada, smoking has been linked to 37,000 deaths, and alcohol has been linked to 4300 deaths. Reducing the consumption of these substance can greatly increase lifespan and improve quality of life.

Get Adequate Sleep. A lack of sleep can not only result in fatigue but can also increase stress and anxiety and reduce your immune system. Getting an adequate amount of sleep each night allows your body to recharge effectively improving your ability to tackle day to day challenges.

Behaviour Modification

Making permanent lifestyle changes is one of the greatest challenges a person can face. This section will explore how changes to behaviour occur, the psychological barriers that hamper efforts to change, and tips for making lasting change. There is a wide range of factors that influence behaviour. Most of these factors can be assigned to the following categories:

- **personal or individual:** Factors that stem from the individual including knowledge, beliefs, attitudes, skills, and genetics
- **social:** Factors that stem from interacting with other individuals including friends, family, and community
- **environmental:** Factors that stem from interactions with an individual's surroundings including weather, the economy, technology, and geography

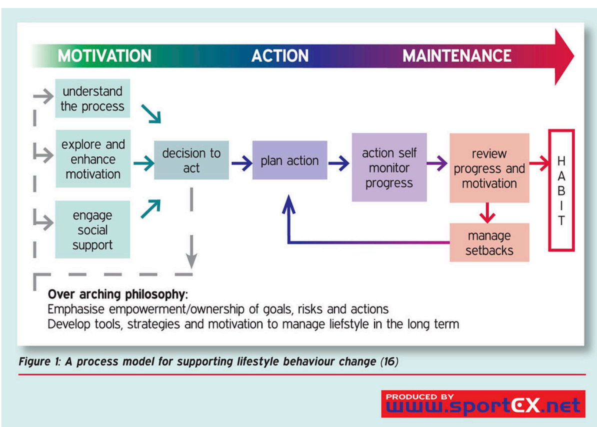
Successful behaviour change often requires each of these categories to be considered. For example, if an individual decides to exercise more by bicycling to work everyday after their beliefs on daily exercise were changed at the individual level, but they do not consider the environmental factors that their work is at the top of a large hill or the social factors that they normally carpooled to work, their behaviour change will be challenging. However, if they consider the environmental factor of the large hill and start by cycling on less challenging terrain they will eventually be able to cycle to work without much difficultly. Additionally, if they decide to eat lunch everyday with their friends instead of carpooling, they will make up for the social factor preventing their behaviour change.

How Changes in Behaviour Occur

Traditionally, health care practitioners relied on providing advice and information to spark behaviour change, assuming that it was a lack of information that was leading to poor behaviour choices. However, behaviour change is now understood to be highly complex process with several external and internal influences. There are several models for behaviour change, and depending on the individual and the behaviour some may be more useful than others.

The **Transtheoretical Model**, also called the **Stages of Change Model**, was developed by James Prochaska and Carlo DiClemente in the late 1970s. Considered the dominant model for describing how behaviour changes occur, it evolved through studies examining the experiences of smokers who quit on their own and comparing them with the experiences of those requiring further treatment. The goal of those studies was to understand why some people were capable of quitting on their own. It was determined that people quit smoking if they were ready to do so. Thus, the **Transtheoretical Model (TTM) focuses on the decision-making of the individual and is a model of intentional change**. The TTM operates on the assumption that people do not change behaviours quickly and decisively. Rather, change in behaviour, especially habitual behaviour, occurs continuously through a cyclical process. The TTM is not a theory but a model; different behavioural theories and constructs can be applied to various stages of the model where they may be most effective.

The TTM posits that individuals move through six stages of change: precontemplation, contemplation, preparation, action, maintenance, and termination. Termination was not part of the original model and is less often used in application of stages of change for health-related behaviours. For each stage of change, different intervention strategies are most effective at moving the person to the next stage of change and subsequently through the model to maintenance, the ideal stage of behaviour.



"A process model for supporting lifestyle behaviour change (16)" by sportEX journals is licensed under CC BY-ND 2.0

1.1.3. Behaviour Change Theory

Transtheoretical Model: Six Stages of Change

Stage 1: Precontemplation. In this stage, people do not intend to take action in the foreseeable future (defined as within the next 6 months). People are often unaware that their behaviour is problematic or produces negative consequences. People in this stage often underestimate the pros of changing behaviour and place too much emphasis on the cons of changing behaviour.

Stage 2: Contemplation. In this stage, people are intending to start the healthy behaviour in the foreseeable future. People recognize that their behaviour may be problematic, and a more thoughtful and practical consideration of the pros and cons of changing the behaviour takes place, with equal emphasis placed on both. Even with this recognition, people may still feel ambivalent toward changing their behaviour.

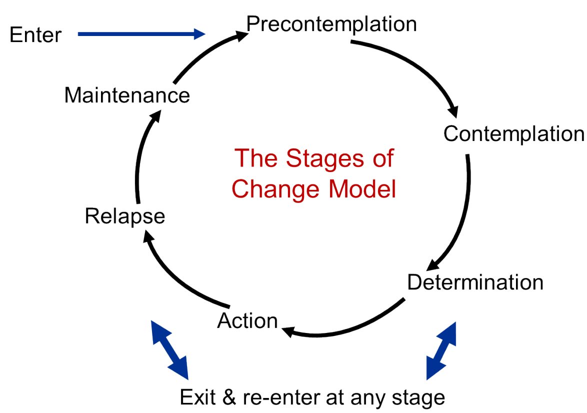
Stage 3: Preparation (Determination). In this stage, people are ready to take action within the next 30 days. People start to take small steps toward the behaviour change, and they believe changing their behaviour can lead to a healthier life.

Stage 4: Action. In this stage, people have recently changed their behaviour and intend to keep moving forward with that behaviour change. People may exhibit this by modifying their problem behaviour or acquiring new healthy behaviours.

Stage 5: Maintenance. In this stage, people have sustained their behaviour change for a while and intend to maintain the behaviour change going forward. People in this stage work to prevent relapse to earlier stages.

Stage 6: Termination. In this stage, people have no desire to return to their unhealthy behaviours and are sure they will not relapse. Since this is rarely reached, and people tend to stay in the maintenance stage, this stage is often not considered in health promotion programs.

Figure 1.1.3.1 *Transtheoretical Model: Stages of Change.*



The transtheoretical model and the six stages of behaviour change. Source: [Healthy Behaviours](#).

To **progress through the stages of change**, people apply cognitive, affective, and evaluative processes. Ten processes of change have been identified, with some processes being more relevant to a specific stage of change than other processes. These processes result in strategies that help people make and maintain change. Source: [Wellness](#)

Ten Processes of Change

- **consciousness raising:** Increasing awareness about the healthy behaviour.
- **dramatic relief:** Emotional arousal about the health behaviour, whether positive or negative arousal.
- **self-reevaluation:** Self-reappraisal to realize the healthy behaviour is part of who they want to be.
- **environmental reevaluation:** Social reappraisal to realize how their unhealthy behaviour affects others.
- **social liberation:** Environmental opportunities that exist to show society is supportive of the healthy behaviour.
- **self-liberation:** Commitment to change behaviour based on the belief that achievement of the healthy behaviour is possible.
- **helping relationships:** Finding supportive relationships that encourage the desired change.
- **counter-conditioning:** Substituting healthy behaviours and thoughts for unhealthy behaviours and thoughts.
- **reinforcement management:** Rewarding the positive behaviour and reducing the rewards that come from negative behaviour.
- **stimulus control:** Re-engineering the environment to have reminders and cues that support and encourage the healthy behaviour and remove those that encourage the unhealthy behaviour.

Limitations of the Transtheoretical Model

Limitations of the model include the following:

- The theory ignores the social context in which change occurs, such as socioeconomic status and income.

- The lines between the stages can be arbitrary with no set criteria of how to determine a person's stage of change. The questionnaires that have been developed to assign a person to a stage of change are not always standardized or validated.
- No clear sense exists for how much time is needed for each stage, or how long a person can remain in a stage.
- The model assumes that individuals make coherent and logical plans in their decision-making process when this is not always true.

The Transtheoretical Model provides suggested strategies for public health interventions to address people at various stages of the decision-making process. Using strategies suggested by TTM can result in interventions that are more effective because they are tailored for a specific group of people. In other words, the interventions involve a message or program component that has been specifically created for a target population's level of knowledge and motivation. The TTM encourages an assessment of an individual's current stage of change and accounts for relapse in people's decision-making process.

For more information about the TTM, especially as it relates to exercise, click on the link below:

TTM for Behaviour Change

One of the most effective tools for changing behaviour is goal setting. The links below provide information on how to set goals effectively to achieve greater success in goal attainment.

Goal Setting Info from Oregon State

One Step at a Time Goal Achievement

Video on S.M.A.R.T. Goals

Making S.M.A.R.T. Goals

You can use the S.M.A.R.T. acronym to guide your goal setting. According to this acronym goals should be:

S	Specific
M	Measurable
A	Achievable
R	Relevant
T	Time bound

Lifestyle Modification Barriers

Dr. James M. Olson, a psychology professor at the University of Western Ontario, London, has identified several psychological barriers that commonly prevent people from taking action, even when inaction poses a threat to their health.

These barriers occur during 3 stages of behaviour modification: admission of the problem, initial attempts to change, and long-term change as outlined below.

Barriers to Admission of the Problem. The first step in lasting change is admitting a problem exists. People often fail to change behaviour that poses a risk to their health because they deny a risk exists, trivialize their personal risk, feel invulnerable, make a faulty conceptualization, (i.e., they attribute early warning signs to a benign cause), or experience debilitating emotions when contemplating preventative measures.

Barriers to Initial Attempts To Change. At this stage, people acknowledge the need to change but struggle to accomplish their goals. This failure is a result of lack of knowledge, low self-efficacy (the belief in one's own ability to succeed at change), and dysfunctional attitudes.

Barriers to Long-Term Change. Just because a person has experienced success in changing a behaviour, that doesn't mean the change is permanent. Barriers to long-term change include cognitive and motivational drift (diminishing enthusiasm for the need to change), lack of perceived improvement, lack of social support, and lapses.

To read more about these barriers to change, including strategies for overcoming these barriers, read Dr. Olson's entire article linked below:

Psychological Barriers to Behaviour Change

A presentation on overcoming barriers to change by the National Institute for Health and Clinical Excellence (NHS) is linked below:

Overcoming Barriers to Change

1.1.4. Ongoing Behavioural Self-Management

Fostering Wellness in Your Life

You are once again feeling motivated to eat better, exercise more, drink less caffeine or make any number of the positive lifestyle changes you have been telling yourself you want to make. You have tried before—probably declaring another attempt as a New Year's resolution—but without experiencing much success. Making a lifestyle change is challenging, especially when you want to transform many things at once. This time, think of those changes not as a resolution but as an evolution.

Lifestyle changes are a process that take time and require support. Once you are ready to make a change, the difficult part is committing and following through. So do your research and make a plan that will prepare you for success. Careful planning means setting small goals and taking things one step at a time.

Here are **five tips from the American Psychological Association** (APA) that will assist you in making lasting, positive lifestyle and behaviour changes.

Make a Plan That Will Stick. Your plan is a map that will guide you on this journey of change. You can even think of it as an adventure. When making your plan, be specific. Want to exercise more? Detail the time of day when you can take walks and how long you will walk. Write everything down, and ask yourself if you are confident that these activities and goals are realistic for you. If not, start with smaller steps. Post your plan where you will most often see it as a reminder.

Start Small. After you've identified realistic short-term and long-term goals, break down your goals into small, manageable steps that are specifically defined and can be measured. Is your long-term goal to lose 20 pounds within the next five months? A good weekly goal would be to lose one pound a week. If you would like to eat healthier, consider as a goal for the week replacing dessert with a healthier option, like fruit or yogurt. At the end of the week, you will feel successful knowing you met your goal.

Change One Behaviour at a Time. Unhealthy behaviours develop over the course of time, so replacing unhealthy behaviours with healthy ones requires time. Many people run into problems when they try to change too much too fast. To improve your success, focus on one goal or change at a time. As new healthy behaviours become a habit, try to add another goal that works toward the overall change you are striving for.

Involve a Buddy. Whether it be a friend, co-worker, or family member, someone else on your journey will keep you motivated and accountable. Perhaps it can be someone who will go to the gym with you or someone who is also trying to stop smoking. Talk about what you are doing. Consider joining a support group. Having someone with whom to share your struggles and successes makes the work easier and the mission less intimidating.

Ask for Support. Accepting help from those who care about you and will listen strengthens your resilience and commitment. If you feel overwhelmed or unable to meet your goals on your own, consider seeking help from a psychologist. Psychologists are uniquely trained to understand the connection between the mind and body, as well as the factors that promote behaviour change. Asking for help does not mean a lifetime of therapy; even just a few sessions can help you examine and set attainable goals or address the emotional issues that may be getting in your way.

Start With "Why?"

Making changes in habitual behaviour requires a deep and abiding belief that change is needed. Your desire to change may be motivated by personal goals, or it may be the result of the impact your improved wellness will have on those you love. Nietzsche said, "He who has a strong enough why can bear almost any how."

Once you have a compelling reason to change, develop a plan and commit to that plan. If you experience a moment of weakness, do not waste time on self-condemnation. Revisit your compelling reason and reaffirm your commitment to change. The health, peace, and sense of wellbeing inherent in the highest level of your own personal wellness is more than worth the effort required to change.

For more information about making permanent lifestyle changes, go to the APA website linked below:

Lifestyle Changes That Last

Boosting Self-Efficacy

Self-efficacy is the belief in one's ability to take action. Having a strong self-efficacy is an important component of successful behaviour change. Below are methods to boost your self-efficacy:

- **Develop your locus of control:** The degree to which people believe that they have control over the outcome of events in their life. Someone with a strong locus of control believes that they have a greater influence on their life than external forces.
- **Use visualization:** The process of envisioning positive outcomes in future events.
- **Use self-talk:** Your internal dialogue. Keeping this dialogue positive instead of negative.
- **Use role models:** Finding individuals who display the behaviour changes you are looking to make.

Dealing With Relapse

Maintaining behaviour change overtime is challenging. Slips or relapses in poor behaviour are common and should be expected. What is important is how you deal with these slips or relapses and understanding that a relapse does not mean failure. Avoid guilt, shame, and self-blame when a replace occurs by doing the following:

1. Forgive yourself.
2. Give yourself credit for the progress you have made.
3. Move on and do not dwell.

Beware of Procrastinating, Rationalizing and Blaming

Behaviour change is hard and therefore it is common that we play psychological games with ourselves to justify avoiding behaviour change. Some of these games include the following:

- **procrastinating:** Putting off plans or change until a later time/date. If you are procrastinating, try breaking down your plans into smaller pieces so they are easier to tackle.
- **rationalizing:** If you find yourself making weak excuses for avoiding your behaviour change you are rationalizing your way out of the positive change you are trying to make. Stop yourself and ask if these are legitimate excuses or if you are just avoiding the challenge of behaviour change.
- **blaming:** If you find yourself blaming others for your inability to make behaviour change, stop yourself and ask if there are ways around these external barriers that you are able to control.

1.1.5. Test Your Knowledge

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https://opentextbooks.concordia.ca/fundamentalsofhealthandphysicalactivity/?p=739

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1.2. NUTRITION: MAKING HEALTHY CHOICES

"Nutrition: Making Healthy Choices" is an adaptation of the chapters "Nutrition Applications" and "Basic Concepts in Nutrition" from *Human Nutrition*, by the University of Hawaiʻi at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. New material has been incorporated that includes Canadian food label guides, Canadian specific links, and the new Canadian Food Guide. Information that is not relevant to this course has been removed.

1.2.1. Learning From Food Labels

Understanding Daily Reference Intakes

Dietary Reference Intakes (DRI) are the recommendation levels for specific nutrients and consist of a number of different types of recommendations. This DRI system is used in both the United States and Canada.

Daily Reference Intakes: A Brief Overview

"Dietary Reference Intakes" (DRI) is an umbrella term for four reference values:

- estimated average requirements (EAR)
- recommended dietary allowances (RDA)
- adequate intakes (AI)
- tolerable upper intake levels (UL)

The DRIs are not minimum or maximum nutritional requirements and are not intended to fit everybody. They are to be used as guides only for the majority of the healthy population.[1]

1. Deng S, West BJ, Jensen CJ. A Quantitative Comparison of Phytochemical Components in Global Noni Fruits and Their Commercial Products. Food Chemistry. 2010;

DRIs are important not only to help the average person determine whether their intake of a particular nutrient is adequate, they are also used by health-care professionals and policy makers to determine nutritional recommendations for special groups of people who may need help reaching nutritional goals. This includes people who are participating in programs such as the Special Supplemental Food Program for Women, Infants, and Children. The DRI is not appropriate for people who are ill or malnourished, even if they were healthy previously.

Determining Dietary Reference Intakes

Each DRI value is derived in a different way. See below for an explanation of how each is determined.

Estimated Average Requirements.

The EAR for a nutrient is determined by a committee of nutrition experts who review the scientific literature to determine a value that meets the requirements of 50 percent of people in their target group within a given life stage and for a particular sex. The requirements of half of the group will fall below the EAR and the other half will be above it. It is important to note that, for each nutrient, a specific bodily function is chosen as the criterion on which to base the EAR. For example, the EAR for calcium is set using a criterion of maximizing bone health. Thus, the EAR for calcium

122(1), 267–70. http://www.sciencedirect.com/science/article/pii/S0308814610001111. Accessed December 4, 2017.

is set at a point that will meet the needs, with respect to bone health, of half of the population. EAR values become the scientific foundation upon which RDA values are set.

Recommended Daily Allowances.

Once the EAR of a nutrient has been established, the RDA can be mathematically determined. While the EAR is set at a point that meets the needs of half the population, RDA values are set to meet the needs of the vast majority (97 to 98 percent) of the target healthy population. It is important to note that RDAs are not the same thing as individual nutritional requirements. The actual nutrient needs of a given individual will be different than the RDA. However, since we know that 97 to 98 percent of the population's needs are met by the RDA, we can assume that if a person is consuming the RDA of a given nutrient, they are most likely meeting their nutritional need for that nutrient. The important thing to remember is that the RDA is meant as a recommendation and meeting the RDA means it is very likely that you are meeting your actual requirement for that nutrient.

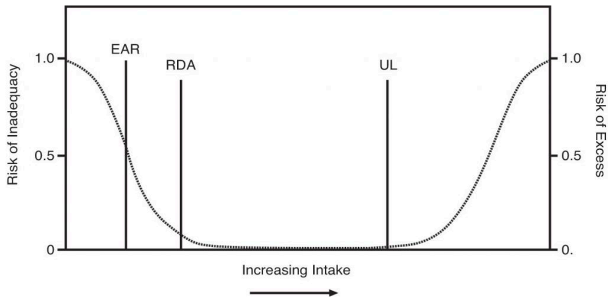
Understanding the Difference

There is a distinct difference between a requirement and a recommendation. For instance, the DRI for vitamin D is a recommended 600 international units each day. However, in order to find out your true personal requirements for vitamin D, a blood test is necessary. The blood test will provide an accurate reading from which a medical professional can gauge your required daily vitamin D amounts. This may be considerably more or less than the DRI, depending on what your level actually is.

Adequate intakes (AIs) are created for nutrients when there is insufficient consistent scientific evidence to set an EAR for the entire population. As with RDAs, AIs can be used as nutrient-intake goals for a given nutrient. For example, there has not been sufficient scientific research into the particular nutritional requirements for infants. Consequently, all of the DRI values for infants are AIs derived from nutrient values in human breast milk. For older babies and children, AI values are derived from human milk coupled with data on adults. The AI is meant for a healthy target group and is not meant to be sufficient for certain at-risk groups, such as premature infants.

The concept of a **tolerable upper intake level** (UL) was established to help distinguish healthful and harmful nutrient intakes. Developed in part as a response to the growing usage of dietary supplements, ULs indicate the highest level of continuous intake of a particular nutrient that may be taken without causing health problems. When a nutrient does not have any known issue if taken in excessive doses, it is not assigned a UL. However, even when a nutrient does not have a UL it is not necessarily safe to consume in large amounts.

Figure 1.2.1.1 *Dietary Reference Intakes Graph.*



Dietary intakes range from inadequacy to risk of excess. EAR: estimated average requirements, RDA: recommended daily allowance, UL: *upper limit. Source: Dietary Reference Intakes Tables and Application. The National Academies of Science, Engineering, and Medicine. Health and Medicine Division. https://www.nap.edu/read/11537/chapter/1#ii. Updated on: 2006. Accessed November 22, 2017.*

This graph illustrates the risks of nutrient inadequacy and nutrient excess as we move from a low intake of a nutrient to a high intake. Starting on the left side of the graph, you can see that when you have a very low intake of a nutrient, your risk of nutrient deficiency is high. As your nutrient intake increases, the chances that you will be deficient in that nutrient decrease. The point at which 50 percent of the population meets their nutrient need is the EAR, and the point at which 97 to 98 percent of the population meets their needs is the RDA. The UL is the highest level at which you can consume a nutrient without it being too much—as nutrient intake increases beyond the UL, the risk of health problems resulting from that nutrient increases.

The Acceptable Macronutrient Distribution Range (AMDR) is the calculated range of how much energy from carbohydrates, fats, and protein is recommended for a healthy diet adequate of the essential nutrients and is associated with a reduced risk of chronic disease. The ranges listed in Table 1.2.1.1 "Acceptable Macronutrient Distribution Ranges (AMDR) For Various Age Groups" allows individuals to personalize their diets taking into consideration that different subgroups in a population often require different requirements. The DRI committee recommends using the midpoint of the AMDRs as an approach to focus on moderation.[2]

Table 1.2.1.1 *Acceptable Macronutrient Distribution Ranges* (AMDR) *For Various Age Groups*

2. Dietary Reference Intakes Tables and Application. The National Academies of Science, Engineering, and Medicine. Health and Medicine Division. http://nationalacademies.org/HMD/Activities/Nutrition/SummaryDRIs/DRI-Tables.aspx. Accessed November 22, 2017.

Age Group	Protein (%)	Carbohydrates (%)	Fat (%)
Children (1–3)	5–20	45–65	30–40
Children and Adolescents (4–18)	10–30	45–65	25–35
Adults (>19)	10–35	45–65	20–35

Source: Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Food and Nutritional Board. Institute of Medicine. https://www.nap.edu/read/10490/chapter/1. Updated on: 2005. Accessed September 12, 2021.

Nutrient needs vary throughout development. Carbohydrates are required the most, followed by fat, then protein.

Tips for Using the Dietary Reference Intakes to Plan Your Diet

You can use the DRIs to help assess and plan your diet. Keep in mind when evaluating your nutritional intake that the values established have been devised with an ample safety margin and should be used as guidance for optimal intakes. Also, the values are meant to assess and plan average intake over time; that is, you don't need to meet these recommendations every single day—meeting them on average over several days is sufficient.

Discovering Nutrition Facts

The Labels on Your Food

Understanding the significance of dietary guidelines and recommendations in planning your nutrient intakes can make you better equipped to select the right foods the next time you go to the supermarket.

In the United States, the Nutrition Labeling and Education Act passed in 1990 and came into effect in 1994. In Canada, mandatory labeling came into effect in 2005. As a result, **all packaged foods sold in the United States and Canada must have nutrition labels that accurately reflect the contents of the food products**. There are several mandated nutrients and some optional ones that manufacturers or packagers include.

In~~,~~ 2017 a new Nutrition Facts label for packaged foods was announced. This label reflects new scientific information and will make it easier for consumers to make informed food choices. Some of the changes made to the label include the following:[3]

- The serving size has been made more
    - consistent, so that it's easier to compare similar foods, and
    - realistic, so that it reflects the amount that Canadians typically eat in one sitting.
- The information on serving size and calories has been made easier to find and read by

3. Food Labelling Changes. Health Canada. https://www.canada.ca/en/health-canada/services/food-labelling-changes.html#a1. Updated on July 24, 2017. Accessed on December 15, 2019.

    - increasing the font size of serving size and calories and
    - adding a bold line under the calories.
- The % daily values have been revised based on updated science.
- A new % daily value for total sugars has been added.
- The list of nutrients has been updated to
    - include potassium, because
        - it's important for maintaining healthy blood pressure, and
        - most Canadians are not getting enough of this nutrient, and
    - remove vitamin A and vitamin C, because most Canadians get enough of these nutrients in their diets.
- The amounts in milligrams (mg) for potassium, calcium and iron have been added.
- A footnote has been added at the bottom of the table about % daily value to help consumers understand
    - how much sugar and other nutrients (like sodium) are in their food, and that
    - 5% or less is a little, and
    - 15% or more is a lot.

Figure 1.2.1.2 [Nutrition facts table changes]

Reading the Label

The first part of the Nutrition Facts panel gives you information on the serving size and how many servings are in the container. For example, a label on a box of crackers might tell you that twenty crackers equals one serving and that the whole box contains 10 servings. All other values listed thereafter, from the calories to the dietary fiber, are based on this one serving. On the panel, the serving size is followed by the number of calories and then a list of selected nutrients. You will also see “Percent Daily Value” on the far right-hand side. This helps you determine if the food is a good source of a particular nutrient or not. The Daily Value (DV) represents the recommended amount of a given nutrient based on the RDI of that nutrient in a 2,000-kilocalorie diet. The percentage of Daily Value (percent DV) represents the proportion of the total daily recommended amount that you will get from one serving of the food. For example, in the older food label in Figure 1.2.1.3 “Reading the Older Nutrition Label,” the percent DV of calcium for one serving of macaroni-and-cheese is 20 percent, which means that one serving of macaroni and cheese provides 20 percent of the daily recommended calcium intake. Since the DV for calcium is 1,000 milligrams, the food producer determined the percent DV for calcium by taking the calcium content in milligrams in each serving, and dividing it by 1,000 milligrams, and then multiplying it by 100 to get it into percentage format. Whether you consume 2,000 calories per day or not you can still use the percent DV as a target reference.

Generally, a percent DV of 5 is considered low and a percent DV of 15 is considered high. This means, as a general rule, for fat, saturated fat, trans fat, cholesterol, or sodium, look for foods with a low percent DV. Alternatively, when concentrating on essential mineral or vitamin intake, look for a high percent DV. To figure out your fat allowance remaining for the day after consuming one serving of macaroni-and-cheese, look at the percent DV for fat, which is 18 percent, and subtract it from 100 percent. To know this amount in grams of fat, read the footnote of the food label to find that the recommended maximum amount of fat grams to consume per day for a 2,000 kilocalories per day diet is 65 grams. Eighteen percent of sixty-five equals about 12 grams. This means that 53 grams of fat are remaining in your fat allowance. Remember, to have a healthy diet the recommendation is to eat less than this amount of fat grams per day, especially if you want to lose weight.

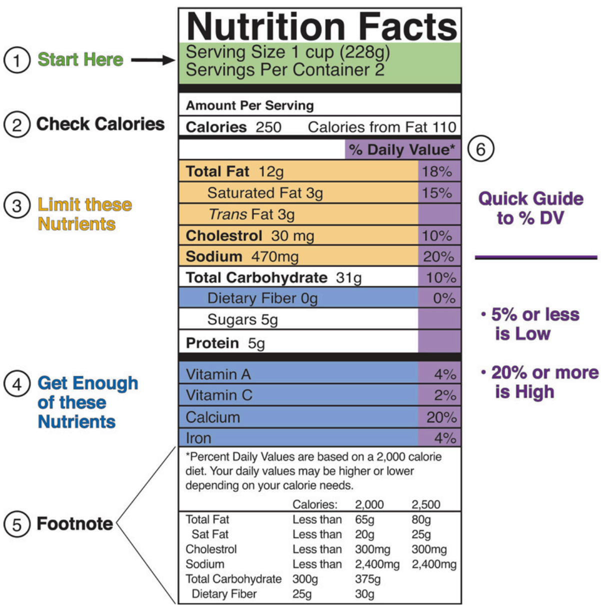
Table 1.2.1.2 *Daily Values Based on a Caloric Intake of 2,000 Calories (For Adults and Children Four or More Years of Age)*

Food Component Component	Daily Values Canada
Total Fat	75 g
Saturated Fat	20 g
Cholesterol	300 mg
Sodium	2300 mg
Sugars	100g
Protein	0.8g/kg body weight
Potassium	4700 mg
Dietary Fiber	28 g
Vitamin A	900 ug
Vitamin C	90 mg
Calcium	1300 mg
Iron	18 mg
Vitamin D	20 ug
Vitamin E	15 mg
Vitamin K	120 ug
Thiamin	1.2 mg
Riboflavin	1.3 mg
Niacin	16 mg
Vitamin B6	1.7 mg
Folate	400 ug
Vitamin B12	2.4 ug
Biotin	30 ug
Pantothenic acid	5 mg
Phosphorus	1250 mg
Iodine	150 ug
Magnesium	420 mg
Zinc	11 mg
Selenium	55 ug

Copper	0.9 mg
Manganese	2.3 mg
Chromium	35 ug
Molybdenum	45 ug
Chloride	2300 mg

Source: Food labelling changes. Health Canada. https://www.canada.ca/en/health-canada/services/food-labelling-changes.html#a2. Updated on March 30, 2020. Accessed on September 12, 2021.

Figure 1.2.1.3 *Reading the Older Nutrition Label.*



A sample label for macaroni and cheese. Source: How to Understand and Use the Nutrition Facts Panel. FDA. http://www.fda.gov/food/labelingnutrition/consumerinformation/ucm078889.htm#dvs. Updated on February 15, 2012. Accessed November 22, 2017. CC BY 4.0 license.

Of course, this is a lot of information to put on a label and some products are too small to accommodate it all. In the case of small packages, such as small containers of yogurt, candy, or fruit bars, permission has been granted to use an abbreviated version of the Nutrition Facts panel. To learn additional details about all of the information contained within the Nutrition Facts panel, see the following website: https://www.canada.ca/en/health-canada/services/food-labelling-changes.html#a1

List of Ingredients

The updated guidelines for food labels also include changes to how ingredients are listed. These changes make it easier to find, read and understand the list of ingredients. Changes include the following:[4]:

- grouping sugars-based ingredients in brackets after the name 'sugars'
  - this will help consumers identify all of the sources of sugars added to a food
- listing food colours by their individual common names
- making the text in black font on white or neutral background
- creating minimum type height requirements for ingredients
- using bullets or commas to separate ingredients
- using both upper and lower case letters for the ingredients in the list
- the same format rules will apply to any 'contains' statement

4. Food Labelling Changes. Health Canada. https://www.canada.ca/en/health-canada/services/food-labelling-changes.html#a1. Updated on July 24, 2017. Accessed on December 15, 2019.

indicating the presence or potential presence of

- priority food allergens,
- gluten sources, or
- added sulphites

Figure 1.2.1.4 List of Ingredients

Serving Size

Changes have been made to how serving sizes are presented to better represent the amount that Canadians eat in one sitting. Serving sizing will also now be more consistent between products making it easier to compare between similar foods and know how many calories and nutrients are being consumed. The changes are different for single serving and multi-serving packages.

Foods in Single Serving Containers

On a single serving container that contains up to 200% of the previous serving amount for that food, the serving size will be the amount in the whole container. For example, the nutrition facts for a 473mL carton of milk would previously be in reference to 250mL of milk however 250mL is less than 200% of 473mL therefore the nutrition label is based on the contents of the entire container. If the container was above 500mL (200% of 250mL) the serving size would not have to be based on the entire container.

Figure 1.2.1.5 Foods in Single Serving Containers

Foods in Multi-Serve Packages

In multi-serve packages serving sizes will be based on an amount that is close to what would be typically consumed. Serving sizes are based on how a food can be categorized. The categories are the following:

- foods that can be measured
- foods that come in pieces or are divided
- amounts of foods that are typically eaten

These factors allow serving sizes between similar foods to be more consistent so consumers can more easily compare.

Foods That Can Be Measured

Foods that can be measured, like yogurt, will be shown as a common household measurement such as

- a cup,
- a teaspoon, or
- a tablespoon.

This will additionally be paired with its metric equivalent in millilitres or grams. Similar products will be required to have the same millilitres or gram amount to allow for easier comparison.

For example in Figure 1.2.1.6 "Foods That Can Be Measured", the reference amount for yogurt is 175g. This is the typical amount of yogurt eaten in one sitting. Now all yogurt labels are required to base their nutrition facts on 175g making it easier to compare between products.

Figure 1.2.1.6 Foods That Can Be Measured

Foods That Come in Pieces or Are Divided

For foods that come in pieces like crackers, or that come pre-sliced before eating like lasagna, the serving sizes will be presented as either

- the number of pieces, or
- as a fraction of the food.

These values will be paired with its weight in grams. Similar products will have the same or very similar gram amounts.

For example the reference amount for crackers is 20g. Therefore all cracker boxes will have to base their nutrition facts label on the number of crackers that is a close to 20g as possible. Therefore the number of crackers may differ between products but the weight will remain consistent making it easier to compare between products.

Figure 1.2.1.7 Foods That Come in Pieces or Are Divided

Amount of Foods That Are Typically Eaten

For foods like sliced bread, the serving size will reflect the way it is typically eaten, followed by its weight in grams.

For example, the serving size on a bag of bread will show 2 slices of bread and its weight in grams. This is because most people eat 2 slices of beard at a time.

Figure 1.2.1.8 Amounts of Foods That Are Typically Eaten

Sugars Information

Information on sugar has been change both in the nutrition facts label and in the list of ingredients.

Nutrition Facts Table

A percent daily value has been added for total sugars to help

- compare the sugar content of different foods and
- identify sugary foods that should be limited, such as those with a daily value of 15% or more.

Figure 1.2.1.9 Sugars Information

The following table provides examples of the sugars percent daily value for some common food items.

Table 1.2.1.3 *Common Food Items in Percent Daily Sugars*

Less than 15% daily value of sugars	**More than 15% daily value o**
Milk (13%)	Chocolate milk (26%)
Plain yogurt (12%)	Flavoured yogurt (31%)
Canned fruit in water (10%)	Canned fruit in light syrup (2
Unsweetened frozen fruit (6%)	Fruit juice (25%)
Unsweetened oat cereal (1%)	Frosted oat cereal (18%)
Mineral water (0%)	Soft drink (39%)

Source: Food labelling changes. Health Canada. https://www.canada.ca/en/health-canada/services/food-labelling-changes.html#a1. Updated on March 31, 2020. Accessed on September 12, 2021.

Foods that are less than 15% daily value of sugar are considered low in sugar and foods that are greater than 15% daily values of sugar are considered high in sugar.

List of Ingredients

All sugars are now listed together, in descending order by weight, after the name 'sugars' in ingredient list to help you

- see the sugars that have been added to the food,
- quickly find the sources of sugars added to your food, and
- understand how much sugars are added to the food compared to other ingredients.

Sugars can include the following:

- white sugar, beet sugar, raw sugar or brown sugar
- agave syrup, honey, maple syrup, barley malt extract or fancy molasses
- fructose, glucose, glucose-fructose (also known as high fructose corn syrup), maltose, sucrose or dextrose
- fruit juice concentrates and purée concentrates that are added to replace sugars in foods

In Figure 1.2.1.10 there is

- more fancy molasses by weight than brown sugar or sugar, and
- more sugars in the food by weight than any other ingredient.

Figure 1.2.1.10 List of Ingredients: Sugars

Front-of-Package Nutrition Labeling

Health Canada is in the process of implementing legislation that will require food products to display front-of-package labeling if they are high in sugar, saturated fat or sodium. The proposed thresholds correspond to a percentage of the recommended daily value of sugar, saturated fat and sodium.

Table 1.2.1.4 *Thresholds for Requiring a Front-of-Package Label*

	Sugar	**Saturated Fat**	**Sodium**
Prepackaged foods	15% Daily Value (DV) (15g)	15% DV (3g)	15% DV (350mg)
Prepackaged meals and main dishes	30% DV (30g)	30% DV (6g)	30% DV (690mg)

Source: Summary of proposed amendments published in Canada Gazette, Part I: nutrition symbols, other labelling provisions, partially hydrogenated oils and vitamin D, https://www.canada.ca/en/health-canada/programs/consultation-front-of-package-nutrition-labelling-cgi/summary-of-proposed-amendments.html. Updated on February 9, 2018. Accessed on December 15, 2019.

When foods contain a certain amount of a nutrient they are required to have front of package labeling indicating this.

Additional Information on Packaging

There are other types of information that are required by law to appear somewhere on the consumer packaging. They include:[5]:

5. Food Labeling. US Food and Drug Administration. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm#highlights. Updated on November 11, 2017. Accessed November 22, 2017.

- name and address of the manufacturer, packager, or distributor
- statement of identity, what the product actually is
- net contents of the package: weight, volume, measure, or numerical count
- ingredients, listed in descending order by weight

The Nutrition Facts panel provides a wealth of information about the nutritional content of the product. The information also allows shoppers to compare products. Because the serving sizes are included on the label, you can see how much of each nutrient is in each serving to make the comparisons. Knowing how to read the label is important because of the way some foods are presented. For example, a bag of peanuts at the grocery store may seem like a healthy snack to eat on the way to class. But have a look at that label. Does it contain one serving, or multiple servings? Unless you are buying the individual serving packages, chances are the bag you picked up is at least eight servings, if not more.

According to the 2010 health and diet survey released by the FDA, 54 percent of first-time buyers of a product will check the food label and will use this information to evaluate fat, calorie, vitamin, and sodium content [6]. The survey also notes that more Americans are using food labels and are showing an increased awareness of the connection between diet and health.

6. Consumer Research on Labeling, Nutrition, Diet and Health. US Food and Drug Administration. https://www.fda.gov/food/foodscienceresearch/consumerbehaviorresearch/ucm275987.ht. Updated on November 17, 2017. Date Accessed: September 12, 2021.

1.2.2. Evaluating Food Information

Claims on Labels

In addition to mandating nutrients and ingredients that must appear on food labels, any nutrient content claims must meet certain requirements. For example, a manufacturer cannot claim that a food is fat-free or low-fat if it is not, in reality, fat-free or low-fat. Low-fat indicates that the product has three or fewer grams of fat; low salt indicates there are fewer than 140 milligrams of sodium per reference amount, low-cholesterol indicates there are fewer than 20 milligrams of cholesterol per reference amount and low saturated fat indicates there are fewer than two grams of saturated fat per reference amount. See Table 1.2.2.1 "Common Label Terms Defined" for some examples.

Table 1.2.2.1 *Common Label Terms Defined*

Term	Explanation
Lean	Fewer than a set amount of grams of fat for that particular cut of meat
High	Contains more than 20% of the nutrient's DV
Good source	Contains 10 to 19% of nutrient's DV
Light/ lite	Contains ⅓ fewer calories or 50% less fat; if more than half of calories come from fat, then fat content must be reduced by 50% or more
Organic	Contains 95% organic ingredients

Note: When foods contain a certain amount of nutrients they are required to use front of package labeling. DV: Daily Value. *Source*: Food Labeling Guide. US Food and Drug Administration. http://www.fda.gov. Updated February 10, 2012. Accessed November 28, 2017.

Health Claims

Often we hear news of a particular nutrient or food product that contributes to our health or may prevent disease. A health claim is a statement that links a particular food with a reduced risk of developing disease. As such, health claims such as "reduces heart disease," must be evaluated by the FDA or the Canadian Food Inspection Agency before it may appear on packaging. Prior to the passage of the NLEA products that made such claims were categorized as drugs and not food. All health claims must be substantiated by scientific evidence in order for it to be approved and put on a food label. To avoid having companies making false claims, laws also regulate how health claims are presented on food packaging. In addition to the claim being backed up by scientific evidence, it may never claim to cure or treat the disease. Click the following link for a detailed list of approved health claims in Canada.

Qualified Health Claims

While health claims must be backed up by hard scientific evidence, qualified health claims have supportive evidence, which is not as definitive as with health claims. The evidence may suggest that the food or nutrient is beneficial. Wording for this type of claim may look like this: "Supportive but not conclusive research shows that consumption of EPA and DHA omega-3 fatty acids may reduce the risk of coronary artery disease. One serving of [name of food] provides [X] grams of EPA and DHA omega-3 fatty acids. [See nutrition information for total fat, saturated fat, and cholesterol content.]

The Canadian Food Inspection Agency announces Qualified Health Claims for Omega-3 Fatty Acids.

Structure/Function Claims

Some companies claim that certain foods and nutrients have benefits for health even though no scientific evidence exists. In these cases, food labels are permitted to claim that you may benefit from the food because it may boost your immune system, for example. There may not be claims of diagnosis, cures, treatment, or disease prevention, and there must be a disclaimer that the FDA has not evaluated the claim.

Allergy Warnings

In Canada food manufacturers are required to list on their packages if the product contains any of the eight most common ingredients that cause food allergies. These eight common allergens are as follows: milk, eggs, peanuts, tree nuts, fish, shellfish, soy, wheat or other gluten sources, mustard, sesame seeds, sulphites. The Canadian Food Inspection Agency requires warnings when cross contamination may have occur during food processing or packaging. For instance, you may notice a label that states, "This product is manufactured in a factory that also processes peanuts." If you have food allergies, it is best to avoid products that may have been contaminated with the allergen.

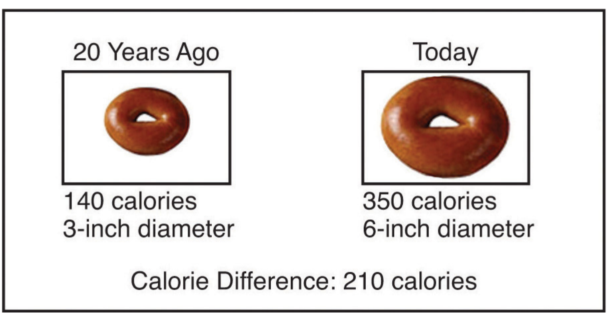
When Enough Is Enough

Estimating Portion Size

Have you ever heard the expression, "Your eyes were bigger than your stomach?" This means that you thought you wanted a lot more food than you could actually eat. Amounts of food can be deceiving to the eye, especially if you have nothing to compare them to. It is very easy to heap a pile of mashed potatoes on your plate, particularly if it is a big plate, and not realize that you have just helped yourself to three portions instead of one.

The food industry has made following the 2019 Dietary Guidelines a challenge. In many restaurants and eating establishments, portion sizes have increased, and consequently the typical meal contains more calories than it used to. In addition, our sedentary lives make it difficult to expend enough calories during normal daily activities. In fact, more than one-third of adults are not physically active at all.

Figure 1.2.2.1 A *Comparison of Serving Sizes.*



Foods used to be much smaller in size and much lower in calorie content. Source: [Discovering Nutrition Facts]

As food sizes and servings increase it is important to limit the portions of food consumed on a regular basis. Dietitians have come up with some good hints to help people tell how large a portion of food they really have. Some suggest using common items such as a deck of cards while others advocate using your hand as a measuring rule. [1]

Table 1.2.2.2 *Determining Food Portions*

Food Product	Amount	Object Comparison	Hand Comparison
Pasta, rice	½ c.	Tennis ball	Cupped hand
Fresh vegetables	1 c.	Baseball	
Cooked vegetables	½ c.		Cupped hand
Meat, poultry, fish	3 oz.	Deck of cards	Palm of your hand
Milk or other beverages	1 c.	Fist	
Salad dressing	1 Tbsp.	Thumb	
Oil	1 tsp.	Thumb tip	

Note: Everyday object comparisons can be used to determine portion sizes.

Source: Discovering Nutrition Facts

Everyday Connections

If you wait many hours between meals, there is a good chance you will overeat. To refrain from overeating try

1. Controlling Portion Sizes. American Cancer Society. http://www.cancer.org/Healthy/EatHealthyGetActive/TakeControlofYourWeight/controlling-portion-sizes. Updated January 12, 2012. Accessed November 30, 2017.

consuming small meals at frequent intervals throughout the day as opposed to two or three large meals. Eat until you are satisfied, not until you feel “stuffed.” Eating slowly and savoring your food allows you to both enjoy what you eat and have time to realize that you are full before you get overfull. Your stomach is about the size of your fist but it expands if you eat excessive amounts of food at one sitting. Eating smaller meals will diminish the size of your appetite over time so you will feel satisfied with smaller amounts of food.

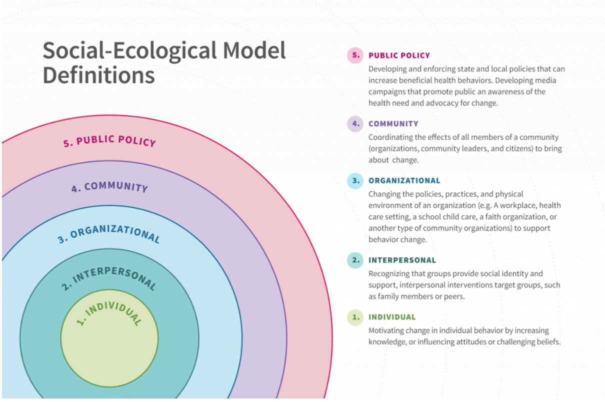
1.2.3. Healthy Eating Patterns

Helping People Make Healthy Choices

It is not just ourselves, the food industry, and federal government that shape our choices of food and physical activity, but also our sex, genetics, disabilities, income, religion, culture, education, lifestyle, age, and environment. All of these factors must be addressed by organizations and individuals that seek to make changes in dietary habits. The socioeconomic model incorporates all of these factors and is used by health-promoting organizations, to determine multiple avenues through which to promote healthy eating patterns, to increase levels of physical activity, and to reduce the risk of chronic disease for all individuals. Lower economic prosperity influences diet specifically by lowering food quality, decreasing food choices, and decreasing access to enough food. Between 2011-2012, 8.3% of Canadian households experienced food insecurity.[1]

Figure 1.2.3.1 *Social-Ecological Model.*

1. Food Insecurity in Canada. Statistics Canada. https://www150.statcan.gc.ca/n1/pub/82-624-x/2015001/article/14138-eng.htm. Created: September 17, 2018. Accessed on: September 12, 2021.



There are five levels to the social-ecological model. These levels range from the individual to public policy. Source: [Building Healthy Eating Patterns.]

Recommendations for Optimal Health

For many years, the Canadian government has been encouraging Canadians to develop healthful dietary habits. The first Canadian Food Guide was released in July 1942. Since then it has undergone several modifications, adapting to the latest scientific findings and the requirements of the Canadian population. The latest version of the Food Guide was released in 2019 and leaves the pervious rainbow schematic for a plate representation of how our diet should be balanced.

Everyday Connections

Interested in another reliable source for nutrition and health information? The "Got Nutrients?" website highlights the importance of meeting essential nutrient needs in order to maintain optimum health. This website, geared for those interested in nutrition, fitness, and health, posts short daily nutrition and health messages. Each short "Daily Tip" includes links to both a popular article and to a related scientific resource. For more information about "Got Nutrients?" visit, http://www.gotnutrients.net. To receive the "Daily Tips" by email, visit http://www.gotnutrients.net/email_alerts/subscribe.cfm

1.2.4. The New Canadian Food Guide

Canada's Food Guide

The new Canada's Food Guide promotes healthy eating and overall nutritional well-being, and supports improvements to the Canadian food environment.

Healthy Eating Recommendations

Healthy eating is more than the foods you eat. It is also about where, when, why and how you eat.

Be mindful of your eating habits

- take time to eat
- notice when you are hungry and when you are full

Cook more often

- plan what you eat
- involve others in planning and preparing meals

Enjoy your food

- culture and food traditions can be a part of healthy eating

Eat meals with others

Make it a habit to eat a variety of healthy foods each day.

Eat plenty of vegetables and fruits, whole grain foods and protein foods. Choose protein foods that come from plants more often.

- choose foods with healthy fats instead of saturated fat

Limit highly processed foods. If you choose these foods, eat them less often and in small amounts.

- prepare meals and snacks using ingredients that have little to no added sodium, sugars or saturated fat
- choose healthier menu options when eating out

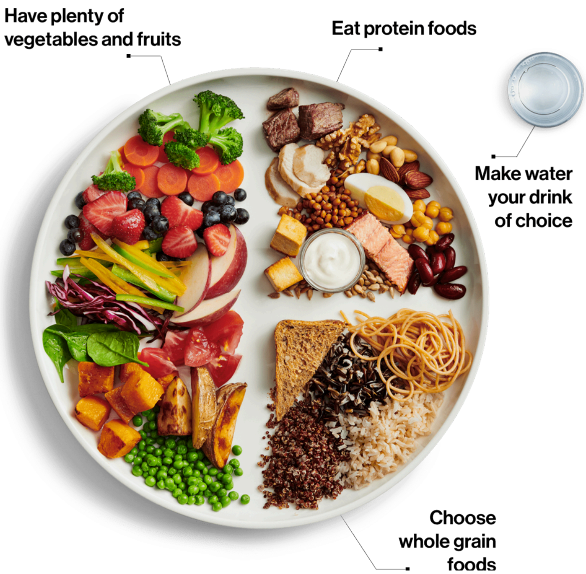
Make water your drink of choice

- replace sugary drinks with water

Use food labels

Be aware that food marketing can influence your choices

Building a Healthy Plate



Source: © All Rights Reserved: Canada's Food Guide: Plate. Health Canada. Adapted and reproduced with permission from the Minister of Health, 2019.

Canada's Food Guide encourages eating vegetables and fruits, whole grain foods and protein foods often to develop a healthy eating pattern and maintain your health.

Vegetables & Fruits

Vegetables and fruits are an important part of a healthy eating pattern. Eating a variety of vegetables and fruits may lower your risk of heart disease

Fill half of your plate with red, orange, and dark green vegetables and fruits, such as kale, bok choy, kalo (taro), tomatoes, sweet potatoes, broccoli, apples, mango, papaya, guavas, blueberries, and strawberries in main and side dishes. Vary your choices to get the benefit of as many different vegetables and fruits as you can. For snacks, eat fruits, vegetables, or unsalted nuts. Water should be your drink of choiceand fruit juices should be avoided as they are now considered sugary drinks.

Vegetables and fruits have important nutrients such as:

- fibre
- vitamins
- minerals

Include plenty of vegetables and fruits in your meals and snacks.

Opt for different textures, colours and shapes to fit your taste. From apples to zucchini, choose plenty of vegetables and fruits.

Try a variety of vegetables and fruits such as:

- pears
- apples
- berries
- broccoli
- peaches
- cabbage
- leafy greens

Choosing and Preparing Healthy Vegetables and Fruits

Fresh, frozen or canned vegetables and fruits can all be healthy options.

Frozen and canned vegetables and fruits, take little time to prepare, are a healthy and convenient option, and are just as nutritious as fresh vegetables and fruits.

Frozen Vegetables and Fruits

Choose frozen vegetables and fruits without:

- added sugars
- added seasonings
- breading or rich sauces

You can add frozen vegetables and fruits to soup or chili.

Canned Vegetables and Fruits

Choose canned vegetables with little to no added sodium.

Drain and rinse canned vegetables to lower the sodium content.

Choose canned fruit with little to no added sugars.

Use the food labels to help you compare canned vegetables and fruits.

The % daily value helps you see if a food has a little or a lot of a nutrient.

Dried Fruit

Dried fruit can be a part of healthy eating, but it can stick to your teeth and cause cavities. If you choose dried fruit, eat it with meals.

Preparing Vegetables

Try healthier cooking methods like:

- baking
- roasting
- steaming
- stir-frying

Enhance the flavour by adding:

- olive oil
- lemon juice
- flavoured vinegar
- fresh or dried herbs or spices

Fruit and Vegetable Snack Ideas

Vegetables and fruits make quick and healthy snacks. There are lots to choose from and many healthy ways to prepare them.

Vegetable Snacking Tips

Keep cut up fresh vegetables in the fridge for a quick and healthy snack. Try:

- broccoli
- cauliflower
- carrot sticks
- celery sticks
- cucumber slices

Fruit Snacking Tips

Keep a bowl of fresh fruit on the counter as an easy snack to grab.
Add fruit to whole grain cereals or lower fat yogurt. Try:

- bananas
- mangoes
- frozen berries
- canned peaches packed in water

Freeze seedless grapes on a tray and enjoy them as a snack.

How To Eat More Vegetables

Here are some easy ways to eat more vegetables:

- Add canned pumpkin or squash purée to any soup to make it extra rich and creamy.
- Wash, chop and refrigerate or freeze extra vegetables when preparing meals so you have extra for meals the next day.
- Use pre-bagged vegetables that can be quickly tossed in a salad, stir-fry or casserole. Try:
    - baby carrots
    - green beans
    - leafy greens
- Serve raw vegetables with your meals. Try:
    - cucumber
    - cherry or grape tomatoes
    - red, yellow or green peppers
- Try new recipes that call for different types of leafy greens such as:
    - kale

    - spinach
    - bok choy
    - Swiss chard
    - mixed salad greens

How To Eat More Fruits

Fruits are a delicious addition to your day. Here are some easy ways to eat more fruit:

- For dessert, choose:
    - oranges
    - fruit salad, with little to no added sugars
- Add fresh fruits to salads. Try adding sliced:
    - pears
    - peaches
    - strawberries
- Add frozen fruits to baking.
- Wash, cut and refrigerate extra fruit so you can have some on hand for meals and snacks.

Whole Grains

Fill a quarter of your plate with quality whole grains such as 100 percent whole-grain cereals, breads, crackers, rice, and pasta. All the grains you choose should be whole grains. Read the ingredients list on food labels carefully to determine if a food is comprised of whole grains.

Whole grain foods have important nutrients such as:

- fibre
- vitamins
- minerals

Whole grain foods are a healthier choice than refined grains because whole grain foods include all parts of the grain. Refined grains have some parts of the grain removed during processing.

Whole grain foods have more fibre than refined grains. Eating foods higher in fibre can help lower your risk of:

- stroke
- colon cancer
- heart disease
- type 2 diabetes

Choosing and Preparing Healthy Whole Grain Foods

Enjoy a variety of whole grain foods such as:

- quinoa
- whole grain pasta
- whole grain bread
- whole oats or oatmeal
- whole grain brown or wild rice

Some grain foods can have a lot of added sodium, sugars or saturated fat. These include foods like:

- breads
- muffins
- crackers
- pasta dishes

Make Sure Your Choices Are Actually Whole Grain

Whole wheat and multi-grain foods may not be whole grain. Some foods may look like they are whole grain because of their colour, but they may not be.

Read the ingredient list and choose foods that have the words "whole grain" followed by the name of the grain as one of the first ingredients like:

- whole grain oats
- whole grain wheat

Whole wheat foods are not whole grain, but can still be a healthy choice as they contain fibre.

Fibre

Use the nutrition facts table to compare the amount of fibre between products. Look at the % daily value to choose those with more fibre.

Preparing Whole Grain Foods

Whole grain foods can be tasty and nutritious without adding highly processed sauces and spreads. Enjoy the true taste of whole grain foods.

Try healthier ways to prepare your whole grain foods by:

- leaving out or reducing the amount of salt added during preparation

- limiting the amount of sauce or spreads you add
- adding vegetables, vegetable oils, spices and herbs to enhance flavours

Whole Grain Snack Ideas

Whole grain foods make quick and healthy snacks. There are lots of choices and many ways to enjoy them. Try:

- whole grain cereals
- whole grain crackers
- whole grain baked pita "chips"

How To Include Whole Grain Foods

Here are some easy ways to eat more whole grain foods:

- Try a new whole grain each week:
    - farro
    - freekah
    - amaranth
    - buckwheat
- Mix different whole grain cereals in your bowl and enjoy with lower fat white milk or unsweetened plant-based beverages.
- Start your day with a bowl of oatmeal, whole grain cereal or whole grain toast.
- Keep a variety of whole grain foods in your pantry. Try:
    - oats
    - quinoa
    - brown rice
    - whole grain pasta

    - whole grain bread

To increase the amount of whole grain foods in your recipes, try adding:

- barley, bulgur and quinoa to soups, salads and stir-fries
- brown or wild rice to white rice for more fibre and a nutty flavour

Protein

Select a variety of protein foods to improve nutrient intake and promote health benefits. Each week, be sure to include a nice array of protein sources in your diet, such as nuts, seeds, beans, legumes, poultry, soy, and fish and shellfish. When choosing meat, select lean cuts. Be conscious to prepare meats using little or no added saturated fat, such as butter.

You can eat a variety of protein foods as part of a healthy eating pattern.

Protein foods have important nutrients such as:

- protein
- vitamins
- minerals

Choose protein foods that come from plants more often. Plant-based protein foods can provide more fibre and less saturated fat than other types of protein foods. This can be beneficial for your heart health.

You don't need to eat large amounts of protein foods to meet your nutritional needs. Try to eat protein foods such as:

- eggs
- lean meats and poultry
    - lean cuts of beef, pork and wild game
    - turkey
    - chicken
- nuts and seeds
    - peanuts
    - almonds
    - cashews
    - nut butters
    - sunflower seeds
- fish and shellfish
    - trout
    - shrimp
    - salmon
    - scallops
    - sardines
    - mackerel
- lower fat dairy products
    - milk
    - yogurt
    - lower sodium cheeses
- beans, peas and lentils
    - brown, green or red or other lentils
    - peas such as chickpeas and split peas
    - dried beans such as black beans and kidney beans
- fortified soy beverages, tofu, soybeans and other soy products

Choosing and Preparing Healthy Protein Foods

There are many different types of protein foods to choose from. Make healthier choices.

Beans, Peas and Lentils

Choose:

- dried beans, peas and lentils to soak and cook at home
- low sodium canned beans, peas and lentils, or rinse and drain them to reduce the amount of sodium

Nuts and Seeds

Choose:

- dry roasted nuts and seeds without added:
    - sugars
    - fat (oils)
    - sodium (salt)
- peanut butter or other nut butters that list peanuts or nuts as the only ingredient. Choose ones with little to no added:
    - sodium
    - sugars
    - saturated fat

Fish and Shellfish

Choose:

- canned fish with little to no added sodium
- fresh or frozen fish and shellfish that has not been:
    - breaded
    - battered

    - deep-fried

Lean Meats

Choose:

- skinless poultry
- lean cuts of meat such as round and loin
- fresh or frozen meat and poultry without rich sauces
- meat prepared with little or no added sodium or saturated fat

Milk and Dairy Products

Choose:

- lower fat cheeses
- unsweetened lower fat yogurt
- unsweetened lower fat milk

Soy Products and Fortified Soy Beverages

Choose:

- low sodium soy products
- unsweetened fortified soy beverages

Preparing Protein Foods

Try healthier ways to prepare your food by:

- draining off extra fat after cooking
- trimming the visible fat from meats
- removing skin from poultry before cooking
- limiting the amount of sauces, butter or gravy

Try cooking methods that use little or no added saturated fat. These include methods such as:

- baking
- grilling
- roasting
- poaching

Enhance the flavour by:

- seasoning with herbs, lemon or salsas
- using small amounts of oils with healthy fats such as olive and canola

Protein Snack Ideas

Protein foods make healthy and delicious snacks. Try these quick and tasty options:

- nuts and seeds
- hard-boiled eggs
- oven roasted chickpeas
- hummus with fresh veggies
- peanut butter on celery sticks

- lower fat yogurt with fresh fruit

How To Eat More Protein Foods That Come From Plants

Here are some easy ways to eat more protein foods that come from plants:

- Add soft tofu to a blended soup to make it thicker and creamier.
- Try a bean salad, lentil and rice pilaf or a bowl of vegetarian chili for lunch.
- Make your own trail mix by combining your favourite whole grain cereal with a handful of nuts and seeds.
- Spread hummus on the inside of a whole grain pita and fill with vegetables such as romaine lettuce and shredded carrots.

Each week, plan a couple of meatless meals. As your main course, try using:

- beans in a burrito
- tofu in a vegetable stir-fry
- chickpeas and beans in tacos
- lentils in a soup, stew or casserole

Dairy as a Source of Protein

If you enjoy drinking milk or eating milk products, such as cheese and yogurt, choose lower-fat or non-fat products. Low-fat and nonfat products contain the same amount of calcium and other essential nutrients as whole-milk products, but with much less fat and calories. Calcium, an important mineral for your body, is also available in lactose-free and fortified soy and rice beverage products. You can also get calcium in vegetables and other fortified foods and beverages.

Foods with Healthy Fat

Oils are essential for your diet as they contain valuable essential fatty acids, but the type you choose and the amount you consume is important. Be sure the oil is plant-based rather than based on animal fat. The goal is to reduce the amount of saturated fats in the diet (fatty meats or cheese) while focusing on consuming foods that have mostly unsaturated fats (avocado or nuts and seeds). You can also get oils from many types of fish, as well as avocados, and unsalted nuts and seeds. It is vital to balance oil consumption with total caloric intake.

Choosing foods that contain mostly healthy fats instead of foods that contain mostly saturated fat can help lower your risk of heart disease. Heart disease is 1 of the leading causes of death in Canada.

The type of fat you eat over time is more important for health than the total amount of fat you eat.

Foods Containing Healthy Fats

These foods contain healthy fats:

- nuts
- seeds
- avocado

- fatty fish
- vegetable oils
- soft margarine

Foods Containing Saturated Fat

These foods contain saturated fat:

- fatty meats
- high fat dairy products
- some highly processed foods
- some tropical oils such as palm oil and coconut oil

How To Choose Food With Healthy Fats

The type of fat you include in your eating pattern matters. Here are some ideas to eat more healthy fats and less saturated fat.

Choose Foods With Healthy Fats

Try different types of fatty fish such as:

- trout
- salmon
- herring
- mackerel

When preparing foods, use oils with healthy fats, such as:

- corn

- olive
- canola
- peanut
- sesame
- soybean
- flaxseed
- safflower
- sunflower

Include small amounts of nuts as a snack.

Try nut butters such as peanut, almond or walnut.

Try pumpkin or sunflower seeds. Toast them for a snack or add them to salads.

Make your own salad dressing with canola, olive or flaxseed oil. Add balsamic, rice wine or other vinegars. Flavour with lemon juice, dry or Dijon mustard, garlic and herbs.

Limit Foods That Contain Saturated Fat

Limit the amount of foods containing saturated fat, such as:

- cream
- higher fat meats
- processed meats
- canned coconut milk or cream
- some frozen desserts like ice cream
- some desserts and bakery products
- most deep fried foods, like French fries
- cheeses and foods containing a lot of cheese

When preparing foods, try to limit the amount of saturated oils and fats like:

- lard

- ghee
- butter
- palm oil
- coconut oil
- hard margarine

Choose lean cuts of meat and skinless poultry. Trim off as much of the visible fat as possible. Drain fat from cooked ground meat. Lean or extra lean cuts of meat can include:

- pork loin
- chicken breast
- sirloin roast or steak
- inside and outside round roast
- lean ground poultry
- wild game such as:
    - deer
    - bison
    - moose
    - caribou

Some processed foods are made with ingredients that are high in saturated fat. Use the food labels to compare products. Choose those with little to no added saturated fat.

Healthy Fat Swaps

Try these swaps to replace saturated fat with healthy fats:

- On your toast, replace cream cheese with nut butters.
- For dipping, try making your own hummus or tzatziki to replace spinach or artichoke dip.
- On bread or rolls, replace butter with olive oil flavoured with

balsamic vinegar.
- When you are cooking, replace shortening, lard or hard margarine with oils with healthy fats such as canola, olive and soybean.

1.2.5. Healthy Eating: Outcomes

The Whole Nutrient Package Versus Disease

A healthy diet incorporating seven or more servings of fruits and vegetables has been shown in many scientific studies to reduce cardiovascular disease and overall deaths attributable to cancer. The World Health Organization (WHO) states that insufficient fruit and vegetable intake is linked to approximately 14 percent of gastrointestinal cancer deaths, about 11 percent of heart attack deaths, and 9 percent of stroke deaths globally [1].

The WHO estimates that, overall, 2.7 million deaths could be avoided annually by increasing fruit and vegetable intake. These preventable deaths place an economic, social, and mental burden on society. This is why, in 2003, the WHO and the Food and Agricultural Organization of the United Nations launched a campaign to promote fruit and vegetable intake worldwide.

Antioxidant Variety in Food Provides Health Benefits

Not only has the several-billion-dollar supplement industry inundated us with FDA-unapproved health claims, but science is continuously advancing and providing us with a multitude of

1. Global Strategies on Diet, Physical Activity, and Health. World Health Organization. http://www.who.int/dietphysicalactivity/fruit/en/index.html. n.d. Accessed September 30, 2011.

promising health benefits from particular fruits, vegetables, teas, herbs, and spices. For instance, blueberries protect against cardiovascular disease, an apple or pear a day reduces stroke risk by over 52 percent, eating more carrots significantly reduces the risk of bladder cancer, drinking tea reduces cholesterol and helps glucose homeostasis, and cinnamon blocks infection and reduces the risk of some cancers. However, recall that science also tells us that no one nutrient alone is shown to provide these effects.

What micronutrient and phytochemical sources are best at protecting against chronic disease? All of them, together. Just as there is no wonder supplement or drug, there is no superior fruit, vegetable, spice, herb, or tea that protects against all diseases. A review in the July–August 2010 issue of Oxidative Medicine and Cellular Longevity concludes that the plant-food benefits to health are attributed to two main factors—that nutrients and phytochemicals are present at low concentrations in general, and that the complex mixtures of nutrients and phytochemicals provides additive and synergistic effects. [2] In short, don't overdo it with supplements and make sure you incorporate a wide variety of nutrients in your diet.

Eating a variety of fruits and vegetables rich in antioxidants and phytochemicals promotes health. Consider these diets:

- **mediterranean diet:** Fresh fruit and vegetables are abundant in

2. Bouayed, J. and T. Bohn. Exogenous Antioxidants—Double-Edged Swords in Cellular Redox State: Health Beneficial Effects at Physiologic Doses versus Deleterious Effects at High Doses. Oxidative Medicine and Cellular Longevity. 2010; 3(4), 228–37. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2952083/?tool=pubmed. Accessed November 22, 2017.

this diet, and the cultural identity of the diet involves multiple herbs and spices. Moreover, olive oil is the main source of fat. Fish and poultry are consumed in low amounts and red meat is consumed in very low amounts. An analysis of twelve studies involving over one million subjects published in the September 2008 issue of the British Medical Journal reports that people who followed the Mediterranean diet had a 9 percent decrease in overall deaths, a 9 percent decrease in cardiovascular death, a 6 percent decrease in cancer deaths, and a 13 percent reduced incidence of Parkinson's disease and Alzheimer's disease. [3] The authors of this study concluded that the Mediterranean diet is useful as a primary prevention against some major chronic diseases.

- **dietary approaches to stop hypertension (DASH diet):** The DASH diet is an eating plan that is low in saturated fat, cholesterol, and total fat. Fruits, vegetables, low-fat dairy foods, whole-grain foods, fish, poultry, and nuts are emphasized while red meats, sweets, and sugar-containing beverages are mostly avoided. Results from a follow-up study published in the December 2009 issue of the Journal of Human Hypertension suggest the low-sodium DASH diet reduces oxidative stress, which may have contributed to the improved blood vessel function observed in salt-sensitive people (between 10 to 20 percent of the population). [4]
- **diets high in fruits and vegetables:** An analysis of The Nurses'

3. Sofi F, et al.Adherence to Mediterranean Diet and Health Status: Meta-Analysis. British Medical Journal (Online). 2008; 337, a1344. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2533524/. Accessed November 22, 2017.
4. Al-Solaiman Y, et al. Low-Sodium DASH Reduces Oxidative Stress and Improves Vascular Function in Salt-Sensitive Humans. J Hum Hypertens. 2009; 12, 826–35.

Health Study and the Health Professionals' Follow-up Study reported that for every increased serving of fruits or vegetables per day, especially green leafy vegetables and vitamin C-rich fruits, there was a 4 percent lower risk for heart disease. [5]

Canadians and Americans Typically Eat Fewer Than the Recommended Servings of High Quality Food-Group Foods

An article in the January 2009 issue of the Medscape Journal of Medicine reports that fewer than one in ten Americans consumes the recommended amount of fruits and vegetables, which is between five and thirteen servings per day. [6] According to this

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2783838/?tool=pubmed. Accessed November 22, 2017.

5. Joshipura KJ, et al. The Effect of Fruit and Vegetable Intake on Risk for Coronary Heart Disease. Ann Intern Med. 2001; 134(12), 1106–14. http://www.ncbi.nlm.nih.gov/pubmed/11412050. Accessed November 12, 2017.
6. Kimmons J, et al. Fruit and Vegetable Intake among Adolescents and Adults in the United States: Percentage Meeting Individualized Recommendations. Medscape Journal of Medicine. 2009; 11(1), 26. http://www.ncbi.nlm.nih.gov/pmc/articles/

study, the largest single contributor to fruit intake was orange juice, and potatoes were the dominant vegetable.

Canadian Food Guide recommends that you fill half your plate with fruits and vegetables. The number of servings of fruits and vegetables that a person should consume every day is dependent on age, sex, and level of physical activity. For example, a forty-year-old male who exercises for sixty minutes per day should consume 2 cups of fruit and 3½ cups of vegetables, while a fifteen-year-old female who exercises for thirty minutes per day should consume 1½ cups of fruit and 2½ cups of vegetables. (One cup of a fruit or vegetable is equal to one banana, one small apple, twelve baby carrots, one orange, or one large sweet potato.)

Improving Fruit and Vegetable Intake at Home and in Your Community

Eating more fruits and vegetables can make you think better, too. According to a study published in 2009 in the Journal of Alzheimer's Disease, no matter your age, eating more fruits and vegetables improves your brain function.[7]

PMC2654704/?tool=pubmed. Accessed November 22, 2017.

7. Polidori MC, et al. High Fruit and Vegetable Intake Is Positively Correlated with Antioxidant Status and Cognitive Performance in Healthy Subjects. Journal of Alzheimer's Disease. 2009; 17(4), 921–7. http://www.ncbi.nlm.nih.gov/pubmed/19542607. Accessed November 22, 2017.

The Centre for Disease Control (CDC) has developed seven strategies to increase intake of fruits and vegetables:[8]

1. Support local and state governments in the implementation of a Food Policy Council, which develops policies and programs that increase the availability of affordable fruits and vegetables.
2. In the food system, increase the availability and affordability of high-quality fruits and vegetables in underserved populations.
3. Promote farm-to-where-you-are programs, which is the delivery of regionally grown farm produce to community institutions, farmers markets, and individuals.
4. Encourage worksites, medical centers, universities, and other community and business establishments to serve more fruits and vegetables in cafeterias and onsite eateries.
5. Support schools in developing healthy food messages to students by incorporating activities such as gardening into curricula.
6. Encourage the development and support of community and home gardens.
7. Have emergency food programs, including food banks and food rescue programs, increase their supply of fruits and vegetables.

The seven strategies developed by the CDC are based on the idea that improving access to and availability of fruits and vegetables will lead to an increase in their consumption.

8. The CDC Guide to Fruit and Vegetable Strategies to Increase Access, Availability, and Consumption. Centers for Disease Control and Prevention. http://www.cdph.ca.gov/SiteCollectionDocuments/StratstoIncreaseFruitVegConsumption.pdf. Updated March 2010. Accessed November 22, 2017.

1.2.6. Nutrient Basics

What Are Nutrients?

The foods we eat contain nutrients. Nutrients are substances required by the body to perform its basic functions. Nutrients must be obtained from our diet, since the human body does not synthesize or produce them.

Nutrients have one or more of three basic functions: they provide **energy**, contribute to **body structure**, and/or **regulate chemical processes** in the body. These basic functions allow us to detect and respond to environmental surroundings, move, excrete wastes, respire (breathe), grow, and reproduce.

There are six classes of nutrients required for the body to function and maintain overall health. These are **carbohydrates, lipids, proteins, water, vitamins,** and **minerals**.

Foods also contain non-nutrients that may be harmful (such as natural toxins common in plant foods and additives like some dyes and preservatives) or beneficial (such as antioxidants).

Macronutrients

Nutrients that are needed in large amounts are called macronutrients. There are three classes of macronutrients: carbohydrates, lipids, and proteins. These can be metabolically processed into cellular energy, utilized to perform work and allowing our bodies to conduct their basic functions.

A unit of measurement of food energy is the calorie. (*On nutrition food labels the amount given for "calories" is actually equivalent to* *each calorie multiplied by one thousand. A kilocalorie (one thousand calories, denoted with a small "c") is synonymous with the "Calorie" (with a capital "C") on nutrition food labels).*

Water is also a macronutrient in the sense that you require a large amount of it, but unlike the other macronutrients, it does not yield calories.

Carbohydrates

Carbohydrates are molecules composed of carbon, hydrogen, and oxygen. The major food sources of carbohydrates are grains, milk, fruits, and starchy vegetables, like potatoes. Non-starchy vegetables also contain carbohydrates, but in lesser quantities. Carbohydrates are broadly classified into two forms based on their chemical structure: simple carbohydrates, often called simple sugars; and complex carbohydrates.

Simple carbohydrates consist of one or two basic units. Examples of simple sugars include sucrose, the type of sugar you would have in a bowl on the breakfast table, and glucose, the type of sugar that circulates in your blood.

Complex carbohydrates are long chains of simple sugars that can be unbranched or branched. During digestion, the body breaks down digestible complex carbohydrates to simple sugars, mostly glucose. Glucose is then transported to all our cells where it is stored, used to make energy, or used to build macromolecules. **Fibre** is also a complex carbohydrate, but it cannot be broken down by digestive enzymes in the human intestine. As a result, it passes through the digestive tract undigested unless the bacteria that inhabit the colon or large intestine break it down.

One gram of digestible carbohydrates yields four kilocalories of energy for the cells in the body to perform work.

In addition to providing energy and serving as building blocks for bigger macromolecules, carbohydrates are essential for proper functioning of the nervous system, heart, and kidneys. As mentioned, glucose can be stored in the body for future use. In humans, the storage molecule of carbohydrates is called glycogen, and in plants, it is known as starch. Glycogen and starch are complex carbohydrates.

Lipids

Lipids are also a family of molecules composed of carbon, hydrogen, and oxygen, but unlike carbohydrates, they are insoluble in water.

Lipids are found predominantly in butter, oils, meats, dairy products, nuts, and seeds, and in many processed foods. The three main types of lipids are triglycerides (triacylglycerols), phospholipids, and sterols. The main job of lipids is to provide or store energy.

Lipids provide more energy per gram than carbohydrates (nine kilocalories per gram of lipids versus four kilocalories per gram of carbohydrates).

In addition to energy storage, lipids serve as a major component of cell membranes, surround and protect organs (in fat-storing tissues), provide insulation to aid in temperature regulation, and regulate many other functions in the body.

Proteins

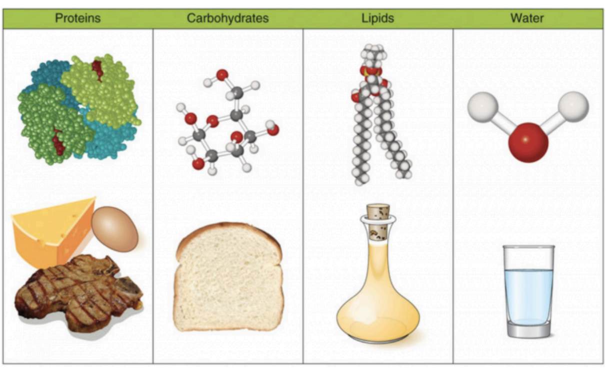
Proteins are macromolecules composed of chains of subunits called **amino acids**. Amino acids are simple subunits composed of carbon, oxygen, hydrogen, and nitrogen.

Food sources of proteins include meats, dairy products, seafood, and a variety of different plant-based foods, most notably soy. The word protein comes from a Greek word meaning "of primary importance," which is an apt description of these macronutrients; they are also known colloquially as the "workhorses" of life.

Proteins provide four kilocalories of energy per gram; however providing energy is not protein's most important function.

Proteins provide structure to bones, muscles and skin, and play a role in conducting most of the chemical reactions that take place in the body. Scientists estimate that greater than one-hundred thousand different proteins exist within the human body. The genetic codes in DNA are basically protein recipes that determine the order in which 20 different amino acids are bound together to make thousands of specific proteins.

Figure 1.2.6.1 *The Macronutrients: Carbohydrates, Lipids, Protein, and Water.*



Macronutrients and the food they come from.

Water

There is one other nutrient that we must have in large quantities: water. Water does not contain carbon, but is composed of two hydrogens and one oxygen per molecule of water.

More than 60 percent of your total body weight is water. Without it, nothing could be transported in or out of the body, chemical reactions would not occur, organs would not be cushioned, and body temperature would fluctuate widely.

On average, an adult consumes just over two liters of water per day from food and drink combined. Since water is so critical for life's basic processes, the amount of water input and output is supremely important.

Micronutrients

Micronutrients are nutrients required by the body in lesser amounts, but are still essential for carrying out bodily functions. Micronutrients include all the essential minerals and vitamins. There are sixteen essential minerals and thirteen vitamins (see Table 1.2.6.1 "Minerals and Their Major Functions" and Table 1.2.6.2 "Vitamins and Their Major Functions" for a complete list and their major functions).

In contrast to carbohydrates, lipids, and proteins, micronutrients are not sources of energy (calories), but they assist in the process as cofactors or components of enzymes (i.e., coenzymes). Enzymes are proteins that catalyze chemical reactions in the body and are involved in all aspects of body functions from producing energy, to digesting nutrients, to building macromolecules. Micronutrients play many essential roles in the body.

Table 1.2.6.1 *Minerals and Their Major Functions*

Minerals	Major Functions
Macro	
Sodium	Fluid balance, nerve transmission, muscle contraction
Chloride	Fluid balance, stomach acid production
Potassium	Fluid balance, nerve transmission, muscle contraction
Calcium	Bone and teeth health maintenance, nerve transmission, muscle contraction, blood clotting
Phosphorus	Bone and teeth health maintenance, acid-base balance
Magnesium	Protein production, nerve transmission, muscle contraction
Sulfur	Protein production
Trace	
Iron	Carries oxygen, assists in energy production
Zinc	Protein and DNA production, wound healing, growth, immune system function
Iodine	Thyroid hormone production, growth, metabolism
Selenium	Antioxidant
Copper	Coenzyme, iron metabolism
Manganese	Coenzyme
Fluoride	Bone and teeth health maintenance, tooth decay prevention
Chromium	Assists insulin in glucose metabolism
Molybdenum	Coenzyme

Note: We consume numerous minerals, each of which has a unique function.

Minerals

Minerals are solid inorganic substances that form crystals and are classified depending on how much of them we need. Trace minerals, such as molybdenum, selenium, zinc, iron, and iodine, are only required in a few milligrams or less. Macrominerals, such as calcium, magnesium, potassium, sodium, and phosphorus, are required in hundreds of milligrams.

Many minerals are critical for enzyme function, others are used to maintain fluid balance, build bone tissue, synthesize hormones, transmit nerve impulses, contract and relax muscles, and protect against harmful free radicals in the body that can cause health problems such as cancer.

Vitamins

The thirteen vitamins are categorized as either water-soluble or fat-soluble. The water-soluble vitamins are vitamin C and all the B vitamins, which include thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folate and cobalamin. The fat-soluble vitamins are A, D, E, and K.

Vitamins are required to perform many functions in the body such as making red blood cells, synthesizing bone tissue, and playing a role in normal vision, nervous system function, and immune system function.

Table 1.2.6.2 *Vitamins and Their Major Functions*

Vitamins	Major Functions
Water-soluble	
Thiamin (B1)	Coenzyme, energy metabolism assistance
Riboflavin (B2)	Coenzyme, energy metabolism assistance
Niacin (B3)	Coenzyme, energy metabolism assistance
Pantothenic acid (B5)	Coenzyme, energy metabolism assistance
Pyridoxine (B6)	Coenzyme, amino acid synthesis assistance
Biotin (B7)	Coenzyme, amino acid and fatty acid metabolism
Folate (B9)	Coenzyme, essential for growth
Cobalamin (B12)	Coenzyme, red blood cell synthesis
C (ascorbic acid)	Collagen synthesis, antioxidant
Fat-soluble	
A	Vision, reproduction, immune system function
D	Bone and teeth health maintenance, immune system function
E	Antioxidant, cell membrane protection
K	Bone and teeth health maintenance, blood clotting

Note: We consume numerous vitamins, all of which have unique functions.

Vitamin deficiencies can cause severe health problems and even death. For example, a deficiency in niacin causes a disease called pellagra, which was common in the early twentieth century in some parts of America. The common signs and symptoms of pellagra are known as the "4D's—diarrhea, dermatitis, dementia, and death." Until scientists found out that better diets relieved the signs and symptoms of pellagra, many people with the disease ended up hospitalized in insane asylums awaiting death. Other vitamins were also found to prevent certain disorders and diseases such as scurvy (vitamin C), night blindness (vitamin A), and rickets (vitamin D).

Table 1.2.6.3 *Functions of Nutrients*

Protein	Necessary for tissue formation, cell reparation, and hormone and enzyme production. It is essential for building strong muscles and a healthy immune system.
Carbohydrates	Provide a ready source of energy for the body and provide structural constituents for the formation of cells.
Fat	Provides stored energy for the body, functions as structural components of cells and also as signaling molecules for proper cellular communication. It provides insulation to vital organs and works to maintain body temperature.
Vitamins	Regulate body processes and promote normal body-system functions.
Minerals	Regulate body processes, are necessary for proper cellular function, and comprise body tissue.
Water	Transports essential nutrients to all body parts, transports waste products for disposal, and aids with body temperature maintenance.

Note: Each nutrient has specific functions in the body.

One measurement of food quality is the amount of nutrients it contains relative to the amount of energy it provides. High-quality foods are nutrient dense, meaning they contain significant amounts of one or more essential nutrients relative to the amount of calories they provide. Nutrient-dense foods are the opposite of "empty-calorie" foods such as carbonated sugary soft drinks, which provide many calories and very little, if any, other nutrients. Food quality is additionally associated with its taste, texture, appearance, microbial content, and how much consumers like it.

Food: A Better Source of Nutrients

It is better to get all your micronutrients from the foods you eat as opposed to from supplements. Supplements contain only what is listed on the label, but foods contain many more macronutrients, micronutrients, and other chemicals, like antioxidants, that benefit health. While vitamins, multivitamins, and supplements are a $20 billion industry in the United States, and more than 50 percent of Americans purchase and use them daily, there is no consistent evidence that they are better than food in promoting health and preventing disease.

Everyday Connection

Make a list of some of your favorite foods and visit the "What's In the Foods You Eat?" search tool provided by the USDA. What are some of the nutrients found in your favorite foods?

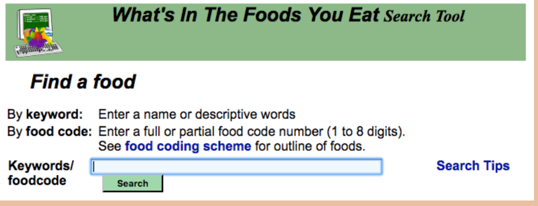


Image by David De Veroli on unsplash.com / CC0

1.2.7. Units of Measure

The Metric and U.S. Customary Systems

In nutrition, there are two systems of commonly used measurements: metric and U.S. customary. We need both because the U.S. won't adopt the metric system completely.

These are commonly used prefixes for the metric system:

Micro- (μ)	1/1,000,000th (one millionth)
Milli- (m)	1/1000th (one thousandth)
Centi- (c)	1/100th (one hundredth)
Deci- (d)	1/10th (one tenth)
Kilo- (k)	1000x (one thousand times)

Mass

Metric system	U.S. customary system	Conversions
Microgram (µg)	Ounce (oz)	1 oz = 28.35 g
Milligram (mg)	Pound (lb)	1 lb = 16 oz
Gram (g)		1 lb = 454 g
Kilogram (kg)		1 kg = 2.2 lbs

Volume

Metric system	U.S. customary system	Conversions
Milliliter (mL)	Teaspoon (tsp)	1 tsp = 5 mL
Deciliter (dL)	Tablespoon (tbsp)	1 tbsp = 3 tsp = 15 mL
Liter (L)	Fluid ounce (fl oz)	1 fl oz = 2 tbsp = 30 mL
	Cup (c)	1 c = 8 fl oz = 237 mL
	Pint (pt)	1 pt = 2 c = 16 fl oz
	Quart (qt)	1 qt = 4 c = 32 fl oz = 0.95 L
	Gallon (gal) = 4 qt	1 gal = 4 qt

Length

Metric system	U.S. customary system	Conversions
Millimeter (mm)	Inch (in)	1 in = 25.4 mm
Centimeter (cm)	Foot (ft)	1 ft= 30.5 cm
Meter (m)	Yard (yd)	1 yd = 0.9 m
Kilometer (km)	Mile (mi)	1 mi = 1.6 km

1.2.8. Test Your Knowledge

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1.3. NUTRITION: MORE ABOUT NUTRIENTS

1.3.1. Choosing Healthy Carbohydrates and Whole Grains

Glycemic Index

The glycemic responses of various foods have been measured and then ranked in comparison to a reference food, usually a slice of white bread or just straight glucose, to create a numeric value called the glycemic index (GI). Foods that have a low GI do not raise blood-glucose levels neither as much nor as fast as foods that have a higher GI. A diet of low-GI foods has been shown in epidemiological and clinical trial studies to increase weight loss and reduce the risk of obesity, Type 2 diabetes, and cardiovascular disease.[1]

Table 1.3.1.1. *The Glycemic Index: Foods in Comparison To Glucose*

1. Brand-Miller J, et al. Dietary Glycemic Index: Health Implications. J Am Coll Nutr. 2009; 28(4), 446S–49S. https://www.ncbi.nlm.nih.gov/pubmed/20234031. Accessed September 27, 2017.

Foods	GI Value
Low GI Foods (< 55)	
Apple, raw	36
Orange, raw	43
Banana, raw	51
Mango, raw	51
Carrots, boiled	39
Taro, boiled	53
Corn tortilla	46
Spaghetti (whole wheat)	37
Baked beans	48
Soy milk	34
Skim milk	37
Whole milk	39
Yogurt, fruit	41
Yogurt, plain	14
Icecream	51
Medium GI Foods (56–69)	
Pineapple, raw	59
Cantaloupe	65
Mashed potatoes	70
Whole-wheat bread	69
Brown rice	55
Cheese pizza	60
Sweet potato, boiled	63
Macaroni and cheese	64
Popcorn	65
High GI Foods (70 and higher)	
Banana (over-ripe)	82
Corn chips	72

Pretzels	83
White bread	70
White rice	72
Bagel	72
Rice milk	86
Cheerios	74
Raisin Bran	73
Fruit roll-up	99
Gatorade	78

Note: Foods can be examined in terms of the glycemic index to determine what their glucose content is. Foods high on the glycemic index are high in glucose whereas foods low on the glycemic index are low in glucose.

For the Glycemic Index on different foods, visit http://www.mendosa.com/gilists.htm.

The type of carbohydrate within a food affects the GI along with its fat and fiber content. Increased fat and fiber in foods increases the time required for digestion and delays the rate of gastric emptying into the small intestine which, ultimately reduces the GI. Processing and cooking also affects a food's GI by increasing their digestibility. Advancements in the technologies of food processing and the high consumer demand for convenient, precooked foods in the United States has created foods that are digested and absorbed more rapidly, independent of the fiber content. Modern breakfast cereals, breads, pastas, and many prepared foods have a high GI. In contrast, most raw foods have a lower GI. (However, the more ripened a fruit or vegetable is, the higher its GI.)

The GI can be used as a guide for choosing healthier carbohydrate choices but has some limitations:

1. GI does not take into account the amount of carbohydrates in a portion of food, only the type of carbohydrate.
2. Combining low- and high-GI foods changes the GI for the

meal.
3. Some nutrient-dense foods have higher GIs than less nutritious food. (For instance, oatmeal has a higher GI than chocolate because the fat content of chocolate is higher.)
4. Meats and fats do not have a GI since they do not contain carbohydrates.

More Resources

Visit this online database to discover the glycemic indices of foods. Foods are listed by category and also by low, medium, or high glycemic index.
http://www.gilisting.com/

The Functions of Carbohydrates in the Body

There are **five primary functions of carbohydrates** in the human body:

- energy production
- energy storage
- sparing protein
- assisting in lipid metabolism

Energy Production

The primary role of carbohydrates is to supply energy to all cells in the body. Many cells prefer glucose as a source of energy versus other compounds like fatty acids. Some cells, such as red blood cells, are only able to produce cellular energy from glucose. The brain is also highly sensitive to low blood-glucose levels because it uses only glucose to produce energy and function (unless under extreme starvation conditions). About 70 percent of the glucose entering the body from digestion is redistributed (by the liver) back into the blood for use by other tissues. Cells that require energy remove the glucose from the blood with a transport protein in their membranes.

Energy Storage

If the body already has enough energy to support its functions, the excess glucose is stored as glycogen (the majority of which is stored in the muscles and liver). A molecule of glycogen may contain in excess of fifty thousand single glucose units and is highly branched, allowing for the rapid dissemination of glucose when it is needed to make cellular energy.

Prolonged muscle use (such as exercise for longer than a few hours) can deplete the glycogen energy reserve. Remember that this is referred to as "hitting the wall" or "bonking" and is characterized by fatigue and a decrease in exercise performance. The weakening of muscles sets in because it takes longer to transform the chemical energy in fatty acids and proteins to usable energy than glucose. After prolonged exercise, glycogen is gone and muscles must rely more on lipids and proteins as an energy source. Athletes can increase their glycogen reserve modestly by reducing training intensity and increasing their carbohydrate intake to between 60 and 70 percent of total calories three to five days prior to an event. People who are not hardcore training and choose to run a 5-kilometer race for fun do not need to consume a big plate of pasta prior to a race since without long-term intense training the adaptation of increased muscle glycogen will not happen.

The liver, like muscle, can store glucose energy as a glycogen, but in contrast to muscle tissue it will sacrifice its stored glucose energy to other tissues in the body when blood glucose is low. Approximately one-quarter of total body glycogen content is in the liver (which is equivalent to about a four-hour supply of glucose) but this is highly dependent on activity level. The liver uses this glycogen reserve as a way to keep blood-glucose levels within a narrow range between meal times. When the liver's glycogen supply is exhausted, glucose is made from amino acids obtained from the destruction of proteins in order to maintain metabolic homeostasis.

Sparing Protein

In a situation where there is not enough glucose to meet the body's needs, glucose is synthesized from amino acids. Because there is no storage molecule of amino acids, this process requires the destruction of proteins, primarily from muscle tissue. The presence of adequate glucose basically spares the breakdown of proteins from being used to make glucose needed by the body.

Lipid Metabolism

As blood-glucose levels rise, the use of lipids as an energy source is inhibited. Thus, glucose additionally has a "fat-sparing" effect. This is because an increase in blood glucose stimulates release of the hormone insulin, which tells cells to use glucose (instead of lipids) to make energy. Adequate glucose levels in the blood also prevent the development of ketosis. Ketosis is a metabolic condition resulting from an elevation of ketone bodies in the blood. Ketone bodies are an alternative energy source that cells can use when glucose supply is insufficient, such as during fasting.

Carbohydrates are critical to support life's most basic function—the production of energy. Without energy none of the other life processes are performed. Although our bodies can synthesize glucose it comes at the cost of protein destruction. As with all nutrients though, carbohydrates are to be consumed in moderation as having too much or too little in the diet may lead to health problems.

Health Consequences and Benefits of High-Carbohydrate Diets

The Food and Nutrition Board of the Institute of Medicine (IOM) defines added sugars as "sugars and syrups that are added to foods during processing or preparation." The IOM goes on to state, "Major sources of added sugars include soft drinks, sports drinks, cakes, cookies, pies, fruitades, fruit punch, dairy desserts, and candy." Processed foods, even microwaveable dinners, also contain added sugars. Added sugars do not include sugars that occur naturally in whole foods (such as an apple), but do include natural sugars such as brown sugar, corn syrup, dextrose, fructose, fruit juice concentrates, maple syrup, sucrose, and raw sugar that are then added to create other foods (such as cookies).

Do Low-Carbohydrate Diets Affect Health?

Since the early 1990s, marketers of low-carbohydrate diets have bombarded us with the idea that eating fewer carbohydrates promotes weight loss and that these diets are superior to others in their effects on weight loss and overall health. The most famous of these low-carbohydrate diets is the Atkins diet. Others include the "South Beach" diet, the "Zone" diet, and the "Earth" diet. Despite the claims these diets make, **there is little scientific evidence to support that low-carbohydrate diets are significantly better than other diets in promoting long-term weight loss.** A study in The Nutritional Journal concluded that all diets, (independent of carbohydrate, fat, and protein content) that incorporated an exercise regimen significantly decreased weight and waist circumference in obese women.[2]

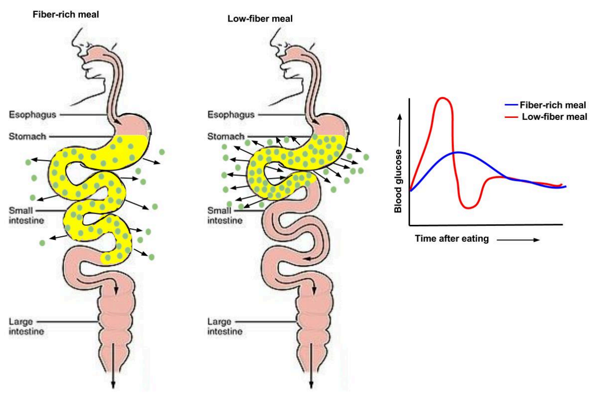
Some studies do provide evidence that in comparison to other diets, low-carbohydrate diets improve insulin levels and other risk factors for Type 2 diabetes and cardiovascular disease. The overall scientific consensus is that consuming fewer calories in a balanced diet will promote health and stimulate weight loss, with significantly better results achieved when combined with regular exercise.

2. Kerksick CM, et al. Changes in Weight Loss, Body Composition, and Cardiovascular Disease Risk after Altering Macronutrient Distributions During a Regular Exercise Program in Obese Women. J Nutr. 2010; 9(59). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3000832/. Accessed September 27, 2017.

Health Benefits of Whole Grains in the Diet

While excessive consumption of simple carbohydrates is potentially bad for your health, consuming more complex carbohydrates is extremely beneficial to health. There is a wealth of scientific evidence supporting that replacing refined grains with whole grains decreases the risk for obesity, Type 2 diabetes, and cardiovascular disease. Whole grains are great dietary sources of fiber, vitamins, minerals, healthy fats, and a vast amount of beneficial plant chemicals, all of which contribute to the effects of whole grains on health. Eating a high-fiber meal as compared to a low-fiber meal (see Figure 1.3.1.1. "Fiber's Role in Carbohydrate Digestion and Absorption") can significantly slow down the absorption process therefore affecting blood glucose levels.

Figure 1.3.1.1. *Fiber's Role in Carbohydrate Digestion and Absorption.*



Fiber slows the absorption of foods resulting in a lower spike in blood glucose following a meal. Source: image by Allison Calabrese / [CC BY 4.0]

Fiber slows the absorption of foods resulting in a lower spike in blood glucose following a meal.

Dietary Sources of Carbohydrates

Carbohydrates are contained in all five food groups: grains, fruits, vegetables, meats, beans (only in some processed meats and beans), and dairy products. Fast-releasing carbohydrates are more prevalent in fruits, fruit juices, and dairy products, while slow-releasing carbohydrates are more plentiful in starchy vegetables, beans, and whole grains. Fast-releasing carbohydrates are also found in large amounts in processed foods, soft drinks, and sweets. On average, a serving of fruits, whole grains, or starches contains 15 grams of carbohydrates. A serving of dairy contains about 12 grams of carbohydrates, and a serving of vegetables contains about 5 grams of carbohydrates. Table 1.3.1.2 "Carbohydrates in Foods (Grams/Serving)" gives the specific amounts of carbohydrates, fiber, and added sugar of various foods.

Table 1.3.1.2. *Carbohydrates in Foods (Grams/Serving)*

Foods	Total Carbohydrates	Sugars	Fiber	Added Sugars
Banana	27 (1 medium)	14.40	3.1	0
Lentils	40 (1 c.)	3.50	16.0	0
Snap beans	8.7 (1 c.)	1.60	4.0	0
Green pepper	5.5 (1 medium)	2.90	2.0	0
Corn tortilla	10.7 (1)	0.20	1.5	0
Bread, wheat bran	17.2 (1 slice)	3.50	1.4	3.4
Bread, rye	15.5 (1 slice)	1.20	1.9	1.0
Bagel (plain)	53 (1 medium)	5.30	2.3	4.8
Brownie	36 (1 square)	20.50	1.2	20.0
Oatmeal cookie	22.3 (1 oz.)	12.00	2.0	7.7
Cornflakes	23 (1 c.)	1.50	0.3	1.5
Pretzels	47 (10 twists)	1.30	1.7	0
Popcorn (homemade)	58 (100 g)	0.50	10.0	0
Skim milk	12 (1 c.)	12.00	0	0
Cream (half and half)	0.65 (1 Tbs.)	0.02	0	0
Cream substitute	1.0 (1 tsp.)	1.00	0	1.0
Cheddar cheese	1.3 (1 slice)	0.50	0	0
Yogurt (with fruit)	32.3 (6 oz.)	32.30	0	19.4
Caesar dressing	2.8 (1 Tbs.)	2.80	0	2.4

Source: (1) National Nutrient Database for Standard Reference. US Department of Agriculture. http://www.nal.usda.gov/fnic/foodcomp/search/. Updated December 7, 2011. Accessed September 17, 2017. (2) Database for the Added Sugars Content of Selected Foods. US Department of Agriculture. http://www.nal.usda.gov/fnic/foodcomp/search/. Published February 2006. Accessed September 27, 2017.

It's the Whole Nutrient Package

In choosing dietary sources of carbohydrates the best ones are those that are nutrient dense, meaning they contain more essential nutrients per calorie of energy. In general, **nutrient-dense carbohydrates are minimally processed and include whole-grain breads and cereals, low-fat dairy products, fruits, vegetables, and beans**. In contrast, **empty-calorie carbohydrate foods are highly processed and often contain added sugars and fats**. Soft drinks, cakes, cookies, and candy are examples of empty-calorie carbohydrates. They are sometimes referred to as 'bad carbohydrates,' as they are known to cause health problems when consumed in excess.

There is limited scientific evidence that consuming products with artificial sweeteners decreases weight. In fact, some studies suggest the intense sweetness of these products increases appetite for sweet foods and may lead to increased weight gain. Also, there is very limited evidence that suggests artificial sweeteners lower blood-glucose levels. Additionally, many foods and beverages containing artificial sweeteners and sugar alcohols are still empty-calorie foods (i.e. chewing sugarless gum or drinking diet soda pop) are not going to better your blood-glucose levels or your health.

Health Concerns

The most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion.

Since the introduction of sugar substitutes to the food and beverage markets, the public has expressed concern about their safety. The health concerns of sugar substitutes originally stemmed from scientific studies, which were misinterpreted by both scientists and the public.

Table 1.3.1.3. *Sweeteners*

Sweeteners with trade name	Calories	Source/ origin	Consumer recommendations	Controversial issues	Pr
Aspartame • NutraSweet • Equal	4 kcal/g	Composed of two amino acids (phenylalanine + aspartic acid) + methanol. Two hundred times sweeter than sucrose.	FDA set maximum Acceptable Daily Intakes (ADI):50 mg/kg body weight = 16 12 oz. diet soft drinks for adults. *Cannot be used in products requiring cooking. People with PKU should not consume aspartame.	Children have potential to reach ADI if consuming many beverages, desserts, frozen desserts, and gums containing aspartame routinely.	Be gel de fru
Saccharin • Sweet 'n' Low	0 kcal/g	Discovered in 1878. The basic substance is benzoic sulfinide. Three hundred times sweeter than sucrose.	ADI: 5 mg/kg body weight.*Can be used in cooking.	1970s, high doses of saccharin associated with bladder cancer in laboratory animals. In 1977, FDA proposed banning saccharin from use in food • protest launched by consumer & interest groups • warning label listed on products about saccharin and cancer risk in animals until 2001 when studies concluded that it did not cause cancer in humans	Ge pu sw all be as Lo Sta fou co ph pro

Acesulfame K • Sunnette • Sweet One	0 kcal/g	Discovered in 1967. Composed of an organic salt, potassium (K). Structure is very similar to saccharin's. It passes through the body unchanged which means it does not provide energy. Two hundred times sweeter than sucrose.	ADI: 15 mg/kg body weight. Body cannot digest it.* Can be used in cooking.		Ch po be mi no cre gel pu ins an
Cyclamates • Sugar Twin	0 kcal/g	Thirty times sweeter than sucrose. Discovered in 1937.	No ADI available.	1949, cyclamate approved by FDA for use. Cyclamate was classified as GRAS (Generally Recognized As Safe) until 1970 when it was removed from GRAS status and banned from use in all food and beverage products within the United States on the basis of one study that indicated it caused bladder cancer in rats. Approval still pending for use in the United States since the ban. Canada and other countries use this type of sweetener.	Re as fo fo 195 go

Sucralose • Splenda	1 Splenda packet contains 3.31 calories = 1g	First discovered in 1976. Approved for use in 1998 in the United States and in 1991 in Canada. Derived from sucrose in which three of its hydroxyl (OH) groups are replaced by chlorine (Cl−).Six hundred times sweeter than sugar.	ADI: 5 mg/kg body weight.*Can be used in cooking.		Ge pu sw ba be ge de fro de ca sa dr die su cu rec as rep for an for
Stevioside • Stevia • Sweet Leaf	N/A	Derived from stevia plant found in South America. Stevia rebaudiana leaves.	Classified as GRAS. Considered to be a dietary supplement and approved not as an additive, but as a dietary supplement.	Used sparingly, stevia may do little harm, but FDA could not approve extensive use of this sweetener due to concerns regarding its effect on reproduction, cancer development, and energy metabolism.	So foo a d su
Sucrose • Sugar	~4 kcal/g	Extracted from either sugar beets or sugar cane, which is then purified and crystallized.	It is illegal to sell true raw sugar in the United States because when raw it contains dirt and insect parts, as well as other byproducts. Raw sugar products sold in the United States have actually gone through more than half of the same steps in the refining process as table sugar.	Over-consumption has been linked to several health effects such as tooth decay or dental caries and contributes to increased risk for chronic diseases.	Bis co pie ca cre an pr

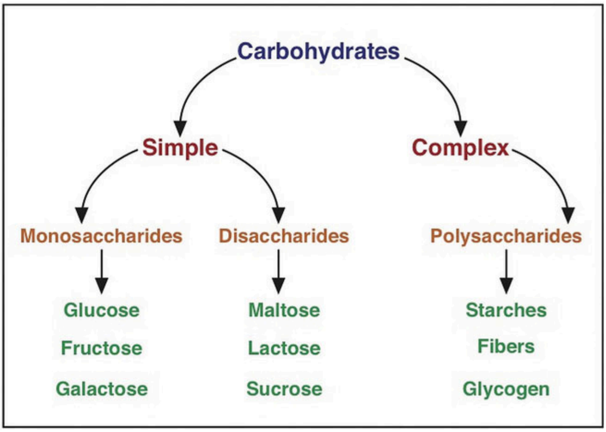
Honey	3 kcal/g	Made from sucrose. Contains nectar of flowering plants. Made by bees. Sucrose is fructose + glucose; however, honey contains more calories than sucrose because honey is denser.	*Considered safe for baking and cooking. Infants under twelve months old should not be given honey because their digestive tracts cannot handle the bacteria found in honey. Older children and adults are immune to these effects. Honey contains some harmful bacteria that can cause fatal food poisoning in infants.		Sw var an su tea be ba
HFCS • high fructose corn syrup	Dry form: 4 kcal/g; Liquid form: 3 kcal/g	Corn is milled to produce corn starch, then the cornstarch is further processed to yield corn syrup.		Controversial because it is found ubiquitously in processed food products, which could lead to overconsumption. Study results are varied regarding its role in chronic disease.	So de ca
Sugar Alcohols • Sorbitol • Xylitol • Mannitol	2–4 kcal/g. Not calorie free	Sugar alcohols. Sorbitol is derived from glucose.	Less likely to cause tooth decay than sucrose. Sugar alcohols have a laxative effect.	May cause diarrhea and gastrointestinal distress if consumed in large amounts.	Pr an in fol su ite jar ch ca ph an pr

Source: Carbohydrates and Personal Diet Choices

1.3.2. More About Carbohydrates

Carbohydrates are the perfect nutrient to meet your body's nutritional needs. They nourish your brain and nervous system, provide energy to all of your cells when within proper caloric limits, and help keep your body fit and lean. Specifically, digestible carbohydrates provide bulk in foods, vitamins, and minerals, while indigestible carbohydrates provide a good amount of fiber with a host of other health benefits. Plants synthesize the fast-releasing carbohydrate, glucose, from carbon dioxide in the air and water, and by harnessing the sun's energy. Recall that plants convert the energy in sunlight to chemical energy in the molecule, glucose. Plants use glucose to make other larger, more slow-releasing carbohydrates. When we eat plants we harvest the energy of glucose to support life's processes.

Figure 1.3.2.1 *Carbohydrate Classification Scheme.*



Carbohydrates are broken down into two subgroups: simple and complex carbohydrates. These subgroups are further categorized as mono-, di-, or polysaccharides. Source: [Carbohydrates]

The simplest unit of a carbohydrate is a monosaccharide. Carbohydrates are broadly classified into two subgroups, **simple** ("fast-releasing") and **complex** ("slow-releasing"). Simple carbohydrates are further grouped into the monosaccharides and disaccharides. Complex carbohydrates are long chains of monosaccharides.

Simple/Fast-Releasing Carbohydrates

Simple carbohydrates are also known more simply as "sugars" and are grouped as either monosaccharides or disaccharides. Monosaccharides include glucose, fructose, and galactose, and the disaccharides include lactose, maltose, and sucrose.

Simple carbohydrates stimulate the sweetness taste sensation, which is the most sensitive of all taste sensations. Even extremely low concentrations of sugars in foods will stimulate the sweetness taste sensation. Sweetness varies between the different carbohydrate types—some are much sweeter than others. Fructose is the top naturally-occurring sugar in sweetness value.

Monosaccharides

For all organisms from bacteria to plants to animals, glucose is the preferred fuel source. **The brain is completely dependent on glucose as its energy source** (except during extreme starvation conditions).

Most absorbed galactose is utilized for energy production in cells after its conversion to glucose. (Galactose is one of two simple sugars that are bound together to make up the sugar found in milk. It is later freed during the digestion process.)

Mostly found in fruits, honey, and sugarcane, fructose is one of the most common monosaccharides in nature. It is also found in soft drinks, cereals, and other products sweetened with high fructose corn syrup.

Lastly, there are the sugar alcohols, which are industrially synthesized derivatives of monosaccharides. Some examples of sugar alcohols are sorbitol, xylitol, and glycerol. (Xylitol is similar in sweetness as table sugar). Sugar alcohols are often used in place of table sugar to sweeten foods as they are incompletely digested and absorbed, and therefore less caloric. The bacteria in your mouth opposes them, hence sugar alcohols do not cause tooth decay. Interestingly, the sensation of "coolness" that occurs when chewing gum that contains sugar alcohols comes from them dissolving in the mouth, a chemical reaction that requires heat from the inside of the mouth.

Disaccharides

Sucrose, which contains both glucose and fructose molecules, is otherwise known as table sugar. Sucrose is also found in many fruits and vegetables, and at high concentrations in sugar beets and sugarcane, which are used to make table sugar.

Lactose, which is commonly known as milk sugar, is composed of one glucose unit and one galactose unit. Lactose is prevalent in dairy products such as milk, yogurt, and cheese.

Maltose consists of two glucose molecules bonded together. It is a common breakdown product of plant starches and is rarely found in foods as a disaccharide.

Complex/Slow-Releasing Carbohydrates

Complex carbohydrates are polysaccharides, long chains of monosaccharides that may be branched or not branched. There are two main groups of polysaccharides: starches and fibers.

Starches

Starch molecules are found in abundance in grains, legumes, and root vegetables, such as potatoes.

Eating raw foods containing starches provides very little energy as the digestive system has a hard time breaking them down. Cooking breaks down the crystal structure of starches, making them much easier to break down in the human body. The starches that remain intact throughout digestion are called resistant starches. Bacteria in the gut can break some of these down and may benefit gastrointestinal health. Isolated and modified starches are used widely in the food industry and during cooking as food thickeners.

Humans and animals store glucose energy from starches in the form of the very large molecule, **glycogen**. It has many branches that allow it to break down quickly when energy is needed by cells in the body. It is predominantly found in liver and muscle tissue in animals.

Dietary Fibers

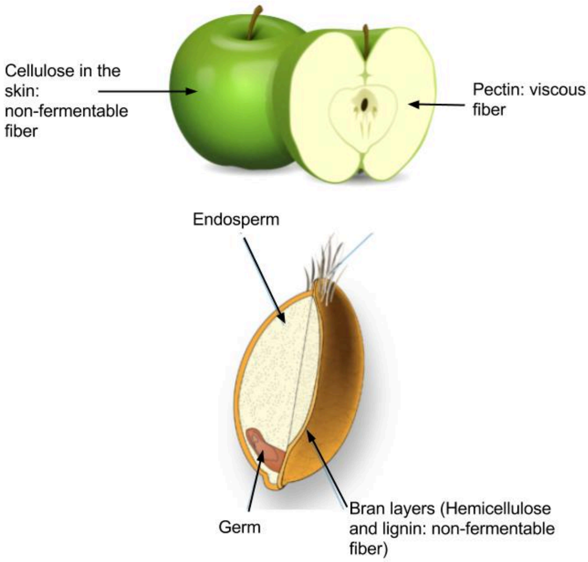
Humans do not produce the enzymes that can break down dietary fiber; however, bacteria in the large intestine (colon) do. Dietary fibers are very beneficial to our health. The Dietary Guidelines Advisory Committee states that there is enough scientific evidence to support that diets high in fiber reduce the risk for obesity and diabetes, which are primary risk factors for cardiovascular disease.[1]

Dietary fiber is categorized as either water-soluble or insoluble. Some examples of soluble fibers are inulin, pectin, and guar gum and they are found in peas, beans, oats, barley, and rye. Cellulose and lignin are insoluble fibers and a few dietary sources of them are whole-grain foods, flax, cauliflower, and avocados. Cellulose is the most abundant fiber in plants, making up the cell walls and providing structure. Soluble fibers are more easily accessible to bacterial enzymes in the large intestine so they can be broken down to a greater extent than insoluble fibers, but even some breakdown of cellulose and other insoluble fibers occurs.

The last class of fiber is functional fiber. **Functional fibers have been added to foods** and have been shown to provide health benefits to humans. **Functional fibers may be extracted from plants and purified or synthetically made**. An example of a functional fiber is psyllium-seed husk. Scientific studies show that consuming psyllium-seed husk reduces blood-cholesterol levels and this health claim has been approved by the FDA. **Total dietary fiber intake is the sum of dietary fiber and functional fiber consumed.**

Figure 1.3.2.2 *Dietary Fiber.*

1. Part D. Section 5: Carbohydrates. In Report of the DGAC on the Dietary Guidelines for Americans, US Department of Agriculture. 2010. http://www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/D-5-Carbohydrates.pdf. Accessed September 30, 2011.



Fiber comes from a variety of sources in the diet. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Digestion and Absorption of Carbohydrates

From the Mouth to the Stomach

The mechanical and chemical digestion of carbohydrates begins in the mouth. Chewing, also known as mastication, crumbles the carbohydrate foods into smaller and smaller pieces. The salivary glands in the oral cavity secrete saliva that coats the food particles. Only about five percent of starches are broken down in the mouth. (This is a good thing as more glucose in the mouth would lead to more tooth decay.) When carbohydrates reach the stomach no further chemical breakdown occurs because the amylase enzyme in saliva does not function in the acidic conditions of the stomach. But mechanical breakdown is ongoing–the strong peristaltic contractions of the stomach mix the carbohydrates into the more uniform mixture of chyme.

From the Stomach to the Small Intestine

The chyme is gradually expelled into the upper part of the small intestine. Upon entry of the chyme into the small intestine, the pancreas releases pancreatic juice through a duct. Once carbohydrates are chemically broken down into single sugar units they are then transported into the inside of intestinal cells.

When people do not have enough of the enzyme lactase, lactose is not sufficiently broken down resulting in a condition called lactose intolerance. The undigested lactose moves to the large intestine where bacteria are able to digest it. The bacterial digestion of lactose produces gases leading to symptoms of diarrhea, bloating, and abdominal cramps. Lactose intolerance usually occurs in adults and is associated with race. The National Digestive Diseases Information Clearing House states that African Americans, Hispanic Americans, American Indians, and Asian Americans have much higher incidences of lactose intolerance while those of northern European descent have the least.[2] Most people with lactose intolerance can tolerate some amount of dairy products in their diet. The severity of the symptoms depends on how much lactose is consumed and the degree of lactase deficiency.

2. Lactose Intolerance. National Digestive Diseases Information Clearing House. http://digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/. Updated April 23, 2012. Accessed September 22, 2017.

Absorption: Going to the Blood Stream

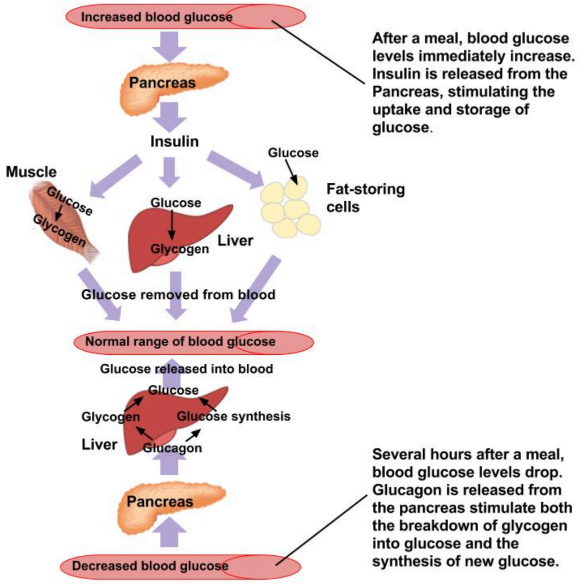
The cells in the **small intestine** have membranes that contain many transport proteins in order to get the monosaccharides and other nutrients into the blood where they can be distributed to the rest of the body. The first organ to receive glucose, fructose, and galactose is the **liver**. The liver takes them up and converts galactose to glucose, breaks fructose into even smaller carbon-containing units, and either stores glucose as glycogen or exports it back to the **blood**. How much glucose the liver exports to the blood is under **hormonal control** and you will soon discover that even the glucose itself regulates its concentrations in the blood.

Maintaining Blood Glucose Levels: The Pancreas and Liver

Glucose levels in the blood are tightly controlled, as having either too much or too little glucose in the blood can have severe health consequences. A glucose thermostat is located within the cells of the pancreas. After eating a meal containing carbohydrates glucose levels rise in the blood.

Insulin-secreting cells in the pancreas sense the increase in blood glucose and release the hormone, insulin, into the blood. Insulin sends a signal to the body's cells to remove glucose from the blood by transporting it into different organ cells around the body and using it to make energy. In the case of muscle tissue and the liver, insulin sends the biological message to store glucose away as glycogen. The presence of insulin in the blood signifies to the body that glucose is available for fuel. As glucose is transported into the cells around the body, the blood glucose levels decrease. Insulin has an opposing hormone called glucagon. Glucagon-secreting cells in the pancreas sense the drop in glucose and, in response, release glucagon into the blood. Glucagon communicates to the cells in the body to stop using all the glucose. More specifically, it signals the liver to break down glycogen and release the stored glucose into the blood, so that glucose levels stay within the target range and all cells get the needed fuel to function properly.

Figure 1.3.2.3 *The Regulation of Glucose.*

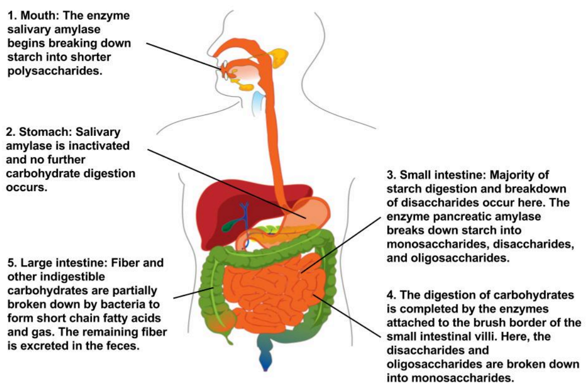


Glucose uptake is regulated in the peripheral organs by insulin, which is secreted by the pancreas. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Leftover Carbohydrates: The Large Intestine

Almost all of the carbohydrates, except for dietary fiber and resistant starches, are efficiently digested and absorbed into the body. Some of the remaining indigestible carbohydrates are broken down by enzymes released by bacteria in the large intestine. The products of bacterial digestion of these slow-releasing carbohydrates are short-chain fatty acids and some gases. The yield of energy from dietary fiber is about 2 kilocalories per gram for humans, but is highly dependent upon the fiber type, with soluble fibers and resistant starches yielding more energy than insoluble fibers. Since dietary fiber is digested much less in the gastrointestinal tract than other carbohydrate types (simple sugars, many starches) the rise in blood glucose after eating them is less, and slower. These physiological attributes of high-fiber foods (i.e. whole grains) are linked to a decrease in weight gain and reduced risk of chronic diseases, such as Type 2 diabetes and cardiovascular disease.

Figure 1.3.2.4 *Overview of Carbohydrate Digestion.*



Carbohydrates are broken down, digested and absorbed at different points in the digestive system. Source: image by Allison Calabrese / [CC BY 4.0]

A Carbohydrate Feast

A typical American Thanksgiving meal contains many foods that are dense in carbohydrates, with the majority of those being simple sugars and starches. These types of carbohydrate foods are **rapidly digested and absorbed**. Blood glucose levels rise quickly causing a spike in insulin levels. Contrastingly, foods containing high amounts of fiber are like **time-release capsules** of sugar. A measurement of the effects of a carbohydrate-containing food on blood-glucose levels is called the **glycemic response**.

1.3.3. Choosing Healthy Fats

Balancing Your Diet With Lipids

You may reason that if some fats are healthier than other fats, why not consume as much healthy fat as desired? Remember, everything in moderation. As we review the established guidelines for daily fat intake, the importance of balancing fat consumption with proper fat sources will be explained.

Identifying Sources of Fat

Population-based studies of North American diets have shown that intake of saturated fat is more excessive than intake of trans fat and cholesterol. Saturated fat is a prominent source of fat for most people as it is so easily found in animal fats, tropical oils such as coconut and palm oil, and full-fat dairy products. Oftentimes the fat in the diet of an average young person comes from foods such as cheese, pizza, cookies, chips, desserts, and animal meats such as chicken, burgers, sausages, and hot dogs. To aim for healthier dietary choices, the American Heart Association (AHA) recommends choosing lean meats and vegetable alternatives, choosing dairy products with low fat content, and minimizing the intake of trans fats. The AHA guidelines also recommend consuming fish, especially oily fish, at least twice per week.[1]

1. Fish and Omega-3 Fatty Acids. American Heart

These more appropriate dietary choices will allow for enjoyment of a wide variety of foods while providing the body with the recommended levels of fat from healthier sources. Evaluate the following sources of fat in your overall dietary pattern:

- **monounsaturated fat:** This type of fat is found in plant oils. Common sources are nuts (almonds, cashews, pecans, peanuts, and walnuts) and nut products, avocados, olive oil, sesame oil, high oleic safflower oil, sunflower oil, and canola oil.
- **polyunsaturated fat:** This type of fat is found mainly in plant-based foods, oils, and fish. Common sources are nuts (walnuts, hazel nuts, pecans, almonds, and peanuts), soybean oil, corn oil, safflower oil, flaxseed oil, canola oil, and fish (trout, herring, and salmon).
- **saturated fat:** This fat is found in animal products, dairy products, palm and coconut oils, and cocoa butter. Limit these products to less than 10 percent of your overall dietary fat consumption.
- **trans fatty acids:** Stick margarines, shortening, fast foods, commercial baked goods, and some snack foods contain trans fats. Limit your consumption of these products to keep trans fats to less than 1 percent of your fat consumption.
- **omega-3 fatty acids (linolenic acid):** Good sources of these are canola oil, flaxseed oil, soybean oil, olive oil, nuts, seeds, whole grains, legumes, and green leafy vegetables.
- **omega-3 fatty acids (DHA and EPA):** Good sources of these are cod liver oil and fish such as tuna, herring, mackerel, salmon, and trout.
- **omega-6 fatty acids (linoleic acid):** Eggs, poultry, most

Association. https://healthyforgood.heart.org/Eat-smart/Articles/Fish-and-Omega-3-Fatty-Acids. Updated March 24, 2017. Accessed October 5, 2017.

vegetable oils, wheat germ oil, whole grains, baked goods, and cereals contain these fatty acids. Omega-6 fatty acids are present abundantly in nuts and seeds such as flaxseeds, sunflower seeds, sesame seeds, and watermelon seeds.

Omega-3 and Omega-6 Fatty Acids

The body requires fatty acids and is adept at synthesizing the majority of these from fat, protein, and carbohydrate. However, when we say essential fatty acid we are referring to the two fatty acids that the body cannot create on its own, namely, linolenic acid and linoleic acid.

Attain the Omega-3 and Omega-6 Balance

As our food choices evolve, the sources of omega-6 fatty acids in our diets are increasing at a much faster rate than sources of omega-3 fatty acids. Omega-3s are plentiful in diets of non-processed foods where grazing animals and foraging chickens roam free, eating grass, clover, alfalfa, and grass-dwelling insects. In contrast, today's western diets are bombarded with sources of omega-6. For example, we have oils derived from seeds and nuts and from the meat of animals that are fed grain. Vegetable oils used in fast-food preparations, most snack-foods, cookies, crackers, and sweet treats are also loaded with omega-6 fatty acids. Also, our bodies synthesize eicosanoids from omega-6 fatty acids and these tend to increase inflammation, blood clotting, and cell proliferation, while the hormones synthesized from omega-3 fatty acids have just the opposite effect.

While omega-6 fatty acids are essential, they can be harmful when they are out of balance with omega-3 fatty acids. Omega-6 fats are required only in small quantities. Researchers believe that when omega-6 fats are out of balance with omega-3 fats in the diet they diminish the effects of omega-3 fats and their benefits. This imbalance may elevate the risks for allergies, arthritis, asthma, coronary heart disease, diabetes, and many types of cancer, autoimmunity, and neurodegenerative diseases, all of which are believed to originate from some form of inflammation in the body.

Lipids and the Food Industry

What is the first thing that comes to mind when you read ingredients such as "partially hydrogenated oil" and "hydrogenated oil" on a food label? Do you think of heart disease, heart health, or atherosclerosis? Most people probably do not. As we uncover what hydrogenation is and why manufacturers use it, you will be better equipped to adhere to healthier dietary choices and promote your heart health.

Hydrogenation: The Good Gone Bad?

Manufacturers favor hydrogenation as a way to prevent oxidation of oils and ensure longer shelf life. Partially hydrogenated vegetable oils are used in the fast food and processed food industries because they impart the desired texture and crispness to baked and fried foods. Partially hydrogenated vegetable oils are more resistant to breakdown from extremely hot cooking temperatures. Because hydrogenated oils have a high smoking point they are very well suited for frying. In addition, processed vegetable oils are cheaper than fats obtained from animal sources, making them a popular choice for the food industry.

Trans fatty acids occur in small amounts in nature, mostly in dairy products. However, the trans fats that are used by the food industry are produced from the hydrogenation process. Trans fats are a result of the partial hydrogenation of unsaturated fatty acids, which cause them to have a trans configuration, rather than the naturally occurring cis configuration.

Health Implications of Trans Fats

No trans fats! Zero trans fats! We see these advertisements on a regular basis. So widespread is the concern over the issue that restaurants, food manufacturers, and even fast-food establishments proudly tout either the absence or the reduction of these fats within their products. Amid the growing awareness that trans fats may not be good for you, let's get right to the heart of the matter. Why are trans fats so bad?

Processing naturally occurring fats to modify their texture from liquid to semisolid and solid forms results in the development of trans fats, which have been linked to an increased risk for heart disease. Trans fats are used in many processed foods such as cookies, cakes, chips, doughnuts, and snack foods to give them their crispy texture and increased shelf life. However, because trans fats can behave like saturated fats, the body processes them as if they were saturated fats. Consuming large amounts of trans fats has been associated with tissue inflammation throughout the body, insulin resistance in some people, weight gain, and digestive troubles. In addition, the hydrogenation process robs the person of the benefits of consuming the original oil because hydrogenation destroys omega-3 and omega-6 fatty acids. The AHA states that, like saturated fats, trans fats raise LDL "bad cholesterol," but unlike saturated fats, trans fats lower HDL "good cholesterol." The AHA advises limiting trans-fat consumption to less than 1 percent.

How can you benefit from this information? When selecting your foods, steer clear of anything that says "hydrogenated," "fractionally hydrogenated," or "partially hydrogenated," and read food labels in the following categories carefully:

- cookies, crackers, cakes, muffins, pie crusts, pizza dough, and breads
- stick margarines and vegetable shortening
- premixed cake mixes, pancake mixes, and drink mixes
- fried foods and hard taco shells
- snack foods (such as chips), candy, and frozen dinners

Choose brands that don't use trans fats and that are low in saturated fats.

Dietary-Fat Substitutes

In response to the rising awareness and concern over the consumption of trans fat, various fat replacers have been developed. Fat substitutes aim to mimic the richness, taste, and smooth feel of fat without the same caloric content as fat. The carbohydrate-based replacers tend to bind water and thus dilute calories. Fat substitutes can also be made from proteins (for example, egg whites and milk whey). However, these are not very stable and are affected by changes in temperature, hence their usefulness is somewhat limited.

Tools for Change

One classic cinnamon roll can have 5 grams of trans fat, which is quite high for a single snack. Many packaged foods often have their nutrient contents listed for a very small serving size—much smaller than what people normally consume—which can easily lead you to eat many "servings." Labeling laws allow foods containing trans fat to be labeled "trans-fat free" if there are fewer than 0.5 grams per serving. This makes it possible to eat too much trans fat when you think you're not eating any at all because it is labeled trans-fat free.

In September of 2018 Canada fully banned the addition of partially hydrogenated oils into foods sold in Canada. This ban was made it attempts to lower Canadian's risk of heart disease.

However other forms of trans fats can still appear in foods. Always review the label for trans fat per serving. Check the ingredient list, especially the first three to four ingredients, for telltale signs of hydrogenated fat. The higher up the words "partially hydrogenated oil" are on the list of ingredients, the more trans fat the product contains.

Measure out one serving and eat one serving only. An even better choice would be to eat a fruit or vegetable. There are no trans fats and the serving size is more reasonable for similar calories. Fruits and vegetables are packed with water, fiber, and many vitamins, minerals, phytonutrients, and antioxidants. At restaurants be aware that phrases such as "cooked in vegetable oil" might mean hydrogenated vegetable oil, and therefore trans fat.

Lipids and Disease

Because heart disease, cancer, and stroke are the three leading causes of death in the United States and Canada, it is critical to address dietary and lifestyle choices that will ultimately decrease risk factors for these diseases. According to the US Department of Health and Human Services (HHS), the following risk factors are controllable: high blood pressure, high cholesterol, cigarette smoking, diabetes, poor diet, physical inactivity, being overweight, and obesity.

In light of that, we present the following informational tips to help you define, evaluate, and implement healthy dietary choices to last a lifetime. The amount and the type of fat that composes a person's dietary profile will have a profound effect upon the way fat and cholesterol is metabolized in the body.

Watch Out for Saturated Fat and Cholesterol

In proper amounts, cholesterol is a compound used by the body to sustain many important body functions. In excess, cholesterol is harmful if it accumulates in the structures of the body's vast network of blood vessels. High blood LDL and low blood HDL are major indicators of blood cholesterol risk. The largest influence on blood cholesterol levels rests in the mix of saturated fat and trans fat in the diet. According to the Harvard School of Public Health, for every extra 2 percent of calories from trans fat consumed per day—about the amount found in a midsize order of French fries at a fast-food establishment—the risk of coronary heart disease increases by 23 percent.[2] A buildup of cholesterol in the blood can lead to brittle blood vessels and a blockage of blood flow to the affected area.

How saturated is the fat in your diet? Is it really necessary to eat saturated fat when the body makes all the saturated fat that it needs? Saturated fats should fall into the "bad" category—the body does not demand this kind of fat and it is proven to be a forerunner of cardiovascular disease. In the United States and other developed

2. Fats and Cholesterol. Harvard T.H. Chan School of Public Health. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/fats-full-story/. Updated 2017. Accessed September 28, 2017.

countries, populations acquire their saturated fat content mostly from meat, seafood, poultry (with skin consumed), and whole-milk dairy products (cheese, milk, and ice cream). Some plant foods are also high in saturated fats, including coconut oil, palm oil, and palm kernel oil.

Food Cholesterol's Effect on Blood Cholesterol

Dietary cholesterol does have a small impact on overall blood cholesterol levels, but not as much as some people may think. Most people display little response to normal dietary cholesterol intake as the body responds by halting its own synthesis of the substance in favor of using the cholesterol obtained through food. Genetic factors may also influence the way a person's body modifies cholesterol. The 2015-2020 US Dietary Guidelines suggest limiting saturated fats, thereby indirectly limiting dietary cholesterol since foods that are high in cholesterol tend to be high in saturated fats also.

A Prelude to Disease

If left unchecked, improper dietary fat consumption can lead down a path to severe health problems. An increased level of lipids, triglycerides, and cholesterol in the blood is called hyperlipidemia. Hyperlipidemia is inclusive of several conditions but more commonly refers to high cholesterol and triglyceride levels. When blood lipid levels are high, any number of adverse health problems may ensue. Consider the following conditions:

- **cardiovascular disease:** According to the AHA, cardiovascular disease encompasses a variety of problems, many of which are related to the process of atherosclerosis. Over time the arteries thicken and harden with plaque buildup, causing restricted or at times low or no blood flow to selected areas of the body.
- **heart attack:** A heart attack happens when blood flow to a section of the heart is cut off due to a blood clot. Many have survived heart attacks and go on to return to their lives and enjoy many more years of life on this earth. However, dietary and lifestyle changes must be implemented to prevent further attacks.
- **ischemic stroke:** The most common type of stroke in the United States, ischemic stroke, occurs when a blood vessel in the brain or leading to the brain becomes blocked, again usually from a blood clot. If part of the brain suffers lack of blood flow and/or oxygen for three minutes or longer, brain cells will start to die.
- **congestive heart failure:** Sometimes referred to as heart failure, this condition indicates that the heart is not pumping blood as well as it should. The heart is still working but it is not meeting the body's demand for blood and oxygen. If left unchecked, it can progress to further levels of malfunction.
- **arrhythmia:** This is an abnormal rhythm of the heart. The heart may beat above one hundred beats per minute (known as tachycardia) or below sixty beats per minute (known as bradycardia), or the beats are not regular. The heart may not be able to pump enough volume of blood to meet the body's needs.
- **heart valve problems:** Stenosis is a condition wherein the heart valves become compromised in their ability to open wide enough to allow proper blood flow. When the heart valves do not close tightly and blood begins to leak between chambers, this is called regurgitation. When valves bulge or prolapse back into the upper chamber, this condition is called mitral valve

prolapse.

- **obesity:** Obesity is defined as the excessive accumulation of body fat. According to US Surgeon General Richard Carmona, obesity is the fastest growing cause of death in America. The HHS reports that the number of adolescents who are overweight has tripled since 1980 and the prevalence of the disease among younger children has doubled.[3]
- **diabetes and heart disease:** Obesity has been linked to increased risks of developing these conditions. To help combat this problem, important dietary changes are necessary. Reducing the type and amount of carbohydrates and sugar consumed daily is critical. Limiting the intake of saturated fats and trans fats, increasing physical activity, and eating fewer calories are all equally important in this fight against obesity.

What You Can Do

Remember that saturated fats are found in large amounts in foods of animal origin. They should be limited within the diet. Polyunsaturated fats are generally obtained from non-animal sources. While they are beneficial for lowering bad cholesterol they also lower good cholesterol. They are better for you than saturated fats but are not to be consumed in excess. Monounsaturated fats

3. Bishop, J. et al. ASPE Research Brief: Childhood Obesity. Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services. May 1, 2005.https://aspe.hhs.gov/basic-report/aspe-childhood-obesity-white-paper. Accessed October 5, 2012.

are of plant origin and are found in most nuts, seeds, seed oils, olive oil, canola oil, and legumes. Monounsaturated fats are excellent because they not only lower bad cholesterol, but also they elevate the good cholesterol. Replace current dietary fats with an increased intake of monounsaturated fats.

Choose whole-grain and high-fiber foods. Reduced risk for cardiovascular disease has been associated with diets that are high in whole grains and fiber. Fiber also slows down cholesterol absorption. The AHA recommends that at least half of daily grain intake should originate from whole grains. The Adequate Intake value for fiber is 14 grams per 1,000 kilocalories. These amounts are based upon the amount of fiber that has been shown to reduce cardiovascular risk.

Do not be sedentary. Get more exercise on a regular basis. Increasing your energy expenditure by just twenty minutes of physical activity at least three times per week will improve your overall health. Physical exercise can help you manage or prevent high blood pressure and blood cholesterol levels. Regular activity raises HDL while at the same time decreases triglycerides and plaque buildup in the arteries. Calories are burned consistently, making it easier to lose and manage weight. Circulation will improve, the body will be better oxygenated, and the heart and blood vessels will function more efficiently.

A Personal Choice About Lipids

A Guide to Making Sense of Dietary Fat

On your next trip to the grocery store prepare yourself to read all food labels carefully and to seriously consider everything that goes into your shopping cart. Create a shopping list and divide your list into columns for “Best,” “Better,” “Good,” “Least Desirable,” and “Infrequent Foods.” As you refine your sense of dietary fat, here are key points to bear in mind.

Shopping for groceries. Don’t be bombarded with gratuitous grams of saturated fats and empty grams of trans fats. Read and decipher food labels carefully so that you know exactly what types of fat a food item contains and how much fat it will contribute to your overall fat intake. For snacks and daily eating, gravitate toward foods that are lowest in or absent of harmful trans fats. Restrict other foods to occasional usage based upon their fat content. For example, if selecting prepared foods, choose the ones without high-fat sauces in favor of adding your own flavorings. If selecting precooked meats, avoid those that are fried, coated, or prepared in high-fat sauces. A popular and healthy precooked meat food choice is the rotisserie chicken that most supermarkets carry. When selecting meats be aware of the need to compare different cuts—notice their fat content, color, and marbling. Higher-fat meats tend to have whiter fat marbled throughout. Choose lean cuts and white meat as these are lower in saturated fat. Always choose plenty of fresh fruits, vegetables, nuts, and seeds, as their phytosterols are a good competitor for cholesterol. Keep a collection of nuts in your freezer that can be added to your salads, stir-fry, one-dish foods, soups, desserts, and yogurts.

Appearance. Saturated and trans fats are not good for you and must be placed in your “Least Desirable” column because they increase cholesterol levels and put you at risk for heart disease. Monounsaturated and polyunsaturated fats are better choices to replace these undesirable fats. The key in identifying the “Best” or “Better” fats from the “Least Desirable” fats while you shop is based upon appearance. When choosing fats remember that saturated fats and trans fats are solid at room temperature; think of butter. Monounsaturated and polyunsaturated fats are liquid at room temperature; think of vegetable oil.

Try to eliminate as much trans fat as possible from your food selections. Avoid commercially baked goods and fast foods. Make these your "Infrequent Foods."

Choose unsaturated fats. Fatty fish, walnuts, flaxseeds, flaxseed oil, and canola oil all have good health benefits and should be on the "Best," "Better," and "Good" fat lists. They each provide essential omega-3 fatty acids necessary for overall body health. To derive the most benefit from including these foods, do not add them to an existing diet full of fat. Use these to replace the "Least Desirable" fats that are being removed from the diet.

Limit saturated fat intake. Reduce red meat consumption, processed meats, and whole-fat dairy products. To reduce full-fat dairy items try their low-fat or nonfat counterparts such as mozzarella cheese.

Low fat does not equal healthy. Remember, a fat-free label does not provide you with a license to consume all the calories you desire. There will be consequences to your weight and your overall health. Common replacements for fat in many fat-free foods are refined carbohydrates, sugar, and calories. Too much of these ingredients can also cause health problems. Choose and consume wisely.

A "better-fat" diet will successfully support weight loss. While cutting "Least Desirable" fat calories are vital to weight loss, remember that "Better" fats are filling and just a handful of nuts can curb an appetite to prevent overeating.

Consume omega-3 fats each day. For optimal health and disease prevention include a moderate serving of fish, walnuts, ground flaxseeds, flaxseed oil, or soybean oil in your diet every day.

How much saturated fat is too much? Your goal is to keep your intake of saturated fat to no more than 10 percent of your total dietary calories on a daily basis. Thus, it is important to learn to reduce the intake of foods high in saturated fat. High-fat foods can be consumed but they must fall within the overall goal for a person's fat allowance for the day.

Home cooking. Limit the use of saturated fats in home preparation of meals. Instead of butter try spreads made from unsaturated oils such as canola or olive oils and the use of cooking sprays. Couple this with the use of herbs and spices to add flavor. Avoid using high-fat meat gravies, cheese, and cream sauces. Limit adding extras to foods such as butter on a baked potato. Use nonfat sour cream instead. Grill, bake, stir-fry, roast, or bake your foods. Never fry in solid fats such as butter or shortening. Marinate foods to be grilled in fruit juices and herbs. Instead of relying upon commercial salad dressings, learn to make your own top-quality dressing from cold-pressed olive oil, flaxseed oil, or sesame oil.

Make sure the fat is flavorful. Adding flavor to food is what makes the eating experience enjoyable. Why not choose unsaturated fats and oils that have strong flavors? In this way you will add good flavor to your meals but use less fat in the process. Some examples are sesame oil, peanut oil, and peanut butter. Replace less flavorful cheeses with small amounts of strongly flavored cheeses such as romano, parmesan, and asiago.

1.3.4. More About Fats

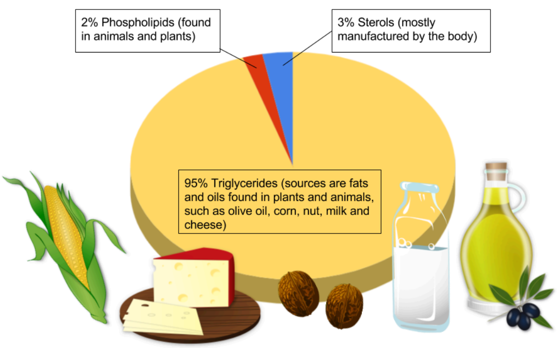
Lipids are important molecules that serve different roles in the human body. A common misconception is that fat is simply fattening. However, fat is probably the reason we are all here. Throughout history, there have been many instances when food was scarce. Our ability to store excess caloric energy as fat for future usage allowed us to continue as a species during these times of famine. So, normal fat reserves are a signal that metabolic processes are efficient and a person is healthy.Lipids are a family of organic compounds that are mostly insoluble in water. Composed of fats and oils, lipids are molecules that yield high energy and have a chemical composition mainly of carbon, hydrogen, and oxygen. Lipids perform three primary biological functions within the body: they serve as **structural components of cell membranes,** function as **energy storehouses**, and function as **important signaling molecules**.

The three main types of lipids are triglycerides, phospholipids, and sterols. Triglycerides make up more than 95 percent of lipids in the diet and are commonly found in fried foods, vegetable oil, butter, whole milk, cheese, cream cheese, and some meats. Naturally occurring triglycerides are found in many foods, including avocados, olives, corn, and nuts. We commonly call the triglycerides in our food "fats" and "oils." Fats are lipids that are solid at room temperature, whereas oils are liquid. As with most fats, triglycerides do not dissolve in water. The terms fats, oils, and triglycerides are discretionary and can be used interchangeably. In this chapter when we use the word fat, we are referring to triglycerides.

Phospholipids make up only about 2 percent of dietary lipids. They are water-soluble and are found in both plants and animals. Phospholipids are crucial for building the protective barrier, or membrane, around your body's cells. In fact, phospholipids are synthesized in the body to form cell and organelle membranes. In blood and body fluids, phospholipids form structures in which fat is enclosed and transported throughout the bloodstream.

Sterols are the least common type of lipid. Cholesterol is perhaps the best well-known sterol. Though cholesterol has a notorious reputation, the body gets only a small amount of its cholesterol through food—the body produces most of it. Cholesterol is an important component of the cell membrane and is required for the synthesis of sex hormones, vitamin D, and bile salts.

Figure 1.3.4.1 *Types of Lipids.*



Lipids can be broken down into three subcategories. Triglycerides are the most common, followed by sterols, then phospholipids. Source: image by Allison Calabrese /

The Functions of Lipids in the Body

Storing Energy

The excess energy from the food we eat is digested and incorporated into adipose tissue, or fatty tissue. Most of the energy required by the human body is provided by carbohydrates and lipids. As discussed in the Carbohydrates chapter, glucose is stored in the body as glycogen. While glycogen provides a ready source of energy, lipids primarily function as an energy reserve. As you may recall, glycogen is quite bulky with heavy water content, thus the body cannot store too much for long. Alternatively, fats are packed together tightly without water and store far greater amounts of energy in a reduced space. A fat gram is densely concentrated with energy—it contains more than double the amount of energy than a gram of carbohydrate. Energy is needed to power the muscles for all the physical work and play an average person or child engages in. For instance, the stored energy in muscles propels an athlete down the track, spurs a dancer's legs to showcase the latest fancy steps, and keeps all the moving parts of the body functioning smoothly.

Unlike other body cells that can store fat in limited supplies, fat cells are specialized for fat storage and are able to expand almost indefinitely in size. An overabundance of adipose tissue can result in undue stress on the body and can be detrimental to your health. A serious impact of excess fat is the accumulation of too much cholesterol in the arterial wall, which can thicken the walls of arteries and lead to cardiovascular disease. Thus, while some body fat is critical to our survival and good health, in large quantities it can be a deterrent to maintaining good health.

Regulating and Signaling

Triglycerides control the body's internal climate, maintaining constant temperature. Those who don't have enough fat in their bodies tend to feel cold sooner, are often fatigued, and have pressure sores on their skin from fatty acid deficiency. Triglycerides also help the body produce and regulate hormones. For example, adipose tissue secretes the hormone leptin, which regulates appetite. In the reproductive system, fatty acids are required for proper reproductive health. Women who lack proper amounts may stop menstruating and become infertile. Omega-3 and omega-6 essential fatty acids help regulate cholesterol and blood clotting and control inflammation in the joints, tissues, and bloodstream. Fats also play important functional roles in sustaining nerve impulse transmission, memory storage, and tissue structure. More specifically in the brain, lipids are focal to brain activity in structure and in function. They help form nerve cell membranes, insulate neurons, and facilitate the signaling of electrical impulses throughout the brain.

Insulating and Protecting

Fat tissue can make up 30% or more of body weight. Some of this is made up of visceral fat or adipose tissue surrounding delicate organs. Vital organs such as the heart, kidneys, and liver are protected by visceral fat. The composition of the brain is outstandingly 60 percent fat, demonstrating the major structural role that fat serves within the body. You may be most familiar with subcutaneous fat, or fat underneath the skin. This blanket layer of tissue insulates the body from extreme temperatures and helps keep the internal climate under control. It pads our hands and buttocks and prevents friction, as these areas frequently come in contact with hard surfaces. It also gives the body the extra padding required when engaging in physically demanding activities such as ice- or roller skating, horseback riding, or snowboarding.

Aiding Digestion and Increasing Bioavailability

The dietary fats in the foods we eat break down in our digestive systems and begin the transport of precious micronutrients. **By carrying fat-soluble nutrients through the digestive process, intestinal absorption is improved. This improved absorption is**

also known as increased bioavailability. Fat-soluble nutrients are especially important for good health and exhibit a variety of functions. Vitamins A, D, E, and K—the fat-soluble vitamins—are mainly found in foods containing fat. Some fat-soluble vitamins (such as vitamin A) are also found in naturally fat-free foods such as green leafy vegetables, carrots, and broccoli. These vitamins are best absorbed when combined with foods containing fat. Fats also increase the bioavailability of compounds known as phytochemicals, which are plant constituents such as lycopene (found in tomatoes) and beta-carotene (found in carrots). Phytochemicals are believed to promote health and well-being. As a result, eating tomatoes with olive oil or salad dressing will facilitate lycopene absorption. Other essential nutrients, such as essential fatty acids, are constituents of the fats themselves and serve as building blocks of a cell.

Figure 1.3.4.2 *Food Sources of Omega 3s*

Tools for Change omega 3 fat sources		
Best	Better	Good
Salmon	Scallops	Halibut
Flax seeds	Cauliflower	Shrimp
Walnuts	Cabbage	Cod
	Cloves	Tuna
	Mustard seeds	Soybeans
		Tofu
		Kale
		Collard greens
		Brussel sprouts

Note that removing the lipid elements from food also takes away the food's fat-soluble vitamin content. When products such as grain and dairy are processed, these essential nutrients are lost. Manufacturers replace these nutrients through a process called enrichment. Foods that have been fortified have undergone an enrichment process. Source: The Functions of Lipids in the Body

The Role of Lipids in Food

High Energy Source

Fat-rich foods naturally have a high caloric density. Foods that are high in fat contain more calories than foods high in protein or carbohydrates. As a result, high-fat foods are a convenient source of energy. For example, **1 gram of fat or oil provides 9 kilocalories of energy, compared with 4 kilocalories found in 1 gram of carbohydrate or protein.** Depending on the level of physical activity and on nutritional needs, fat requirements vary greatly from person to person. When energy needs are high, the body welcomes the high-caloric density of fats. For instance, infants and growing children require proper amounts of fat to support normal growth and development. If an infant or child is given a low-fat diet for an extended period, growth and development will not progress normally. Other individuals with high-energy needs are athletes, people who have physically demanding jobs/ lifestyles, and those recuperating from illness.

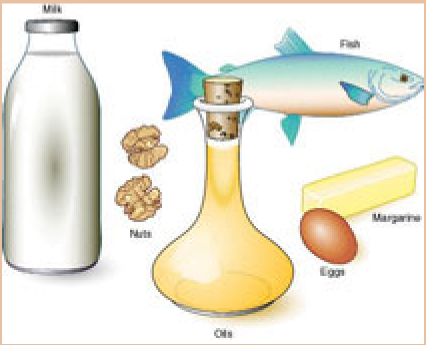
When the body has used all of its calories from carbohydrates (this can occur after just twenty minutes of exercise), it initiates fat usage. A professional swimmer must consume large amounts of food energy to meet the demands of swimming long distances, so eating fat-rich foods makes sense. In contrast, if a person who leads a sedentary lifestyle eats the same high-density fat foods, they will intake more fat calories than their body requires within just a few bites. Use caution—consumption of calories over and beyond energy requirements is a contributing factor to obesity.

Smell and Taste

Fat contains dissolved compounds that contribute to mouth-watering aromas and flavors. Fat also adds texture to food. Baked foods are supple and moist. Frying foods locks in flavor and lessens cooking time. How long does it take you to recall the smell of your favorite food cooking? What would a meal be without that savory aroma to delight your senses and heighten your preparedness for eating a meal?

Fat plays another valuable role in nutrition. Fat contributes to satiety, or the sensation of fullness. When fatty foods are swallowed the body responds by enabling the processes controlling digestion to retard the movement of food along the digestive tract, thus promoting an overall sense of fullness. Oftentimes before the feeling of fullness arrives, people overindulge in fat-rich foods, finding the delectable taste irresistible. Indeed, the very things that make fat-rich foods attractive also make them a hindrance to maintaining a healthful diet.

Tools for Change



Source: [The Role of Lipids in Food]

There are many sources of omega-3 foods.

It is important to strike a proper balance between omega-3 and omega-6 fats in your diet. Research suggests that a diet that is too high in omega-6 fats distorts the balance of proinflammatory agents, promoting chronic inflammation and causing the potential for health problems such as asthma, arthritis, allergies, or diabetes. Omega-6 fats compete with omega-3 fats for enzymes and will actually replace omega-3 fats. The typical western diet is characterized by an excessive consumption of foods high in omega-6 fatty acids. To gain proper balance between the two, increase your omega-3 fat intake by eating more fatty fish or other sources of omega-3 fatty acids at least two times per week.

Degrees of Saturation

Fatty acid chains are held together by carbon atoms that attach to each other and to hydrogen atoms.

Foods that have a high percentage of saturated fatty acids tend to be solid at room temperature. Examples of these are fats found in chocolate and meat. Foods rich in unsaturated fatty acids, such as olive oil tend to be liquid at room temperature. Flaxseed oil is rich in alpha-linolenic acid, which is an unsaturated fatty acid and becomes a thin liquid at room temperature.

If you decide to limit or redirect your intake of fat products, then choosing unsaturated fat is more beneficial than choosing a saturated fat. This choice is easy enough to make because unsaturated fats tend to be liquid at room temperature (for example, olive oil) whereas saturated fats tend to be solid at room temperature (for example, butter). Avocados are rich in unsaturated fats. Most vegetable and fish oils contain high quantities of polyunsaturated fats. Olive oil and canola oil are also rich in monounsaturated fats.

Conversely, tropical oils are an exception to this rule in that they are liquid at room temperature yet high in saturated fat. Palm oil (often used in food processing) is highly saturated and has been proven to raise blood cholesterol. Shortening, margarine, and commercially prepared products (in general) report to use only vegetable-derived fats in their processing. But even so, much of the fat they use may be in the saturated and trans fat categories.

Trans Fatty Acids

Hydrogenation is the process of adding hydrogen to the carbon double bonds, thus making the fatty acid saturated (or less unsaturated, in the case of partial hydrogenation). This is how vegetable oils are converted into semisolid fats for use in the manufacturing process.

According to the ongoing Harvard Nurses' Health Study, trans fatty acids have been associated with increased risk for coronary heart disease because of the way they negatively impact blood cholesterol levels.[1]

Interestingly, some naturally occurring trans fats do not pose

1. Introduction to "Fats and Cholesterol. Harvard T.H. Chan School of Public Health. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/fats-full-story/#references. Updated 2017. Accessed September 28, 2017.

the same health risks as their artificially engineered counterparts. These trans fats are found in ruminant animals such as cows, sheep, and goats, resulting in trans fatty acids being present in our meat, milk, and other dairy product supply. Reports from the US Department of Agriculture (USDA) indicate that these trans fats comprise 15 to 20 percent of the total trans-fat intake in our diet. While we know that trans fats are not exactly harmless, it seems that any negative effect naturally occurring trans fats have are counteracted by the presence of other fatty acid molecules in these animal products, which work to promote human health.

Nonessential and Essential Fatty Acids

Fatty acids are vital for the normal operation of all body systems. The circulatory system, respiratory system, immune system, brain, skin and other organs require fatty acids for proper function. The body is capable of synthesizing most of the fatty acids it needs from food. These fatty acids are known as nonessential fatty acids. However, there are some fatty acids that the body cannot synthesize and these are called essential fatty acids. It is important to note that **nonessential fatty acids doesn't mean unimportant; the classification is based solely on the ability of the body to synthesize the fatty acid.**

Essential fatty acids must be obtained from food. They fall into two categories—**omega-3** and **omega-6**. The 3 and 6 refer to the position of the first carbon double bond and the omega refers to the methyl end of the chain. Omega-3 and omega-6 fatty acids are precursors to important compounds called eicosanoids. Eicosanoids are powerful hormones that control many other hormones and important body functions, such as the central nervous system and the immune system. Eicosanoids derived from omega-6 fatty acids are known to increase blood pressure, immune response, and inflammation. In contrast, eicosanoids derived from omega-3 fatty acids are known to have heart-healthy effects. Given the contrasting effects of the omega-3 and omega-6 fatty acids, a proper dietary balance between the two must be achieved to ensure optimal health benefits.

Essential fatty acids play an important role in the life and death of cardiac cells, immune system function, and blood pressure regulation. Docosahexaenoic acid (DHA) is an omega-3 essential fatty acid shown to play important roles in synaptic transmission in the brain during fetal development.

Some excellent sources of omega-3 and omega-6 essential fatty acids are fish, flaxseed oil, hemp, walnuts, and leafy vegetables. Because these essential fatty acids are easily accessible, essential fatty acid deficiency is extremely rare.

Fatty Acid Types in the Body

The fatty-acid profile of the diet directly correlates to the tissue lipid profile of the body. It may not solely be the quantity of dietary fat that matters. More directly, the type of dietary fat ingested has been shown to affect body weight, composition, and metabolism. The fatty acids consumed are often incorporated into the triglycerides within the body. Evidence confirms that saturated fatty acids are linked to higher rates of weight retention when compared to other types of fatty acids. Alternatively, the fatty acids found in fish oil are proven to reduce the rate of weight gain as compared to other fatty acids.[2]

Phospholipids

In the body phospholipids bind together to form cell membranes. Phospholipids are ideal emulsifiers that can keep oil and water mixed. Emulsions are mixtures of two liquids that do not mix. Without emulsifiers, the fat and water content would be somewhat separate within food. Lecithin (phosphatidylcholine), found in egg yolk, honey, and mustard, is a popular food emulsifier. Mayonnaise demonstrates lecithin's ability to blend vinegar and oil to create the stable, spreadable condiment that so many enjoy. Food emulsifiers play an important role in making the appearance of food appetizing. Adding emulsifiers to sauces and creams not only enhances their appearance but also increases their freshness.

Lecithin's crucial role within the body is clear, because it is present in every cell throughout the body; 28 percent of brain matter is composed of lecithin and 66 percent of the fat in the liver is lecithin. Many people attribute health-promoting properties to

2. Mori T et al. Dietary fish oil upregulates intestinal lipid metabolism and reduces body weight gain in C57BL/6J mice. The Journal of Nutrition. 2007; 137(12), 2629-34. http://www.ncbi.nlm.nih.gov/pubmed/18029475. Accessed September 22, 2017.

lecithin, such as its ability to lower blood cholesterol and aid with weight loss. There are several lecithin supplements on the market broadcasting these claims. However, as the body can make most phospholipids, it is not necessary to consume them in a pill. The body is capable of making all of the lecithin that it needs.

Sterols

Sterols have a very different structure from triglycerides and phospholipids.

Cholesterol is the best-known sterol because of its role in heart disease. It forms a large part of the plaque that narrows the arteries in atherosclerosis. In stark contrast, cholesterol does have specific beneficial functions to perform in the body. Like phospholipids, cholesterol is present in all body cells as it is an important substance in cell membrane structure. Approximately 25 percent of cholesterol in the body is localized in brain tissue. Cholesterol is used in the body to make a number of important things, including vitamin D, glucocorticoids, and the sex hormones, progesterone, testosterone, and estrogens. Notably, the sterols found in plants resemble cholesterol in structure. However, plant sterols inhibit cholesterol absorption in the human body, which can contribute to lower cholesterol levels.

Although cholesterol is preceded by its infamous reputation, it is clearly a vital substance in the body that poses a concern only when there is excess accumulation of it in the blood. Like lecithin, the body can synthesize cholesterol.

Digestion and Absorption of Lipids

Lipids are large molecules and generally are not water-soluble. Like carbohydrates and protein, lipids are broken into small components for absorption. Since most of our digestive enzymes are water-based, how does the body break down fat and make it available for the various functions it must perform in the human body?

From the Mouth to the Stomach

The first step in the digestion of triglycerides and phospholipids begins in the mouth as lipids encounter saliva. Next, the physical action of chewing coupled with the action of emulsifiers enables the digestive enzymes to do their tasks. These actions cause the fats to become more accessible to the digestive enzymes. As a result, the fats become tiny droplets and separate from the watery components.

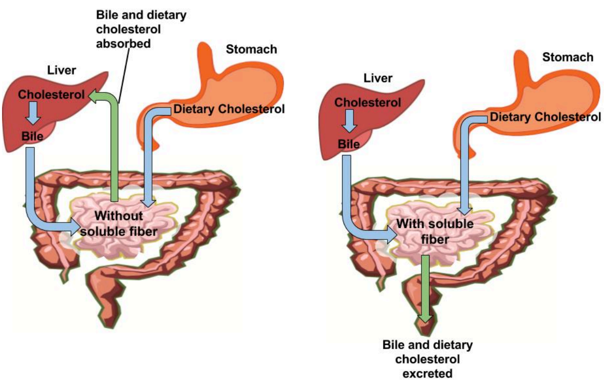
The stomach's churning and contractions help to disperse the fat molecules, while the diglycerides derived in this process act as further emulsifiers. However, even amid all of this activity, very little fat digestion occurs in the stomach.

Going to the Bloodstream

As stomach contents enter the small intestine, the digestive system sets out to manage a small hurdle, namely, to combine the separated fats with its own watery fluids. The solution to this hurdle is bile. **Bile** contains bile salts, lecithin, and substances derived from cholesterol so it acts as an emulsifier. It attracts and holds onto fat while it is simultaneously attracted to and held on to by water. Emulsification increases the surface area of lipids over a thousand-fold, making them more accessible to the digestive enzymes.

Cholesterols are poorly absorbed when compared to phospholipids and triglycerides. Cholesterol absorption is aided by an increase in dietary fat components and is hindered by high fiber content. This is the reason that **a high intake of fiber is recommended to decrease blood cholesterol**. Foods high in fiber such as fresh fruits, vegetables, and oats can bind bile salts and cholesterol, preventing their absorption and carrying them out of the colon.

Figure 1.3.4.3 *Cholesterol and Soluble Fiber*



Bile and dietary cholesterol can either be absorbed by the liver or excreted. Source: image by Allison Calabrese / [CC BY 4.0]

Storing and Using Body Fat

Before the prepackaged food industry, fitness centers, and weight-loss programs, our ancestors worked hard to even locate a meal. They made plans, not for losing those last ten pounds to fit into a bathing suit for vacation, but rather for finding food. Today, this is why we can go long periods without eating, whether we are sick with a vanished appetite, our physical activity level has increased, or there is simply no food available. Our bodies reserve fuel for a rainy day.

One way the body stores fat was previously touched upon in the Carbohydrates chapter. The body transforms carbohydrates into glycogen that is in turn stored in the muscles for energy. When the muscles reach their capacity for glycogen storage, the excess is returned to the liver, where it is converted into triglycerides and then stored as fat.

In a similar manner, much of the triglycerides the body receives from food is transported to fat storehouses within the body if not used for producing energy.

Muscle cells may also take up the fatty acids and use them for muscular work and generating energy. When a person's energy requirements exceed the amount of available fuel presented from a recent meal or extended physical activity has exhausted glycogen energy reserves, fat reserves are retrieved for energy utilization.

Understanding Blood Cholesterol

You may have heard of the abbreviations LDL and HDL with respect to heart health. These abbreviations refer to low-density lipoprotein (LDL) and high-density lipoprotein (HDL), respectively. Lipoproteins are characterized by size, density, and composition. As the size of the lipoprotein increases, the density decreases. This means that HDL is smaller than LDL. Why are they referred to as "good" and "bad" cholesterol? What should you know about these lipoproteins?

Major Lipoproteins

LDLs. As low-density lipoproteins are commonly known as the "bad cholesterol" it is imperative that we understand their function in the body so as to make healthy dietary and lifestyle choices. LDLs carry cholesterol and other lipids from the liver to tissue throughout the body. LDLs are comprised of very small amounts of triglycerides, and house over 50 percent cholesterol and cholesterol esters. How does the body receive the lipids contained therein? As the LDLs deliver cholesterol and other lipids to the cells, each cell's surface has receptor systems specifically designed to bind with LDLs. Circulating LDLs in the bloodstream bind to these LDL receptors and are consumed. Once inside the cell, the LDL is taken apart and its cholesterol is released. In liver cells these receptor systems aid in controlling blood cholesterol levels as they bind the LDLs. A deficiency of these LDL binding mechanisms will leave a high quantity of cholesterol traveling in the bloodstream, which can lead to heart disease or atherosclerosis. Diets rich in saturated fats will prohibit the LDL receptors which, are critical for regulating cholesterol levels.

HDLs. High-density lipoproteins are responsible for carrying cholesterol out of the bloodstream and into the liver, where it is either reused or removed from the body with bile. HDLs have a very large protein composition coupled with low cholesterol content (20 to 30 percent) compared to the other lipoproteins. Hence, these high-density lipoproteins are commonly called "good cholesterol."

Blood Cholesterol Recommendations

In short, elevated LDL blood lipid profiles indicate an increased risk of heart attack, while elevated HDL blood lipid profiles indicate a reduced risk. The University of Maryland Medical Center reports that omega-3 fatty acids promote lower total cholesterol and lower triglycerides in people with high cholesterol.[3]

3. Doctors Should Consider Prescribing Purified Omega-3 Capsules to Reduce Heart Risks in Those with Moderately High Triglyceride Levels. University of Maryland Medical Center. http://www.umm.edu/

It is suggested that people consume omega-3 fatty acids such as alpha-linolenic acid in their diets regularly. Polyunsaturated fatty acids are especially beneficial to consume because they both lower LDL and elevate HDL, thus contributing to healthy blood cholesterol levels. The study also reveals that saturated and trans fatty acids serve as catalysts for the increase of LDL cholesterol. Additionally, trans fatty acids decrease HDL levels, which can impact negatively on total blood cholesterol.

Tools for Change

Being conscious of the need to reduce cholesterol means limiting the consumption of saturated fats and trans fats. Remember that saturated fats found in some meat, whole-fat dairy products, and tropical oils elevate your total cholesterol. Trans fats, such as the ones often found in margarines, processed cookies, pastries, crackers, fried foods, and snack foods also elevate your cholesterol levels. Read and select from the following suggestions as you plan ahead:

1. Soluble fiber reduces cholesterol absorption in the bloodstream. Try eating more oatmeal, oat bran,

altmed/articles/omega-3-000316.htm. Updated August 19, 2019. Accessed September 12, 2021.

kidney beans, apples, pears, citrus fruits, barley, and prunes.

2. Fatty fish are heart-healthy due to high levels of omega-3 fatty acids that reduce inflammation and lower cholesterol levels. Consume mackerel, lake trout, herring, sardines, tuna, salmon, and halibut. Grilling or baking is the best to avoid unhealthy trans fats that could be added from frying oil.
3. Walnuts, almonds, peanuts, hazelnuts, pecans, some pine nuts, and pistachios all contain high levels of unsaturated fatty acids that aid in lowering LDL. Make sure the nuts are raw and unsalted. Avoid sugary or salty nuts. One ounce each day is a good amount.
4. Olive oil contains a strong mix of antioxidants and monounsaturated fat, and may lower LDL while leaving HDL intact. Two tablespoons per day in place of less healthy saturated fats may contribute to these heart-healthy effects without adding extra calories. Extra virgin olive oil promises a greater effect, as the oil is minimally processed and contains more heart-healthy antioxidants.

Testing Your Lipid Profile

The danger of consuming foods rich in cholesterol and saturated and trans fats cannot be overemphasized. Regular testing can provide the foreknowledge necessary to take action to help prevent any life-threatening events.

Current guidelines recommend testing for anyone over age twenty. If there is family history of high cholesterol, your healthcare provider may suggest a test sooner than this. Testing calls for a blood sample to be drawn after nine to twelve hours of fasting for an accurate reading. (By this time, most of the fats ingested from the previous meal have circulated through the body and the concentration of lipoproteins in the blood will be stabilized.)

1.3.5. Choosing Healthy Proteins

Proteins in a Nutshell

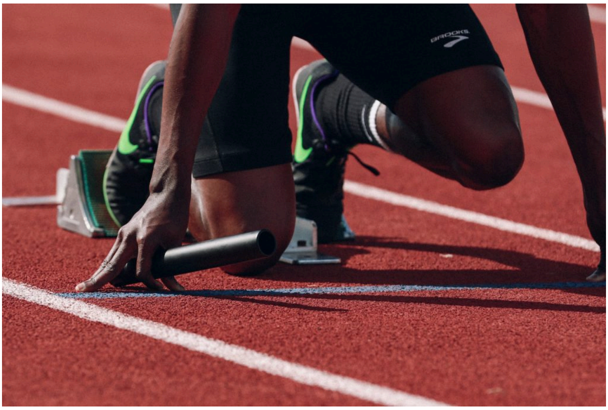


Image by Braden Collum on unsplash.com / CC0

Proteins are long chains of amino acids folded into precise structures that determine their functions, which are in the tens of thousands. They are the primary construction materials of the body serving as building blocks for bone, skin, hair, muscle, hormones, and antibodies. Without them we cannot breakdown or build macromolecules, grow, or heal from a wound. Too little protein impairs bodily functions and too much can lead to chronic disease. Eat proteins in moderation, at least 10 percent of the calories you take in and not more than 35 percent. Proteins are in a variety of foods. More complete sources are in animal-based foods, but choose those low in saturated fat and cholesterol. Some plant-based foods are also complete protein sources and don't add much to your saturated fat or cholesterol intake. Incomplete protein sources can easily be combined in the daily diet and provide all of the essential amino acids at adequate levels. Growing children and the elderly need to ensure they get enough protein in their diet to help build and maintain muscle strength. Even if you're a hardcore athlete, get your proteins from nutrient-dense foods as you need more than just protein to power up for an event. Nuts are one nutrient-dense food with a whole lot of protein. One ounce of pistachios, which is about fifty nuts, has the same amount of protein as an egg and contains a lot of vitamins, minerals, healthy polyunsaturated fats, and antioxidants. Moreover, the FDA says that eating one ounce of nuts per day can lower your risk for heart disease. Can you be a hardcore athlete and a vegetarian?

The analysis of vegetarian diets by the Dietary Guidelines Advisory Committee (DGAC) did not find professional athletes were inadequate in any nutrients, but did state that people who obtain proteins solely from plants should make sure they consume foods with vitamin B12, vitamin D, calcium, omega-3 fatty acids, and choline. Iron and zinc may also be of concern especially for female athletes. Being a vegetarian athlete requires that you pay more attention to what you eat, however this is also a true statement for all athletes. For an exhaustive list that provides the protein, calcium, cholesterol, fat, and fiber content, as well as the number of calories, of numerous foods, go to the website, http://www.soystache.com/protein.htm.

Everyday Connection

Getting All the Nutrients You Need—The Plant-Based Way

Below are five ways to assure you are getting all the nutrients needed on a plant-based diet:

- Get your protein from foods such as soybeans, tofu, tempeh, lentils, and beans, beans, and more beans. Many of these foods are high in zinc too.
- Eat foods fortified with vitamins B12 and D and calcium. Some examples are soy milk and fortified cereals.
- Get enough iron in your diet by eating kidney beans, lentils, whole-grain cereals, and leafy green vegetables.
- To increase iron absorption, eat foods with vitamin C at the same time.
- Don't forget that carbohydrates and fats are required in your diet too, especially if you are training. Eat whole-grain breads, cereals, and pastas. For fats, eat an avocado, add some olive oil to a salad or stir-fry, or spread some peanut or cashew butter on a bran muffin.

Proteins, Diet, and Personal Choices

How Much Protein Does a Person Need in Their Diet?

Protein Input = Protein Used by the Body + Protein Excreted

The appropriate amount of protein in a person's diet is that which maintains a balance between what is taken in and what is used.

For healthy adults, this amount of protein was determined to be 0.8 grams of protein per kilogram of body weight. You can calculate your exact recommended protein intake per day based on your weight by using the following equation:

Protein Intake (g) = 0.8 g x body weight (kg)

(Weight in lbs to kg : 2.2 lbs = 1 kg)

(**Note that if a person is overweight, the amount of dietary protein recommended can be overestimated**.)

During child growth or pregnancy, the body requires more protein to build new tissues, so more of what gets consumed gets used up and less nitrogen is excreted. A person healing from a severe wound may also be in positive nitrogen balance because protein is being used up to repair tissues.

Dietary Sources of Protein

The protein food group consists of foods made from meat, seafood, poultry, eggs, soy, dry beans, peas, and seeds. Different protein sources differ in their additional components, so it is necessary to pay attention to the whole nutrient "package." Protein-rich animal-based foods commonly have high amounts of B vitamins, vitamin E, iron, magnesium, and zinc. Seafood often contains healthy fats, and plant sources of protein contain a high amount of fiber. Some animal-based, protein-rich foods have an unhealthy amount of saturated fat and cholesterol. When choosing your dietary sources of protein, take note of the other nutrients and also the non-nutrients, such as cholesterol, dyes, and preservatives, in order to make good selections that will benefit your health. For instance, a hamburger patty made from 80 percent lean meat contains 22 grams of protein, 5.7 grams of saturated fat, and 77 milligrams of cholesterol. A burger made from 95 percent lean meat also contains 22 grams of protein, but has 2.3 grams of saturated fat and 60 milligrams of cholesterol. A cup of boiled soybeans contains 29 grams of protein, 2.2 grams of saturated fat, and no cholesterol. For more comparisons of protein-rich foods, see Table 1.3.5.1 "Sources of Dietary Protein".

Table 1.3.5.1 *Sources of Dietary Protein*

Food	Protein content (g)	Saturated fat (g)	Cholesterol (mg)	Calories
Hamburger patty 3 oz. (80% lean)	22.0	5.7	77	230
Hamburger patty 3 oz. (95% lean)	22.0	2.3	60	139
Top sirloin 3 oz.	25.8	2.0	76	158
Beef chuck 3 oz. (lean, trimmed)	22.2	1.8	51	135
Pork loin 3 oz.	24.3	3.0	69	178
Pork ribs (country style, 1 piece)	56.4	22.2	222	790
Chicken breast (roasted, 1 c.)	43.4	1.4	119	231
Chicken thigh (roasted, 1 thigh)	13.5	1.6	49	109
Chicken leg (roasted, 1 leg)	29.6	4.2	105	264
Salmon 3 oz.	18.8	2.1	54	175
Tilapia 3 oz.	22.2	0.8	48	109
Halibut 3 oz.	22.7	0.4	35	119
Shrimp 3 oz.	17.8	0.2	166	84
Shrimp (breaded, fried, 6–8 pcs.)	18.9	5.4	200	454
Tuna 3 oz. (canned)	21.7	0.2	26	99
Soybeans 1 c. (boiled)	29.0	2.2	0	298
Lentils 1 c. (boiled)	17.9	0.1	0	226
Kidney beans 1 c. (canned)	13.5	0.2	0	215
Sunflower seeds 1 c.	9.6	2.0	0	269

Source: [Proteins, Diets and Personal Choices]()

Protein Quality

While protein is contained in a wide variety of foods, it differs in quality. High-quality protein contains all the essential amino acids in the proportions needed by the human body. The amino acid profile of different foods is therefore one component of protein quality. Foods that contain some of the essential amino acids are called incomplete protein sources, while those that contain all nine essential amino acids are called complete protein sources, or high-quality protein sources. Foods that are complete protein sources include animal foods such as milk, cheese, eggs, fish, poultry, and meat, and a few plant foods, such as soy and quinoa. The only animal-based protein that is not complete is gelatin, which is made of the protein, collagen.

Figure 1.3.5.1 *Complete and Incomplete Protein Sources*

Examples of complete protein sources include soy, dairy products, meat, and seafood. Examples of incomplete protein sources include legumes and corn. Source: "Protein-rich Foods" by [Smastronardo]() / [CC BY-SA 4.0]().

Most plant-based foods are deficient in at least one essential amino acid and therefore are incomplete protein sources. For example, grains are usually deficient in the amino acid lysine, and legumes are deficient in methionine or tryptophan. Because grains and legumes are not deficient in the same amino acids they can complement each other in a diet. Incomplete protein foods are called **complementary foods** because when consumed in tandem they contain all nine essential amino acids at adequate levels. Some examples of complementary protein foods are given in Table 1.3.5.2 "Complementing Protein Sources the Vegan Way". Complementary protein sources do not have to be consumed at the same time—as long as they are consumed within the same day, you will meet your protein needs.

Table 1.3.5.2 *Complementing Protein Sources the Vegan Way*

Foods	Lacking amino acids	Complementary food	Complementary menu
Legumes	Methionine, tryptophan	Grains, nuts, and seeds	Hummus and whole-wheat pita
Grains	Lysine, isoleucine, threonine	Legumes	Cornbread and kidney bean chili
Nuts and seeds	Lysine, isoleucine	Legumes	Stir-fried tofu with cashews

Note: In a vegetarian or vegan diet certain foods can be eaten together to increase protein absorption.

The second component of protein quality is **digestibility**, as not all protein sources are equally digested. In general, animal-based proteins are completely broken down during the process of digestion, whereas plant-based proteins are not. This is because some proteins are contained in the plant's fibrous cell walls and these pass through the digestive tract unabsorbed by the body.

Protein Needs: Special Considerations

Some groups may need to examine how to meet their protein needs more closely than others. We will take a closer look at the special protein considerations for vegetarians, the elderly, and athletes.

Vegetarians and Vegans

People who follow variations of the vegetarian diet and consume eggs and/or dairy products can meet their protein requirements by consuming adequate amounts of these foods. Vegetarians and vegans can also attain their recommended protein intakes if they give a little more attention to high-quality plant-based protein sources. However, when following a vegetarian diet, the amino acid lysine can be challenging to acquire. Grains, nuts, and seeds are lysine-poor foods, but tofu, soy, quinoa, and pistachios are all good sources of lysine. Following a vegetarian diet and getting the recommended protein intake is also made a little more difficult because the digestibility of plant-based protein sources is lower than the digestibility of animal-based protein.

Elderly People

As we age, muscle mass gradually declines. This is a process referred to as **sarcopenia**. A person is sarcopenic when their amount of muscle tissue is significantly lower than the average value for a healthy person of the same age. A significantly lower muscle mass is associated with weakness, movement disorders, and a generally poor quality of life.

Currently, the RDA for protein for elderly persons is the same as that for the rest of the adult population, but several clinical trials are ongoing and are focused on determining the amount of protein in the diet that prevents the significant loss of muscle mass specifically in older adults.

Athletes

Muscle tissue is rich in protein composition and has a very high turnover rate. During exercise, especially when it is performed for longer than two to three hours, muscle tissue is broken down and some of the amino acids are catabolized to fuel muscle contraction. To avert excessive borrowing of amino acids from muscle tissue to synthesize energy during prolonged exercise, protein needs to be obtained from the diet. Intense exercise, such as strength training, stresses muscle tissue so that afterward, the body adapts by building bigger, stronger, and healthier muscle tissue. The body requires protein post-exercise to accomplish this. The IOM does not set different RDAs for protein intakes for athletes, but the AND, the American College of Sports Medicine, and Dietitians of Canada have the following position statements[1]:

> Nitrogen balance studies suggest that dietary protein intake necessary to support nitrogen balance in **endurance**

1. American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians of Canada. Joint Position Statement: Nutrition and Athletic Performance. Medicine & Science in Sports & Exercise. 2009; 41(3), 709-31. http://journals.lww.com/acsm-msse/fulltext/2009/03000/Nutrition_and_Athletic_Performance.27.aspx. Accessed September 28, 2017.

> **athletes** ranges from 1.2 to 1.4 grams per kilogram of body weight per day.
>
> Recommended protein intakes for **strength-trained athletes** range from approximately 1.2 to 1.7 grams per kilogram of weight per day.

An endurance athlete who weighs 170 pounds should take in 93 to 108 grams of protein per day (170lbs = 77kg, protein intake = 77 × 1.2 or = 77 × 1.4). On a 3,000-kilocalorie diet, that amount is between 12 and 14 percent of total kilocalories and within the AMDR. There is general scientific agreement that endurance and strength athletes should consume protein from high-quality sources, such as dairy, eggs, lean meats, or soy; however **eating an excessive amount of protein at one time does not further stimulate muscle-protein synthesis. Nutrition experts also recommend that athletes consume some protein within one hour after exercise to enhance muscle tissue repair during the recovery phase, but some carbohydrates and water should be consumed as well. The recommended ratio from nutrition experts for exercise-recovery foods is 4 grams of carbohydrates to 1 gram of protein**.

Table 1.3.5.3 *Snacks for Exercise Recovery*

Foods	**Protein (g)**	**Carbohydrates (g)**	**Calories**
Whole grain cereal with nonfat milk	14	53	260
Medium banana with nonfat milk	10	39	191
Power bar	10	43	250
Chocolate Milk	8	32	210

Note: There are numerous foods that can be eaten post exercise to ensure all the nutrients required for recovery are present.

In response to hard training, a person's body also adapts by becoming more efficient in metabolizing nutrient fuels both for energy production and building macromolecules. However, this raises another question: if athletes are more efficient at using protein, is it necessary to take in more protein from dietary sources than the average person? There are two scientific schools of thought on this matter. One side believes athletes need more protein and the other thinks the protein requirements of athletes are the same as for nonathletes. There is scientific evidence to support both sides of this debate. The consensus of both sides is that **few people exercise at the intensity that makes this debate relevant.** It is good to remember that the increased protein intake recommended by the AND, American College of Sports Medicine, and Dietitians of Canada still lies within the AMDR for protein.

Protein Supplements

Protein supplements include powders made from compounds such as whey, soy or amino acids that either come as a powder or in capsules. We have noted that the protein requirements for most people, even those that are active, is not high. Is taking protein supplements ever justified, then? **Neither protein nor amino acid supplements have been scientifically proven to improve exercise performance or increase strength**. **In addition, the average North American already consumes more protein than is required.** Despite these facts, many highly physically active individuals use protein or amino acid supplements. **According to the AND, American College of Sports Medicine, and Dietitians of Canada, "the current evidence indicates that protein and amino acid supplements are no more or no less effective than food when energy is adequate for gaining lean body mass**."[2]

2. American College of Sports Medicine, Academy of

Branched-chain amino acids, such as leucine, are often touted as a way to build muscle tissue and enhance athletic performance. Despite these marketing claims, a review in the June 2005 issue of The Journal of Nutrition shows that most studies that evaluated a variety of exercise types failed to show any performance-enhancing effects of taking branched-chain amino acids.[3]

Moreover, the author of this review claims that high-quality protein foods are a better and cheaper source for branched-chain amino acids and says that a chicken breast (100 grams) contains the equivalent of seven times the amount of branched-chain amino acids as one supplement tablet. This means **if you are interested in enhancing exercise performance or building muscle, you do not need to support the $20 billion supplement industry.**

Although the evidence for protein and amino acid supplements impacting athletic performance is lacking, there is some scientific evidence that supports consuming high-quality dairy proteins, such as casein and whey, and soy proteins positively influences muscle recovery in response to hard training. If you choose to buy a bucket of whey protein, use it to make a protein shake after an intense

Nutrition and Dietetics, and Dietitians of Canada. Joint Position Statement: Nutrition and Athletic Performance. Medicine & Science in Sports & Exercise. 2009; 41(3), 709-31. http://journals.lww.com/acsm-msse/fulltext/2009/03000/Nutrition_and_Athletic_Performance.27.aspx. Accessed September 28, 2017.

3. Gleeson, M. Interrelationship between Physical Activity and Branched-Chain Amino Acids. *The Journal of Nutrition*. 2005; 135(6), 1591S–5S. http://jn.nutrition.org/content/135/6/1591S.long. Accessed October 1, 2017.

workout and do not add more than what is required to obtain 20 to 25 grams of protein. As always, choosing high-quality protein foods will help you build muscle and not empty your wallet as much as buying supplements. Moreover, **relying on supplements for extra protein instead of food will not provide you with any of the other essential nutrients that food contains**. The bottom line is that whether you are an endurance athlete or strength athlete, or just someone who takes Zumba classes, there is very little need to put your money into commercially sold protein and amino acid supplements. The evidence to show that they are superior to regular food in enhancing exercise performance is not sufficient.

What about the numerous protein shakes and protein bars on the market? Are they a good source of dietary protein? Do they help you build muscle or lose weight as marketers claim? These are not such a bad idea for an endurance or strength athlete who has little time to fix a nutritious exercise-recovery snack. However, before you ingest any supplement, do your homework. Read the label, be selective, and don't use them to replace meals, but rather as exercise-recovery snacks now and then. Some protein bars have a high amount of carbohydrates from added sugars and are not actually the best source for protein, especially if you are not an athlete. Protein bars are nutritionally designed to restore carbohydrates and protein after endurance or strength training; therefore they are not good meal replacements. **If you want a low-cost alternative after an intense workout, make yourself a peanut butter sandwich on whole-grain bread and add some sliced banana for less than fifty cents.**

Supermarket and health-food store shelves offer an extraordinary number of high-protein shake mixes. While the carbohydrate count is lower now in some of these products than a few years ago, they still contain added fats and sugars. They also cost, on average, more than two dollars per can. If you want more nutritional bang for your buck, make your own shakes from whole foods. Use the AMDRs for macronutrients as a guide to fill up the blender. Your homemade shake can now replace some of the whole foods on your breakfast, lunch, or dinner plate. Unless you are an endurance or strength athlete and consume commercially sold protein bars and shakes only post exercise, these products are not a good dietary source of protein.

1.3.6. More About Protein

Defining Protein

Protein makes up approximately 20 percent of the human body and is present in every single cell. The word protein is a Greek word, meaning "of utmost importance." Proteins are called the workhorses of life as they provide the body with structure and perform a vast array of functions. You can stand, walk, run, skate, swim, and more because of your protein-rich muscles. Protein is necessary for proper immune system function, digestion, and hair and nail growth, and is involved in numerous other body functions. In fact, it is estimated that more than one hundred thousand different proteins exist within the human body. In this chapter you will learn about the components of protein, the important roles that protein serves within the body, how the body uses protein, the risks and consequences associated with too much or too little protein, and where to find healthy sources of it in your diet.

What Is Protein?

Proteins, simply put, are macromolecules composed of amino acids. Amino acids are commonly called protein's building blocks. Proteins are crucial for the nourishment, renewal, and continuance of life. Proteins contain the elements carbon, hydrogen, and oxygen just as carbohydrates and lipids do, but proteins are the only macronutrient that contains nitrogen.

Essential and Nonessential Amino Acids

Amino acids are further classified based on nutritional aspects. Recall that there are twenty different amino acids, and we require all of them to make the many different proteins found throughout the body. **Eleven of these are called nonessential amino acids because the body can synthesize them. However, nine of the amino acids are called essential amino acids because we cannot synthesize them either at all or in sufficient amounts**. **These must be obtained from the diet.** The nutritional value of a protein is dependent on what amino acids it contains and in what quantities.

The Role of Proteins in Foods

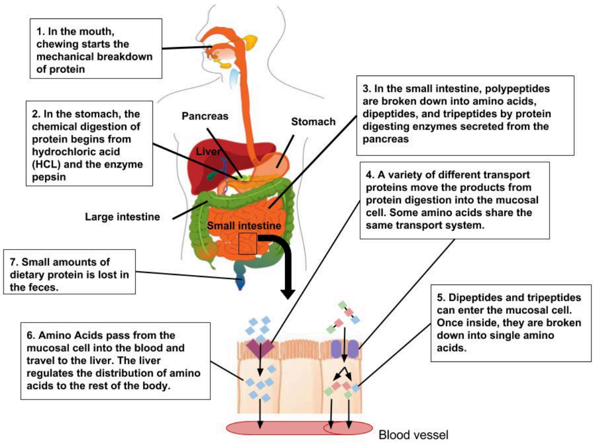
In addition to having many vital functions within the body, proteins perform different roles in our foods by adding certain functional qualities to them. Protein provides food with structure and texture and enables water retention. For example, proteins foam when agitated. (Picture whisking egg whites to make angel food cake. The foam bubbles are what give the angel food cake its airy texture.) Yogurt is another good example of proteins providing texture. Milk proteins called caseins coagulate, increasing yogurt's thickness. Cooked proteins add some color and flavor to foods as the amino group binds with carbohydrates and produces a brown pigment and aroma. Eggs are between 10 and 15 percent protein by weight. Most cake recipes use eggs because the egg proteins help bind all the other ingredients together into a uniform cake batter. The proteins aggregate into a network during mixing and baking that gives cake structure.

Image by Annie Spratt on unspash.com / CC0

Protein Digestion and Absorption

How do the proteins from foods, denatured or not, get processed into amino acids that cells can use to make new proteins? When you eat food the body's digestive system breaks down the protein into the individual amino acids, which are absorbed and used by cells to build other proteins and a few other macromolecules, such as DNA. We previously discussed the general process of food digestion, let's follow the specific path that proteins take down the gastrointestinal tract and into the circulatory system (Figure 1.3.6.1 "Digestion and Absorption of Protein"). Eggs are a good dietary source of protein and will be used as our example to describe the path of proteins in the processes of digestion and absorption. One egg, whether raw, hard-boiled, scrambled, or fried, supplies about six grams of protein.

Figure 1.3.6.1 *Digestion and Absorption of Protein*



Protein is digested, absorbed and excreted throughout the digestive system. Source: image by Allison Calabrese / [CC BY 4.0]

From the Mouth to the Stomach

Unless you are eating it raw, the first step in egg digestion (or any other protein food) involves chewing. The teeth begin the mechanical breakdown of the large egg pieces into smaller pieces that can be swallowed. The salivary glands provide some saliva to aid swallowing and the passage of the partially mashed egg through the esophagus. The mashed egg pieces enter the stomach through the esophageal sphincter. The stomach releases gastric juices containing hydrochloric acid and the enzyme, pepsin, which initiate the breakdown of the protein. The acidity of the stomach facilitates the unfolding of the proteins that still retain part of their three-dimensional structure after cooking and helps break down the protein aggregates formed during cooking. Pepsin, which is secreted by the cells that line the stomach, dismantles the protein chains into smaller and smaller fragments. Egg proteins are large globular molecules and their chemical breakdown requires time and mixing. The powerful mechanical stomach contractions churn the partially digested protein into a more uniform mixture called chyme. **Protein digestion in the stomach takes a longer time than**

carbohydrate digestion, but a shorter time than fat digestion. Eating a high-protein meal increases the amount of time required to sufficiently break down the meal in the stomach. Food remains in the stomach longer, making you feel full longer.

From the Stomach to the Small Intestine

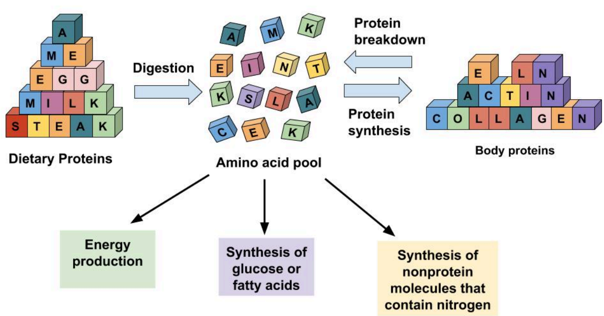
The stomach empties the chyme containing the broken down egg pieces into the small intestine, where the majority of protein digestion occurs. The pancreas secretes digestive juice that contains more enzymes that further break down the protein fragments. The cells that line the small intestine release additional enzymes that finally break apart the smaller protein fragments into the individual amino acids. The muscle contractions of the small intestine mix and propel the digested proteins to the absorption sites. In the lower parts of the small intestine, the amino acids are transported from the intestinal lumen through the intestinal cells to the blood. This movement of individual amino acids requires special transport proteins and the cellular energy molecule, adenosine triphosphate (ATP). Once the amino acids are in the blood, they are transported to the liver. As with other macronutrients, the liver is the checkpoint for amino acid distribution and any further breakdown of amino acids, which is very minimal. Recall that amino acids contain nitrogen, so further catabolism of amino acids releases nitrogen-containing ammonia. Because ammonia is toxic, the liver transforms it into urea, which is then transported to the kidney and excreted in the urine. Urea is a molecule that contains two nitrogens and is highly soluble in water. This makes it a good choice for transporting excess nitrogen out of the body. Because amino acids are building blocks that the body reserves in order to synthesize other proteins, more than 90 percent of the protein ingested does not get broken down further than the amino acid monomers.

Amino Acids Are Recycled

Just as some plastics can be recycled to make new products, amino acids are recycled to make new proteins. All cells in the body continually break down proteins and build new ones, a process referred to as protein turnover. Every day over 250 grams of protein in your body are dismantled and 250 grams of new protein are built. To form these new proteins, amino acids from food and those from protein destruction are placed into a "pool." Though it is not a literal pool, **when an amino acid is required to build another protein it can be acquired from the additional amino acids that exist within the body**. Amino acids are used not only to build proteins, but also to build other biological molecules containing nitrogen, such as DNA, RNA, and to some extent to produce energy. **It is critical to maintain amino acid levels within this cellular pool by consuming high-quality proteins in the diet, or the amino acids needed for building new proteins will be obtained by increasing protein destruction from other tissues within the body, especially muscle**.

This amino acid pool is less than one percent of total body-protein content. Thus, **the body does not store protein as it does with carbohydrates (as glycogen in the muscles and liver) and lipids (as triglycerides in adipose tissue).**

Figure 1.3.6.2 *Options for Amino Acid Use in the Human Body*

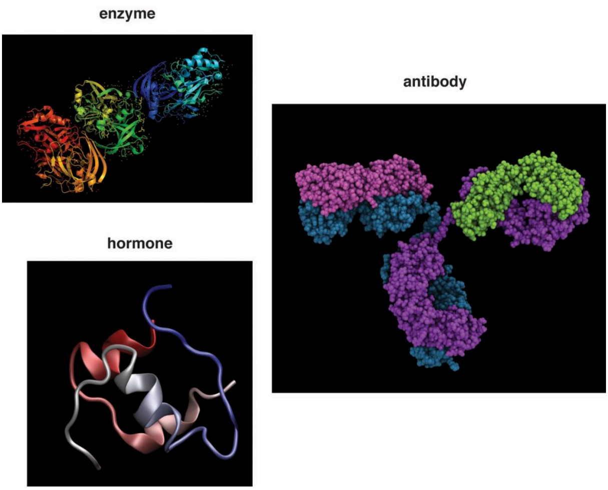


Amino acids come from numerous sources and are used in a variety of processes in the body. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Amino acids in the cellular pool come from dietary protein and from the destruction of cellular proteins. The amino acids in this pool need to be replenished because amino acids are outsourced to make new proteins, energy, and other biological molecules.

The Functions of Proteins in the Body

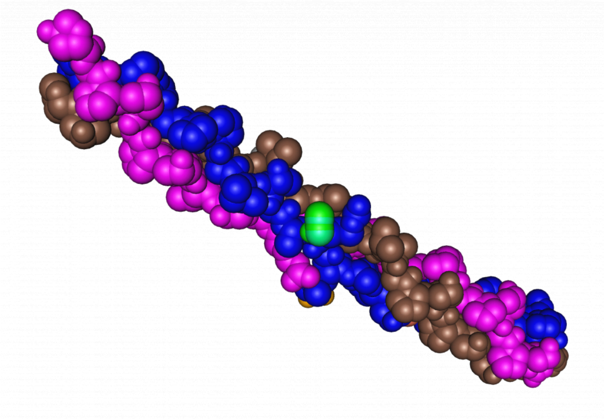
Figure 1.3.6.3 *Proteins*



Proteins are the "workhorses" of the body and participate in many bodily functions. Proteins come in all sizes and shapes and each is specifically structured for its particular function. Source: [Protein's Functions in the Body]

Structure and Motion

Figure 1.3.6.4 *Collagen Structure*



Source: "Collagen Triple Helix" by [Nevit Dilmen](#) / [CC BY-SA 3.0](#).

More than one hundred different structural proteins have been discovered in the human body, but the most abundant by far is collagen, which makes up about 6 percent of total body weight. Collagen makes up 30 percent of bone tissue and comprises large amounts of tendons, ligaments, cartilage, skin, and muscle. Collagen is a strong, fibrous protein in a highly ordered structure even stronger than steel fibers of the same size. Collagen makes bones strong, but flexible. Collagen fibers in the skin's dermis provide it with structure, and the accompanying elastin protein fibrils make it flexible. Pinch the skin on your hand and then let go; the collagen and elastin proteins in skin allow it to go back to its original shape. Smooth-muscle cells that secrete collagen and elastin proteins surround blood vessels, providing the vessels with structure and the ability to stretch back after blood is pumped through them. Another strong, fibrous protein is keratin, which is what skin, hair, and nails are made of. The closely packed collagen fibrils in tendons and ligaments allow for synchronous mechanical movements of bones and muscle and the ability of these tissues to spring back after a movement is complete.

Enzymes

Although proteins are found in the greatest amounts in connective tissues such as bone, their most extraordinary function is as enzymes. **Enzymes are proteins that conduct specific chemical reactions**. An enzyme's job is to provide a site for a chemical reaction and to lower the amount of energy and time it takes for that chemical reaction to happen (this is known as "catalysis"). On average, more than one hundred chemical reactions occur in cells every single second and most of them require enzymes. The liver alone contains over one thousand enzyme systems. Enzymes are specific and will use only particular substrates that fit into their active site, similar to the way a lock can be opened only with a specific key. Nearly every chemical reaction requires a specific enzyme. Fortunately, an enzyme can fulfill its role as a catalyst over and over again, although eventually it is destroyed and rebuilt. All bodily functions, including the breakdown of nutrients in the stomach and small intestine, the transformation of nutrients into molecules a cell can use, and building all macromolecules, including protein itself, involve enzymes.

Hormones

Proteins are responsible for hormone synthesis. Hormones are the chemical messages produced by the endocrine glands. When an endocrine gland is stimulated, it releases a hormone. The hormone is then transported in the blood to its target cell, where it communicates a message to initiate a specific reaction or cellular process. For instance, after you eat a meal, your blood glucose levels rise. In response to the increased blood glucose, the pancreas releases the hormone insulin. Insulin tells the cells of the body that glucose is available and to take it up from the blood and store it or use it for making energy or building macromolecules. A major function of hormones is to turn enzymes on and off, so some proteins can even regulate the actions of other proteins. While not all hormones are made from proteins, many of them are.

Fluid and Acid-Base Balance

Proper protein intake enables the basic biological processes of the body to maintain the status quo in a changing environment. Fluid balance refers to maintaining the distribution of water in the body. If too much water in the blood suddenly moves into a tissue, the results are swelling and, potentially, cell death. Water always flows from an area of high concentration to one of a low concentration. As a result, water moves toward areas that have higher concentrations of other solutes, such as proteins and glucose. To keep the water evenly distributed between blood and cells, proteins continuously circulate at high concentrations in the blood. The most abundant protein in blood is the butterfly-shaped protein known as albumin. Albumin's presence in the blood makes the protein concentration in the blood similar to that in cells. Therefore, fluid exchange between the blood and cells is not in the extreme, but rather is minimized to preserve the status quo.

Protein is also essential in maintaining proper pH balance (the measure of how acidic or basic a substance is) in the blood. Blood pH is maintained between 7.35 and 7.45, which is slightly basic. Even a slight change in blood pH can affect body functions.

Albumin acts as a buffer against abrupt changes in the concentrations of other molecules, thereby balancing blood pH and maintaining the status quo. The protein **hemoglobin** also participates in acid-base balance by binding and releasing protons.

Transport

Albumin and hemoglobin also play a role in molecular transport. Albumin chemically binds to hormones, fatty acids, some vitamins, essential minerals, and drugs, and transports them throughout the circulatory system. Each red blood cell contains millions of hemoglobin molecules that bind oxygen in the lungs and transport it to all the tissues in the body.

A cell's plasma membrane is usually not permeable to large polar molecules, so to get the required nutrients and molecules into the cell many transport proteins exist in the cell membrane. Some of these proteins are channels that allow particular molecules to move in and out of cells. Others act as one-way taxis and require energy to function.

Protection

Earlier we discussed that the strong collagen fibers in skin provide it with structure and support. The skin's dense network of collagen fibers also serves as a barricade against harmful substances. The immune system's attack and destroy functions are dependent on enzymes and antibodies, which are also proteins. An enzyme called lysozyme is secreted in the saliva and attacks the walls of bacteria, causing them to rupture. Certain proteins circulating in the blood can be directed to build a molecular knife that stabs the cellular membranes of foreign invaders. The antibodies secreted by the white blood cells survey the entire circulatory system looking for harmful bacteria and viruses to surround and destroy. Antibodies also trigger other factors in the immune system to seek and destroy unwanted intruders.

Wound Healing and Tissue Regeneration

Proteins are involved in all aspects of **wound healing, a process that takes place in three phases: inflammatory, proliferative, and remodeling**. For example, if you were sewing and pricked your finger with a needle, your flesh would turn red and become inflamed. Within a few seconds bleeding would stop. The healing process begins with proteins, which dilate blood vessels at the site of injury. An additional protein helps to secure platelets that form a clot to stop the bleeding. Next, in the proliferative phase, cells move in and mend the injured tissue by installing newly made collagen fibers. The collagen fibers help pull the wound edges together. In the remodeling phase, more collagen is deposited, forming a scar. Scar tissue is only about 80 percent as functional as normal uninjured tissue. If a diet is insufficient in protein, the process of wound healing is markedly slowed.

While **wound healing** takes place only after an injury is sustained, a different process called **tissue regeneration** is ongoing in the body. The main difference between wound healing and tissue regeneration is in the process of regenerating an exact structural and functional copy of the lost tissue. Thus, old, dying tissue is not replaced with scar tissue but with brand new, fully functional tissue. Some cells (such as skin, hair, nails, and intestinal cells) have a very high rate of regeneration, while others, (such as heart-muscle cells and nerve cells) do not regenerate at any appreciable levels. Tissue regeneration is the creation of new cells (cell division), which requires many different proteins including enzymes that synthesize RNA and proteins, transport proteins, hormones, and collagen. In a hair follicle, cells divide and a hair grows in length. Hair growth averages 1 centimeter per month and fingernails about 1 centimeter every one hundred days. The cells lining the intestine regenerate every three to five days. **Protein-inadequate diets impair tissue regeneration, causing many health problems including**

impairment of nutrient digestion and absorption and, most visibly, hair and nail growth.

Energy Production

Some of the amino acids in proteins can be disassembled and used to make energy (Figure 1.3.6.2 "Options for Amino Acid Use in the Human Body"). Only about 10 percent of dietary proteins are catabolized each day to make cellular energy.

If a person's diet does not contain enough carbohydrates and fats their body will use more amino acids to make energy, which compromises the synthesis of new proteins and destroys muscle proteins. Alternatively, if a person's diet contains more protein than the body needs, the extra amino acids will be broken down and transformed into fat.

Diseases Involving Proteins

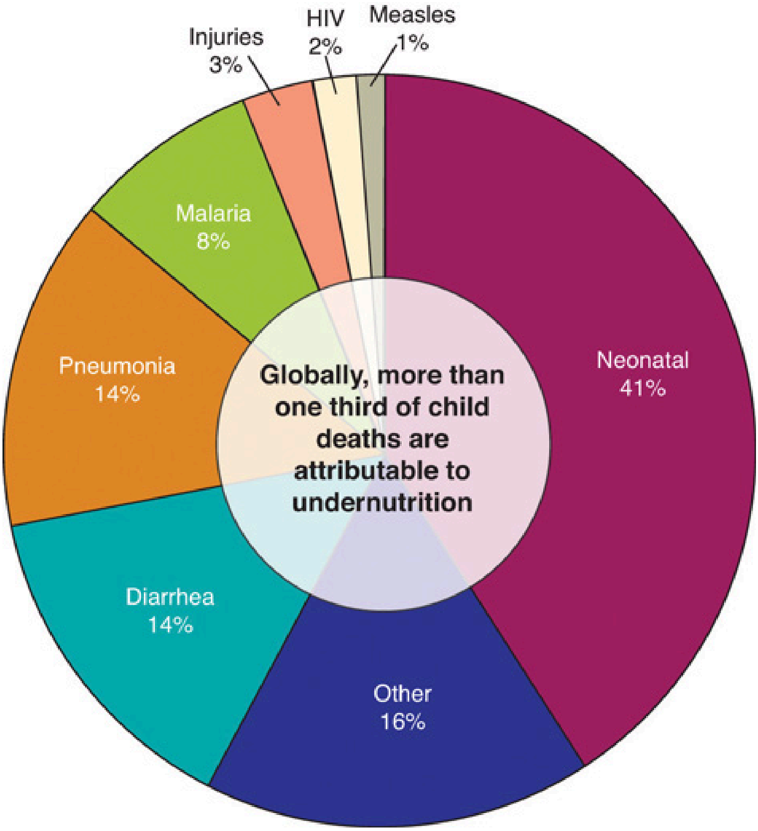
As you may recall, moderation refers to having the proper amount of a nutrient—having neither too little nor too much. A healthy diet incorporates all nutrients in moderation. Low protein intake has several health consequences, and a severe lack of protein in the diet eventually causes death. Although severe protein deficiency is a rare occurrence in children and adults in North America, it is estimated that more than half of the elderly in nursing homes are protein-deficient. The Acceptable Macronutrient Distribution Range (AMDR) for protein for adults is between 10 and 35 percent of kilocalories, which is a fairly wide range. The percent of protein in the diet that is associated with malnutrition and its health consequences is less than 10 percent, but this is often accompanied by deficiencies in calories and other micronutrients.

Health Consequences of Protein Deficiency

Recall that one of protein's functional roles in the body is fluid balance. Diets extremely low in protein do not provide enough amino acids for the synthesis of albumin. One of the functions of albumin is to hold water in the blood vessels, so having lower concentrations of blood albumin results in water moving out of the blood vessels and into tissues, causing swelling. Primary symptoms include not only swelling, but also diarrhea, fatigue, peeling skin, and irritability. Severe protein deficiency in addition to other micronutrient deficiencies, such as folate (vitamin B9), iodine, iron, and vitamin C all contribute to the many health manifestations of this syndrome.

Although organ system function is compromised by undernutrition, the ultimate cause of death from protein deficiency is usually infection. Undernutrition is intricately linked with suppression of the immune system at multiple levels, so undernourished children commonly die from severe diarrhea and/or pneumonia resulting from bacterial or viral infection. The United Nations Children's Fund (UNICEF), the most prominent agency with the mission of changing the world to improve children's lives, reports that undernutrition causes at least one-third of deaths of young children. As of 2008, the prevalence of children under age five who were underweight was 26 percent. The percentage of underweight children has declined less than 5 percent in the last eighteen years despite the Millennium Development Goal of halving the proportion of people who suffer from hunger by the year 2015.

Figure 1.3.6.6 *Causes of Death for Children Under the Age of Five, Worldwide*



Source: Diseases Involving Proteins

Health Consequences of Too Much Protein in the Diet

An explicit definition of a high-protein diet has not yet been developed by the Food and Nutrition Board of the Institute of Medicine (IOM), but typically diets high in protein are considered as those that derive more than 30 percent of calories from protein. Many people follow high-protein diets because marketers tout protein's ability to stimulate weight loss. It is true that following high-protein diets increases weight loss in some people. However the number of individuals that remain on this type of diet is low and many people who try the diet and stop *will* regain the weight they had lost. Additionally, there is a scientific hypothesis that there may be health consequences of remaining on high-protein diets for the long-term, but clinical trials are ongoing or scheduled to examine this hypothesis further. As the high-protein diet trend arose so did the intensely debated issue of whether there are any health consequences of eating too much protein. Observational studies conducted in the general population suggest diets high in animal protein, specifically those in which the primary protein source is red meat, are linked to a higher risk for kidney stones, kidney disease, liver malfunction, colorectal cancer, and osteoporosis. However, diets that include lots of red meat are also high in saturated fat and cholesterol and sometimes linked to unhealthy lifestyles, so it is difficult to conclude that the high protein content is the culprit.

High protein diets appear to only increase the progression of kidney disease and liver malfunction in people who already have kidney or liver malfunction, and not to cause these problems. However, the prevalence of kidney disorders is relatively high and under diagnosed. In regard to colon cancer, an assessment of more than ten studies performed around the world published in the June 2011 issue of PLoS purports that a high intake of red meat and processed meat is associated with a significant increase in colon cancer risk.[1] Although there are a few ideas, the exact mechanism of

1. Chan DS, Lau R, Aune D et al. Red and Processed Meat and Colorectal Cancer Incidence: Meta-Analysis of Prospective Studies. PLoS One. 2011; 6(6), e20456. http://dx.plos.org/10.1371/journal.pone.0020456. Accessed September 30, 2017.

how proteins, specifically those in red and processed meats, causes colon cancer is not known and requires further study.

Some scientists hypothesize that high-protein diets may accelerate bone-tissue loss because under some conditions the acids in protein block absorption of calcium in the gut, and, once in the blood, amino acids promote calcium loss from bone; however even these effects have not been consistently observed in scientific studies. Results from the Nurses' Health Study suggest that women who eat more than 95 grams of protein each day have a 20 percent higher risk for wrist fracture.[2]

Other studies have not produced consistent results. The scientific data on high protein diets and increased risk for osteoporosis remains highly controversial and more research is needed to come to any conclusions about the association between the two.[3]

High-protein diets can restrict other essential nutrients. The American Heart Association (AHA) states that "High-protein diets are not recommended because they restrict healthful foods that provide essential nutrients and do not provide the variety of foods needed to adequately meet nutritional needs. Individuals who follow

2. Uriel S. Barzel, Linda K. Massey. Excess Dietary Protein Can Adversely Affect Bone. J Nutr. 1998; 128(6), 1051–53. http://jn.nutrition.org/content/128/6/1051.long. Accessed September 28, 2017.
3. St. Jeor ST, Howard BV, Prewitt TE et al. Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association. Circulation. 2001; 104, 1869–74. http://circ.ahajournals.org/cgi/pmidlookup?view=long&pmid=11591629. Accessed September 28, 2017.

these diets are therefore at risk for compromised vitamin and mineral intake, as well as potential cardiac, renal, bone, and liver abnormalities overall."[4]

As with any nutrient, protein must be eaten in proper amounts. Moderation and variety are key strategies to achieving a healthy diet and need to be considered when optimizing protein intake. While the scientific community continues its debate about the particulars regarding the health consequences of too much protein in the diet, you may be wondering just how much protein you should consume to be healthy.

4. St. Jeor ST, Howard BV, Prewitt TE et al. Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association. Circulation. 2001; 104, 1869–74. http://circ.ahajournals.org/cgi/pmidlookup?view=long&pmid=11591629. Accessed September 28, 2017.

1.3.7. Vitamins: Summary Chart

Summary of Fat-Soluble Vitamins

Table 1.3.7.1 *Fat-Soluble Vitamins*

Vitamin	Sources	Recommended intake for adults	Major functions	Deficiency diseases and symptoms	Group risk of deficie
Vitamin A (retinol, retinal, retinoic acid, carotene, beta-carotene)	Retinol: beef and chicken liver, skim milk, whole milk, cheddar cheese; Carotenoids: pumpkin, carrots, squash, collards, peas	700-900 mcg/day	Antioxidant, vision, cell differentiation, reproduction, immune function	Xerophthalmia, night blindness, eye infections; poor growth, dry skin, impaired immune function	People living i povert (espec infants childre prema infants pregna and lactati women people consu low-fa low-pr diets
Vitamin D	Swordfish, salmon, tuna, orange juice (fortified), milk (fortified), sardines, egg, synthesis from sunlight	600-800 IU/day (15-20 mcg/day)	Absorption and regulation of calcium and phosphorus, maintenance of bone	Rickets in children: abnormal growth, misshapen bones, bowed legs, soft bones; osteomalacia in adults	Breast infants older a people limited exposu people dark sl
Vitamin E	Sunflower seeds, almonds, hazelnuts, peanuts	15 mg/day	Antioxidant, protects cell membranes	Broken red blood cells, nerve damage	People poor fa absorp prema infants
Vitamin K	Vegetable oils, leafy greens, synthesis by intestinal bacteria	90-120 mcg/day	Synthesis of blood clotting proteins and proteins needed for bone health and cell growth	Hemorrhage	Newbo people long te antibio

Source: [Fat Soluble Vitamins]

Summary of Water-Soluble Vitamins

Table 1.3.7.2 *Water-Soluble Vitamins*

Vitamin	Sources	Recommended intake for adults	Major functions	Deficiency diseases and symptoms	Grou risk c defic
Vitamin C (ascorbic acid)	Orange juice, grapefruit juice, strawberries, tomato, sweet red pepper	75-90 mg/day	Antioxidant, collagen synthesis, hormone and neurotransmitter synthesis	Scurvy, bleeding gums, joint pain, poor wound healing,	Smok alcoh elder
Thiamin (B1)	Pork, enriched and whole grains, fish, legumes	1.1-1.2 mg/day	Coenzyme: assists in glucose metabolism, RNA, DNA, and ATP synthesis	Beriberi: fatigue, confusion, movement impairment, swelling, heart failure	Alcoh older adult eatin disor
Riboflavin (B2)	Beef liver, enriched breakfast cereals, yogurt, steak, mushrooms, almonds, eggs	1.1-1.3 mg/day	Coenzyme: assists in glucose, fat and carbohydrate metabolism, electron carrier, other B vitamins are dependent on	Ariboflavinosis: dry scaly skin, mouth inflammation and sores, sore throat, itchy eyes, light sensitivity	None
Niacin (B3)	Meat, poultry, fish, peanuts, enriched grains	14-16 NE/day	Coenzyme: assists in glucose, fat, and protein metabolism, electron carrier	Pellagra: diarrhea, dermatitis, dementia, death	Alcoh
Pantothenic Acid (B5)	Sunflower seeds, fish, dairy products, widespread in foods	5 mg/day	Coenzyme: assists in glucose, fat, and protein metabolism, cholesterol and neurotransmitter synthesis	Muscle numbness and pain, fatigue, irritability	Alcoh
B6 (Pyridoxine)	Meat, poultry, fish, legumes, nuts	1.3-1.7 mg/day	Coenzyme; assists in amino-acid synthesis, glycogneolysis, neurotransmitter and hemoglobin synthesis	Muscle weakness, dermatitis, mouth sores, fatigue, confusion	Alcoh

Biotin	Egg yolks, fish, pork, nuts and seeds	30 mcg/day	Coenzyme; assists in glucose, fat, and protein metabolism, amino-acid synthesis	Muscle weakness, dermatitis, fatigue, hair loss	Thos consu raw e white
Folate	Leafy green vegetables, enriched grains, orange juice	400 mcg/day	Coenzyme; amino acid synthesis, RNA, DNA, and red blood cell synthesis	Diarrhea, mouth sores, confusion, anemia, neural-tube defects	Pregn wom alcoh
B12 (cobalamin)	Meats, poultry, fish	2.4 mcg/day	Coenzyme; fat and protein catabolism, folate function, red-blood-cell synthesis	Muscle weakness, sore tongue, anemia, nerve damage, neural-tube defects	Vegar elder
Choline	Egg yolk, wheat, meat, fish, synthesis in the body	425-550 mg/day	Synthesis of neurotransmitters and cell membranes, lipid transport	Non-alcoholic fatty liver disease, muscle damage, interfered brain development in fetus	None

Source: Water Soluble Vitamins

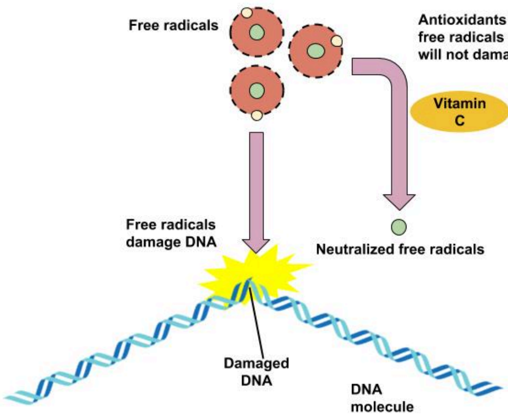
1.3.8. Vitamins: Antioxidants and Phytochemicals

Antioxidants

The market is flooded with advertisements for “super antioxidant” supplements teeming with molecules that block free radical production, stimulate the immune system, prevent cancer, and reduce the signs of aging. Based on the antioxidant-supplement industry’s success, the general public appears to believe these health claims. However, these claims are not backed by scientific evidence; rather, **there is some evidence suggesting supplements can actually cause harm**.

While scientists have found evidence supporting the consumption of antioxidant-rich foods as a method of reducing the risk of chronic disease, there is no “miracle cure”; no pill or supplement alone can provide the same benefits as a healthy diet. Remember, **it is the combination of antioxidants and other nutrients in healthy foods that is beneficial**. In this section, we will review how particular antioxidants function in the body, learn how they work together to protect the body against free radicals, and explore the best nutrient-rich dietary sources of antioxidants. One dietary source of antioxidants is vitamins. In our discussion of antioxidant vitamins, we will focus on vitamins E, C, and A.

Figure 1.3.8.1 *Role of Antioxidants*



Source: image by Allison Calabrese / [CC BY 4.0](#).

Antioxidant Chemicals Obtained From the Diet

There are many different antioxidants in food, including selenium, which is one of the major antioxidants. However, the antioxidants you may be the most familiar with are vitamins. The "big three" vitamin antioxidants are vitamins E, A, and C, although it may be that they are called the "big three" only because they are the most studied.

Table 1.3.8.1 *Some Antioxidants Obtained from Diet and Their Related Functions*

Antioxidant	Functions attributed to antioxidant capacity
Vitamin A	Protects cellular membranes, prevents glutathione depletion, maintains free radical detoxifying enzyme systems, reduces inflammation
Vitamin E	Protects cellular membranes, prevents glutathione depletion
Vitamin C	Protects DNA, RNA, proteins, and lipids, aids in regenerating vitamin E
Carotenoids	Free radical scavengers
Lipoic acid	Free radical scavenger, aids in regeneration of vitamins C and E
Phenolic acids	Free radical scavengers, protect cellular membranes

Source: http://pressbooks.oer.hawaii.edu/humannutrition/chapter/antioxidants/. Accessed Nov 14, 2020.

The Body's Offense

While our bodies have acquired multiple defenses against free radicals, we also use free radicals to support its functions. For example, the immune system uses the cell-damaging properties of free radicals to kill pathogens. First, immune cells engulf an invader (such as a bacterium), then they expose it to free radicals such as hydrogen peroxide, which destroys its membrane. The invader is thus neutralized. Scientific studies also suggest hydrogen peroxide acts as a signaling molecule that calls immune cells to injury sites, meaning free radicals may aid with tissue repair when you get cut. Free radicals are necessary for many other bodily functions as well. The thyroid gland synthesizes its own hydrogen peroxide, which is required for the production of thyroid hormone. Reactive oxygen species and reactive nitrogen species, which are free radicals containing nitrogen, have been found to interact with proteins in cells to produce signaling molecules. The free radical nitric oxide has been found to help dilate blood vessels and act as a chemical messenger in the brain. By acting as signaling molecules, free radicals are involved in the control of their own synthesis, stress responses, regulation of cell growth and death, and metabolism.

Sources of Free Radicals in the Environment

Substances and energy sources from the environment can add to or accelerate the production of free radicals within the body. Exposure to excessive sunlight, ozone, smoke, heavy metals, ionizing radiation, asbestos, and other toxic chemicals increase the amount of free radicals in the body. They do so by being free radicals themselves or by adding energy that provokes electrons to move between atoms. Excessive exposure to environmental sources of free radicals can contribute to disease by overwhelming the free radical detoxifying systems and those processes involved in repairing oxidative damage.

Oxidative Stress

Oxidative stress refers to an imbalance in any cell, tissue, or organ between the amount of free radicals and the capabilities of the detoxifying and repair systems. Sustained oxidative damage results only under conditions of oxidative stress—when the detoxifying and repair systems are insufficient. Free radical-induced damage, when left unrepaired, destroys lipids, proteins, RNA, and DNA, and can contribute to disease. Oxidative stress has been implicated as a contributing factor to cancer, atherosclerosis (hardening of arteries), arthritis, diabetes, kidney disease, Alzheimer's disease, Parkinson's disease, schizophrenia, bipolar disorder, emphysema, and cataracts.

Aging is a process that is genetically determined but modulated by factors in the environment. In the process of aging, tissue function declines. The idea that oxidative stress is the primary contributor to age-related tissue decline has been around for decades, and it is true that tissues accumulate free radical-induced damage as we age. Recent scientific evidence slightly modifies this theory by suggesting oxidative stress is not the initial trigger for age-related decline of tissues; it is suggested that the true culprit is progressive dysfunction of metabolic processes, which leads to increases in free radical production, thus influencing the stress response of tissues as they age.

Phytochemicals

Phytochemicals are chemicals in plants that may provide some health benefit. Photochemical is a broader term that encompasses antioxidants. Some phytochemicals and their food sources can be found in Table 1.3.8.2 "Phytochemicals and Their Food Sources."

Table 1.3.8.2 *Phytochemicals and Their Food Sources*

Phytochemical	Food source
Capsaicin	Chili peppers
Flavonoids	Oranges, lemons, apples
Resveratrol	Grapes, wine, peanuts
Polyphenols	Green and black teas

Phytochemicals also include carotenoids, indoles, lignans, phytoestrogens, stanols, saponins, terpenes, anthocyanidins, phenolic acids, and many more. They are found not only in fruits and vegetables, but also in grains, seeds, nuts, and legumes. Many phytochemicals act as antioxidants, but they have several other functions, such as mimicking hormones, altering absorption of cholesterol, inhibiting inflammatory responses, and blocking the actions of certain enzymes.

Phytochemicals are present in small amounts in the food supply, and although thousands have been and are currently being scientifically studied, their health benefits remain largely unknown. Also largely unknown is their potential for toxicity, which could be substantial if taken in large amounts in the form of supplements. Moreover, phytochemicals often act in conjunction with each other and with micronutrients. Thus, supplementing with only a few may impair the functions of other phytochemicals or micronutrients. **As with the antioxidant vitamins, it is the mixture and variety of phytochemicals in foods that are linked to health benefits.**

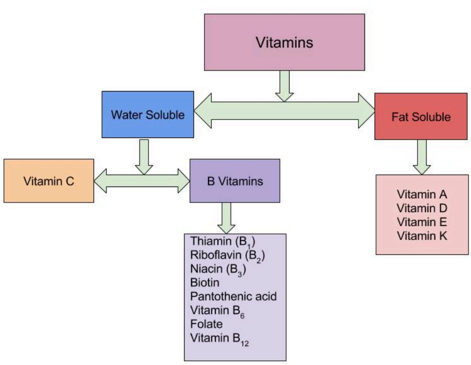
From the Canadian Cancer Society – Prevention and Phytochemicals

1.3.9. More About Vitamins

Introduction

Vitamins are obtained from the different types of foods that we consume. If a diet is lacking a certain type of nutrient, a vitamin deficiency may occur. Vitamins are organic compounds that are traditionally assigned to two groups fat-soluble (hydrophobic) or water-soluble (hydrophilic). This classification determines where they act in the body. Water-soluble vitamins act in the cytosol of cells or in extracellular fluids such as blood; fat-soluble vitamins are largely responsible for protecting cell membranes from free radical damage. The body can synthesize some vitamins, but others must be obtained from the diet.

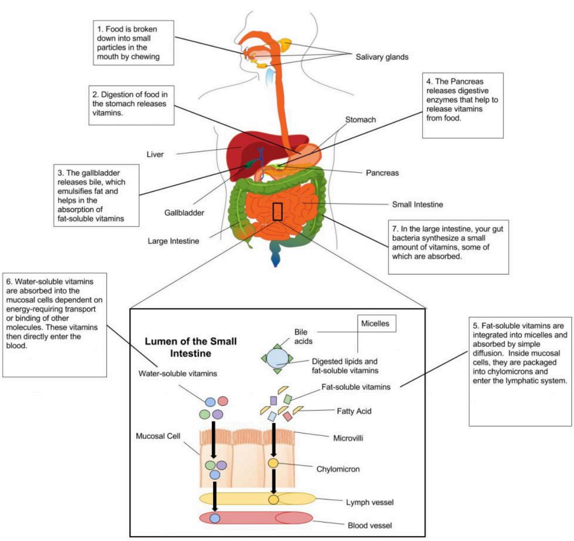
Figure 1.3.9.1 *The Vitamins*



A breakdown of vitamin subclassifications. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

One major difference between fat-soluble vitamins and water-soluble vitamins is the way they are absorbed in the body. Vitamins are absorbed primarily in the small intestine and their bioavailability is dependent on the food composition of the diet. **Fat-soluble vitamins are absorbed along with dietary fat.** Therefore, if a meal is very low in fat, the absorption of the fat-soluble vitamins will be impaired. Once fat-soluble vitamins have been absorbed in the small intestine, they are packaged and incorporated along with other fatty acids and transported in the lymphatic system to the liver. Water-soluble vitamins on the other hand are absorbed in the small intestine but are transported to the liver through blood vessels. (Figure 1.3.9.2 "Absorption of Fat-Soluble and Water-Soluble Vitamins").

Figure 1.3.9.2 *Absorption of Fat-Soluble and Water-Soluble Vitamins*



Water-soluble and fat-soluble vitamins are absorbed though different pathways. Source: image by Allison Calabrese / CC BY 4.0.

Fat-Soluble Vitamins

Vitamin A

Vitamin A is a generic term for a group of similar compounds called retinoids. Retinol is the form of vitamin A found in animal-derived foods, and is converted in the body to the biologically active forms of vitamin A: retinal and retinoic acid (thus retinol is sometimes referred to as “preformed vitamin A”). About 10 percent of plant-derived carotenoids, including beta-carotene, can be converted in the body to retinoids and are another source of functional vitamin A. Carotenoids are pigments synthesized by plants that give them their yellow, orange, and red color. Over six hundred carotenoids have been identified and, with just a few exceptions, all are found in the plant kingdom. There are two classes of carotenoids—the xanthophylls, which contain oxygen, and the carotenes, which do not.

In plants, carotenoids absorb light for use in photosynthesis and act as **antioxidants**. Many biological actions of carotenoids are attributed to their antioxidant activity, but they likely act by other mechanisms, too.

Vitamin A is fat-soluble and is packaged into chylomicrons in small intestine, and transported to the liver. The liver stores and exports vitamin A as needed; it is released into the blood bound to a retinol-binding protein, which transports it to cells. Carotenoids are not absorbed as well as vitamin A, but similar to vitamin A, they do require fat in the meal for absorption. In intestinal cells, carotenoids are packaged into the lipid-containing chylomicrons inside small intestine mucosal cells and then transported to the liver. In the liver, carotenoids are repackaged into lipoproteins, which transport them to cells.

The retinoids are aptly named as their **most notable function is in the retina of the eye where they aid in vision, particularly**

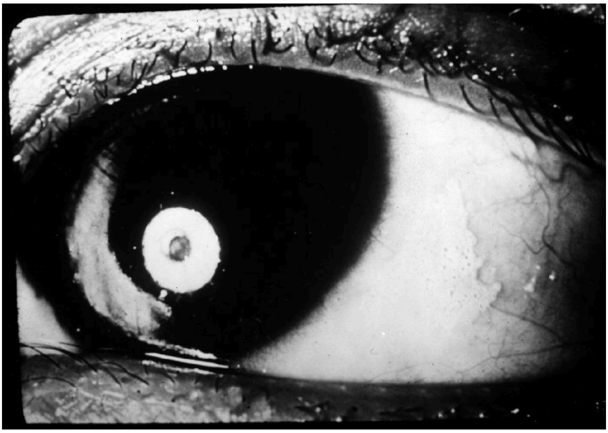
in seeing under low-light conditions. This is why night blindness is the most definitive sign of vitamin A deficiency. Vitamin A has several important functions in the body, including **maintaining vision and a healthy immune system**. Many of vitamin A's functions in the body are similar to the functions of hormones (for example, vitamin A can interact with DNA, causing a change in protein function). Vitamin A assists in maintaining healthy skin and the linings and coverings of tissues; it also regulates growth and development. As an antioxidant, vitamin A protects cellular membranes, helps in maintaining glutathione levels, and influences the amount and activity of enzymes that detoxify free radicals.

Vision

Retinol that is circulating in the blood is taken up by cells in the eye retina, where it is converted to retinal and is used to help the pigment rhodopsin, which is involved in the eye's ability to see under low light conditions. A deficiency in vitamin A thus results in less rhodopsin and a decrease in the detection of low-level light, a condition referred to as night-blindness.

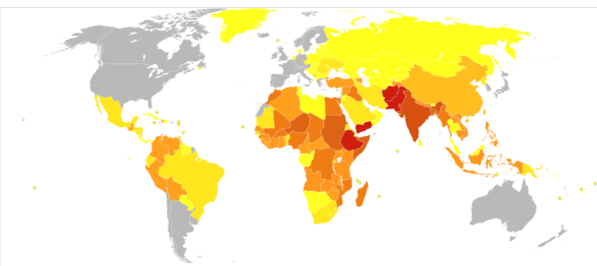
Insufficient intake of dietary vitamin A over time can also cause complete vision loss. In fact, vitamin A deficiency is the number one cause of preventable blindness worldwide. Vitamin A not only supports the vision function of eyes but also maintains the coverings and linings of the eyes. Vitamin A deficiency can lead to the dysfunction of the linings and coverings of the eye (eg. Bitot spots), causing dryness of the eyes, a condition called xerophthalmia. The progression of this condition can cause ulceration of the cornea and eventually blindness.

Figure 1.3.9.3 *Bitot Spot Caused by Vitamin A Deficiency*

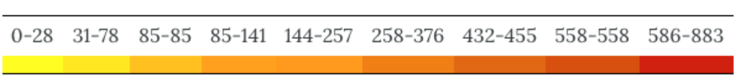


Bitot's Spots caused by vitamin A deficiency. Source: "Malnutrition-Bitot's Spots/ Bitot's Spots caused by vitamin A deficiency" by [CDC / Nutrition Program](). [CC BY 4.0 license]().

Figure 1.3.9.4 *Vitamin A Deficiency World Map*



Legend: Disability-adjusted life years (DALY) lost from Vitamin A deficiency in 2012 per million persons. Source: map by Wikipedia user [Chris55]() / [CC BY-SA 4.0]()



Immunity

In the twenty-first century, science has demonstrated that vitamin A greatly affects the immune system. What we are still lacking are clinical trials investigating the proper doses of vitamin A required to help ward off infectious disease and how large of an effect vitamin A supplementation has on populations that are not deficient in this vitamin. This brings up one of our common themes in this text—micronutrient deficiencies may contribute to the development, progression, and severity of a disease, but this does not mean that an increased intake of these micronutrients will solely prevent or cure disease. The effect, as usual, is cumulative and depends on the diet as a whole, among other things.

Growth and Development

Vitamin A acts similarly to some hormones in that it is able to change the amount of proteins in cells by interacting with DNA. This is the primary way that vitamin A affects growth and development. Vitamin A deficiency in children is linked to growth retardation; however, vitamin A deficiency is often accompanied by protein malnutrition and iron deficiency, thereby confounding the investigation of vitamin A's specific effects on growth and development.

In the fetal stages of life, vitamin A is important for limb, heart, eye, and ear development and in both deficiency and excess, vitamin A causes birth defects. Furthermore, both males and females require vitamin A in the diet to effectively reproduce.

Vitamin A Toxicity

Vitamin A toxicity, or hypervitaminosis A, is rare. Typically it requires you to ingest ten times the RDA of preformed vitamin A in the form of supplements (it would be hard to consume such high levels from a regular diet) for a substantial amount of time, although some people may be more susceptible to vitamin A toxicity at lower doses. The signs and symptoms of vitamin A toxicity include dry, itchy skin, loss of appetite, swelling of the brain, and joint pain. In severe cases, vitamin A toxicity may cause liver damage and coma.

Vitamin A is essential during pregnancy, but doses above 3,000 micrograms per day (10,000 international units) have been linked to an increased incidence of birth defects. Pregnant women should check the amount of vitamin A contained in any prenatal or pregnancy multivitamin she is taking to assure the amount is below the UL.

Dietary Sources of Vitamin A and Beta-Carotene

Preformed vitamin A is found only in foods from animals, with the liver being the richest source because that's where vitamin A is stored (see Table 1.3.9.1 "Vitamin A Content of Various Foods"). The dietary sources of carotenoids will be given in the following text.

Table 1.3.9.1 *Vitamin A Content of Various Foods*

Food	Serving	Vitamin A (IU)	Percent Daily Value
Beef liver	3 oz.	27,185	545
Chicken liver	3 oz.	12,325	245
Milk, skim	1 c.	500	10
Milk, whole	1 c.	249	5
Cheddar cheese	1 oz.	284	6

Source: Dietary Supplement Fact Sheet: Vitamin A. Office of Dietary Supplements, National Institutes of Health. http://ods.od.nih.gov/factsheets/VitaminA-QuickFacts/. Updated September 5, 2012. Accessed October 7, 2017.

Table 1.3.9.2 *Alpha- and Beta-Carotene Content of Various Foods*

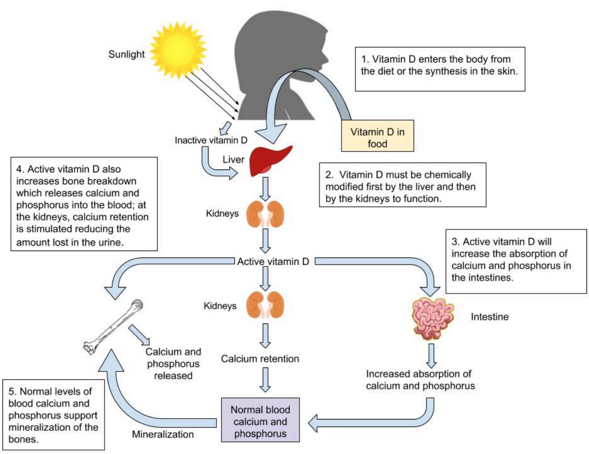
Food	**Serving**	**Beta-carotene (mg)**	**Alpha-carotene (mg)**
Pumpkin, canned	1c.	17.00	11.70
Carrot juice	1c.	22.00	10.20
Carrots, cooked	1c.	13.00	5.90
Carrots, raw	1 medium	5.10	2.10
Winter squash, baked	1c.	5.70	1.40
Collards, cooked	1c.	11.60	0.20
Tomato	1 medium	0.55	0.10
Tangerine	1 medium	0.13	0.09
Peas, cooked	1c.	1.20	0.09

Source: USDA National Nutrient Database for Standard Reference, Release 23. Agricultural Research Service, U.S., Department of Agriculture,. http://www.ars.usda.gov/ba/bhnrc/ndl. Updated: October 22, 2017. Accessed: August 31, 2021.

Vitamin D

Vitamin D refers to a group of fat-soluble vitamins derived from cholesterol. Vitamins D2 (ergocalciferol) and D3 (calcitriol) are the only ones known to have biological actions in the human body. The skin synthesizes vitamin D when exposed to sunlight. In fact, for most people, more than 90 percent of their vitamin D3 comes from the casual exposure to the UVB rays in sunlight. Anything that reduces your exposure to the sun's UVB rays decreases the amount of vitamin D3 your skin synthesizes. That would include long winters, your home's altitude, whether you are wearing sunscreen, and the color of your skin (including tanned skin). Do you ever wonder about an increased risk for skin cancer by spending too much time in the sun? Do not fret. **Less than thirty minutes of sun exposure to the arms and legs will increase blood levels of vitamin D3 more than orally taking 10,000 IU (250 micrograms) of vitamin D3.**

Figure 1.3.9.5 *The Functions of Vitamin D*



Vitamin D is absorbed through our skin and also the foods we eat. Vitamin D has a variety of functions in the body the main one being bone formation. Source: image by Allison Calabrese / [CC BY 4.0]

Vitamin D's Functional Role

Activated vitamin D3 (calcitriol) regulates blood calcium levels in concert with parathyroid hormone. In the absence of an adequate intake of vitamin D, less than 15 percent of calcium is absorbed from foods or supplements. The effects of calcitriol on calcium homeostasis are critical for bone health. A deficiency of vitamin

D in children causes the bone disease nutritional rickets. Rickets is very common among children in developing countries and is characterized by soft, weak, deformed bones that are exceptionally susceptible to fracture. In adults, vitamin D deficiency causes a similar disease called osteomalacia, which is characterized by low BMD. Osteomalacia has the same symptoms and consequences as osteoporosis and often coexists with osteoporosis. Vitamin D deficiency is common, especially in the elderly population, dark-skinned populations, and in the many people who live in the northern latitudes where sunlight exposure is much decreased during the long winter season.

Figure 1.3.9.6 *Rickets in Children*

Rickets is characterized by a bowing of the legs. Source: "Rickets, stages of development for children" from [Wellcome Images](#) / [CC BY 4.0](#)

Health Benefits

Observational studies have shown that people with low levels of vitamin D in their blood have lower BMD and an increased incidence of osteoporosis. In contrast, diets with high intakes of salmon, which contains a large amount of vitamin D, are linked with better bone health. A review of twelve clinical trials, published in the May 2005 issue of the Journal of the American Medical Association, concluded that oral vitamin D supplements at doses of 700–800 international units per day, with or without coadministration of calcium supplements, reduced the incidence of hip fracture by 26 percent and other nonvertebral fractures by 23 percent.[1] A reduction in fracture risk was not observed when people took vitamin D supplements at doses of 400 international units.

Many other health benefits have been linked to higher intakes of vitamin D, from decreased cardiovascular disease to the prevention of infection. Furthermore, evidence from laboratory studies conducted in cells, tissues, and animals suggest vitamin D prevents the growth of certain cancers, blocks inflammatory pathways, reverses atherosclerosis, increases insulin secretion, and blocks viral and bacterial infection and many other things. Vitamin D deficiency has been linked to an increased risk for autoimmune diseases. Immune diseases, rheumatoid arthritis, multiple sclerosis, and Type 1 diabetes have been observed in populations with inadequate vitamin D levels. Additionally, vitamin D deficiency is linked to an increased incidence of hypertension. Until the results

1. Bischoff-Ferrari, HA.,et al. Fracture Prevention with Vitamin D Supplementation: A Meta-Analysis of Randomized Controlled Trials. JAMA. 2005; 293(18), 2257–64. http://jama.ama-assn.org/content/293/18/2257.long. Accessed October 12, 2017.

come out from the VITAL study, the bulk of scientific evidence touting other health benefits of vitamin D is from laboratory and observational studies and requires confirmation in clinical intervention studies.

Vitamin D Toxicity

Although vitamin D toxicity is rare, too much can cause high levels of calcium concentrations or hypercalcemia. Hypercalcemia can lead to a large amount of calcium to be excreted through the urine which can cause kidney damage. Calcium deposits may also develop in soft tissues such as the kidneys, blood vessels, or other parts of the cardiovascular system. However, it is important to know that the synthesis of vitamin D from the sun does not cause vitamin D toxicity due to the skin production of vitamin D3 being a tightly regulated process.

Toxicity from excess vitamin D is rare, but certain diseases such as hyperparathyroidism, lymphoma, and tuberculosis make people more sensitive to the increases in calcium caused by high intakes of vitamin D.

Dietary Sources of Vitamin D

Table 1.3.9.3 *Vitamin D Content of Various Foods*

Food	Serving	Vitamin D (IU)	Percent daily value
Swordfish	3 oz.	566	142
Salmon	3 oz.	447	112
Tuna fish, canned in water, drained	3 oz.	154	39
Orange juice fortified with vitamin D	1 c.	137	34
Milk, nonfat, reduced fat, and whole, vitamin D- fortified	1 c.	115-124	29-31
Margarine, fortified	1 tbsp.	60	15
Sardines, canned in oil, drained	2 e.	46	12
Beef liver	3 oz.	42	11
Egg, large	1 e.	41	10

Source: Dietary Supplement Fact Sheet: Vitamin D. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#h3. Updated September 5, 2012. Accessed October 22, 2017.

Vitamin E

Vitamin E occurs in eight chemical forms, of which alpha-tocopherol appears to be the only form that is recognized to meet human requirements. Alpha-tocopherol and vitamin E's other constituents are fat-soluble and **primarily responsible for protecting cell membranes against lipid destruction caused by free radicals, therefore making it an antioxidant**. When alpha-tocopherol interacts with a free radical it is no longer capable of acting as an antioxidant unless it is enzymatically regenerated. Vitamin C helps to regenerate some of the alpha-tocopherol, but the remainder is eliminated from the body. Therefore, to maintain vitamin E levels, you ingest it as part of your diet.

Insufficient levels are rare (signs and symptoms of such conditions are not always evident) but are primarily the result of nerve degeneration. People with malabsorption disorders, such as Crohn's disease or cystic fibrosis, and babies born prematurely, are at higher risk for vitamin E deficiency.

Vitamin E has many other important roles and functions in the body such as **boosting the immune system by helping to fight off bacteria and viruses**. It also **enhances the dilation of blood vessels and inhibiting the formation of blood clotting**. Despite vitamin E's numerous beneficial functions when taken in recommended amounts, large studies do not support the idea that taking higher doses of this vitamin will increase its power to prevent or reduce disease risk.[23]

Fat in the diet is required for vitamin E absorption as it is packaged into lipid-rich chylomicrons in intestinal cells and transported to the liver. The liver stores some of the vitamin E or packages it into lipoproteins, which deliver it to cells.

Eye Conditions

Oxidative stress plays a role in age-related loss of vision, called

2. Goodman M, Bostlick RM, Kucuk O, Jones DP. Clinical trials of antioxidants as cancer prevention agents: past, present, and future. Free Radic Biol Med. 2011; 51(5), 1068–84. https://www.ncbi.nlm.nih.gov/pubmed/21683786. Accessed October 5, 2017.
3. McGinley C, Shafat A. Donnelly AE. Does antioxidant vitamin supplementation protect against muscle damage. Sports Med. 2009; 39(12), 1011–32. https://www.ncbi.nlm.nih.gov/pubmed/19902983. Accessed October 5, 2017.

macular degeneration. Age-related macular degeneration (AMD) primarily occurs in people over age fifty and is the progressive loss of central vision resulting from damage to the center of the retina, referred to as the macula. There are two forms of AMD, dry and wet, with wet being the more severe form.

In the dry form, deposits form in the macula; the deposits may or may not directly impair vision, at least in the early stages of the disease. In the wet form, abnormal blood vessel growth in the macula causes vision loss. Clinical trials evaluating the effects of vitamin E supplements on AMD and cataracts (clouding of the lens of an eye) did not consistently observe a decreased risk for either. However, scientists do believe vitamin E in combination with other antioxidants such as zinc and copper may slow the progression of macular degeneration in people with early-stage disease.

Dementia

The brain's high glucose consumption makes it more vulnerable than other organs to oxidative stress. Oxidative stress has been implicated as a major contributing factor to dementia and Alzheimer's disease. Some studies suggest vitamin E supplements delay the progression of Alzheimer's disease and cognitive decline, but again, not all of the studies confirm the relationship. A recent study with over five thousand participants published in the July 2010 issue of the Archives of Neurology demonstrated that people with the highest intakes of dietary vitamin E were 25 percent less likely to develop dementia than those with the lowest intakes of vitamin E.[4]

4. Devore EE, et al. Dietary Antioxidants and Long-Term Risk of Dementia. Arch Neurol. 2010; 67(7), 819–25.

More studies are needed to better assess the dose and dietary requirements of vitamin E and, for that matter, whether other antioxidants lower the risk of dementia, a disease that not only devastates the mind, but also puts a substantial burden on loved ones, caretakers, and society in general.

Vitamin E Toxicity

Currently, researchers have not found any adverse effects from consuming vitamin E in food. Although that may be the case, supplementation of alpha-tocopherol in animals has shown to cause hemorrhage and disrupt blood coagulation. Extremely high levels of vitamin E can interact with vitamin K-dependent clotting factors causing an inhibition of blood clotting.[5]

Vitamin E supplements often contain more than 400 international units, which is almost twenty times the RDA. The UL for vitamin E is set at 1,500 international units for adults. There is some evidence that taking vitamin E supplements at high doses has negative effects on health. As mentioned, vitamin E inhibits blood clotting and a few clinical trials have found that people taking vitamin E supplements have an increased risk of stroke. In contrast to vitamin E from supplements, there is no evidence that consuming foods containing vitamin E compromises health.

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923546/?tool=pubmed. Accessed October 5, 2017.

5. Dietary Supplement Fact Sheet: Vitamin E.National Institutes of Health, Office of Dietary Supplements. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/. Updated October 11, 2011. Accessed October 5, 2017.

Dietary Sources of Vitamin E

Add some nuts to your salad and make your own dressing to get a healthy dietary dose of vitamin E.

Image by rawpixel.com on unsplash.com / CC0

Vitamin E is found in many foods, especially those higher in fat, such as nuts and oils. Some spices, such as paprika and red chili pepper, and herbs, such as oregano, basil, cumin, and thyme, also contain vitamin E. (Keep in mind spices and herbs are commonly used in small amounts in cooking and therefore are a lesser source of dietary vitamin E.) See Table 1.3.9.4 "Vitamin E Content of Various Foods" for a list of foods and their vitamin E contents.

Everyday Connection

To increase your dietary intake of vitamin E from plant-based foods try a spinach salad with tomatoes and sunflower seeds, and add a dressing made with sunflower oil, oregano, and basil. The oil from the sunflower seeds and oil will aid in the absorption of vitamin E from the spinach and tomatoes.

Table 1.3.9.4 *Vitamin E Content of Various Foods*

Food	Serving size	Vitamin E (mg)	Percent daily value
Sunflower seeds	1 oz.	7.4	37
Almonds	1 oz.	6.8	34
Sunflower oil	1 Tbsp	5.6	28
Hazelnuts 1 oz.	1 oz.	4.3	22
Peanut butter	2 Tbsp.	2.9	15
Peanuts 1 oz.	1 oz.	2.2	11
Corn oil 1 Tbsp.	1 Tbsp.	1.9	10
Kiwi	1 medium	1.1	6
Tomato	1 medium	0.7	4
Spinach	1 c. raw	0.6	3

Source: Dietary Supplement Fact Sheet: Vitamin E.Office of Dietary Supplements, National Institutes of Health. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/. Updated October 11, 2011. Accessed October 5, 2017.

Vitamin K

Vitamin K refers to a group of fat-soluble vitamins that are similar in chemical structure. Vitamin K is **critical for blood function** acting as coenzymes which play an essential role in blood coagulation (aka blood clotting). Blood-clotting proteins are continuously circulating in the blood. Upon injury to a blood vessel, platelets stick to the wound forming a plug. Without vitamin K, blood would not clot.

A deficiency in vitamin K causes bleeding disorders. It is relatively rare, but people who have liver or pancreatic disease, celiac disease, or malabsorption conditions are at higher risk for vitamin K deficiency. Signs and symptoms include nosebleeds, easy bruising, broken blood vessels, bleeding gums, and heavy menstrual bleeding in women. The function of the anticoagulant drug warfarin is impaired by excess vitamin K intake from supplements. Calcium additionally plays a role in activation of blood-clotting proteins.

Bone Health

Vitamin K is also required for **maintaining bone health.** It modifies the protein osteocalcin, which is involved in the bone remodeling process. All the functions of osteocalcin and the other vitamin K-dependent proteins in bone tissue are not well understood and are under intense study. Some studies do show that people who have diets low in vitamin K also have an increased risk for bone fractures.

Dietary Sources of Vitamin K

Vitamin K is present in many foods. It is found in highest concentrations in green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce. Additionally, vitamin K can be synthesized via bacteria in the large intestine. The exact amount of vitamin K synthesized by bacteria that is actually absorbed in the lower intestine is not known, but likely contributes less than 10 percent of the recommended intake. Newborns have low vitamin K stores and it takes time for the sterile newborn gut to acquire the good bacteria it needs to produce vitamin K. So, it has become a routine practice to inject newborns with a single intramuscular dose of vitamin K. This practice has basically eliminated vitamin K-dependent bleeding disorders in babies.

Table 1.3.9.5 *Dietary Sources of Vitamin K*

Food	Serving	Vitamin K (mcg)	Percent daily value
Broccoli	½ c.	160	133
Asparagus	4 spears	34	28
Cabbage	½ c.	56	47
Spinach	½ c.	27	23
Green peas	½ c.	16	13
Cheese	1 oz.	10	8
Ham	3 oz.	13	11
Ground beef	3 oz.	6	5
Bread	1 slice	1.1	<1
Orange	1 e.	1.3	1

Source: National Institutes of Health. https://ods.od.nih.gov/factsheets/VitaminK-Consumer/#h3. Updated on Feb 24, 2020. Accessed on Nov 14, 2020.

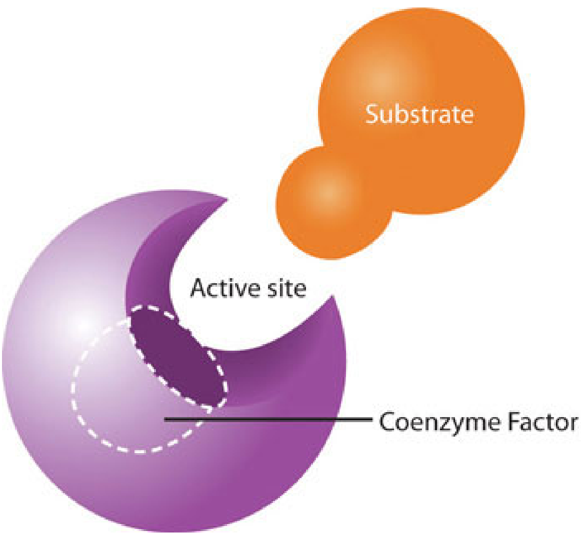
Water-Soluble Vitamins

All water-soluble vitamins play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage. Vitamins and minerals that make up part of enzymes are referred to as coenzymes and cofactors, respectively. Coenzymes and cofactors are required by enzymes to catalyze a specific reaction. They assist in converting a substrate to an end-product. Coenzymes and cofactors are

essential in catabolic pathways and play a role in many anabolic pathways too.

In addition to being essential for metabolism, many vitamins and minerals are required for **blood renewal and function**. At insufficient levels in the diet these vitamins and minerals impair the health of blood and consequently the delivery of nutrients in and wastes out, among many other functions. In this section we will focus on the vitamins that take part in metabolism and blood function and renewal.

Figure 1.3.9.7 *Enzyme Active Site for Cofactors*



Coenzymes and cofactors are the particular vitamin or mineral required for enzymes to catalyze a specific reaction. Source: Water-Soluble Vitamins.

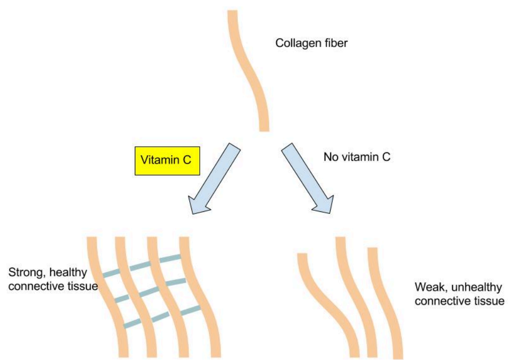
Vitamin C

Vitamin C, also commonly called ascorbic acid, is a water-soluble micronutrient essential in the diet for humans, although most other mammals can readily synthesize it. Vitamin C's ability to **easily donate electrons makes it a highly effective antioxidant. It is**

effective in scavenging reactive oxygen species, reactive nitrogen species, and many other free radicals. It protects lipids both by disabling free radicals and by aiding in the regeneration of vitamin E.

In addition to its role as an antioxidant, vitamin C is a **required part of several enzymes like signaling molecules in the brain, some hormones, and amino acids**. Vitamin C is also **essential for the synthesis and maintenance of collagen**. Collagen is the most abundant protein in the body and used for different functions such as the structure for ligaments, tendons, and blood vessels and also scars that bind wounds together. Vitamin C acts as the glue that holds the collagen fibers together and without sufficient levels in the body, collagen strands are weak and abnormal (see Figure 1.3.9.8. "The Role of Vitamin C in Collagen Synthesis").

Figure 1.3.9.8 *The Role of Vitamin C in Collagen Synthesis*



Vitamin C is required for the formation of strong connective tissue. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Vitamin C levels in the body are affected by the amount in the diet, which influences how much is absorbed and how much the kidney allows to be excreted, such that the higher the intake, the more vitamin C is excreted. Vitamin C is not stored in any significant amount in the body, but once it has reduced a free radical, it is very effectively regenerated and therefore it can exist in the body as a functioning antioxidant for many weeks.

The classic condition associated with vitamin C deficiency is scurvy. The signs and symptoms of scurvy include skin disorders, bleeding gums, painful joints, weakness, depression, and increased susceptibility to infections. Scurvy is prevented by having an adequate intake of fruits and vegetables rich in vitamin C.

Figure 1.3.9.9 *Bleeding Gums Associated with Scurvy*

Source: Water-Soluble Vitamins.

Cardiovascular Disease

Vitamin C's ability to prevent disease has been debated for many years. Overall, higher dietary intakes of vitamin C (via food intake, not supplements), are linked to decreased disease risk. A review of multiple studies published in the April 2009 issue of the Archives of Internal Medicine concludes there is moderate scientific evidence supporting the idea that higher dietary vitamin C intakes are correlated with reduced cardiovascular disease risk, but there is insufficient evidence to conclude that taking vitamin C supplements influences cardiovascular disease risk.[6] Vitamin C levels in the body have been shown to correlate well with fruit and vegetable intake, and higher plasma vitamin C levels are linked to reduced risk of some chronic diseases. In a study involving over twenty thousand participants, people with the highest levels of circulating vitamin C had a 42 percent decreased risk for having a stroke.[7]

Cancer

There is some evidence that a higher vitamin C intake is linked to a reduced risk of cancers of the mouth, throat, esophagus, stomach, colon, and lung, but not all studies confirm this is true. As with the studies on cardiovascular disease, the reduced risk of cancer is the result of eating foods rich in vitamin C, such as fruits and vegetables, not from taking vitamin C supplements. In these studies, the specific protective effects of vitamin C cannot be separated from the many other beneficial chemicals in fruits and vegetables.

6. Mente A, et al. A Systematic Review of the Evidence Supporting a Causal Link between Dietary Factors and Coronary Heart Disease. Arch Intern Med. 2009; 169(7), 659–69. http://archinte.ama-assn.org/cgi/content/full/169/7/659. Accessed October 5, 2017.
7. Myint PK, et al. Plasma Vitamin C Concentrations Predict Risk of Incident Stroke Over 10 Years in 20,649 Participants of the European Prospective Investigation into Cancer, Norfolk Prospective Population Study. Am J Clin Nutr. 2008; 87(1), 64–69. http://www.ajcn.org/content/87/1/64.long. Accessed September 22, 2017.

Immunity

Vitamin C does have several roles in the immune system, and many people increase vitamin C intake either from diet or supplements when they have a cold. Many others take vitamin C supplements routinely to prevent colds. Contrary to this popular practice, however, there is no good evidence that vitamin C prevents a cold. A review of more than fifty years of studies published in 2004 in the Cochrane Database of Systematic Reviews concluded that taking vitamin C routinely does not prevent colds in most people, but it **does slightly reduce cold severity and duration**. Moreover, taking megadoses (up to 4 grams per day) at the onset of a cold provides no benefits.[8]

Gout is a disease caused by elevated circulating levels of uric acid and is characterized by recurrent attacks of tender, hot, and painful joints. There is some evidence that a higher intake of vitamin C reduces the risk of gout.

Vitamin C Toxicity

High doses of vitamin C have been reported to cause numerous problems, but the only consistently shown side effects are gastrointestinal upset and diarrhea. To prevent these discomforts

8. Douglas RM, et al. Vitamin C for Preventing and Treating the Common Cold. Cochrane Database of Systematic Reviews. 2004; 4. CD000980. http://www.ncbi.nlm.nih.gov/pubmed/15495002?dopt=Abstract. Accessed October 5, 2017.

the IOM has set a UL for adults at 2,000 milligrams per day (greater than twenty times the RDA).

At very high doses in combination with iron, vitamin C has sometimes been found to increase oxidative stress, reaffirming that getting your antioxidants from foods is better than getting them from supplements, as that helps regulate your intake levels. There is some evidence that taking vitamin C supplements at high doses increases the likelihood of developing kidney stones, however, this effect is most often observed in people that already have multiple risk factors for kidney stones.

Dietary Sources of Vitamin C

Citrus fruits are great sources of vitamin C and so are many vegetables. In fact, British sailors in the past were often referred to as "limeys" as they carried sacks of limes onto ships to prevent scurvy. Vitamin C is not found in significant amounts in animal-based foods.

Because vitamin C is water-soluble, it leaches away from foods considerably during cooking, freezing, thawing, and canning. Up to 50 percent of vitamin C can be boiled away. Therefore, to maximize vitamin C intake from foods, you should eat fruits and vegetables raw or lightly steamed. For the vitamin C content of various foods, see Table 1.3.9.6 "Vitamin C Content of Various Foods."

Table 1.3.9.6 *Vitamin C Content of Various Foods*

Food	Serving	Vitamin C (mg)	Percent daily value
Orange juice	6 oz.	93	155
Grapefruit juice	6 oz.	70	117
Orange	1 medium	70	117
Strawberries	1 c.	85	164
Tomato	1 medium	17	28
Sweet red pepper	½ c. raw	95	158
Broccoli	½ c. cooked	51	65
Romaine lettuce	2 c.	28	47
Cauliflower	1 c. boiled	55	86
Potato	1 medium, baked	17	28

Source: Dietary Supplement Fact Sheet: Vitamin C. Office of Dietary Supplements, National Institutes of Health. http://ods.od.nih.gov/factsheets/VitaminC-QuickFacts/. Updated June 24, 2011. Accessed October 5, 2017.

Thiamin (B_1)

Thiamin is especially important in glucose metabolism. It acts as a cofactor for enzymes that break down glucose for energy production. Thiamin plays a key role in nerve cells as the glucose that is catabolized by thiamin is needed for an energy source. Additionally, thiamin plays a role in the synthesis of neurotransmitters and is therefore required for RNA, DNA, and ATP synthesis.

The brain and heart are most affected by a deficiency in thiamin. Thiamin deficiency, also known as beriberi, can cause symptoms of fatigue, confusion, movement impairment, pain in the lower extremities, swelling, and heart failure. It is prevalent in societies whose main dietary staple is white rice. During the processing of white rice, the bran is removed, along with what were called in the early nineteenth century, “accessory factors,” that are vital for metabolism.

Another common thiamin deficiency known as Wernicke-Korsakoff syndrome can cause similar symptoms as beriberi such as confusion, loss of coordination, vision changes, hallucinations, and may progress to coma and death. This condition is specific to alcoholics as diets high in alcohol can cause thiamin deficiency. Other individuals at risk include individuals who also consume diets typically low in micronutrients such as those with eating disorders, elderly, and individuals who have gone through gastric bypass surgery.[9]

Dietary Sources

Whole grains, meat and fish are great sources of thiamin. The United States as well as many other countries, fortify their refined breads and cereals. For the thiamin content of various foods, see Table 1.3.9.7 “Thiamin Content of Various Foods.”

Table 1.3.9.7 *Thiamin content of various foods*

9. Fact Sheets for Health Professionals: Thiamin. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Thiamin-HealthProfessional/. Updated Feburary 11, 2016. Accessed October 22, 2017.

Food	Serving	Thiamin (mg)	Percent daily value
Breakfast cereals, fortified	1 serving	1.5	100
White rice, enriched	½ c.	1.4	73
Pork chop, broiled	3 oz.	0.4	27
Black beans, boiled	½ c.	0.4	27
Tuna, cooked	3 oz.	0.2	13
Brown rice, cooked, not enriched	½ c.	0.1	7
Whole wheat bread	1 slice	0.1	7
2% Milk	8 oz.	0.1	7
Cheddar cheese	1 ½ oz	0	0
Apple, sliced	1 c.	0	0

Source: Health Professional Fact Sheet: Thiamin. Office of Dietary Supplements, National Institutes of Health.https://ods.od.nih.gov/factsheets/Thiamin-HealthProfessional/ . Updated February 11, 2016 . Accessed October 5, 2017.

Riboflavin (B2)

Riboflavin is an essential component of flavoproteins, which are coenzymes **involved in many metabolic pathways of carbohydrate, lipid, and protein metabolism. Flavoproteins aid in the transfer of electrons in the electron transport chain. Furthermore, the functions of other B-vitamin coenzymes, such as vitamin B_6 and folate, are dependent on the actions of flavoproteins**. The "flavin" portion of riboflavin gives a bright yellow color to riboflavin, an attribute that helped lead to its discovery as a vitamin. When riboflavin is taken in excess amounts (supplement form) the excess will be excreted through your kidneys and show up in your urine. Although the color may alarm you, it is harmless. There are no adverse effects of high doses of riboflavin from foods or supplements that have been reported.

Riboflavin deficiency, sometimes referred to as ariboflavinosis, is often accompanied by other dietary deficiencies (most notably protein) and can be common in people that suffer from alcoholism. This deficiency will usually also occur in conjunction with deficiencies of other B vitamins because the majority of B vitamins have similar food sources. Its signs and symptoms include dry, scaly skin, cracking of the lips and at the corners of the mouth, sore throat, itchy eyes, and light sensitivity.

Dietary Sources

Riboflavin can be found in a variety of different foods but it is important to remember that it can be destroyed by sunlight. Milk is one of the best sources of riboflavin in the diet and was once delivered and packaged in glass bottles. This packaging has changed to cloudy plastic containers or cardboard to help block the light from destroying the riboflavin in milk. For the riboflavin content of various foods, see Table 1.2.9.8 "Riboflavin Content of Various Foods."

Table 1.3.9.8 *Riboflavin Content of Various Foods*

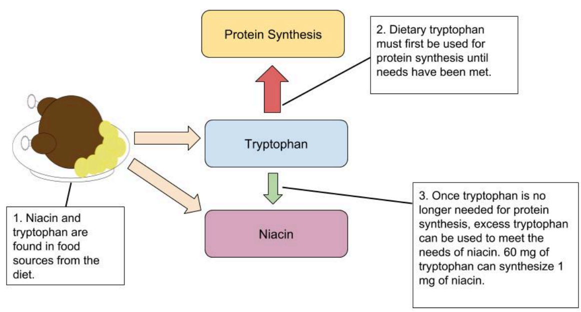
Food	Serving	Riboflavin (mg)	Percent Daily Value
Beef liver	3 oz.	2.9	171
Breakfast cereals, fortified	1 serving	1.7	100
Instant oats, fortified	1 c.	1.1	65
Plain yogurt, fat free	1 c.	0.6	35
2% milk	8 oz.	0.5	29
Beef, tenderloin steak	3 oz.	0.4	24
Portabella mushrooms, sliced	½ c.	0.3	18
Almonds, dry roasted	1 oz.	0.3	18
Egg, scrambled	1 large	0.2	12
Quinoa	1 c.	0.2	12
Salmon, canned	3 oz.	0.2	12
Spinach, raw	1 c.	0.1	6
Brown rice	½ c.	0	0

Source: Fact Sheet for Health Professionals, Riboflavin. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/Riboflavin-HealthProfessional/. Updated February 11, 2016. Accessed October 22, 2017.

Niacin (B3)

Niacin is a component of the coenzymes NADH and NADPH, which are **involved in the catabolism and/or anabolism of carbohydrates, lipids, and proteins. NADH is the predominant electron carrier and transfers electrons to the electron-transport chain to make ATP. NADPH is also required for the anabolic pathways of fatty-acid and cholesterol synthesis**. In contrast to other vitamins, niacin can be synthesized by humans from the amino acid tryptophan in an anabolic process requiring enzymes dependent on riboflavin, vitamin B_6, and iron. Niacin is made from tryptophan only after tryptophan has met all of its other needs in the body. The contribution of tryptophan-derived niacin to niacin needs in the body varies widely and a few scientific studies have demonstrated that diets high in tryptophan have very little effect on niacin deficiency. Niacin deficiency is commonly known as pellagra and the symptoms include fatigue, decreased appetite, and indigestion. These symptoms are then commonly followed by the four D's: diarrhea, dermatitis, dementia, and sometimes death.

Figure 1.3.9.10 *Conversion of Tryptophan to Niacin*



Tryptophan and niacin are both essential in protein synthesis. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Dietary Sources

Niacin can be found in a variety of different foods such as yeast, meat, poultry, red fish, and cereal. In plants, especially mature grains, niacin can be bound to sugar molecules which can significantly decrease the niacin bioavailability. For the niacin content of various foods, see Table 1.3.9.9 "Niacin Content of Various Foods."

Table 1.3.9.9 *Niacin Content of Various Foods*

Food	Serving	Niacin (mg)	Percent Daily Value
Chicken	3 oz.	7.3	36.5
Tuna	3 oz.	8.6	43
Turkey	3 oz.	10.0	50
Salmon	3 oz.	8.5	42.5
Beef (90% lean)	3 oz.	4.4	22
Cereal (unfortified)	1 c.	5	25
Cereal (fortified)	1 c.	20	100
Peanuts	1 oz.	3.8	19
Whole wheat bread	1 slice	1.3	6.5
Coffee	8 oz.	0.5	2.5

Source: Micronutrient Information Center: Niacin. Oregon State University, Linus Pauling Institute. http://lpi.oregonstate.edu/mic/vitamins/niacin. Updated in July 2013. Accessed October 22, 2017.

Pantothenic Acid (B5)

Pantothenic acid forms coenzyme A, which is the main carrier of carbon molecules in a cell.

Coenzyme A is also involved in the synthesis of lipids, cholesterol, and acetylcholine (a neurotransmitter). A Pantothenic Acid deficiency is exceptionally rare. Signs and symptoms include fatigue, irritability, numbness, muscle pain, and cramps. You may have seen pantothenic acid on many ingredients lists for skin and hair care products; however there is no good scientific evidence that pantothenic acid improves human skin or hair.

Dietary Sources

Pantothenic Acid is widely distributed in all types of food, which is why a deficiency in this nutrient is rare. Pantothenic Acid gets its name from the greek word “pantothen” which means “from everywhere.” For the pantothenic acid content of various foods, see Table 1.3.9.10 Pantothenic Acid Content of Various Foods.”

Table 1.3.9.10 *Pantothenic Acid Content of Various Foods*

Food	Serving	Pantothenic Acid (mg)	Percent Daily Value
Sunflower seeds	1 oz.	2	20
Fish, trout	3 oz.	1.9	19
Yogurt, plain nonfat	8 oz.	1.6	16
Lobster	3 oz.	1.4	14
Avocado	½ fruit	1	10
Sweet potato	1 medium	1	10
Milk	8 fl oz.	0.87	8.7
Egg	1 large	0.7	7
Orange	1 whole	0.3	3
Whole wheat bread	1 slice	0. 21	2.1

Source: Micronutrient Information Center: Pantothenic Acid. Oregon State University, Linus Pauling Institute. http://lpi.oregonstate.edu/mic/vitamins/patothenic-acid . Updated in July 2013. Accessed October 22, 2017.

Biotin

Biotin is required as a coenzyme in the citric acid cycle and in **lipid**

metabolism. It is also required as an enzyme in the synthesis of glucose and some nonessential amino acids. A specific enzyme, biotinidase, is required to release biotin from protein so that it can be absorbed in the gut. There is some bacterial synthesis of biotin that occurs in the colon; however this is not a significant source of biotin. Biotin deficiency is rare, but can be caused by eating large amounts of egg whites over an extended period of time. This is because a protein in egg whites tightly binds to biotin making it unavailable for absorption. A rare genetic disease-causing malfunction of the biotinidase enzyme also results in biotin deficiency. Symptoms of biotin deficiency are similar to those of other B vitamins, but may also include hair loss when severe.

Dietary Sources

Biotin can be found in foods such as eggs, fish, meat, seeds, nuts and certain vegetables. For the pantothenic acid content of various foods, see Table 1.3.9.11 "Biotin Content of Various Foods."

Table 1.3.9.11 *Biotin Content of Various Foods*

Food	Serving	Biotin (mcg)	Percent daily value*
Eggs	1 large	10	33.3
Salmon, canned	3 oz.	5	16.6
Pork chop	3 oz.	3.8	12.6
Sunflower seeds	¼ c.	2.6	8.6
Sweet potato	½ c.	2.4	8
Almonds	¼ c.	1.5	5
Tuna, canned	3 oz.	0.6	2
Broccoli	½ c.	0.4	1.3
Banana	½ c.	0.2	0.6
* Current AI used to determine Percent Daily Value			

Source: Fact Sheet for Health Professionals: Biotin. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/. Updated October 3, 2017. Accessed November 10, 2017.

Vitamin B_6 (Pyridoxine)

Vitamin B_6 is the coenzyme involved in a wide variety of functions in the body. One major function is the **nitrogen transfer between amino acids which plays a role in amino-acid synthesis and catabolism. Also, it functions to release glucose from glycogen in the catabolic pathway of glycogenolysis and is required by enzymes for the synthesis of multiple neurotransmitters and hemoglobin**

Vitamin B_6 is also a required coenzyme for the **synthesis of hemoglobin.** A deficiency in vitamin B_6 can cause anemia, but it is of a different type than that caused by insufficient folate, cobalamin, or iron; although the symptoms are similar. The size of red blood cells is normal or somewhat smaller but the hemoglobin content is lower. This means each red blood cell has less capacity for carrying oxygen, resulting in muscle weakness, fatigue, and shortness of breath. Other deficiency symptoms of vitamin B_6 can cause dermatitis, mouth sores, and confusion.

The vitamin B6 coenzyme is needed for a number of different reactions that are essential for **amino acid synthesis, catabolism for energy, and the synthesis of glucose and neurotransmitters**.

Vitamin B6 coenzyme is essential for the conversion of amino acid methionine into cysteine. With low levels of Vitamin B6, homocysteine will build up in the blood. High levels of homocysteine **increases the risk for heart disease**.

Vitamin B_6 Toxicity

Currently, there are no adverse effects that have been associated with a high dietary intake of vitamin B6, but large supplemental doses can cause severe nerve impairment. To prevent this from occurring, the UL for adults is set at 100 mg/day.

Dietary Sources

Vitamin B_6 can be found in a variety of foods. The richest sources include fish, beef liver and other organ meats, potatoes, and other starchy vegetables and fruits. For the Vitamin B_6 content of various foods, see Table 1.3.9.12 "Vitamin B_6 Content of Various Foods."

Table 1.3.9.12 *Vitamin B_6 Content of Various Foods*

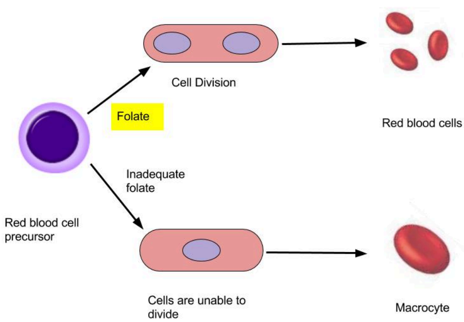
Food	Serving	Vitamin B6 (mg)	Percent Daily Value
Chickpeas	1 c.	1.1	55
Tuna, fresh	3 oz.	0.9	45
Salmon	3 oz.	0.6	30
Potatoes	1 c.	0.4	20
Banana	1 medium	0.4	20
Ground beef patty	3 oz.	0.3	10
White rice, enriched	1 c.	0.1	5
Spinach	½ c	0.1	5

Source: Dietary Supplement Fact Sheet: Vitamin B6. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/VitaminB6-HealthProfessional/. Updates February 11, 2016. Accessed October 22, 2017.

Folate

Folate is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, **rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem cells. When folate is deficient, cells cannot divide normally** A consequence of folate deficiency is macrocytic or megaloblastic anemia. Macrocytic and megaloblastic mean "big cell," and anemia refers to fewer red blood cells or red blood cells containing less hemoglobin. Macrocytic anemia is characterized by larger and fewer red blood cells. It is caused by red blood cells being unable to produce DNA and RNA fast enough—cells grow but do not divide, making them large in size (see Figure 1.3.9.11. "Folate and the Formation of Macrocytic Anemia").

Figure 1.3.9.11 *Folate and the Formation of Macrocytic Anemia*

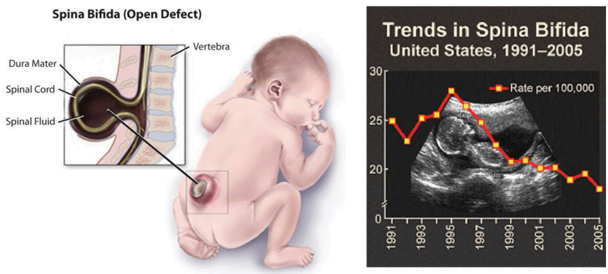


Folate is essential for the formation of healthy blood cells. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Folate is especially essential for the growth and specialization of cells of the central nervous system. Children whose mothers were folate-deficient during pregnancy have a higher risk of neural-tube birth defects. Folate deficiency is causally linked to the development of spina bifida, a neural-tube defect that occurs when the spine does not completely enclose the spinal cord. Spina bifida can lead to many physical and mental disabilities (Figure 1.3.9.12 "Spina Bifida in Infants"). Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 1996 in the United States (and 1998 in Canada) compared to before grain products were fortified with folate.

Additionally, results of clinical trials have demonstrated that neural-tube defects are significantly decreased in the offspring of mothers who began taking folate supplements one month prior to becoming pregnant and throughout the pregnancy. In response to the scientific evidence, the Food and Nutrition Board of the Institute of Medicine (IOM) raised the RDA for folate to 600 micrograms per day for pregnant women. Some were concerned that higher folate intakes may cause colon cancer; however, scientific studies refute this hypothesis.

Figure 1.3.9.12 *Spina Bifida in Infants*



Spina bifida is a neural-tube defect that can have severe health consequences. Source: Water-Soluble Vitamins.

Dietary Reference Intakes

The RDAs and ULs for different age groups for folate are listed in Table 1.3.9.13 "Dietary Reference Intakes for Folate." Folate is a compound that is found naturally in foods. Folic acid however is the chemical structure form that is used in dietary supplements as well as enriched foods such as grains. The FNB has developed dietary folate equivalents (DFE) to reflect the fact that folic acid is more bioavailable and easily absorbed than folate found in food. The conversions for the different forms are listed below.

1 mcg DFE = 1 mcg food folate

1mcg DFE = 0.6 mcg folic acid from fortified foods or dietary supplements consumed with foods

1 mcg DFE = 0.5 mcg folic acid from dietary supplements taken on an empty stomach

Table 1.3.9.13 *Dietary Reference Intakes for Folate*

Age Group	RDA Males and Females mcg DFE/day	UL
Infants (0–6 months)	65*	Not possible to determine
Infants (7–12 months)	80*	Not possible to determine
Children (1–3 years)	150	300
Children (4–8 years)	200	400
Children (9–13 years)	300	600
Adolescents (14–18 years)	400	800
Adults (> 19 years)	400	1000
*denotes Adequate Intake		

Source: Dietary Supplement Fact Sheet: Folate. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/Folate-HealthProfessional/. Updated April 20, 2016. Accessed October 22, 2017.

Dietary Sources

Folate is found naturally in a wide variety of food especially in dark leafy vegetables, fruits, and animal products. The U.S. Food and Drug Administration (FDA) began requiring manufacturers to fortify enriched breads, cereals, flours, and cornmeal to increase the consumption of folate in the American diet. For the folate content of various foods, see Table 1.3.9.14 "Folate Content of Various Foods."

Table 1.3.9.14 *Folate Content of Various Foods*

Food	Serving	Folate (mcg DFE)	Percent Daily Value
Beef Liver	3 oz.	215	54
Fortified breakfast cereals	¾ c.	400	100
Spinach	½ c.	131	33
White rice, enriched	½ c.	90	23
Asparagus	4 spears	85	20
White bread, enriched	1 slice	43	11
Broccoli	2 spears	45	10
Avocado	½ c.	59	15
Orange juice	6 oz.	35	9
Egg	1 large	22	6

Source: Dietary Supplement Fact Sheet: Folate. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/Folate-HealthProfessional/. Updated April 20, 2016. Accessed October 22, 2017.

Vitamin B_{12} (Cobalamin)

Vitamin B_{12} contains cobalt, making it the only vitamin that contains a metal ion. Vitamin B_{12} is an essential part of coenzymes. It is **necessary for fat and protein catabolism, for folate coenzyme function, and for hemoglobin synthesis. An enzyme requiring vitamin B_{12} is needed by a folate-dependent enzyme to synthesize DNA. Thus, a deficiency in vitamin B_{12} has similar consequences to health as folate deficiency. In children and adults vitamin B_{12} deficiency causes macrocytic anemia, and in babies born to cobalamin-deficient mothers there is an increased risk for neural-tube defects**. In order for the human body to absorb vitamin B_{12}, the stomach, pancreas, and small intestine must be functioning properly. Cells in the stomach secrete a protein called intrinsic factor that is necessary for vitamin B_{12} absorption, which occurs in the small intestine. Impairment of secretion of this protein either caused by an autoimmune disease or by chronic inflammation of the stomach (such as that occurring in some people with H.pylori infection), can lead to the disease pernicious anemia, a type of macrocytic anemia. Vitamin B_{12} malabsorption is most common in the elderly, who may have impaired functioning of digestive organs, a normal consequence of aging. Pernicious anemia is treated by large oral doses of vitamin B_{12} or by putting the vitamin under the tongue, where it is absorbed into the bloodstream without passing through the intestine. In patients that do not respond to oral or sublingual treatment vitamin $B_{12}$is given by injection.

Vitamin B_{12} and folate play key roles in converting homocysteine to amino acid methionine.

High levels of homocysteine in the blood increases the risk for heart disease. Low levels of vitamin B_{12}, folate or vitamin B6 will increase homocysteine levels therefore increasing the risk of heart disease.

When there is a deficiency in vitamin B_{12} , inactive folate (from food) is unable to be converted to active folate and used in the body for the synthesis of DNA. Folic Acid however (that comes from supplements or fortified foods) is available to be used as active folate in the body without vitamin B_{12} .Therefore, if there is a deficiency in vitamin B_{12} macrocytic anemia may occur. With the fortification of foods incorporated into people's diets, the risk of an individual developing macrocytic anemia is decreased.

Dietary Sources

Vitamin B_{12} is found naturally in animal products such as fish, meat, poultry, eggs, and milk products. Although vitamin B_{12} is not generally present in plant foods, fortified breakfast cereals are also a good source of vitamin B_{12}. For the vitamin B_{12} content of various foods, see Table 1.3.9.15 "Vitamin B_{12} Content of Various Foods."

Table 1.3.9.15 *Vitamin B_{12} Content of Various Foods*

Food	**Serving**	**Vitamin B12 (mcg)**	**Percent Daily Value**
Clams	3 oz.	84.1	1,402
Salmon	3 oz.	4.8	80
Tuna, canned	3 oz.	2.5	42
Breakfast cereals, fortified	1 serving	1.5	25
Beef, top sirloin	3 oz.	1.4	23
Milk, lowfat	8 fl oz.	1.2	18
Yogurt, lowfat	8 oz.	1.1	18
Cheese, swiss	1 oz.	0.9	15
Egg	1 large	0.6	10

Source: Dietary Supplement Fact Sheet: Vitamin B12. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/. Updated February 11, 2016. Accessed October 28, 2017.

Choline

Choline is a water-soluble substance that is not classified as a vitamin because it can be synthesized by the body. However, the synthesis of choline is limited and therefore it is recognized as an essential nutrient. Choline is need to perform functions such as the **synthesis of neurotransmitter acetylcholine, the synthesis of phospholipids used to make cell membranes, lipid transport, and also homocysteine metabolism**. A deficiency in choline may lead to interfered brain development in the fetus during pregnancy, and in adults cause fatty liver and muscle damage.

Dietary Sources

Choline can be found in a variety of different foods. The main dietary sources of choline in the United States consist of primarily animal based products. For the Choline content of various foods, see Table 1.3.9.16 "Choline Content of Various Foods."

Table 1.3.9.16 *Choline Content of Various Foods*

Food	Serving	Choline (mg)	Percent Daily Value
Egg	1 large	147	27
Soybeans	½ cup	107	19
Chicken breast	3 oz.	72	13
Mushrooms, shiitake	½ c.	58	11
Potatoes	1 large	57	10
Kidney beans	½ c.	45	8
Peanuts	¼ c.	24	4
Brown rice	1 c.	19	3

Source: Fact Sheet for Health Professionals: Choline. Office of Dietary Supplements, National Institutes of Health. https://ods.od.nih.gov/factsheets/Choline-HealthProfessional/. Updated January 25, 2017. Accessed October 28, 2017.

Do B-Vitamin Supplements Provide an Energy Boost?

Although some marketers claim taking a vitamin that contains one-thousand times the daily value of certain B vitamins boosts energy and performance, this is a myth that is not backed by science. The "feeling" of more energy from energy-boosting supplements stems from the high amount of added sugars, caffeine, and other herbal stimulants that accompany the high doses of B vitamins. As discussed, B vitamins are needed to support energy metabolism and growth, but taking in more than required does not supply you with more energy. A great analogy of this phenomenon is the gas in your car. Does it drive faster with a half-tank of gas or a full one? It does not matter; the car drives just as fast as long as it has gas. Similarly, depletion of B vitamins will cause problems in energy metabolism, but having more than is required to run metabolism does not speed it up. Buyers of B-vitamin supplements beware; B vitamins are not stored in the body and all excess will be flushed down the toilet along with the extra money spent.

B vitamins are naturally present in numerous foods, and many other foods are enriched with them. In North America B-vitamin deficiencies are rare; however in the nineteenth century some vitamin-B deficiencies plagued many people in North America. Niacin deficiency, also known as pellagra, was prominent in poorer Americans whose main dietary staple was refined cornmeal. Its symptoms were severe and included diarrhea, dermatitis, dementia, and even death. Some of the health consequences of pellagra are the result of niacin being in insufficient supply to support the body's metabolic functions.

1.3.10. Minerals: Summary Charts

Summary of Major Minerals

Table 1.3.10.1 A *Summary of the Major Minerals*

Micronutrient	Sources	Recommended intakes for Adults	Major functions	Deficiency diseases and symptoms	Groups for defi
Calcium	Yogurt, cheese, sardines, milk, orange juice, turnip	1,000 mg/day	Component of mineralized bone, provides structure and microarchitecture	Increased risk of osteoporosis	Postme women who are intolera vegan
Phosphorus	Salmon, yogurt, turkey, chicken, beef, lentils	700 mg/day	Structural component of bones, cell membrane, DNA and RNA, and ATP	Bone loss, weak bones	Older a alcoholi
Magnesium	Whole grains and legumes, almonds, cashews, hazelnuts, beets, collards, and kelp	420 mg/day	Component of mineralized bone, ATP synthesis and utilization, carbohydrate, lipid, protein, RNA, and DNA synthesis	Tremor, muscle spasms, loss of appetite, nausea	Alcohol individu kidney a gastroir disease
Sulfur	Protein foods	None specified	Structure of some vitamins and amino acids, acid-base balance	None when protein needs are met	None
Sodium	Processed foods, table salt, pork, chicken	< 2,300 mg/ day; ideally 1,500 mg/day	Major positive extracellular ion, nerve transmission, muscle contraction, fluid balance	Muscle cramps	People consum much w excessiv sweatin with vo or diarr
Potassium	Fruits, vegetables, legumes, whole grains, milk	4700 mg/day	Major positive intracellular ion, nerve transmission, muscle contraction, fluid balance	Irregular heartbeat, muscle cramps	People consum diets hi process meats, t with vo or diarr
Chloride	Table salt, processed foods	<3600 mg/ day; ideally 2300 mg/day	Major negative extracellular ion, fluid balance	Unlikely	none

Source: Summary of Major Minerals

Summary of Trace Minerals

Table 1.3.10.2 A *Summary of the Trace Minerals*

Micronutrient	Sources	Recommended intakes for adults	Major functions	Deficiency diseases an symptoms
Iron	Red meat, egg yolks, dark leafy vegetables, dried fruit, iron-fortified foods	8-18 mg/day	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fat paleness, fa heart rate
Copper	Nuts, seeds, whole grains, seafood	900 mcg/day	Assists in energy production, iron metabolism	Anemia: fat paleness, fa heart rate
Zinc	oysters, wheat germ, pumpkin seeds, squash,, beans, sesame seeds, tahini, beef, lamb	8-11 mg/day	Assists in energy production, protein, RNA and DNA synthesis; required for hemoglobin synthesis	Growth retardation children, ha loss, diarrh skin sores, l of appetite, weight loss
Selenium	Meat, seafood, eggs, nuts	55 mcg/day	Essential for thyroid hormone activity	Fatigue, mu pain, weakn Keshan dise
Iodine	Iodized salt, seaweed, dairy products	150 mcg/day	Making thyroid hormone, metabolism, growth and development	Goiter, cretinism, c signs and symptoms include fati depression, weight gain itchy skin, l heart-rate
Chromium		25-35 mcg/day	Assists insulin in carbohydrate, lipid and protein metabolism	abnormal glucose metabolism
Fluoride	Fluoridated water, foods prepared in fluoridated water, seafood	3-4 mg/day	Component of mineralized bone, provides structure and microarchitecture, stimulates new bone growth	Increased r of dental ca

Manganese	Legumes, nuts, leafy green vegetables	1.8-2.3 mg/day	Glucose synthesis, amino-acid catabolism	Impaired growth, ske abnormaliti abnormal glucose metabolism
Molybdenum	Milk, grains, legumes	45 mcg/day	Cofactor for a number of enzymes	Unknown

Source: Summary of Trace Minerals

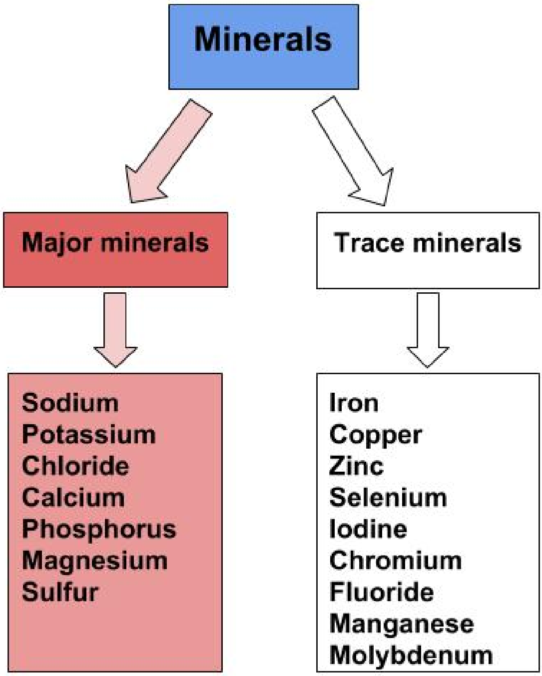
1.3.11. More About Major Minerals

Introduction

Similarly to vitamins, minerals are essential to human health and can be obtained in our diet from different types of food. Minerals are abundant in our everyday lives. From the soil in your front yard to the jewelry you wear on your body, we interact with minerals constantly. **There are 20 essential minerals that must be consumed in our diets to remain healthy**. The amount of each mineral found in our bodies vary greatly and therefore, so does consumption of those minerals. When there is a deficiency in an essential mineral, health problems may arise. Major minerals are classified as minerals that are required in the diet each day in amounts larger than 100 milligrams. These include sodium, potassium, chloride, calcium, phosphorus, magnesium, and sulfur. These major minerals can be found in various foods. Consuming a varied diet significantly improves an individual's ability to meet their nutrient needs. [1]

1. Pobocik RS, Trager A, Monson LM. Dietary Patterns and Food Choices of a Population Sample of Adults on Guam. Asia Pacific Journal of Clinical Nutrition. 2008; 17(1), 94-100. http://apjcn.nhri.org.tw/server/APJCN/17/1/94.pdf. Accessed February 16, 2018.

Figure 1.3.11.1 *The Major Minerals*



Minerals can be divided into major and minor classifications. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Bioavailability

Minerals are not as efficiently absorbed as most vitamins and so the bioavailability of minerals can be very low. Plant-based foods often contain factors, that bind to minerals and inhibit their absorption. In general, minerals are better absorbed from animal-based foods. In most cases, if dietary intake of a particular mineral is increased, absorption will decrease. Some minerals influence the absorption of others. For instance, excess zinc in the diet can impair iron and copper absorption. Conversely, certain vitamins enhance mineral absorption. For example, vitamin C boosts iron absorption, and vitamin D boosts calcium and magnesium absorption. As is the case with vitamins, certain gastrointestinal disorders and diseases, such as Crohn's disease and kidney disease, as well as the aging process, impair mineral absorption, putting people with malabsorption conditions and the elderly at higher risk for mineral deficiencies.

Calcium

Calcium's Functional Roles

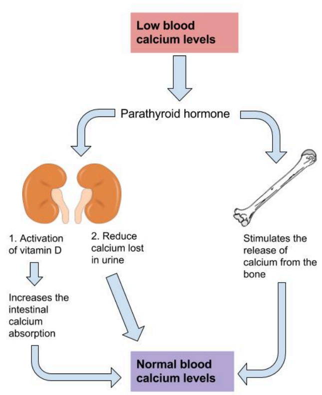
Calcium is the most abundant mineral in the body and greater than 99 percent of it is stored in bone tissue. Although only 1 percent of the calcium in the human body is found in the blood and soft tissues, it is here that it performs the most critical functions. Blood calcium levels are rigorously controlled so that if blood levels drop the body will rapidly respond by stimulating bone resorption, thereby releasing stored calcium into the blood. Thus, bone tissue sacrifices its stored calcium to maintain blood calcium levels. This is why bone health is dependent on the intake of dietary calcium and also why blood levels of calcium do not always correspond to dietary intake.

Calcium plays a role in a number of different functions in the body like **bone and tooth formation**. The most well-known calcium function is to build and strengthen bones and teeth.

When your diet is calcium deficient, the mineral content of bone decreases causing it to become brittle and weak. Thus, increased calcium intake helps to increase the mineralized content of bone tissue. Greater mineralized bone tissue corresponds to a greater BMD, and to greater bone strength. The remaining calcium plays a role in **nerve impulse transmission** by facilitating electrical impulse transmission from one nerve cell to another. Calcium in muscle cells is **essential for muscle contraction** because the flow of calcium ions are needed for the muscle proteins (actin and myosin) to interact. Calcium is also **essential in blood clotting** by activating clotting factors to fix damaged tissue.

In addition to calcium's four primary functions calcium has several other minor functions that are also critical for maintaining normal physiology. For example, without calcium, the hormone **insulin** could not be released from cells in the pancreas and **glycogen** could not be broken down in muscle cells and used to provide energy for muscle contraction.

Figure 1.3.11.2 *Maintaining Blood Calcium Levels*



Calcium levels are regulated by reducing the release of calcium from kidneys and by stimulation of calcium release from bones. Source: *image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).*

Other Health Benefits of Calcium in the Body

Besides forming and maintaining strong bones and teeth, calcium has been shown to affect other aspects of health, including:

- **cancer**: The National Cancer Institute reports that there is enough scientific evidence to conclude that higher intakes of calcium decrease colon cancer risk and may suppress the growth of polyps that often precipitate cancer. Although higher calcium consumption protects against colon cancer, some studies have looked at the relationship between calcium and prostate cancer and found higher intakes may increase the risk for prostate cancer; however the data is inconsistent and more studies are needed to confirm any negative association.

- **blood pressure**: Multiple studies provide clear evidence that higher calcium consumption reduces blood pressure. A review of twenty-three observational studies concluded that for every 100 milligrams of calcium consumed daily, systolic blood pressure is reduced 0.34 millimeters of mercury (mmHg) and diastolic blood pressure is decreased by 0.15 mmHg.[1]
- **cardiovascular health:** There is emerging evidence that higher calcium intakes prevent against other risk factors for cardiovascular disease, such as high cholesterol and obesity, but the scientific evidence is weak or inconclusive.
- **kidney stones**: Another health benefit of a high-calcium diet is that it blocks kidney stone formation. Calcium inhibits the absorption of oxalate, a chemical in plants such as parsley and spinach, which is associated with an increased risk for developing kidney stones. Calcium's protective effects on kidney stone formation occur only when you obtain calcium from dietary sources. Calcium supplements may actually increase the risk for kidney stones in susceptible people.

Figure 1.3.11.3 *Calcium's Effect on Aging*

1. [2]
2. [1]

Calcium inadequacy is most prevalent in adolescent girls and the elderly. Proper dietary intake of calcium is critical for proper bone health. Source: image by [James Heilman, MD](#) / [CC BY-SA 3.0](#)

Despite the wealth of evidence supporting the many health benefits of calcium (particularly bone health), the average North American diet falls short of achieving the recommended dietary intakes of calcium. In fact, in females older than nine years of age, the average daily intake of calcium is only about 70 percent of the recommended intake. Here we will take a closer look at particular groups of people who may require extra calcium intake:

- **adolescent teens**: A calcium-deficient diet is common in teenage girls as their dairy consumption often considerably drops during adolescence.
- **amenorrheic women and the "female athlete triad":** Amenorrhea refers to the absence of a menstrual cycle. Women who fail to menstruate suffer from reduced estrogen levels, which can disrupt and have a negative impact on the calcium balance in their bodies. The "female athlete triad" is a combination of three conditions characterized by amenorrhea, disrupted eating patterns, and osteoporosis. Exercise-induced amenorrhea and anorexia nervosa-related amenorrhea can decrease bone mass.[3] In female athletes, as well as active women in the military, low BMD, menstrual irregularities, and individual dietary habits together with a history of previous stress issues are related to an increased susceptibility to future stress fractures.[4]
- **elderly people:** As people age, calcium bioavailability is reduced, the kidneys lose their capacity to convert vitamin D to its most active form, the kidneys are no longer efficient in

3. Drinkwater B, Bruemner B, Chesnut C. Menstrual History As a Determinant of Current Bone Density in Young Athletes. JAMA. 1990; 263(4), 545–8. http://www.ncbi.nlm.nih.gov/pubmed/2294327?dopt=Abstract. . Accessed November 22, 2017.
4. Nattiv A. Stress Fractures and Bone Health in Track and Field Athletes. J Sci Med Sport. 2000; 3(3), 268–79. http://www.ncbi.nlm.nih.gov/pubmed/11101266?dopt=Abstract. Accessed November 22, 2017.

retaining calcium, the skin is less effective at synthesizing vitamin D, there are changes in overall dietary patterns, and older people tend to get less exposure to sunlight. Thus the risk for calcium inadequacy is great.[5]

- **postmenopausal women**: Estrogen enhances calcium absorption. The decline in this hormone during and after menopause puts postmenopausal women especially at risk for calcium deficiency. Decreases in estrogen production are responsible for an increase in bone resorption and a decrease in calcium absorption. During the first years of menopause, annual decreases in bone mass range from 3–5 percent. After age sixty-five, decreases are typically less than 1 percent.[6]
- **lactose-intolerant people**: Groups of people, such as those who are lactose intolerant, or who adhere to diets that avoid dairy products, may not have an adequate calcium intake.
- **vegans**: Vegans typically absorb reduced amounts of calcium because their diets favour plant-based foods that contain oxalates and phytates. [7]In addition, because vegans avoid dairy

5. Calcium and Vitamin D in the Elderly. International Osteoporosis Foundation. http://www.iofbonehealth.org/patients-public/about-osteoporosis/prevention/nutrition/calcium-and-vitamin-d-in-the-elderly.html. Published 2012. Accessed November 22, 2017.
6. Daniels CE. Estrogen Therapy for Osteoporosis Prevention in Postmenopausal Women. National Institute of Health: Pharmacy. Update March/April 2000.
7. Ross. C., et al. Dietary Reference Intakes for Calcium and Vitamin D.Food and Nutrition Board, Institute of Medicine. Washington, DC: National Academy Press.

products, their overall consumption of calcium-rich foods may be less.

If you are lactose intolerant, have a milk allergy, are a vegan, or you simply do not like dairy products, remember that there are many plant-based foods that have a good amount of calcium and there are also some low-lactose and lactose-free dairy products on the market.

Diet, Supplements, and Chelated Supplements

In general, calcium supplements perform to a lesser degree than dietary sources of calcium in providing many of the health benefits linked to higher calcium intake. This is partly attributed to the fact that dietary sources of calcium supply additional nutrients with health-promoting activities.

Vitamin D has to be activated and in the bloodstream to promote calcium absorption. Thus, it is important to maintain an adequate intake of vitamin D.

Dietary Sources of Calcium

In the typical North American diet, calcium is obtained mostly from dairy products, primarily cheese. A slice of cheddar or Swiss cheese contains just over 200 milligrams of calcium. One cup of nonfat milk contains approximately 300 milligrams of calcium, which is about a third of the RDA for calcium for most adults. Foods fortified with

2010. https://pubmed.ncbi.nlm.nih.gov/21796828/. Accessed Nov 14, 2020.

calcium such as cereals, soy milk, and orange juice also provide one third or greater of the calcium RDA. Although the typical American diet relies mostly on dairy products for obtaining calcium, there are other good non-dairy sources of calcium.

Tools for Change

If you need to increase calcium intake, are a vegan, or have a food allergy to dairy products, it is helpful to know that there are some plant-based foods that are high in calcium. Tofu (made with calcium sulfate), turnip greens, mustard greens, and Chinese cabbage are good sources. For a list of non-dairy sources you can find the calcium content for thousands of foods by visiting the USDA National Nutrient Database (http://www.nal.usda.gov/fnic/foodcomp/search/). When obtaining your calcium from a vegan diet, it is important to know that some plant-based foods significantly impair the absorption of calcium. These include spinach, Swiss chard, rhubarb, beets, cashews, and peanuts. With careful planning and good selections, you can ensure that you are getting enough calcium in your diet even if you do not drink milk or consume other dairy products.

Table 1.3.11.1 *Calcium Content of Various Foods*

Food	Serving	Calcium (mg)	Percent Daily Value
Yogurt, low fat	8 oz.	415	42
Mozzarella	1.5 oz.	333	33
Sardines, canned with bones	3 oz.	325	33
Cheddar Cheese	1.5 oz.	307	31
Milk, nonfat	8 oz.	299	30
Soymilk, calcium fortified	8 oz.	299	30
Orange juice, calcium fortified	6 oz.	261	26
Tofu, firm, made with calcium sulfate	½ c.	253	25
Salmon, canned with bones	3 oz.	181	18
Turnip, boiled	½ c.	99	10
Kale, cooked	1 c.	94	9
Vanilla Ice Cream	½ c.	84	8
White bread	1 slice	73	7
Kale, raw	1 c.	24	2
Broccoli, raw	½ c.	21	2

Source: Fact Sheet for Health Professionals: Calcium. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/. Updated November 17, 2016. Accessed November 12, 2017.

Calcium Bioavailability

In the small intestine, calcium absorption primarily takes place in the duodenum (first section of the small intestine) when intakes are low, but calcium is also absorbed passively in the jejunum and ileum (second and third sections of the small intestine), especially when intakes are higher. The body doesn't completely absorb all the calcium in food. Interestingly, the calcium in some vegetables such as kale, brussel sprouts, and bok choy is better absorbed by the body than are dairy products. About 30 percent of calcium is absorbed from milk and other dairy products.

The greatest positive influence on calcium absorption comes from having an adequate intake of vitamin D. People deficient in vitamin D absorb less than 15 percent of calcium from the foods they eat. The hormone estrogen is another factor that enhances calcium bioavailability. Thus, as a woman ages and goes through menopause, during which estrogen levels fall, the amount of calcium absorbed decreases and the risk for bone disease increases. Some fibers, such as inulin, found in jicama, onions, and garlic, also promote calcium intestinal uptake.

Chemicals that bind to calcium decrease its bioavailability. These negative effectors of calcium absorption include the oxalates in certain plants, the tannins in tea, phytates in nuts, seeds, and grains, and some fibers. Oxalates are found in high concentrations in spinach, parsley, cocoa, and beets. In general, the calcium bioavailability is inversely correlated to the oxalate content in foods. High-fiber, low-fat diets also decrease the amount of calcium absorbed, an effect likely related to how fiber and fat influence the amount of time food stays in the gut. Anything that causes diarrhea, including sickness, medications, and certain symptoms related to old age, decreases the transit time of calcium in the gut and therefore decreases calcium absorption. As we get older, stomach acidity sometimes decreases, diarrhea occurs more often, kidney function is impaired, and vitamin D absorption and activation is compromised, all of which contribute to a decrease in calcium bioavailability.

Phosphorus

Phosphorus is present in our bodies as part of a chemical group called a phosphate group. These phosphate groups are essential as a structural component of cell membranes (as phospholipids), DNA and RNA, energy production (ATP), and regulation of acid-base homeostasis. Phosphorus however is mostly associated with calcium as a part of the mineral structure of bones and teeth. Blood phosphorus levels are not controlled as strictly as calcium so the PTH stimulates renal excretion of phosphate so that it does not accumulate to toxic levels.

In comparison to calcium, most Americans are not at risk for having a phosphate deficiency. Phosphate is present in many foods popular in the American diet including meat, fish, dairy products, processed foods, and beverages. Phosphate is added to many foods because it acts as an emulsifying agent, prevents clumping, improves texture and taste, and extends shelf-life.

Dietary Sources of Phosphorus

Table 1.3.11.2 *Phosphorus Content of Various Foods*

Foods	Serving	Phosphorus (mg)	Percent Daily Value 1000
Salmon	3 oz.	315	32
Yogurt, nonfat	8 oz.	306	31
Turkey, light meat	3 oz.	217	22
Chicken, light meat	3 oz.	135	14
Beef	3 oz.	179	18
Lentils*	½ c.	178	18
Almonds*	1 oz.	136	14
Mozzarella	1 oz.	131	13
Peanuts*	1 oz.	108	11
Whole wheat bread	1 slice	68	7
Egg	1 large	86	9
Carbonated cola drink	12 oz.	41	4
Bread, enriched	1 slice	25	3

Source: Micronutrient Information Center: Phosphorus. Oregon State University, Linus Pauling Institute. http://lpi.oregonstate.edu/mic/minerals/phosphorus. Updated in July 2013. Accessed October 22, 2017.

Sulphur

Sulphur's Functions in the Body

Sulphur is the third most abundant mineral in the body, after calcium and phosphorus. Sulphur is incorporated into protein structures in the body. Amino acids, methionine and cysteine contain sulfur which are essential for the antioxidant enzyme glutathione peroxidase. Some vitamins like thiamin and biotin also contain sulphur which are important in regulating acidity in the body. Sulphur is additional essential for insulin production, which regulates blood glucose levels.

Sulphur is a major mineral with no recommended intake or deficiencies when protein needs are met.

Dietary Sources of Sulphur

Sulfur is mostly consumed as a part of dietary proteins and sulfur containing vitamins. Sulphur can be found in diary, meats, onions, garlic, and kale.

Table 1.3.11.3 *Sulphur Content of Various Foods*

Food	**Serving**	**Sulphur (mg)**
White bread	25g	80
Spagetti noodles	120g	30
Rice	160g	30
Egg, boiled	55g	180
Butter, salted	10g	–
Haddock	100g	290
Tuna, canned	120g	–
Apricots, dried	25g	160
Chicken	100g	300
Cheddar	25g	230
Onions	¼=20g	50
Spinach, boiled	60g	90

Source: Elements – 31: Sulphur. National Human Rights Institutions. http://apjcn.nhri.org.tw/server/info/books-phds/books/foodfacts/html/data/data5g.html. Accessed Jan 1, 2020.

Magnesium

Magnesium's Functional Role

In addition to participating in bone maintenance, magnesium has several other functions in the body. In every reaction involving the cellular energy molecule, ATP, magnesium is required. More than three hundred enzymatic reactions require magnesium. Magnesium plays a role in the synthesis of DNA and RNA, carbohydrates, and lipids, and is essential for nerve conduction and muscle contraction. Another health benefit of magnesium is that it may decrease blood pressure.

Many Americans do not get the recommended intake of magnesium from their diets. Some observational studies suggest mild magnesium deficiency is linked to increased risk for cardiovascular disease. Signs and symptoms of severe magnesium deficiency may include tremor, muscle spasms, loss of appetite, and nausea.

Dietary Sources of Magnesium

Magnesium is part of the green pigment, chlorophyll, which is vital for photosynthesis in plants; therefore green leafy vegetables are a good dietary source for magnesium. Magnesium is also found in high concentrations in fish, dairy products, meats, whole grains, and nuts. Additionally chocolate, coffee, and hard water contain a good amount of magnesium. Most people in America do not fulfill the RDA for magnesium in their diets. Typically, Western diets lean toward a low fish intake and the unbalanced consumption of refined grains versus whole grains.

Table 1.3.11.4 *Magnesium Content of Various Foods*

Food	Serving	Magnesium (mg)	Percent daily value
Almonds	1 oz.	80	20
Cashews	1 oz.	74	19
Soymilk	1 c.	61	15
Black beans	½ c.	60	15
Edamame	½ c.	50	13
Bread	2 slices	46	12
Avocado	1 c.	44	11
Brown rice	½ c.	42	11
Yogurt	8 oz.	42	11
Oatmeal, instant	1 packet	36	9
Salmon	3 oz.	26	7
Chicken breasts	3 oz.	22	6
Apple	1 medium	9	2

Source: Dietary Supplement Fact Sheet: Magnesium. National Institutes of Health, Office of Dietary Supplements. http://ods.od.nih.gov/factsheets/Magnesium-HealthProfessional/. Updated July 13, 2009. Accessed November 12, 2017.

Sodium

Sodium's Functional Role

Sodium is an essential nutrient found in salt and many foods. In the body sodium functions to maintain the balance of water in cells, allows for proper muscle and nerve function and helps to maintain a stable blood pressure. Although a small amount of sodium is necessary for health, too much sodium can lead to numerous health conditions such as high blood pressure, stroke, heart disease and kidney disease. High sodium intake has also been linked to an increased risk for osteoporosis, stomach cancer and asthma. [8]

The recommended dietary intake of sodium in Canada is between 1000-1500 mg per day. People who are 14 years or older should not consume more than 2300 mg of sodium per day as consumption this high increases the risk of an adverse health event. [9]

Dietary Sources of Sodium

The average Canadian eats 3400mg of sodium each day, more than double the amount needed. Sodium is added to many foods to add flavor and is used as a preservative. Most of the sodium we eat comes from processed and pre-packaged foods. Deli meat, frozen pizzas and fast foods are examples of these foods. The second highest dietary source of sodium comes from naturally occurring sources such as milk, fresh meat and fruits and vegetables. The third highest dietary source of sodium is the in the products we add during cooking. These include sauces, pre-mixed spices and

8. Sodium in Canada. Health Canada. https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/sodium.html. Updated March 1, 2017. Accessed January 1, 2020.
9. Sodium in Canada. Health Canada. https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/sodium.html. Updated March 1, 2017. Accessed January 1, 2020.

condiments. Lastly, the salt we add at the table makes up the smallest source of dietary sodium that we consume.[10]

Follow this link to see a detailed break down of the leading dietary sources of sodium in Canada.

Table 1.3.11.5 *Sodium Content of Various Foods*

Food	Serving	Sodium (mg)	Percent daily value
Salted nuts	100g	780	52
Tuna	100g	310	20
Canned tomatoes	100g	420	28
Chicken soup	100g	385	26
Table salt	1 tsp	2300	153
Soy sauce	1 tsp	1032	69
Sausage	100g	1235	82
Smoked salmon	100g	784	52
Hamburger	100g	561	37
Cheddar cheese	100g	620	41
Mozzarella	100g	373	25
Butter	100g	286	19
Corn flakes	100	900	60

Source: Sodium Content Chart. https://i.pinimg.com/736x/7e/5f/2a/7e5f2a60ec28602951f07470ea14359f–at-the-table-charts.jpg Accessed January 1, 2020.

10. Sodium Detector. Health Canada. https://health.canada.ca/en/health-canada/services/food-nutrition/food-guides-healthy-eating/nutrients/sodium/detector.html. Updated January 16, 2018. Accessed January 1, 2020.

Salt Sensitivity

High dietary intake of sodium is one risk factor for hypertension and contributes to high blood pressure in many people. However, studies have shown that not everyone's blood pressure is affected by lowering sodium intake. About 10 to 20 percent of the population is considered to be salt-sensitive, meaning their blood pressure is affected by salt intake. Genetics, race, gender, weight, and physical activity level are determinants of salt sensitivity. African Americans, women, and overweight individuals are more salt-sensitive than others. Also, if hypertension runs in a person's family, that person is more likely to be salt-sensitive.

The Benefits of Sodium Reduction

In Canada it has been estimated that if the average sodium intake was reduced by 1840 mg per day there would be a 30% decrease in the prevalence of high blood pressure. [11]

Everyone can benefit from eating less sodium. When choosing foods remember that a sodium content of 5% or less is a little sodium and 15% or more is a lot of sodium. When at the grocery store avoid processed, pre-packaged foods. Always check the sodium content to ensure you are not purchasing a product that

11. Sodium in Canada. Health Canada. https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/sodium.html. Updated March 1, 2017. Accessed January 1, 2020.

contains high amounts of hidden sodium. Additionally, add flavor to foods with herds, whole spices or lemon juice instead of salt. [12]

Potassium

Potassium's Functional Roles

Potassium is an essential mineral found in many foods. Potassium is involved in many of the same functions as sodium. Potassium helps to regulate fluid balance, muscle contractions and nerve signals. Contrary to sodium, a high potassium diet may help reduce blood pressure and protect against stroke, osteoporosis and kidney disease. Whereas a low potassium intake has been associated with hypertension and several chronic diseases [13]

12. About Sodium. Health Canada. https://www.canada.ca/en/health-canada/services/nutrients/sodium/sodium.html. Updated January 12, 2012. Accessed January 1, 2020.
13. Dietary Potassium. Hypertension Canada. https://hypertension.ca/wp-content/uploads/2019/01/Position-Statement-on-Dietary-Potassium-Hypertension-Canada-January-2019.pdf. Updated January 2019. Accessed January 1, 2020.

Dietary Sources of Potassium

Potassium can be found in a variety of foods. Foods containing high sources of potassium include bananas, apricots, kiwifruit, milk and yogurt, salmon and cooked vegetables such as broccoli, spinach and potatoes.[14] Most Canadians will get enough potassium as long as they are eating a well balanced diet. However, in several developed countries, including Canada, diets are high in processed foods and low in fresh fruits and vegetables leading to a potassium consumption that is too low compared to sodium consumption.

In Canada it is recommended that individuals over the age of 14 consume 4700 mg of potassium per day. The healthy individual can obtain their required potassium intake through a proper diet. Potassium supplements should not be used unless a doctor has recommended them.

Potassium salt (potassium chloride) can be used as an alternative to salt both at the table and in the making of processed foods to reduce sodium content without sacrificing flavor. Health Canada is in the processed of approving several potassium additives to replace sodium additives in the making of processed and preserved foods.[15]

14. Dietary Potassium. Hypertension Canada. https://hypertension.ca/wp-content/uploads/2019/01/Position-Statement-on-Dietary-Potassium-Hypertension-Canada-January-2019.pdf. Updated January 2019. Accessed January 1, 2020.
15. Health Canada's Proposal to Enable the Use of Potassium Acetate and Potassium Diacetate as Preservatives in Meat and Poultry Products. Health Canada. https://www.canada.ca/en/health-canada/

Vegetables and fruits are the best sources of potassium. Grains, dairy, lentils and meat also contain potassium. The table below details a variety of foods and their potassium contents.

Table 1.3.11.6 *Potassium Content of Various Foods*

Food	Serving	Potassium (mg)	Percent daily value
Tomato paste	60 mL (¼ cup)	658	14
Potato, baked	1 (12cm x 6cm)	610	13
Pinto or kidney beans	175 mL (3/4 cup)	566 to 591	13
Lentils	175 mL (3/4 cup)	579	12
Avocado	½ whole	487	10
Squash, baked	125 mL (1/2 cup)	473	10
Banana	1 medium	422	9
Papaya	½ medium	392	8
Milk, 2%	250 mL (1 cup)	387	8
Chickpeas	175 mL (3/4 cup)	378	8
Yogurt	175 g (3/4 cup)	362	8
Fish	75 g (2 ½ oz)	313	7

Source: What you need to know about potassium. Unlock food.

services/food-nutrition/public-involvement-partnerships/proposal-use-potassium-acetate-potassium-diacetate-preservatives-meat-poultry-products/consultation.html. Updated June 7, 2016. Accessed January 1, 2020.

https://www.unlockfood.ca/en/Articles/Vitamins-and-Minerals/What-You-Need-to-Know-About-Potassium.aspx]. Updated March 21, 2019. Accessed January 1, 2020.

Chloride

Chloride's Functional Roles

Chloride's main function in the body is to maintain fluid balance. It also helps to maintain blood volume, blood pressure and the pH of body fluids. Chloride toxicity is rarely observed in humans, except in some diseased states. A healthy individual can tolerate high quantities of chloride as long as there is a source of clean drinking water.

Dietary Sources of Chloride

Chloride is consumed as sodium chloride (NaCl) and potassium chloride (KCl) salts which are widely distributed in a variety of food sources. Table salt is mainly composed of sodium chloride, therefore a diet that contains salt with also contain chloride. Chloride is also found in drinking water as a results of natural salt depositions in the earth. Data from several of Canada's provinces indicates that chloride's content in drinking water is often relatively low at 10mg/L. [16]

16. Guidelines for Canadian Drinking Water Quality. Health Canada. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-

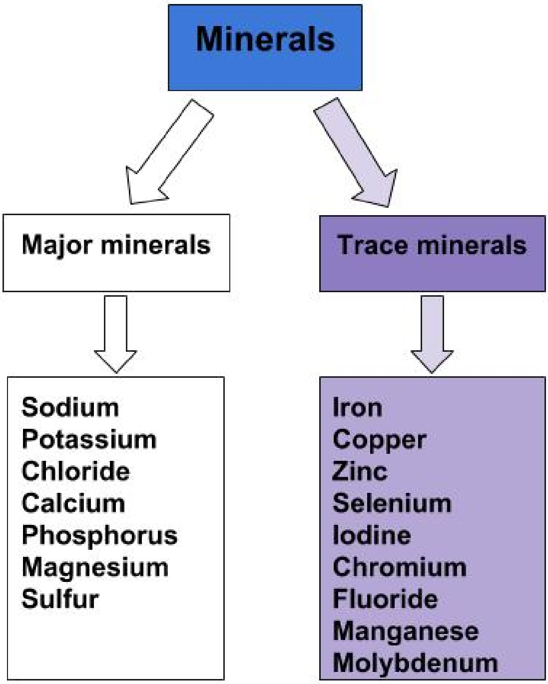
canadian-drinking-water-quality-guideline-technical-document-chloride.html. Updated January 7, 2008. Accessed January 1, 2020.

1.3.12. More About Trace Minerals

Introduction

Trace minerals are classified as minerals required in the diet each day in smaller amounts, specifically 100 milligrams or less. These include copper, zinc, selenium, iodine, chromium, fluoride, manganese, molybdenum, and others. Although trace minerals are needed in smaller amounts it is important to remember that a deficiency in a trace mineral can be just as detrimental to your health as a major mineral deficiency. Iodine deficiency is a major concern in countries around the world.

Figure 1.3.12.1 *The Trace Minerals*

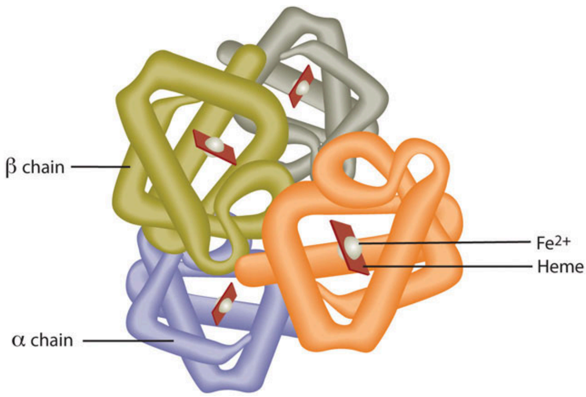


Minerals can be divided into major and minor classifications. Source: image by Allison Calabrese / CC BY 4.0.

Iron

Red blood cells contain the oxygen-carrier protein hemoglobin. It is composed of four globular peptides, each containing a heme complex. In the center of each heme, lies iron (Figure 1.3.12.2 "The Structure of Hemoglobin"). Iron is needed for the production of other **iron-containing proteins such as myoglobin**. Myoglobin is a protein found in the muscle tissues that enhances the amount of available oxygen for muscle contraction. Iron is also a key component of hundreds of **metabolic enzymes**. Many of the proteins of the electron-transport chain contain iron–sulfur clusters involved in the **transfer of high-energy electrons and ultimately ATP synthesis**. Iron is also involved in **numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis**. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

Figure 1.3.12.2 *The Structure of Hemoglobin*



Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center. Source: [Iron].

The iron in hemoglobin binds to oxygen in the capillaries of the lungs and transports it to cells where the oxygen is released. If iron level is low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in **anemia**. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with chronic blood loss or low intake. When blood cells are decommissioned for use, the body recycles the iron back to the bone marrow where red blood cells are made. The body stores some iron in the bone marrow, liver, spleen, and skeletal muscle. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources.

The bioavailability of iron is highly dependent on dietary sources. In animal-based foods about 60 percent of iron is bound to hemoglobin, and **heme iron is more bioavailable than nonheme iron**. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in **vitamin C at the same time as iron-containing foods markedly increases iron absorption**. A review in the American Journal of Clinical Nutrition reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent, and that from vegetarian diets ranges between 5 and 12 percent.[1] Vegans are at higher risk for iron deficiency, but careful meal planning does prevent its development. **Iron deficiency is the most common of all micronutrient deficiencies.**

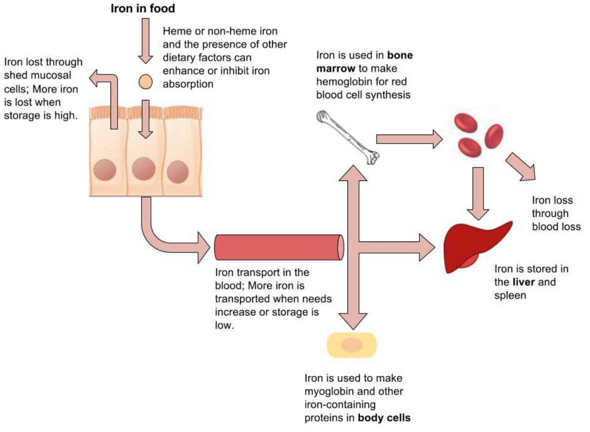
Table 1.3.12.1 *Enhancers and Inhibitors of Iron Absorption*

1. Centers for Disease Control and Prevention. "Iron and Iron Deficiency." Accessed October 2, 2011. http://www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html.

Enhancer	Inhibitor
Meat	Phosphate
Fish	Calcium
Poultry	Tea
Seafood	Coffee
Stomach acid	Colas
	Soy protein
	High doses of minerals (antacids)
	Bran/fiber
	Phytates
	Oxalates
	Polyphenols

Source: Iron.

Figure 1.3.12.3 *Iron Absorption, Functions, and Loss*



Iron absorption occurs in the intestine and is stored in the liver. Source: image by Allison Calabrese / CC BY 4.0.

Iron Toxicity

The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity. In children, death has occurred from ingesting as little as 200 mg of iron and therefore it is critical to keep iron supplements out of children's reach. Health Canada has set tolerable upper intake levels of iron at 40 for those under 14 years and 45 mg/day for those over the age of 14 years. Mostly a hereditary disease, hemochromatosis is the result of a genetic mutation that leads to abnormal iron metabolism and an accumulation of iron in certain tissues such as the liver, pancreas, and heart. The signs and symptoms of hemochromatosis are similar to those of iron overload in tissues caused by high dietary intake of iron or other non-genetic metabolic abnormalities, but are often increased in severity.

Dietary Sources of Iron

Table 1.3.12.2 *Iron Content of Various Foods*

Food	Serving	Iron (mg)	Percent daily value
Breakfast cereals, fortified	1 serving	18	100
Oysters	3 oz.	8	44
Dark chocolate	3 oz.	7	39
Beef liver	3 oz.	5	28
Lentils	½ c.	3	17
Spinach, boiled	½ c.	3	17
Tofu, firm	½ c.	3	17
Kidney beans	½ c.	2	11
Sardines	3 oz.	2	11

Source: Iron.

Iron-Deficiency Anemia

Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body resulting in **fewer and smaller red blood cells containing lower amounts of hemoglobin**. Regardless of the cause (be it from low dietary intake of iron or via excessive blood loss), iron-deficiency anemia has the following signs and symptoms, which are linked to the essential functions of iron in energy metabolism and blood health:

- fatigue
- weakness
- pale skin
- shortness of breath
- dizziness
- swollen, sore tongue
- abnormal heart rate

Iron-deficiency anemia is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron. Iron supplements have some adverse side effects including nausea, constipation, diarrhea, vomiting, and abdominal pain. Reducing the dose at first and then gradually increasing to the full dose often minimizes the side effects of iron supplements. Avoiding foods and beverages high in phytates and also tea (which contains tannic acid and polyphenols, both of which impair iron absorption), is important for people who have iron-deficiency anemia. Eating a dietary source of vitamin C at the same time as iron-containing foods improves absorption of nonheme iron in the gut. Additionally, unknown compounds that likely reside in muscle tissue of meat, poultry, and fish increase iron absorption from both heme and nonheme sources. See Table 1.3.12.1 "Enhancers and Inhibitors of Iron Absorption" for more enhancers and inhibitors for iron absorption.

Iron Deficiency: A Worldwide Nutritional Health Problem

The Centers for Disease Control and Prevention reports that iron deficiency is the most common nutritional deficiency worldwide.[2] The main causes of iron deficiency worldwide are parasitic worm infections in the gut causing excessive blood loss, and malaria, a parasitic disease causing the destruction of red blood cells. In the

2. Iron and Iron Deficiency. Centers for Disease Control and Prevention. http://www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html.Accessed October 2, 2011.

developed world, iron deficiency is more the result of dietary insufficiency and/or excessive blood loss occurring during menstruation or childbirth.

At-Risk Populations

Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes. Infants, children, and even teens require more iron because iron is essential for growth. In these populations, iron deficiency (and eventually iron-deficiency anemia) can also cause the following signs and symptoms: poor growth, failure to thrive, and poor performance in school, as well as mental, motor, and behavioral disorders. Women who experience heavy menstrual bleeding or who are pregnant require more iron in the diet. One more high-risk group is the elderly. Both elderly men and women have a high incidence of anemia and the most common causes are dietary iron deficiency and chronic disease such as ulcer, inflammatory diseases, and cancer. Additionally, those who have recently suffered from traumatic blood loss, frequently donate blood, or take excessive antacids for heartburn need more iron in the diet.

Preventing Iron-Deficiency Anemia

In young children iron-deficiency anemia can cause significant motor, mental, and behavioral abnormalities that are long-lasting. In the United States, the high incidence of iron-deficiency anemia in infants and children was a major public-health problem prior to the early 1970s, but now the incidence has been greatly reduced. This achievement was accomplished by implementing the screening of infants for iron-deficiency anemia in the health sector as a common practice, advocating the fortification of infant formulas and cereals with iron, and distributing them in supplemental food programs, such as that within Women, Infants, and Children (WIC). Breastfeeding, iron supplementation, and delaying the introduction of cow's milk for at least the first twelve months of life were also encouraged. These practices were implemented across the socioeconomic spectrum and by the 1980s iron-deficiency anemia in infants had significantly declined. Other solutions had to be introduced in young children, who no longer were fed breast milk or fortified formulas and were consuming cow's milk. The following solutions were introduced to parents: provide a diet rich in sources of iron and vitamin C, limit cow's milk consumption to less than twenty-four ounces per day, and a multivitamin containing iron.

In the third world, iron-deficiency anemia remains a significant public-health challenge. The World Bank claims that a million deaths occur every year from anemia and that the majority of those occur in Africa and Southeast Asia. The World Bank states five key interventions to combat anemia:

- Provide at-risk groups with iron supplements.
- Fortify staple foods with iron and other micronutrients whose deficiencies are linked with anemia.
- Prevent the spread of malaria and treat the hundreds of millions with the disease.
- Provide insecticide-treated bed netting to prevent parasitic infections.
- Treat parasitic-worm infestations in high-risk populations.

Also, there is ongoing investigation as to whether supplying iron cookware to at-risk populations is effective in preventing and treating iron-deficiency anemia.

Copper

Copper, like iron, assists in **electron transfer** in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for **iron absorption and transport**. The other important function of copper is as an **antioxidant**. Symptoms of mild to moderate copper deficiency are rare. More severe copper deficiency can cause anemia from the lack of iron mobilization in the body for red blood cell synthesis. Other signs and symptoms include growth retardation in children and neurological problems, because copper is a cofactor for an enzyme that synthesizes myelin, which surrounds many nerves.

Zinc

Zinc is a cofactor for over two hundred enzymes in the human body and plays a **direct role in RNA, DNA, and protein synthesis**. Zinc also is a cofactor for enzymes involved in **energy metabolism**. As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world's population has a zinc-deficient diet.[3]

3. Prasad, A., "Zinc deficiency." Br Med J. 2003 February 22; 326(7386): 409–10. http://www.ncbi.nlm.nih.gov/pmc/

This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, loss of appetite, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and severely deficient zinc diets can result in anemia.

Dietary Sources of Zinc

Table 1.3.12.3 *Zinc Content of Various Foods*

Food	Serving	Zinc (mg)	Percent daily value
Oysters	3 oz.	74	493
Beef, chuck roast	3 oz.	7	47
Crab	3 oz.	6.5	43
Lobster	3 oz.	3.4	23
Pork loin	3 oz.	2.9	19
Baked beans	½ c.	2.9	19
Yogurt, low fat	8 oz.	1.7	11
Oatmeal, instant	1 packet	1.1	7
Almonds	1 oz.	0.9	6

Source: Fact Sheet for Health Professionals: Zinc. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Zinc-HealthProfessional/. Updated February 11, 2016. Accessed November 10, 2017.

articles/PMC1125304/?tool=pmcentrez. Accessed October 2, 2011.

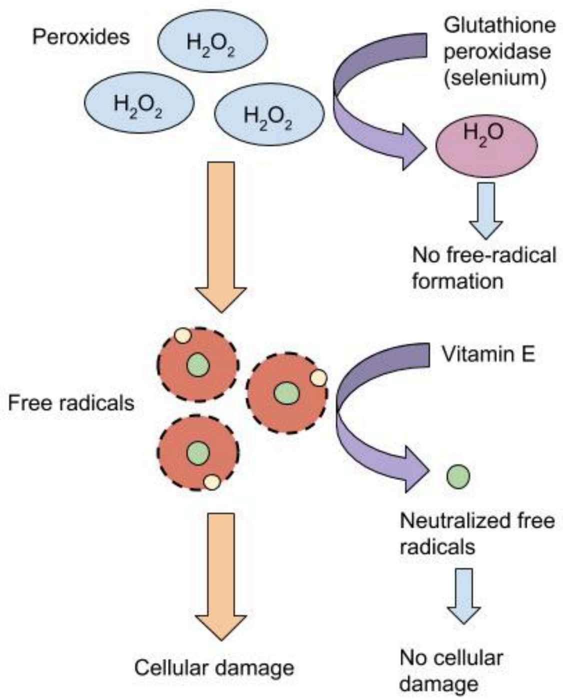
Selenium

Selenium is a cofactor of enzymes that **release active thyroid hormone in cells** and therefore low levels can cause similar signs and symptoms as iodine deficiency. The other important function of selenium is as an antioxidant.

Selenium Functions and Health Benefits

Around **twenty-five known proteins require selenium to function**. Some are enzymes involved in detoxifying free radicals. Selenium also helps protect lipids from free radicals, and, in doing so, spares vitamin E. This is just one example of how antioxidants work together to protect the body against free-radical induced damage. Other functions of selenium-containing proteins include protecting endothelial cells that line tissues, converting the inactive thyroid hormone to the active form in cells, and mediating inflammatory and immune system responses.

Figure 1.3.12.4 *Selenium's Role in Detoxifying Free Radicals*



Selenium plays a major role in the neutralization of free radicals, reducing cellular damage. Source: image by Allison Calabrese / [CC BY 4.0](#).

Selenium at doses several thousand times the RDA can cause acute toxicity, and when ingested in gram quantities can be fatal. Chronic exposure to foods grown in soils containing high levels of selenium (significantly above the UL) can cause brittle hair and nails, gastrointestinal discomfort, skin rashes, halitosis, fatigue, and irritability.

Dietary Sources of Selenium

Organ meats, muscle meats, and seafood have the highest selenium content. Plants do not require selenium, so the selenium content in fruits and vegetables is usually low. Animals fed grains from selenium-rich soils do contain some selenium. Grains and some nuts contain selenium when grown in selenium-containing soils. See Table 1.3.12.4. "Selenium Contents of Various Foods" for the selenium content of various foods.

Table 1.3.12.4 *Selenium Contents of Various Foods*

Food	Serving	Selenium (mcg)	Percent daily value
Brazil nuts	1 oz.	544	777
Shrimp	3 oz.	34	49
Crab meat	3 oz.	41	59
Ricotta cheese	1 c.	41	59
Salmon	3 oz.	40	57
Pork	3 oz.	35	50
Ground beef	3 oz.	18	26
Round steak	3 oz.	28.5	41
Beef liver	3 oz.	28	40
Chicken	3 oz.	13	19
Whole-wheat bread	2 slices	23	33
Couscous	1 c.	43	61
Barley, cooked	1 c.	13.5	19
Milk, low-fat	1 c.	8	11
Walnuts, black	1 oz.	5	7

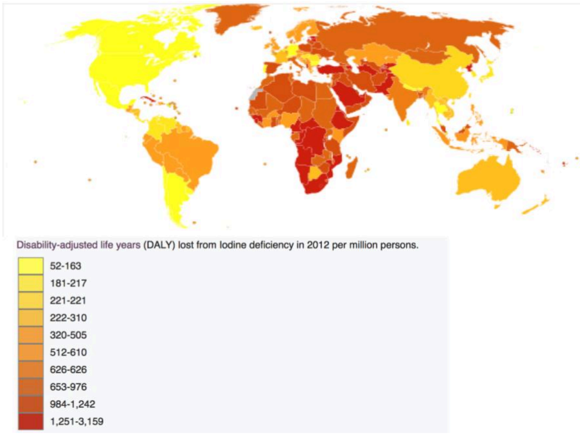
Source: US Department of Agriculture, Agricultural Research Service. 2010. USDA National Nutrient Database for Standard Reference, Release 23. http://www.ars.usda.gov/ba/bhnrc/ndl. Updated December 10, 2019. Accessed October 24, 2020.

Iodine

Recall the discovery of iodine and its use as a means of preventing goiter, a gross enlargement of the thyroid gland in the neck. Iodine is **essential for the synthesis of thyroid hormone, which regulates basal metabolism, growth, and development**. Low iodine levels and consequently hypothyroidism has many signs and symptoms including fatigue, sensitivity to cold, constipation, weight gain, depression, and dry, itchy skin and paleness. The development of goiter may often be the most visible sign of chronic iodine deficiency, but the consequences of low levels of thyroid hormone can be severe during infancy, childhood, and adolescence as it affects all stages of growth and development. Thyroid hormone plays a major role in brain development and growth and fetuses and infants with severe iodine deficiency develop a condition known as cretinism, in which physical and neurological impairment can be severe. The World Health Organization (WHO) estimates iodine deficiency affects over two billion people worldwide and it is the number-one cause of preventable brain damage worldwide.[4]

Figure 1.3.12.5 *Deaths Due to Iodine Deficiency Worldwide in 2012*

4. World Health Organization. "Iodine Status Worldwide." http://whqlibdoc.who.int/publications/2004/9241592001.pdf. Accessed October 2, 2011.



Source: image by [Chris55](#) / [CC BY 4.0](#).

Figure 1.3.12.6 *Iodine Deficiency: Goiter*

A large goiter. Source: [Dr. J.S.Bhandari, India](#) / [CC BY-SA 3.0](#)

Dietary Sources of Iodine

The mineral content of foods is greatly affected by the soil from which it grew, and thus geographic location is the primary determinant of the mineral content of foods. For instance, iodine comes mostly from seawater so the greater the distance from the sea the lesser the iodine content in the soil.

Table 1.3.12.5 *Iodine Content of Various Foods*

Food	Serving	Iodine (mcg)	Percent daily value
Seaweed	1 g.	16 to 2,984	11 to 1,989
Cod fish	3 oz.	99	66
Yogurt, low fat	8 oz.	75	50
Iodized salt	1.5 g.	71	47
Milk, reduced fat	8 oz.	56	37
Ice cream, chocolate	½ c.	30	20
Egg	1 large	24	16
Tuna, canned	3 oz.	17	11
Prunes, dried	5 prunes	13	9
Banana	1 medium	3	2

Source: Health Professional Fact Sheet: Iodine. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Iodine-HealthProfessional/. Updated June 24, 2011. Accessed November 10, 2017.

Chromium

The functioning of chromium in the body is less understood than that of most other minerals. It **enhances the actions of insulin so plays a role in carbohydrate, fat, and protein metabolism**. More research is needed to better determine if chromium is helpful in treating certain chronic diseases and, if so, at what doses. Dietary sources of chromium include nuts, whole grains, and yeast.

Manganese

Manganese is a cofactor for enzymes that are required for **carbohydrate and cholesterol metabolism**, **bone formation, and the synthesis of urea**. Manganese deficiency is uncommon. The best food sources for manganese are whole grains, nuts, legumes, and green vegetables.

Molybdenum

Molybdenum also acts as a cofactor that is required for the **metabolism of sulfur-containing amino acids, nitrogen-containing compounds found in DNA and RNA, and various other functions**. The food sources of molybdenum is varies depending on the content in the soil in the specific region.

Fluoride

Fluoride's Functional Role

Fluoride is known mostly as the mineral that **combats tooth decay. It assists in tooth and bone development and maintenance.** Fluoride combats tooth decay via three mechanisms:

- blocking acid formation by bacteria
- preventing demineralization of teeth
- enhancing remineralization of destroyed enamel

Fluoride was first added to drinking water in 1945 in Grand Rapids, Michigan; now over 60 percent of the US population consumes fluoridated drinking water. The Centers for Disease Control and Prevention (CDC) has reported that fluoridation of water prevents, on average, 27 percent of cavities in children and between 20 and 40 percent of cavities in adults. The CDC considers water fluoridation one of the ten great public health achievements in the twentieth century.[5]

Exposure to fluoride at three to five times this concentration before the growth of permanent teeth can cause fluorosis, which is the mottling and discoloring of the teeth.

Fluoride's benefits to mineralized tissues of the teeth are well substantiated, but the effects of fluoride on bone are not as well known. In general, it appears that at low doses, fluoride treatment increases BMD in people with osteoporosis and is more effective in increasing bone quality when the intakes of calcium and vitamin D are adequate.

Dietary Sources of Fluoride

Greater than 70 percent of a person's fluoride comes from drinking fluoridated water when they live in a community that fluoridates the drinking water. Other beverages with a high amount of fluoride include teas and grape juice. Solid foods do not contain a large amount of fluoride. Fluoride content in foods depends on whether

5. 10 Great Public Health Achievements in the 20th Century. Centers for Disease Control, Morbidity and Mortality Weekly Report. 1999; 48(12), 241–43. http://www.cdc.gov/about/history/tengpha.htm. Accessed November 22, 2017.

it was grown in soils and water that contained fluoride or cooked with fluoridated water. Canned meats and fish that contain bones do contain some fluoride.

Table 1.3.12.6 *Fluoride Content of Various Foods*

Food	Serving	Fluoride (mg)	Percent daily value*
Fruit Juice	3.5 fl oz.	0.02-2.1	0.7-70
Crab, canned	3.5 oz.	0.21	7
Rice, cooked	3.5 oz.	0.04	1.3
Fish, cooked	3.5 oz.	0.02	0.7
Chicken	3.5 oz.	0.015	0.5
* Current AI used to determine Percent Daily Value			

Source: Micronutrient Information Center: Fluoride. Oregon State University, Linus Pauling Institute. lpi.oregonstate.edu/mic/minerals/fluoride . Updated in April 29, 2015. Accessed October 22, 2017.

1.3.13 Test Your Knowledge

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1.4. FOOD SAFETY

“Food Safety” is an adaptation of the chapter “Food Safety” from *Human Nutrition*, by the University of Hawai‘i at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. Information that is not relevant to this course has been removed.

1.4.1. Preventing Foodborne Illness

Efforts on the Consumer Level: What You Can Do

Consumers can also take steps to prevent foodborne illness and protect their health. Although you can often detect when mold is present, you can't see, smell, or taste bacteria or other agents of foodborne disease. Therefore, it is crucial to take measures to protect yourself from disease. The four most important steps for handling, preparing, and serving food are:[1]

- **clean:** Wash hands thoroughly. Clean surfaces often and wash utensils after each use. Wash fruits and vegetables (even if you plan to peel them).
- **separate:** Don't cross-contaminate food during preparation and storage. Use separate cutting boards for produce and for meat, poultry, seafood, and eggs. Store food products separately in the refrigerator.
- **cook:** Heat food to proper temperatures. Use a food thermometer to check the temperature of food while it is cooking. Keep food hot after it has been cooked.
- **chill:** Refrigerate any leftovers within two hours. Never thaw or

1. US Department of Health and Human Services. Keep Food Safe. Food Safety.gov. Accessed December 21, 2011. http://www.foodsafety.gov/keep/index.html.

marinate food on the counter.

Know when to keep food and when to throw it out. It can be helpful to check the website http://www.stilltasty.com, which explains how long refrigerated food remains fresh.

Buying Food

It is best to buy your food from reputable grocers with clean, sanitary facilities, that keep products at appropriate temperatures. Consumers should examine food carefully before they purchase it. It is important to look at food in glass jars, check the stems on fresh produce, and avoid bruised fruit. Do not buy canned goods with dents or bulges, which are at risk for contamination with Clostridium botulinum. Fresh meat and poultry are usually free from mould, but cured and cooked meats should be examined carefully. Also, avoid torn, crushed, or open food packages, and do not buy food with frost or ice crystals, which indicates that the product has been stored for a long time, or thawed and refrozen. It is also a good idea to keep meat, poultry, seafood, and eggs separate from other items in your shopping cart as you move through the grocery store.

Storing Food

Refrigerate perishable foods quickly; they should not be left out for more than two hours. The refrigerator should be kept at 40°F (or 4°C) or colder, and checked periodically with a thermometer. Store eggs in a carton on a shelf in the refrigerator, and not on the refrigerator door where the temperature is warmest. Wrap meat packages tightly and store them at the bottom of the refrigerator, so juices won't leak out onto other foods. Raw meat, poultry, and seafood should be kept in a refrigerator for only two days. Otherwise, they should be stored in the freezer, which should be kept at 0°F (or −18°C). Store potatoes and onions in a cool, dark place, but not under a sink because leakage from pipes could contaminate them. Empty cans of perishable foods or beverages that have been opened into containers, and promptly place them in a refrigerator. Also, be sure to consume leftovers within three to five days, so mold does not have a chance to grow.

Preparing Food

Wash hands thoroughly with warm, soapy water for at least twenty seconds before preparing food and every time after handling raw foods. Washing hands is important for many reasons. One is to prevent cross-contamination between foods. Also, some pathogens can be passed from person to person, so hand washing can help to prevent this. Fresh fruits and vegetables should also be rinsed thoroughly under running water to clean off pesticide residue.[2]

This is particularly important for produce that contains a high level of residue, such as apples, pears, spinach, and potatoes. Washing also removes most dirt and bacteria from the surface of produce.

Other tips to keep foods safe during preparation include defrosting meat, poultry, and seafood in the refrigerator,

2. California Department of Pesticide Regulation. Pesticides and Food: How We Test for Safety. Pesticide Info: What You Should Know about Pesticides, no. #E09/REV. Accessed December 21, 2011. http://www.cdpr.ca.gov/docs/dept/factshts/residu2.

microwave, or in a water-tight plastic bag submerged in cold water. Never defrost at room temperature because that is an ideal temperature for bacteria to grow. Also, marinate foods in the refrigerator and discard leftover marinade after use because it contains raw juices. Always use clean cutting boards, which should be washed with soap and warm water by hand or in a dishwasher after each use. Another way to sanitize cutting boards is to rinse them with a solution of 5 milliliters (1 teaspoon) chlorine bleach to about 1 liter (1 quart) of water. If possible, use separate cutting boards for fresh produce and for raw meat. Also, wash the top before opening canned foods to prevent dirt from coming into contact with food.

Cooking Food

Cooked food is safe to eat only after it has been heated to an internal temperature that is high enough to kill bacteria. You cannot judge the state of "cooked" by color and texture alone. Instead, use a food thermometer to be sure. The appropriate minimum cooking temperature varies depending on the type of food. Seafood should be cooked to an internal temperature of 145°F, beef, lamb, and pork to 160°F, ground chicken and turkey to 165°F, poultry breasts to 165°F, and whole poultry and thighs to 180°F. When microwaving, rotate the dish and stir contents several times to ensure even cooking.

Serving Food

After food has been cooked, the possibility of bacterial growth increases as the temperature drops. So, food should be kept above the safe temperature of 140°F, using a heat source such as a chafing dish, warming tray, or slow cooker. Cold foods should be kept at 40°F or lower. When serving food, keep it covered to block exposure to any mold spores hanging in the air. Use plastic wrap to cover foods that you want to remain moist, such as fresh fruits, vegetables, and salads. After a meal, do not keep leftovers at room temperature for more than two hours. They should be refrigerated as promptly as possible. It is also helpful to date leftovers, so they can be used within a safe time, which is generally three to five days when stored in a refrigerator.

1.4.2. Public Health

Protecting Public Health

Most foodborne infections go unreported and undiagnosed. For example, the (U.S.) CDC estimates that about seventy-six million people in the United States become ill from foodborne pathogens or other agents every year. In North America, a number of government agencies work to educate the public about food infections and intoxications, prevent the spread of disease, and quell any major problems or outbreaks. They include the CDC, the FDA, and the USDA, among other Canadian organizations.

Efforts on the Governmental Level

A number of government agencies work to ensure food safety and to protect the public from foodborne illness. Food regulatory agencies work to protect the consumer and ensure the safety of our food including production, processing, packaging.

The (US) FDA and agencies of Health Canada oversee many food-related issues including the safety of domestic and imported foods, policies and monitoring of agricultural practices such as animal and crop safety, food safety research and education programs for farmers and consumers. ~~It~~ They also monitor supplements, food labels, claims that corporations make about the benefits of products, and pharmaceutical drugs.

Government agencies also conduct environmental assessment, education, research, and regulation and work to prevent pollution and protect natural resources. Two among many regulatory practices in the area of agriculture include overseeing water quality and the use of pesticides, approving pesticides and other chemicals used in agriculture and setting limits on how much residue can remain on food. Processing methods can either reduce or concentrate pesticide residue in foods.

The Food System

Image by Morten Just / CC BY-NC 3.0

The food system is a network of farmers and related operations, including food processing, wholesale and distribution, retail, industry technology, and marketing. The milk industry, for example, includes everything from the farm that raises livestock, to the milking facility that extracts the product, to the processing company that pasteurizes milk and packages it into cartons, to the shipping company that delivers the product to stores, to the markets and groceries that stock and sell the product, to the advertising agency that touts the product to consumers. All of these components play a part in a very large system.

Two important aspects of a food system are preservation and processing. Each provides for or protects consumers in different ways. Food preservation includes the handling or treating of food to prevent or slow down spoilage. Food processing involves transforming raw ingredients into packaged food, from fresh-baked goods to frozen dinners. Although there are numerous benefits to both, preservation and processing also pose some concerns, in terms of both nutrition and sustainability.

Food Irradiation: What You Need To Know

Irradiation does not make foods radioactive, compromise nutritional quality, or noticeably change the taste, texture, or appearance of food. In fact, any changes made by irradiation are so minimal that it is not easy to tell if a food has been irradiated.

Food irradiation (the application of ionizing radiation to food) is a technology that improves the safety and extends the shelf life of foods by reducing or eliminating microorganisms and insects. Like pasteurizing milk and canning fruits and vegetables, irradiation can make food safer for the consumer.

Why Irradiate Food?

Irradiation can serve many purposes.

- **prevention of foodborne illness**: to effectively eliminate organisms that cause foodborne illness, such as Salmonella and E. coli.
- **preservation**: to destroy or inactivate organisms that cause spoilage and decomposition and extend the shelf life of foods.
- **control of insects**: to destroy insects in or on tropical fruits

imported into the United States. Irradiation also decreases the need for other pest-control practices that may harm the fruit.

- **delay of sprouting and ripening:** to inhibit sprouting (e.g., potatoes) and delay ripening of fruit to increase longevity.
- **sterilization**: irradiation can be used to sterilize foods, which can then be stored for years without refrigeration. Sterilized foods are useful in hospitals for patients with severely impaired immune systems, such as patients with AIDS or undergoing chemotherapy. Foods that are sterilized by irradiation are exposed to substantially higher levels of treatment than those approved for general use.

Is Irradiated Food Safe to Eat?

The FDA has evaluated the safety of irradiated food for more than 30 years and has found the process to be safe.

The World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC) and the U.S. Department of Agriculture (USDA) have also endorsed the safety of irradiated food.

Figure 1.4.2.1 *Radura Symbol*

Source: https://www.mdpi.com/2304-8158/5/4/79/htm. Updated in 2016. Accessed on Nov 14, 2020. [*CC BY 4.0 license*]

How Will I Know if My Food Has Been Irradiated?

Look for the Radura symbol along with the statement "Treated with radiation" or "Treated by irradiation" on the food label.

It is important to remember that irradiation is not a replacement for proper food handling practices by producers, processors, and consumers. Irradiated foods need to be stored, handled, and cooked in the same way as non-irradiated foods, because they could still become contaminated with disease-causing organisms after irradiation if the rules of basic food safety are not followed.[1]

Food Processing

Food processing includes the methods and techniques used to transform raw ingredients into packaged food. Workers in this industry use harvested crops or slaughtered and butchered livestock to create products that are marketed to the public. There are different ways in which food can be processed, from a one-off product, such as a wedding cake, to a mass-produced product, such as a line of cupcakes packaged and sold in stores.

1. Food Irradiation. U.S. Food and Drug Administration. https://www.fda.gov/food/resourcesforyou/consumers/ucm261680.htm. Updated January 4, 2018. Accessed January 18, 2018.

The Pros and Cons of Food Processing

Image by [Dean Hochman](#) / [CC BY 2.0](#)

Food processing has a number of important benefits, such as creating products that have a much longer shelf life than raw foods. Also, food processing protects the health of the consumer and allows for easier shipment and the marketing of foods by corporations. However, there are certain drawbacks. Food processing can reduce the nutritional content of raw ingredients. For example, canning involves the use of heat, which destroys the vitamin C in canned fruit. Also, certain food additives that are included during processing, such as high fructose corn syrup, can affect the health of a consumer. However, the level of added sugar can make a major difference. Small amounts of added sugar and other sweeteners, about 6 to 9 teaspoons a day or less, are not considered harmful.[2]

2. Sugar and Carbohydrates. American Heart Association.

Food Additives

If you examine the label for a processed food product, it is not unusual to see a long list of added materials. These natural or synthetic substances are food additives and there are more than three hundred used during food processing today. The most popular additives are benzoates, nitrites, sulfites, and sorbates, which prevent molds and yeast from growing on food.[3] Food additives are introduced in the processing stage for a variety of reasons. Some control acidity and alkalinity, while others enhance the color or flavor of food. Some additives stabilize food and keep it from breaking down, while others add body or texture. Table 1.4.2.1 "Food Additives" lists some common food additives and their uses:

Table 1.4.2.1 *Food Additives*

http://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Sugars-and-Carbohydrates_UCM_303296_Article.jsp#. Updated April 20, 2017. Accessed January 4, 2018.

3. The Dangers of Food Additives. How Stuff Works. http://health.howstuffworks.com/wellness/food-nutrition/facts/dangers-of-food-additives.htm. Accessed October 5, 2011.

Additive	Reason for adding
Beta-carotene	Adds artificial colouring to food
Caffeine	Acts as a stimulant
Citric acid	Increases tartness to prevent food from becoming rancid
Dextrin	Thickens gravies, sauces, and baking mixes
Gelatin	Stabilizes, thickens, or texturizes food
Modified food starch	Keeps ingredients from separating and prevents lumps
MSG	Enhances flavor in a variety of foods
Pectin	Gives candies and jams a gel-like texture
Polysorbates	Blends oil and water and keep them from separating
Soy lecithin	Emulsifies and stabilizes chocolate, margarine, and other items
Sulfites	Prevent discoloration in dried fruits
Xanthan gum	Thickens, emulsifies, and stabilizes dairy products and dressings

Source: Chemical Cuisine: Learn about Food Additives. Center for Science in the Public Interest.http://www.cspinet.org/reports/chemcuisine.htm. Published 2012. Accessed January 20, 2018.

There are numerous foods additives that are added to processed and prepackaged foods. The consumption of these should be kept to a minimum.

The Pros and Cons of Food Additives

Food additives are typically included in the processing stage to improve the quality and consistency of a product. Many additives also make items more "shelf stable," meaning they will last a lot longer on store shelves and can generate more profit for store owners. Additives can also help to prevent spoilage that results from changes in temperature, damage during distribution, and other adverse conditions. In addition, food additives can protect consumers from exposure to rancid products and foodborne illnesses.

Food additives aren't always beneficial, however. Some substances have been associated with certain diseases if consumed in large amounts. For example, the **(U.S.)** FDA estimates that sulfites can cause allergic reactions in 1 percent of the general population and in 5 percent of asthmatics. Similarly, the additive monosodium glutamate, which is commonly known as MSG, may cause headaches, nausea, weakness, difficulty breathing, rapid heartbeat, and chest pain in some individuals.[4]

The Effect of New Technologies

As mentioned earlier, new technology has had a tremendous effect on the food we eat and the customs and culture related to food consumption. For example, microwaves are used to reduce cooking time or to heat up leftover food. Refrigerators and freezers allow produce to travel great distances and last longer. On the extreme end of making food last longer, there is special food for astronauts that is appropriate for consumption in space. It is safe to store, easy to prepare in the low-gravity environment of a spacecraft, and contains balanced nutrition to promote the health of people

4. The Issues: Additives. Sustainable Table. http://www.sustainabletable.org/issues/additives/#fn14. Accessed October 10, 2011.

working in space. In the military, soldiers consume Meals Ready-to-Eat (MREs), which contain an entire meal in a single pouch.

Genetically Modified Foods (GMOs)

Genetically modified foods (also known as GM or GMO foods), are plants or animals that have undergone some form of genetic engineering. In the United States, much of the soybean, corn, and canola crop is genetically modified. The process involves the alteration of an organism's DNA, which allows farmers to cultivate plants with desirable characteristics.[5] For example, scientists could extract a gene that produces a chemical with antifreeze properties from a fish that lives in an arctic region (such as a flounder). They could then splice that gene into a completely different species, such as a tomato, to make it resistant to frost, which would enable farms to grow that crop year-round.[6]

Certain modifications can be beneficial in resisting pests or pesticides, improving the ripening process, increasing the nutritional content of food, or providing resistance to common viruses. Although genetic engineering has improved productivity

5. What Are Genetically Modified Foods?. Genomics.Energy.gov. http://www.ornl.gov/sci/techresources/Human_Genome/elsi/gmfood.shtml. Last modified November 5, 2008. Accessed October 11, 2011.
6. Whitman DB. Genetically Modified Foods: Harmful or Helpful?. CSA Discovery Guides. 2000; 1-13. https://biomed.brown.edu/arise/resources/docs/GM%20foods%20review.pdf. Accessed January 20, 2018.

for farmers, it has also stirred up debate about consumer safety and environmental protection. Possible side effects related to the consumption of GM foods include an increase in allergenicity, or tendencies to provoke allergic reactions. There is also some concern related to the possible transfer of the genes used to create genetically engineered foods from plants to people. This could influence human health if antibiotic-resistant genes are transferred to the consumer. Therefore, the World Health Organization (WHO) and other groups have encouraged the use of genetic engineering without antibiotic-resistance genes. Genetically modified plants may adversely affect the environment as well and could lead to the contamination of non-genetically engineered organisms.[7]

7. Food Safety: 20 Questions on Genetically Modified Foods. World Health Organization. http://www.who.int/foodsafety/publications/biotech/20questions/en/. Updated May 2014. Accessed January 18, 2018.

1.4.3. Causes of Foodborne Illness

Foodborne Illness and Food Safety

Foodborne illness is a serious threat to health. Sometimes called "food poisoning," foodborne illness is a common public health problem that can result from exposure to a pathogen or a toxin via food or beverages. Raw foods, such as seafood, produce, and meats, can all be contaminated during harvest (or slaughter for meats), processing, packaging, or during distribution, though meat and poultry are the most common source of foodborne illness. For all kinds of food, contamination also can occur during preparation and cooking in a home kitchen or in a restaurant. For example, in 2009 the Marshall Islands reported 174 cases presenting with vomiting and diarrhea. After an epidemiological investigation was completed, they identified the cause to be egg sandwiches that had been left at room temperature too long resulting in the growth of foodborne toxins in the egg sandwiches.[1]

In many developing nations, contaminated water is also a major source of foodborne illness. Many people are affected by foodborne illness each year, making food safety a very important issue.

1. Thein CC, Trinidad RM, Pavlin B. A Large Foodborne Outbreak on a Small Pacific Island. Pacific Health Dialogue. 2010, 16(1). pp.75-80. https://www.ncbi.nlm.nih.gov/pubmed/20968238. Accessed January 28, 2018.

Annually, one out of six Americans becomes sick after consuming contaminated foods or beverages.[2] Foodborne illness can range from mild stomach upset to severe symptoms, or even fatalities. The problem of food contamination can not only be dangerous to your health, it can also be harmful to your wallet. Medical costs and lost wages due to salmonellosis, just one foodborne disease, are estimated at over $1 billion per year.

At-Risk Groups

No one is immune from consuming contaminated food but, whether you become seriously ill depends on the microorganism, the amount you have consumed, and your overall health. In addition, some groups have a higher risk than others for developing severe complications to foodborne disease. Who is most at risk? Young children, elderly people, and pregnant women all have a higher chance of becoming very sick after consuming contaminated food. Other high-risk groups include people with compromised immune systems due to HIV/AIDS, immunosuppressive medications (such as after an organ transplant), and long-term steroid use for asthma or arthritis. Exposure to contaminated food could also pose problems for diabetics, cancer patients, people who have liver disease, and people who have stomach problems as a result of low stomach acid or previous stomach surgery. People in all of these groups should handle food carefully, make sure that what they eat has been

2. Foodborne Illnesses and Germs. Centers for Disease Control and Prevention.https://www.cdc.gov/foodsafety/foodborne-germs.html . Updated January 23, 2018. Accessed January 28, 2017.

cooked thoroughly, and avoid taking any chances that could lead to exposure.

The Major Types of Food Borne Illness

Foodborne illnesses are either **infectious** or **toxic** in nature. The difference depends on the agent that causes the condition. Microbes, such as bacteria, cause food infections, while toxins, such as the kind produced by molds, cause intoxications. Different diseases manifest in different ways, so signs and symptoms can vary with the source of contamination. However the illness occurs, the microbe or toxin enters the body through the gastrointestinal tract, and as a result common symptoms include diarrhea, nausea, and abdominal pain. Additional symptoms may include vomiting, dehydration, lightheadedness, and rapid heartbeat. More severe complications can include a high fever, diarrhea that lasts more than three days, prolonged vomiting, bloody stools, and signs of shock.

One of the biggest misconceptions about foodborne illness is that it is always triggered by the last meal that a person ate. However, it may take several days or more before the onset of symptoms. If you develop a foodborne illness, you should rest and drink plenty of fluids. Avoid anti-diarrheal/-vomiting medications, because they could slow the elimination of the contaminant.

The Reproduction of Microorganisms

The conditions under which microorganisms reproduce within food are as follows:

- **temperature**: Between 40°F and 140°F (4°C–60°C), which is called the danger zone, bacteria grow rapidly.

- **time**: More than two hours in the danger zone.
- **water**: High moisture content is helpful. Fresh fruits and vegetables have the highest moisture content.
- **oxygen**: Most microorganisms need oxygen to grow and multiply, but a few are anaerobic and do not.
- **acidity and pH level**: Foods that have a low level of acidity (or a high pH level) provide an ideal environment, since most microorganisms grow best around pH 7.0 and not many will grow below pH 4.0 . Examples of higher pH foods include egg, meat, seafood, milk, and corn. Examples of low pH foods include citrus fruits, sauerkraut, tomatoes, and pineapples.
- **nutrient content**: Microorganisms need protein, starch, sugars, fats, and other compounds to grow. Typically high-protein foods are better for bacterial growth.

Bacteria

All foods naturally contain small amounts of bacteria. However, poor handling and preparation of food, along with improper cooking or storage can multiply bacteria and cause illness. In addition, bacteria can multiply quickly when cooked food is left out at room temperature for more than a few hours. Most bacteria grow undetected because they do not change the color or texture of food or produce a bad odor. Freezing and refrigeration slow or stop the growth of bacteria, but does not destroy the bacteria completely. The microbes can reactivate when the food is taken out and thawed.

Image by NIH NIAID / CC BY 2.0

Viruses, Parasites, and Toxins

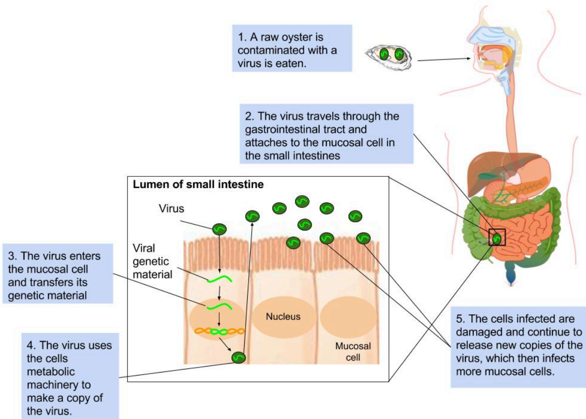
Hepatitis A is an example of one of the more well-known food-contaminating viruses. Sources include raw shellfish from polluted water, and food handled by an infected person. This virus can go undetected for weeks and, on average, symptoms do not appear until about one month after exposure. At first, symptoms include malaise, loss of appetite, nausea, vomiting, and fever. Three to ten days later, additional symptoms can manifest, including jaundice and darkened urine. Severe cases of a hepatitis A can result in liver damage and death.

The most common form of contamination from handled foods is the norovirus.

Parasitic protozoa are microscopic organisms that may be spread in food and water. They include microscopic worms from (example) raw fish, and other parasites from water, meats, fruits and vegetables.

Toxins from moulds, visible or invisible in grains and nuts, also apples, celery, and other produce can cause allergic reactions, respiratory problems, intestinal illnesses, liver failure, liver cancer, and in some cases death.

Figure 1.4.3.1 *Viruses in the Human Body*



Food contaminated with a virus makes its way to the small intestine, where it is absorbed and infects the body. Source: image by Allison Calabrese / CC BY 4.0.

Figure 1.4.3.2 *Mouldy Nectarines*

Source: "Moldy nectarines" by Roger McLassus 1951 / CC BY-SA 3.0.

Pesticides

Pesticides are important in food production to control diseases, insects, and other pests. They protect crops and ensure a large yield. However, synthetic pesticides can leave behind residues, particularly on produce, that can be harmful to human health. Foods that contain the **highest levels of pesticide residue include conventionally-grown peaches, apples, bell peppers, celery, nectarines, strawberries, cherries, pears, spinach, lettuce, and potatoes**. (In general these are foods which have skins that we eat). Foods that contain the **lowest levels of pesticide residue include avocados, pineapples, bananas, mangoes, asparagus, cabbage, and broccoli**.[3] (In general these are foods which have skins that we do not eat). In many cases, the amount of pesticide exposure is too small to pose a risk. However, harmful exposures can lead to certain health problems and complications, including cancer. Also, infants and young children are more susceptible to the hazards of pesticides than adults. In addition, using synthetic pesticides, herbicides, and fertilizers contributes to soil and water pollution and can be hazardous to farm workers.

To protect the public and their workers, many farmers now rely on alternatives to synthetic pesticide use, including crop rotation, natural pesticides, and planting non food crops nearby to lure pests away. Some consumers choose to reduce their exposure to pesticides by purchasing organic produce. You can protect yourself against pesticides by thoroughly rising all fruits and vegetables that you but. Alternatively, organic foods are grown or produced without

3. Pesticide Residues in Food. World Health Organization. http://www.who.int/mediacentre/factsheets/pesticide-residues-food/en/. Updated January 2018. Accessed January 28, 2018.

synthetic pesticides or fertilizer, and all growers and processors must be certified by government agencies. However, conventionally-grown produce should be fine for fruits and vegetables that appear on the low-residue list.

Pollutants

Pollutants are another kind of chemical contaminant that can make food harmful. Chemical runoff from factories can pollute food products and drinking water. For example, dioxins are chemical compounds created in industrial processes, such as manufacturing and bleaching pulp and paper. Fish that swim in dioxin-polluted waters can contain significant amounts of this pollutant, which causes cancer. When metals contaminate food, it can result in serious and even life-threatening health problems. A common metal contaminant is lead, which can be present in drinking water, soil, and air. Lead exposure most often affects children, who can suffer from physical and mental developmental delays as a result.

Methyl mercury occurs naturally in the environment and is also produced by human activities. Fish can absorb it, and the predatory fish that consume smaller, contaminated fish can have very high levels. This highly toxic chemical can cause mercury poisoning, which leads to developmental problems in children, as well as autoimmune effects. A condition called Minamata disease was identified in 1956 in Japan. It was named for the town of Minamata, which was the site of an environmental disaster when methyl mercury was released into the surface water near a factory. Many residents experienced neurological issues, including numbness in hands and feet, muscle weakness, a narrowing of the field of vision, damage to hearing and speech, and ataxia, which is a lack of muscle coordination.[4]

PCBs, or polychlorinated biphenyls, are man-made organic compounds that consists of carbon, hydrogen and chlorine. Due to their non-flammability, chemically stable, and high boiling points PCBs were manufactured and used commercially from 1929 until 1979 when it was banned. Like methylmercury, higher concentrations of this contaminant are found in predatory fish. Health effects include complications in physical and neurological development in children, and this compound is potentially a carcinogen. PCB contamination also can affect the immune, reproductive, nervous, and endocrine systems.[5]

4. Minamata Disease: The History and Measures. Ministry of the Environment, Government of Japan.http://www.env.go.jp/en/chemi/hs/minamata2002/. Published 2002. Accessed December 21, 2011.
5. Learn About Polychlorinated Biphenyls. US Environmental Protection Agency. https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs. Updated August 10, 2017. Accessed January 28, 2018.

1.4.4. Test Your Knowledge

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1.5. NUTRITION, LIFESTYLE, AND BEHAVIOUR CHANGE

"Nutrition, Lifestyle, and Behaviour Change" is an adaptation of the chapter "Basic Concepts in Nutrition" from *Human Nutrition*, by the University of Hawaiʻi at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. New material has been incorporated that includes Canadian exercise guidelines and Canadian drinking guidelines. Information that is not relevant to this course has been removed.

1.5.1. Lifestyle Choices

Image by John Towner on unsplash.com / CC0

Aspects of Lifestyle

In addition to nutrition, health is affected by genetics, the environment, life cycle, and lifestyle. One facet of lifestyle is your dietary habits. Dietary habits include what a person eats, how much a person eats during a meal, how frequently meals are consumed, and how often a person eats out.

Other aspects of lifestyle include physical activity level, recreational drug use, and sleeping patterns, all of which play a role in health and impact nutrition. Following a healthy lifestyle improves your overall health.

Physical Activity

Canada has set Physical Activity Guidelines, which are available at the website of [The Canadian Society for Exercise Physiology].

The Canadian Physical Activity Guidelines are broken into the following age categories; Early Years: 0-4, Children + Youth: 5-17, Adults: 18-64 and Older Adults: 65+. Guidelines do not differ between genders, sex, race or ethnicity and there are no limitations to the ways that individuals can reach the recommend levels of activity. By abiding by these guidelines you will reduce your risk of premature death, cardiovascular disease, stroke, hypertension, colon cancer, breast cancer, type 2 diabetes and osteoporosis. It can also lead to improved fitness, strength and mental health. [1]

Recommendation For Adults (18-64yrs)[2]

- At least **150 minutes** of moderate to vigorous intensity aerobic physical activity per week in bouts of 10 minutes or more.
- Additionally it is beneficial to add muscle and bone strengthening activities using major muscle groups at least 2 days per week
- More physical activity provides greater health benefits

Moderate intensity activity causes a little sweat and harder breathing. Examples include **brisk walking** and **bike riding**.

Vigorous intensity activity causes you to sweat and lose your breath. Examples include **jogging** and **cross-country skiing**.

To reach your 150 minutes, you could:

- join a running group

1. Canadian Physical Activity Guidelines for Adults. Canadian Society for Exercise Physiology. Accessed on December 16, 2019.
2. Canadian Physical Activity Guidelines for Adults. Canadian Society for Exercise Physiology. Accessed on December 16, 2019.

- go for a brisk walk
- join an exercise class
- bike or walk to work or the grocery store
- perform household chores such as raking, vacuuming, and cleaning
- join a sports team

Recreational Drug Use

Recreational drug use, which includes tobacco-smoking, electronic smoking device use, and alcohol consumption along with narcotic and other illegal drug use, has a large impact on health. Smoking cigarettes is the leading cause of lung cancer and is directly linked to eleven other types of cancer, heart disease, and several other disorders or diseases that markedly decrease quality of life and increase mortality. In the United States, smoking causes more than four hundred thousand deaths every single year, which is far more than deaths associated with any other lifestyle component. [1]

Also, according to the Centers for Disease Control and Prevention (CDC), excessive alcohol intake causes an estimated seventy-five thousand deaths per year. [2] Staying away from excessive alcohol intake lowers blood pressure, the risk of injury, heart disease, stroke, liver problems, and some types of cancer. While excessive alcohol consumption can be linked to poor health, consuming alcohol in moderation has been found to promote health such as reducing the risk for heart disease and Type 2 diabetes in some

1. Centers for Disease Control and Prevention (CDC). "Smoking and Tobacco Use." http://www.cdc.gov/tobacco/data_statistics/fact_sheets/health_effects/tobacco_related_mortality/Index.htm. Updated December 1, 2016. Accessed September 20, 2017.
2. Centers for Disease Control and Prevention. "Alcohol and Drug Use." http://www.cdc.gov/healthyyouth/alcoholdrug/. Updated June 7, 2012. Accessed September 20, 2017.

people. The United States Department of Health and Human Services (HHS) defines drinking in moderation as no more than one drink a day for women and two drinks a day for men. [3] To reduce your harm from drinking, the Canadian Centre on Substance and Addition latest guidelines recommend that females consume no more than 10 drinks a week with no more than 2 drinks on most days and that males consume no more than 15 drinks a week with no more than 3 drinks on most days.

llicit and prescription drug abuse are associated with decreased health and is a prominent problem in the United States and Canada. The health effects of drug abuse can be far-reaching, including the increased risk of stroke, heart disease, cancer, lung disease, and liver disease. [4]

Sleeping Patterns

Inadequate amounts of sleep, or not sleeping well, can also have remarkable effects on a person's health. In fact, sleeping can affect your health just as much as your diet. Scientific studies have shown that insufficient sleep increases the risk for heart disease, Type 2

3. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 – 2020 Dietary Guidelines for Americans. 8th Edition. http://health.gov/dietaryguidelines/2015/guidelines/. Published December 2015. Accessed September 2017.
4. National Institute on Drug Abuse. Health Consequences of Drug Misuse. https://www.drugabuse.gov/related-topics/health-consequences-drug-misuse. Updated March, 2017. Accessed September 20, 2017.

diabetes, obesity, and depression. Abnormal breathing during sleep, a condition called sleep apnea, is also linked to an increased risk for chronic disease.[5]

Personal Choice: The Challenge of Choosing Foods

There are other factors besides environment and lifestyle that influence the foods you choose to eat. Different foods affect energy level, mood, how much is eaten, how long before you eat again, and if cravings are satisfied. We have talked about some of the physical effects of food on your body, but there are other effects too.

Food regulates your appetite and how you feel. Multiple studies have demonstrated that some high fiber foods and high-protein foods decrease appetite by slowing the digestive process and prolonging the feeling of being full or satiety.

The effects of individual foods and nutrients on mood are not backed by consistent scientific evidence, but in general, most studies support that healthier diets are associated with a decrease in depression and improved well-being. To date, science has not been able to track the exact path in the brain that occurs in response to eating a particular food, but it is quite clear that foods, in general, stimulate emotional responses in people. Food also has psychological, cultural, and religious significance, so your personal choices of food affect your mind, as well as your body.

The social implications of food have a great deal to do with what

5. National Sleep Foundation. Sleep Disorders. https://sleepfoundation.org/sleep-disorders-problems. Updated 2017. Accessed September 2017.

people eat, as well as how and when. Special events in individual lives—from birthdays to funerals—are commemorated with equally special foods. National food traditions are carried to other countries when people immigrate. Being aware of these forces can help people make healthier food choices—and still honor the traditions and ties they hold dear.

Factors That Drive Food Choices

Along with these influences, a number of other factors affect the dietary choices individuals make, including the following:

- **taste, texture, and appearance**: Individuals have a wide range of tastes which influence their food choices, leading some to dislike milk and others to hate raw vegetables. Some foods that are very healthy, such as tofu, may be unappealing at first to many people. However, creative cooks can adapt healthy foods to meet most people's taste.
- **economics.** Access to fresh fruits and vegetables may be scant, particularly for those who live in economically disadvantaged or remote areas, where cheaper food options are limited to convenience stores and fast food.
- **early food experiences:** People who were not exposed to different foods as children, or who were forced to swallow every last bite of overcooked vegetables, may make limited food choices as adults.
- **habits:** It's common to establish eating routines, which can work both for and against optimal health. Habitually grabbing a fast food sandwich for breakfast can seem convenient, but might not offer substantial nutrition. Yet getting in the habit of drinking an ample amount of water each day can yield multiple benefits.
- **culture:** The culture in which one grows up affects how one

sees food in daily life and on special occasions.

- **geography:** Where a person lives influences food choices. For instance, people who live in Midwestern US states have less access to seafood than those living along the coasts.
- **advertising:** The media greatly influences food choice by persuading consumers to eat certain foods. In modern society the foods that have larger advertising campaigns tend to be products of larger corporations and in general have worse nutritional content ie. McDonalds Big Mac vs. a local grown apple.
- **social factors:** Any school lunchroom observer can testify to the impact of peer pressure on eating habits, and this influence lasts through adulthood. People make food choices based on how they see others and want others to see them. For example, individuals who are surrounded by others who consume fast food are more likely to do the same.
- **health concerns:** Some people have significant food allergies, to peanuts for example, and need to avoid those foods. Others may have developed health issues which require them to follow a low salt diet. In addition, people who have never worried about their weight have a very different approach to eating than those who have long struggled with excess weight.
- **emotions:** There is a wide range in how emotional issues affect eating habits. When faced with a great deal of stress, some people tend to overeat, while others find it hard to eat at all.
- **green food/sustainability choices:** Based on a growing understanding of diet as a public and personal issue, more and more people are starting to make food choices based on their environmental impact. Realizing that their food choices help shape the world, many individuals are opting for a vegetarian diet, or, if they do eat animal products, striving to find the most "cruelty-free" options possible. Purchasing local and organic food products and items grown through sustainable products also helps shrink the size of one's dietary footprint.

People choose a vegetarian diet for various reasons, including religious doctrines, health concerns, ecological and animal welfare concerns, or simply because they dislike the taste of meat. There are different types of vegetarians, but a common theme is that vegetarians do not eat meat. Four common forms of vegetarianism are:

- **lacto-ovo vegetarian:** This is the most common form. This type of vegetarian diet includes the animal foods eggs and dairy products.
- **lacto-vegetarian:** This type of vegetarian diet includes dairy products but not eggs.
- **ovo-vegetarian:** This type of vegetarian diet includes eggs but not dairy products.
- **vegan:** This type of vegetarian diet does not include dairy, eggs, or any type of animal product or animal by-product.

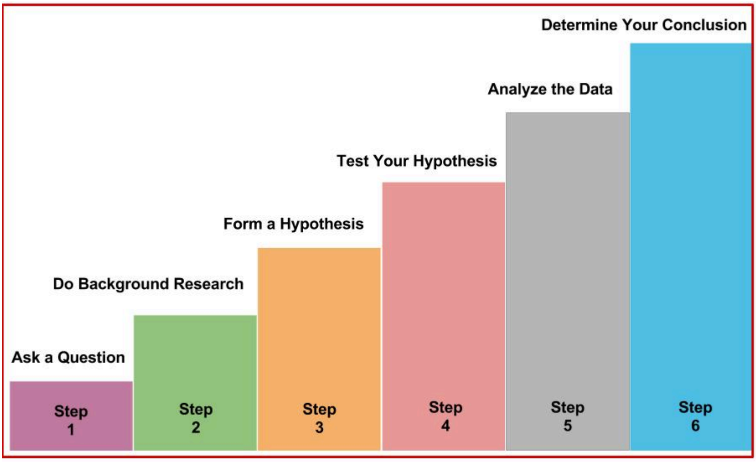
1.5.2. Nutritional Science

Research and the Scientific Method

Photo by Jonathon Simcoe on unsplash.com / CC0

Nutritional scientists discover the health effects of food and its nutrients by first making an ***observation***. Once observations are made, they come up with a ***hypothesis***, test their hypothesis, and then interpret the results. After this, they ***gather additional evidence from multiple sources*** and finally come up with a ***conclusion***. This organized process of inquiry used in science is called the scientific method.

Figure 1.5.2.1 *Scientific Method Steps*



Source: [Research and Scientific Methods]

The Scientific Method in Action

In 1811, French chemist Bernard Courtois was isolating saltpeter for producing gunpowder to be used by Napoleon's army. To carry out this isolation, he burned some seaweed and in the process, observed an intense violet vapor that crystallized when he exposed it to a cold surface. He sent the violet crystals to an expert on gases, Joseph Gay-Lussac, who identified the crystal as a new element. It was named iodine, the Greek word for violet. The following scientific record is some of what took place in order to conclude that iodine is a nutrient.

Observation. Eating seaweed is a cure for goiter, a gross enlargement of the thyroid gland in the neck.

Hypothesis. In 1813, Swiss physician Jean-Francois Coindet hypothesized that the seaweed contained iodine, and that iodine could be used instead of seaweed to treat his patients [1].

Experimental test. Coindet administered iodine tincture orally to his patients with goiter.

Interpret results. Coindet's iodine treatment was successful.

Hypothesis. French chemist Chatin proposed that the low iodine content in food and water in certain areas far away from the ocean was the primary cause of goiter, and renounced the theory that goiter was the result of poor hygiene.

Experimental test. In the late 1860s the program, "The stamping-out of goiter," started with people in several villages in France being given iodine tablets.

Results. The program was effective and 80 percent of goitrous children were cured.

Hypothesis. In 1918, Swiss doctor Bayard proposed iodizing salt as a good way to treat areas endemic with goiter.

Experimental test. Iodized salt was transported by mules to a small village at the base of the Matterhorn where more than 75 percent of school children were goitrous. It was given to families to use for six months.

Results. The iodized salt was beneficial in treating goiter in this remote population.

Experimental test. Physician David Marine conducted the first experiment of treating goiter with iodized salt in America in Akron, Ohio. [2]

1. Zimmerman, M.B. Research on Iodine Deficiency and Goiter in the 19th and Early 20th Centuries. Journal of Nutrition. 2008; 138(11), 2060–63. http://jn.nutrition.org/content/138/11/2060.full Accessed September 17, 2017.
2. Carpenter, K.J. David Marine and the Problem of Goiter. Journal of Nutrition. 2005; 135(4),

Results. This study was conducted on over four-thousand school children, and found that iodized salt prevented goiter.

Conclusions. Seven other studies similar to Marine's were conducted in Italy and Switzerland, which also demonstrated the effectiveness of iodized salt in treating goiter. In 1924, US public health officials initiated the program of iodizing salt and started eliminating the scourge of goiter. Today, more than 70% of American households use iodized salt and many other countries have followed the same public health strategy to reduce the health consequences of iodine deficiency.

Everyday Connection

What are some of the ways in which you think like a scientist, and use the scientific method in your everyday life? Any decision-making process uses some aspect of the scientific method. Think about some of the major decisions you have made in your life and the research you conducted that supported your decision. For example, what brand of computer do you own? Where is your money invested? What college do you attend?

675–80. http://jn.nutrition.org/content/135/4/675.full?sid=d06fdd35-566f -42a2-a3fd- efbe0736b7ba Accessed September 17, 2017.

Evidence-Based Approach to Nutrition

It took more than one hundred years from iodine's discovery as an effective treatment for goiter until public health programs recognized it as such. Although a lengthy process, the scientific method is a productive way to define essential nutrients and determine their ability to promote health and prevent disease. The scientific method is part of the overall evidence-based approach to designing nutritional guidelines. [3] An evidence-based approach to nutrition includes [4]:

- defining the problem or uncertainty (e.g., the incidence of goiter is lower in people who consume seaweed)
- formulating it as a question (e.g., Does eating seaweed decrease the risk of goiter?)
- setting criteria for quality evidence
- evaluating the body of evidence
- summarizing the body of evidence and making decisions
- specifying the strength of the supporting evidence required to make decisions

3. Myers E. Systems for Evaluating Nutrition Research for Nutrition Care Guidelines: Do They Apply to Population Dietary Guidelines? J Am Diet Assoc. 2003; 12(2), 34–41. http://jandonline.org/article/S0002-8223(03)01378-6/abstract. Accessed September 17, 2017.
4. Briss PA, Zara S, et al. Developing an Evidence-Based Guide to Community Preventive Services—Methods. Am J Prev Med. 2000; 18(1S), 35–43. https://www.ncbi.nlm.nih.gov/pubmed/10806978. Accessed September 17, 2017.

- disseminating the findings

The Food and Nutrition Board of the Institute of Medicine, a nonprofit, non-governmental organization, constructs its nutrient recommendations (i.e., Dietary Reference Intakes, or DRI) using an evidence-based approach to nutrition. The entire procedure for setting the DRI is documented and made available to the public. The same approach is used by the USDA and HHS, which are departments of the US federal government. The USDA and HHS websites are great tools for discovering ways to optimize health; however, it is important to gather nutrition information from multiple resources, as there are often differences in opinion among various scientists and public health organizations. Full text versions of the DRI publications are available in pdf format at https://www.nap.edu/, along with many other free publications.

Types of Scientific Studies

There are various types of scientific studies on humans that can be used to provide supporting evidence for a particular hypothesis. These include epidemiological studies, interventional clinical trials, and randomized clinical trials. Valuable nutrition knowledge also is obtained from animal studies and cellular and molecular biology research.

Table 1.5.2.1 *Types of Scientific Studies*

Type	Description	Example	Notes
Epidemiological studies	Observational study of populations around the world and the impact of nutrition on health.	Diets with a high consumption of saturated fat are associated with an increased risk of heart attacks.	Does not determine cause-and-effect relationships.
Intervention clinical trials	Scientific investigations where a variable is changed between groups.	Testing the effect of different diets on blood pressure. One group consumes an American diet, group 2 eats a diet rich in fruits and vegetables, and group 3 eats a combination of groups 1 and 2.	If done correctly, it does determine cause-and-effect relationships.
Randomized clinical trials (RCTs)	Participants are assigned by chance to separate groups that compare different treatments. Neither the researchers nor the participants can choose which group a participant is assigned.	Testing the effect of calcium supplements on women with osteoporosis. Participants are given a pill daily of a placebo or calcium supplement. Neither the participant nor the researcher know what group the participant is in.	Considered the "gold" standard for scientific studies.
Studies of animal and cellular biology	Studies are conducted on animals or on cells.	Testing the effects of a new blood pressure drug on guinea pigs or on the lipid membrane of a cell.	Less expensive than human trials. Study is not on whole humans so it may be not applicable.

Note: There are various type of scientific studies that can be conducted. These studies range in strength with RCTs being the gold standard.

Nutrition Assessment

Nutritional assessment is the interpretation of anthropometric, biochemical (laboratory), clinical and dietary data to determine whether a person or groups of people are well nourished or malnourished (overnourished or undernourished).

Nutritional assessment can be done using the ABCD methods. These refer to the following:

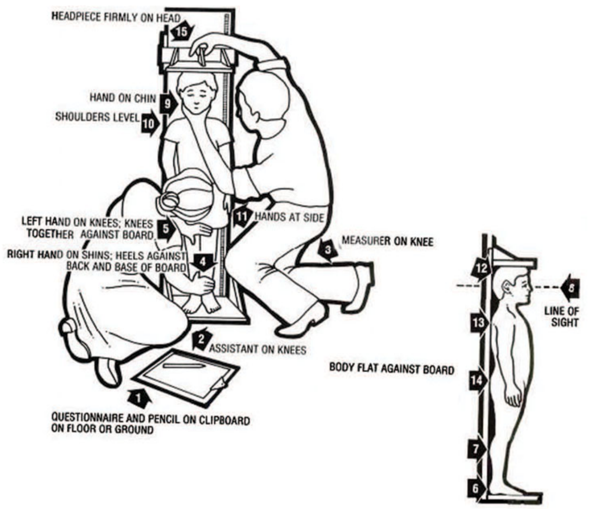
- **A**: Anthropometry
- **B**: Biochemical methods
- **C**: Clinical methods
- **D**: Dietary methods

Anthropometry Methods of Assessing Nutritional Status

The word anthropometry comes from two words: Anthropo means 'human' and metry means 'measurement'. The different measurements taken to assess growth and body composition are presented below.

To assess growth, several different measurements including length, height, weight, head circumference, mid-arm circumference, skin-fold thickness, head/chest ratio, and hip/waist ratio can be used. Height and weight measurements are essential in children to evaluate physical growth. As an additional resource, the NHANES Anthropometry Procedures Manual (revised January 2004) can be viewed here https://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/BM.pdf

Figure 1.5.2.2 *Measuring Height*



Source: UNICEF, 1986, How to weigh and measure children: assessing the nutrition status of young children. [CC BY 4.0](#) *[license](#)*

Biochemical Methods of Assessing Nutritional Status

Biochemical or laboratory methods of assessment include measuring a nutrient or its metabolite in the blood, feces, urine or other tissues that have a relationship with the nutrient. An example of this method would be to take blood samples to measure levels of glucose in the body. This method is useful for determining if an individual has diabetes.

Figure 1.5.2.3 *Measuring Blood Glucose Levels*

Source: image by TesaPhotography / CC0.

Clinical Methods of Assessing Nutritional Status

In addition to the anthropometric assessments, you can also assess clinical signs and symptoms that might indicate potential specific nutrient deficiency. Special attention are given to organs such as skin, eyes, tongue, ears, mouth, hair, nails, and gums. Clinical methods of assessing nutritional status involve checking signs of deficiency at specific places on the body or asking the patient whether they have any symptoms that might suggest nutrient deficiency.

Dietary Methods of Assessing Nutritional Status

Dietary methods of assessment include looking at past or current intakes of nutrients from food by individuals or a group to determine their nutritional status. There are several methods used to do this:

24 Hour Recall

A trained professional asks the subject to recall all food and drink consumed in the previous 24 hours. This is a quick and easy method. However, it is dependent upon the subject's short-term memory and may not be very accurate.

Food Frequency Questionnaire

The subject is given a list of foods and asked to indicate intake per day, per week, and per month. This method is inexpensive and easy to administer. It is more accurate than the 24 hour recall.

Food Diary

Food intake is recorded by the subject at the time of eating. This method is reliable but difficult to maintain. Also known as a food journal or food record.

Observed Food Consumption

This method requires food to be weighed and exactly calculated. It is very accurate but rarely used because it is time-consuming and expensive.

Evolving Science

Science is always moving forward, albeit sometimes slowly. One study is not enough to make a guideline or a recommendation, or cure a disease. Science is a stepwise process that builds on past evidence and finally culminates into a well-accepted conclusion. Unfortunately, not all scientific conclusions are developed in the interest of human health, and some can be biased. Therefore, it is important to know where a scientific study was conducted and who provided the funding, as this can have an impact on the scientific conclusions being made. For example, an air quality study paid for by a tobacco company diminishes its value in the minds of readers as well as a red meat study performed at a laboratory funded by a national beef association.

Nutritional Science Evolution

One of the newest areas in the realm of nutritional science is the scientific discipline of nutritional genetics, also called nutrigenomics. Genes are part of DNA and contain the genetic information that make up all of our traits. Genes are codes for proteins and when they are turned "on" or "off," they change how the body works. While we know that health is defined as more than just the absence of disease, there are currently very few accurate genetic markers of good health. Rather, there are many more genetic markers for disease. However, science is evolving, and nutritional genetics aims to identify what nutrients to eat to "turn on" healthy genes and "turn off" genes that cause disease.

Using Science and Technology To Change the

Future

As science evolves, so does technology. Both can be used to create a healthy diet, optimize health, and prevent disease. Picture yourself not too far into the future: you are wearing a small "dietary watch" that painlessly samples your blood, and downloads the information to your cell phone, which has an app that evaluates the nutrient profile of your blood and then recommends a snack or dinner menu to assure you maintain adequate nutrient levels. What else is not far off? How about another app that provides a shopping list that adheres to all dietary guidelines and is emailed to the central server at your local grocer, who then delivers the food to your home? The food is then stored in your smart fridge which documents your daily diet at home and delivers your weekly dietary assessment to your home computer. At your computer, you can compare your diet with other diets aimed at weight loss, optimal strength training, reduction in risk for specific diseases or any other health goals you may have. You also may delve into the field of nutritional genetics and download your gene expression profiles to a database that analyzes your genes against millions of others.

Nutrition and the Media

A motivational speaker once said, "A smart person believes half of what they read. An intelligent person knows which half to believe." In this age of information, where instant Internet access is just a click away, it is easy to be misled if you do not know where to go for reliable nutrition information.

Using Eyes of Discernment

"New study shows that margarine contributes to arterial plaque."

"Asian study reveals that two cups of coffee per day can have detrimental effects on the nervous system."

How do you react when you read news of this nature? Do you boycott margarine and coffee? When reading nutrition-related claims, articles, websites, or advertisements, always remember that one study does not substantiate a fact. One study neither proves nor disproves anything. Readers who may be looking for complex answers to nutritional dilemmas can quickly misconstrue such statements and be led down a path of misinformation. Listed below are ways that you can develop discerning eyes when reading nutritional news:

1. The scientific study under discussion should be published in a **peer reviewed journal**, such as the Journal of Nutrition. Question studies that come from less trustworthy sources (such as non peer-reviewed journals or websites) or that are not formally published.
2. The report should disclose the **methods** used by the researcher(s). Did the study last for three or thirty weeks? Were there ten or one hundred participants? What did the participants actually do? Did the researcher(s) observe the results themselves or did they rely on self reports from program participants?
3. Who were the **subjects** of this study? Humans or animals? If human, are any traits/characteristics noted? You may realize you have more in common with certain program participants and can use that as a basis to gauge if the study applies to you.
4. Credible reports often disseminate new findings in the **context of previous research**. A single study on its own gives you very limited information, but if a body of literature supports a finding, it adds to credibility.

5. Peer-reviewed articles deliver a **broad perspective and are inclusive of findings of many studies** on the exact same subject.
6. When reading such news, ask yourself, "Is this **making sense**?" Even if coffee does adversely affect the nervous system, do you drink enough of it to see any negative effects? Remember, if a headline professes a new remedy for a nutrition-related topic, it may well be a research-supported piece of news, but more often than not, it is a sensational story designed to catch the attention of an unsuspecting consumer. Track down the original journal article to see if it really supports the conclusions being drawn in the news report.

When reading information on websites, remember the following criteria for discerning if the site is valid:

1. Who sponsors the website?
2. Are names and credentials disclosed?
3. Is an editorial board identified?
4. Does the site contain links to other credible informational websites?
5. Even better, does it reference peer-reviewed journal articles? If so, do those journal articles actually back up the claims being made on the website?
6. How often is the website updated?
7. Are you being sold something at this website?
8. Does the website charge a fee?

For more information, visit http://www.csuchico.edu/lins/handouts/eval_websites.pdf

Trustworthy Sources

Now let's consider some reputable organizations and websites from which you can usually obtain valid nutrition information.

Organizations Active in Nutrition Policy and Research

Authoritative nutritional news will be based upon solid scientific evidence, supported by multiple studies, and published in peer-reviewed journals. Whatever the source of your nutritional news, remember to apply the criteria outlined above to help ensure the validity of the information presented. Below are some examples of websites which can be considered credible sources for nutritional news:

- Health Canada provides information on an extensive number of subjects relating to the Health of Canadian citizen. Topics include but are not limited to; healthy living, food and nutrition, environmental and workplace health and drugs and health products. Visit their website to explore their content.
- Canadian Society for Exercise Physiology (CSEP) website provides physical activity guidelines and recommendations for Canadians of all ages.
- US Department of Agriculture Food and Nutrition Information Center. The USDA site http://fnic.nal.usda.gov has more than 2,500 links to information about diet, nutrition, diet and disease, weight and obesity, food-safety and food-labeling, packaging, dietary supplements and consumer questions. Using this interactive site, you can find tips and resources on how to eat a healthy diet, nutritional information, and a food planner.

- The Academy of Nutrition and Dietetics (AND). The AND promotes scientific, evidenced-based, research-supported food and nutrition related information on its website, http://www.eatright.org. It is focused on informing the public about recent scientific discoveries and studies, weight-loss concerns, food safety topics, nutrition issues, and disease prevention.
- Department of Health and Human Services (HHS). The HHS website, HealthFinder.gov, provides credible information about healthful lifestyles and the latest in health news. A variety of online tools are available to assist with food-planning, weight maintenance, physical activity, and dietary goals. You can also find healthful tips for all age groups, tips for preventing disease, and information on daily health issues in general.
- Centers for Disease Control and Prevention (CDC). The Centers for Disease Control and Prevention (http://www.cdc.gov) distributes an online newsletter called CDC Vital Signs which provides up-to-date public health information and data regarding food, nutrition, cholesterol, high blood pressure, obesity, teenage drinking, and tobacco usage.

1.5.3. Test Your Knowledge

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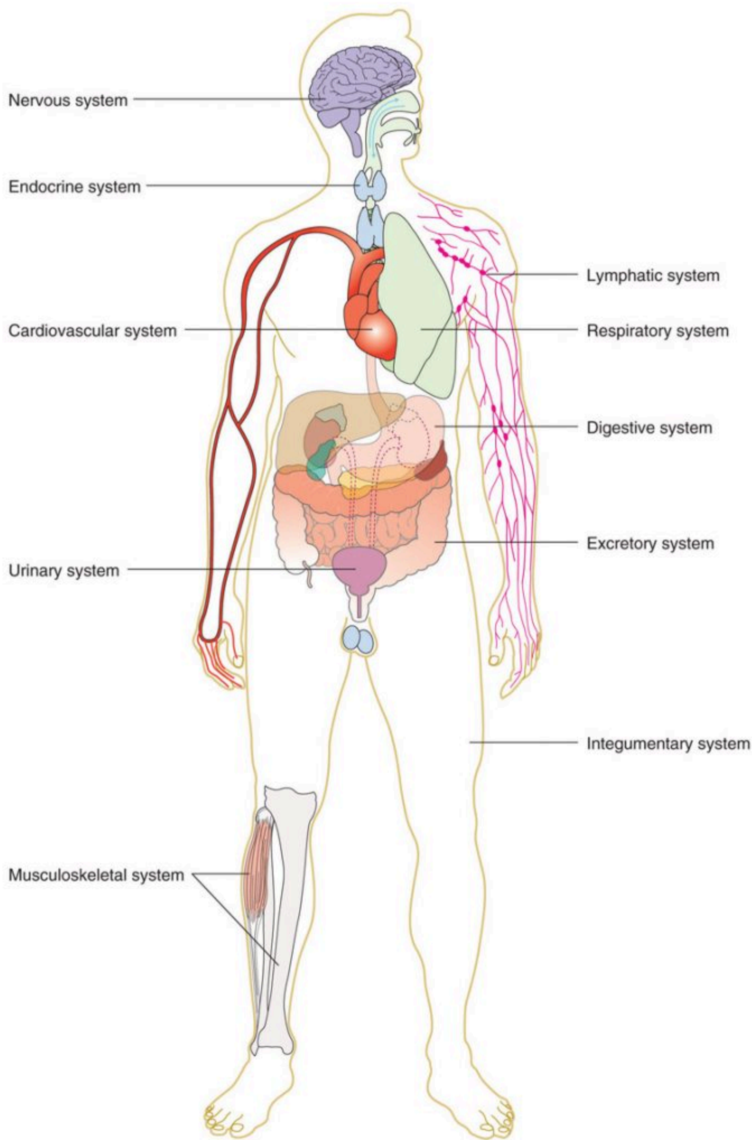
2.1. BODY SYSTEMS

2.1.1. Basics of Biology, Anatomy, and Physiology

The Basic Structural and Functional Unit of Life: The Cell

Figure 2.1.1.1 *Components of Organ Systems in the Human Body*



Source: [Basics of Biology anatomy and human physiology.]

What distinguishes a living organism from an inanimate object? A living organism conducts self-sustaining biological processes. A cell is the smallest and most basic form of life.

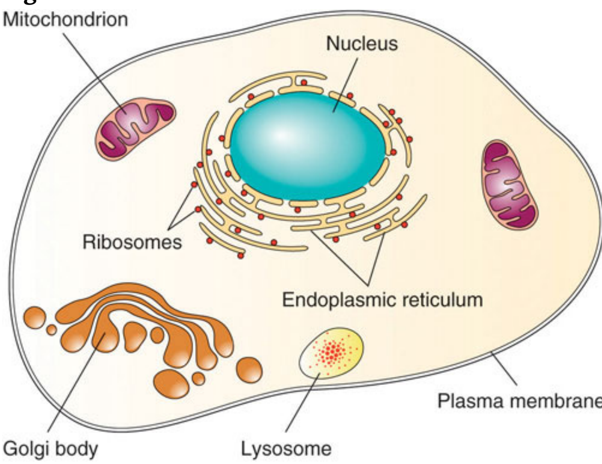
The cell theory incorporates three principles.

Cells are the most basic building units of life. All living things are composed of cells. New cells are made from preexisting cells, which divide in two. Who you are has been determined because of two cells that came together inside your mother's womb. The two cells containing all of your genetic information (DNA) united to begin making new life. Cells divided and differentiated into other cells with specific roles that led to the formation of the body's numerous body organs, systems, blood, blood vessels, bone, tissue, and skin. As an adult, you are made up of trillions of cells. Each of your individual cells is a compact and efficient form of life—self-sufficient, yet interdependent upon the other cells within your body to supply its needs.

Independent single-celled organisms must conduct all the basic processes of life. The single-celled organism must take in nutrients (energy capture), excrete wastes, detect and respond to its environment, move, breathe, grow, and reproduce. Even a one-celled organism must be organized to perform these essential processes. All cells are organized from the atomic level to all its larger forms. Oxygen and hydrogen atoms combine to make the molecule (H2O). Molecules bond together to make bigger macromolecules. The carbon atom is often referred to as the backbone of life because it can readily bond with four other elements to form long chains and more complex macromolecules. Four macromolecules—carbohydrates, proteins, and nucleic acids—make up all of the structural and functional units of cells.

Although we defined the cell as the "most basic" unit of life, it is structurally and functionally complex (Figure 2.1.1.2. "The Cell Structure"). A cell can be thought of as a mini-organism consisting of tiny organs called organelles. The organelles are structural and functional units constructed from several macromolecules bonded together. A typical animal cell contains the following organelles: the **nucleus** (which houses the genetic material DNA), **mitochondria** (which generate energy), **ribosomes** (which produce protein), the **endoplasmic reticulum** (which is a packaging and transport facility), and the **golgi apparatus** (which distributes macromolecules). In addition, animal cells contain little **digestive pouches,** called lysosomes and peroxisomes, which break down macromolecules and destroy foreign invaders. All of the organelles are anchored in the cell's cytoplasm via a cytoskeleton. The cell's organelles are isolated from the surrounding environment by a **plasma membrane**.

Figure 2.1.1.2 *The Cell Structure*



Source: Basics of Biology anatomy and human physiology.

The cell is structurally and functionally complex.

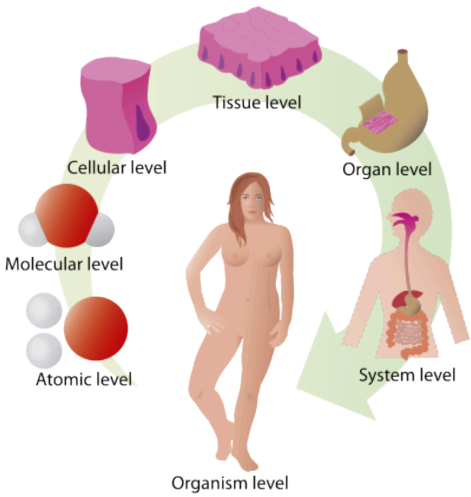
Tissues, Organs, Organ Systems, and Organisms

Unicellular (single-celled) organisms can function independently, but the cells of multicellular organisms are dependent upon each other and are organized into five different levels in order to coordinate their specific functions and carry out all of life's biological processes (see Figure 2.1.1.3 "Organization of Life").

- **Cells** are the basic structural and functional unit of all life. Examples include red blood cells and nerve cells. There are hundreds of types of cells. All cells in a person contain the same genetic information in DNA. However, each cell only expresses the genetic codes that relate to the cell's specific structure and function.

- **Tissues** are groups of cells that share a common structure and function and work together. There are four basic types of human tissues: connective, which connects tissues; epithelial, which lines and protects organs; muscle, which contracts for movement and support; and nerve, which responds and reacts to signals in the environment.
- **Organs** are a group of tissues arranged in a specific manner to support a common physiological function. Examples include the brain, liver, and heart.
- **Organ systems** are two or more organs that support a specific physiological function. Examples include the digestive system and central nervous system. There are eleven organ systems in the human body (see Table 2.1.1.1 "The Eleven Organ Systems in the Human Body and Their Major Functions").
- An **organism** is the complete living system capable of conducting all of life's biological processes.

Figure 2.1.1.3 *Organization of Life*



The human body is made from a variety of structures, the smallest being at the atomic level and the largest at the system and organism level. Source: [“Organization Levels of Human Body”](#) by [Laia Martinez](#) / [CC BY-SA 4.0](#)

Table 2.1.1.1 *The Eleven Organ Systems in the Human Body and Their Major Functions*

Organ system	Organ components	Major function
Cardiovascular	heart, blood/lymph vessels, blood, lymph	Transport nutrients and waste products
Digestive	mouth, esophagus, stomach, intestines	Digestion and absorption
Endocrine	all glands (thyroid, ovaries, pancreas)	Produce and release hormones
Immune	white blood cells, lymphatic tissue, marrow	Defend against foreign invaders
Integumentary	skin, nails, hair, sweat glands	Protective, body temperature regulation
Muscular	skeletal, smooth, and cardiac muscle	Body movement
Nervous	brain, spinal cord, nerves	Interprets and responds to stimuli
Reproductive	gonads, genitals	Reproduction and sexual characteristics
Respiratory	lungs, nose, mouth, throat, trachea	Gas exchange
Skeletal	bones, tendons, ligaments, joints	Structure and support
Urinary	kidneys, bladder, ureters	Waste excretion, water balance

Note: There are 11 organ systems in the body which are all made up of specific components and all have different functions to sustain life. Source: Basics of Biology anatomy and human physiology.

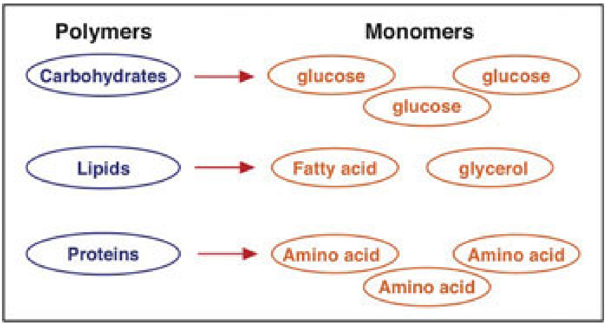
2.1.2. The Digestive System

The Process of Digestion

The process of digestion begins even before you put food into your mouth. When you feel hungry, your body sends a message to your brain that it is time to eat. Sights and smells influence your body's preparedness for food. Smelling food sends a message to your brain. Your brain then tells the mouth to get ready, and you start to salivate in preparation for a meal.

Once you have eaten, your digestive system starts the process that breaks down the components of food into smaller components that can be absorbed and taken into the body. To do this, the digestive system functions on two levels, mechanically to move and mix ingested food and chemically to break down large molecules. The smaller nutrient molecules can then be absorbed and processed by cells throughout the body for energy or used as building blocks for new cells. The digestive system is one of the eleven organ systems of the human body, and it is composed of several hollow tube-shaped organs including the mouth, pharynx, esophagus, stomach, small intestine, large intestine (colon), rectum, and anus. It is lined with **mucosal tissue** that secretes digestive juices (which aid in the breakdown of food) and **mucus** (which facilitates the propulsion of food through the tract). Smooth muscle tissue surrounds the digestive tract and its contraction produces waves, known as **peristalsis**, that propel food down the tract. Nutrients, as well as some non-nutrients, are absorbed. Substances such as fiber get left behind and are appropriately excreted.

Figure 2.1.2.1 *Digestion Breakdown of Macronutrients*



Macronutrients are broken down into numerous monomers. Source: [The Digestive System]

Digestion converts components of the food we eat into smaller molecules that can be absorbed into the body and utilized for energy needs or as building blocks for making larger molecules in cells.

Everyday Connection

Image by Gabriel Lee / CC BY-NC-SA

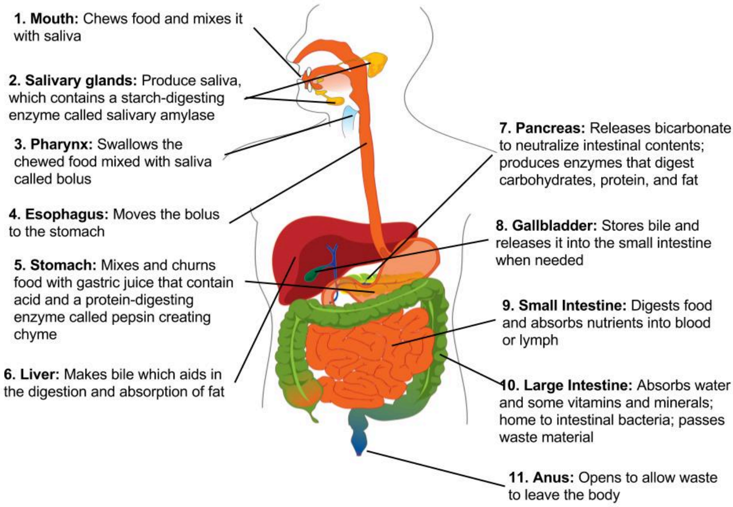
There has been significant talk about pre- and probiotic foods in the mainstream media. The World Health Organization defines probiotics as live bacteria that confer beneficial health effects on their host. They are sometimes called "friendly bacteria." The most common bacteria labeled as probiotic is lactic acid bacteria (lactobacilli). They are added as live cultures to certain fermented foods such as yogurt. Prebiotics are indigestible foods, primarily soluble fibers, that stimulate the growth of certain strains of bacteria in the large intestine and provide health benefits to the host. A review article in the June 2008 issue of the Journal of Nutrition concludes that there is scientific consensus that probiotics ward off viral-induced diarrhea and reduce the symptoms of lactose intolerance.[1]

Expert nutritionists agree that more health benefits of pre- and probiotics will likely reach scientific consensus. As the fields of pre- and probiotic manufacturing and their clinical study progress, more information on proper dosing and what exact strains of bacteria are potentially "friendly" will become available.

You may be interested in trying some of these foods in your diet. A simple food to try is kefir. Several websites provide good recipes, including http://www.kefir.net/recipes.htm.
Kefir, a dairy product fermented with probiotic bacteria, can make a pleasant tasting milkshake.

1. Farnworth ER. The Evidence to Support Health Claims for Probiotics. J Nutr. 2008; 138(6), 1250S–54S. http://jn.nutrition.org/content/138/6/1250S.long. Accessed September 22, 2017.

Figure 2.1.2.2 *The Human Digestive System*



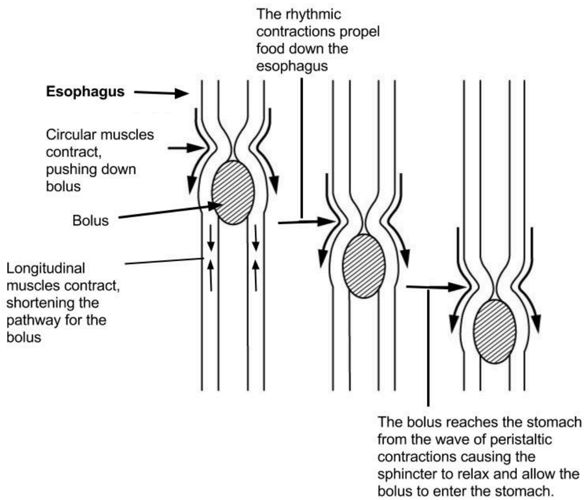
The human digestive system is composed of numerous organs that all work together to break down and digest foods, absorb nutrients and excrete waste. Source: *original figure by* LadyofHats *(Public Domain) with labels added by* Allison Calabrese /

From the Mouth to the Stomach

There are four steps in the digestion process (Figure 2.1.2.2 "The Human Digestive System"). The first step is ingestion, which is the intake of food into the digestive tract. It may seem a simple process, but ingestion involves smelling food, thinking about food, and the involuntary release of saliva in the mouth to prepare for food entry. In the mouth, where the second step of digestion starts, the mechanical and chemical breakdown of food begins. The chemical breakdown of food involves enzymes, such as salivary amylase that starts the breakdown of large starch molecules into smaller components.

Mechanical breakdown starts with mastication (chewing) in the mouth. Teeth crush and grind large food particles, while saliva provides lubrication and enables food movement downward. The slippery mass of partially broken-down food is called a bolus, which moves down the digestive tract as you swallow. Swallowing may seem voluntary at first because it requires conscious effort to push the food with the tongue back toward the throat, but after this, swallowing proceeds involuntarily, meaning it cannot be stopped once it begins. As you swallow, the bolus is pushed from the mouth through the pharynx and into a muscular tube called the esophagus. As the bolus travels through the pharynx, a small flap called the epiglottis closes to prevent choking by keeping food from going into the trachea. Peristaltic contractions also known as peristalsis in the esophagus propel the food bolus down to the stomach (Figure 2.1.2.3 “Peristalsis in the Esophagus”). At the junction between the esophagus and stomach there is a sphincter muscle that remains closed until the food bolus approaches. The pressure of the food bolus stimulates the lower esophageal sphincter to relax and open and food then moves from the esophagus into the stomach. The mechanical breakdown of food is accentuated by the muscular contractions of the stomach and small intestine that mash, mix, slosh, and propel food down the alimentary canal. Solid food takes between four and eight seconds to travel down the esophagus, and liquids take about one second.

Figure 2.1.2.3 *Peristalsis in the Esophagus*



The rhythmic contractions of the esophagus propel foods in the shape of a bolus from the mouth to the stomach. Source: image by Allison Calabrese / [CC BY 4.0]

From the Stomach to the Small Intestine

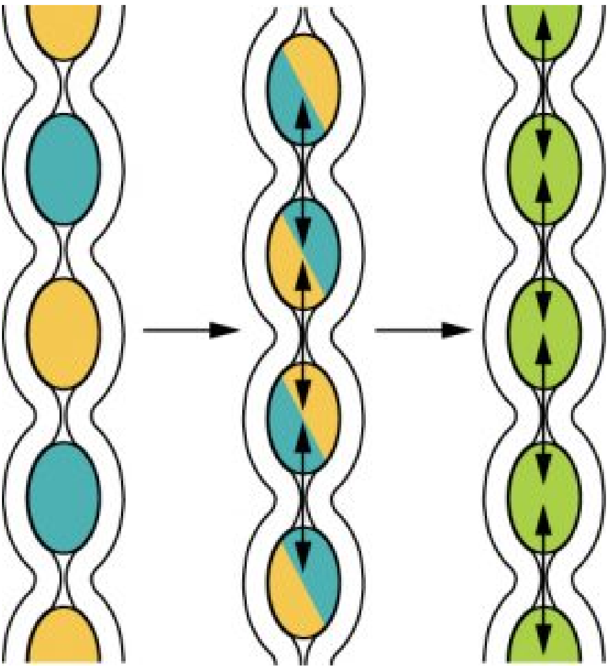
When food enters the stomach, a highly muscular organ, powerful peristaltic contractions help mash, pulverize, and churn food into chyme. Chyme is a semiliquid mass of partially digested food that also contains gastric juices secreted by cells in the stomach. These gastric juices contain hydrochloric acid and the enzyme pepsin, that chemically start breakdown of the protein components of food.

The length of time food spends in the stomach varies by the macronutrient composition of the meal. A high-fat or high-protein meal takes longer to break down than one rich in carbohydrates. It usually takes a few hours after a meal to empty the stomach contents completely into the small intestine.

The small intestine is divided into three structural parts: the duodenum, the jejunum, and the ileum. Once the chyme enters the duodenum (the first segment of the small intestine), the pancreas and gallbladder are stimulated and release juices that aid in digestion. The pancreas secretes up to 1.5 liters (.4 US gallons) of pancreatic juice through a duct into the duodenum per day. This fluid consists mostly of water, but it also contains bicarbonate ions that neutralize the acidity of the stomach-derived chyme and enzymes that further break down proteins, carbohydrates, and lipids. The gallbladder secretes a much smaller amount of a fluid called bile that helps to digest fats. Bile passes through a duct that joins the pancreatic ducts and is released into the duodenum. Bile is made in the liver and stored in the gall bladder. Bile's components act like detergents by surrounding fats similar to the way dish soap removes grease from a frying pan. This allows for the movement of fats in the watery environment of the small intestine. Two different types of muscular contractions, called peristalsis and segmentation, control the movement and mixing of the food in various stages of digestion through the small intestine.

Similar to what occurs in the esophagus and stomach, peristalsis is circular waves of smooth muscle contraction that propel food forward. Segmentation from circular muscle contraction slows movement in the small intestine by forming temporary "sausage link" type of segments that allows chyme to slosh food back and forth in both directions to promote mixing of the chyme and enhance absorption of nutrients (Figure 2.1.2.4 "Segmentation"). Almost all the components of food are completely broken down to their simplest units within the first 25 centimeters of the small intestine. Instead of proteins, carbohydrates, and lipids, the chyme now consists of amino acids, monosaccharides, and emulsified components of triglycerides.

Figure 2.1.2.4 *Segmentation*

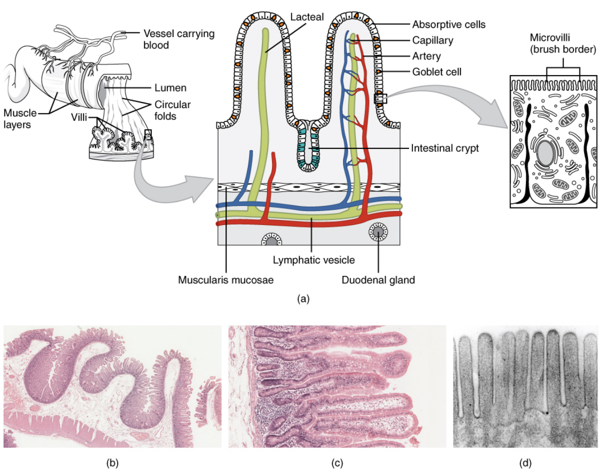


Foods are combined through segmentation. Source: "Segmentation" by [OpenStax College](#) / [CC BY 3.0](#)

The third step of digestion (nutrient absorption) takes place mainly in the remaining length of the small intestine, or ileum (> 5 meters). The way the small intestine is structured gives it a huge surface area to maximize nutrient absorption. The surface area is increased by folds, villi, and microvilli. Digested nutrients are absorbed into either capillaries or lymphatic vessels contained within each microvillus.

The small intestine is perfectly structured for maximizing nutrient absorption. Its surface area is greater than 200 square meters, which is about the size of a tennis court. The large surface area is due to the multiple levels of folding. The internal tissue of the small intestine is covered in villi, which are tiny finger-like projections that are covered with even smaller projections, called microvilli (Figure 2.1.2.5 "Structure of the Small Intestine"). The digested nutrients pass through the absorptive cells of the intestine via diffusion or special transport proteins. Amino acids, short fatty acids, and monosaccharides (sugars) are transported from the intestinal cells into capillaries, but the larger fatty acids, fat-soluble vitamins, and other lipids are transported first through lymphatic vessels, which soon meet up with blood vessels.

Figure 2.1.2.5 *Structure of the Small Intestine*



The small intestine is composed of numerous small villi, which are structures that trap foods so they can be absorbed. Source: "Histology Small Intestines" by [OpenStax College](#) / [CC BY 3.0](#)

From the Small Intestine to the Large Intestine

The process of digestion is fairly efficient. Any food that is still incompletely broken down (usually less than ten percent of food consumed) and the food's indigestible fiber content move from the small intestine to the large intestine (colon) through a connecting valve. A main task of the large intestine is to absorb much of the remaining water. Remember, water is present not only in solid foods and beverages, but also the stomach releases a few hundred milliliters of gastric juice, and the pancreas adds approximately 500 milliliters during the digestion of the meal. For the body to conserve water, it is important that excessive water is not lost in fecal matter. In the large intestine, no further chemical or mechanical breakdown of food takes place unless it is accomplished by the bacteria that inhabit this portion of the intestinal tract. The number of bacteria residing in the large intestine is estimated to be greater than 1014, which is more than the total number of cells in the human body (1013). This may seem rather unpleasant, but the great majority of bacteria in the large intestine are harmless and many are even beneficial.

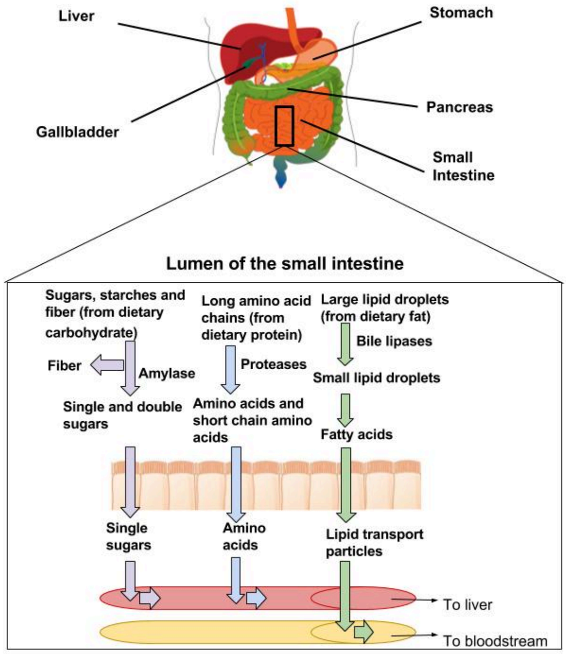
From the Large Intestine to the Anus

After a few hours in the stomach, plus three to six hours in the small intestine, and about sixteen hours in the large intestine, the digestion process enters step four, which is the elimination of indigestible food matter as feces. Feces contain indigestible food components and gut bacteria (almost 50 percent of content). It is stored in the rectum until it is expelled through the anus via defecation.

Nutrients Are Essential for Cell and Organ Function

When the digestive system has broken down food to its nutrient components, the body eagerly awaits delivery. Water soluble nutrients absorbed into the blood travel directly to the liver via a major blood vessel called the portal vein. One of the liver's primary functions is to regulate metabolic homeostasis. Metabolic homeostasis is achieved when the nutrients consumed and absorbed match the energy required to carry out life's biological processes. Simply put, nutrient energy intake equals energy output. Whereas glucose and amino acids are directly transported from the small intestine to the liver, lipids are transported to the liver by a more circuitous route involving the lymphatic system. The lymphatic system is a one-way system of vessels that transports lymph, a fluid rich in white blood cells, and lipid soluble substances after a meal containing lipids. The lymphatic system slowly moves its contents through the lymphatic vessels and empties into blood vessels in the upper chest area. Now, the absorbed lipid soluble components are in the blood where they can be distributed throughout the body and utilized by cells (see Figure 2.1.2.6 "The Absorption of Nutrients").

Figure 2.1.2.6 *The Absorption of Nutrients*



Sugars, amino acids and lipids are absorbed in the small intestine. Sugars and amino acids are first directed towards the liver where they are filtered, whereas lipids are sent directly into the circulation. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

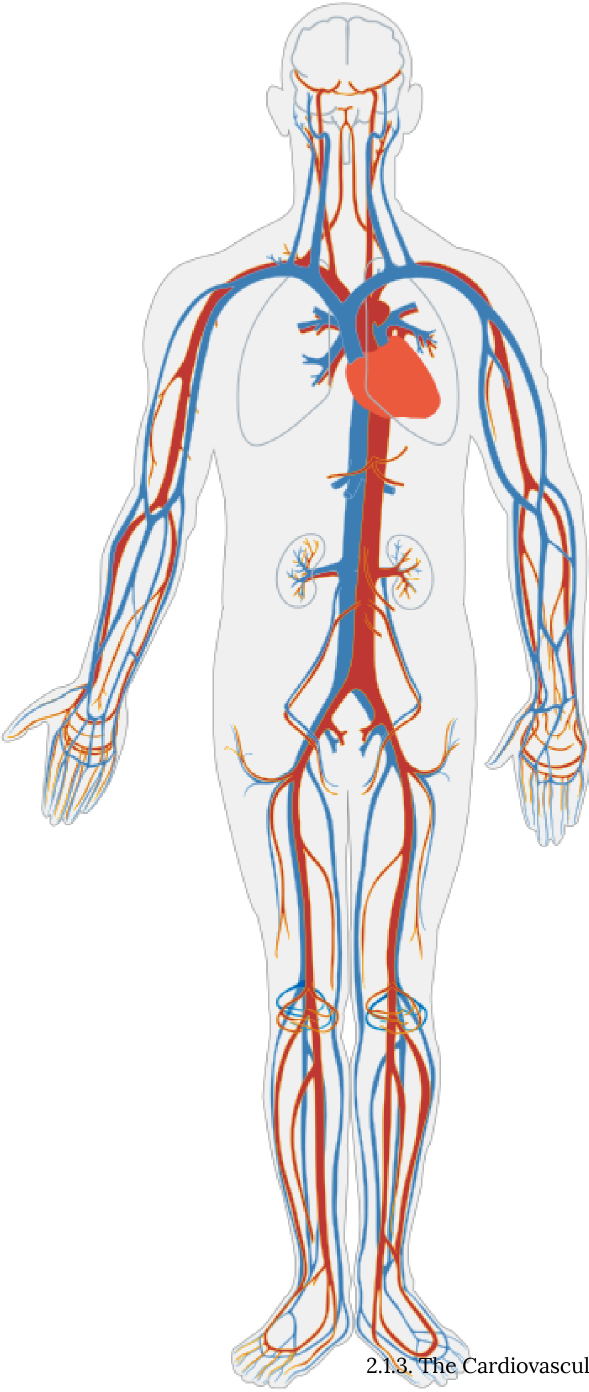
Maintaining the body's energy status quo is crucial because when metabolic homeostasis is disturbed by an eating disorder or disease, bodily function suffers. This will be discussed in more depth in the last section of this chapter. The liver is the only organ in the human body that is capable of exporting nutrients for energy production to other tissues. Therefore, when a person is in between meals (fasted state) the liver exports nutrients, and when a person has just eaten (fed state) the liver stores nutrients within itself. Nutrient levels and the hormones that respond to their levels in the blood provide the input so that the liver can distinguish between the fasted and fed states and distribute nutrients appropriately. Although not considered to be an organ, adipose tissue stores fat in the fed state and mobilizes fat components to supply energy to other parts of the body when energy is needed.

All eleven organ systems in the human body require nutrient input to perform their specific biological functions. Overall health and the ability to carry out all of life's basic processes is fueled by energy-supplying nutrients (carbohydrate, fat, and protein). Without them, organ systems would fail, humans would not reproduce, and the race would disappear. In this section, we will discuss some of the critical nutrients that support specific organ system functions.

2.1.3. The Cardiovascular System

The Cardiovascular System Transports Nutrients

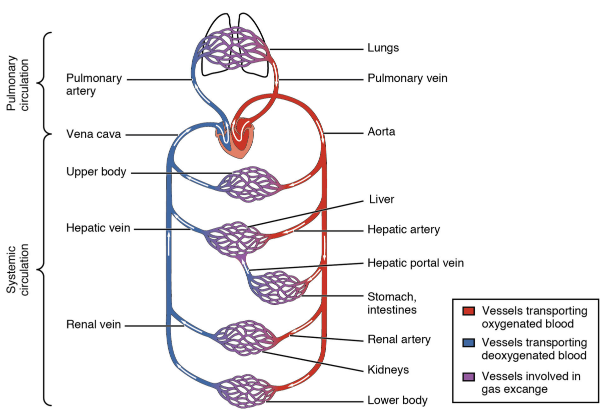
Figure 2.1.3.1 *The Cardiovascular System*



Source: "Simplified diagram of the human Circulatory system in anterior view" by [Mariana Ruiz](#) / [Public Domain](#)

The cardiovascular system is one of the eleven organ systems of the human body. Its main function is to transport nutrients to cells and wastes from cells (Figure 2.1.3.3 "Cardiovascular Transportation of Nutrients"). This system consists of the **heart, blood, and blood vessels.** The heart pumps the blood, and the blood is the transportation fluid. The transportation route to all tissues, a highly intricate blood-vessel network, comprises arteries, veins, and capillaries. Nutrients absorbed in the small intestine travel mainly to the liver through the hepatic portal vein. From the liver, nutrients travel upward through the inferior vena cava blood vessel to the heart. The heart forcefully pumps the nutrient-rich blood first to the lungs to pick up some oxygen and then to all other cells in the body. Arteries become smaller and smaller on their way to cells, so that by the time blood reaches a cell, the artery's diameter is extremely small and the vessel is now called a capillary. The reduced diameter of the blood vessel substantially slows the speed of blood flow. This dramatic reduction in blood flow gives cells time to harvest the nutrients in blood and exchange metabolic wastes.

Figure 2.1.3.2 *The Blood Flow in the Cardiovascular System*



The pathways of blood flow throughout the body from the heart. Source: "Blood Flow Through the Heart" by [OpenStax College](#) / [CC BY 3.0](#)

Blood’s Function in the Body and in Metabolism Support

You know you cannot live without blood, and that your heart pumps your blood over a vast network of veins and arteries within your body, carrying oxygen to your cells. However, beyond these basic facts, what do you know about your blood?

Blood transports absorbed nutrients to cells and waste products from cells. It supports cellular metabolism by transporting synthesized macromolecules from one cell type to another and carrying waste products away from cells. Additionally, it transports molecules, such as hormones, allowing for communication between organs. The volume of blood coursing throughout an adult human body is about 5 liters (1.3 US gallons) and accounts for approximately 8 percent of human body weight.

What Makes Up Blood and How Do These Substances Support Blood Function?

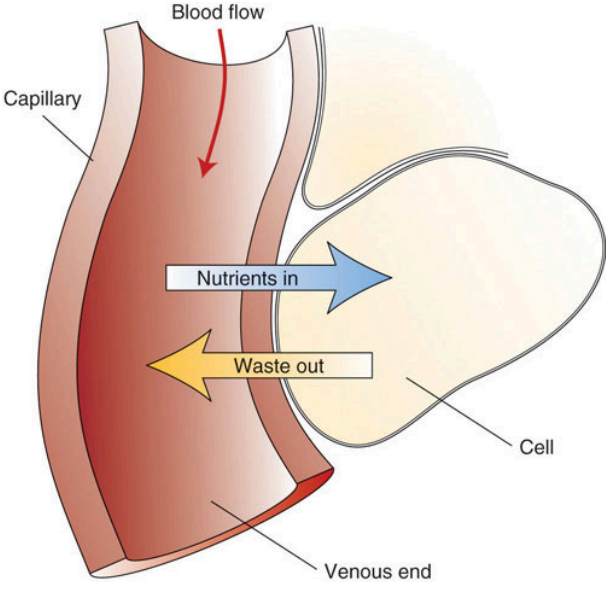
Blood is about 78 percent water and 22 percent solids by volume. The liquid part of blood is called **plasma** and it is mostly water (95 percent), but also contains proteins, ions, glucose, lipids, vitamins, minerals, waste products, gases, enzymes, and hormones. We have learned that the protein albumin is found in high concentrations in the blood. Albumin helps maintain fluid balance between blood and tissues, as well as helping to maintain a constant blood pH. We have also learned that the water component of blood is essential for its actions as a transport vehicle, and that the electrolytes carried in blood help to maintain fluid balance and a constant pH. Furthermore, the high water content of blood helps maintain body temperature, and the constant flow of blood distributes heat throughout the body. Blood is exceptionally good at temperature control, so much so that the many small blood vessels in your nose are capable of warming frigid air to body temperature before it reaches the lungs.

The cellular components of blood include red blood cells, white blood cells, and platelets. Red blood cells are the most numerous of the components. Each drop of blood contains millions of them. Red blood cells are red because they each contain approximately 270 million hemoglobin proteins, which contain the mineral iron, which turns red when bound to oxygen. The most vital duty of red blood cells is to transport oxygen from the lungs to all cells in the body so that cells can utilize oxygen to produce energy via aerobic metabolism.

The white blood cells that circulate in blood are part of the immune system, and they survey the entire body looking for foreign invaders to destroy. They make up about 1 percent of blood volume.

Platelets are fragments of cells that are always circulating in the blood in case of an emergency. When blood vessels are injured, platelets rush to the site of injury to plug the wound. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow. Red blood cells live for about 120 days, white blood cells live anywhere from eighteen hours to one year, or even longer, and platelets have a lifespan of about ten days.

Figure 2.1.3.3 *Cardiovascular Transportation of Nutrients*



The cardiovascular system transports nutrients to all cells and carries wastes out. Source: [The Cardiovascular System]

Nutrients In

Once absorbed from the small intestine, all nutrients require transport to cells in need of their support. Additionally, molecules manufactured in other cells sometimes require delivery to other organ systems. Blood is the conduit and blood vessels are the highway that support nutrient and molecule transport to all cells. **Water-soluble** molecules, such as some vitamins, minerals, sugars, and many proteins, move independently in blood. **Fat-soluble** vitamins, triglycerides, cholesterol, and other lipids are packaged into lipoproteins that allow for transport in the watery milieu of blood. Many proteins, drugs, and hormones are dependent on transport carriers, primarily by the plasma protein albumin. In addition to transporting all of these molecules, blood transfers oxygen taken in by the lungs to all cells in the body. As discussed, the iron-containing hemoglobin molecule in red blood cells serves as the oxygen carrier.

Wastes Out

In the metabolism of macronutrients to energy, cells produce the waste products carbon dioxide and water. As blood travels through smaller and smaller vessels, the rate of blood flow is dramatically reduced, allowing for efficient exchange of nutrients and oxygen for cellular waste products through tiny capillaries. The kidneys remove any excess water from the blood, and blood delivers the carbon dioxide to the lungs where it is exhaled. Also, the liver produces the waste product urea from the breakdown of amino acids and detoxifies many harmful substances, all of which require transport in the blood to the kidneys for excretion.

All for One, One for All

The eleven organ systems in the body completely depend on each other for continued survival as a complex organism. Blood allows for transport of nutrients, wastes, water, and heat, and is also a conduit of communication between organ systems. **Example:** Blood's importance to the rest of the body is aptly presented in its role in glucose delivery, especially to the brain. The brain metabolizes, on average, 6 grams of glucose per hour. In order to avert confusion, coma, and death, glucose must be readily available to the brain at all times. To accomplish this task, cells in the pancreas sense glucose levels in the blood. If glucose levels are low, the hormone glucagon is released into the blood and is transported to the liver where it communicates the signal to ramp-up glycogen breakdown and glucose synthesis. The liver does just that, and glucose is released into the blood, which transports it to the brain. Concurrently, blood transports oxygen to support the metabolism of glucose to provide energy in the brain. Healthy blood conducts its duties rapidly, avoiding hypoglycemic coma and death. This is just one example of the body's survival mechanisms exemplifying life's mantra "All for one, one for all."

What Makes Blood Healthy?

Maintaining healthy blood, including its continuous renewal, is essential to support its vast array of vital functions. Blood is healthy when it contains the appropriate amount of water and cellular components and proper concentrations of dissolved substances, such as albumin and electrolytes. As with all other tissues, blood needs macro- and micronutrients to optimally function. In the bone marrow, where blood cells are made, amino acids are required to build the massive amount of hemoglobin packed within every red blood cell, along with all other enzymes and cellular organelles contained in each blood cell.

Red blood cells, similar to the brain, use only glucose as fuel, and it must be in constant supply to support red-blood-cell metabolism. As with all other cells, the cells in the blood are surrounded by a plasma membrane, which is composed of mainly lipids. Blood health is also acutely sensitive to deficiencies in some vitamins and minerals more than others.

What Can Blood Tests Tell You About Your Health?

Figure 2.1.3.4 *Blood Tests*

Blood tests are helpful tools in diagnosing disease and provide lots of information on overall health. Source: image by Thirteen of Clubs. Source: [The Cardiovascular System]

Since blood is the conduit of metabolic products and wastes, measuring the components of blood, and particular substances in blood, can reveal not only the health of blood, but also the health of other organ systems. In standard blood tests performed during an annual physical, the typical blood tests conducted can tell your physician about the functioning of a particular organ or about disease risk.

A biomarker is defined as a measurable molecule or trait that is connected with a specific disease or health condition. The concentrations of biomarkers in blood are indicative of disease risk. Some biomarkers are cholesterol, triglycerides, glucose, and prostate-specific antigen. The results of a blood test give the concentrations of substances in a person's blood and display the normal ranges for a certain population group. Many factors, such as physical activity level, diet, alcohol intake, and medicine intake can influence a person's blood-test levels and cause them to fall outside the normal range, so results of blood tests outside the "normal" range are not always indicative of health problems.

The assessment of multiple blood parameters aids in the diagnosis of disease risk and is indicative of overall health status. See Table 2.1.3.1 "Blood Tests" for a partial list of substances measured in a typical blood test. This table notes only a few of the things that their levels tell us about health.

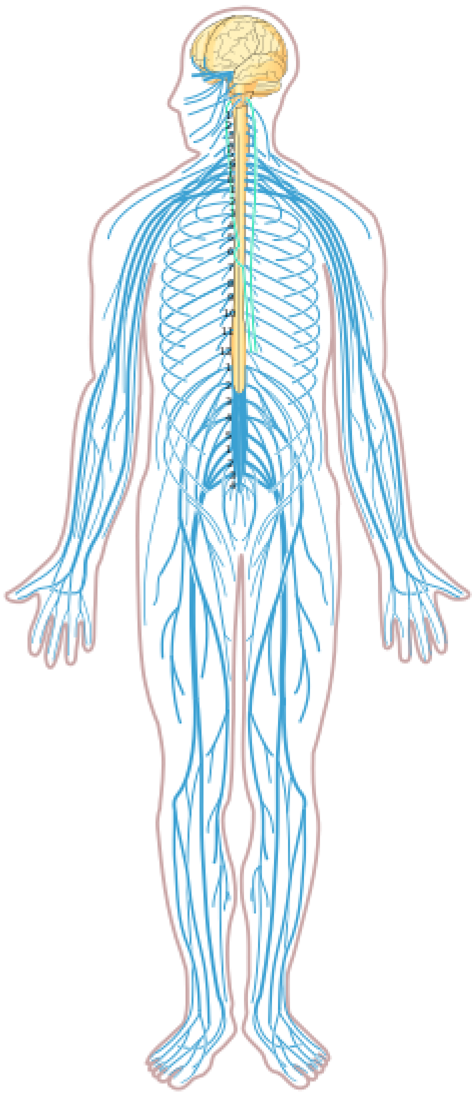
Table 2.1.3.1 *Blood Tests*

Substance measured	Indicates
Red-blood-cell count	Oxygen-carrying capacity
Hematocrit (red-blood-cell volume)	Anemia risk
White-blood-cell count	Presence of infection
Platelet count	Bleeding disorders, atherosclerosis risk
pH	Metabolic, kidney, respiratory abnormalities
Albumin	Liver, kidney, and Crohn's disease, dehydration, protein deficiency
Bilirubin	Liver-function abnormality
Oxygen/Carbon Dioxide	Respiratory or metabolic abnormality
Hemoglobin	Oxygen-carrying capacity
Iron	Anemia risk
Magnesium	Magnesium deficiency
Electrolytes (calcium, chloride, magnesium, potassium)	Many illnesses (kidney, metabolic, etc.)
Cholesterol	Cardiovascular disease risk
Triglycerides	Cardiovascular disease risk
Glucose	Diabetes risk
Hormones	Many illnesses (diabetes, reproductive abnormalities)

Note: There are numerous measures that can be taken in a sample of blood. These measures can be used to determine if and illness or disease is present. *Source:* National Heart Lung and Blood Institute. Types of Blood Tests.http://www.nhlbi.nih.gov/health/health-topics/topics/bdt/types.html. Published January 6, 2012. Accessed September 22,2017.

2.1.4. The Central Nervous System

Figure 2.1.4.1 *The Central Nervous System*



The nervous system is extensive, spreading throughout the body. Source: "Nervous System" by [William Crochot](#) / [CC BY-SA 4.0](#)

The human brain (which weighs only about 3 pounds, or 1,300 grams) is estimated to contain over one hundred billion neurons.

Neurons form the core of the central nervous system, which consists of the brain, spinal cord, and other nerve bundles in the body. **The main function of the central nervous system is to sense changes in the external environment and create a reaction to them**. For instance, if your finger comes into contact with a thorn on a rose bush, a sensory neuron transmits a signal from your finger up through the spinal cord and into the brain. Another neuron in the brain sends a signal that travels back to the muscles in your hand and stimulates muscles to contract and you jerk your finger away. All of this happens within a tenth of a second.

All nerve impulses travel by the movement of charged sodium, potassium, calcium, and chloride atoms. Nerves communicate with each other via chemicals built from amino acids called neurotransmitters. Eating adequate protein from a variety of sources will ensure the body gets all of the different amino acids that are important for central nervous system function.

The brain's main fuel is glucose and only in extreme starvation will it use anything else. For acute mental alertness and clear thinking, glucose must be systematically delivered to the brain. This does not mean that sucking down a can of sugary soda before your next exam is a good thing. Just as too much glucose is bad for other organs, such as the kidneys and pancreas, it also produces negative effects upon the brain. Excessive glucose levels in the blood can cause a loss of cognitive function, and chronically high blood-glucose levels can damage brain cells. **The brain's cognitive functions include language processing, learning, perceiving, and thinking**. Recent scientific studies demonstrate that having continuously high blood-glucose levels substantially elevates the risk for developing Alzheimer's disease, which is the greatest cause of age-related cognitive decline.

The good news is that much research is directed toward determining the best diets and foods that slow cognitive decline and maximize brain health. A study in the June 2010 issue of the Archives of Neurology reports that people over age 65 who adhered to diets that consisted of higher intakes of nuts, fish, poultry, tomatoes, cruciferous vegetables, fruits, salad dressing, and dark green, and leafy vegetables, as well as a lower intake of high-fat dairy products, red meat, organ meat, and butter, had a much reduced risk for Alzheimer's disease.[1]

Other scientific studies provide supporting evidence that foods rich in omega-3 fatty acids and/or antioxidants provide the brain with protection against Alzheimer's disease. **Example of a study providing information of interest:** One potential "brain food" is the blueberry. The protective effects of blueberries upon the brain are linked to their high content of anthocyanins, which are potent antioxidants and reduce inflammation. A small study published in the April 2010 issue of the Journal of Agricultural and Food Chemistry found that elderly people who consumed blueberry juice every day for twelve weeks had improved learning and memorization skills in comparison to other subjects given a placebo drink.[2]

However, it is important to keep in mind that this was a short-term study. Blueberries also are high in manganese, and high intake of manganese over time is known to have neurotoxic effects. Variety in the diet is perhaps the most important concept in applied nutrition. More clinical trials are evaluating the effects of

1. Gu Y, Nieves JW, et al. Food Combination and Alzheimer Disease Risk: A Protective Diet. Arch Neurol. 2010; 67(6), 699–706. https://www.ncbi.nlm.nih.gov/pubmed/20385883. Accessed September 22, 2017.
2. Krikorian R, Shidler MD, et al. Blueberry Supplementation Improves Memory in Older Adults. J Agric Food Chem. 2010; 58(7), 3996-4000. https://www.ncbi.nlm.nih.gov/pubmed/20047325. Accessed September 22, 2017.

blueberries and other foods that benefit the brain and preserve its function as we age.

2.1.5. The Respiratory System

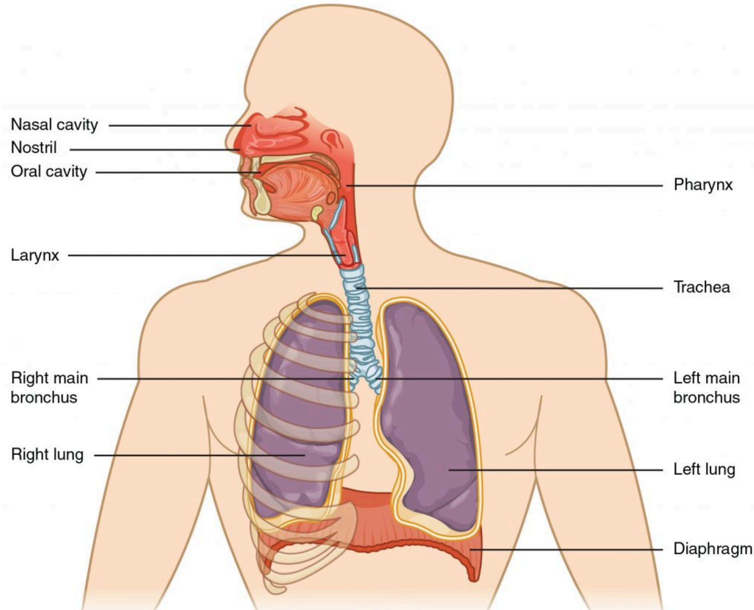
Introduction

A typical human cannot survive without breathing for more than 3 minutes, and even if you wanted to hold your breath longer, your autonomic nervous system would take control. This is because cells need to maintain oxidative metabolism for energy production that continuously regenerates adenosine triphosphate (ATP). For oxidative phosphorylation to occur, oxygen is used as a reactant and carbon dioxide is released as a waste product. You may be surprised to learn that although oxygen is a critical need for cells, it is actually the accumulation of carbon dioxide that primarily drives your need to breathe. Carbon dioxide is exhaled and oxygen is inhaled through the **respiratory system, which includes muscles to move air into and out of the lungs, passageways through which air moves, and microscopic gas exchange surfaces covered by capillaries**. The cardiovascular system transports gases from the lungs to tissues throughout the body and vice versa.

A variety of diseases can affect the respiratory system, such as asthma, emphysema, chronic obstructive pulmonary disorder (COPD), and lung cancer. All of these conditions affect the gas exchange process and result in labored breathing and other difficulties.

The major organs of the respiratory system function primarily to provide oxygen to body tissues for cellular respiration, remove the waste product carbon dioxide, and help to maintain acid-base balance. Portions of the respiratory system are also used for non-vital functions, such as sensing odors, producing speech, and for straining, such as during childbirth or coughing.

Figure 2.1.5.1 *Major Respiratory Structures*



The major respiratory structures span the nasal cavity to the diaphragm. Functionally, the respiratory system can be divided into a conducting zone and a respiratory zone. The conducting zone of the respiratory system includes the organs and structures not directly involved in gas exchange (trachea and bronchi). The gas exchange occurs in the respiratory zone. Source: [The Respiratory System]

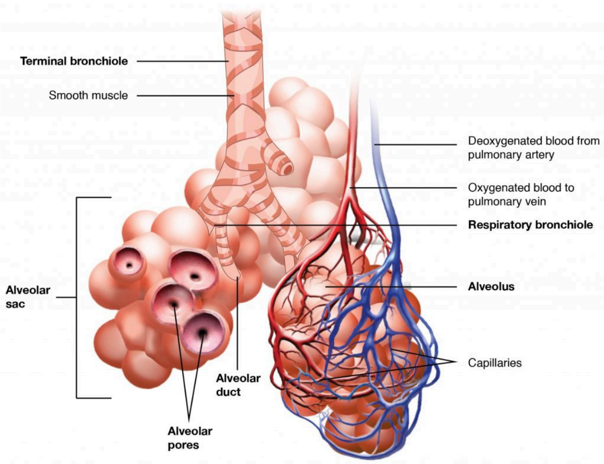
Conducting Zone

The major functions of the conducting zone are to provide a route for incoming and outgoing air, remove debris and pathogens from the incoming air, and warm and humidify the incoming air. Several structures within the conducting zone perform other functions as well. The epithelium of the nasal passages, for example, is essential to sensing odors, and the bronchial epithelium that lines the lungs can metabolize some airborne carcinogens. The conducting zone includes the **nose and its adjacent structures, the pharynx, the larynx, the trachea, and the bronchi.**

Respiratory Zone

In contrast to the conducting zone, the respiratory zone includes **structures that are directly involved in gas exchange**. The respiratory zone begins where the terminal bronchioles join a respiratory bronchiole, the smallest type of bronchiole (Figure 2.1.5.2 "Respiratory Zone"), which then leads to an alveolar duct, opening into a cluster of alveoli.

Figure 2.1.5.2 *Respiratory Zone*



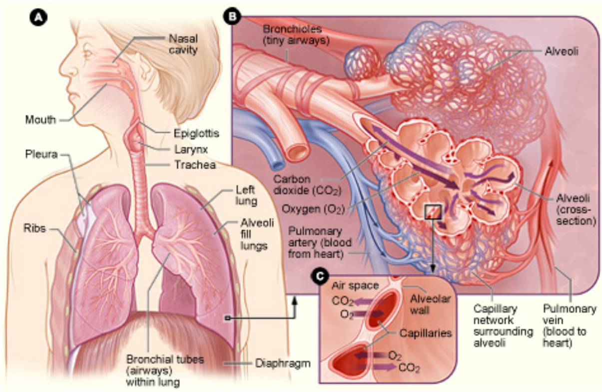
Bronchioles lead to alveolar sacs in the respiratory zone, where gas exchange occurs. Source: [The Respiratory System]

Alveoli

An alveolar duct is a tube composed of smooth muscle and connective tissue, which opens into a cluster of alveoli. An alveolus is one of the many small, grape-like sacs that are attached to the alveolar ducts.

An alveolar sac is a cluster of many individual alveoli that are responsible for gas exchange. An alveolus is approximately 200 μm in diameter with elastic walls that allow the alveolus to stretch during air intake, which greatly increases the surface area available for gas exchange. Alveoli are connected to their neighbors by alveolar pores, which help maintain equal air pressure throughout the alveoli and lung.

Figure 2.1.5.3 *Location of Respiratory System*



The respiratory system is made up of the lungs, which contain alveoli, the site of oxygen exchange. Source: [“Human Respiratory System”]() by *United States National Institute of Health: National Heart, Lung and Blood Institute / [Public Domain]()* Source: [The Respiratory System]()

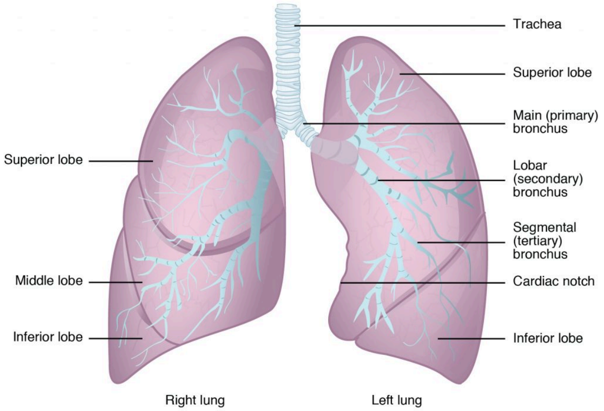
Figure 2.1.5.3. shows the location of the respiratory structures in the body. Figure 2.1.5.3**B** is an enlarged view of the airways, alveoli (air sacs), and capillaries (tiny blood vessels). Figure 2.1.5.3**C** is a close-up view of gas exchange between the capillaries and alveoli. CO_2 is carbon dioxide, and O_2 is oxygen.

A major organ of the respiratory system, each lung houses structures of both the conducting and respiratory zones. The main function of the lungs is to perform the exchange of oxygen and carbon dioxide with air from the atmosphere. To this end, the lungs exchange respiratory gases across a very large epithelial surface area—about 70 square meters—that is highly permeable to gases.

Gross Anatomy of the Lungs

The lungs are pyramid-shaped, paired organs that are connected to the trachea by the right and left bronchi; below the lungs is the diaphragm, a flat, dome-shaped muscle located at the base of the lungs and thoracic cavity.

Figure 2.1.5.4 *Basic Anatomy of the Lungs*



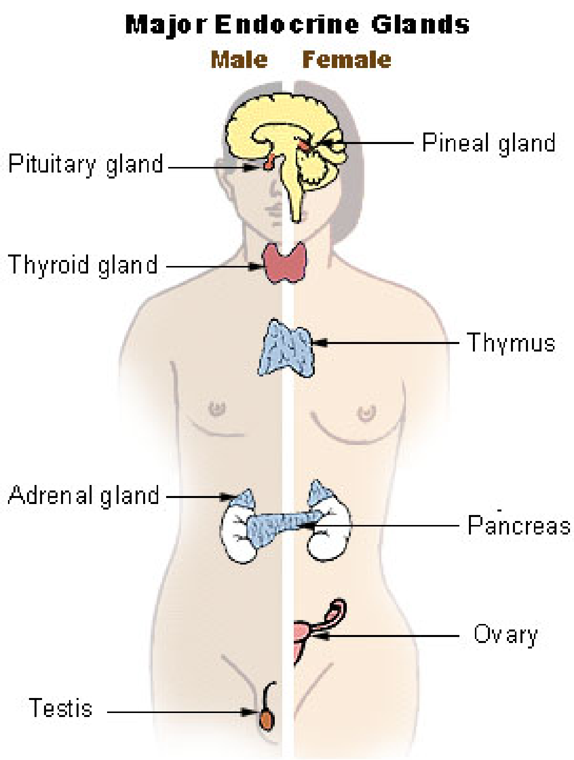
Each lung is composed of smaller units called lobes. Fissures separate these lobes from each other. The right lung consists of three lobes: the superior, middle, and inferior lobes. The left lung consists of two lobes: the superior and inferior lobes. Source: [The Respiratory System]

Blood Supply

The major function of the lungs is to perform gas exchange, which requires blood flowing through the lung tissues (the pulmonary circulation). This blood supply contains deoxygenated blood and travels to the lungs where erythrocytes, also known as red blood cells, pick up oxygen to be transported to tissues throughout the body. The pulmonary artery carries deoxygenated blood to the lungs. The pulmonary artery branches multiple times as it follows the bronchi, and each branch becomes progressively smaller in diameter down to the tiny capillaries where the alveoli release carbon dioxide from blood into the lungs to be exhaled and take up oxygen from inhaled air to oxygenate the blood. Once the blood is oxygenated, it drains from the alveoli by way of multiple pulmonary veins that exit the lungs to carry oxygen to the rest of the body.

2.1.6. The Endocrine System

Figure 2.1.6.1 *The Endocrine System*



The major endocrine glands throughout the body. Source: "Major Endocrine Glands" by National Cancer Institute / Public Domain

The functions of the endocrine system are intricately connected to the body's nutrition. This organ system is **responsible for regulating appetite, nutrient absorption, nutrient storage, and nutrient usage, in addition to other functions, such as reproduction.**

The glands in the endocrine system are the pituitary, thyroid, parathyroid, adrenals, thymus, pineal, pancreas, ovaries, and testes. The glands secrete hormones, which are biological molecules that regulate cellular processes in other target tissues, so they require transportation by the circulatory system.

Adequate nutrition is critical for the functioning of all the glands in the endocrine system. A protein deficiency impairs gonadal-hormone release, preventing reproduction. Athletic teenage girls with very little body fat often do not menstruate. Children who are malnourished usually do not produce enough growth hormone and fail to reach normal height for their age group. Probably the most popularized connection between nutrition and the functions of the endocrine system is that unhealthy dietary patterns are linked to obesity and the development of Type 2 diabetes. The Centers for Disease Control and Prevention (CDC) estimates that twenty-six million Americans have Type 2 diabetes as of 2011. This is 8.3 percent of the US population. The most recent statistics Canada report (2013-2014) found that about 3 million Canadians or 8.1% of the Canadian population was living with diabetes. Counties with the highest incidence of obesity also have the highest incidence of Type 2 diabetes. To see how the rise in obesity in this country is paralleled by the rise in Type 2 diabetes, review this report by the CDC.

What is the causal relationship between overnutrition and Type 2 diabetes? The prevailing theory is that the overconsumption of high-fat and high-sugar foods causes changes in muscle, fat, and liver cells that leads to a diminished response from the pancreatic hormone insulin. These cells are called "insulin-resistant." Insulin is released after a meal and instructs the liver and other tissues to take up glucose and fatty acids that are circulating in the blood. When cells are resistant to insulin they do not take up enough glucose and fatty acids, so glucose and fatty acids remain at high concentrations in the blood. The chronic elevation of glucose and fatty acids in the blood also causes damage to other tissues over time, so that people who have Type 2 diabetes are at increased risk for cardiovascular disease, kidney disease, nerve damage, and eye disease.

Career Connection

Do your part to slow the rising tide of obesity and Type 2 diabetes in this country. On the individual level, improve your own family's diet; at the local community level, support the development of more nutritious school lunch programs; and at the national level, support your nation's nutrition goals. Visit the CDC Diabetes Public Health Resource website at https://www.cdc.gov/diabetes/. It provides information on education resources, projects, and programs, and spotlights news on diabetes. For helpful information on obesity, visit https://www.cdc.gov/obesity/. The CDC also has workplace web-based resources with the mission of designing work sites that prevent obesity. See https://www.cdc.gov/workplacehealthpromotion/index.html or more details.

2.1.7. The Urinary System

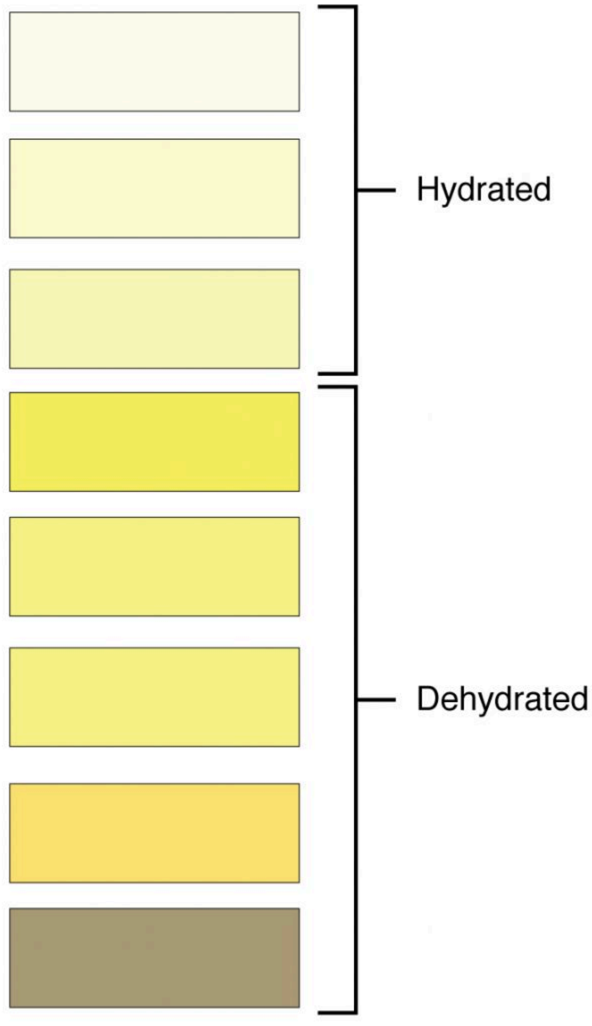
The urinary system has roles you may be well aware of: cleansing the blood and ridding the body of wastes probably come to mind. However, there are additional, equally important functions played by the system. Take for example, regulation of pH, a function shared with the lungs and the buffers in the blood. Additionally, the regulation of blood pressure is a role shared with the heart and blood vessels. What about regulating the concentration of solutes in the blood? Did you know that the kidney is important in determining the concentration of red blood cells? Eighty-five percent of the erythropoietin (EPO) produced to stimulate red blood cell production is produced in the kidneys. The kidneys also perform the final synthesis step of vitamin D production, converting calcidiol to calcitriol, the active form of vitamin D.

If the kidneys fail, these functions are compromised or lost altogether, with devastating effects on homeostasis. The affected individual might experience weakness, lethargy, shortness of breath, anemia, widespread edema (swelling), metabolic acidosis, rising potassium levels, heart arrhythmias, and more. Each of these functions is vital to your well-being and survival.

The urinary system, controlled by the nervous system, also stores urine until a convenient time for disposal and then provides the anatomical structures to transport this waste liquid to the outside of the body. Failure of nervous control or the anatomical structures leading to a loss of control of urination results in a condition called incontinence.

Characteristics of the urine change, depending on influences such as water intake, exercise, environmental temperature, nutrient intake, and other factors . Some of the characteristics such as color and odor are rough descriptors of your state of hydration. For example, if you exercise or work outside, and sweat a great deal, your urine will turn darker and produce a slight odor, even if you drink plenty of water. Athletes are often advised to consume water until their urine is clear. This is good advice; however, it takes time for the kidneys to process body fluids and store it in the bladder. Another way of looking at this is that the quality of the urine produced is an average over the time it takes to make that urine. Producing clear urine may take only a few minutes if you are drinking a lot of water or several hours if you are working outside and not drinking much.

Figure 2.1.7.1 *Urine Color*

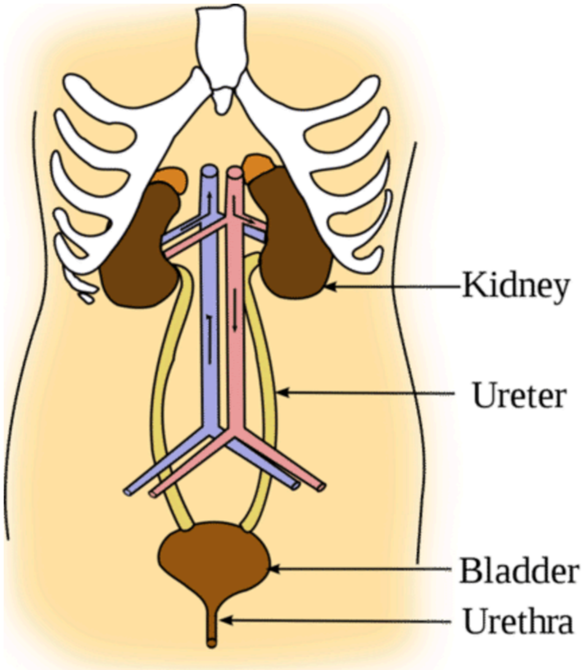


The more clear your urine is the more hydrated you are. Dark yellow/ brown urine is a sign of dehydration. Source: "Urine Color" by [OpenStax College](#) / [CC BY 3.0](#)

Urine volume varies considerably. The normal range is one to two liters per day. The kidneys must produce a minimum urine volume of about 500 mL/day to rid the body of wastes. Output below this level may be caused by severe dehydration or renal disease and is termed oliguria. The virtual absence of urine production is termed anuria. Excessive urine production is polyuria, which may occur in diabetes mellitus when blood glucose levels exceed the filtration capacity of the kidneys and glucose appears in the urine. The osmotic nature of glucose attracts water, leading to increased water loss in the urine.

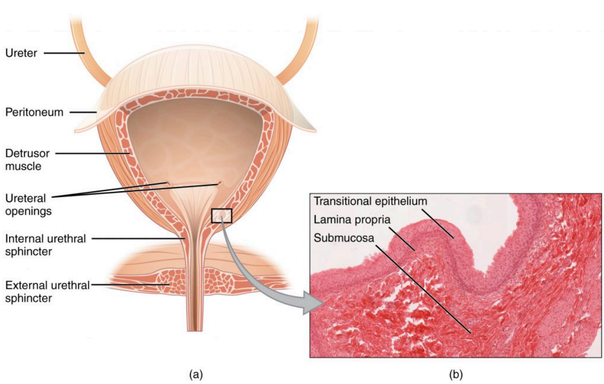
Urine is a fluid of variable composition that requires specialized structures to remove it from the body safely and efficiently. Blood is filtered, and the filtrate is transformed into urine at a relatively constant rate throughout the day. This processed liquid is stored until a convenient time for excretion. All structures involved in the transport and storage of the urine are large enough to be visible to the naked eye. This transport and storage system not only stores the waste, but it protects the tissues from damage due to the wide range of pH and osmolarity of the urine, prevents infection by foreign organisms, and for the male, provides reproductive functions. The urinary bladder collects urine from both ureters (Figure 2.1.7.2 “Urinary System Location”).

Figure 2.1.7.2 *Urinary System Location*



Components of the urinary system. Source: "Illu Urinary System" by Thstehle / Public Domain

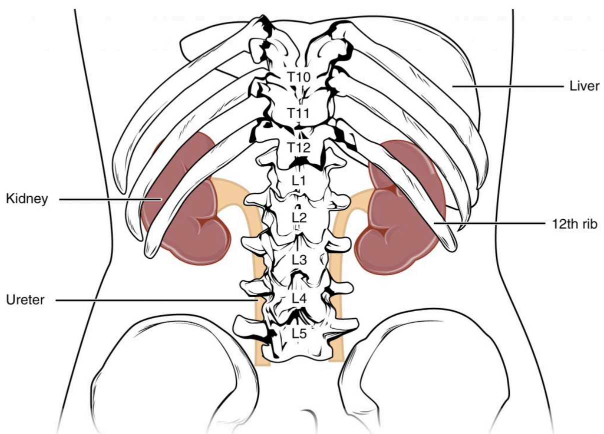
Figure 2.1.7.3 *The Bladder*



A structural view of the bladder. Source: "The Bladder" by OpenStax College / CC BY 3.0

The kidneys lie on either side of the spine in the retroperitoneal space behind the main body cavity that contains the intestines. The kidneys are well protected by muscle, fat, and the lower ribs. They are roughly the size of your fist, and the male kidney is typically a bit larger than the female kidney. The kidneys are well vascularized, receiving about 25 percent of the cardiac output at rest.

Figure 2.1.7.4 *The Kidneys*



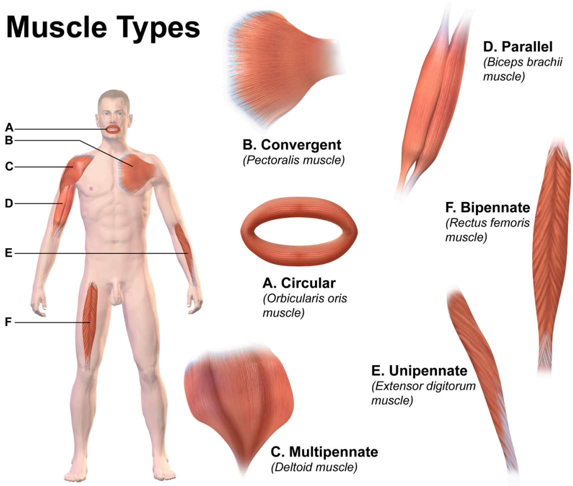
The kidneys (as viewed from the back of the body) are slightly protected by the ribs and are surrounded by fat for protection (not shown). Source: "Kidney Position in Abdomen" by [OpenStax College](#) / [CC BY 3.0](#)

The effects of failure of parts of the urinary system may range from inconvenient (incontinence) to fatal (loss of filtration and many other functions). The kidneys catalyze the final reaction in the synthesis of active vitamin D that in turn helps regulate Ca++. The kidney hormone EPO stimulates erythrocyte development and promotes adequate O_2 transport. The kidneys help regulate blood pressure through Na^+ and water retention and loss. The kidneys work with the adrenal cortex, lungs, and liver in the renin–angiotensin–aldosterone system to regulate blood pressure. They regulate osmolarity of the blood by regulating both solutes and water. Three electrolytes are more closely regulated than others: Na^+, Ca^{++}, and K^+. The kidneys share pH regulation with the lungs and plasma buffers, so that proteins can preserve their three-dimensional conformation and thus their function.

2.1.8. The Muscular System

The muscular system allows the body to move voluntarily, but it also controls involuntary movements of other organ systems such as heartbeat in the circulatory system and peristaltic waves in the digestive system. It consists of over six hundred skeletal muscles, as well as the heart muscle, the smooth muscles that surround your entire alimentary canal, and all your arterial blood vessels (see Figure 2.1.8.1 “The Muscular System in the Human Body”). Muscle contraction relies on energy delivery to the muscle. Each movement uses up cellular energy, and without an adequate energy supply, muscle function suffers. Muscle, like the liver, can store the energy from glucose in the large polymeric molecule glycogen. But unlike the liver, muscles use up all of their own stored energy and do not export it to other organs in the body. Muscle is not as susceptible to low levels of blood glucose as the brain because it will readily use alternate fuels such as fatty acids and protein to produce cellular energy.

Figure 2.1.8.1 *The Muscular System in the Human Body*



There are numerous muscle types that serve different functions throughout the body. Source: "Muscle Types" by [BruceBlaus](#) / [CC BY-SA 4.0](#).

2.1.9. The Skeletal System

Bone Structure and Function

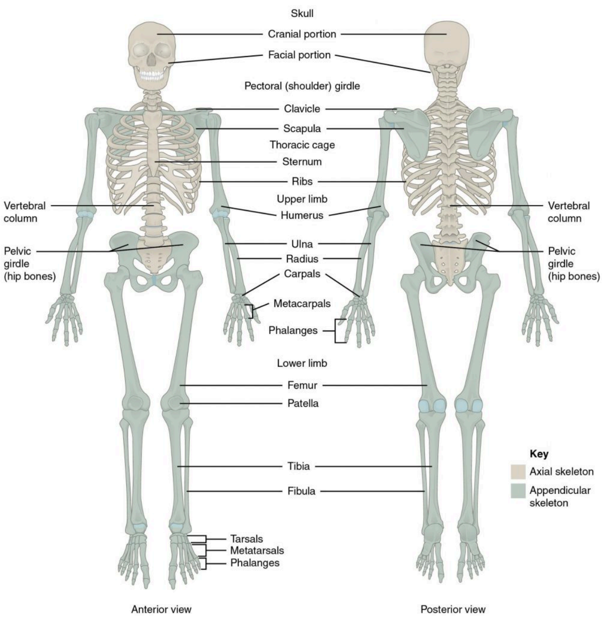
Your bones are stronger than reinforced concrete. Bone tissue is a composite of fibrous strands of collagen (a type of protein) that resemble the steel rebar in concrete and a hardened mineralized matrix that contains large amounts of calcium, just like concrete. But this is where the similarities end. Bone outperforms reinforced concrete by several orders of magnitude in compression and tension strength tests. Why? The microarchitecture of bone is complex and built to withstand extreme forces. Moreover, bone is a living tissue that is continuously breaking down and forming new bone to adapt to mechanical stresses.

Why Is the Skeletal System Important?

The human skeleton consists of 206 bones and other connective tissues called ligaments, tendons, and cartilage. Ligaments connect bones to other bones, tendons connect bones to muscles, and cartilage provides bones with more flexibility and acts as a cushion in the joints between bones.

The skeleton's many bones and connective tissues allow for multiple types of movement such as typing and running. The skeleton provides structural support and protection for all the other organ systems in the body. The skull, or cranium, is like a helmet and protects the eyes, ears, and brain. The ribs form a cage that surrounds and protects the lungs and heart. In addition to aiding in movement, protecting organs, and providing structural support, red and white blood cells and platelets are synthesized in bone marrow. Another vital function of bones is that they act as a storage depot for minerals such as calcium, phosphorous, and magnesium. Although bone tissue may look inactive at first glance, at the microscopic level you will find that bones are continuously breaking down and reforming. Bones also contain a complex network of canals, blood vessels, and nerves that allow for nutrient transport and communication with other organ systems.

Figure 2.1.9.1 *Human Skeletal Structure*



The human skeleton contains 206 bones. It is divided into two main parts, the axial and appendicular. Source: "Axial Skeleton" by [Openstax College](#) / [CC BY 3.0](#)

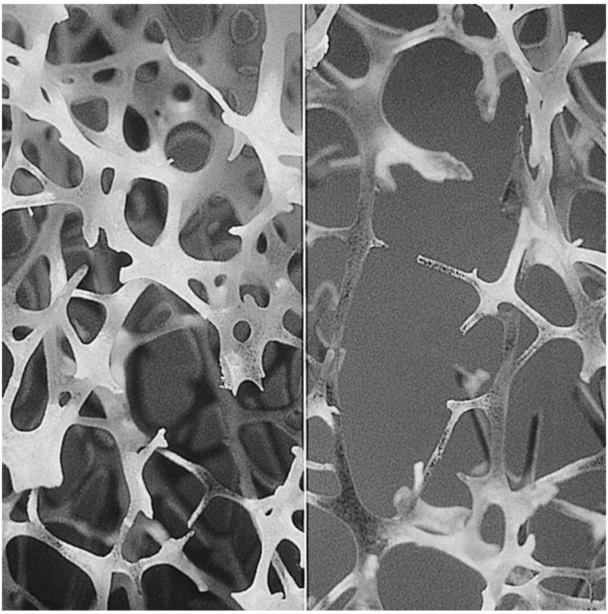
Bone Anatomy and Structure

To optimize bone health through nutrition, it is important to understand bone anatomy. The skeleton is composed of two main parts, the axial and the appendicular parts. The **axial skeleton** consists of the skull, vertebral column, and rib cage, and is composed of eighty bones. The **appendicular skeleton** consists of the shoulder girdle, pelvic girdle, and upper and lower extremities, and is composed of 126 bones.

Bones are also categorized by size and shape. There are four types of bone: long bones, short bones, flat bones, and irregular bones. The longest bone in your body is the femur (thigh bone), which extends from your hip to your knee. It is a long bone and functions to support your weight as you stand, walk, or run. Your wrist is composed of eight irregular-shaped bones, which allow for the intricate movements of your hands. Your twelve ribs on each side of your body are curved flat bones that protect your heart and lungs. Thus, the bones' different sizes and shapes allow for their different functions.

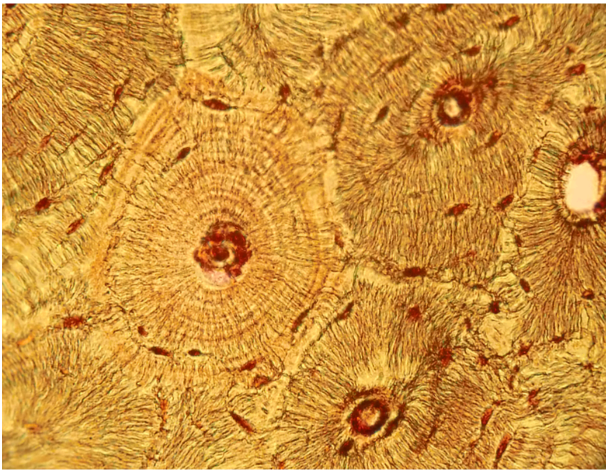
Bones are composed of approximately 65 percent inorganic material known as mineralized matrix. This mineralized matrix consists of mostly crystallized hydroxyapatite. The bone's hard crystal matrix of bone tissue gives it its rigid structure. The other 35 percent of bone is organic material, most of which is the fibrous protein collagen. The collagen fibers are networked throughout bone tissue and provide it with flexibility and strength. The bones' inorganic and organic materials are structured into two different tissue types. There is spongy bone, also called trabecular or cancellous bone, and compact bone, also called cortical bone (Figure 2.1.9.2 "The Arrangement of Bone Tissues"). The two tissue types differ in their microarchitecture and porosity. Trabecular bone is 50 to 90 percent porous and appears as a lattice-like structure under the microscope. It is found at the ends of long bones, in the cores of vertebrae, and in the pelvis. Trabecular bone tissue makes up about 20 percent of the adult skeleton. The more dense cortical bone is about 10 percent porous and it looks like many concentric circles, similar to the rings in a tree trunk, sandwiched together (Figure 2.1.9.3 "Cortical (Compact) Bone"). Cortical bone tissue makes up approximately 80 percent of the adult skeleton. It surrounds all trabecular tissue and is the only bone tissue in the shafts of long bones.

Figure 2.1.9.2 *The Arrangement of Bone Tissues*



The two basic tissue types of bones are trabecular and cortical. This photo shows normal (left) and degraded (right) trabecular (spongy) bone. Source: image by Gtirouflet / CC BY-SA 3.0

Figure 2.1.9.3 *Cortical (Compact) Bone*



Source: "Compact Bone with osteons" by [Lord of Konrad](#) / [CC0](#)

Bone tissue is arranged in an organized manner. A thin membrane, called the periosteum, surrounds the bone. It contains connective tissue with many blood vessels and nerves. Lying below the periosteum is the cortical bone. In some bones, the cortical bone surrounds the less-dense trabecular bone and the bone marrow lies within the trabecular bone, but not all bones contain trabecular tissue or marrow.

Bone Tissues and Cells

Bone tissue contains many different cell types that constantly resize and reshape bones throughout growth and adulthood. Bone tissue cells include osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes. The osteoprogenitor cells are cells that have not matured yet. Once they are stimulated, some will become osteoblasts, the bone builders, and others will become osteoclasts, the cells that break bone down. **Osteoblasts** are bone builders, and **osteoclasts** are cells that break bone down. **Osteocytes** are the most abundant cells in bone tissue. Osteocytes are star-shaped cells that are networked throughout the bone via their long cytoplasmic arms that allow for the exchange of nutrients and other factors from bones to the blood and lymph.

Bone Modeling and Remodeling

During infancy, childhood, and adolescence, bones are continuously growing and changing shape through two processes called **growth (ossification)** and **modeling.** In fact, in the first year of life, almost 100 percent of the bone tissue in the skeleton is replaced. In the process of modeling, bone tissue is dismantled at one site and built up at a different site. In adulthood, our bones stop growing and modeling, but continue to go through a process of bone **remodeling**. In the process of remodeling, bone tissue is degraded and built up at the same location. About 10 percent of bone tissue is remodeled each year in adults. Bones adapt their structure to the forces acting upon them, even in adulthood. This phenomenon is called Wolff's law, which states that bones will develop a structure that is best able to resist the forces acting upon them. This is why exercising, especially when it involves weight-bearing activities, increases bone strength.

The first step in bone remodeling is osteocyte activation. Osteocytes detect changes in mechanical forces, calcium homeostasis, or hormone levels. In the second step, osteoclasts are recruited to the site of the degradation. Osteoclasts are large cells with a highly irregular ruffled membrane. These cells fuse tightly to the bone and secrete hydrogen ions, which acidify the local environment and dissolve the minerals in the bone tissue matrix. This process is called bone resorption and resembles pit excavation. Our bodies excavate pits in our bone tissue because bones act as storehouses for calcium and other minerals. Bones supply these minerals to other body tissues as the demand arises. Bone tissue also remodels when it breaks so that it can repair itself. Moreover, if you decide to train to run a marathon your bones will restructure themselves by remodeling to be better able to sustain the forces of their new function.

After a certain amount of bone is excavated, the osteoclasts begin to die and bone resorption stops. In the third step of bone remodeling, the site is prepared for building. In this stage, sugars and proteins accumulate along the bone's surface, forming a cement line which acts to form a strong bond between the old bone and the new bone that will be made. These first three steps take approximately two to three weeks to complete. In the last step of bone remodeling, osteoblasts lay down new osteoid tissue that fills up the cavities that were excavated during the resorption process. Osteoid is bone matrix tissue that is composed of proteins such as collagen and is not mineralized yet. To make collagen, vitamin C is required.

A symptom of vitamin C deficiency (known as scurvy) is bone pain, which is caused by diminished bone remodeling. After the osteoid tissue is built up, the bone tissue begins to mineralize.

The last step of bone remodeling continues for months, and for a much longer time afterward the mineralized bone is continuously packed in a more dense fashion.

Thus, we can say that bone is a living tissue that continually adapts itself to mechanical stress through the process of remodeling. For bone tissue to remodel certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K are required.

Bone Mineral Density Is an Indicator of Bone Health

Bone mineral density (BMD) is a measurement of the amount of calcified tissue in grams per centimeter squared of bone tissue. BMD can be thought of as the total amount of bone mass in a defined area. When BMD is high, bone strength will be great. Similar to measuring blood pressure to predict the risk of stroke, a BMD measurement can help predict the risk of bone fracture. The most common tool used to measure BMD is called dual energy X-ray absorptiometry (DEXA). During this procedure, a person lies on their back and a DEXA scanner passes two X-ray beams through their body. The amount of X-ray energy that passes through the bone is measured for both beams. The total amount of the X-ray energy that passes through a person varies depending on their bone thickness. Using this information and a defined area of bone, the amount of calcified tissue in grams per unit area (cm_2) is calculated. Most often the DEXA scan focuses on measuring BMD in the hip and the spine. These measurements are then used as indicators of overall bone strength and health. DEXA is the cheapest and most accurate way to measure BMD. It also uses the lowest dose of radiation. People at risk for developing bone disease are advised to have a DEXA scan.

2.1.10. The Immune System

The immune system comprises several types of white blood cells that circulate in the blood and lymph. Their jobs are to seek, recruit, attack, and destroy foreign invaders, such as bacteria and viruses. Other less realized components of the immune system are the **skin** (which acts as a barricade), **mucus** (which traps and entangles microorganisms), and even the **bacteria in the large intestine** (which prevent the colonization of bad bacteria in the gut).

Immune system functions are completely dependent on dietary nutrients. In fact, malnutrition is the leading cause of immune-system deficiency worldwide. When immune system functions are inadequate there is a marked increase in the chance of getting an infection. Children in many poor, developing countries have protein- and/or energy-deficient diets that are causative of two different syndromes, kwashiorkor and marasmus. These children often die from infections that their bodies would normally have fought off, but because their protein and/or energy intake is so low, the immune system cannot perform its functions.

Other nutrients, such as iron, zinc, selenium, copper, folate, and vitamins A, B6, C, D, and E, all provide benefits to immune system function. Deficiencies in these nutrients can cause an increased risk for infection and death. Zinc deficiency results in suppression of the immune system's barrier functions by damaging skin cells; it is also associated with a decrease in the number of circulating white blood cells. A review of several studies in the journal Pediatrics concluded that zinc supplements administered to children under age five for longer than three months significantly reduces the incidence and severity of diarrhea and respiratory illnesses.[1]

1. Aggarwal R, Sentz J, Miller MA. Role of Zinc Administration in Prevention of Childhood Diarrhea and

Zinc supplementation also has been found to be therapeutically beneficial for the treatment of leprosy, tuberculosis, pneumonia, and the common cold. Equally important to remember is that **multiple studies show that it is best to obtain your minerals and vitamins from eating a variety of healthy foods**.

Just as undernutrition compromises immune system health, so does overnutrition. People who are obese are at increased risk for developing immune system disorders such as asthma, rheumatoid arthritis, and some cancers. **Both the quality and quantity of fat intake affect immune system function**. High intakes of saturated and trans fats negatively affect the immune system, whereas increasing your intake of omega-3 fatty acids, found in salmon and other oily fish, decreases inflammatory responses. High intakes of omega-3 fatty acids are linked to a reduction in the risk of developing certain autoimmune disorders, such as rheumatoid arthritis, and are used as part of a comprehensive treatment for rheumatoid arthritis.

Respiratory Illnesses: A Meta-Analysis. Pediatrics. 2007; 119(6), 1120–30. https://www.ncbi.nlm.nih.gov/pubmed/17545379. Accessed September 22, 2017.

2.1.11. Test Your Knowledge

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2.2. WEIGHT MANAGEMENT BASICS

“Weight Management Basics” is an adaptation of the chapter “Weight Management” from *Concepts of Fitness and Wellness*, by Scott Flynn, Lisa Jellum, Althea Moser, Jonathan Howard, Sharryse Henderson, Christin Collins, Amanda West, and David Mathis, and the chapter “Indicators of Health: Body Mass Index, Body Fat Content, and Fat Distribution” from *Human Nutrition*, by the University of Hawaiʻi at Mānoa Food Science and Human Nutrition Program. Both are licensed under a CC BY 4.0 license. New material has been incorporated that includes Canadian guidelines. Information that is not relevant to this course has been removed.

2.2.1. Caloric Balance

Weight Management

The majority of North Americans are unhappy with their current weight. Almost everyone would like to lose at least 5 pounds. A growing percentage of North Americans are carrying enough excess weight to put them at risk for many diseases and even death. Few people, however, know enough about their own bodies to successfully manage their weight. Anyone planning to start a weight loss program should begin by carefully considering the following factors:

- How many calories are being consumed daily?
- How many calories are being expended?
- How much fluids are being consumed?
- How well are electrolytes being managed?

Weight Management Through Diet

The more people know about their diet, the better equipped they will be to manage their weight. Most people focus on the number of calories consumed. However, it is also important for them to know how many macronutrients are in the foods they eat. An effective way to do this is performing a 3-day nutritional intake analysis. These analyses are best done on consecutive days to account for the habitual ebb and flow of one's daily food intake.

Remaining healthy during any weight loss program is paramount. Fad diets that promise quick results do not consider the effects of rapid weight loss on the body. Restricting weight loss to 1 to 2 pounds a week is a healthier and more effective approach. Slow weight loss also prevents the body from burning lean muscle since the body can only burn a certain amount of fat in a week. Dieters who experience slow, steady declines in weight are more likely to keep the weight off. The term "diet" is often synonymous with strict routines that require drastic changes in one's eating habits. In reality, the term "diet" simply describes the intake of food. Overall the focus should move away from "dieting" towards implementing health, lasting lifestyle changes.

To lose weight, individuals need a clear understanding of how weight loss occurs. One pound of fat loss is going to require a reduction in caloric intake of 3,500 calories. When viewed in terms of daily food intake, to lose a pound a week, an individual needs to reduce their daily food intake by 500 calories a day: 3,500 calories/7 days= 500 calories per day. To successfully lose 2 pounds per week, that reduction would have to be doubled to 1,000 calories per day. (1 kg per week=1,100 calories/day, 2 kg per week=2,200 calories/ day) Attempting to lose 2 pounds or more per week would require a calorie reduction too drastic to be maintained and too restrictive to be healthy. Thus the recommendation of combining diet and exercise is the most effective method for experiencing weight loss. Subtracting 500 calories of food intake and exerting 500 calories in exercise will provide that same 1000 calorie reduction, but in a manner that is far easier to maintain, certainly more enjoyable, and adds numerous physical and psychological benefits associated with regular exercise.

No matter what your weight loss goal is, even a modest weight loss, such as 5 to 10 percent of your total body weight, has been shown to produce health benefits, such as improvements in blood pressure, blood cholesterol, and blood sugars.

Getting Started with Weight Loss

The Centers for Disease Control and Prevention (CDC) recommends following the step-by-step guide published on its website, on this page: Healthy Weight: Losing Weight. This information is consistent with recommended behaviour change techniques and is reprinted below:

Step 1: Make a commitment. Start simply by making a commitment to yourself. Many people find it helpful to sign a written contract committing to the process and outlining desired outcomes. This contract may include things like the amount of weight you want to lose, the date you would like to lose the weight by, the dietary changes you will make to establish healthy eating habits, and a plan for increasing regular physical activity.

Writing down the reasons why you want to lose weight can also help. It might be because you have a family history of heart disease, or because you want to see your kids get married, or simply because you want to feel better in your clothes. Post these reasons where they serve as a daily reminder of why you want to make this change.

Step 2: Take stock of where you are. Consider talking to your health care provider. They can evaluate your height, weight, and explore other weight-related risk factors you may have. Ask for a follow-up appointment to monitor changes in your weight or any related health conditions.

Keep a "food diary" for a few days, in which you write down everything you eat. By doing this, you become more aware of what you are eating and when you are eating. This awareness can help you avoid mindless eating.

Next, examine your current lifestyle. Identify things that might pose challenges to your weight loss efforts. For example, does your work or travel schedule make it difficult to get enough physical activity? Do you find yourself eating sugary foods because that is what you buy for your kids? Do your coworkers frequently bring high- calorie items, such as doughnuts, to the workplace to share with everyone? Think through things you can do to help overcome these challenges.

Finally, think about aspects of your lifestyle that can help you lose weight. For example, is there an area near your workplace where you and some coworkers can take a walk at lunchtime? Is there a place in your community, such as a YMCA, with exercise facilities for you and child care for your kids?

Step 3: Set realistic goals. Set some short-term goals and reward your efforts along the way. If your long-term goal is to lose 40 pounds and to control your high blood pressure, some short-term eating and physical activity goals might be to start eating breakfast, taking a 15-minute walk in the evenings, or having a salad or vegetable with supper.

Focus on two or three goals at a time. Great, effective goals are S.M.A.R.T.:

- **S**: specific
- **M:** measurable
- **A:** attainable
- **R:** relevant
- **T:** timely

For example, “Exercise more” is not a specific goal. But if you say, “I will walk 15 minutes, 3 days a week for the first week,” you are setting a specific and realistic goal for the first week.

Remember, small changes every day can lead to big results in the long run. Also, remember that realistic goals are achievable goals. By achieving your short- term goals day by day and week by week, you will feel good about your progress and be motivated to continue. Setting unrealistic goals, such as losing 20 pounds in 2 weeks, can leave you feeling defeated and frustrated.

Being realistic also means expecting occasional setbacks. Setbacks happen when you get away from your plan for whatever reason—maybe the holidays, longer work hours, or another life change. When setbacks happen, don't waste energy dwelling on them – get back on track as quickly as possible. Also, take some time to think about what you would do differently if a similar situation happens, to prevent setbacks.

Keep in mind everyone is different—what works for someone else might not be right for you. Just because your neighbor lost weight by taking up running, doesn't mean running is the best option for you. Try a variety of activities: walking, swimming, tennis, or group exercise classes, to see what you enjoy most and can fit into your life. These activities will be easier to stick with over the long term.

Step 4: Identify resources for information and support. Find family members or friends who will support your weight loss efforts. Making lifestyle changes can feel easier when you have others you can talk to and rely on for support. You might have coworkers or neighbors with similar goals, and together you can share healthful recipes and plan group exercise. Joining a weight loss group or visiting a health care professional, such as a registered dietitian, can help.

Step 5: Continually "check in" with yourself to monitor your progress. Revisit the goals you set for yourself in Step 3, and evaluate your progress regularly. If you set a goal to walk each morning but are having trouble fitting it in before work, see if you can shift your work hours or if you can get your walk in at lunchtime or after work. Evaluate which parts of your plan are working well and which ones need tweaking. Then rewrite your goals and plan accordingly.

If you are consistently achieving a particular goal, add a new goal to help you continue on your pathway to success.

Reward yourself for your successes! Recognize when you are meeting your goals and be proud of your progress. Use non- food rewards, such as a bouquet of freshly picked flowers, a sports outing with friends, or a relaxing bath. Rewards help keep you motivated on the path to better health.[1]

The Importance of Physical Activity in Maintaining a Healthy Weight

Consistent with Health Canada guidelines, information from the CDC website "Healthy Weight: Physical Activity for a Health Weight" explains the importance of including physical activity as part of any weight loss program.

Why Is Physical Activity Important?

Regular physical activity is important for good health, and it is especially important if you are trying to lose weight or to maintain a healthy weight.

When losing weight, more physical activity increases the number of calories your body uses for energy or "burns off." The burning of calories through physical activity, combined with reducing the number of calories you eat, creates a "calorie deficit" that results in weight loss. Most weight loss occurs because of decreased caloric intake. However, evidence shows the only way to maintain weight loss is to be engaged in regular physical activity. Most importantly, physical activity reduces risks of cardiovascular disease and diabetes beyond that produced by weight reduction alone.

Physical activity also helps to

1. CDC's step by step guide.https://www.cdc.gov/healthyweight/losing_weight/getting_started.html.

- maintain weight;
- reduce high blood pressure;
- reduce risk for type 2 diabetes, heart attack, stroke, and several forms of cancer;
- reduce arthritis pain and associated disability;
- reduce risk for osteoporosis and falls; and
- improve mood (reduce symptoms of depression and anxiety).

How much physical activity do I need?

When it comes to weight management, people vary greatly in how much physical activity they need. Here are some guidelines to follow:

- **To maintain your weight:** Work your way up to 150 minutes of moderate-intensity aerobic activity, 75 minutes of vigorous-intensity aerobic activity, or an equivalent mix of the two each week. Strong scientific evidence shows that physical activity can help you maintain your weight over time. However, the exact amount of physical activity needed to do this is not clear since it varies greatly from person to person. It is possible that you may need to do more than the equivalent of 150 minutes of moderate-intensity activity a week to maintain your weight.
- **To lose weight and keep it off:** You will need a high amount of physical activity unless you also adjust your diet and reduce the amount of calories you are eating and drinking. Getting to and staying at a healthy weight requires both regular physical activity and a healthy eating plan.

What do moderate and vigorous intensity mean?

Moderate: While performing the physical activity, if your breathing and heart rate is noticeably faster but you can still carry on a conversation, it is probably moderately intense.

Examples include:

- light yard work (raking/bagging leaves or using a lawn mower)
- walking briskly (a 15-minute mile)
- light snow shoveling
- actively playing with children
- biking at a casual pace

Vigorous: If your heart rate is increased substantially, and you are breathing too hard and fast to have a conversation, it is probably vigorously intense.

Examples include the following:[2]

- jogging/running
- swimming laps
- rollerblading/inline skating at a brisk pace
- cross-country skiing.
- most competitive sports (football, basketball, or soccer)
- jumping rope

Table 2.2.1.1 *Common Physical Activities and the Average Calories Expended During Those Activities*

2. CDC's page on physical activity.

Moderate physical activity	Approximate calories/30 min for a 154 lb person[a]	Approximate calories/hr for a 154 lb person[a]
Hiking	185	370
Light gardening/ yard work	165	330
Dancing	165	330
Golf (walking and carrying clubs)	165	330
Bicycling (<10 mph)	145	290
Walking (3.5 mph)	140	280
Weight lifting (general light workout)	110	220
Stretching	90	180
Vigorous physical activity	**Approximate calories/30 min for a 154 lb person[a]**	**Approximate calories/hr for a 154 lb person[a]**
Running/jogging (5 mph)	295	590
Bicycling (>10 mph)	295	590
Swimming (slow freestyle laps)	255	510
Aerobics	240	480
Walking (4.5 mph)	230	460
Heavy yard work (chopping wood)	220	440
Weightlifting (vigorous effort)	220	440
Basketball (vigorous)	220	440

[a]Calories burned per hour will be higher for persons who weigh more than 154 lb (70 kg) and lower for persons who weigh less. *Source:* Adapted from Dietary Guidelines for Americans 2005, page 16, Table 4.

2.2.2. Adjust Your Eating Habits

Keeping the Weight Off

Consistent with Health Canada guidelines, information from the CDC website "Healthy Weight: Improving Your Eating Habits" states that permanent weight loss is a result of making changes to eating habits that become **a long-term part of a healthier lifestyle**.

Reflect, Replace, Reinforce: A Process for Improving Your Eating Habits

1. Create a list of your eating habits. Keeping a food diary for a few days, in which you write down everything you eat and the time of day you ate it, will help you uncover your habits. For example, you might discover that you always seek a sweet snack to get you through the mid- afternoon energy slump. Use this diary to help. It's good to note how you were feeling when you decided to eat, especially if you were eating when not hungry. Were you tired? Stressed out?
2. Highlight the habits on your list that may be leading you to overeat. Common eating habits that can lead to weight gain include the following:

    - eating too fast
    - always cleaning your plate
    - eating when not hungry

- eating while standing up (may lead to eating mindlessly or too quickly)
- always eating dessert
- skipping meals (or maybe just breakfast)

3. Look at the unhealthy eating habits you have highlighted. Be sure you have identified all the triggers that cause you to engage in those habits. Identify a few you would like to work on improving first. Don't forget to pat yourself on the back for the things you are doing right. Maybe you almost always eat fruit for dessert, or you drink low-fat or fat- free milk. These are good habits! Recognizing your successes will help encourage you to make more changes.
4. Create a list of "cues" by reviewing your food diary to become more aware of when and where you are "triggered" to eat for reasons other than hunger. Note how you are typically feeling at those times. Often an environmental "cue," or a particular emotional state, is what encourages eating for non-hunger reasons. Some common triggers for eating when not hungry include the following:

   - opening up the cabinet and seeing your favorite snack food
   - sitting at home watching television
   - feeling stressed before or after a difficult meeting or situation at work
   - coming home after work and having no idea what's for dinner
   - having someone offer you a dish they made "just for you!"
   - walking past a candy dish on the counter
   - sitting in the break room beside the vending machine
   - seeing a plate of doughnuts at the morning staff meeting
   - swinging through your favorite drive-through every morning
   - feeling bored or tired and thinking food might offer a pick-

me-up

Circle the "cues" on your list that you face on a daily or weekly basis. Going home for the Thanksgiving holiday may be a trigger for you to overeat, and eventually, you want to have a plan for as many eating cues as you can. But for now, focus on the ones you face more often.

Ask yourself these questions for each "cue" you have circled:

Is there anything I can do to avoid the cue or situation? This option works best for cues that don't involve others. For example, could you choose a different route to work to avoid stopping at a fast food restaurant on the way? Is there another place in the break room where you can sit so you are not next to the vending machine?

For things I cannot avoid, can I do something differently that would be healthier? Obviously, you cannot avoid all situations that trigger your unhealthy eating habits, like staff meetings at work. In these situations, evaluate your options. Could you suggest or bring healthier snacks or beverages? Could you offer to take notes to distract your attention? Could you sit farther away from the food so it won't be as easy to grab something? Could you plan ahead and eat a healthy snack before the meeting?

5. Replace unhealthy habits with new, healthy ones. For example, in reflecting upon your eating habits, you may realize that you eat too fast when you eat alone. So, make a commitment to share a lunch each week with a colleague, or have a neighbor over for dinner one night a week. Other strategies might include putting your fork down between bites or minimizing other distractions (i.e., watching the news during dinner) that might keep you from paying attention to how quickly—and how much—you are eating.

More ideas to help you replace unhealthy habits[1]

- Eat more slowly. If you eat too quickly, you may "clean your plate" instead of paying attention to whether your hunger is satisfied.
- Eat only when you are truly hungry instead of when you are tired, anxious, or feeling an emotion besides hunger. If you find yourself eating when you are experiencing an emotion besides hunger, such as boredom or anxiety, try to find a non-eating activity to do instead. You may find a quick walk or phone call with a friend helps you feel better.
- Plan meals ahead of time to ensure that you eat a healthy well-balanced meal.
- Reinforce your new, healthy habits and be patient with yourself. Habits take time to develop. It doesn't happen overnight. When you do find yourself engaging in an unhealthy habit, stop as quickly as possible and ask yourself: Why do I do this? When did I start doing this? What changes do I need to make?
- Be careful not to berate yourself or think that one mistake "blows" a whole day's worth of healthy habits. You can do it! It just takes one day at a time!

1. Improving your eating habits. Centre for disease control. https://www.cdc.gov/healthyweight/losing_weight/eating_habits.html. August 17, 2020. Accessed on: August 31, 2021.

2.2.3. Body Composition and Health

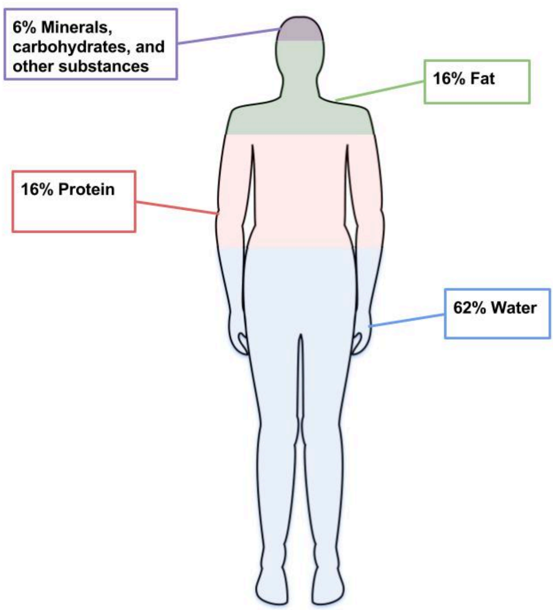
Body Composition

Although the terms overweight and obese are often used interchangeably and considered as gradations of the same thing, they denote different things. The major physical factors contributing to body weight are water weight, muscle tissue mass, bone tissue mass, and fat tissue mass. Overweight refers to having more weight than normal for a particular height and may be the result of water weight, muscle weight, or fat mass. Obese refers specifically to having excess body fat. In most cases people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population.

The "ideal" healthy body weight for a particular person is dependent on many things, such as frame size, sex, muscle mass, bone density, age, and height. The perception of the "ideal" body weight is additionally dependent on cultural factors and the mainstream societal advertisement of beauty.

To standardize the "ideal" body weight and relate it to health, scientists have devised mathematical formulas to better define a healthy weight. These mathematically derived measurements are used by health professionals to correlate disease risk with populations of people and at the individual level. A clinician will take two measurements, one of weight and one of fat mass, in order to diagnose obesity. Some measurements of weight and body fat that do not require using technical equipment can easily be calculated and help provide an individual with information on weight, fat mass, and distribution, and their relative risk of some chronic diseases.

Figure 2.2.3.1 *Body Composition*



The human body is made up of water, protein, fat, minerals, carbohydrates, and other substances. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Body Mass Index: How to Measure It and Its Limitations

Body mass index (BMI) is calculated using height and weight measurements and is more predictive of body fatness than weight alone. BMI measurements are used to indicate whether an individual may be underweight (with a BMI less than 18.5), overweight (with a BMI over 25), or obese (with a BMI over 30). High BMI measurements can be warning signs of health hazards ahead, such as cardiovascular disease, Type 2 diabetes, and other chronic diseases. BMI-associated health risks vary by race. Asians face greater health risks for the same BMI than Caucasians, and

Caucasians face greater health risks for the same BMI than African Americans.

Calculating BMI

To calculate your BMI, multiply your weight in pounds by 703 (conversion factor for converting to metric units) and then divide the product by your height in inches, squared.

BMI = [weight (lb) x 703] / height $(in)^2$

or

BMI = [weight (kg)] / height $(m)^2$

More Ways to Calculate

The National Heart, Lung, and Blood Institute and the CDC have automatic BMI calculators on their websites:

- https://www.nhlbisupport.com/bmi/
- https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html

To see how your BMI indicates the weight category you are in, see Table 2.2.3.1 "BMI Categories" or use a chart of weight and height to figure out your BMI.

Table 2.2.3.1 *BMI Categories*

Categories	BMI (kg/m^2)
Underweight	< 18.5
Normal weight	18.5–24.9
Overweight	25–29.9
Obese	> 30.0

Source: National Heart, Lung, and Blood Institute. Accessed November 4, 2012. https://www.nhlbi.nih.gov.

BMI Limitations

A BMI is a fairly simple measurement and does not take into account fat mass or fat distribution in the body, both of which are additional predictors of disease risk. Body fat weighs less than muscle mass. Therefore, BMI can sometimes underestimate the amount of body fat in overweight or obese people and overestimate it in more muscular people. For instance, a muscular athlete will have more muscle mass (which is heavier than fat mass) than a sedentary individual of the same height. Based on their BMIs the muscular athlete would be less "ideal" and may be categorized as more overweight or obese than the sedentary individual; however this is an infrequent problem with BMI calculation. Additionally, an older person with osteoporosis (decreased bone mass) will have a lower BMI than an older person of the same height without osteoporosis, even though the person with osteoporosis may have more fat mass. **BMI is a useful inexpensive tool to categorize people and is highly correlative with disease risk, but other measurements are needed to diagnose obesity and more accurately assess disease risk.**

Body Fat and Its Distribution

Next we will discuss how to measure body fat, and why distribution of body fat is also important to consider when determining health.

Measuring Body Fat Content

Water, organs, bone tissue, fat, and muscle tissue make up a person's weight. Having more fat mass may be indicative of disease risk, but fat mass also varies with sex, age, and physical activity level. Females have more fat mass, which is needed for reproduction and, in part, is a consequence of different levels of hormones. The optimal fat content of a female is between 20 and 30 percent of her total weight and for a male is between 12 and 20 percent. Fat mass can be measured in a variety of ways. The simplest and lowest-cost way is the skin-fold test. A health professional uses a caliper to measure the thickness of skin on the back, arm, and other parts of the body and compares it to standards to assess body fatness. It is a noninvasive and fairly accurate method of measuring fat mass, but similar to BMI, is compared to standards of mostly young to middle-aged adults.

Other methods of measuring fat mass are more expensive and more technically challenging. They include the following:

- **underwater weighing:** This technique requires a chamber full of water big enough for the whole body to fit in. First, a person is weighed outside the chamber and then weighed again while immersed in water. Bone and muscle weigh more than water, but fat does not—therefore a person with a higher muscle and bone mass will weigh more when in water than a person with less bone and muscle mass.
- **bioelectric Impedance Analysis (BIA)**: This device is based on

the fact that fat slows down the passage of electricity through the body. When a small amount of electricity is passed through the body, the rate at which it travels is used to determine body composition. These devices are also sold for home use and commonly called body composition scales.

- **dual-energy X-ray absorptiometry (DEXA)**: This can be used to measure bone density. It also can determine fat content via the same method, which directs two low-dose X-ray beams through the body and determines the amount of the energy absorbed from the beams. The amount of energy absorbed is dependent on the body's content of bone, lean tissue mass, and fat mass. Using standard mathematical formulas, fat content can be accurately estimated.

Figure 2.2.3.3 BIA *Hand Device*

Bioelectrical impedance analysis (BIA) *being conducted on a participant.* Source: *image by* [United States Marine Corps](#) / [Public Domain](#)

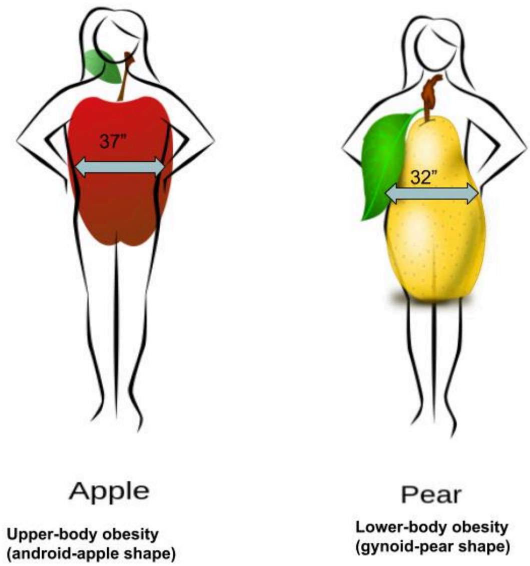
Figure 2.2.3.4 *Dual-Energy X-Ray Absorptiometry* (DEXA)

Source: "A Dual-energy X-ray absorptiometry (DEXA) scan" by Nick Smith / CC BY-SA 3.0

Measuring Fat Distribution

Total body-fat mass is one predictor of health; another is how the fat is distributed in the body. You may have heard that fat on the hips is better than fat in the belly—this is true. Fat can be found in different areas in the body and it does not all act the same, meaning it differs physiologically based on location. Fat deposited in the abdominal cavity is called visceral fat and it is a better predictor of disease risk than total fat mass. **Visceral fat releases hormones and inflammatory factors that contribute to disease risk**. The only tool required for measuring visceral fat is a measuring tape. The measurement (of waist circumference) is taken just above the belly button. Men with a waist circumference greater than 40 inches and women with a waist circumference greater than 35 inches are predicted to face greater health risks.

Figure 2.2.3.5 *Fat Distribution*



Shapes of body composition for upper body and lower body obesity. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

The waist-to-hip ratio is often considered a better measurement than waist circumference alone in predicting disease risk. To calculate your waist-to-hip ratio, use a measuring tape to measure your waist circumference and then measure your hip circumference at its widest part. Next, divide the waist circumference by the hip circumference to arrive at the waist-to-hip ratio. Observational studies have demonstrated that people with "apple-shaped" bodies, (who carry more weight around the waist) have greater risks for chronic disease than those with "pear-shaped" bodies, (who carry more weight around the hips). A study published in the November 2005 issue of Lancet with more than twenty-seven thousand participants from fifty-two countries concluded that the waist-to-hip ratio is highly correlated with heart attack risk worldwide and is a better predictor of heart attacks than BMI.[1] Abdominal obesity is defined by the World Health Organization (WHO) as having a waist-to-hip ratio above 0.90 for males and above 0.85 for females. Health Canada uses waist circumference to indicate increased disease risk. Disease risk is increased in women with a waist circumference greater than 88cm and in men with a waist circumference greater than 102cm.

1. Yusuf S, Hawken S, et al. Obesity and the Risk of Myocardial Infarction in 27,000 Participants from 52 Countries: A Case-Control Study. Lancet. 2005; 366(9497), 1640–9. http://www.ncbi.nlm.nih.gov/pubmed/16271645 ?dopt=AbstractPlus. Accessed September 22, 2017.

2.2.4. Test Your Knowledge

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2.3. ENERGY AND BODY WEIGHT

“Energy and Body Weight” is an adaptation of the chapter “Energy” from *Human Nutrition*, by the University of Hawai‘i at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. New material has been incorporated that includes Canadian content and further explanations of adaptive thermogenesis and food advertising. Information that is not relevant to this course has been removed.

2.3.1. Energy Overview

Introduction

Energy is essential to life. Normal function of the human body requires a constant input and output of energy to maintain life. Various chemical components of food provide the input of energy to the body. The chemical breakdown of those chemicals provides the energy needed to carry out thousands of body functions that allow the body to perform daily functions and tasks such as breathing, walking up a flight of steps, and studying for a test.

Energy is classified as either **potential** or **kinetic**. Potential energy is stored energy, or energy waiting to happen. Kinetic energy is energy in motion. To illustrate this, think of an Olympic swimmer standing at the pool's edge awaiting the sound of the whistle to begin the race. While he waits for the signal, they have potential energy. When the whistle sounds and they dive into the pool and begins to swim, their energy is kinetic (in motion).

In food and in components of the human body, potential energy resides in the chemical bonds of specific molecules such as carbohydrates, fats, proteins, and alcohol. This **potential energy is converted into kinetic energy in the body that drives many body functions ranging from muscle and nerve function to driving the synthesis of body protein for growth. After potential energy is released to provide kinetic energy, it ultimately becomes thermal energy or heat.** You can notice this when you exercise and your body heats up.

The Calorie Is a Unit of Energy

The amount of energy in nutrients or the amount of energy expended by the body can be quantified with a variety of units used to measure energy.

The kilocalorie (kcal) is most commonly used and is often just referred to as a calorie. Strictly speaking, a kcal is 1000 calories. In nutrition, the term calories almost always refers to kcals. Sometimes the kcal is indicated by capitalizing calories as "Calories." **A kilocalorie is the amount of energy in the form of heat that is required to heat one kilogram of water one degree Celsius.**

Most other countries use the kilojoule (kJ) as their standard unit of energy. The Joule is a measure of energy based on work accomplished – the energy needed to produce a specific amount of force. Since calories and Joules are both measures of energy, one can be converted to the other – 1 kcal = 4.18 kJ.

Estimating Caloric Content

The energy contained in energy-yielding nutrients differs because the energy-yielding nutrients are composed of different types of chemical bonds. The carbohydrate or protein in a food yields approximately 4 kilocalories per gram, whereas the triglycerides that compose the fat in a food yield 9 kilocalories per gram. (A kilocalorie of energy performs one thousand times more work than a calorie. On the Nutrition Facts panel found on packaged food, the calories listed for a particular food are actually kilocalories).

Estimating the number of calories in commercially prepared food is fairly easy since the total number of calories in a serving of a particular food is listed on the Nutrition Facts panel. If you wanted to know the number of calories in the breakfast you consumed this morning just add up the number of calories in each food. For example, if you ate one serving of yogurt that contained 150 calories, on which you sprinkled half of a cup of low-fat granola cereal that contained 209 calories, and drank a glass of orange juice that contained 100 calories, the total number of calories you consumed at breakfast is 150 + 209 + 100 = 459 calories.

Nutrient and Energy Flow

Plants harvest energy from the sun and capture it in the molecule glucose. Humans harvest the energy in glucose and capture it into the molecule ATP.

Food Quality

One measurement of food quality is the amount of nutrients it contains relative to the amount of energy it provides. High-quality foods are **nutrient dense, meaning they contain lots of nutrients relative to the amount of calories they provide**. Nutrient-dense foods are the opposite of "**empty-calorie" foods such as carbonated sugary soft drinks, which provide many calories and very little, if any, other nutrients**. Food quality is additionally associated with its taste, texture, appearance, microbial content, and how much consumers like it.

Metabolism Overview

Metabolism is defined as the sum of all chemical reactions required to support cellular function and hence the life of an

organism. Metabolism is either categorized as **catabolism**, referring to all metabolic processes involved in molecule breakdown, or **anabolism**, which includes all metabolic processes involved in building bigger molecules.

Generally, catabolic processes release energy and **anabolic processes consume energy**. **The overall goals of metabolism are energy transfer and matter transport**.

Energy is transformed from food macronutrients into cellular energy, which is used to perform cellular work. Metabolism transforms the matter of macronutrients into substances a cell can use to grow and reproduce and also into waste products. For example, enzymes are proteins and their job is to catalyze chemical reactions. **Catalyze means to speed-up a chemical reaction and reduce the energy required to complete the chemical reaction, without the catalyst being used up in the reaction**. Without enzymes, chemical reactions would not happen at a fast enough rate and would use up too much energy for life to exist.

A metabolic pathway is a series of enzyme catalyzed reactions that transform the starting material (known as a substrate) into intermediates, that are the substrates for subsequent enzymatic reactions in the pathway, until, finally, an end product is synthesized by the last enzymatic reaction in the pathway. Some metabolic pathways are complex and involve many enzymatic reactions, and others involve only a few chemical reactions.

To ensure cellular efficiency, the metabolic pathways involved in catabolism and anabolism are regulated in concert by energy status, hormones, and substrate and end-product levels. The concerted regulation of metabolic pathways prevents cells from inefficiently building a molecule when it is already available. Just as it would be inefficient to build a wall at the same time as it is being broken down, it is not metabolically efficient for a cell to synthesize fatty acids and break them down at the same time.

Catabolism of food molecules begins when food enters the mouth, as the enzyme *salivary amylase*initiates the breakdown of the starch in foods. The entire process of digestion converts the large polymers in food to monomers that can be absorbed. Starches are broken down to monosaccharides, lipids are broken down to fatty acids, and proteins are broken down to amino acids. These monomers are absorbed into the bloodstream either directly, as is the case with monosaccharides and amino acids, or repackaged in intestinal cells for transport by an indirect route through lymphatic vessels, as is the case with most fatty acids and other fat-soluble molecules.

Once absorbed, water-soluble nutrients first travel to the liver which controls their passage into the blood that transports the nutrients to cells throughout the body. The fat-soluble nutrients gradually pass from the lymphatic vessels into blood flowing to body cells. Cells requiring energy or building blocks take up the nutrients from the blood and process them in either catabolic or anabolic pathways. **The organ systems of the body require fuel and building blocks to perform the many functions of the body, such as digesting, absorbing, breathing, pumping blood, transporting nutrients in and wastes out, maintaining body temperature, and making new cells**.

Energy metabolism refers more specifically to the metabolic pathways that release or store energy. Some of these are catabolic pathways, like the splitting of glucose, fatty-acid breakdown, and amino acid catabolism. Others are anabolic pathways, and include those involved in storing excess energy and synthesizing triglycerides.

Catabolism: The Breakdown

All cells are in tune to their energy balance. **When energy levels are high cells build molecules, and when energy levels are low catabolic pathways are initiated to make energy**. Glucose is the preferred energy source by most tissues, but fatty acids and amino acids also can be catabolized to release energy that can drive the formation of ATP. **ATP is a high energy molecule that can drive chemical reactions that require energy**.

Anabolism: The Building

The energy released by catabolic pathways **powers anabolic pathways in the building of macromolecules such as the proteins RNA and DNA, and even entire new cells and tissues**. Anabolic pathways are required to build new tissue, such as muscle, after prolonged exercise or the remodeling of bone tissue, a process involving both catabolic and anabolic pathways. **Anabolic pathways also build energy-storage molecules, such as glycogen and triglycerides.**

Anabolic pathways are regulated by their end-products, but even more so by the energy state of the cell. **When there is ample energy, bigger molecules, such as protein, RNA and DNA, will be built as needed. Alternatively, when energy is insufficient, proteins and other molecules will be destroyed and catabolized to release energy.**

Energy Storage

In contrast, in the "fed" state (when energy levels are high), extra energy from nutrients will be stored. Glucose is stored mainly in muscle and liver tissues. In these tissues it is stored as **glycogen**, a highly branched macromolecule consisting of thousands of glucose molecules held together by chemical bonds. For each molecule of glucose stored, one molecule of ATP is used. Therefore, **it costs energy to store energy**.

Glycogen levels do not take long to reach their physiological limit and when this happens excess glucose will be converted to fat. In response, the rate of catabolism is slowed or shut off and the synthesis of fatty acids is turned on. The newly made fatty acids are transported to fat cells where they are stored as triglycerides. Fat is a better alternative to glycogen for energy storage as it is more compact (per unit of energy) and, unlike glycogen, the body does not store water along with fat. Water weighs a significant amount, and increased glycogen stores, which are accompanied by water, would dramatically increase body weight. **When the body is in positive-energy balance, excess carbohydrates, lipids, and protein can all be metabolized to fat.**

2.3.2. Managing Energy Balance

Weight Management

The health consequences of too much body fat are numerous, including increased risks for cardiovascular disease, Type 2 diabetes, and some cancers.

With obesity at epidemic proportions in North America it is paramount that policies be implemented or reinforced at all levels of society, and include education, agriculture, industry, urban planning, healthcare, and government.

The following are some **main** ideas for constructing an environment that promotes health and confronts the obesity epidemic.

At the individual level:

- Purchase fewer prepared foods and eat more whole foods.
- Decrease portion sizes when eating or serving food.
- Eat out less, and when you do eat out choose low-calorie options.
- Walk or bike to work. If this is not feasible, walk while you are at work.
- Take the stairs when you come upon them or better yet, seek them out.
- Walk your neighborhood and know your surroundings. This benefits both health and safety.
- Watch less television.

At the community level:

- Request that your college/workplace provides more access to healthy low-cost foods.
- Support changes in school lunch programs.
- Participate in cleaning up local green spaces and then enjoy them during your leisure time.
- Patronize local farms and fruit-and-vegetable stands.
- Talk to your grocer and ask for better whole-food choices and seafood at a decent price.
- Ask the restaurants you frequently go to, to serve more nutritious food and to accurately display calories of menu items.

At the national level:

- Support policies that increase the walkability of cities.
- Support national campaigns addressing obesity
- Support policies that support local farmers and the increased access and affordability of healthy food.

Balancing Energy Input With Energy Output

To Maintain Weight, Energy Intake Must Balance Energy Output

Recall that the macronutrients you consume are either converted to energy, stored, or used to synthesize macromolecules. A nutrient's metabolic path is dependent upon energy balance. When you are in a positive energy balance the excess nutrient energy will be stored or used to grow (e.g., during childhood, pregnancy, and wound healing). When you are in negative energy balance you aren't taking in enough energy to meet your needs, so your body will need to use its stores to provide energy. **Energy balance is achieved when intake of energy is equal to energy expended**. **Weight can be thought of as a whole body estimate of energy balance; body weight is maintained when the body is in energy balance, lost when it is in negative energy balance, and gained when it is in positive energy balance.** In general, weight is a good predictor of energy balance, but many other factors play a role in energy intake and energy expenditure. Some of these factors are under your control and others are not. Let us begin with the basics on how to estimate energy intake, energy requirement, and energy output. Then we will consider the other factors that play a role in maintaining energy balance and hence, body weight.

While knowing the number of calories you need each day is useful, it is also pertinent to obtain your calories from nutrient-dense foods and consume the various macronutrients in their Acceptable Macronutrient Distribution Ranges (AMDRs).

Total Energy Expenditure (Output)

The amount of energy you expend every day includes not only the calories you burn during **physical activity**, but also the calories you burn while **at rest** (basal metabolism), and the calories you burn when you **digest food**. The sum of caloric expenditure is referred to as total energy expenditure (TEE).

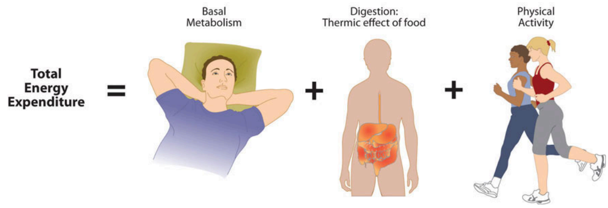
Basal metabolism refers to those metabolic pathways necessary to support and maintain the body's basic functions (e.g. breathing, heartbeat, liver and kidney function) while at rest. The basal metabolic rate (BMR) is the amount of energy required by the body to conduct its basic functions over a certain time period. **The great majority of energy expended (50-70%) daily is from conducting life's basic processes**. Of all the organs, the liver requires the most energy (Table 2.3.2.1 "Energy Breakdown of Organs"). Unfortunately, you cannot tell your liver to ramp up its activity level to expend more energy so you can lose weight. BMR is dependent on body size, body composition, sex, age, nutritional status, and genetics. People with a **larger frame size** have a higher BMR simply because they have more mass. Muscle tissue burns more calories than fat tissue even while at rest and thus the **more muscle mass** a person has, the higher their BMR. Since **females** typically have less muscle mass and a smaller frame size than men, their BMRs are generally lower than men's. As we get **older** muscle mass declines and thus so does BMR. **Nutritional status** also affects basal metabolism. **Caloric restriction**, as occurs while dieting, for example, causes a decline in BMR. This is because the body attempts to maintain homeostasis and will adapt by slowing down its basic functions to offset the decrease in energy intake. **Body temperature** and **thyroid hormone levels** are additional determinants of BMR.

Table 2.3.2.1 *Energy Breakdown of Organs*

Organ	Percent of energy expended
Liver	27
Brain	19
Heart	7
Kidneys	10
Skeletal muscle (at rest)	18
Other organs	19

Note: Different organs use different amounts of energy. The liver has the highest energy consumption and the heart has the lowest. *Source*: FAO/WHO/UNU, 1985. Energy and Protein Requirements. World Health Organization Technical Report Series 724. http://www.fao.org/doCReP/003/aa040e/AA040E00.htm. Updated 1991. Accessed September 17, 2017.

Figure 2.3.2.1 *Total Energy Expenditure*



Total energy expenditure is the sum of energy expended at rest, during digestion, and during physical activity. Source: [Weight Management]

The energy required for all the enzymatic reactions that take place during food digestion and absorption of nutrients is called the "**thermic effect of food**" (TEF) and accounts for about 10% of total energy expended per day.

The other energy required during the day is for physical activity and is referred to as "**non-resting energy expenditure**" (NREE). Depending on lifestyle, the energy required for this ranges between 15-30% of total energy expended. The main control a person has over TEE is to increase physical activity.

Factors Affecting Energy Intake

Physiology

In the last few decades scientific studies have revealed that **how much we eat and what we eat is controlled not only by our own desires, but also is regulated physiologically and influenced by genetics**. The hypothalamus in the brain is the main control point of appetite. It receives hormonal and neural signals, which determine if you feel hungry or full. Hunger is an unpleasant sensation of feeling empty that is communicated to the brain by both mechanical and chemical signals from the periphery. Conversely, satiety is the sensation of feeling full and it also is determined by mechanical and chemical signals relayed from the periphery. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety.

Hunger pangs are real and so is a "growling" stomach. When the stomach is empty it contracts, producing the characteristic pang and "growl." The stomach's mechanical movements relay neural signals to the hypothalamus, which relays other neural signals to parts of the brain. This results in the conscious feeling of the need to eat. Alternatively, after you eat a meal the stomach stretches and sends a neural signal to the brain stimulating the sensation of satiety and relaying the message to stop eating. The stomach also sends out certain hormones when it is full and others when it is empty. These hormones communicate to the hypothalamus and other areas of the brain either to stop eating or to find some food.

Fat tissue also plays a role in regulating food intake. Fat tissue produces the hormone leptin, which communicates to the satiety center in the hypothalamus that the body is in positive energy balance. The discovery of leptin's functions sparked a craze in the research world and the diet pill industry, as it was hypothesized that if you give leptin to a person who is overweight, they will decrease their food intake. Alas, this is not the case. In several clinical trials it was found that people who are overweight or obese are actually resistant to the hormone, meaning their brain does not respond as well to it. [1] Therefore, when you administer leptin to

1. Dardeno TA, Chou, SH, et al. Leptin in Human Physiology and Therapeutics. Front Neuroendocrinol. 2010; 31(3), 377–93. http://www.ncbi.nlm.nih.gov/pmc/articles/

an overweight or obese person there is no sustained effect on food intake.

Nutrients themselves also play a role in influencing food intake. The hypothalamus senses nutrient levels in the blood. When they are low the hunger center is stimulated, and when they are high the satiety center is stimulated. Furthermore, cravings for salty and sweet foods have an underlying physiological basis. Both undernutrition and overnutrition affect hormone levels and the neural circuitry controlling appetite, which makes losing or gaining weight a substantial physiological hurdle.

Furthermore, there is extensive evidence showing that the body's physiological systems fight weight loss to favour weight gain. From an evolutionary standpoint this makes sense, as in times of famine, weight loss would be life threatening. Therefore the body has adapted to prevent weight loss. The set-point-theory states that each individual has a set weight that their body has become accustomed to living at. Any threat to decrease this weight will result in the body to adapt its functions to reduce energy expenditure. Unfortunately, this adaptation does not work in the other direction and our body openly accepts excess calories and resulting weight gain. This effect is called **adaptive thermogenesis** and is defined as the greater than predicted reduction in energy expenditure following weight loss. Adaptive thermogenesis is part of the reason why it is so hard for the majority of individuals to maintain any weight loss that they have achieved.

Genetic Influences

Genetics certainly play a role in body fatness and weight and also

PMC2916735/?tool=pubmed. Accessed September 22, 2017.

affects food intake. Children who have been adopted typically are similar in weight and body fatness to their biological parents. Moreover, identical twins are twice as likely to be of similar weights as compared to fraternal twins. The scientific search for obesity genes is ongoing and a few have been identified, such as the gene that encodes for leptin. However, overweight and obesity that manifests in millions of people is not likely to be attributed to one or even a few genes, but the interactions of hundreds of genes with the environment. In fact, when an individual has a mutated version of the gene coding for leptin, they are obese, but only a few dozen people around the world have been identified as having a completely defective leptin gene. **Even though genetics can influence weight, having an "obesity gene" does not destine you to be overweight.** Obesity genes simply increase you risk of developing obesity. With proper nutrition and physical activity a health weight can still be maintained.

Psychological/Behavioural Influences

When your mouth waters in response to the smell of a roasting Thanksgiving turkey and steaming hot pies, you are experiencing a psychological influence on food intake. A person's perception of good-smelling and good-tasting food influences what they eat and how much they eat. Mood and emotions are associated with food intake. Depression, low self-esteem, compulsive disorders, and emotional trauma are sometimes linked with increased food intake and obesity.

Certain behaviours can be predictive of how much a person eats. Some of these are how much food a person heaps onto their plate, how often they snack on calorie-dense, salty foods, how often they watch television or sit at a computer, and how often they eat out. A study published in a 2008 issue of Obesity looked at characteristics of Chinese buffet patrons. The study found that those who chose to immediately eat before browsing the buffet used larger plates, used a fork rather than chopsticks, chewed less per bite of food, and had higher BMIs than patrons who did not exhibit these behaviours.[2]

Of course many behaviours are reflective of what we have easy access to—a concept we will discuss next.

Societal Influences

It is without a doubt that the North American society affects what and how much we eat. Portion sizes have increased dramatically in the past few decades.

To generalize, most fast food items have little nutritional merit as they are highly processed and rich in saturated fat, salt, and added sugars. The fast food business is likely to continue to grow in North America (and the rest of the world) and greatly affect the diets of whole populations. Because it is unrealistic to say that North Americans should abruptly quit eating fast food to save their health (because they will not) **society needs to come up with ideas that push nutrient-dense whole foods into the fast food industry**. You may have observed that this largely consumer-driven push is having some effect on the foods the fast food industry serves (just watch a recent Subway commercial, or check the options now available in a McDonald's Happy Meal). Pushing the fast food industry to

2. Levin BE. Developmental Gene X Environment Interactions Affecting Systems Regulating Energy Homeostasis and Obesity. Front Neuroendocrinol. 2010; 3, 270–83. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2903638/?tool=pubmed. Accessed September 22, 2017.

serve healthier foods is a realistic and positive way to improve the American diet.

Currently we are living in the most complex food system of all time. Never have there been so many advertisements to navigate and choices to be made. Knowing what is truly healthy for us and what is not is nearly impossible. Certainly education is a large part of making the right choices. However a general rule is to **look for the foods that have the least advertising** ie. an apple compared to an apple juice. You will never see an advertisement for an apple because there is a lack of industry behind it. However, the apple juice which has been processed and likely loaded with excess sugar comes from a company looking to make money, therefore there will be health claims and other advertising tricks to get you to buy it. Often it is the quietest foods that are the healthiest for us. Additionally be critical of advertising claims such as "cholesterol free" or "GMO free". These are purposefully placed to entice you to buy this product over others. Sometime foods would have never even contained cholesterol or GMOs to start with.

Tools for Change

Support the consumer movement of pushing the fast food industry and your favorite local restaurants into serving more nutrient-dense foods. You can begin this task by starting simple, such as requesting extra tomatoes and lettuce on your burger and more nutrient-dense choices in the salad bar. Also, choose their low-calorie menu options and help support the emerging market of healthier choices in the fast food industry. In today's fast-paced society, it is difficult for most people to avoid fast food all the time.

When you do need a quick bite on the run, choose the fast food restaurants that serve healthier foods. Also, start asking for caloric contents of foods so that the restaurant becomes more aware that their patrons are being calorie conscious.

Factors Affecting Energy Expenditure

Physiological and Genetic Influences

Why is it so difficult for some people to lose weight and for others to gain weight? **One theory is that every person has a "set point" of energy balance**. This set point can also be called a fat-stat or lipostat, meaning the brain senses body fatness and triggers changes in energy intake or expenditure to maintain body fatness within a target range. Some believe that this theory provides an explanation as to why after dieting, most people return to their original weight not long after stopping the diet. Another theory is referred to as the "settling" point system, which takes into account (more so than the "set-point" theory) the contribution of **an obesity-promoting environment** to weight gain. In this model, the reservoir of body fatness responds to energy intake or energy expenditure, such that if a person is exposed to a greater amount of food, body fatness increases, or if a person watches more television body fatness increases. A major problem with these theories is that they overgeneralize and do not take into account that not all individuals respond in the same way to changes in food intake or energy expenditure. This brings up the importance of the interactions of genes and the environment.

Not all individuals who take a weight-loss drug lose weight and not all people who smoke are thin. An explanation for these discrepancies is that **each individual's genes respond differently to a specific environment**. Alternatively, environmental factors can influence a person's gene profile, which is exemplified by the effects of the prenatal environment on body weight and fatness and disease incidence later in life.[3]

One example is a study of the offspring of women who were overweight during pregnancy had a greater propensity for being overweight and for developing Type 2 diabetes. Thus, undernutrition and overnutrition during pregnancy influence body weight and disease risk for offspring later in life. They do so by adapting energy metabolism to the early nutrient and hormonal environment in the womb.

Psychological/Behavioural Influence

Sedentary behaviour is defined as the participation in the pursuits in which energy expenditure is no more than one-and-one-half times the amount of energy expended while at rest and

3. Matthews CE, Chen KY, et al. Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004. Am J Epidemiol. 2008; 167(7), 875–81. https://www.ncbi.nlm.nih.gov/pubmed/18303006. Accessed September 22, 2017.

include sitting, reclining, or lying down while awake. Of course, the sedentary lifestyle of many North Americans contributes to their average energy expenditure in daily life. Simply put, the more you sit, the less energy you expend. A study published in a 2008 issue of the American Journal of Epidemiology reports that 55 percent of Americans spend 7.7 hours in sedentary behaviour daily.[4]

Fortunately, including only a small amount of low-level physical activity benefits weight control. A study published in the June 2001 issue of the International Journal of Behavioral Nutrition and Physical Activity reports that **even breaking up sitting-time with frequent but brief increased energy expenditure activities, such as walking for five minutes every hour, helps maintain weight and even aids in weight loss**.[5]

North Americans partake in an excessive amount of screen time, which is a sedentary behaviour that not only reduces energy expenditure, but also contributes to weight gain because of the exposure to aggressive advertising campaigns for unhealthy foods.

4. Matthews CE, Chen KY, et al. Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004. Am J Epidemiol. 2008; 167(7), 875–81. https://www.ncbi.nlm.nih.gov/pubmed/18303006. Accessed September 22, 2017.
5. Wu Y. Overweight and Obesity in China. Br Med J. 2006; 333(7564), 362-363. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1550451/. Accessed September 22, 2017.

Societal Influence

Many societal factors influence the number of calories burned in a day. **Escalators, moving walkways, and elevators (not to mention cars!) are common modes of transportation that reduce average daily energy expenditure**. Office work, high-stress jobs, and occupations requiring extended working hours are all societal pressures that reduce the time allotted for exercise. Even the remote controls that many have for various electronic devices in their homes contribute to society being less active.

Socioeconomic status has been found to be inversely proportional to weight gain. One reason for this relationship is that inhabitants of low-income neighborhoods have reduced access to safe streets and parks for walking. Another is that fitness clubs are expensive and few are found in lower-income neighborhoods.

Chronic Diseases

Chronic diseases are ongoing, life-threatening, and life-altering health challenges. They are the leading cause of death worldwide **and are increasing in frequency. They cause significant physical and emotional suffering and are an impediment to economic growth and vitality**. It is important, now more than ever, to understand the different risk factors for chronic disease and to learn how to prevent their development.

The Risk Factors of Chronic Disease

A risk factor is an indicator that your chances for acquiring a chronic disease may be increased. However having or being exposed to a risk factors does not 100% guarantee that the disease will develop. Risk factors therefore correlate to disease development but cannot be said with 100% certainty that they are the sole causation. For example, if a person gets sick with the flu, we can say with certainty that the illness was caused by a virus. Whereas, even though the risk factor of a sedentary lifestyle is highly correlated to the development of cardiovascular disease, we cannot say that this risk factor caused cardiovascular disease because there are several other factors that may have contributed to the development of this disease.

Chronic disease usually develops alongside a combination of the following risk factors:

- genetics
- age
- a prior disease such as obesity or hypertension
- dietary and lifestyle choices
- environmental problems

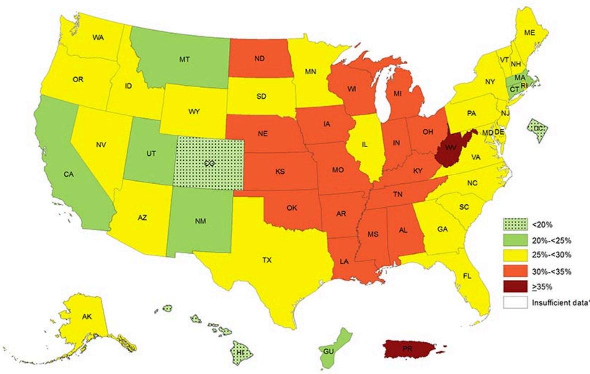
Risk factors such as genetics and age cannot be changed. However, **some risk factors can be altered to promote health and wellness**, such as diet. For example, a person who continuously eats a diet high in sugars, saturated fats, and red meat is at risk for becoming obese and developing Type 2 diabetes, cardiovascular disease, or several other conditions. Making more healthy dietary choices can greatly reduce that risk. Being a woman over age sixty-five is a risk factor for developing osteoporosis, but that cannot be changed. Also, people without a genetic predisposition for a particular chronic illness can still develop it. Not having a genetic predisposition for a chronic disease is not a guarantee of immunity.

Identifying Your Risk Factors

To estimate your own risk factors for developing certain chronic diseases, search through your family's medical history. What diseases do you note showing up among close blood relatives? At your next physical, pay attention to your blood tests and ask the doctor if any results are out of normal range. It is also helpful to note your vital signs, particularly your blood pressure and resting heart rate. In addition, you may wish to keep a food diary to make a note of the dietary choices that you make on a regular basis and be aware of foods that are high in saturated fat, among other unhealthy options. As a general rule, **it is important to look for risk factors that you can modify to promote your health**. For example, if you discover that your grandmother, aunt, and uncle all suffered from high blood pressure, then you may decide to avoid a high sodium diet. Identifying your risk factors can arm you with the information you need to help ward off disease.

Health Risks of Being Overweight and Being Obese

State Map of the Prevalence of Obesity in America



Visit https://www.cdc.gov/obesity/data/prevalence-maps.html to see the prevalence of self-reported obesity among U.S. adults from 2014-2016. Source: [Weight Management]()

As BMIs increase over 25, health **risk increases** for heart disease, Type 2 diabetes, hypertension, endometrial cancer, postmenopausal breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. The WHO reports that **overweight and obesity are the fifth leading cause for deaths globally**, and estimates that more than 2.8 million adults die annually as a result of being overweight or obese.[6] Moreover, **overweight and obesity contribute to 44% of the Type 2 diabetes burden, 23% of the heart disease burden, and between 7 and 41% of the burden of certain cancers**.[7]

Similar to other public health organizations, the WHO states the **main causes of the obesity epidemic worldwide are the increased intake of energy-dense food and decreased level of physical activity that is mainly associated with modernization, industrialization, and urbanization**. The environmental changes that contribute to the dietary and physical activity patterns of the world today are associated with the **lack of policies that address the obesity epidemic**in the food and health industry, urban planning, agriculture, and education sectors.

The Crisis of Obesity

Excessive weight gain has become an epidemic. According to Health Canada, between 2007 and 2017, 34% of Canadians were overweight and 27% of Canadians were had obesity. [8] Obesity in particular puts people at risk for a host of complications, including Type 2 diabetes, heart disease, high cholesterol, hypertension, osteoarthritis, and

6. Obesity and Overweight. World Health Organization. http://www.who.int/mediacentre/factsheets/fs311/en/. Updated June 2016. Accessed September 22, 2017.
7. Obesity and Overweight. World Health Organization. http://www.who.int/mediacentre/factsheets/fs311/en/. Updated June 2016. Accessed September 22, 2017.
8. https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2018033-eng.htm

some forms of cancer. The more overweight a person is, the greater his or her risk of developing life-threatening complications. There is no single cause of obesity and no single way to treat it. However, a healthy, nutritious diet is generally the first step, including consuming more fruits and vegetables, whole grains, and lean meats and dairy products and less processed high sugar and fat foods.[9]

Diabetes

What Is Diabetes?

Diabetes is one of the top three diseases in North America. It affects millions of people and causes tens of thousands of deaths each year. Diabetes is a metabolic disease of insulin deficiency and glucose over-sufficiency. Like other diseases, genetics, nutrition, environment, and lifestyle are all involved in determining a person's risk for developing diabetes. One sure way to decrease your chances of getting diabetes is to maintain an optimal body weight by adhering to a diet that is balanced in carbohydrate, fat, and protein intake. There are three different types of diabetes: Type 1 diabetes, Type 2 diabetes, and gestational diabetes.

9. Overweight and Obesity Statistics.National Institute of Diabetes and Digestive and Kidney Diseases. https://www.niddk.nih.gov/health-information/health-statistics/overweight-obesity. Accessed April 15, 2018.

Type 1 Diabetes

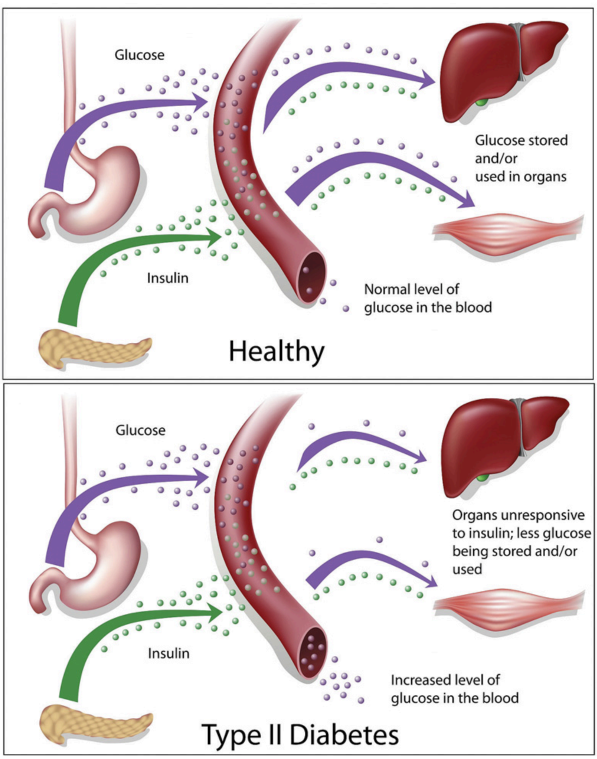
Type 1 diabetes is a metabolic disease in which insulin-secreting cells in the pancreas are killed by an abnormal response of the immune system, causing a lack of insulin in the body. Its onset typically occurs before the age of thirty. The only way to prevent the deadly symptoms of this disease is to inject insulin under the skin.

A person with Type 1 diabetes usually has a rapid onset of symptoms that include hunger, excessive thirst and urination, and rapid weight loss. Because the main function of glucose is to provide energy for the body, when insulin is no longer present there is no message sent to cells to take up glucose from the blood. Instead, cells use fat and proteins to make energy, resulting in weight loss. If Type 1 diabetes goes untreated individuals with the disease will develop a life-threatening condition called ketoacidosis. This condition occurs when the body uses fats and not glucose to make energy, resulting in a build-up of ketone bodies in the blood. It is a severe form of ketosis with symptoms of vomiting, dehydration, rapid breathing, and confusion and eventually coma and death. Upon insulin injection these severe symptoms are treated and death is avoided. Unfortunately, while insulin injection prevents death, it is not considered a cure. People who have this disease must adhere to a strict diet to prevent the development of serious complications. Type 1 diabetics are advised to consume a diet low in the types of carbohydrates that rapidly spike glucose levels (high-Glucose Index (GI) foods), to count the carbohydrates they eat, to consume healthy-carbohydrate foods, and to eat small meals frequently. These guidelines are aimed at preventing large fluctuations in blood glucose. Frequent exercise also helps manage blood-glucose levels. Type 1 diabetes accounts for between 5 and 10 percent of diabetes cases.

Type 2 Diabetes

The other 90 to 95 percent of diabetes cases are Type 2 diabetes. Type 2 diabetes is defined as a metabolic disease of insulin insufficiency, but it is also caused by muscle, liver, and fat cells no longer responding to the insulin in the body (Figure 2.3.2.2 "Healthy Individuals and Type 2 Diabetes"). In brief, **cells in the body have become resistant to insulin and no longer receive the full physiological message of insulin to take up glucose from the blood**. Thus, similar to patients with Type 1 diabetes, those with Type 2 diabetes also have high blood-glucose levels.

Figure 2.3.2.2 *Healthy Individuals and Type 2 Diabetes*



In Type 2 diabetes insulin resistance develops. The liver and muscle no longer react to insulin and as a results blood glucose levels rise. Source: [Weight Management](#)

For Type 2 diabetics, the onset of symptoms is more gradual and less noticeable than for Type 1 diabetics:

1. The first stage of Type 2 diabetes is characterized by high glucose and insulin levels. This is because the insulin-secreting cells in the pancreas attempt to compensate for insulin resistance by making more insulin.
2. In the second stage of Type 2 diabetes, the insulin-secreting cells in the pancreas become exhausted and die. At this point, Type 2 diabetics also have to be treated with insulin injections.

The goal of healthcare providers is to prevent the second stage from happening. As with Type 1 diabetes, chronically high-glucose levels cause big detriments to health over time, so another goal for patients with Type 2 diabetes is to properly manage their blood-glucose levels. The front-line approach for treating Type 2 diabetes includes eating a healthy diet and increasing physical activity.

According to the most recent data, about 3.0 million Canadians (8.1%) were living with diagnosed diabetes in 2013–2014, representing 1 in 300 children and youth (1–19 years), and 1 in 10 adults (20 years and older).[10]Nov 14, 2017.https://www.canada.ca/en/public-health/services/publications/diseases-conditions/diabetes-canada-highlights-chronic-disease-surveillance-system.html

The Centers for Disease Control Prevention (CDC) estimates that as of 2010, 25.8 million Americans have diabetes, which is 8.3 percent of the population.[11] In 2007 the cost of diabetes to the

10. Nov 14, 2017. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/diabetes-canada-highlights-chronic-disease-surveillance-system.html
11. Diabetes Research and Statistics. Centers for Disease

United States was estimated at $174 billion.[12] The incidence of Type 2 diabetes has more than doubled in America in the past thirty years and the rise is partly attributed to the increase in obesity in this country.

Genetics, environment, nutrition, and lifestyle all play a role in determining a person's risk for Type 2 diabetes. We have the power to change some of the determinants of disease but not others. The Diabetes Prevention Trial that studied lifestyle and drug interventions in more than three thousand participants who were at high risk for Type 2 diabetes found that intensive lifestyle intervention reduced the chances of getting Type 2 diabetes by 58 percent.[13]

Gestational Diabetes

During pregnancy some women develop gestational diabetes. Gestational diabetes is characterized by high blood-glucose levels

Control and Prevention. https://www.cdc.gov/diabetes/data/index.html. Updated March 14, 2018. Accessed April 15, 2018.

12. Diabetes Quick Facts. Centers for Disease Control and Prevention. https://www.cdc.gov/diabetes/basics/quick-facts.html. Updated July 24, 2017. Accessed April 15, 2018.
13. Knowler WC. Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin. The New England Journal of Medicine. 2002; 346(6), 393–403. http://www.nejm.org/doi/full/10.1056/NEJMoa012512. Accessed April 15, 2018.

and insulin resistance. The exact cause is not known but does involve the effects of pregnancy hormones on how cells respond to insulin. Gestational diabetes can cause pregnancy complications and it is common practice for healthcare practitioners to screen pregnant women for this metabolic disorder. The disorder normally ceases when the pregnancy is over, but the National Diabetes Information Clearing House notes that women who had gestational diabetes have between a 40 and 60 percent likelihood of developing Type 2 diabetes within the next ten years.[14] Gestational diabetes not only affects the health of a pregnant woman but also is associated with an increased risk of obesity and Type 2 diabetes in her child.

Prediabetes

As the term infers, prediabetes is a metabolic condition in which people have moderately high glucose levels, but do not meet the criteria for diagnosis as a diabetic. Over seventy-nine million Americans are prediabetic and at increased risk for Type 2 diabetes and cardiovascular disease.[15] The National Diabetes Information Clearing House reports that 35 percent of adults aged twenty and

14. Diabetes Overview. National Institute of Diabetes and Digestive and Kidney Disease. https://www.niddk.nih.gov/health-information/diabetes/overview. Accessed April 15, 2018.
15. Diabetes Overview. National Institute of Diabetes and Digestive and Kidney Disease. https://www.niddk.nih.gov/health-information/diabetes/overview. Accessed April 15, 2018.

older, and 50 percent of those over the age of sixty-five have prediabetes.[16]

Long-Term Health Consequences of Diabetes

The long-term health consequences of diabetes are severe. They are the result of chronically high glucose concentrations in the blood accompanied by other metabolic abnormalities such as high blood-lipid levels. People with diabetes are between two and four times more likely to die from cardiovascular disease. Diabetes is the number one cause of new cases of blindness, lower-limb amputations, and kidney failure. Many people with diabetes develop peripheral neuropathy, characterized by muscle weakness, loss of feeling and pain in the lower extremities. More recently, there is scientific evidence to suggest people with diabetes are also at increased risk for Alzheimer's disease.

Diabetes Treatment

Keeping blood-glucose levels in the target range (70–130 mg/dL before a meal) requires careful monitoring of blood-glucose levels with a blood-glucose meter, strict adherence to a healthy diet, and increased physical activity. Type 1 diabetics begin insulin injections as soon as they are diagnosed. Type 2 diabetics may require oral medications and insulin injections to maintain blood-glucose levels

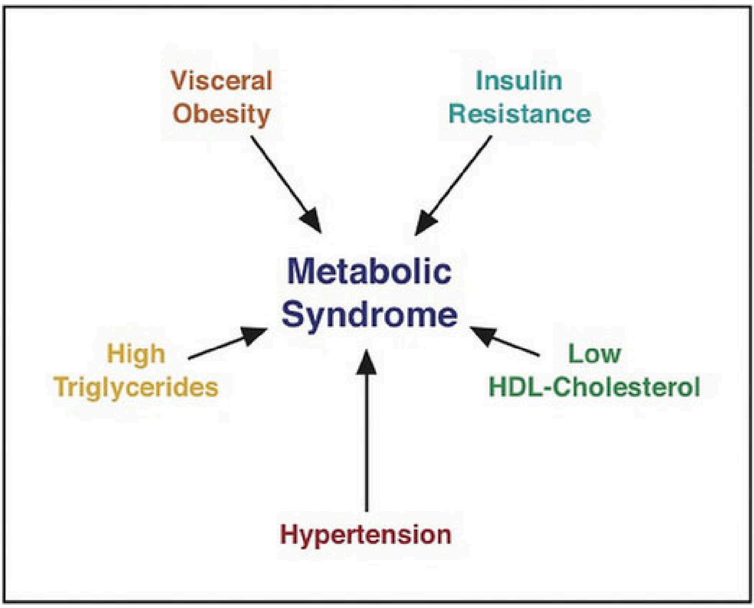
16. Diabetes Overview. National Institute of Diabetes and Digestive and Kidney Disease. https://www.niddk.nih.gov/health-information/diabetes/overview. Accessed April 15, 2018.

in the target range. The symptoms of high blood glucose, also called hyperglycemia, are difficult to recognize, diminish in the course of diabetes, and are mostly not apparent until levels become very high. The symptoms are increased thirst and frequent urination. Having too low blood glucose levels, known as hypoglycemia, is also detrimental to health. Hypoglycemia is more common in Type 1 diabetics and is most often caused by injecting too much insulin or injecting it at the wrong time. The symptoms of hypoglycemia are more acute including shakiness, sweating, nausea, hunger, clamminess, fatigue, confusion, irritability, stupor, seizures, and coma. Hypoglycemia can be rapidly and simply treated by eating foods containing about ten to twenty grams of fast-releasing carbohydrates. If symptoms are severe a person is either treated by emergency care providers with an intravenous solution of glucose or given an injection of glucagon, which mobilizes glucose from glycogen in the liver. Some people who are not diabetic may experience reactive hypoglycemia. This is a condition in which people are sensitive to the intake of sugars, refined starches, and high glucose index foods. Individuals with reactive hypoglycemia have some symptoms of hypoglycemia. Symptoms are caused by a higher than normal increase in blood-insulin levels. This rapidly decreases blood-glucose levels to a level below what is required for proper brain function.

The major determinants of Type 2 diabetes that can be changed are **overnutrition** and a **sedentary lifestyle**. Therefore, reversing or improving these factors by lifestyle interventions markedly improve the overall health of Type 2 diabetics and lower blood-glucose levels. In fact it has been shown that when people are overweight, losing as little as 5% of total body weight (10lb for a 200lb person) decreases blood-glucose levels in Type 2 diabetics. Furthermore, the Diabetes Prevention Trial demonstrated that when individuals at risk for Type 2 diabetes first adhered to a diet containing between 1,200-1,800 kcal/day with a dietary fat intake of <25% and second increase physical activity to at least 150 min/week they achieved an average weight loss of 7% and significantly decreased their chances of developing Type 2 diabetes.[17]

The American Diabetes Association (ADA) has a website that provides information and tips for helping diabetics answer the question, “What Can I Eat”. In regard to carbohydrates the ADA recommends diabetics keep track of the carbohydrates they eat and set a limit. These dietary practices will help keep blood-glucose levels in the target range.

Figure 2.3.2.3 *Metabolic Syndrome*



17. Knowler WC. Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin. The New England Journal of Medicine. 2002; 346(6), 393–403. http://www.nejm.org/doi/full/10.1056/NEJMoa012512. Accessed April 15, 2018.

Source: Weight Management

A Combination of Risk Factors Increases the Chances for Chronic Disease

Having more than one risk factor for Type 2 diabetes substantially increases a person's chances for developing the disease. Metabolic syndrome refers to **a medical condition in which people have three or more risk factors for Type 2 diabetes and cardiovascular disease.** According to the International Diabetes Federation (IDF) people are diagnosed with this syndrome if they have central (abdominal) obesity and any two of the following health parameters: triglycerides greater than 150 mg/dL; high density lipoproteins (HDL) lower than 40 mg/dL; systolic blood pressure above 130mmHg, or diastolic above 85 mmHg; fasting blood-glucose levels greater than 100 mg/dL.[18] The IDF estimates that between 20 and 25 percent of adults worldwide have metabolic syndrome. Studies vary, but people with metabolic syndrome have between a 9 and 30 times greater chance for developing Type 2 diabetes than those who do not have the syndrome.[19]

18. The IDF Consensus Worldwide Definition of the Metabolic Syndrome. International Diabetes Federation.https://www.idf.org/our-activities/advocacy-awareness/resources-and-tools/60:idfconsensus-worldwide-definitionof-the-metabolic-syndrome.html. Accessed April 15, 2018.
19. The IDF Consensus Worldwide Definition of the Metabolic Syndrome. International Diabetes Federation.https://www.idf.org/our-activities/advocacy-awareness/resources-and-tools/

Disease Prevention and Management

Eating fresh, healthy foods not only stimulates your taste buds, but also can improve your quality of life and help you to live longer. As discussed, food fuels your body and helps you to maintain a healthy weight. Nutrition also contributes to longevity and plays an important role in preventing a number of diseases and disorders, from obesity to cardiovascular disease. Some dietary changes can also help to manage certain chronic conditions, including high blood pressure and diabetes. A doctor or a nutritionist can provide guidance to determine the dietary changes needed to ensure and maintain your health.

60:idfconsensus-worldwide-definitionof-the-metabolic-syndrome.html. Accessed April 15, 2018. ?

2.3.3. Weight Management Recommendations

Photo by Igor Ovsyannikov on unsplash.com / CC0

Weight Management

Successful weight loss is defined as individuals intentionally losing at least 10 percent of their body weight and keeping it off for at least one year.[1] Results from lifestyle intervention studies suggest **fewer than 20 percent of participants are successful at weight loss**.

The National Weight Control Registry (NWCR) tracks over ten

1. Wing RR, Hill JO. Successful Weight Loss Maintenance. Annu Rev Nutr. 2001; 21, 323–41. http://www.ncbi.nlm.nih.gov/pubmed/11375440?dopt=Abstract. Accessed September 22, 2017. Wing RR, Hill JO. Successful Weight Loss Maintenance. Annu Rev Nutr. 2001; 21, 323–41. http://www.ncbi.nlm.nih.gov/pubmed/11375440?dopt=Abstract. Accessed September 22, 2017.

thousand people who have been successful in losing at least 30 pounds and maintaining this weight loss for at least one year. Their research findings are that **98% of participants in the registry modified their food intake and 94% increased their physical activity (mainly walking)**.[2]

Although there are a great variety of approaches taken by NWCR members to achieve successful weight loss, **most report that their approach involved adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day). Moreover, most members eat breakfast every day, watch fewer than ten hours of television per week, and weigh themselves at least once per week**. About half of them lost weight on their own, and the other half used some type of weight-loss program. **In most scientific studies successful weight loss is accomplished only by changing the diet and by increasing physical activity**. Doing one without the other limits the amount of weight lost and the length of time that weight loss is sustained. On an individual level it is quite possible to achieve successful weight loss, as over ten thousand Americans can attest. **Moreover, losing as little as 10 percent (i.e. 18 lbs for an individual weighing 180 lbs) of your body weight can significantly improve health and reduce disease risk**.[3]

You do not have to be overweight or obese to reap benefits from

2. Research Findings. The National Weight Control Registry. http://www.nwcr.ws/Research/default.htm. Accessed September 22, 2017.
3. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report. National Heart, Lung, and Blood Institute. 1998, 51S–210S. http://www.ncbi.nlm.nih.gov/books/NBK2003/. Accessed September 22, 2017.

eating a healthier diet and increasing physical activity as both provide numerous benefits beyond weight loss and maintenance.

The "Small-Change" Approach

Gradual rise in overweight is happening because, on average, people consume slightly more calories daily than they expend, resulting in a gradual weight gain of one to two pounds (0.45–0.91 kg) a year. In 2003 the idea was first published that promoting small lifestyle changes to reduce weight gain occurring over time in all age groups may better reduce obesity rates in the American population.[4]

Scientific studies have demonstrated that asking people to increase the number of steps they take each day while providing them with pedometers that count the steps they take each day successfully prevented weight gain. A "small-changes" study published in the October 2007 issue of Pediatrics evaluated whether families that made two small lifestyle changes, which were to walk an additional two thousand steps per day and to eliminate 100 kilocalories per day from their typical diet by replacing dietary sugar with a noncaloric sweetener, would prevent weight gain in overweight children.[5] The results of this study were that a higher

4. Hill JO. Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. Am J Clin Nutr. 2009; 89(2), 477–84. http://www.ajcn.org/content/89/2/477.long. Accessed September 22, 2017.
5. Rodearmel SJ, Wyatt HR, et al. Small Changes in Dietary

percentage of children who made the small changes maintained or reduced their BMI in comparison to children of families given a pedometer but not asked to also make physical activity or dietary changes.[6] Several more studies funded by the National Institutes of Health and USDA are ongoing and are evaluating the effectiveness of the “small-changes” approach in reducing weight gain.

In 2009, a report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council proposed that the “small-changes” approach when supported at the community, industry, and governmental levels will be more effective than current strategies in gradually reducing the obesity rate in America.[7]

Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study. Pediatrics. 2007; 120(4), e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. Accessed September 22, 2017.

6. Rodearmel SJ, Wyatt HR, et al. Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study. Pediatrics. 2007; 120(4), e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. Accessed September 22, 2017.
7. Hill JO. Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council. Am J Clin Nutr. 2009; 89(2), 477–84. http://www.ajcn.org/content/89/2/477.long. Accessed September 22, 2017.

2.3.4. Test Your Knowledge

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2.4. DIETS AND FOOD PLANS

2.4.1. Nutrition

Undernutrition, Overnutrition and Malnutrition

Good nutrition equates to receiving enough (but not too much) of the macronutrients (proteins, carbohydrates, fats, and water) and micronutrients (vitamins and minerals) so that the body can stay healthy, grow properly, and work effectively. The phrase "you are what you eat" means that your body will respond to the food it receives, either good or bad. Processed, sugary, high-fat, and excessively salted foods leave the body unable to perform effectively. By contrast, eating a variety of foods from all food groups fuels the body by providing what it needs to produce energy, promote metabolic activity, prevent micronutrient deficiencies, ward off chronic disease, and bolstering a sense of overall health and well-being.

Hundreds of years ago, when food was less accessible and daily life required much more physical activity, people worried less about obesity and more about simply getting enough to eat. In today's industrialized nations, conveniences have solved some problems and introduced new ones, including the hand-in-hand obesity and diabetes epidemics. Fad diets gained popularity as more North Americans struggled with excess pounds. However, new evidence-based approaches that emphasize more holistic measures are on the rise. These new dietary trends encourage those seeking to lose weight to eat healthy, whole foods first, while adopting a more active lifestyle.

Functional Foods

Many people seek out foods that provide the greatest health benefits. This trend is giving rise to the idea of functional foods, which not only help meet basic nutritional needs but also are reported to fight illness and aging. According to the Academy of Nutrition and Dietetics (AND), formerly known as the The American Dietetic Association, **functional foods may reduce the risk of disease or promote optimal health**. The AND recognizes four types of functional foods. They are: conventional foods, modified foods, medical foods, and special dietary use foods.[1]

The first group, **conventional foods**, represents the simplest form of functional foods. They are **whole foods that have not been modified**. Examples include whole fruits and vegetables (which are abundant in phytochemicals and antioxidants), yogurt and kefir (which contain natural probiotic bacteria that can help maintain digestive system health), and moderate amounts of dark chocolate, made with 70% or more cacao (which contains antioxidants).

Modified foods have been fortified, enriched, or enhanced with additional nutrients or bioactive compounds. Foods are modified using biotechnology to improve their nutritional value and health attributes. Examples of modified foods include calcium-fortified orange juice, breads enriched with B vitamins, iodized salt, cereals fortified with vitamins and minerals, margarine enhanced with plant sterols, and energy drinks that have been enriched with herbs (ginseng or guarana) or amino acids (taurine). It is important to consider that the health claims of some modified foods may be

1. Functional Foods. The Academy of Nutrition and Dietetics. https://www.eatright.org/food/nutrition/healthy-eating/functional-foods. Published July 5, 2018. Accessed April 15, 2018.

debatable, or entirely fraudulent. Check with a health professional regarding the effects of modified foods on your health.

Medical foods are created to meet very specific nutritional requirements. Examples of medical foods include liquid formulas for people with kidney disease, liver disease, diabetes, or other health issues. Medical food is also given to comatose patients through a gastronomy tube because they cannot eat by mouth.

Special dietary use foods do not have to be administered under a doctor's care and can be found in a variety of stores. Similar to medical foods, they address **special dietary needs and meet the nutritional requirements of certain health conditions**. For example, a bottled oral supplement administered under medical supervision is a medical food, but it becomes a special dietary use food when it is sold to retail customers. Examples of special dietary use foods include gluten-free foods, lactose-free dairy products, and formulas and shakes that promote weight loss.

2.4.2. Popular Diets

Popular Diets

The concept of functional foods represents initiatives aimed at addressing health problems. Certain diet plans take this concept one step further, by striving to prevent or treat specific conditions. For example, it is widely understood that people with diabetes need to follow a particular diet. Although some of these diet plans may be nutritionally sound, use caution because **some diets may be fads or be so extreme that they actually cause health problems**.

Before experimenting with a diet, discuss your plans with your doctor or a registered dietitian. Some of the more popular diets fall under the category of fad diets, while others are backed by scientific evidence. Those that fall into the latter category provide a good foundation to build a solid regimen for optimal health **including weight management**.

The DASH Diet

The Dietary Approaches to Stop Hypertension, or DASH diet, focuses on reducing sodium intake to either 2,300 milligrams per day (as recommended by the Dietary Guidelines for Americans and Health Canada) or 1,500 milligrams per day for certain populations. The DASH diet is an evidence-based eating plan that can help reduce high blood pressure. This plan may also decrease the risk of heart attack, stroke, diabetes, osteoporosis, and certain cancers.[1]

DASH tips to lower sodium include the following:

- **using spices instead of salt to add flavor**
- **reading sodium content on processed or canned food labels, and choosing low-sodium options**
- **removing some sodium from canned foods (such as beans) by rinsing the product before consumption**
- **avoiding salt when cooking**

DASH dieters are recommended to consume a variety of whole grains and high-fiber fruits and vegetables, and moderate amounts of low-fat dairy products, lean meats, and heart-healthy fish.

In addition, DASH limits the use of saturated fats to less than 7 percent of total calories, and limits the consumption of sweets and alcohol.

The DASH diet also calls for consuming less added sugar and drinking fewer sugar-sweetened drinks.

DASH replaces red meat with fish and legumes and calls for increased calcium, magnesium, potassium, and fiber. Also, even though some people on the DASH diet may find it lowers their HDL (good) cholesterol along with their LDL (bad) cholesterol, it still has a positive cumulative effect on heart health.[2]

1. DASH Diet Eating Plan. DASH Diet Oregon. http://www.dashdietoregon.org/. Accessed April 12, 2018.
2. DASH Diet Eating Plan. DASH Diet Oregon. http://www.dashdietoregon.org/. Accessed April 12, 2018.

The Gluten-Free Diet

The gluten-free diet helps people whose bodies cannot tolerate gluten, **a protein found in wheat, barley, and rye**. One of the most important ways to treat this condition is to avoid the problematic foods, which is not easy. Although following a gluten-free diet is challenging, it is prescribed for patients with gluten intolerance and celiac disease, an autoimmune disorder with a genetic link. People who have celiac disease cannot consume gluten products without damaging their intestinal lining. Eating a gluten-free diet means finding replacements for bread, cereal, pasta, and more. It also means emphasizing fresh fruits, vegetables, and other foods without gluten.

However, it is important to note that the **gluten-free trend has become something of a fad even for those without a gluten intolerance**. Celiac disease is a relatively rare condition found in only 1 percent of the population. Therefore, a gluten-free diet should be followed only with a physician's recommendation.

Low-Carb Diets

Low-carb diets, which include the Atkins Diet and the South Beach Diet, focus on limiting carbohydrates—such as grains, fruit, and starchy vegetables—to promote weight loss. The theory behind the low-carb diet is based on the fact that insulin prevents the breakdown of fat by allowing sugar in the form of blood glucose to be used for energy. Proponents of this approach believe that because limiting carbs generally lowers insulin levels, it would then cause the body to burn stored fat instead. They believe this method not only brings about weight loss, but also reduces the risk factors for a number of conditions. However, some studies have shown that people who followed certain low-carb diet plans for two years lost an average of nearly 9 pounds, which is similar to the amount of weight lost on higher carbohydrate diets.[3]

The benefits of this kind of diet include an emphasis on whole, unprocessed foods and a de-emphasis of refined carbohydrates, such as white flour, white bread, and white sugar. However, there are a number of downsides. Typically, the first two weeks allow for only 20 grams of carbs per day, which can be dangerously low. In addition, **dieters using the low-carb approach tend to consume twice as many saturated fats as people on a diet high in healthy carbohydrates. Low-carb diets are also associated with a higher energy intake, and the notion that "calories don't count," which is prevalent in this kind of diet, is not supported by scientific evidence**.[4]

The Macrobiotic Diet

The macrobiotic diet is part of a health and wellness regimen based in Eastern philosophy. It combines certain tenets of Zen Buddhism with a vegetarian diet and supports a balance of the oppositional forces of yin and yang. Foods are paired based on their so-called yin or yang characteristics. Yin foods are thought to be sweet, cold,

3. Low-Carb Diet: Can It Help You Lose Weight?.The Mayo Clinic. http://www.mayoclinic.com/health/low-carb-diet/NU00279. Accessed March 6, 2018.
4. Steele V. Health and Nutritional Effects of Popular Diets. Kellogg Nutrition Symposium, The Team of Registered Dietitians & Nutrition Professionals at Kellogg Canada Inc. Insert to Canadian Journal of Dietetic Practice and Research 64, no. 3.

and passive, while yang foods are considered to be salty, hot, and aggressive.

Whole grains make up about 50 percent of the calories consumed and are believed to have the best balance of yin and yang. Raw and cooked vegetables comprise about 30 percent of the diet and include kale, cabbage, collards, bok choy, and broccoli on a daily basis, along with mushrooms and celery a few times a week. Bean or vegetable-based soups and broths can make up 5 to 10 percent of daily caloric intake. Additionally, the diet allows small amounts of fish and seafood several times a week, along with a few servings of nuts. The macrobiotic diet prohibits certain foods, such as chocolate, tropical fruits, and animal products, because they are believed to fall on the far end of the yin-yang spectrum, which would make it difficult to achieve a Zen-like balance.

The macrobiotic diet **focuses on foods that are low in saturated fats and high in fiber, which can help to lower the risk of cardiovascular disease**. Proponents of this diet also believe that it may protect against cancer. However, many nutritionists and healthcare providers express concerns, particularly if the diet is followed strictly. **Extreme macrobiotic eating can be low in protein, low in calories, and pose a risk for starvation. In addition, the diet is also very low in essential vitamins and minerals**.[5]

The Mediterranean Diet

The traditional Mediterranean diet incorporates many elements of the dietary choices of people living in Greece and southern Italy.

5. Zelman, KM. Macrobiotic Diet. http://www.webmd.com/diet/features/macrobiotic-diet. Updated February 9, 2018. Accessed April 12, 2018.

The Mediterranean diet focuses on small portions of nutritionally-sound food. This diet features food from plant sources, including vegetables, fruits, whole grains, beans, nuts, seeds, breads and potatoes, and olive oil. It also limits the consumption of processed foods and recommends eating locally grown foods rich in micronutrients and antioxidants. Other aspects of this eating plan include consuming fish and poultry at least twice per week, eating red meat only a few times per month, having up to seven eggs per week, and drinking red wine in moderation. Unlike most diets, the Mediterranean diet does not cut fat consumption across the board. Instead, it incorporates low-fat cheese and dairy products, and it substitutes olive oil, canola oil, and other healthy oils for butter and margarine.

More than fifty years of nutritional and epidemiological research has shown that people who follow the Mediterranean diet have some of the lowest rates of chronic disease and the highest rates of longevity among the populations of the world. Studies have shown that the Mediterranean diet also helps to decrease excess body weight, blood pressure, blood fats, and blood sugar and insulin levels significantly.[6]

Tools for Change

For six years, researchers from the University of

6. Robinson, K. The Mediterranean Diet. http://www.webmd.com/diet/features/the-mediterranean-diet. Published February 6, 2018. Accessed April 15, 2018.

Bordeaux in France followed the dietary habits of more than seven thousand individuals age sixty-five and over. Participants who described greater consumption of extra-virgin olive oil reportedly lowered their risk of suffering a stroke by 41 percent. The study controlled for stroke risk factors, such as smoking, alcohol intake, high blood pressure, and a sedentary lifestyle. To increase the amount of olive oil in your diet, try spreading olive oil instead of butter on your toast, making your own salad dressing using olive oil, vinegar or lemon juice, and herbs, cooking with olive oil exclusively, or simply adding a dose of it to your favorite meal.[7]

The Raw Food Diet

The raw food diet is followed by those who avoid cooking as much as possible in order to take advantage of the full nutrient content of foods. The principle behind raw foodism is that plant foods in their natural state are the most wholesome for the body. The raw food diet is not a weight-loss plan, it is a lifestyle choice. People who practice raw foodism eat only uncooked and unprocessed foods, emphasizing whole fruits and vegetables. Staples of the raw food diet include whole grains, beans, dried fruits, seeds and nuts, seaweed, sprouts, and unprocessed produce. As a result, **food**

7. More Olive Oil in Diet Could Cut Stroke Risk: Study. MedicineNet.com. https://www.medicinenet.com/script/main/art.asp?articlekey=145823. Published 2011. Accessed April 15,2018.

preparation mostly involves peeling, chopping, blending, straining, and dehydrating fruits and vegetables.

The positive aspects of this eating method include consuming foods that are high in fiber and nutrients, and low in calories and saturated fat. However, the **raw food diet offers little in the way of protein, dairy, or fats, which can cause deficiencies of the vitamins A, D, E, and K. In addition, not all foods are healthier uncooked, such as spinach and tomatoes. Also, cooking eliminates potentially harmful microorganisms that can cause foodborne illnesses**. Therefore, people who primarily eat raw foods should thoroughly clean all fruit and vegetables before eating them. Poultry and other meats should always be cooked before eating.[8]

Vegetarian and Vegan Diets

Vegetarian and vegan diets have been followed for thousands of years for different reasons, including as part of a spiritual practice, to show respect for living things, for health reasons, or because of environmental concerns. For many people, being a vegetarian is a logical outgrowth of "thinking green." A meat-based food system requires more energy, land, and water resources than a plant-based food system. This may suggest that the plant-based diet is more sustainable than the average meat-based diet in the U.S. By avoiding animal flesh, vegetarians hope to look after their own health and that of the planet at the same time. Broadly speaking, vegetarians eat beans, grains, and fruits and vegetables, and do not eat red meat, poultry, seafood, or any other animal flesh. Some vegetarians,

8. Raw Food Diet. WebMD.com.https://www.webmd.com/diet/a-z/raw-foods-diet. Published November 21, 2016. Accessed April 15, 2018.

known as lacto vegetarians, will eat dairy products. Others, known as lacto-ovo vegetarians, will eat dairy products and eggs. A vegan diet is the most restrictive vegetarian diet—vegans do not eat dairy, eggs, or other animal products, and some do not eat honey.

Vegetarian diets have a number of benefits. Well-balanced eating plans can lower the risk of a number of chronic conditions, including heart disease, diabetes, and obesity. They also help to promote sustainable agriculture. However, if a vegetarian does not vary his or her food choices, the diet may be insufficient in calcium, iron, omega-3 fatty acids, zinc, and vitamin B12. Also, if people who follow these diets do not plan out their meals, they may gravitate toward foods high in fats.

See Table 2.4.2.1 "The Pros and Cons of Seven Popular Diets" for a summary of this discussion.

Table 2.4.2.1 *The Pros and Cons of Seven Popular Diets*

Diet	Pros	Cons
DASH diet	• Recommended by the National Heart, Lung, and Blood Institute, the American Heart Association, and many physicians • Helps to lower blood pressure and cholesterol • Reduces risk of heart disease and stroke • Reduces risk of certain cancers • Reduces diabetes risk	• There are very few negative factors associated with the DASH diet • Risk for hyponatremia
Gluten-free diet	• Reduces the symptoms of gluten intolerance, such as chronic diarrhea, cramping, constipation, and bloating • Promotes healing of the small intestines for people with celiac disease, preventing malnutrition • May be beneficial for other autoimmune diseases, such as Parkinson's disease, rheumatoid arthritis, and multiple sclerosis	• Risk of folate, iron, thiamin, riboflavin, niacin, and vitamin B6 deficiencies • Special gluten-free products can be hard to find and expensive • Requires constant vigilance and careful food label reading, since gluten is found in many products
Low-carb diet	• Restricts refined carbohydrates, such as white flour and white sugar • May temporarily improve blood sugar or blood cholesterol levels	• Not entirely evidence-based • Results in higher fat and protein consumption • Does not meet the RDA for carbohydrates to provide glucose to the brain

Macrobiotic diet	• Low in saturated fats and high in fiber • Emphasizes whole foods and de-emphasizes processed foods • Rich in phytoestrogens, which may reduce the risk of estrogen-related cancers	• Not entirely evidence-based • Lacks certain vitamins and minerals; supplements are often required • Can result in a very low caloric intake • Lack of energy may result from inadequate protein
Mediterranean diet	• A reduced risk of cardiovascular disease and mortality • A lower risk of cancer • De-emphasizes processed foods and emphasizes whole foods and healthy fats • Lower sodium intake, due to fewer processed foods • Emphasis on monosaturated fats leads to lower cholesterol • Highlighting fruits and vegetables raises consumption of antioxidants	• Does not specify daily serving amounts • Potential for high fat and high calorie intake as nuts and oils are calorie-dense foods • Drinking one to two glasses of wine per day may not be healthy for those with certain conditions
Raw food diet	• Emphasizes whole foods • Focuses on nutritionally-rich foods	• Not entirely evidence-based • Very restrictive and limits protein and healthy fat intake • Could encourage the development of foodborne illness • Extremely difficult to follow • High in fiber which can cause essential nutrient deficiencies

Vegetarianism and veganism	• May reduce some chronic diseases such as cancer, heart disease, and Type 2 diabetes • May help with weight reduction and weight maintenance	• Guidelines regarding fat and nutrient consumption must be followed • Higher risk for nutrient deficiencies such as protein, iron, zinc, omega-3, vitamin B12 • Consumption of a high fiber diet interferes with mineral and nutrient bioavailability • Vegetarian and vegan protein sources are lower quality with majority missing at least one essential amino acids

2.4.3. Test Your Knowledge

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2.5. UNHEALTHY BODY WEIGHT

2.5.1. Unhealthy Body Weight

Malnutrition

Malnutrition refers to one not receiving proper nutrition and does not distinguish between the consequences of overnutrition or undernutrition, both of which impair overall health. Someone who is 150 pounds overweight can be malnourished.

Undernutrition is characterized by a lack of nutrients and insufficient energy supply, whereas overnutrition is characterized by excessive nutrient and energy intake. Therefore someone with overnutrition can still be malnourished because the foods they are consuming lack essential nutrients. Overnutrition can result in obesity, a growing global health threat. Obesity is defined as a metabolic disorder that leads to an overaccumulation of fat tissue.

Although not as prevalent in North America as it is in developing countries, undernutrition is not uncommon and affects many subpopulations, including the elderly, those with certain diseases, and those in poverty. Many people who live with diseases either have no appetite or may not be able to digest food properly. Some medical causes of malnutrition include cancer, inflammatory bowel syndrome (IBS), AIDS, Alzheimer's disease, illnesses or conditions that cause chronic pain, psychiatric illnesses, such as anorexia nervosa, or as a result of side effects from medications. **Overnutrition is an epidemic in the United States and Canada and is known to be a risk factor for many diseases, including Type 2 diabetes, cardiovascular disease, inflammatory disorders (such as rheumatoid arthritis), and cancer**.

Health Risks of Being Underweight

The 2003–2006 National Health and Nutrition Examination Survey (NHANES) estimated that 1.8 percent of adults and 3.3 percent of children and adolescents in the United States are underweight.[1]

Being underweight is linked to nutritional deficiencies, **especially iron-deficiency anemia, and to other problems such as delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth**. The most common underlying cause of underweight in America is inadequate nutrition. Other causes are wasting diseases, such as cancer, multiple sclerosis, tuberculosis, and eating disorders. People with wasting diseases are encouraged to seek nutritional counseling, as a healthy diet greatly affects survival and improves responses to disease treatments. Eating disorders that result in underweight affect about eight million Americans (seven million women and one million men).

Anorexia Nervosa

Anorexia nervosa, more often referred to as "anorexia," is a **psychiatric illness in which a person obsesses about their weight**

1. Prevalence of Underweight among Children and Adolescents: United States, 2003–2006. Centers for Disease Control and Prevention. http://www.cdc.gov/nchs/data/hestat/underweight/underweight_children.htm. Updated November 6, 2015. Accessed April 15, 2018.

and about food that they eat. Anorexia results in extreme nutrient inadequacy and eventually to organ malfunction. The National Institute of Mental Health (NIMH) reports that 0.9 percent of females and 0.3 percent of males will have anorexia at some point in their lifetime, but it is an extreme example of how an unbalanced diet can affect health.[2]

Anorexia frequently manifests during adolescence and it has the highest rate of mortality of all mental illnesses. People with anorexia consume, on average, fewer than 1,000 kilocalories per day and exercise excessively. They are in a tremendous caloric imbalance. Moreover, some may participate in binge eating, self-induced vomiting, and purging with laxatives or enemas. The very first time a person starves him- or herself may trigger the onset of anorexia. The exact causes of anorexia are not completely known, but many things contribute to its development including economic status, as it is most prevalent in high-income families. It is a genetic disease and is often passed from one generation to the next. Pregnancy complications and abnormalities in the brain, endocrine system, and immune system may all contribute to the development of this illness.

The primary signs of anorexia are fear of being overweight, extreme dieting, an unusual perception of body image, and depression. The secondary signs and symptoms of anorexia are all related to the caloric and nutrient deficiencies of the unbalanced diet and include excessive weight loss, a multitude of **skin abnormalities, diarrhea, cavities and tooth loss, osteoporosis, and liver, kidney, and heart failure**. There is no physical test that can be used to diagnose anorexia and distinguish it from other mental

2. Eating Disorders. The National Institute of Mental Health. https://www.nimh.nih.gov/health/statistics/eating-disorders.shtml#part_155061. Accessed April 15, 2018.

illnesses. Therefore a correct diagnosis involves eliminating other mental illnesses, hormonal imbalances, and nervous system abnormalities. Eliminating these other possibilities involves numerous blood tests, urine tests, and x-rays. Coexisting organ malfunction is also examined.

Treatment of any mental illness involves not only the individual, but also family, friends, and a psychiatric counselor. Treating anorexia also involves a dietitian, who helps to provide dietary solutions that often have to be adjusted over time. The goals of treatment for anorexia are to restore a healthy body weight and significantly reduce the behaviours associated with causing the eating disorder. Relapse to an unbalanced diet is high. Many people do recover from anorexia, however most continue to have a lower-than-normal body weight for the rest of their lives.

Bulimia

Bulimia, like anorexia, is a psychiatric illness that can have severe health consequences. The NIMH reports that 0.5 percent of females and 0.1 percent of males will have bulimia at some point in their lifetime.[3]

Bulimia is characterized by **episodes of eating large amounts of food followed by purging, which is accomplished by vomiting and with the use of laxatives and diuretics**. Unlike people with anorexia, those with bulimia often have a normal weight, making the disorder more difficult to detect and diagnose. The disorder is

3. Eating Disorders. The National Institute of Mental Health. https://www.nimh.nih.gov/health/statistics/eating-disorders.shtml#part_155061. Accessed April 15, 2018.

characterized by **signs similar to anorexia such as fear of being overweight, extreme dieting, and bouts of excessive exercise. Secondary signs and symptoms include gastric reflux, severe erosion of tooth enamel, dehydration, electrolyte imbalances, lacerations in the mouth from vomiting, and peptic ulcers**.

Repeated damage to the esophagus puts people with bulimia at an increased risk for esophageal cancer. The disorder is also highly genetic, linked to depression and anxiety disorders, and most commonly occurs in adolescent girls and young women. **Treatment often involves antidepressant medications and, like anorexia, has better results when both the family and the individual with the disorder participate in nutritional and psychiatric counselling.**

Binge-Eating Disorder

Similar to those who experience anorexia and bulimia, **people who have a binge-eating disorder have lost control over their eating**. According to the NIMH, binge-eating disorder is **more prevalent than anorexia and bulimia**, and affects 3.5 percent of females and 2.0 percent of males at some point during their lifetime.[4]

Binge-eating disorder is not currently diagnosed as a distinct psychiatric illness, although there is a proposal from the American Psychiatric Association to categorize it more specifically. **People with binge-eating disorder will periodically overeat to the extreme, but their loss of control over eating is not followed by fasting, purging, or compulsive exercise. As a result, people with**

4. Eating Disorders. The National Institute of Mental Health. https://www.nimh.nih.gov/health/statistics/eating-disorders.shtml#part_155061. Accessed April 15, 2018.

this disorder are often overweight or obese, and their chronic disease risks are those linked to having an abnormally high body weight such as hypertension, cardiovascular disease, and Type 2 diabetes. Additionally, they often experience guilt, shame, and depression. Binge-eating disorder is commonly associated with depression and anxiety disorders. Treatment often involves antidepressant medication as well as nutritional and psychiatric counseling.

The Healing Process

With all wounds, from a paper cut to major surgery, the body must heal itself. Healing is facilitated through proper nutrition while malnutrition inhibits and complicates this vital process. The following nutrients are important for proper healing:[5]

- **Vitamin A** helps to enable the epithelial tissue (the thin outer layer of the body and the lining that protects your organs) and bone cells form.
- **Vitamin C** helps form collagen, an important protein in many body tissues.
- **Protein** facilitates tissue formation.
- **Fats** play a key role in the formation and function of cell membranes.
- **Carbohydrates** fuel cellular activity, supplying needed energy to support the inflammatory response that promotes healing.

5. MacKay D, Miller AL. Nutritional Support for Wound Healing. Alternative Medicine Review. 2003 8(4), 359–77. https://www.ncbi.nlm.nih.gov/pubmed/14653765. Accessed April 15, 2018.

2.5.2. Test Your Knowledge

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2.6. HEALTH CONCERNS

"Health Concerns" is an adaptation of the chapter "Nutritional Issues" from *Human Nutrition*, by the University of Hawaiʻi at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. Canadian content has been added and information that is not relevant to this course has been removed.

2.6.1. Avoiding Chronic Conditions

Disorders That Can Compromise Health

When nutrients and energy are in short supply, cells, tissues, organs, and organ systems do not function properly. Unbalanced diets can cause diseases and, conversely, certain illnesses and diseases can cause an inadequate intake and absorption of nutrients, simulating the health consequences of an unbalanced diet. Overeating high-fat foods and nutrient-poor foods can lead to obesity and exacerbate the symptoms of gastroesophageal reflux disease (GERD) and irritable bowel syndrome (IBS). Many diseases and illnesses, such as celiac disease, interfere with the body getting its nutritional requirements. A host of other conditions and illnesses, such as food allergies, cancer, stomach ulcers, Crohn's disease, and kidney and liver disease, also can impair the process of digestion and/or negatively affect nutrient balance and decrease overall health. Some illnesses that can compromise health are **chronic** and persist for a long time, some are **communicable** meaning they can be transmitted between people, and some are **non-communicable** meaning they can not be transmitted between people.

Gastresophageal Reflux Disease

Gastro-esophageal reflux disease (GERD) is a persistent form of acid reflux that occurs more than two times per week. Acid reflux occurs when the acidic contents of the stomach leak backward into the esophagus and cause irritation. It is estimated that GERD affects 13% percent of the Canadian population weekly and 24% experiences **heartburn** daily or more frequently.[1] GERD tends to be much more prevalent in people with obesity.[2] The most common GERD symptom is heartburn, but people with GERD may also experience regurgitation (flow of the stomach's acidic contents into the mouth), frequent coughing, and trouble swallowing.

There are other causative factors of GERD that may be separate from or intertwined with obesity. The sphincter that separates the stomach's internal contents from the esophagus often does not function properly and acidic gastric contents seep upward. Sometimes the peristaltic contractions of the esophagus are also sluggish and compromise the clearance of acidic contents. In addition to having an unbalanced, high-fat diet, some people with GERD are sensitive to particular foods—chocolate, garlic, spicy foods, fried foods, and tomato-based foods—which worsen symptoms. Drinks containing alcohol or caffeine may also worsen GERD symptoms.

The first approach to GERD treatment is dietary and lifestyle modifications. Suggestions are to reduce weight if you are overweight or obese, avoid foods that worsen GERD symptoms, eat smaller meals, stop smoking, and remain upright for at least three hours after a meal. People with GERD may not take in the

1. https://cdhf.ca/digestive-disorders/gerd/statistics/(https://cdhf.ca/digestive-disorders/gerd/statistics/)
2. Hampel H, Abraham NS, El-Serag HB. Meta-Analysis: Obesity and the Risk for Gastroesophageal Reflux Disease and Its Complications. Ann Intern Med, 143(3), 199–211. http://www.ncbi.nlm.nih.gov/pubmed/16061918. Accessed April 12, 2018.

nutrients they need because of the pain and discomfort associated with eating. As a result, GERD can be caused by an unbalanced diet and its symptoms can lead to a worsening of nutrient inadequacy, a vicious cycle that further compromises health. Some evidence from scientific studies indicates that medications used to treat GERD may accentuate certain nutrient deficiencies, namely zinc and magnesium. When these treatment approaches do not work surgery is an option. The most common surgery involves reinforcing the sphincter that serves as a barrier between the stomach and esophagus.

Irritable Bowel Syndrome

Irritable bowel syndrome (IBS) is characterized by muscle spasms in the colon that result in abdominal pain, bloating, constipation, and/or diarrhea. Interestingly, IBS produces no permanent structural damage to the large intestine as often happens to patients who have Crohn's disease or inflammatory bowel disease. It is estimated that one in five Americans displays symptoms of IBS. The disorder is more prevalent in women than men. Two primary factors that contribute to IBS are an unbalanced diet and stress.

Symptoms of IBS significantly decrease a person's quality of life as they are present for at least twelve consecutive or nonconsecutive weeks in a year. Large meals and foods high in fat and added sugars, or those that contain wheat, rye, barley, peppermint, and chocolate intensify or bring about symptoms of IBS. Additionally, beverages containing caffeine or alcohol may worsen IBS. Stress and depression compound the severity and frequency of IBS symptoms. As with GERD, the first treatment approaches for IBS are diet and lifestyle modifications. People with IBS are often told to keep a daily food journal to help identify and eliminate foods that cause the most problems. Other recommendations are to eat slower, add more fiber to the diet, drink more water, and to exercise. There are some medications (many of which can be purchased over-the-counter) to treat IBS and the resulting diarrhea or constipation. Sometimes antidepressants and drugs to relax the colon are prescribed.

Celiac Disease

Celiac disease is an autoimmune disorder affecting between 0.5 and 1.0 percent of Americans—that is, one in every one- to two-hundred people. It is caused by an abnormal immune reaction of small intestine cells to a type of protein, called gluten. For those who are sensitive to gluten, it is good to know that corn, millet, buckwheat, and oats do not contain the proteins that make gluten. However, some people who have celiac disease also may have a response to products containing oats. This is most likely the result of cross-contamination of grains during harvest, storage, packaging, and processing.

Celiac disease is most common in people of European descent and is rare in people of African American, Japanese, and Chinese descent. It is much more prevalent in women and in people with Type 1 diabetes, autoimmune thyroid disease, and Down and Turner syndromes. Symptoms can range from mild to severe and can include pale, fatty, loose stools, gastrointestinal upset, abdominal pain, weight loss and, in children, a failure to grow and thrive. The symptoms can appear in infancy or much later in life, even by age seventy. Celiac disease is not always diagnosed because the symptoms may be mild. A large number of people have what is referred to as "silent" or "latent" celiac disease.

The destruction of the absorptive surface of the small intestine also results in the malabsorption of nutrients, so that while people with this disease may eat enough, nutrients do not make it to the bloodstream because absorption is reduced. The effects of nutrient malabsorption are most apparent in children and the elderly as they are especially susceptible to nutrient deficiencies. Over time these nutrient deficiencies can cause health problems. Poor absorption of iron and folic acid can cause anemia, which is a decrease in red blood cells. Anemia impairs oxygen transport to all cells in the body. Calcium and vitamin D deficiencies can lead to osteoporosis, a disease in which bones become brittle.

If you think you or someone close to you may have celiac disease, do not despair; it is a very treatable disease. Once diagnosed, a person follows a gluten-free diet for life. This requires dedication and careful detective work to seek out foods with hidden gluten, but some stores carry gluten-free foods. After eliminating gluten from the diet, the tissues of the small intestine rapidly repair themselves and heal in less than six months.

Food Allergies

Paying attention to the way individuals react to various foods is essential in determining what foods may specifically affect a person adversely. Food allergies are one of the many ways in which different body make-ups affect nutritional concerns. Although an estimated twelve million Americans have food allergies, there are likely many more people who say they have food allergies than actually do. This is because **food sensitization is different from a medically-determined food allergy**. When someone has a food allergy, the immune system mistakenly attacks a certain kind of food (usually the protein component of a food), such as peanuts, as if it were a threat and IgE antibodies are produced.

Food allergy symptoms usually develop within a few minutes to two hours after a person has eaten a food to which they are allergic. These symptoms can range from the annoying to the potentially fatal, and include the following:

- a tingling mouth
- swelling tongue and/or throat

- difficulty breathing
- hives
- stomach cramps
- diarrhea
- vomiting
- drop in blood pressure
- loss of consciousness
- death

There are no clear treatments for food allergies. Epinephrine is sometimes used to control severe reactions, and individuals with known and dangerous allergies may get prescriptions for self-injectable devices called EpiPens. The only certain way to avoid allergic reactions to food is to avoid the foods that cause them. Beyond avoidance, this can mean reading food labels carefully, or even calling manufacturers for product information.

Ninety percent of food allergies are caused by these eight foods:

- milk
- eggs
- peanuts
- tree nuts
- fish
- shellfish
- sheat
- soy

Oral Disease

Oral health refers not only to healthy teeth and gums, but also to the health of all the supporting tissues in the mouth such as ligaments, nerves, jawbone, chewing muscles, and salivary glands. Over ten years ago the Surgeon General produced its first report dedicated to oral health, stating that oral health and health in general are not separate entities.[3]

Instead, oral health is an integral part of overall health and well-being. Soft drinks, sports drinks, candies, desserts, and fruit juices are the main sources of "fermentable sugars" in the American diet. (Fermentable sugars are those that are easily metabolized by bacteria in a process known as fermentation. Glucose, fructose, and maltose are three examples.) Bacteria that inhabit the mouth metabolize fermentable sugars and starches in refined grains to acids that erode tooth enamel and deeper bone tissues. The acid creates holes (cavities) in the teeth that can be extremely painful. Gums are also damaged by bacteria produced by acids, leading to gingivitis (characterized by inflamed and bleeding gums). Saliva is actually a natural mouthwash that neutralizes the acids and aids in building up teeth that have been damaged.

Figure 2.6.1.1 *Gingivitis*

Reddening of the gums around the teeth a sign of gingivitis. Source: "Gingivitis"/ CC0 1.0

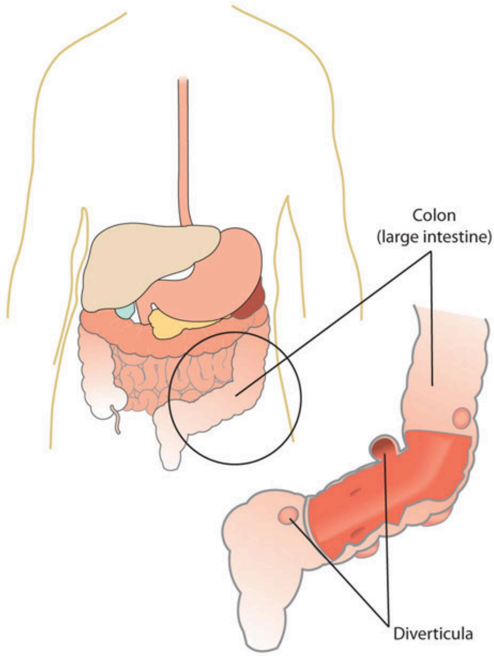
3. Office of the Surgeon General (US). National Call To Action To Promote Oral Health. National Institute of Dental and Craniofacial Research (US). 2003; 03-5303. https://www.ncbi.nlm.nih.gov/books/NBK47472/. Accessed April 15, 2018.

Colon Health

A substantial health benefit of whole grain foods is that fiber actively supports digestion and optimizes colon health. (This can be more specifically attributed to the insoluble fiber content of whole grains.) There is good evidence supporting that insoluble fiber prevents the irritating problem of constipation and the development of diverticulosis and diverticulitis. Diverticulosis is a benign condition characterized by outpouches of the colon. Diverticulitis occurs when the outpouches in the lining of the colon become inflamed. Symptoms include lower abdominal pain, nausea, and alternating between constipation and diarrhea.

The chances of developing diverticulosis can be reduced with fiber intake because of what the breakdown products of the fiber do for the colon. The bacterial breakdown of fiber in the large intestine releases short-chain fatty acids. These molecules have been found to nourish colonic cells, inhibit colonic inflammation, and stimulate the immune system (thereby providing protection of the colon from harmful substances). Additionally, the bacterial indigestible fiber, mostly insoluble, increases stool bulk and softness increasing transit time in the large intestine and facilitating feces elimination. One phenomenon of consuming foods high in fiber is increased gas, since the byproducts of bacterial digestion of fiber are gases.

Figure 2.6.1.2 *Diverticulitis: A Disease of Fiber Deficiency*



Diverticulitis develops in the large intestine as a results of fiber deficiency. Source: [*Nutrition, Health, Disease*]

Osteoporosis

There are several factors that lead to loss of bone quality during aging, including a reduction in hormone levels, decreased calcium absorption, and increased muscle deterioration. It is comparable to being charged with the task of maintaining and repairing the structure of your home without having all of the necessary materials to do so. However, you will learn that there are many ways to maximize your bone health at any age.

Osteoporosis is the excessive loss of bone over time. It leads to decreased bone strength and an increased susceptibility to bone fracture. **An estimated 1.5 million (10%) Canadians 40 years of age or older reported having been diagnosed with osteoporosis.** [4]

Osteoporosis is a debilitating disease that markedly increases the risks of suffering from bone fractures. A fracture in the hip causes the most serious consequences—and approximately 20 percent of senior citizens who have one will die in the year after the injury. Osteoporosis affects more women than men, but men are also at risk for developing osteoporosis, especially after the age of seventy.

As previously discussed, bones grow and mineralize predominantly during infancy, childhood, and puberty. During this time, bone growth exceeds bone loss. By age twenty, bone growth is fairly complete and only a small amount (about 10 percent) of bone mass accumulates in the third decade of life. By age thirty, bone mass is at its greatest in both men and women and then gradually declines after age forty. Bone mass refers to the total weight of bone tissue in the human body. The greatest quantity of bone tissue a person develops during his or her lifetime is called **peak bone mass**. The decline in bone mass after age forty occurs because bone loss is greater than bone growth. The increased bone degradation decreases the mineral content of bone tissue leading to a decrease in bone strength and increased fracture risk.

Osteoporosis is referred to as a silent disease, much like high blood pressure, because symptoms are rarely exhibited. A person with osteoporosis may not know he has the disease until he experiences a bone break or fracture. Detection and treatment of

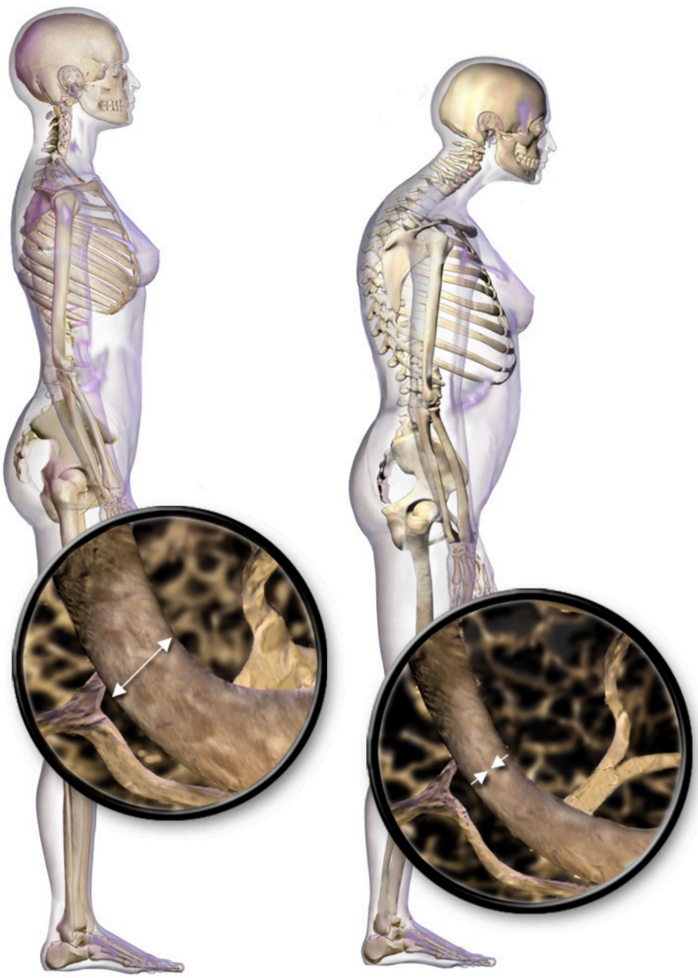
4. https://www.canada.ca/en/public-health/services/chronic-diseases/osteoporosis/what-impact-osteoporosis-what-canadians-doing-maintain-healthy-bones.html (https://www.canada.ca/en/public-health/services/chronic-diseases/osteoporosis/what-impact-osteoporosis-what-canadians-doing-maintain-healthy-bones.html)

osteoporosis, before the occurrence of a fracture, can significantly improve the quality of life. To detect **osteopenia (lower-than-normal bone mineral density)** or **osteoporosis**, bone mineral density (BMD) must be measured by a DEXA scan.

During the course of osteoporosis, BMD decreases and the bone tissue microarchitecture is compromised. Excessive bone resorption in the trabecular tissue increases the size of the holes in the lattice-like structure making it more porous and weaker. A disproportionate amount of resorption of the strong cortical bone causes it to become thinner. The deterioration of one or both types of bone tissue causes bones to weaken and, consequently, become more susceptible to fractures. The American Academy of Orthopaedic Surgeons reports that one in two women and one in five men older than sixty-five will experience a bone fracture caused by osteoporosis.[5]

Figure 2.6.1.3 *Osteoporosis in Vertebrae*

5. Osteoporosis. American Academy of Orthopaedic Surgeons.OrthoInfo. http://orthoinfo.aaos.org/topic.cfm?topic=a00232. Updated August 2009. Accessed April 16, 2018.



When the vertebral bone tissue is weakened, it can cause the spine to curve. The increase in spine curvature not only causes pain, but also decreases a person's height. Curvature of the upper spine produces kyphosis. Severe upper-spine deformity can compress the chest cavity and cause difficulty breathing. It may also cause abdominal pain and loss of appetite because of the increased pressure on the abdomen. Source: [Nutrition, Health, Disease]

Risk Factors for Osteoporosis

A **risk factor** is defined as a variable that is linked to an increased probability of developing a disease or adverse outcome. Recall that advanced age and being female increases the likelihood for developing osteoporosis. Risk factors such as age, sex, and race are biological risk factors, and are based on genetics that cannot be changed. By contrast, there are other risk factors that can be modified, such as physical activity, alcohol intake, and diet. The changeable risk factors for osteoporosis provide a mechanism to improve bone health even though some people may be genetically predisposed to the disease.

Image by Tomasz Sienick/ CC BY- SA 3.0

Physical Activity

Bone is a living tissue, like muscle, that reacts to exercise by gaining strength. Physical inactivity lowers peak bone mass, decreases bone mineral density (BMD) at all ages, and is linked to an increase in fracture risk, especially in the elderly. Recall that mechanical stress increases bone remodeling and leads to increased bone strength and quality. Weight-bearing exercise puts mechanical stress on bones and therefore increases bone quality. Weight-bearing exercises such as strength training with weights, and aerobic weight-bearing activities, such as walking, running, and stair climbing are the most helpful for maintaining BMD. Certain aerobic exercises such as biking and swimming do not build bones, although they are very good for cardiovascular fitness. The stimulation of new bone growth occurs when a person participates in weight-bearing or resistance activities that force the body to work against gravity. Research has shown that this is an excellent way to activate osteoblasts to build more new bone. Conversely, physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly.

Being Underweight

Being underweight significantly increases the risk for developing osteoporosis. This is because people who are underweight often also have a smaller frame size and therefore have a lower peak bone mass. Maintaining a normal, healthy weight is important and acts as a form of weight-bearing exercise for the skeletal system as a person moves about. Additionally, inadequate nutrition negatively impacts peak bone mass and BMD. The most striking relationship between being underweight and bone health is seen in people with the psychiatric illness anorexia nervosa. Anorexia nervosa is strongly correlated with low peak bone mass and a low BMD. In fact, more than 50 percent of men and women who have this illness develop osteoporosis and sometimes it occurs very early in life.[6]

6. Mehler PS, Weiner K. The Risk of Osteoporosis in Anorexia Nervosa. Eating Disorders Recovery Today.

Women with anorexia nervosa are especially at risk because they not only have **inadequate nutrition** and **low body weight**, but also the illness is also associated with **estrogen deficiency**.

Smoking, Alcohol, and Caffeine

Smoking cigarettes has long been connected to a decrease in BMD and an increased risk for osteoporosis and fractures. However, because people who smoke are more likely to be physically inactive and have poor diets, it is difficult to determine whether smoking itself causes osteoporosis. What is more, smoking is linked to earlier menopause and therefore the increased risk for developing osteoporosis among female smokers may also be attributed, at least in part, to having stopped estrogen production at an earlier age. A review of several studies, published in the British Medical Journal in 1997, reports that in postmenopausal women who smoked, BMD was decreased an additional 2 percent for every ten-year increase in age and that these women had a substantial increase in the incidence of hip fractures.[7]

Alcohol intake's effect on bone health is less clear. The International Osteoporosis Foundation states that consuming more than two alcoholic drinks per day is a risk factor for developing

http://www.eatingdisordersrecoverytoday.com/the-risk-of-osteoporosis-in-anorexia-nervosa/. Published May 14, 2017. Accessed April 15, 2018.

7. Law MR, Hackshaw, AK. A Meta-Analysis of Cigarette Smoking, Bone Mineral Density and Risk of Hip Fracture: Recognition of a Major Effect. British Medical Journal. 1997.315 (7112), 841–6. http://www.ncbi.nlm.nih.gov/pubmed/9353503. Accessed April 15, 2018.

osteoporosis and sustaining a hip fracture in both men and women.[8] Moreover, excessive alcohol intake during adolescence and young adulthood has a more profound effect on BMD and osteoporosis risk than drinking too much alcohol later in life, likely because young adulthood is a pivotal time for bone development.

Overall, the evidence that caffeine consumption poses a risk for developing osteoporosis is minimal, especially when calcium intake is sufficient. Some evidence suggests that carbonated soft drinks negatively affect BMD and increase fracture risk. Their effects, if any, on bone health are not attributed to caffeine content or carbonation. It is probable that any effects of the excessive consumption of soft drinks, caffeinated or not, on bone health can be attributed to the displacement of milk as a dietary source of calcium.

Nutrition

Ensuring adequate nutrition is a key component in maintaining bone health. Having low dietary intakes of **calcium** and **vitamin D** are strong risk factors for developing osteoporosis. Another key nutrient for bone health is **protein**. Remember that the protein collagen comprises almost one third of bone tissue. A diet inadequate in protein is a risk factor for osteoporosis. Multiple large

8. New IOF Report Shows Smoking, Alcohol, Being Underweight, and Poor Nutrition Harm Our Bones. International Osteoporosis Foundation. https://www.iofbonehealth.org/new-iof-report-shows-smoking-alcohol-being-underweight-and-poor-nutrition-harm-our-bones. Published October 19, 2007. Accessed April 15, 2018.

observational studies have shown that diets high in protein increase BMD and reduce fracture risk and that diets low in protein correlate to decreased BMD and increased fracture risk. There has been some debate over whether diets super high in animal protein decreases bone quality by stimulating bone resorption and increasing calcium excretion in the urine. A review in the May 2008 issue of the American Journal of Clinical Nutrition concludes that there is more evidence that diets adequate in protein play a role in maximizing bone health and there is little consistent evidence that suggests high protein diets negatively affect bone health when calcium intake is adequate.[9]

Osteoporosis Prevention and Treatment

Although the symptoms of osteoporosis do not occur until old age, osteoporosis is referred to as a childhood disease with old-age consequences. Thus, preventing osteoporosis in old age begins with building strong bones when you are growing. Remember, the more bone mass a person has to start with, the greater the loss a person can withstand without developing osteopenia or osteoporosis. Growing and maintaining healthy bones requires good nutrition, adequate intake of minerals and vitamins that are involved in maintaining bone health, and weight-bearing exercise.

Prevention extends throughout life, and people with one or more **risk factors** for osteoporosis should have their BMD measured. The

9. Heaney, RP, Layman DK. Amount and Type of Protein Influences Bone Health. The American Journal of Clinical Nutrition. 2008; 87(5), 1567S–70S. http://www.ajcn.org/content/87/5/1567S.long. Accessed April 15, 2018.

National Osteoporosis Foundation recommends the following groups of people get BMD screening:[10]

- women who are sixty-five or older
- men who are seventy or older
- women and men who break a bone after age fifty
- women going through menopause with other risk factors
- men fifty to sixty-nine years of age with risk factors

10. Bone Density Exam/Test. National Osteoporosis Foundation. https://www.nof.org/patients/diagnosis-information/bone-density-examtesting/. Accessed April 15, 2018.

2.6.2. Test Your Knowledge

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2.7. CARDIOVASCULAR HEALTH

"Cardiovascular Health" is an adaptation of the chapter "Threats to Health" from *Human Nutrition*, by the University of Hawai'i at Mānoa Food Science and Human Nutrition Program, and the chapter "Cardiovascular Disease" from *Concepts of Fitness and Wellness*, by Scott Flynn, Lisa Jellum, Althea Moser, Jonathan Howard, Sharryse Henderson, Christin Collins, Amanda West, and David Mathis. Both are licensed under a CC BY 4.0 license. New material has been incorporated that includes Canadian content; heart, mind and brain connections; and additional information on hypertension. Information that is not relevant to this course has been removed.

2.7.1. Cardiovascular Disease: Risk and Prevention

What Is Cardiovascular Disease?

Cardiovascular disease generally starts with atherosclerosis, or a hardening of the arteries, a chronic condition so common that most people show signs of it by the time they turn thirty. However, the beginning signs of atherosclerosis have been observed in children as young at 12 years. [1] As atherosclerosis develops, arteries start to narrow and harden when fats accumulate along their inner walls and form **plaques**. A plaque is made of fat, cholesterol, calcium, and other substances found in blood.

Plaque formation causes arteries to narrow and harden, which elevates blood pressure because the **vessels can't expand** effectively to accommodate blood pulses. Higher blood pressure **strains the heart** and causes more damage. Arterial walls can become so weakened due to high blood pressure that they balloon and form what is known as an **aneurysm**. If the aneurysm bursts, it becomes a life-threatening event. The plaques themselves can also rupture due to a spike in blood pressure or a tremor along an arterial wall, and the body responds to this perceived injury by forming **blood clots**. These clots are serious health threats, whether they are stationary (a thrombus) or moving (an embolus). A stable clot can slowly kill off surrounding tissue, or grow so big that it blocks blood circulation and causes thrombosis. When a moving clot becomes stuck in an

1. https://link.springer.com/article/10.1007%2Fs00467-014-2836-1

artery too small for its passage, it cuts off blood flow and causes cell death. This is referred to as an embolism. Blood clots in heart cause **heart attacks** and in the brain cause **strokes**.

There are numerous risk factors for cardiovascular disease; some are modifiable and others are not.

Table 2.7.1.1 *The Risk Factors for Cardiovascular Disease*

Unmodifiable risk factors	
Age	Risk increases for men at forty-five, and for women at fifty-five.
Sex	Men have a higher risk than women, though the risk for women steeply rises after menopause.
Family history	The more family members who have heart disease, the greater the risk.
Modifiable Risk Factors	
Cigarette smoking	Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of atherosclerosis.
Obesity	Excess weight worsens other risk factors.
Diabetes	This condition is associated with an increased risk of heart disease. Both types have certain risk factors in common, including obesity and high blood pressure.
Physical inactivity	Lack of exercise is associated with heart disease.
Cholesterol levels	High levels of blood cholesterol can increase the risk. A high level of low-density lipoprotein (LDL), or the “bad” cholesterol, is a common contributing factor. However, a low level of high-density lipoprotein (HDL), or “good” cholesterol, can also promote atherosclerosis.

Source: Cardiovascular Diseases

Heart Disease

Heart disease is a disorder of the blood vessels that can lead to heart failure. Heart disease is the second leading cause of death in Canada [Heart Disease in Canada. Government of Canada. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html. Updated on February 10, 2017. Accessed on January 25, 2020]. This disorder can be congenital and/or the result of lifestyle. Most people associate heart disease with heart attacks. A heart attack, also known as a **myocardial infarction**, happens when an artery becomes blocked, preventing oxygen and nutrients from getting to the heart.

Other types of heart disease include the following:

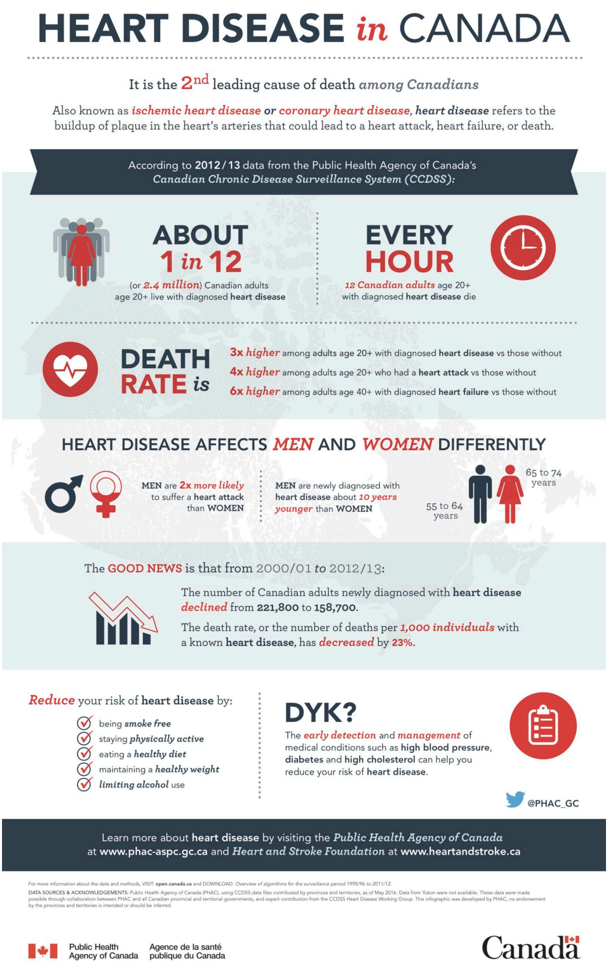
- **coronary artery disease**: Damage or disease in the heart's major blood vessels
- **high blood pressure**: A condition in which the force of the blood against the artery walls is too high.
- **cardiac Arrest**: Sudden, unexpected loss of heart function, breathing, and consciousness.
- **congestive heart failure**: A chronic condition in which the heart does not pump blood as well as it should.
- **arrhythmia**: Improper beating of the heart, whether irregular, too fast, or too slow.
- **peripheral artery disease**: A circulatory condition in which narrowed blood vessels reduce blood flow to the limbs.
- **congenital heart disease**: An abnormality in the heart that develops before birth.

The good news: [2]

- The number of new Canadians diagnosed with heart disease has decreased by just under 30%.
- In Canada, the death rate in individuals with a known heart disease has decreased by 23%.

Figure 2.7.1.1 *Heart Disease in Canada*

2. Heart Disease in Canada. Government of Canada. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html. Updated on February 10, 2017. Accessed on January 25, 2020



Source: "Heart Disease in Canada". © All rights reserved. Public Health Agency of Canada and Heart & Stroke Foundation. Adapted and reproduced with permission from the Minister of Health, 2020.

Stroke

This type of CVD affects the arteries leading to the brain and blood vessels within the brain. A stroke occurs when a blood vessel that carries oxygen and nutrients to the brain is either blocked by a clot or ruptures. When that happens, part of the brain cannot get the blood and oxygen it needs and as a result, brain cells begin to die. Women are disproportionally affected by stroke in Canada with 45% more women dying of stroke than men [(Dis)connected. Heart and Stroke Foundation. https://www.heartandstroke.ca/-/media/pdf-files/canada/2019-report/heartandstrokereport2019.ashx. Updated in 2019. Accessed on January 26, 2020.]

A stroke that occurs as the result of a blockage is called an **ischemic stroke**. A **hemorrhagic stroke** is the result of a rupture and accounts for only 15% of all strokes.

The Cincinnati Stroke Scale provides early warning signs of a stroke:

F	**Face:** Is one side of the face drooping down?
A	**Arm:** Can the person raise both arms, or is one arm weak?
S	**Speech:** Is speech slurred or confusing?
T	**Time:** If the conditions listed above are present call 9-1-1 immediately! Time is critical!

In 2019, the Heart and Stroke foundation released a full report on Heart, Stroke and Vascular Impairment in Canada.

Heart, Brain and Mind Connection

The body is a highly interconnected unit. Increasingly there is evidence connecting heart, brain and mind health. The brain is the control system for the whole body. When there is stress, coming from and internal or external source, the heart can be negatively affected. The heart is responsible to pumping nutrient and oxygen rich blood throughout the body. When the heart is not doing its job properly the health of the rest of the body is sacrificed. This is particularly important in the brain as if the brain is oxygen or nutrient deprived it cannot function properly, affecting the rest of the body. Altered blood flow in the brain has additionally been associated with the development of cognitive impairment and dementia. Individuals with stroke and heart failure are 2.2 and 2.6 times more likely to experience cognitive impairment. [3]

Hypertension

High blood pressure (hypertension) should be taken seriously. Increased blood pressure is the leading risk for death in countries like Canada.[4] About 19% of the Canadian adults population has high blood pressure and 9 in 10 Canadians will develop high blood pressure or hypertension during their lives.[5] High sodium

3. (Dis)connected. Heart and Stroke Foundation. https://www.heartandstroke.ca/-/media/pdf-files/canada/2019-report/heartandstrokereport2019.ashx. Updated in 2019. Accessed on January 26, 2020.
4. My Blood Pressure Action Plan. Heart & Stroke. https://www.heartandstroke.ca/-/media/pdf-files/canada/health-information-catalogue/en-get-your-blood-pressure-under-control-v21-web.ashx?la=en&hash=20493566724F3F87387717A720D49F60521C1CF2. Updated in 2015. Accessed on January 29, 2020.
5. [My Blood Pressure Action Plan. Heart & Stroke. https://www.heartandstroke.ca/-/media/pdf-files/canada/health-information-catalogue/en-get-your-blood-pressure-under-control-v21-web.ashx?la=en&hash=20493566724F3F87387717A720

consumption is a main cause of high blood pressure. Hypertension is also associated with higher body weight. Hypertension is a major cause of heart attacks and strokes, yet it has no symptoms until blood pressure reaches very high levels, which is why it is known as “the silent killer.” The only way to find out if you have high blood pressure is to get an accurate reading of your resting blood pressure rate. This is is best done by a medical professional after sitting and resting for several minutes so your blood pressure can stabilize to resting levels. Blood pressure should be monitored regularly. Blood pressure is made up of two numbers. The systolic or top number represents the force of the blood against your artery walls when your heart pumps. The diastolic or bottom number represents the force in your artery walls when your heart is resting.

Table 2.7.1.2 *Blood Pressure Categories*

Blood pressure categories	Blood pressure
Low risk	120/80 mmHg
Medium Risk	121–139/80-89 mmHg
High Risk	140+/90 mmHg

Having high blood pressure can damage the lining of arteries throughout the body. This means that all organs and tissue can be affected by high blood pressure. Additionally, if high blood pressure is untreated it can lead to atherosclerosis which can results in conditions such as the following:

- stroke
- heart attack
- heart failure
- kidney failure

D49F60521C1CF2. Updated in 2015. Accessed on January 29, 2020.

- peripheral vascular disease
- impotence
- retinal/ eye damage

There are several modifiable and unmodifiable risk factors for hypertension.

Table 2.7.1.3 *The Risk Factors for Hypertension*

Unmodifiable risk factors	
Age	After fifty-five, the risk of developing high blood pressure is 90 percent.
Race	African-Americans are more likely to develop hypertension, manifest it at a younger age, and have higher blood pressure readings.
Family history	There is a strong genetic component to high blood pressure, and an individual's risk goes up along with the number of family members who have hypertension.
Modifiable Risk Factors	
Weight	Roughly 60 percent of people with hypertension are obese.
Sodium consumption	The more salt in a person's diet, the more likely they are to have high blood pressure.
Alcohol	Drinking more than two drinks per day for men and one drink for women increases the likelihood of hypertension.
Diet	In addition to salt and alcohol consumption, other dietary factors increase chances of developing hypertension.

There are lots of things you can do to keep your blood pressure in a healthy range. These include the following:

- make sure you have your blood pressure checked at least once a year
- maintain a healthy body weight

- eat a healthy balance diet with reduced fat
- reduce the amount of salt in your diet
- check with your health care provider to see if you should eat foods that are rich in potassium as potassium can lower blood pressure
- participate in regular physical activity
- be smoke-free
- limit alcohol intake
- find healthy ways to manage stress
- follow the DASH diet

Public Blood Pressure Machines

Using public blood pressure machines is a convenient way to track your blood pressure. However, using these machines should not replace regular doctor appointments, and they cannot inform you what are the next steps if you have high blood pressure.

To get accurate readings you have to

- sit quietly for a least 5 minutes before taking your blood pressure,
- avoid eating, smoking, doing heavy physical activity or drinking tea or coffee for at least 2 hours before taking your blood pressure, and
- place your arm on the table at about heart level.

What Causes CVD?

The following four unmodifiable risk factors, which are beyond a person's control, can be linked to cardiovascular disease:

- **age:** There is a strong correlation between CVD and age. As a person ages, the risk for CVD increases also. Although, with males, the risk seems to be when they are younger and females seem to be at higher risk post-menopausal.
- **sex:** Males have a higher risk for CVD, especially at younger ages. On average males are diagnosed with heart disease 10 years younger than women. Men are 2 time more likely to suffer a hear attack than women.[6] Women experience higher risk later in their lives.
- **race:** African Americans have the highest risk factor for CVD.
- **family history:** A person's genes can be one of the strongest predictors of CVD, but also has the smallest correlation to to CVD overall.

The following five modifiable conditions are also linked to cardiovascular disease, but these *are* within a person's power to change:

- **tobacco use:** The strongest predictor of CVD is the use of tobacco. The use of tobacco accounts for 30% of CVD risk. There is a significant reduction in risk for those who do not use tobacco.
- **obesity:** Those that have a BMI greater than 30 have a higher than normal risk than those that do not have a BMI greater than 30. "The "obesity epidemic" experienced by the United States over the past several decades threatens to reverse important progress against heart disease.

6. Heart Disease in Canada. Government of Canada. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html. Updated on February 10, 2017. Accessed on January 25, 2020

- **diet**: CVD can be correlated to high intake of saturated fat and cholesterol. Risk of dietary cholesterol intake can be correlated to atherosclerosis.
- **diabetes:** This condition is viewed as seriously as any of the other factors, such as smoking, high blood pressure, and high blood cholesterol, that a person can control. In fact, those with Type II diabetes have the same level of risk for a heart attack as those who have already had a heart attack.
- **alcohol use**: High alcohol intake is associated with cardiovascular disease. Keeping alcohol intake to the recommended levels can reduce you risk of heart disease.

Personal Risk Assessment

Early detection and treatment of conditions related to heart disease can reduce your risk of developing heart disease and death.

There are three screening tests used to a assess a person's risk for developing CVD: lipoprotein profile, blood pressure, and fasting plasma glucose.

Lipoprotein Profile

What: A blood test that measures total cholesterol, LDL "bad" cholesterol, HDL "good" cholesterol, and triglycerides (another form of fat in the blood). The test is given after a 9- to 12-hour fast.
Why: To find out if you have any of the following: high blood cholesterol (high total and LDL cholesterol), low HDL cholesterol, or high triglyceride levels. All affect your risk for heart disease.
When: All healthy adults should have a lipoprotein profile done at least once every 5 years. Depending on the results, your doctor may want to repeat the test more frequently.

Blood Pressure

What: A simple, test using an inflatable arm cuff.
Why: To find out if you have high blood pressure (also called hypertension) or prehypertension. Both are risk factors for heart disease.
When: At least every 2 years, or more often if you have high blood pressure or prehypertension.

Fasting Plasma Glucose

What: The preferred test for diagnosing diabetes. After you have fasted overnight, you will be given a blood test the following morning.
Why: To find out if you have diabetes or are likely to develop the disease. Fasting plasma glucose levels of 126 mg/dL or higher in two tests on different days mean that you have diabetes. Levels between 100 and 125 mg/dL mean that you have an increased risk of developing diabetes and may have prediabetes. Diabetes is an important risk factor for heart disease and other medical disorders.
When: At least every 3 years, beginning at age 45. If you have risk factors for diabetes, you should be tested at a younger age and more often.

Steps to Reducing the Risk of Cardiovascular Disease

Diet and nutrition can play a significant role in reducing the risk of cardiovascular disease. It is helpful to lower sodium intake, increase consumption of dietary fiber, and limit consumption of saturated fat, which promotes plaque formation. In addition, it is important to replace refined starches and added sugar, which can boost triglycerides, with whole grains, fruits, and vegetables. Eating foods rich in omega-3 fatty acids, especially fish, using alcohol in moderation, and opting for low or no-fat dairy products can all help reduce your cardiovascular disease risk. Emphasizing vegetable-based sources of protein, such as beans and legumes, can be beneficial, as well as consuming more soy products. It is also important to maintain a healthy weight and avoid smoking or chewing tobacco.

2.7.2. Cardio-Respiratory Function

The Circulatory and Respiratory Systems Work in Tandem

Animals are complex multicellular organisms that require a mechanism for transporting nutrients throughout their bodies and removing wastes. The human circulatory system has a complex network of blood vessels that reach all parts of the body. This extensive network supplies the cells, tissues, and organs with oxygen and nutrients, and removes carbon dioxide and waste compounds.

The medium for transport of gases and other molecules is the blood, which continually circulates through the system. Pressure differences within the system cause the movement of the blood and are created by the pumping of the heart.

Gas exchange between tissues and the blood is an essential function of the circulatory system. In humans, other mammals, and birds, blood absorbs oxygen and releases carbon dioxide in the lungs. Thus the circulatory and respiratory system, whose function is to obtain oxygen and discharge carbon dioxide, work in tandem.

The Respiratory System

Take a breath in and hold it. Wait several seconds and then let it out. Humans, when they are not exerting themselves, breathe approximately 15 times per minute on average. This equates to about 900 breaths an hour or 21,600 breaths per day. With every inhalation, air fills the lungs, and with every exhalation, it rushes back out. That air is doing more than just inflating and deflating the lungs in the chest cavity. The air contains oxygen that crosses the lung tissue, enters the bloodstream, and travels to organs and tissues. There, oxygen is exchanged for carbon dioxide, which is a cellular waste material. Carbon dioxide exits the cells, enters the bloodstream, travels back to the lungs, and is expired out of the body during exhalation.

Breathing is both a voluntary and an involuntary event. How often a breath is taken and how much air is inhaled or exhaled is regulated by the respiratory center in the brain in response to signals it receives about the carbon dioxide content of the blood. However, it is possible to override this automatic regulation for activities such as speaking, singing and swimming under water.

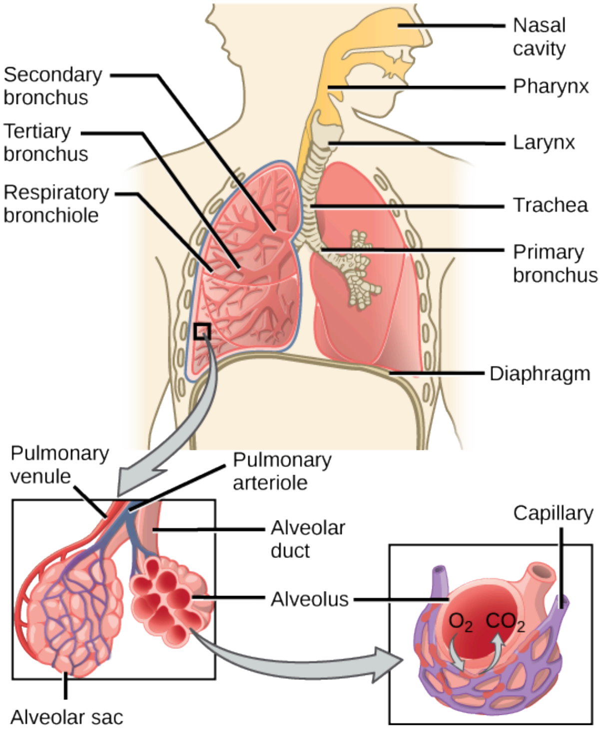
During inhalation the diaphragm descends creating a negative pressure around the lungs and they begin to inflate, drawing in air from outside the body. The air enters the body through the nasal cavity located just inside the nose (Figure 2.7.2.1). As the air passes through the nasal cavity, the air is warmed to body temperature and humidified by moisture from mucous membranes. These processes help equilibrate the air to the body conditions, reducing any damage that cold, dry air can cause. Particulate matter that is floating in the air is removed in the nasal passages by hairs, mucus, and cilia. Air is also chemically sampled by the sense of smell.

From the nasal cavity, air passes through the pharynx (throat) and the larynx (voice box) as it makes its way to the trachea (Figure 2.7.2.1). The main function of the trachea is to funnel the inhaled air to the lungs and the exhaled air back out of the body. The human trachea is a cylinder, about 25 to 30 cm (9.8–11.8 in) long, which sits in front of the esophagus and extends from the pharynx into the chest cavity to the lungs. It is made of incomplete rings of cartilage and smooth muscle. The cartilage provides strength and support to the trachea to keep the passage open. The trachea is lined with cells that have cilia and secrete mucus. The mucus catches particles that have been inhaled, and the cilia move the particles toward the pharynx.

The end of the trachea divides into two bronchi that enter the right and left lung. Air enters the lungs through the primary bronchi. The primary bronchus divides, creating smaller and smaller diameter bronchi until the passages are under 1 mm (.03 in) in diameter when they are called bronchioles as they split and spread through the lung. Like the trachea, the bronchus and bronchioles are made of cartilage and smooth muscle. Bronchi are innervated by nerves of both the parasympathetic and sympathetic nervous systems that control muscle contraction (parasympathetic) or relaxation (sympathetic) in the bronchi and bronchioles, depending on the nervous system's cues. The final bronchioles are the respiratory bronchioles. Alveolar ducts are attached to the end of each respiratory bronchiole. At the end of each duct are alveolar sacs, each containing 20 to 30 alveoli. Gas exchange occurs only in the alveoli. The alveoli are thin-walled and look like tiny bubbles within the sacs. The alveoli are in direct contact with capillaries of the circulatory system. Such intimate contact ensures that oxygen will diffuse from the alveoli into the blood. In addition, carbon dioxide will diffuse from the blood into the alveoli to be exhaled. The anatomical arrangement of capillaries and alveoli emphasizes the structural and functional relationship of the respiratory and circulatory systems. Estimates for the surface area of alveoli in the lungs vary around 100 m^2. This large area is about the area of half a tennis court. This large surface area, combined with the thin-walled nature of the alveolar cells, allows gases to easily diffuse across the cells.

VISUAL CONNECTION

Figure 2.7.2.1



Air enters the respiratory system through the nasal cavity, and then passes through the pharynx and the trachea into the lungs. Source: modification of work by NCI. [CC BY 4.0 *license*].

CONCEPTS IN ACTION

Watch this [video] for a review of the respiratory system.

The Circulatory System

The circulatory system is a network of vessels—the arteries, veins, and capillaries—and a pump, the heart. In all vertebrate organisms this is a closed-loop system, in which the blood is largely separated from the body's other extracellular fluid compartment, the interstitial fluid, which is the fluid bathing the cells. Blood circulates inside blood vessels and circulates uni-directionally from the heart around one of two circulatory routes, then returns to the heart again; this is a closed circulatory system. Open circulatory systems are found in invertebrate animals in which the circulatory fluid bathes the internal organs directly even though it may be moved about with a pumping heart.

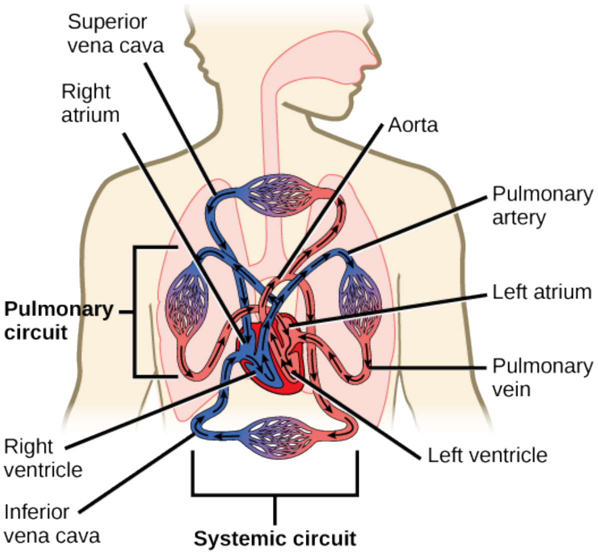
The Heart

The heart is a complex muscle that consists of two pumps: one that pumps blood through pulmonary circulation to the lungs, and the other that pumps blood through systemic circulation to the rest of the body's tissues (and the heart itself).

The heart is asymmetrical, with the left side being larger than the right side, correlating with the different sizes of the pulmonary and systemic circuits (Figure 2.7.2.2). In humans, the heart is about the size of a clenched fist; it is divided into four chambers: two atria and two ventricles. There is one atrium and one ventricle on the right side and one atrium and one ventricle on the left side. The right atrium receives deoxygenated blood from the systemic circulation through the major veins: the superior vena cava, which drains blood from the head and from the veins that come from the arms, as well as the inferior vena cava, which drains blood from the veins that come from the lower organs and the legs. This deoxygenated blood then passes to the right ventricle through the tricuspid valve, which prevents the backflow of blood. After it is filled, the right ventricle contracts, pumping the blood to the lungs for reoxygenation. The left atrium receives the oxygen-rich blood from the lungs. This blood passes through the bicuspid valve to the left ventricle where the blood is pumped into the aorta. The aorta is the major artery of the body, taking oxygenated blood to the organs and muscles of the body. This pattern of pumping is referred to as double circulation and is found in all mammals (Figure 2.7.2.2).

VISUAL CONNECTION

Figure 2.7.2.2

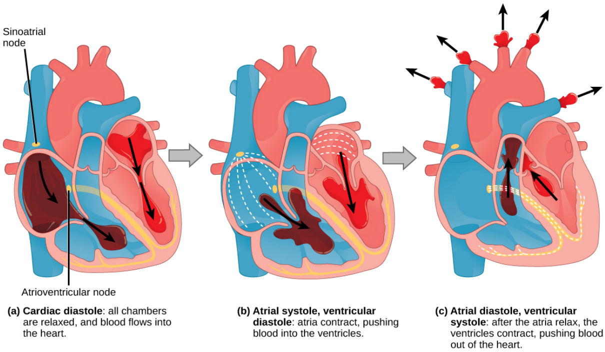


The heart is divided into four chambers: two atria and two ventricles. The chambers are separated by one-way valves. The right side of the heart receives deoxygenated blood from the body and pumps it to the lungs. The left side of the heart pumps blood to the rest of the body.

The Cardiac Cycle

The main purpose of the heart is to pump blood through the body; it does so in a repeating sequence called the cardiac cycle. The cardiac cycle is the flow of blood through the heart coordinated by electrochemical signals that cause the heart muscle to contract and relax. In each cardiac cycle, a sequence of contractions pushes out the blood, pumping it through the body; this is followed by a relaxation phase, where the heart fills with blood. These two phases are called the systole (contraction) and diastole (relaxation), respectively (Figure 2.7.2.3). The signal for contraction begins at a location on the outside of the right atrium. The electrochemical signal moves from there across the atria causing them to contract. The contraction of the atria forces blood through the valves into the ventricles. Closing of these valves caused by the contraction of the ventricles produces a "lub" sound. The signal has, by this time, passed down the walls of the heart, through a point between the right atrium and right ventricle. The signal then causes the ventricles to contract. The ventricles contract together forcing blood into the aorta and the pulmonary arteries. Closing of the valves to these arteries caused by blood being drawn back toward the heart during ventricular relaxation produces a monosyllabic "dub" sound.

Figure 2.7.2.3



In each cardiac cycle, a series of contractions (systoles) and relaxations (diastoles) pumps blood through the heart and through the body. (a) During cardiac diastole, blood flows into the heart while all chambers are relaxed. (b) Then the ventricles remain relaxed while atrial systole pushes blood into the ventricles. (c) Once the atria relax again, ventricle systole pushes blood out of the heart.

The pumping of the heart is a function of the cardiac muscle cells, or cardiomyocytes, that make up the heart muscle. Cardiomyocytes are distinctive muscle cells that are striated like skeletal muscle but pump rhythmically and involuntarily like smooth muscle; adjacent cells are connected by intercalated disks found only in cardiac muscle. These connections allow the electrical signal to travel directly to neighboring muscle cells.

The electrical impulses in the heart produce electrical currents that flow through the body and can be measured on the skin using electrodes. This information can be observed as an electrocardiogram (ECG) a recording of the electrical impulses of the cardiac muscle.

CONCEPTS IN ACTION

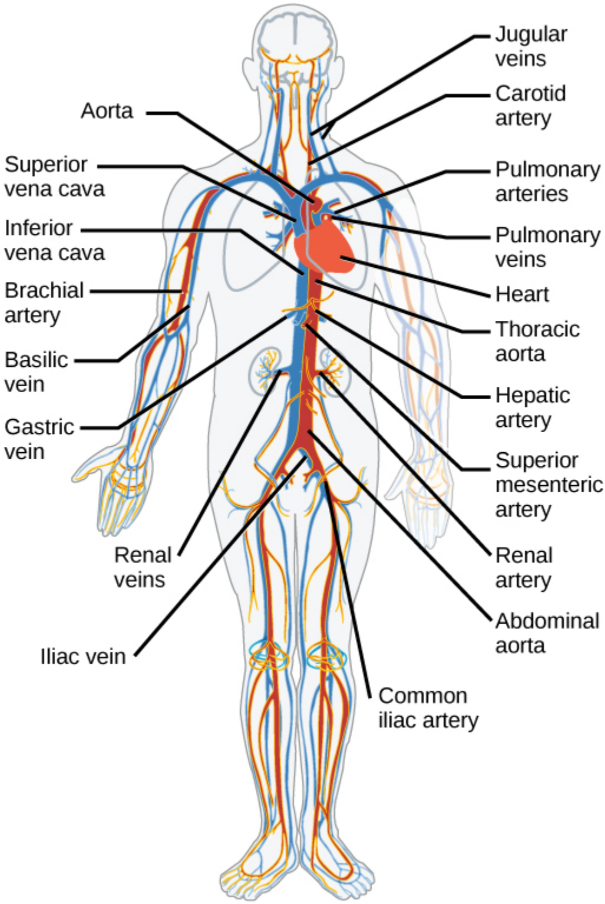
Visit this site and select the dropdown "Your Heart's Electrical System" to see the heart's pacemaker, or electrocardiogram system, in action.

Blood Vessels

The blood from the heart is carried through the body by a complex network of blood vessels (Figure 2.7.2.4). Arteries take blood away from the heart. The main artery of the systemic circulation is the aorta; it branches into major arteries that take blood to different limbs and organs. The aorta and arteries near the heart have heavy but elastic walls that respond to and smooth out the pressure differences caused by the beating heart. Arteries farther away from the heart have more muscle tissue in their walls that can constrict to affect flow rates of blood. The major arteries diverge into minor arteries, and then smaller vessels called arterioles, to reach more deeply into the muscles and organs of the body.

Arterioles diverge into capillary beds. Capillary beds contain a large number, 10's to 100's of capillaries that branch among the cells of the body. Capillaries are narrow-diameter tubes that can fit single red blood cells and are the sites for the exchange of nutrients, waste, and oxygen with tissues at the cellular level. Fluid also leaks from the blood into the interstitial space from the capillaries. The capillaries converge again into venules that connect to minor veins that finally connect to major veins. Veins are blood vessels that bring blood high in carbon dioxide back to the heart. Veins are not as thick-walled as arteries, since pressure is lower, and they have valves along their length that prevent backflow of blood away from the heart. The major veins drain blood from the same organs and limbs that the major arteries supply.

Figure 2.7.2.4



The arteries of the body, indicated in red, start at the aortic arch and branch to supply the organs and muscles of the body with oxygenated blood. The veins of the body, indicated in blue, return blood to the heart. The pulmonary arteries are blue to reflect the fact that they are deoxygenated, and the pulmonary veins are red to reflect that they are oxygenated. Source: modification of work by Mariana Ruiz Villareal. [CC BY 4.0 license]

2.7.3. Test Your Knowledge

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2.8. CANCER

"Cancer" is an adaptation of the chapter "Cancer" from *Concepts of Fitness and Wellness, 2nd Edition*, by Scott Flynn, Lisa Jellum, Jonathan Howard, Althea Moser, David Mathis, Christin Collins, Sharryse Henderson, and Connie Watjen, which is licensed under a CC BY NC SA 4.0 license. New material has been incorporated that includes Canadian cancer statistics and guidelines. Information that is not relevant to this course has been removed.

2.8.1. What is Cancer?

What Is Cancer?

Cancer is the name given to a collection of related diseases in which the body's cells begin to divide without stopping and spread into surrounding tissues.

Many cancers form solid tumors, which are masses of tissue. Cancers of the blood, such as leukemias, generally do not form solid tumors.

Cancerous tumors are malignant, which means they can spread into, or invade, nearby tissues. In addition, as these tumors grow, some cancer cells can break off and travel to distant places in the body through the blood or the lymph system and form new tumors far from the original tumour. Each person's cancer has a unique combination of genetic changes. As the cancer continues to grow, additional changes will occur. Even within the same tumor, different cells may have different genetic changes.

Unlike malignant tumors, benign tumors do not invade nearby tissues. However, some benign tumors can be quite large. When removed, they usually do not grow back, whereas malignant tumors sometimes do. Unlike most benign tumors elsewhere in the body, benign tumors in the brain can be life threatening.

More than one hundred diseases are classified as different forms of cancer, all of them characterized by the **uncontrolled growth of abnormal cells.** Cancer is triggered by mutations in a cell's genetic material. The cause of these changes may be inherited, or it may result from exposure to carcinogens, which are agents that can cause cancer. Carcinogens include chemicals, viruses, certain medical treatments such as radiation, pollution, or other substances and exposures that are known or suspected to cause cancer.[1] The National Institutes of Health has classified fifty-four different compounds as known cancer-causing agents in humans.[2]

Under normal conditions, a healthy cell will either repair any damage that has been done or self destruct so that no future cells will be affected. Cells become cancerous when their DNA is damaged, but they do not self-destruct or stop reproducing as normal cells would. As these abnormal cells continue their rapid growth, in most cancers they coalesce in a mass called a tumor. Cancer cells can overwhelm healthy cells and interfere with the healthy functioning of the body. They can also invade other organs and spread throughout the body in a process known as metastasis. Scientists and the medical community are giving considerable attention to the early stages of cancer, from the moment a healthy cell is exposed to a carcinogen to the point where cells with damaged DNA are replicating out of control. Intervention at any of these early stages could prove to be quite beneficial, because it is thought that most cancers are the result of lifestyle choices and environmental exposure.

The risk factors for different cancers can vary. For example,

1. Known and Probable Human Carcinogens. American Cancer Society.http://www.cancer.org/Cancer/CancerCauses/OtherCarcinogens/GeneralInformationaboutCarcinogens/known-and-probable -human-carcinogens. Updated November 3, 2016. Accessed April 15, 2018.
2. Israel B. How Many Cancers Are Caused by the Environment?. https://www.scientificamerican.com/article/how-many-cancers-are-caused-by-the-environment. Published May 10, 2010. Accessed April 15, 2018.

exposure to ultraviolet radiation from the sun and from tanning beds is a risk factor for skin cancer, while exposure to asbestos is a risk factor for mesothelioma cancer. Table 2.8.1.1 "The Risk Factors for Cancer" shows some common risk factors for a number of different types of cancer.

Table 2.8.1.1 *The Risk Factors for Cancer*

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age:** Most cancers occur in people over the age of sixty-five. However, people of all ages, including children, can get cancer. • **Family history:** Certain types of cancer have a genetic link. However, environmental factors may also play a part.	• **Tobacco**: Smoking or chewing tobacco greatly increases the risk for certain cancers, including cancer of the lungs, bladder, cervix, kidneys, mouth, and pancreas. • **Alcohol**: Drinking alcohol is linked to cancers of the mouth, throat, esophagus, and breast, as well as to cancers of the neck and head. • **Obesity**: Linked to cancers of the colon, uterus, pancreas, esophagus, kidney, and breast. • **Cooking techniques:** Grilling, smoking, and preparing meat at high temperatures forms carcinogens. • **Red meat:** The risk of colon cancer seems to increase with the consumption of red meat and processed meat. • **Cured meats:** According to a recent study, there is a mild risk of pancreatic cancer with the consumption of cured meats, such as sausage, pepperoni, bacon, ham, smoked turkey, salami, and hot dogs. • **Physical inactivity:** Linked to colon, breast, and other cancers. • **Exposure to chemicals:** People who have jobs that expose them to chemicals on a regular basis, such as construction workers and painters, have an increased risk of cancer. • **Viruses or bacteria:** Certain viruses or bacteria may increase the risk of developing cancer. For example, human papillomaviruses, which are sexually transmitted, are the primary cause of cervical cancer.

Note: There are numerous risk factors for cancers some of which are modifiable and others of which are not. Source: Cancer

Cancer Statistics

Cancer severely impacts Canadians and societies throughout the world. Cancer is surely the number one cause of death in Canada. Cancer statistics describe what happens in large groups of people and provide a picture in time of the burden of cancer on society. Statistics indicate how many people are diagnosed with and die from cancer each year, the number of people who are currently living after a cancer diagnosis, and the average age at diagnosis. They also reveal differences among groups defined by age, sex, racial/ethnic group, geographic location, and other categories.

Although statistical trends are usually not directly applicable to individual patients, they are essential for governments, policymakers, health professionals, and researchers to understand the impact of cancer on the population and to develop strategies to address the challenges that cancer poses to society. Statistical trends are also important for measuring the success of efforts to control and manage cancer.

Canadian Cancer Stats and Facts: [3]

- 43% of Canadian women and 45% of Canadian men will develop some type of cancer in their lifetime.
- 1 in 4 Canadians will die of cancer.
- The number of new cancer cases is steadily rising in Canada as the population increases in number and age.
- The risk of developing cancer increases significantly with age.
- Finding cancer early is imperative. The early you are diagnosed

3. Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer.html. Updated on February 10, 2019. Accessed on January 26, 2020

the faster you can receive treatment.

- In 2019 is was estimated that there would be 220,400 new cases of cancer in Canada with 82,100 people dying from cancer.
- Lung, colorectal, breast and prostate cancer made up half of all cancer diagnosis in 2019.
- The most common cancer diagnosis are breast cancer in women and prostate cancer in men.
- The leading cause of cancer death for both sexes is lung cancer.

Steps to Reducing the Risk of Cancer

On average, 604 Canadians will be diagnosed with cancer every day. On average, 225 Canadians will die from cancer every day.[4]

Although cancer is one of the leading causes of death worldwide, ongoing research and innovations in treatment have improved the outlook for cancer patients to the point where millions now survive or live with cancer, making it a chronic disease.

The American Institute for Cancer Research (AICR) and the Canadian Cancer Society (CCS) have published guidelines for preventing cancer and staying healthy They include several dietary and lifestyle choices, such as participating in physical activity and maintaining a healthy weight. In addition, AICR and CCS recommends consuming a plant-based diet.[5]

4. https://www.cancer.ca/en/cancer-information/cancer-101/cancer-statistics-at-a-glance/?region=on
5. Cancer Prevention and Early Detection Facts and Figures 2013. American Cancer Society. https://www.cancer.org/content/dam/cancer-org/

Several epidemiological studies have found a link between eating plenty of fruits and vegetables and a low incidence of certain cancers. Fruits and vegetables containing a wide variety of nutrients and phytochemicals may either prevent or reduce the oxidative damage to cell structures. Cruciferous vegetables, such as cauliflower, broccoli, and brussels sprouts, may also reduce the risk of certain cancers, such as endometrial, esophageal, and others. Also, studies have shown that the more fiber you have in your diet, the lower your risk of colon cancer. [6]

Supplementation may also be helpful to a limited degree. Vitamin D and antioxidants have been linked to lowering the risk of some cancers (however taking an iron supplement may promote others), but, **obtaining vital nutrients from food first is the best way to help prevent or manage cancer**. In addition, regular and vigorous exercise can lower the risk of breast and colon cancers, among others. Also, wear sunblock, stay in the shade, and avoid the midday sun to protect yourself from skin cancer, which is one of the most common kinds of cancer.[7]

research/cancer-facts-and-statistics/cancer-prevention-and-early-detection-facts-and-figures/cancer-prevention-and-early-detection-facts-and-figures-2013.pdf. Published 2013. Accessed April 15, 2018.

6. https://www.cancer.ca/en/prevention-and-screening/reduce-cancer-risk/make-healthy-choices/eat-well/antioxidants-and-phytochemicals/?region=on
7. Cancer Prevention: 7 Steps to Reduce Your Risk. Mayo Clinic. http://www.mayoclinic.com/health/cancer-prevention/CA00024. Updated November 29, 2017. Accessed April 15, 2018.

2.8.2. Types of Cancer

Introduction

There are more than 100 types of cancer. Types of cancer are usually named for the organs or tissues where the cancers form. For example, lung cancer starts in cells of the lung and brain cancer starts in cells of the brain. Cancers may also be described by the type of cell that formed them, such as an epithelial cell or a squamous cell.

Breast Cancer

Breast cancer is the second most common form of cancer in women, following non-melanoma skin cancer. One in 8 women are expected to develop breast cancer and 1 in 33 will die from it. [1] The breast is made up of glands called lobules that can make milk and thin tubes called ducts that carry the milk from the lobules to the nipple. Breast tissue also contains fat and connective tissue, lymph nodes, and blood vessels.

The most common type of breast cancer is ductal carcinoma, which

1. Breast Cancer. Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/breast-cancer.html. Updated on December 9, 2019. Accessed on January 26, 2020.

begins in the cells of the ducts. Breast cancer can also begin in the cells of the lobules and in other tissues in the breast. Ductal carcinoma in situ is a condition in which abnormal cells are found in the lining of the ducts but have not spread outside the duct. Breast cancer that has spread from where it began in the ducts or lobules to surrounding tissue is called invasive breast cancer. In inflammatory breast cancer, the breast looks red and swollen and feels warm because the cancer cells block the lymph vessels in the skin.

Breast cancer can occur in both men and women, but it is rare in men. Each year there are about 100 times more new cases of breast cancer in women than in men.

There is no single cause of breast cancer, but some factors that increase the risk of developing breast cancer include the following:[2]

- age
- obesity
- alcohol use
- family history
- in post-menopausal women, obesity and physical inactivity
- beginning to menstruate at an early age
- later than average menopause
- taking hormone replacement therapy

2. Breast Cancer. Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/breast-cancer.html. Updated on December 9, 2019. Accessed on January 26, 2020.

Screening for Breast Cancer

Clinical breast exams and regular breast self-exams. Routine examinations of the breasts by health care providers or by women themselves have not been shown to reduce deaths from breast cancer. However, if a woman or her health care provider notices a lump or other unusual change in the breast, it is important for her to get it checked out. The following link describes how to perform a breast self-exam.

Mammography. This screening method for breast cancer has been shown to reduce mortality from the disease among women aged from 40 to 74, especially those aged 50 or older.

Breast MRI. This imaging test is often used for women who carry a harmful mutation in the BRCA1 gene or theBRCA2 gene; such women have a high risk of developing breast cancer, as well as increased risk for other cancers.

Cervical Cancer

The cervix is the lower, narrow end of the uterus, the organ where a fetus grows. The cervix leads from the uterus to the vagina, also known as the birth canal.

The main types of cervical cancer are squamous cell carcinoma and adenocarcinoma. Squamous cell carcinoma begins in the thin, flat cells that line the cervix. Adenocarcinoma begins in cervical cells that make mucus and other fluids.

Long-lasting infections with certain types of human papillomavirus (HPV) cause almost all cases of cervical cancer. Vaccines that protect against infection with these types of HPV can greatly reduce the risk of cervical cancer.

Cervical cancer can usually be cured if it is found and treated in the early stages. In 2019 it was estimated that 1,350 women would develop cervical caner and that 410 would die from it.[3]

Risk factors for developing cervical cancer include the following:[4]

- becoming sexual active at a young age
- smoking
- a weakened immune system
- the use of birth control pills for extended periods
- giving birth several times

Screening for Cervical Cancer

Pap test and human papillomavirus (HPV) testing. Having a Pap test to check for abnormal cells in the cervix, or a test to check for HPV, can find cells that may become cervical cancer. These cells can be treated before cancer forms. Testing is generally recommended to begin at age 21 and to end at age 65,as long as recent results have been normal.

3. Cervical Cancer. Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/cervical-cancer.html. Updated on November 23, 2019. Accessed on January 26, 2020.
4. Cervical Cancer. Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/cervical-cancer.html. Updated on November 23, 2019. Accessed on January 26, 2020.

Colorectal Cancer

Colorectal cancer is cancer that starts in the colon or rectum. The colon and the rectum are parts of the large intestine, which is the lower part of the body's digestive system. During digestion, food moves through the stomach and small intestine into the colon. The colon absorbs water and nutrients from the food and stores waste matter called stool. Stool moves from the colon into the rectum before it leaves the body.

Most colorectal cancers are adenocarcinomas, cancers that begin in cells that make and release mucus and other fluids. Colorectal cancer often begins as an abnormal colon growth called a polyp, which may form on the inner wall of the colon or rectum. Some polyps may develop into cancer over time. Finding and removing polyps can prevent colorectal cancer.

Colorectal cancer is the one of the most common types of cancer in men and women in the Canada. It was estimated that 26,300 Canadian would be diagnosed with colorectal cancer in 2019 and that 9,500 would die from the disease.[5]

Risk factors for developing colorectal cancer include the following:[6]

- age (those over 50 years of age are particularly vulnerable)

5. Colorectal Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/colorectal-cancer.html. Updated on December 9, 2019. Accessed on January 26, 2020
6. Colorectal Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/colorectal-cancer.html.

- sex (males are more affected than females)
- family history
- obesity
- diet high in red or processed meat
- physical inactivity
- heavy alcohol consumption
- living with inflammatory bowel disease

Screening for Colorectal Cancer

The screening tests for colorectal cancer are **colonoscopy, sigmoidoscopy, and high-sensitivity fecal occult blood tests (FOBTs).** Deaths from colorectal cancer have decreased with the use of colonoscopies and fecal occult blood tests, which check for blood in the stool. Colonoscopy and sigmoidoscopy also help prevent colorectal cancer because they can detect polyps that can be removed before they develop into cancer. Expert groups generally recommend that people who are at average risk for colorectal cancer have screening beginning at age 50 through age 75.

Lung Cancer

Most lung cancer diagnoses are either non-small cell lung cancer or small cell lung cancer, depending on the way the cells look under a microscope. Non-small cell lung cancer is much more common than small cell lung cancer.

Updated on December 9, 2019. Accessed on January 26, 2020

Most cases of lung cancer are caused by smoking. Lung cancer is the leading cause of death from cancer in the United States. It was estimated that 29,300 Canadians would develop lung cancer in 2019 and that 21,000 would die from it.[7]

For most patients with lung cancer, current treatments do not cure the cancer.

Risk factors for developing lung cancer include the following:[8]

- smoking
- family history
- air pollution
- exposure to harsh chemicals

Symptoms of lung cancer include the following:[9]

- problems breathing
- chest pain
- coughing up blood
- chest infections

7. Lung Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/lung-cancer.html. Updated on October 21, 2019. Accessed on January 26, 2020.
8. Lung Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/lung-cancer.html. Updated on October 21, 2019. Accessed on January 26, 2020.
9. Lung Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/chronic-diseases/cancer/lung-cancer.html. Updated on October 21, 2019. Accessed on January 26, 2020.

- fatigue
- unexplained weight loss and lack of appetite

Screening for Lung Cancer

Screening tests are not recommended unless you have symptoms or family history of lung cancer. These tests include the following:

- **low-dose helical computed tomography:** This test has been shown to reduce lung cancer deaths among heavy smokers aged from 55 to 74.
- **biopsy:** In this test, a small sample of lung tissue is taken for analysis.
- **analysis of phlegm:** The mucus that is coughed up is analyzed.
- **bronchoscopy:** A thin tube is put through your mouth into the lung to look for tumours.

Prostate Cancer

The prostate gland makes fluid that forms part of semen. The prostate lies just below the bladder in front of the rectum. It surrounds the urethra, the tube that carries urine and semen through the penis and out of the body.

Prostate cancer is the most common cancer in men in Canada. It occurs more often in African-American men than in white men. African-American men with prostate cancer are more likely to die from the disease than white men with prostate cancer. In Canada 1 in 9 men will be diagnosed with prostate cancer with about 22,900 being diagnosed in 2019.[10]

Almost all prostate cancers are adenocarcinomas, cancers that begin in cells that make and release mucus and other fluids. Prostate cancer often has no early symptoms. Advanced prostate cancer can cause men to urinate more often or have a weaker flow of urine, but these symptoms can also be caused by benign prostate conditions.

Prostate cancer usually grows very slowly. Most men with prostate cancer are older than 65 years and do not die from the disease. Finding and treating prostate cancer before symptoms occur may not improve a patient's health or help him live longer. Men are advised to consult their doctor about their risk of prostate cancer and whether they need screening tests.

Risk factors for prostate cancer include the following:[11]

- age
- family history
- ethnicity
- diet high in fat, red meat and dairy
- inherited gene mutations

10. Prostate Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/prostate-cancer.html. Updated on October 21, 2019. Accessed on January 26, 2020.
11. Prostate Cancer. The Government of Canada. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/prostate-cancer.html. Updated on October 21, 2019. Accessed on January 26, 2020.

Ninety percent of prostate cancer cases are diagnosed early at stage I and II and 93% of Canadian men diagnosed with prostate cancer will live 5 years or more after their diagnosis.

Screening for Prostate Cancer

Screening tests are not recommended unless there is an increased risk for developing the cancer.

The screening test used for prostate cancer is the **PSA test**. This blood test, which is often done along with a digital rectal exam, is able to detect prostate cancer at an early stage. However, expert groups no longer recommend routine PSA testing for most men because studies have shown that it has little or no effect on prostate cancer deaths and leads to overdiagnosis and overtreatment.

Skin Cancer

Skin cancer is the most common type of cancer. About one third of all new cancer cases in Canada are skin cancer. Skin cancer usually forms in skin that has been exposed to sunlight or UV rays but can occur anywhere on the body. Skin consists of several layers. Skin cancer begins in the epidermis, or outer layer, which is made up of squamous cells, basal cells, and melanocytes.

There are several different types of skin cancer. Squamous cell and basal cell skin cancers are sometimes called **nonmelanoma skin cancers**. Nonmelanoma skin cancer usually responds to treatment and rarely spreads to other parts of the body.

Melanoma is more aggressive than most other types of skin cancer. Unless melanoma is diagnosed early, it is likely to invade nearby tissues and spread to other parts of the body. The number of cases of melanoma increases each year. Only 2 percent of all skin cancers are melanoma, but it causes the most deaths from skin cancer.

Look for the ABCDE warning signs:[12]

- **A**symmetry. Do the two halves not match if you imagine drawing a line through the mole?
- **B**orders. Are the edges uneven, scalloped or notched?
- **C**olours. Are there many shades (brown, red, white, blue or black)?
- **D**iameter greater than 6mm. Is the mole the size of a pencil eraser or larger?
- **E**volution. Has there been a change in size, shape, color, or height? Has a new symptom developed (like bleeding, itching or crusting)?

Screening for Skin Cancer

Skin exams. Doctors often recommend that people who are at risk for skin cancer examine their skin regularly or have a health care provider do so. Such exams have not been shown to decrease the risk of dying from skin cancer, and they may lead to overtreatment. However, people should be aware of changes in their skin, such as a new mole or a change to an existing mole, and report these to their doctor promptly.

12. Skin Cancer, The Government of Canada. https://www.canada.ca/en/public-health/services/sun-safety/skin-cancer.html. Updated on September 4, 2019. Accessed on January 26, 2020

Testicular Cancer

The testicles are two glands inside the scrotum, a sac of loose skin below the penis. The testicles make sperm and the hormone testosterone. Testicular cancer is the most common cancer in men aged from 15 to 34 years. The two main types of testicular tumors are seminoma and nonseminoma. Nonseminomas tend to grow and spread more quickly than seminomas. It was estimate that about 1,150 men would be diagnosed with testicular cancer in 2019 and that 35 would die from the disease.[13]

The most common sign of testicular cancer is a lump or swelling in the testicle. Most testicular cancers can be cured, even if they are diagnosed at an advanced stage. Treatment for testicular cancer can cause infertility by decreasing the amount of sperm made by the body. Men who want to have children may want to use sperm banking to store sperm before they begin treatment.

Screening for Testicular Cancer

There is no standard or routine screening test for testicular cancer. Most often, testicular cancer is first found by men themselves, either by chance or during self-exam. Sometimes the cancer is found by a doctor during a routine physical exam. The following link explains how to perform a testicular self-exam.

13. Testicular Cancer Statistics. The Cancer Society of Canada. https://www.cancer.ca/en/cancer-information/cancer-type/testicular/statistics/?region=on. Updated in 2019, Accessed on January 26, 2020.

Leukemia

Leukemia is cancer of the blood cells. Most blood cells form in the bone marrow. In leukemia, immature blood cells become cancer. These cells do not work the way they should and crowd out the healthy blood cells in the bone marrow.

Different types of leukemia depend on the type of blood cell that becomes cancer. For example, lymphoblastic leukemia is a cancer of the lymphoblasts, white blood cells that fight infection. White blood cells are the most common type of blood cell to become cancer. But red blood cells, cells that carry oxygen from the lungs to the rest of the body, and platelets, cells that clot the blood, may also become cancerous.

Leukemia occurs most often in adults older than 55 years, but it is also the most common cancer in children younger than 15 years.

Leukemia can be either acute or chronic. Acute leukemia is a fast-growing cancer that usually gets worse quickly. Chronic leukemia is a slower-growing cancer that gets worse slowly over time. The treatment and prognosis for leukemia depend on the type of blood cell affected and whether the leukemia is acute or chronic.

Lymphoma

Lymphoma is cancer that begins in cells of the lymph system. The lymph system is part of the immune system, which helps the body fight infection and disease. Because lymph tissue is found all through the body, lymphoma can begin almost anywhere.

The two main types of lymphoma are Hodgkin lymphoma and non-Hodgkin lymphoma (NHL). These can occur in both children and adults. The treatment and probability of a cure depend on the stage and the type of lymphoma.

2.8.3. Risk Factors for Cancer

Introduction

It is usually impossible to know why one person develops cancer and another does not. But research has shown that certain risk factors may increase a person's chances of developing cancer. There are also factors–called protective risk factors, or just protective factors–that are linked to a lower risk of cancer.

Cancer risk factors include exposure to chemicals or other substances, as well as certain behaviours. They also include circumstances that people cannot control, like age and family history. A family history of certain cancers can be a sign of a possible inherited cancer syndrome.

Most cancer risks, as well as protective factors, are initially identified in epidemiology studies. In these studies, scientists look at large groups of people and compare those who develop cancer with those who do not. These studies may show that those who develop cancer are more or less likely to behave in certain ways, or to be exposed to certain substances, than those who do not develop cancer.

On their own, such studies cannot prove that a behaviour or substance causes cancer. For example, the finding could be a result of chance, or the true risk factor could be something other than the suspected risk factor. But findings of this type sometimes get attention in the media, and this can lead to false beliefs about how cancer starts and spreads.

When many studies all point to a similar association between a potential risk factor and an increased risk of cancer, and when a possible mechanism exists that could explain how the risk factor could actually cause cancer, scientists can be more confident about the relationship between the two.

Although some risk factors can be avoided, others—such as growing older—cannot. Limiting exposure to avoidable risk factors may lower a person's risk of developing certain cancers.

Some of the most studied risk factors for cancer are listed below.

Age

Advancing age is the most important risk factor for cancer overall, and for many specific types of cancer. According to the most recent statistical data from the National Cancer Institute's Surveillance, Epidemiology, and End Results program, the median age of a cancer diagnosis is 66 years. This means that half of cancer cases occur in people below this age and half in people above this age. One-quarter of new cancer cases are diagnosed in people aged from 65 to 74.

But the disease can occur at any age. For example, bone cancer is most frequently diagnosed among people under age 20, with more than one-fourth of cases occurring in this age group. And 10 percent of leukemias are diagnosed in children and adolescents under 20 years of age, whereas only 1 percent of cancer overall is diagnosed in that age group.

Alcohol

Drinking alcohol can increase a person's risk of cancer of the mouth, throat, esophagus, larynx (voice box), liver, and breast. The more a person consumes alcohol, the higher his or her risk. The risk of cancer is much higher for those who drink alcohol and also use tobacco.

Doctors advise people who drink to do so in moderate amounts. The federal government's Dietary Guidelines for Americans defines moderate alcohol drinking as up to one drink per day for women and up to two drinks per day for men.

It has been suggested that certain substances in red wine, such as resveratrol, have anticancer properties. However, no evidence exists that drinking red wine reduces the risk of cancer.

Cancer-Causing Substances in the Environment

Cancer is caused by changes to certain genes that alter the way our cells function. Some of these genetic changes occur naturally when DNA is replicated during the process of cell division. But others are the result of environmental exposures that damage DNA. These exposures may include substances known as carcinogens, any substance that causes cancer, such as the chemicals in tobacco smoke; and radiation, such as ultraviolet rays from the sun. People can avoid some cancer-causing exposures, such as tobacco smoke and the sun's rays. But others are harder to avoid, especially if they are found in the air, water, and food, or the materials people use to do their jobs. Scientists are studying which exposures may cause or contribute to the development of cancer. Understanding which exposures are harmful, and where they are found, may help people avoid them.

Simply because a substance has been designated as a carcinogen, however, that does not mean that the substance will necessarily cause cancer. Many factors influence whether a person exposed to a carcinogen will develop cancer, including the amount and duration of the exposure and the individual's genetic background.

Diet

Many studies have looked at the possibility that specific dietary components or nutrients are associated with increases or decreases in cancer risk. Studies of cancer cells in the laboratory and of animal models have sometimes provided evidence that isolated compounds may be carcinogenic, or have anticancer activity.

But with few exceptions, studies of human populations have not yet shown definitively that any dietary component causes or protects against cancer. Sometimes the results of epidemiologic studies, which compare the diets of people with and without cancer have indicated that people with and without cancer differ in their intake of a particular dietary component.

However, these results show only that the dietary component is associated with a change in cancer risk, not that the dietary component is responsible for, or causes, the change in risk. For example, participants with and without cancer could differ in other ways besides their diet, and it is possible that some other difference accounts for the variance in cancer risk.

Hormones

Estrogens, a group of female sex hormones, are known human carcinogens. Although these hormones have essential physiological roles in both females and males, they have also been associated with an increased risk of certain cancers. For instance, taking combined menopausal hormone therapy (estrogen plus progestin, which is a synthetic version of the female hormone progesterone) can increase a woman's risk of breast cancer. Menopausal hormone therapy with estrogen alone increases the risk of endometrial cancer and is used only in women who have had a hysterectomy.

A woman who is considering menopausal hormone therapy should discuss the possible risks and benefits with her doctor.

Studies have also shown that a woman's risk of breast cancer is related to the estrogen and progesterone made by her ovaries, known as endogenous estrogen and progesterone. Being exposed for a long time and/or to high levels of these hormones has been linked to an increased risk of breast cancer. Increases in exposure can be caused by starting menstruation early, going through menopause late, being older at first pregnancy, and never having given birth. Conversely, having given birth is a protective factor for breast cancer.

Obesity

People who are obese may have an increased risk of several types of cancer, including cancers of the breast (in women who have been through menopause), colon, rectum, esophagus, kidney, pancreas, gallbladder, and the lining of the uterus, called the endometrium.

Conversely, eating a healthy diet, being physically active, and maintaining a healthy weight may reduce the risk of some cancers. These healthy behaviours also lessen the risk of other illnesses, such as heart disease, type II diabetes, and high blood pressure.

Sunlight

The sun, sunlamps, and tanning booths all give off ultraviolet (UV) radiation. Exposure to UV radiation causes early aging of the skin and skin damage that can lead to skin cancer.

People of all ages should limit the amount of time they spend in the sun, especially between mid-morning and late afternoon, and avoid other sources of UV radiation, such as tanning beds. It is important to keep in mind that UV radiation is reflected by sand, water, snow, and ice and can go through windshields and windows.

The best way to lessen UV damage when spending time in the sun is to wear long sleeves, long pants, a hat with a wide brim, and sunglasses with lenses that absorb UV radiation. Sunscreen with a sun protection factor (SPF) of at least 15 may help prevent skin cancer but does not work as well as staying out of the sun and wearing protective clothing.

Tobacco

Tobacco use is a leading cause of cancer and of death from cancer. People who use tobacco products, or are regularly exposed to environmental tobacco smoke (called secondhand smoke), have an increased risk of cancer because tobacco products and secondhand smoke have many chemicals that damage DNA.

Tobacco use causes many types of cancer, including cancer of the lung, larynx, mouth, esophagus, throat, bladder, kidney, liver, stomach, pancreas, colon and rectum, and cervix, as well as acute myeloid leukemia. People who use smokeless tobacco, such as snuff or chewing tobacco, have increased risks of cancers of the mouth, esophagus, and pancreas.

No level of tobacco use is safe. People who use any type of tobacco product are strongly urged to quit. People who quit smoking, regardless of their age, have substantial gains in life expectancy compared with those who continue to smoke. Also, quitting smoking at the time of a cancer diagnosis reduces the risk of death.

2.8.4. Cancer Prevention

Cancer Prevention Overview

Cancer prevention is action taken to lower the chance of getting cancer. In addition to the physical problems and emotional distress caused by cancer, the high costs of care are also a burden to patients, their families, and to the public. Preventative measures can lower the number of new cases and cancer deaths, and reduce the burden of cancer on society.

Scientists are studying ways to prevent cancer, including the following:

- avoiding or controlling factors known to cause cancer
- improving diet and adopting a healthier lifestyle
- finding precancerous conditions early
- incorporating chemoprevention (the use of medicines that treat precancerous conditions or prevent cancer from starting)

Antioxidants and Phytochemicals

It is not simply vitamins and minerals alone that help fight against disease but their form within food and their combination with other substances within food. It is therefore best to choose whole foods to get vitamin and minerals than take supplements.[1]

1. What are antioxidants and phytochemicals? The Canadian Cancer Society. https://www.cancer.ca/en/

Antioxidants are certain vitamins and minerals found mainly in vegetables and fruits. Examples of these include the following:

- vitamin A
- vitamin C
- vitamin E
- selenium

Phytochemicals are found in fruits, vegetables and grains. Some phytochemicals act as antioxidants. Examples of these include the following:

- carotenoids
- flavonoids
- indoles
- isoflavones

How do they protect against cancer?

Antioxidants protect our body against free radicals. Free radicals can damage cells which may lead to cancer. Antioxidants are believed to protect by removing free radicals before they cause damage. Phytochemical's may help reduce the risk of cancer, however there is still lots to be learnt about them. The best way to benefit from antioxidants and phytochemical's is to eat a well balanced diet containing a variety of fruits, vegetables and grains.

prevention-and-screening/reduce-cancer-risk/make-healthy-choices/eat-well/antioxidants-and-phytochemicals/?region=on. Updated in 2020. Accessed February 2, 2020

2.8.5. Cancer Treatment

Patients and their doctors must choose from a plethora of cancer treatments. The types of treatment a patient receives depend on the type of cancer a person has and how advanced it is. Some people with cancer will have only one treatment. But most people have a combination of treatments, such as surgery with chemotherapy and/or radiation therapy. They may also undergo immunotherapy, targeted therapy, or hormone therapy.

Clinical trials are also an option for some patients. Clinical trials are research studies that involve people. Understanding what they are and how they work can help patients decide if taking part in a trial is a good option.

When seeking treatment for cancer, patients have a lot to learn and consider. It is normal for them to feel overwhelmed and confused. Talking with their doctor and learning all they can about their treatment options, including clinical trials, can help them make a decision they feel good about.

2.8.6. Test Your Knowledge

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2.9. MENTAL HEALTH

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2.9.1. Mental Health Overview

What Is Mental Health?

> This chapter is an adaptation of "About Mental Health," a Government of Canada webpage.

Mental health is the state of your psychological and emotional well-being. It is a necessary resource for living a healthy life and a main factor in overall health. It does not mean the same thing as mental illness. However, poor mental health can lead to mental and physical illness.

Good mental health allows you to feel, think and act in ways that help you enjoy life and cope with its challenges. This can be positively or negatively influenced by:

- life experiences, such as:
  - family situation
  - the death of a loved one
  - financial and employment status
- relationships with others, such as your:
  - friends
  - family members
  - co-workers
  - schoolmates
- work or school environment
- physical health, such as problems caused by:
  - long-term illness

    - problematic substance use
- the type of community you live in
    - is it a supportive and trusting community or one where everyone keeps to themselves?

How Can You Take Care of Your Mental Health?

Take care of your mental health in the same way you would take care of your physical health. It takes practise, patience and support.

You can maintain or improve your mental health by following the advice below:

- Know and accept that life can be challenging.
- Know and accept your strengths and weaknesses.
- Set realistic goals for yourself.
- Accept yourself and others. This is the basis of self-esteem.
- Learn to recognize and understand that you and others have both positive and negative feelings.
- Create a sense of meaning in your life by learning and trying new activities, like starting a hobby.
- Create healthy, trusting relationships with people who accept and support you.

Building a supportive community is an important way to improve mental health. Making meaningful connections with your family, friends, peers, colleagues and other members of your community can help you feel:

- like you belong
- safe and secure
- free to express your thoughts and feelings on issues that are important to you

You can help create a healthy and safe environment where you live, learn, work and play by:

- knowing and accepting that everyone has difficulties in their lives
- taking part in local events and getting to know your neighbours
- finding ways to get involved and giving back to your community
- supporting and including people of different ages and backgrounds in your community

How Does Being Mentally Healthy Benefit You?

Being mentally healthy can:

- increase **coping skills** (how we handle difficult experiences and stresses),
- improve **self-esteem** (feeling confident in your worth and abilities), and
- improve **resiliency** (your ability to successfully move on after a negative event and regain control of your life).

Increasing coping skills, self-esteem and resiliency encourages people to

- create healthy relationships,
- positively interact with their community, and
- talk openly about their mental health, including their needs and wants.

Feeling confident and competent in these areas can improve emotional strength. In turn, this can help improve and maintain your level of mental health.

2.9.2. Mental Health Disorders

While support is an essential part of helping someone with a mental health disorder, it is also important to encourage individuals to seek professional help.

Anxiety Disorders

This section is adapted from "Mental Health – Anxiety Disorders," a Government of Canada webpage.

The Issue

Anxiety disorders are the most common of all mental health problems. It is estimated that one in 10 Canadians is affected by them. These disorders can be successfully treated so it is important to recognize the difference between being anxious in response to a real event, and an anxiety disorder which produces fear or distress that is out of proportion to the situation.

Background

Everyone feels anxious at certain times. Workplace pressure, planning a big event or writing an exam can cause feelings of wariness, or even fear. While these situations are uncomfortable, they may be more severe for those who suffer from an anxiety disorder.

People who suffer from anxiety disorders have long periods of intense feelings of fear or distress out of proportion to real events. Their brains interpret real or imagined events to be much more risky or dangerous than they really are. Their lives are full of unease and fear, which interferes with their personal and professional relationships.

Anxiety disorders affect children as well as adults. All too often, people mistake these disorders for mental weakness or instability. The social stigma attached to mental illness often prevents those with anxiety disorders from asking for help.

Anxiety disorders affect behaviour, thoughts, emotions and physical health. It is believed that a combination of biological factors, brain functions, personal circumstances, combined with social and economic factors, cause anxiety disorders, the same way that heart disease or diabetes are caused by a combination of factors.

People often suffer from more than one anxiety disorder, and those with anxiety disorders often suffer from depression, eating disorders or substance abuse as well. The good news is that anxiety disorders can be successfully treated once they are recognized.

Types and Symptoms of Anxiety Disorders

Panic Disorder

People with this disorder have panic attacks in which they are suddenly terrified, without warning. They may also have one or more of the following symptoms:

- chest pain
- heart palpitations
- shortness of breath
- dizziness
- stomach discomfort
- feelings of unreality
- fear of dying

If you avoid situations that may cause a panic attack, the condition is known as panic disorder with agoraphobia.

Phobias

Phobias are only considered disorders if they keep the affected person from leading a normal life. For example, people who have a phobia (or fear) of being in places or situations from which escape might be difficult (or embarrassing) may be too fearful to even leave the house. This type of phobia is called agoraphobia.

There are two categories of phobias:

- social phobia (fear of social situations), and
- specific phobias, such as fear of flying, spiders, blood or heights.

Social Phobia

People with a social phobia are intensely fearful of a social situations. Being with people can paralyze them and make them feel unnaturally self-conscious. They're worried about being judged, and are terrified of doing something wrong in front of other people. Because their feelings are so intense, they tend to avoid situations that might trigger their fear. This dramatically limits their ability to lead a normal life or to interact with others.

Specific Phobia

People with a specific phobia have an overwhelming, irrational fear of a specific environment or object. Examples include fears of flying, bugs, snakes, heights or open spaces. They are unable to control their terror, even though they may recognize that their fears are ungrounded. Exposure to the feared situation causes them extreme anxiety and panic

Post-Traumatic Stress Disorder

This is a disorder that is triggered by a victim reliving a terrifying experience in which they were threatened with, or suffered, physical, mental or emotional harm. Survivors of rape, natural disasters, child abuse or war may all develop post-traumatic stress disorder. The most common symptoms are the following:

- flashbacks, in which you re-live the terrifying experience
- nightmares
- depression
- feelings of anger or irritability.

Obsessive-Compulsive Disorder

People with this disorder suffer from persistent unwanted thoughts (obsessions) and/or behavioural habits (compulsions), which they cannot control. Typical obsessions are:

- contamination (there are germs all over you)
- doubt (Did I turn off the stove or the iron?)
- disturbing sexual thoughts
- disturbing religious thoughts.

Compulsions include constant:

- washing
- organizing
- checking
- counting.

Generalized Anxiety Disorder

With this disorder, people worry excessively about ordinary, everyday situations and events. The condition usually lasts for at least six months. During this time the affected person expects the worst to happen, even when there is no evidence that it will. The physical symptoms may include the following:

- nausea
- trembling
- fatigue
- muscle tension
- headache

Treatment of Anxiety Disorders

Anxiety disorders can be successfully treated. The most common form of treatment is a combination of drug therapy and cognitive-behavioural therapy (CBT).

Because most anxiety disorders have some biological basis, the most common drugs prescribed are anti-depressants and anti-anxiety drugs.

CBT involves helping people to turn their anxious thoughts and feelings into more rational ones. Sometimes people will benefit from being exposed in a controlled way to the object and situation they fear. Some CBT techniques have been developed to deal with specific disorders. For example, people with panic disorder can benefit from learning new breathing and meditation techniques, which can help them deal with their anxiety.

Support groups and learning more about the disorder can also help a great many people deal with anxiety disorders. Involving family and friends who are also affected by the disorder, can help people recover or learn how to cope with their condition.

The most important first step in treatment is to get a proper diagnosis from a specialist in anxiety disorders. Many people suffer for 10 years or more before getting the right treatment.

Minimizing Your Risk

If you suspect that you or someone you know suffers from an anxiety disorder, talk to your health care provider. They can recommend you to a specialist in anxiety disorders or direct you to a specialized anxiety disorder clinic. These points may also help you cope:

- Pick a time and place to do your worrying and make it the same time and place every day. Spend 30 minutes thinking about your fears and what you can do about them. Don't dwell on what 'might' happen, focus on what is actually happening.

- Learn to relax. Yoga, muscle relaxation, biofeedback and deep breathing can all help you deal with your anxieties. See the link in the Need More Info? section for more information. For muscle relaxation, simply lie down and focus on one muscle group at a time, starting with your feet or your head. Tense the muscle for a few seconds then let it go. Move on to the next muscle.
- Get plenty of sleep; it will help you put things in perspective.
- Confront the things that have made you anxious in the past. You might start by making a list. Then picture yourself confronting these situations. This way you can develop techniques to deal with them before you are actually anxious. You might also try examining the level of your anxiety, on a scale of one to 10.
- Exercise regularly; it can give you a sense of well-being and help lessen the anxiety.
- Avoid alcohol and recreational drugs. Although they may seem to relax you while you are taking them, afterwards they can lead to even more anxiety and depression.
- Avoid the caffeine found in coffee, tea, soft drinks and chocolate. They can increase your level of anxiety. Also avoid over-the-counter diet pills, and cough and cold medications.
- For more information and help, contact the mental health organizations listed in the Need More Info? section.

Depression

This section is an adaptation of "What is Depression," a Government of Canada webpage.

Everybody goes through "ups and downs" in their lives. Sometimes we use the term "depression", or "depressed" to describe these everyday feelings.

But the normal experiences of life shouldn't be confused with the serious medical illnesses known as mood disorders. There are different kinds of depressive mood disorders, including bipolar disorder (manic-depressive illness), perinatal depression, but clinical depression, or major depression is the most common mood disorder.

Mood disorders are very real illnesses that can have serious and sometimes fatal results. They affect the entire body and not just the mind. Their physical symptoms can range from fatigue to stomach complaints or muscle and joint pain. Many people never realize that they are suffering from depression.

Mood disorders are one of the most common mental illnesses in the general population. According to Statistics Canada's 2012 Canadian Community Health Survey (CCHS) on Mental Health, 5.4% of the Canadian population aged 15 years and over reported symptoms that met the criteria for a mood disorder in the previous 12 months, including 4.7% for major depression and 1.5% for bipolar disorder.

Further, almost one in 8 adults (12.6%) identified symptoms that met the criteria for a mood disorder at some point during their lifetime, including 11.3% for depression and 2.6% for bipolar disorder.[Footnote 1]

Studies have consistently documented higher rates of depression among women than among men: the female-to-male ratio averages 2:1.[Footnote 2]

What Causes Mood Disorders?

Mood disorders have no single cause, but several risk factors interact to produce the clinical symptoms of the various mood disorders. Individuals with depression and bipolar disorder often find a history of these disorders among immediate family members.[Footnote 3],[Footnote 4] Many different genes may act together and in combination with other factors to cause a mood disorder. Research is getting closer to identifying the specific genes that contribute to depression.

One episode of major depression is a strong predictor of future episodes. More than 50% of individuals who have an episode of major depression experience a recurrence.[3] Traditionally, stress has been viewed as a major risk factor for depression. Recent research suggests that stress may only predispose individuals for an initial episode, but not for recurring episodes.[Footnote 5] Some individuals are more susceptible than others to depression following traumatic life vents, when in difficult or abusive relationships, or as a result of socio-economic factors such as income, housing, prejudice and workplace stress. A strong association exists between various chronic medical conditions and an increased prevalence of major depression.[Footnote 6] Several chronic medical conditions, such as stroke and heart disease, obesity, Parkinson's disease, epilepsy, arthritis, cancer, AIDS, chronic obstructive pulmonary disease (COPD), and dementia and Alzheimer's Disease may contribute to depression. This association may result from physiological changes associated with these conditions, such as changes in various neurotransmitters, hormones and the immune system, or from associated disability and poor quality of life. In addition, some medications used to treat physical illnesses tend to cause depression. People who cope with more than one medical condition may be at particular risk for depression. Effective treatment of chronic physical illness includes the assessment, early detection and treatment of depression.

What Are the Symptoms of Depression?

Each person is different and will have unique symptoms, but here are some of the more common symptoms of depression:

- depressed mood
- feelings of guilt, worthlessness, helplessness or hopelessness
- loss of interest or pleasure in usually-enjoyed activities
- change in weight or appetite
- sleep disturbances
- decreased energy or fatigue (without significant physical exertion)
- thoughts of death
- poor concentration of difficulty making decisions

If you or someone you know has had any of these symptoms most days for more than two or three weeks, contact your doctor, or a registered mental health professional to discuss the symptoms.

If you or someone you know is having recurring thoughts of suicide it's very important that they get medical help right away.

Additional Resources

- Screening for Depression
- What can I do to help myself I feel depressed?
- What should I know about bipolar disorder (manic

depression)?
- What causes depression and how can Aboriginal individuals and communities deal with it?
- Report from the Canadian Chronic Disease Surveillance System: Mood and Anxiety Disorders in Canada, 2016
- Report from the Canadian Chronic Disease Surveillance System: Mental Illness in Canada, 2015
- Mood and anxiety disorders in Canada
- Human Face of Mental Health and Mental Illness
- Data Blogs
    - Mental Illness in Canada
    - Mental Health Awareness Week
    - Mood & Anxiety Disorders in Canada
- Mood Disorders Society of Canada
- Canadian Psychological Association
- Canadian Psychiatric Association
- Canadian Mental Health Association
- Mental Health Commission of Canada
- Centre for Addiction and Mental Health

Bipolar Disorder

This section is an adaptation of "What Should I Know About Bipolar Disorder (Manic-Depression)?," a Government of Canada webpage.

What Should I Know About Bipolar Disorder (Manic-Depression)?

Bipolar disorder (formerly called manic-depression) is a bio-chemical condition that results in an imbalance of the neurotransmitters in the brain. Genetic make-up is thought to play a role but so too are environmental pressures such as your family, work and social environment, stress, injury, illness and hormone imbalances.

Bipolar disorder is characterized by mood swings that can last for days, weeks or even months. These swings range from mild to severe. The "bi" in bipolar disorder refers to the dual nature of these mood swings – from feelings of great happiness and elation to sadness and despair. In its most severe expression, bipolar disorder can result in mania which is defined as strongly held beliefs that you are a famous person, have special physical abilities or knowledge, or that you are invincible. People can experience mania as a euphoric period. Unfortunately, mania is also accompanied by unwise behaviours tied to the false beliefs. These can include spending sprees, risky sexual activity, excessive drinking or drug use, and other reckless activities or decisions. Bouts of mania are followed by the depths of depression where people feel worthless and hopeless. This phase of bipolar disorder is excruciatingly painful. The mood swings of bipolar disorder deeply affect relationships, social and work functioning and can, in the extreme, bring people into contact with the law.

Symptoms of mania can include the following:

- feelings of invincibility
- more physical energy
- less need for sleep
- inappropriate excitement
- irritability or excessive anger
- increased activity, talking and moving

- increased sexual thoughts and activity, sometimes resulting in promiscuity and inappropriate or unsafe behaviour
- disconnected and racing thoughts
- racing speech
- loss of self-control and impulsive or reckless behaviour
- inappropriate spending
- hallucinations and delusions

Some symptoms of depression may include the following:

- feelings of sadness and loss
- feelings of guilt and worthlessness
- feelings of extreme impatience, irritability, or a short temper
- loss of interest or pleasure in usually-enjoyed activities
- changes in weight or appetite
- changes in sleeping patterns like insomnia
- reduced ability to think clearly or make decisions
- difficulties in concentrating or with short-term memory loss
- constantly feeling tired
- noticeable lack of motivation
- anxiety and restlessness, sometimes leading to panic attacks
- muscle and joint pain
- constipation or other intestinal problems
- frequent headaches
- lack of interest in sex
- recurring thoughts of suicide or self-harm
- withdrawal from friends and family

The aftermath of a manic episode can be devastating both for individuals and for families and loved ones. They may now be dealing with financial hardship, the health and relational effects of risky sexual practices or the physical consequences of substance abuse or personal injury accidents or assaults that may have occurred during mania. The depressive phase can involve the risk of suicide.

Bipolar disorder is a serious illness but with treatment, people can recover and lead fulfilling lives.

If you think you or someone you know has bi-polar disorder it is important to get help from mental health professionals, most often a psychiatrist alone with a team of providers who have a variety of skills. Help involves a diagnosis – which can take some time while the mental health professional gets to know you or person you are concerned about and their symptoms. Next, psychiatric medication will be prescribed. Again, it may take time to get the right one at the right dosage level. You or the person you are concerned about will also learn that people with bipolar disorder do best with a combination of medication and personal therapy – which may extend to family therapy. Peer support and self-help are invaluable as nothing can substitute for the message that "you are not alone."

Living with bipolar illness is not easy but full recovery is possible. The first step is taking personal responsibility for your own health.

Some Statistics

- One percent (1%) of Canadians aged 15 years and over reported symptoms that met the criteria for a bipolar disorder in the previous 12 months. About 1 in 50 adults aged 25-44 years or 45-64 years reported symptoms consistent with bipolar disorder at some point in their lifetime. The proportion of men and women who met the lifetime criteria for bipolar disorder decreased slightly with age. (2002 Mental Health and Wellbeing Survey, Statistics Canada)
- Nearly 9 out of 10 Canadians who reported symptoms that met the 12-month criteria for bipolar disorder (86. 9%) reported that the condition interfered with their lives. (2002 Mental Health and Wellbeing Survey, Statistics Canada)
- While most people with bi-polar disorder (or depression) will not commit suicide, the risk of suicide among those with

bipolar disorder is higher than in the general population.

Additional Resources

More information on bipolar disorder can be found in the Public Health Agency Report: "The Human Face of Mental Health and Mental Illness In Canada 2006".

More information and resources on bipolar disorder can be found at the following web sites:

- Mood Disorders Society of Canada
- Canadian Psychological Association
- Canadian Psychiatric Association
- Canadian Mental Health Association
- Centre for Addiction and Mental Health
- Centre For Applied Research In Mental Health and Addiction

Eating Disorders

> This section is a reproduction of "Eating Disorders in Teens: Information for Parents and Caregivers," a Government of Canada webpage.

What Are the Warning Signs of an Eating

Disorder?

If they are not recognized and addressed, eating disorder behaviours can result in serious physical and emotional problems.

Here are some signs that your teen may be struggling with an eating disorder and needs immediate help:

- irritability, depression and social withdrawal
- excessive preoccupation with calories, food or "healthy eating"
- frequent negative comments about their weight and shape
- restriction of food intake
- making excuses to avoid eating
- significant weight loss or weight gain (regardless of previous weight)
- compulsive exercising
- frequently eating excessive amounts of food in a short period of time
- consuming food alone, at night or secretly
- using laxatives or diet pills
- going to the bathroom immediately after eating

How To Help Someone With an Eating Disorder

You know your teen better than anyone. If you notice unusual behaviours and are concerned your teen may have an eating disorder, your first step will be to talk to them. Encourage them to express their worries and concerns. Use "I" statements and let them know that you are aware they are struggling. For example, you may say: "I've noticed that you may be going through a rough time lately. I'm happy to listen or talk and see if I can help."

Stay calm and avoid judging or blaming your teen. A teen who is struggling with an eating disorder may resist disclosing his or her behaviours or feelings. Let your teen know you care about them no matter what and you will support them through difficult times.

You can find out more about eating disorders and how to help your teen by checking out the links at the end of this information sheet.

Prevention and Treatment of Eating Disorders

Eating disorders can be prevented if action is taken at the first signs of recurrent preoccupation with body weight and image.

Teens can learn healthy ways to cope with their worries and life challenges. Parents, schools and the community all have a role to play in building healthy coping skills that will help avoid eating disorders.

If the symptoms of an eating disorder are severe, medical treatment may be needed to reverse a physical condition that could otherwise become critical. If you notice that your teen's mental and physical health is rapidly deteriorating, don't hesitate to seek immediate help from your primary health care provider or community health care centre.

The majority of teens with eating disorders are able to recover with support from their family, friends and community. There are many resources available across Canada that can help you find reliable information and connect to your local resources.

Where Can I Find Information and Resources About Eating Disorders?

- National Eating Disorder Information Centre (NEDIC)
  1-866-663-4220 or 416-340-4156 in TorontoCategory: National information resource centre and help lineNEDIC provides

information and resources about eating disorders, helps individuals find local treatment and support and offers support through Canada's only national toll-free helpline. NEDIC holds a national database of service providers that work with eating disorders.

- Canadian Mental Health Association (CMHA)Category: Raising awareness and providing resources on a national levelCMHA is a nation-wide, voluntary organization that promotes the mental health of all and supports the resilience and recovery of people experiencing mental illness.
- Eating Disorders Association of Canada (EDAC)Category: Canadian organization of professionals working in the field of eating disordersEDAC is a Canadian organization whose mandate is to best serve the needs of those whose lives are impacted by eating disorders.
- National Initiative for Eating Disorders (NIED)Category: Raising awareness and providing resources on a national levelNIED aims to increase awareness and education of the chronic situation facing those with eating disorders and their families in Canada.
- Families Empowered and Supporting Treatment of Eating Disorders (F.E.A.S.T.)Category: Canadian task force of parents supporting parents and providing resourcesF.E.A.S.T. is an international non-profit organization of and for caregivers of loved ones suffering from eating disorders. Their mission is to support, promote evidence-based treatment and advocate for research and education.
- Eating Disorder Foundation of Canada (EDFC)Category: Support to community groups making progress in the field of eating disordersThe EDFC raises funds to support education, treatment, research and supportive housing and plays a leadership role in bringing local, provincial and national initiatives together.
- Anorexia and Bulimia QuébecCategory: Resources and information in English and in French for those suffering

directly and indirectly from eating disordersAnorexia and bulimia Quebec guarantees immediate, free professional support to people affected by eating disorders. All services are offered in French and in English.
- The Link Program – New BrunswickCategory: Provides assistance for individuals to access local services in French and EnglishThe Link Program enables individuals with any kind of problem including eating disorders to access local help services through a Link Companion in New Brunswick.To find community-specific information about eating disorders go to "Helping Tree" on the top menu bar of THE LINK Program web site and then choose your community.

Schizophrenia

This section is a reproduction of "Schizophrenia in Canada," a Government of Canada webpage.

Schizophrenia in Canada

Schizophrenia is a psychotic disorder that can affect the way a person interacts with and understands the world.

Symptoms of active schizophrenia include delusions, hallucinations, disorganized speech and/or behaviour, and impaired cognitive ability.[Footnote 1] The severity, duration and frequency of these symptoms can cause social and occupational challenges.

Causes of schizophrenia are not fully understood. Structural changes in the brain and genetics, combined with lifestyle and environmental factors, may play a role.

While there is no cure for schizophrenia, programs and treatments are available to help manage symptoms in the community and at work. Reducing public misunderstanding and fear of the disease can reduce stigma and support affected individuals.[Footnote 2]

According to national data (2016-2017), of Canadians aged 10+:[Footnote 3]

- 1 out of 100 were living with diagnosed schizophrenia:
  - 56% were men
  - 44% were women
- About 30% of newly diagnosed cases were aged 20 to 34 years old.
- Among this group, the rate of new cases was more than 2x higher in men compared to women. In general, men experience an earlier onset of schizophrenia than women.
- The all-cause mortality rate in people diagnosed with schizophrenia was 2.8x higher than those without.
- Of people aged 1+, over 147,500 Canadians used health services for schizophrenia.[Footnote 3]
  - 60% were men
  - 40% were women

Have Rates of Schizophrenia Changed Over Time?

Between 2002-2016:

- The number of Canadians living with diagnosed schizophrenia increased by an average of 3% per year.[Footnote 3]

- The number of new cases declined during this period.Footnote 3Footnote 4

The Canadian Chronic Disease Surveillance System (CCDSS) is supported by a pan-Canadian partnership between the Public Health Agency of Canada and all provinces and territories. Schizophrenia data in CCDSS are updated biennially.

Learn More About Schizophrenia

Get Data Canadian Chronic Disease Surveillance System – Public Health Infobase
More Schizophrenia Society of Canada | World Health Organization

Personality Disorder

> This section is adapted from Statistics Canada "Section F – Personality Disorders" (2015). This does not constitute an endorsement by Statistics Canada of this product.

A personality disorder (PD) is characterized by a stable pattern of inner experience and behaviour that deviates significantly from the expectations of society, and can lead to marked impairments in social and occupational functioning. PDs are considered a major mental health problem because of their prevalence and the disability they produce.[69] Ultimately, individuals with a PD have difficulties with interpersonal relationships, and often demonstrate irritability, hostility, and fearfulness. Their personality traits (i.e., attitudes, thoughts, behaviours, temperament) are expressed inappropriately and become maladaptive. According to the DSM-IV,[7] there are ten PDs that are distinctively diagnosed and are grouped into three clusters based on descriptive similarities: Cluster A includes Paranoid, Schizoid, and Schizotypal PDs—individuals with these disorders likely appear odd or eccentric; Cluster B includes Antisocial, Borderline, Histrionic, and Narcissistic PDs—individuals with these PDs often appear dramatic, emotional or unpredictable; Cluster C includes Avoidant, Dependent, and Obsessive-Compulsive PDs—individuals with these disorders tend to appear anxious or fearful.[7] The functional limitations associated with all personality disorders are similar in terms of attribute levels, therefore only one health state is described for an individual diagnosed with an unspecified personality disorder.

PDs affect between 6% and 15% of the population.[125,126] The most common of the PDs are obsessive-compulsive (with a prevalence rate of 7.7% according to DSM-IV criteria), avoidant (6.6%), paranoid (5.6%), borderline (5.4%), and schizotypal (5.2%).[126] PDs typically become recognizable by adolescence or early adulthood, although some individuals may not seek clinical attention until much later. It is possible for a PD to become exacerbated after the loss of a significant supporting person or situation.[7] The course of a PD is relatively stable over time.

The DSM-IV diagnoses a PD if an individual exhibits maladaptive behavioural and cognitive patterns which are evident in at least two of the following areas: cognition, affectivity, interpersonal functioning, or impulse control. In addition, the pattern must be pervasive and inflexible across a wide range of personal and social situations, and cause clinically significant distress in social, occupational, or other areas of functioning. Evidence of the PD must have been present in at least adolescence or early adulthood, with a stable pattern of long duration. The pattern cannot be due to another mental disorder, or due to the physiological effects of a substance or a general medical condition.[7] Specific (types of)

PDs require their own criteria, which are presented in the DSM-IV manual.[7] PD diagnoses apply only to the completely formed personality, thus, they are rarely made before age 18 and are therefore not usually assessed in children and adolescents.[69]

The causes of developing a PD are unknown. Researchers believe that a specific situation or event (e.g., loss of a parent or friend) can trigger the behaviours common in PDs, particularly events in early childhood that have the potential to influence behaviour in later life. A genetic vulnerability to developing a PD has also been suggested.[127,128,129] Social factors, such as parental neglect, overprotection, or abuse may contribute to personality or other psychiatric problems in children. Because onset of PDs is usually in adolescence, a time when the personality stabilizes and matures, individuals with PDs are prone to developing maladaptive coping mechanisms and low self-esteem.[127,128,129]

Overall, there is no cure for a PD, but treatments are available to improve prognosis. Depending on the PD, pharmacological interventions can be targeted at reducing impulsivity (e.g., olanzapine, neuroleptics) and depression (e.g., serotonin reuptake inhibitors); antipsychotics may be used in cases of distorted thinking. Psychotherapy (individual, group, or family) is directed towards management of the disorder, including education about the illness, support, and social skills training. Psychotherapy, however, may be difficult for an individual with a PD because they may be reluctant to build a trusting relationship with the therapist. Character modification may be necessary to improve mood instability and impulsive behaviours, or for the individual to learn ways to cope with rejection and abandonment fears, self-destructive behaviours, or other traits associated with the particular PD being treated. Inpatient care is rarely required.

Due to the generally low rate of compliance with treatment, the following health state describes the functional limitations associated with an individual diagnosed with a PD who is not undergoing treatment.

Individuals with a PD exhibit the whole spectrum of personality features that do not allow for adequate social functioning. Some tend to be extremely unstable emotionally – feelings range from intense and inappropriate anger, to feelings of guilt and shame and depression, to feelings of inadequacy and inferiority. Others may show impulsive behaviour, sexual promiscuity or reckless driving, and possibly suicide attempts, particularly at times of crisis (i.e., a change in job or relationships, a therapist's or family member's vacation). Mentally, individuals with a PDmay have an unstable self image and identity confusion, or may be hypersensitive to rejection and feel hurt by criticism or disapproval. Interpersonal relationships are extremely unstable as well; attitudes towards family members or friends may suddenly shift from great admiration and love to disappointment, dislike and anger. A major characteristic of a PD is social withdrawal or rejection. Individuals with a PD tend to have an impaired capacity for attachment. Family life is often disrupted, and occupational and social functioning are limited. Anxiety is experienced. Occasionally, individuals with a PD may perform self-harmful behaviours.

Suicide

This section is a reproduction of "Suicide Prevention," a Government of Canada webpage.

Defining Suicide

Suicide is the intentional action of ending one's life.

A suicide attempt is when someone tries to end their life. An attempt often means that a person needs help and may be at high risk for suicide.

Suicide-Related Behaviours

Suicide-related behaviours can include the following:

- thinking about or considering suicide
- planning suicide
- attempting suicide

Suicide Survivors

Survivors are those who have

- lost someone through suicide and/or
- survived a suicide attempt and may continue to experience thoughts of suicide or suicide-related behaviours.

Suffering and Suicide

People who die by suicide don't necessarily want to end their lives. They often want to stop significant or unbearable mental, emotional or physical pain. They want to end their suffering or put an end to a situation that seems overwhelming to them.

If you or someone you know is struggling with thoughts of suicide or suicide-related behaviours, you're not alone. Learn more about the warning signs and how to ask for help.

How To Talk About Suicide

We use the terms "attempt" and "died by suicide" because they help break the stigma around suicide and mental illness. Stigma is the negative associations made about certain:

- people
- qualities
- activities
- behaviours
- circumstances

To use the term "commit suicide" is like saying it's a criminal offence. Suicide isn't a crime. These types of negative associations can make it harder for

- someone to ask for help when they need it and
- survivors to heal after being affected by suicide.

Those Affected by Suicide

Suicide affects more than just one person. It's a tragedy that affects many people in society, including

- peers,
- friends,
- coworkers,
- communities, and
- family members.

It also affects

- coaches,

- teachers,
- spiritual leaders,
- recreational staff,
- community workers,
- mental health professionals, and
- health and social service providers.

It can also affect first responders who contribute to suicide prevention. They may experience increased risk of suicide because of their exposure to trauma on the job. First responders can include

- firefighters,
- paramedics,
- police officers,
- military personnel,
- correctional officers, and
- other emergency personnel.

If you're struggling with your mental health or are worried about someone, you're not alone. Get help now.

Warning Signs of Suicide

Warning signs that might suggest someone is at risk of suicide include

- thinking or talking about suicide or
- having a plan for suicide.

Other signs and behaviours that might suggest that someone is at risk of suicide include the following:

- withdrawal from family, friends or activities
- feeling like you have no purpose in life or reason for living

- increasing substance use, like drugs, alcohol and inhalants
- feeling trapped or that there's no other way out of a situation
- feeling hopeless about the future or feeling like life will never get better
- talking about being a burden to someone or about being in unbearable pain
- anxiety or significant mood changes, such as anger, sadness or helplessness

Factors That Increase the Risk of Suicide

No single cause can explain or predict suicide. Thoughts of suicide or suicide-related behaviours are a result of a combination of personal, social and cultural factors. The presence of these factors is different from person to person over their lifetime.

Factors that may increase the risk of suicide include the following:

- a prior suicide attempt
- mental illness like depression
- a sense of hopelessness or helplessness
    - this means that you believe your life or current situation won't improve
- misuse of alcohol or substances
- chronic (long-term) physical pain or illness
- trauma, for example:
    - violence
    - victimization, like bullying
    - childhood abuse or neglect
    - suicide by a family member or friend
    - events that affect multiple generations of your family

Other factors that can increase the risk of suicide include the following:

- significant loss, including:
    - personal (relationships)
    - social
    - cultural
    - financial (job loss)
- major life changes or stressors, such as:
    - unemployment
    - homelessness
    - poor physical health or physical illness
    - the death of a loved one
    - harassment
    - discrimination
- lack of access to or availability of mental health services
- personal identity struggles (sexual, cultural)
- lack of support from family, friends or your community
- sense of isolation

What Helps To Prevent Suicide

There are a number of things that can help to guard against suicide, including the following:

- positive mental health and well-being
- a sense of hope, purpose, belonging and meaning
- social support
- healthy self-esteem and confidence in yourself
- asking for help if you're having thoughts of suicide
- a sense of belonging and connectedness with your:
    - family
    - friends
    - culture
    - community

Other ways to help protect against risk of suicide include the following:

- a strong identity (personal, sexual, cultural)
- access to appropriate mental health services and support
- good coping and problems-solving skills, and the ability to adapt to change and new situations
- supportive environments where you're accepted and valued (school, workplace, community)
- positive relationships (peers, family, partner)

If you're struggling with your mental health or are worried about someone, you're not alone. Get help now.

Get Help

If you need to talk and you

- are not feeling yourself,
- are experiencing a crisis,
- have emotional pain, or
- know someone who needs help.

Crisis Services Canada

Available to all Canadians seeking support. Visit Crisis Services Canada for the distress centres and crisis organizations nearest you.

If you or someone you know is thinking about suicide, call the Canada Suicide Prevention Service at 1-833-456-4566 (24/7) or text 45645 (4 PM – 12 AM ET).

Kids Help Phone

Call 1-800-668-6868 (toll-free) or text CONNECT to 686868.

Available 24 hours a day to Canadians aged 5 to 29 who want confidential and anonymous care from professional counsellors.

Download the Always There app for additional support or access the Kids Help Phone website.

Hope for Wellness Help Line

Call 1-855-242-3310 (toll-free) or connect to the online Hope for Wellness chat.

Available to all Indigenous peoples across Canada who need immediate crisis intervention. Experienced and culturally sensitive help line counsellors can help if you want to talk or are distressed.

Telephone and online counselling are available in English and French. On request, telephone counselling is also available in Cree, Ojibway and Inuktitut.

How To Help Someone in Crisis

Talking honestly, responsibly and safely about suicide can help you determine if someone needs help. If you want to help someone in crisis, try:

- listening and showing concern
  - showing concern can be an immediate way to help someone
  - listening won't increase the risk of suicide and it may save

a life

- talking with them and reassuring them that they're not alone
- letting them know you care
- connecting them with a:
    - crisis line
    - counsellor
    - trusted person (neighbour, friend, family member or Elder)

2.9.3. Where To Find Help

Where To Find Help in the Montreal and Concordia Community

In Crisis?

- L'Appoint
- Association Iris
- L'Autre Maison
- Centre de crise de l'Ouest-de-l'Île de Montréal
- Équipe mobile de crise Résolution (anciennement l'Entremise)
- Tracom
- Le Transit
- Montreal General: Provides care for short and long term stays
- You can also access **Concordia Students' Nightline**, an anonymous, confidential, non-judgemental listening service run by Concordia students for those in need of aid or support or just to talk.
  New temporary number: 438-812-6484.
  Thursday, Friday and Saturday nights: 6 p.m. – 3 a.m

Services at Concordia

1. Concordia offers **10 counselling appointments** to every student. Appointments can be made at both the Loyola and Down Town Campuses. Book an appointment.
2. If you have a learning disability you are able to take advantage

of the services offered by the Access Centre for Students with Disabilities (ACSD). You can make an appointment at the following email: acsd.intake@concordia.ca

3. Various groups and workshops can be accessed to improve different areas of health.
4. You can also access **Concordia Students' Nightline**, an anonymous, confidential, non-judgemental listening service run by Concordia students for those in need of aid or support or just to talk.
   New temporary number: 438-812-6484.
   Thursday, Friday and Saturday nights: 6 p.m. – 3 a.m
5. **For immediate support**, all Concordia students can connect with qualified counsellors, consultants, and life coaches for a variety of issues through **Empower Me**. Services are available 24/7 and are delivered in-person, by telephone, by video-counselling, or by e-counselling. **Password: Studentcare**

2.10. STRESS

"Stress" is an adaptation of the chapter "Stress" from *Concepts of Fitness and Wellness, 2nd Edition*, by Scott Flynn, Lisa Jellum, Jonathan Howard, Althea Moser, David Mathis, Christin Collins, Sharryse Henderson, and Connie Watjen, which is licensed under a CC BY NC SA 4.0 license, and the chapter "Stress, Lifestyle, and Health" from *Psychology* by Rose M. Spielman, Kathryn Dumper, William Jenkins, Arlene Lacombe, Marilyn Lovett, Marion Perlmutter, which is published by OpenStax and licensed under a CC BY 4.0 license. Information that is not relevant to this course has been removed.

2.10.1. Stress: A Brief Overview

Introduction

In today's fast-paced society, many people complain about feeling stressed. The word carries many negative connotations and is associated with an unpleasant or traumatic event. As such, people mistakenly believe that stress is simply the nervousness and tension experienced prior to, during, or after a negative event. In fact, the effects of stress are physiological, emotional, *and* psychological.

Additionally, not all stress is detrimental. The stress athletes experience right before a big game or college students feel right before an exam can enhance focus and increase their ability to concentrate. Stress is either good or bad depending on how long it persists and how it is perceived by the individual.

This chapter will provide a deeper understanding of what stress is and provide effective strategies for managing stress.

What Is Stress and How Does It Affect Wellness?

Stress is defined as the body's physical, mental, and emotional response to a particular stimulus, called a **stressor**. This adaption/coping-response helps the body prepare for challenging situations. **It is the level of a person's response to a stressor that determines whether the experience is positive or negative**. As a hardworking college student, you may feel as if you know the meaning of stress all too well. You may dream of a future where the demands on your time are diminished, so you can escape the high levels of stress you are feeling now. Unfortunately, regardless of their situation, everyone experiences stress on a regular basis. The good news is, not all stress is bad! Small levels of stress can enhance cognitive brain function. Eustress is define as good stress where is distress is define as bad stress. Stress may provide the motivation and concentration you need to write an essay, practice a speech, or prepare for a job interview. For most people, these types of stressors are manageable and not harmful. Stressors that have the potential for harm include the sudden loss of a loved one, the unexpected ending of a romantic relationship, or the unfair demands of an unreasonable boss.

Defining Stress

Stress, then, is more than simply the tension and apprehension generated by problems, obstacles, or traumatic events. **Stress is the body's automatic response (physical, mental, and emotional) to any stressor.** It is a natural and unavoidable part of life, and it can be empowering and motivating, or harmful and potentially dangerous.

Effects of Stress on Wellness

As stated previously, not all stress is bad. In fact, the stress associated with riding a roller coaster, watching a scary movie, or scaling a cliff can enhance these experiences. Regardless of whether the stress experienced is negative or positive, the effects on the body are identical.

When a person senses that a situation demands action, the body responds by releasing chemicals into the blood. The hypothalamus signals the adrenal glands to release a surge of hormones that include adrenaline and cortisol. The physiological effects of those chemicals—enhanced focus, quicker reaction time, and increased heart rate, energy, and strength—are quite beneficial when faced with a potentially dangerous situation that is temporary.

Unfortunately, most of the stressors people face—work, school, finances, relationships—are a part of everyday life, and thus, inescapable. Experiencing ongoing, unavoidable stress can result in some very unpleasant and harmful effects, both mental and physical. Chronic stress can cause upset stomach, headaches, sleep problems, and heart disease. It can also cause depression, anxiety, and even memory loss.

What Are the Strategies for Managing Stress?

Although stress in everyday life is unavoidable, there are ways to cope with it that will minimize or eliminate its harmful effects.

The Anxiety and Depression Association of America (ADAA) provides a list of effective strategies for coping with stress.

When you are feeling anxious or stressed, these strategies will help you cope:

- **Take a time-out:** Practice yoga, listen to music, meditate, get a massage, or learn relaxation techniques. Stepping back from the problem helps clear your head.
- **Eat well-balanced meals:** Do not skip any meals. Do keep healthful, energy-boosting snacks on hand.
- **Limit alcohol and caffeine:** These can aggravate anxiety and trigger panic attacks.
- **Get enough sleep:** When stressed, your body needs additional

sleep and rest.

- **Exercise daily:** Daily exercise can help you feel good and maintain your health. Check out the fitness tips below.
- **Take deep breaths**: Inhale and exhale slowly.
- **Count to 10 slowly**: Repeat, and count to 20 if necessary.
- **Do your best**: Instead of aiming for perfection, which isn't possible, be proud of however close you get.
- **Accept that you cannot control everything**: Put your stress in perspective: Is it really as bad as you think?
- **Welcome humor**: A good laugh goes a long way.
- **Maintain a positive attitude**: Make an effort to replace negative thoughts with positive ones.
- **Get involved:** Volunteer or find another way to be active in your community, which creates a support network and gives you a break from everyday stress.
- **Learn what triggers your anxiety:** Is it work, family, school, or something else you can identify? Write in a journal when you're feeling stressed or anxious and look for a pattern.
- **Talk to someone:** Tell friends and family you're feeling overwhelmed, and let them know how they can help you. Talk to a physician or therapist for professional help.
- **Get help online:** Anxiety Canada has a tool for developing "My Anxiety Plan".

Fitness Tips: Stay Healthy, Manage Stress

To receive the greatest benefits from exercising, try to include at least 2 1/2 hours of moderate-intensity physical activity (e.g. brisk walking) each week, 1 1/4 hours of a vigorous-intensity activity (such as jogging or swimming laps), or a combination of the two.

- **5 × 30:** Jog, walk, bike, or dance three to five times a week for 30 minutes.

- **Set small daily goals:** Aim for daily consistency rather than perfect workouts. It is better to walk every day for 15–20 minutes than to wait until the weekend for a three-hour fitness marathon. Lots of scientific data suggests that frequency is most important.
- **Find forms of exercise that are fun or enjoyable:** Extroverted people often like classes and group activities. People who are more introverted often prefer solo pursuits.
- **Distract yourself:** Use an iPod or other portable media player to download audiobooks, podcasts, or music. Many people find it is more fun to exercise while listening to material they enjoy.
- **Recruit an "exercise buddy":** It is often easier to stick to your exercise routine when you have to stay committed to a friend, partner, or colleague.
- **Be patient when you start a new exercise program:** Most sedentary people require about four to eight weeks to feel coordinated and sufficiently in shape so that exercise feels easier.

2.10.2. The Study of Stress

Introduction

Figure 2.10.2.1

Exams are a stressful, but unavoidable, element of college life. Source: "left": modification of work by Travis K. Mendoza; credit "center": modification of work by "albertogp123"/Flickr; credit "right": modification of work by Jeffrey Pioquinto, SJ.

Few would deny that today's college students are under a lot of pressure. In addition to many usual stresses and strains incidental to the college experience (e.g., exams, term papers, and the dreaded freshman 15), students today are faced with increased college tuitions, burdensome debt, and difficulty finding employment after graduation. A significant population of non-traditional college students may face additional stressors, such as raising children or holding down a full-time job while working toward a degree.

Of course, life is filled with many additional challenges beyond those incurred in college or the workplace. We might have concerns with financial security, difficulties with friends or neighbors, family responsibilities, and we may not have enough time to do the things we want to do. Even minor hassles—losing things, traffic jams, and loss of internet service—all involve pressure and demands that can make life seem like a struggle and that can compromise our sense of well-being. That is, all can be stressful in some way.

Scientific interest in stress, including how we adapt and cope, has been longstanding in psychology; indeed, after nearly a century of research on the topic, much has been learned and many insights have been developed. This chapter examines stress and highlights our current understanding of the phenomenon, including its psychological and physiological natures, its causes and consequences, and the steps we can take to master stress rather than become its victim.

What is Stress?

We often use the term loosely in describing a variety of unpleasant feeling states; for example, we often say we are stressed out when we feel frustrated, angry, conflicted, overwhelmed, or fatigued. Despite the widespread use of the term, stress is a fairly vague concept that is difficult to define with precision.

Researchers have had a difficult time agreeing on an acceptable definition of stress. Some have conceptualized stress as a demanding or threatening event or situation (e.g., a high-stress job, overcrowding, and long commutes to work). Such conceptualizations are known as stimulus-based definitions because they characterize stress as a stimulus that causes certain reactions. Stimulus-based definitions of stress are problematic, however, because they fail to recognize that people differ in how they view and react to challenging life events and situations. For example, a conscientious student who has studied diligently all semester would likely experience less stress during final exams week than would a less responsible, unprepared student.

Others have conceptualized stress in ways that emphasize the physiological responses that occur when faced with demanding or threatening situations (e.g., increased arousal). These conceptualizations are referred to as response-based definitions because they describe stress as a response to environmental conditions. For example, the endocrinologist Hans Selye, a famous stress researcher, once defined stress as the "**response of the body to any demand, whether it is caused by, or results in, pleasant or unpleasant conditions**" (Selye, 1976, p. 74). Selye's definition of stress is response-based in that it conceptualizes stress chiefly in terms of the body's physiological reaction to any demand that is placed on it. Neither stimulus-based nor response-based definitions provide a complete definition of stress. Many of the physiological reactions that occur when faced with demanding situations (e.g., accelerated heart rate) can also occur in response to things that most people would not consider to be genuinely stressful, such as receiving unanticipated good news: an unexpected promotion or raise.

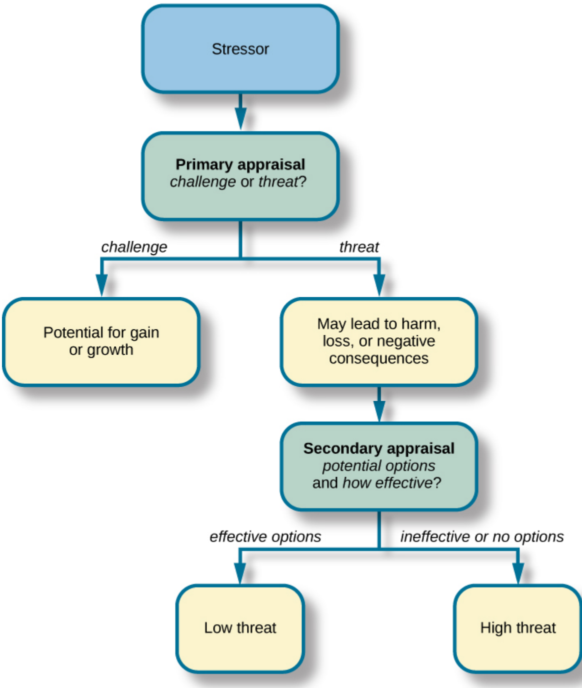
A useful way to conceptualize stress is to view it as a process whereby an individual perceives and responds to events that he appraises as overwhelming or threatening to his well-being (Lazarus & Folkman, 1984). **A critical element of this definition is that it emphasizes the importance of how we appraise—that is, judge—demanding or threatening events (often referred to as stressors); these appraisals, in turn, influence our reactions to such events**. Two kinds of appraisals of a stressor are especially important in this regard: primary and secondary appraisals. A primary appraisal involves judgment about the degree of potential harm or threat to well-being that a stressor might entail. A stressor would likely be appraised as a **threat** if one anticipates that it could lead to some kind of harm, loss, or other negative consequence; conversely, a stressor would likely be appraised as a **challenge** if one believes that it carries the potential for gain or personal growth. For example, an employee who is promoted to a leadership position would likely perceive the promotion as a much greater threat if she believed the promotion would lead to excessive work demands than if she viewed it as an opportunity to gain new skills and grow professionally. Similarly, a college student on the cusp of graduation may face the change as a threat or a challenge (Figure 2.10.2.2).

Figure 2.10.2.2

Graduating from college and entering the workforce can be viewed as either a threat (loss of financial support) or a challenge (opportunity for independence and growth). Source: Timothy Zanker. Source: [*What is Stress?*]

The perception of a threat triggers a secondary appraisal: **judgment of the options available to cope with a stressor**, as well as perceptions of how effective such options will be (Lyon, 2012) (Figure 2.10.2.3). As you may recall from what you learned about self-efficacy, an individual's belief in his ability to complete a task is important (Bandura, 1994). A threat tends to be viewed as less catastrophic if one believes something can be done about it (Lazarus & Folkman, 1984). Imagine that two middle-aged women, Robin and Maria, perform breast self-examinations one morning and each woman notices a lump on the lower region of her left breast. Although both women view the breast lump as a potential threat (primary appraisal), their secondary appraisals differ considerably. In considering the breast lump, some of the thoughts racing through Robin's mind are, "Oh my God, I could have breast cancer! What if the cancer has spread to the rest of my body and I cannot recover? What if I have to go through chemotherapy? I've heard that experience is awful! What if I have to quit my job? My husband and I won't have enough money to pay the mortgage. Oh, this is just horrible…I can't deal with it!" On the other hand, Maria thinks, "Hmm, this may not be good. Although most times these things turn out to be benign, I need to have it checked out. If it turns out to be breast cancer, there are doctors who can take care of it because the medical technology today is quite advanced. I'll have a lot of different options, and I'll be just fine." Clearly, Robin and Maria have different outlooks on what might turn out to be a very serious situation: Robin seems to think that little could be done about it, whereas Maria believes that, worst case scenario, a number of options that are likely to be effective would be available. As such, Robin would clearly experience greater stress than would Maria.

Figure 2.10.2.3



When encountering a stressor, a person judges its potential threat (primary appraisal) and then determines if effective options are available to manage the situation. Stress is likely to result if a stressor is perceived as extremely threatening or threatening with few or no effective coping options available. Source: [What is Stress?]

To be sure, some stressors are inherently more stressful than others in that they are more threatening and leave less potential for variation in cognitive appraisals (e.g., objective threats to one's health or safety). Nevertheless, appraisal will still play a role in augmenting or diminishing our reactions to such events (Everly & Lating, 2002).

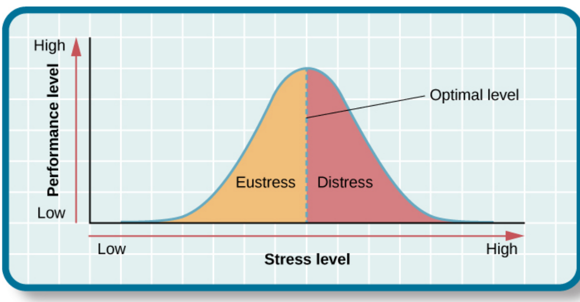
If a person appraises an event as harmful and believes that the demands imposed by the event exceed the available resources to manage or adapt to it, the person will subjectively experience a state of stress. In contrast, if one does not appraise the same event as harmful or threatening, she is unlikely to experience stress. According to this definition, environmental events trigger stress reactions by the way they are interpreted and the meanings they are assigned. In short, **stress is largely in the eye of the beholder: it's not so much what happens to you as it is how you respond** (Selye, 1976).

Good Stress?

Although stress carries a negative connotation, at times it may be of some benefit. Stress can motivate us to do things in our best interests, such as study for exams, visit the doctor regularly, exercise, and perform to the best of our ability at work. Indeed, Selye (1974) pointed out that not all stress is harmful. He argued that stress can sometimes be a positive, motivating force that can improve the quality of our lives. This kind of stress, which Selye called eustress(from the Greek *eu*= "good"), is a **good kind of stress associated with positive feelings, optimal health, and performance**. A moderate amount of stress can be beneficial in challenging situations. For example, athletes may be motivated and energized by pregame stress, and students may experience similar beneficial stress before a major exam. Indeed, research shows that moderate stress can enhance both immediate and delayed recall of educational material. Male participants in one study who memorized a scientific text passage showed improved memory of the passage immediately after exposure to a mild stressor as well as one day following exposure to the stressor (Hupbach & Fieman, 2012).

Increasing one's level of stress will cause performance to change in a predictable way. As shown in Figure 2.10.2.4, as stress increases, so do performance and general well-being (eustress); when stress levels reach an optimal level (the highest point of the curve), performance reaches its peak. A person at this stress level is colloquially at the top of his game, meaning he feels fully energized, focused, and can work with minimal effort and maximum efficiency. But when stress exceeds this optimal level, it is no longer a positive force—it becomes excessive and debilitating, or what Selye termed distress(from the Latin *dis*= "bad"). People who reach this level of stress feel burned out; they are fatigued, exhausted, and their performance begins to decline. If the stress remains excessive, health may begin to erode as well (Everly & Lating, 2002).

Figure 2.10.2.4

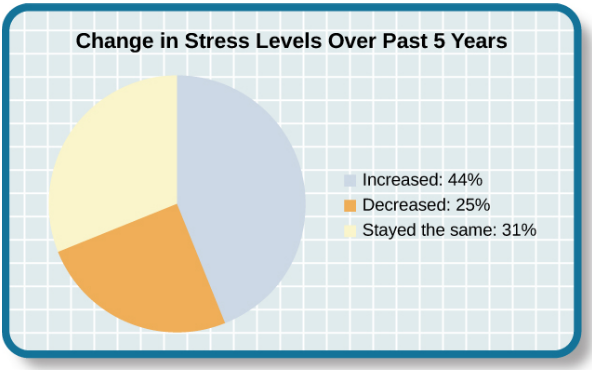


As the stress level increases from low to moderate, so does performance (eustress). At the optimal level (the peak of the curve), performance has reached its peak. If stress exceeds the optimal level, it will reach the distress region, where it will become excessive and debilitating, and performance will decline (Everly & Lating, 2002). Source: [What is Stress?]

The Prevalence of Stress

Stress is everywhere and, as shown in Figure 2.10.2.5, it has been on the rise over the last several years. Each of us is acquainted with stress—some are more familiar than others. In many ways, stress feels like a load you just can't carry—a feeling you experience when, for example, you have to drive somewhere in a crippling blizzard, when you wake up late the morning of an important job interview, when you run out of money before the next pay period, and before taking an important exam for which you realize you are not fully prepared.

Figure 2.10.2.5



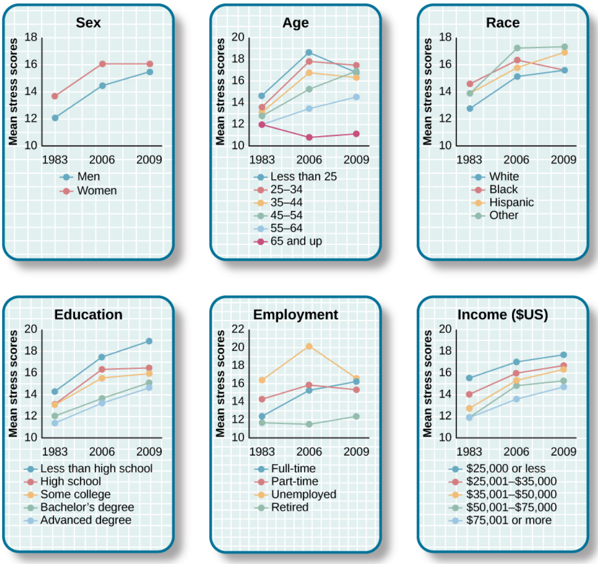
Nearly half of U.S. adults indicated that their stress levels have increased over the last five years (Neelakantan, 2013). Source: [What is Stress?]

Stress is an experience that evokes a variety of responses, including those that are **physiological** (e.g., accelerated heart rate, headaches, or gastrointestinal problems), cognitive (e.g., difficulty concentrating or making decisions), and behavioural (e.g., drinking alcohol, smoking, or taking actions directed at eliminating the cause of the stress). Although stress can be positive at times, it can have deleterious health implications, contributing to the onset and progression of a variety of physical illnesses and diseases (Cohen & Herbert, 1996).

The scientific study of how stress and other psychological factors impact health falls within the realm of health psychology, a subfield of psychology devoted to understanding the importance of psychological influences on health, illness, and how people respond when they become ill (Taylor, 1999). Health psychology emerged as a discipline in the 1970s, a time during which there was increasing awareness of the role behavioural and lifestyle factors play in the development of illnesses and diseases (Straub, 2007). In addition to studying the connection between stress and illness, health psychologists investigate issues such as why people make certain lifestyle choices (e.g., smoking or eating unhealthy food despite knowing the potential adverse health implications of such behaviours). Health psychologists also design and investigate the effectiveness of interventions aimed at changing unhealthy behaviours. Perhaps one of the more fundamental tasks of health psychologists is to identify which groups of people are especially at risk for negative health outcomes, based on psychological or behavioural factors. For example, measuring differences in stress levels among demographic groups and how these levels change over time can help identify populations who may have an increased risk for illness or disease.

Figure 2.10.2.6 depicts the results of three national surveys in which several thousand individuals from different demographic groups completed a brief stress questionnaire; the surveys were administered in 1983, 2006, and 2009 (Cohen & Janicki-Deverts, 2012). All three surveys demonstrated higher stress in women than in men. Unemployed individuals reported high levels of stress in all three surveys, as did those with less education and income; retired persons reported the lowest stress levels. However, from 2006 to 2009 the greatest increase in stress levels occurred among men, Whites, people aged 45–64, college graduates, and those with full-time employment. One interpretation of these findings is that concerns surrounding the 2008–2009 economic downturn (e.g., threat of or actual job loss and substantial loss of retirement savings) may have been especially stressful to White, college-educated, employed men with limited time remaining in their working careers.

Figure 2.10.2.6



The charts above, adapted from Cohen & Janicki-Deverts (2012), depict the mean stress level scores among different demographic groups during the years 1983, 2006, and 2009. Across categories of sex, age, race, education level, employment status, and income, stress levels generally show a marked increase over this quarter-century time span. Source: [What is Stress?]

Early Contributions to the Study of Stress

As previously stated, scientific interest in stress goes back nearly a century. One of the early pioneers in the study of stress was Walter Cannon, an eminent American physiologist at Harvard Medical School (Figure 2.10.2.7). In the early part of the 20th century, Cannon was the first to identify the body's physiological reactions to stress.

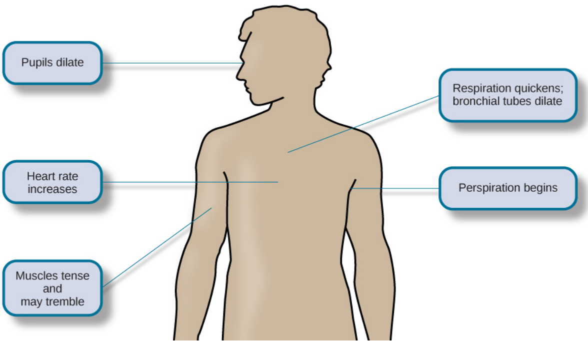
Figure 2.10.2.7

Harvard physiologist Walter Cannon first articulated and named the fight-or-flight response, the nervous system's sympathetic response to a significant stressor. Source: [What is Stress?]

Cannon and the Fight-or-Flight Response

Imagine that you are hiking in the beautiful mountains of Colorado on a warm and sunny spring day. At one point during your hike, a large, frightening-looking black bear appears from behind a stand of trees and sits about 50 yards from you. The bear notices you, sits up, and begins to lumber in your direction. In addition to thinking, "This is definitely not good," a constellation of physiological reactions begins to take place inside you. Prompted by a deluge of epinephrine (adrenaline) and norepinephrine (noradrenaline) from your adrenal glands, your pupils begin to dilate. Your heart starts to pound and speeds up, you begin to breathe heavily and perspire, you get butterflies in your stomach, and your muscles become tense, preparing you to take some kind of direct action. Cannon proposed that this reaction, which he called the fight-or-flight response, occurs when a person experiences very strong emotions—especially those associated with a perceived threat (Cannon, 1932). During the fight-or-flight response, the body is rapidly aroused by activation of both the sympathetic nervous system and the endocrine system(Figure 2.10.2.8). This arousal helps prepare the person to either fight or flee from a perceived threat.

Figure 2.10.2.8



Fight or flight is a physiological response to a stressor. Source: [What is Stress?]

According to Cannon, the fight-or-flight response is a built-in mechanism that assists in maintaining homeostasis—an internal environment in which physiological variables such as blood pressure, respiration, digestion, and temperature are stabilized at levels optimal for survival. Thus, Cannon viewed the fight-or-flight response as adaptive because it enables us to adjust internally and externally to changes in our surroundings, which is helpful in species survival.

Selye and the General Adaptation Syndrome

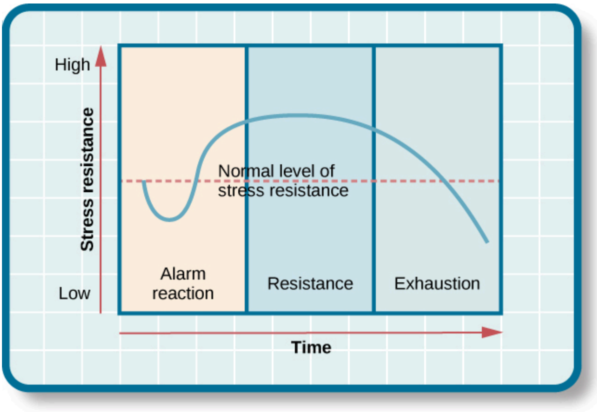
Another important early contributor to the stress field was Hans Selye, mentioned earlier. He would eventually become one of the world's foremost experts in the study of stress (Figure 2.10.2.9). As a young assistant in the biochemistry department at McGill University in the 1930s, Selye was engaged in research involving sex hormones in rats. Although he was unable to find an answer for what he was initially researching, he incidentally discovered that when exposed to prolonged negative stimulation (stressors)—such as extreme cold, surgical injury, excessive muscular exercise, and shock—the rats showed signs of adrenal enlargement, thymus and lymph node shrinkage, and stomach ulceration. Selye realized that these responses were triggered by a coordinated series of physiological reactions that unfold over time during continued exposure to a stressor. These physiological reactions were nonspecific, which means that regardless of the type of stressor, the same pattern of reactions would occur. What Selye discovered was the general adaptation syndrome, the body's nonspecific physiological response to stress.

Figure 2.10.2.9

Hans Selye specialized in research about stress. In 2009, his native Hungary honored his work with this stamp, released in conjunction with the 2nd annual World Conference on Stress. Source: [What is Stress?]

The general adaptation syndrome, shown in Figure 2.10.2.10, consists of three stages: (1) alarm reaction, (2) stage of resistance, and (3) stage of exhaustion (Selye, 1936; 1976). Alarm reaction describes the body's immediate reaction upon facing a threatening situation or emergency, and it is roughly analogous to the **fight-or-flight response** described by Cannon. During an alarm reaction, you are alerted to a stressor, and your body alarms you with a cascade of physiological reactions that provide you with the energy to manage the situation. A person who wakes up in the middle of the night to discover her house is on fire, for example, is experiencing an alarm reaction.

Figure 2.10.2.10



The three stages of Selye's general adaptation syndrome are shown in this graph. Prolonged stress ultimately results in exhaustion. Source: [What is Stress?]

If exposure to a stressor is prolonged, the organism will enter the stage of resistance. During this stage, the initial shock of alarm reaction has worn off and the body has adapted to the stressor. Nevertheless, the body also remains on alert and is prepared to respond as it did during the alarm reaction, although with less intensity. For example, suppose a child who went missing is still missing 72 hours later. Although the parents would obviously remain extremely disturbed, the magnitude of physiological reactions would likely have diminished over the 72 intervening hours due to some adaptation to this event.

If exposure to a stressor continues over a longer period of time, the stage of exhaustion ensues. At this stage, the person is no longer able to adapt to the stressor: the body's ability to resist becomes depleted as physical wear takes its toll on the body's tissues and organs. As a result, illness, disease, and other permanent damage to the body—even death—may occur. If a missing child still remained missing after three months, the long-term stress associated with this situation may cause a parent to literally faint with exhaustion at some point or even to develop a serious and irreversible illness.

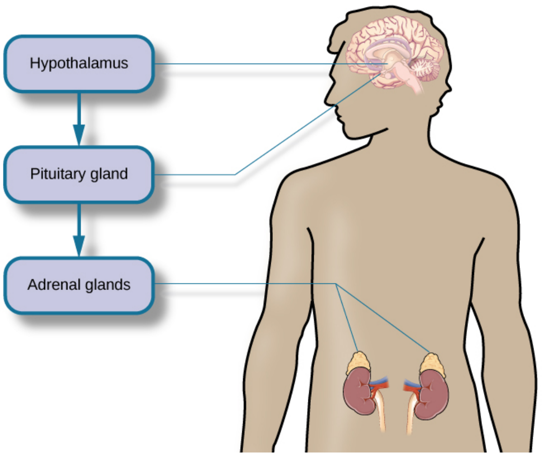
In short, **Selye's general adaptation syndrome suggests that**

stressors tax the body via a three-phase process—an initial jolt, subsequent readjustment, and a later depletion of all physical resources—that ultimately lays the groundwork for serious health problems and even death. It should be pointed out, however, that this model is a response-based conceptualization of stress, focusing exclusively on the body's physical responses while largely ignoring psychological factors such as appraisal and interpretation of threats. Nevertheless, Selye's model has had an enormous impact on the field of stress because it offers a general explanation for how stress can lead to physical damage and, thus, disease. As we shall discuss later, prolonged or repeated stress has been implicated in development of a number of disorders such as hypertension and coronary artery disease.

The Physiological Basis of Stress

What goes on inside our bodies when we experience stress? The physiological mechanisms of stress are extremely complex, but they generally involve the work of two systems—the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis. When a person first perceives something as stressful (Selye's alarm reaction), the sympathetic nervous system triggers arousal via the release of adrenaline from the adrenal glands. Release of these hormones activates the fight-or-flight responses to stress, such as accelerated heart rate and respiration. At the same time, the HPA axis, which is primarily endocrine in nature, becomes especially active, although it works much more slowly than the sympathetic nervous system. In response to stress, the hypothalamus (one of the limbic structures in the brain) releases corticotrophin-releasing factor, a hormone that causes the pituitary gland to release adrenocorticotropic hormone (ACTH) (Figure 2.10.2.11).The ACTH then activates the adrenal glands to secrete a number of hormones into the bloodstream; an important one is cortisol, which can affect virtually every organ within the body. Cortisol is commonly known as a stress hormone and helps provide that boost of energy when we first encounter a stressor, preparing us to run away or fight. However, sustained elevated levels of cortisol weaken the immune system.

Figure 2.10.2.11



This diagram shows the functioning of the hypothalamic-pituitary-adrenal (HPA) *axis. The hypothalamus activates the pituitary gland, which in turn activates the adrenal glands, increasing their secretion of cortisol. Source:* [*What is Stress?*]

In short bursts, this process can have some favorable effects, such as providing extra energy, improving immune system functioning temporarily, and decreasing pain sensitivity. However, extended release of cortisol—as would happen with prolonged or chronic stress—often comes at a high price. High levels of cortisol have been shown to produce a number of harmful effects. For example, increases in cortisol can significantly weaken our immune system (Glaser & Kiecolt-Glaser, 2005), and high levels are frequently observed among depressed individuals (Geoffroy, Hertzman, Li, &

Power, 2013). In summary, a stressful event causes a variety of physiological reactions that activate the adrenal glands, which in turn release epinephrine, norepinephrine, and cortisol. These hormones affect a number of bodily processes in ways that prepare the stressed person to take direct action, but also in ways that may heighten the potential for illness.

When stress is extreme or chronic, it can have profoundly negative consequences. For example, stress often contributes to the development of certain psychological disorders, including post-traumatic stress disorder, major depressive disorder, and other serious psychiatric conditions. Additionally, we noted earlier that stress is linked to the development and progression of a variety of physical illnesses and diseases. For example, researchers in one study found that people injured during the September 11, 2001, World Trade Center disaster or who developed post-traumatic stress symptoms afterward later suffered significantly elevated rates of heart disease (Jordan, Miller-Archie, Cone, Morabia, & Stellman, 2011). Another investigation yielded that self-reported stress symptoms among aging and retired Finnish food industry workers were associated with morbidity 11 years later. This study also predicted the onset of musculoskeletal, nervous system, and endocrine and metabolic disorders (Salonen, Arola, Nygård, & Huhtala, 2008). Another study reported that male South Korean manufacturing employees who reported high levels of work-related stress were more likely to catch the common cold over the next several months than were those employees who reported lower work-related stress levels (Park et al., 2011). Later, you will explore the mechanisms through which stress can produce physical illness and disease.

2.10.3. Stressors

Introduction

For an individual to experience stress, he must first encounter a potential stressor. In general, stressors can be placed into one of two broad categories: chronic and acute. Chronic stressors include events that persist over an extended period of time, such as caring for a parent with dementia, long-term unemployment, or imprisonment. Acute stressors involve brief focal events that sometimes continue to be experienced as overwhelming well after the event has ended, such as falling on an icy sidewalk and breaking your leg (Cohen, Janicki-Deverts, & Miller, 2007). Whether chronic or acute, potential stressors come in many shapes and sizes. They can include major traumatic events, significant life changes, daily hassles, as well as other situations in which a person is regularly exposed to threat, challenge, or danger.

Traumatic Events

Some stressors involve traumatic events or situations in which a person is exposed to actual or threatened death or serious injury. Stressors in this category include exposure to military combat, threatened or actual physical assaults (e.g., physical attacks, sexual assault, robbery, childhood abuse), terrorist attacks, natural disasters (e.g., earthquakes, floods, hurricanes), and automobile accidents. Men, non-Whites, and individuals in lower socioeconomic status (SES) groups report experiencing a greater number of traumatic events than do women, Whites, and individuals in higher SES groups (Hatch & Dohrenwend, 2007). Some individuals who are exposed to stressors of extreme magnitude develop post-traumatic stress disorder (PTSD): a chronic stress reaction characterized by experiences and behaviours that may include intrusive and painful memories of the stressor event, jumpiness, persistent negative emotional states, detachment from others, angry outbursts, and avoidance of reminders of the event (American Psychiatric Association [APA], 2013).

Life Changes

Most stressors that we encounter are not nearly as intense as the ones described above. Many potential stressors we face involve events or situations that require us to make changes in our ongoing lives and require time as we adjust to those changes. Examples include death of a close family member, marriage, divorce, and moving (Figure 2.10.3.1).

Figure 2.10.3.1

Some fairly typical life events, such as moving, can be significant stressors. Even when the move is intentional and positive, the amount of resulting change in daily life can cause stress. Source: "Jellaluna"/Flickr

In the 1960s, psychiatrists Thomas Holmesand Richard Rahewanted to examine the link between life stressors and physical illness, based on the hypothesis that life events requiring significant changes in a person's normal life routines are stressful, whether these events are desirable or undesirable. They developed the Social Readjustment Rating Scale (SRRS), consisting of 43 life events that require varying degrees of personal readjustment (Holmes & Rahe, 1967). Many life events that most people would consider pleasant (e.g., holidays, retirement, marriage) are among those listed on the SRRS; these are examples of eustress. Holmes and Rahe also proposed that life events can add up over time, and that experiencing a cluster of stressful events increases one's risk of developing physical illnesses.

In developing their scale, Holmes and Rahe asked 394 participants to provide a numerical estimate for each of the 43 items; each estimate corresponded to how much readjustment participants felt each event would require. These estimates resulted in mean value scores for each event—often called life change units (LCUs) (Rahe, McKeen, & Arthur, 1967). The numerical scores ranged from 11 to 100, representing the perceived magnitude of life change each event entails. Death of a spouse ranked highest on the scale with 100 LCUs, and divorce ranked second highest with 73 LCUs. In addition, personal injury or illness, marriage, and job termination also ranked highly on the scale with 53, 50, and 47 LCUs, respectively. Conversely, change in residence (20 LCUs), change in eating habits (15 LCUs), and vacation (13 LCUs) ranked low on the scale. Minor violations of the law ranked the lowest with 11 LCUs. To complete the scale, participants checked yes for events experienced within the last 12 months. LCUs for each checked item are summed for a score quantifying the amount of life change. Agreement on the amount of adjustment required by the various life events on the SRRS is highly consistent, even cross-culturally (Holmes & Masuda, 1974).

Table 14.1 Some Stressors on the Social Readjustment Rating Scale (Holmes & Rahe, 1967)	
Life event	**Life change units**
Change in living conditions	25
Change in working hours or conditions	20
Change in residence	20
Change in schools	20
Change in social activities	18
Change in sleeping habits	16
Change in eating habits	15
Minor violation of the law	11

Extensive research has demonstrated that accumulating a high number of life change units within a brief period of time (one or two years) is related to a wide range of physical illnesses (even accidents and athletic injuries) and mental health problems (Monat & Lazarus, 1991; Scully, Tosi, & Banning, 2000). In an early demonstration, researchers obtained LCU scores for U.S. and Norwegian Navy personnel who were about to embark on a six-month voyage. A later examination of medical records revealed positive (but small) correlations between LCU scores prior to the voyage and subsequent illness symptoms during the ensuing six-month journey (Rahe, 1974). In addition, people tend to experience more physical symptoms, such as backache, upset stomach, diarrhea, and acne, on specific days in which self-reported LCU values are considerably higher than normal, such as the day of a family member's wedding (Holmes & Holmes, 1970).

The Social Readjustment Rating Scale (SRRS) provides researchers a simple, easy-to-administer way of assessing the amount of stress in people's lives, and it has been used in hundreds of studies (Thoits, 2010). Despite its widespread use, the scale has been subject to criticism. First, many of the items on the SRRS are vague; for example, death of a close friend could involve the death of a long-absent childhood friend that requires little social readjustment (Dohrenwend, 2006). In addition, some have challenged its assumption that undesirable life events are no more stressful than desirable ones (Derogatis & Coons, 1993). However, most of the available evidence suggests that, at least as far as mental health is concerned, undesirable or negative events are more strongly associated with poor outcomes (such as depression) than are desirable, positive events (Hatch & Dohrenwend, 2007). Perhaps the most serious criticism is that the scale does not take into consideration respondents' appraisals of the life events it contains. As you recall, appraisal of a stressor is a key element in the conceptualization and overall experience of stress. Being fired from work may be devastating to some but a welcome opportunity to obtain a better job for others. The SRRS remains one of the most well-known instruments in the study of stress, and it is a useful tool for identifying potential stress-related health outcomes (Scully et al., 2000).

Exercises

Go to this site to complete the SRRS scale and determine the total number of LCUs you have experienced over the last year.

Hassles

Potential stressors do not always involve major life events. Daily hassles—the minor irritations and annoyances that are part of our everyday lives (e.g., rush hour traffic, lost keys, obnoxious coworkers, inclement weather, arguments with friends or family)—can build on one another and leave us just as stressed as life change events (Figure 2.10.3.2) (Kanner, Coyne, Schaefer, & Lazarus, 1981).

Figure 2.10.3.2

(a) (b)

Daily commutes, whether (a) on the road or (b) via public transportation, can be hassles that contribute to our feelings of everyday stress. Source: (a), modification of work by Jeff Turner; (b), modification of work by "epSos.de"/Flickr. Source: [Stressors 14.2]

Researchers have demonstrated that the frequency of daily hassles is actually a better predictor of both physical and psychological health than are life change units. In a well-known study of San Francisco residents, the frequency of daily hassles was found to be more strongly associated with physical health problems than were life change events (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982). In addition, daily minor hassles, especially interpersonal conflicts, often lead to negative and distressed mood states (Bolger, DeLongis, Kessler, & Schilling, 1989). Cyber hassles that occur on social media may represent a new source of stress. In one investigation, undergraduates who, over a 10-week period, reported greater Facebook-induced stress (e.g., guilt or discomfort over rejecting friend requests and anger or sadness over being unfriended by another) experienced increased rates of upper respiratory infections, especially if they had larger social networks (Campisi et al., 2012). Clearly, daily hassles can add up and take a toll on us both emotionally and physically.

Other Stressors

Stressors can include situations in which one is frequently exposed to challenging and unpleasant events, such as difficult, demanding, or unsafe working conditions. Although most **jobs and occupations** can at times be demanding, some are clearly more stressful than others (Figure 2.10.3.3). For example, most people would likely agree that a firefighter's work is inherently more stressful than that of a florist. Equally likely, most would agree that jobs containing various unpleasant elements, such as those requiring exposure to loud noise (heavy equipment operator), constant harassment and threats of physical violence (prison guard), perpetual frustration (bus driver in a major city), or those mandating that an employee work alternating day and night shifts (hotel desk clerk), are much more demanding—and thus, more stressful—than those that do not contain such elements. Table 14.2 lists several occupations and some of the specific stressors associated with those occupations (Sulsky & Smith, 2005).

Figure 2.10.3.3

(a) (b)

(a) Police officers and (b) firefighters hold high stress occupations. Source: (a), modification of work by Australian Civil-Military Centre; (b), modification of work by Andrew Magill. Source: [*Stressors 14.2*]()

Table 14.2 Occupations and Their Related Stressors

Occupation	Stressors Specific to Occupation (Sulsky & Smith, 2005)
Police officer	physical dangers, excessive paperwork, red tape, dealing with court system, coworker and supervisor conflict, lack of support from the public
Firefighter	uncertainty over whether a serious fire or hazard awaits after an alarm
Social worker	little positive feedback from jobs or from the public, unsafe work environments, frustration in dealing with bureaucracy, excessive paperwork, sense of personal responsibility for clients, work overload
Teacher	Excessive paperwork, lack of adequate supplies or facilities, work overload, lack of positive feedback, vandalism, threat of physical violence
Nurse	Work overload, heavy physical work, patient concerns (dealing with death and medical concerns), interpersonal problems with other medical staff (especially physicians)
Emergency medical worker	Unpredictable and extreme nature of the job, inexperience

Source: [Stressors 14.2]()

Although the specific stressors for these occupations are diverse, they seem to share two common denominators: **heavy workload** and **uncertainty about and lack of control over certain**

aspects of a job. Both of these factors contribute to job strain, a work situation that combines excessive job demands and workload with little discretion in decision making or job control (Karasek & Theorell, 1990). Clearly, many occupations other than the ones listed in Table 14.2 involve at least a moderate amount of job strain in that they often involve heavy workloads and little job control (e.g., inability to decide when to take breaks). Such jobs are often low-status and include those of factory workers, postal clerks, supermarket cashiers, taxi drivers, and short-order cooks. Job strain can have adverse consequences on both physical and mental health; it has been shown to be associated with increased risk of hypertension (Schnall & Landsbergis, 1994), heart attacks (Theorell et al., 1998), recurrence of heart disease after a first heart attack (Aboa-Éboulé et al., 2007), significant weight loss or gain (Kivimäki et al., 2006), and major depressive disorder (Stansfeld, Shipley, Head, & Fuhrer, 2012). A longitudinal study of over 10,000 British civil servants reported that workers under 50 years old who earlier had reported high job strain were 68% more likely to later develop heart disease than were those workers under 50 years old who reported little job strain (Chandola et al., 2008).

Some people who are exposed to chronically stressful work conditions can experience job **burnout**, which is a general sense of emotional exhaustion and cynicism in relation to one's job (Maslach & Jackson, 1981). Job burnout occurs frequently among those in human service jobs (e.g., social workers, teachers, therapists, and police officers). Job burnout consists of three dimensions. The first dimension is exhaustion—a sense that one's emotional resources are drained or that one is at the end of her rope and has nothing more to give at a psychological level. Second, job burnout is characterized by depersonalization: a sense of emotional detachment between the worker and the recipients of his services, often resulting in callous, cynical, or indifferent attitudes toward these individuals. Third, job burnout is characterized by diminished personal accomplishment, which is the tendency to evaluate one's work negatively by, for example, experiencing dissatisfaction with one's job-related accomplishments or feeling as though one has categorically failed to influence others' lives through one's work.

Job strain appears to be one of the greatest risk factors leading to job burnout, which is most commonly observed in workers who are older (ages 55–64), unmarried, and whose jobs involve manual labor. Heavy alcohol consumption, physical inactivity, being overweight, and having a physical or lifetime mental disorder are also associated with job burnout (Ahola, et al., 2006). In addition, depression often co-occurs with job burnout. One large-scale study of over 3,000 Finnish employees reported that half of the participants with severe job burnout had some form of depressive disorder (Ahola et al., 2005). Job burnout is often precipitated by feelings of having invested considerable energy, effort, and time into one's work while receiving little in return (e.g., little respect or support from others or low pay) (Tatris, Peeters, Le Blanc, Schreurs, & Schaufeli, 2001).

As an illustration, consider CharlieAnn, a nursing assistant who worked in a nursing home. CharlieAnn worked long hours for little pay in a difficult facility. Her supervisor was domineering, unpleasant, and unsupportive; he was disrespectful of CharlieAnn's personal time, frequently informing her at the last minute she must work several additional hours after her shift ended or that she must report to work on weekends. CharlieAnn had very little autonomy at her job. She had little say in her day-to-day duties and how to perform them, and she was not permitted to take breaks unless her supervisor explicitly told her that she could. CharlieAnn did not feel as though her hard work was appreciated, either by supervisory staff or by the residents of the home. She was very unhappy over her low pay, and she felt that many of the residents treated her disrespectfully.

After several years, CharlieAnn began to hate her job. She dreaded going to work in the morning, and she gradually developed a callous, hostile attitude toward many of the residents. Eventually, she began to feel as though she could no longer help the nursing home residents. CharlieAnn's absenteeism from work increased, and one day she decided that she had had enough and quit. She now has a job in sales, vowing never to work in nursing again.

Finally, our **close relationships with friends and family**—particularly the negative aspects of these relationships—can be a potent source of stress. Negative aspects of close relationships can include adverse exchanges and conflicts, lack of emotional support or confiding, and lack of reciprocity. All of these can be overwhelming, threatening to the relationship, and thus stressful. Such stressors can take a toll both emotionally and physically. A longitudinal investigation of over 9,000 British civil servants found that those who at one point had reported the highest levels of negative interactions in their closest relationship were 34% more likely to experience serious heart problems (fatal or nonfatal heart attacks) over a 13–15 year period, compared to those who experienced the lowest levels of negative interaction (De Vogli, Chandola & Marmot, 2007).

2.10.4. Stress and Illness

Introduction

In this section, we will discuss stress and illness. As stress researcher Robert Sapolsky (1998) describes, stress-related disease emerges, predominantly, out of the fact that we so often activate a physiological system that has evolved for responding to acute physical emergencies, but we turn it on for months on end, worrying about mortgages, relationships, and promotions.

The stress response, as noted earlier, consists of a coordinated but complex system of physiological reactions that are called upon as needed. These reactions are beneficial at times because they prepare us to deal with potentially dangerous or threatening situations (for example, recall our old friend, the fearsome bear on the trail). However, health is affected when physiological reactions are sustained, as can happen in response to ongoing stress.

Psychophysiological Disorders

If the reactions that compose the stress response are chronic or if they frequently exceed normal ranges, they can lead to cumulative wear and tear on the body, in much the same way that running your air conditioner on full blast all summer will eventually cause wear and tear on it. For example, the high blood pressure that a person under considerable job strain experiences might eventually take a toll on his heart and set the stage for a heart attack or heart failure. Also, someone exposed to high levels of the stress hormone cortisol might become vulnerable to infection or disease because of weakened immune system functioning (McEwen, 1998).

Physical disorders or diseases whose symptoms are brought about or worsened by stress and emotional factors are called psychophysiological disorders. The physical symptoms of psychophysiological disorders are real and they can be produced or exacerbated by psychological factors (hence the *psycho*and *physiological*in psychophysiological). A list of frequently encountered psychophysiological disorders is provided in Table 14.3.

Table 14.3 Types of Psychophysiological Disorders (adapted from Everly & Lating, 2002)

Type of Psychophysiological Disorder	Examples
Cardiovascular	hypertension, coronary heart disease
Gastrointestinal	irritable bowel syndrome
Respiratory	asthma, allergy
Musculoskeletal	low back pain, tension headaches
Skin	acne, eczema, psoriasis

In addition to stress itself, emotional upset and certain stressful personality traits have been proposed as potential contributors to ill health. Franz Alexander (1950), an early-20th-century psychoanalyst and physician, once postulated that various diseases are caused by specific unconscious conflicts. For example, he linked hypertension to repressed anger, asthma to separation anxiety, and ulcers to an unconscious desire to "remain in the dependent infantile situation—to be loved and cared for" (Alexander, 1950, p. 102). Although hypertension does appear to be linked to anger (as you will learn below), Alexander's assertions have not been supported by research. Years later, Friedman and Booth-Kewley (1987), after statistically reviewing 101 studies examining the link between personality and illness, proposed the existence of disease-prone personality characteristics, including depression, anger/hostility, and anxiety. Indeed, a study of over 61,000 Norwegians identified depression as a risk factor for all major disease-related causes of death (Mykletun et al., 2007). In addition, neuroticism—a personality trait that reflects how anxious, moody, and sad one is—has been identified as a risk factor for chronic health problems and mortality (Ploubidis & Grundy, 2009).

Below, we discuss two kinds of psychophysiological disorders about which a great deal is known: cardiovascular disorders and asthma. First, however, it is necessary to turn our attention to a discussion of the immune system—one of the major pathways through which stress and emotional factors can lead to illness and disease.

Stress and the Immune System

In a sense, the immune system is the body's surveillance system. It consists of a variety of structures, cells, and mechanisms that serve to protect the body from invading toxins and microorganisms that can harm or damage the body's tissues and organs. When the immune system is working as it should, it keeps us healthy and disease free by eliminating bacteria, viruses, and other foreign substances that have entered the body (Everly & Lating, 2002).

Immune System Errors

Sometimes, the immune system will function erroneously. For example, sometimes it can go awry by mistaking your body's own healthy cells for invaders and repeatedly attacking them. When this happens, the person is said to have an autoimmune disease, which can affect almost any part of the body. How an autoimmune disease affects a person depends on what part of the body is targeted. For instance, rheumatoid arthritis, an autoimmune disease that affects the joints, results in joint pain, stiffness, and loss of function. Systemic lupus erythematosus, an autoimmune disease that affects the skin, can result in rashes and swelling of the skin. Grave's disease, an autoimmune disease that affects the thyroid gland, can result in fatigue, weight gain, and muscle aches (National Institute of Arthritis and Musculoskeletal and Skin Diseases [NIAMS], 2012).

In addition, the immune system may sometimes break down and be unable to do its job. This situation is referred to as immunosuppression, the decreased effectiveness of the immune system. When people experience immunosuppression, they become susceptible to any number of infections, illness, and diseases. For example, acquired immune deficiency syndrome (AIDS) is a serious and lethal disease that is caused by human immunodeficiency virus (HIV), which greatly weakens the immune system by infecting and destroying antibody-producing cells, thus rendering a person vulnerable to any of a number of opportunistic infections (Powell, 1996).

Stressors and Immune Function

The question of whether stress and negative emotional states can influence immune function has captivated researchers for over three decades, and discoveries made over that time have dramatically changed the face of health psychology (Kiecolt-Glaser, 2009). Psychoneuroimmunology is the field that studies how psychological factors such as stress influence the immune system and immune functioning. The term psychoneuroimmunology was first coined in 1981, when it appeared as the title of a book that reviewed available evidence for associations between the brain, endocrine system, and immune system (Zacharie, 2009). To a large extent, this field evolved from the discovery that there is a connection between the central nervous system and the immune system.

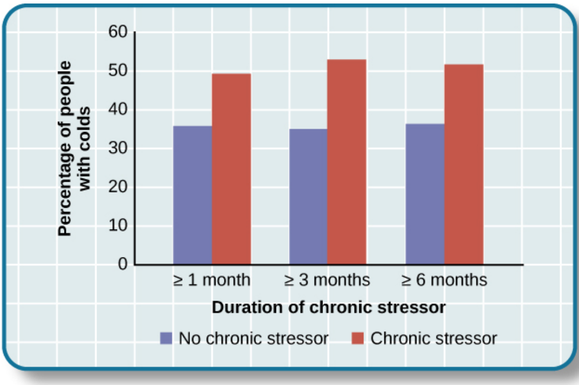
Some of the most compelling evidence for a connection between the brain and the immune system comes from studies in which researchers demonstrated that immune responses in animals could be classically conditioned (Everly & Lating, 2002). For example, Ader and Cohen (1975) paired flavored water (the conditioned stimulus) with the presentation of an immunosuppressive drug (the unconditioned stimulus), causing sickness (an unconditioned response). Not surprisingly, rats exposed to this pairing developed a conditioned aversion to the flavored water. However, the taste of the water itself later produced immunosuppression (a conditioned response), indicating that the immune system itself had been conditioned. Many subsequent studies over the years have further demonstrated that immune responses can be classically conditioned in both animals and humans (Ader & Cohen, 2001). Thus, if classical conditioning can alter immunity, other psychological factors should be capable of altering it as well.

Hundreds of studies involving tens of thousands of participants have tested many kinds of brief and chronic stressors and their effect on the immune system (e.g., public speaking, medical school examinations, unemployment, marital discord, divorce, death of spouse, burnout and job strain, caring for a relative with Alzheimer's disease, and exposure to the harsh climate of Antarctica). It has been repeatedly demonstrated that many kinds of stressors are associated with poor or weakened immune functioning (Glaser & Kiecolt-Glaser, 2005; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002; Segerstrom & Miller, 2004).

When evaluating these findings, it is important to remember that there is a tangible physiological connection between the brain and the immune system. For example, the sympathetic nervous system innervates immune organs such as the thymus, bone marrow, spleen, and even lymph nodes (Maier, Watkins, & Fleshner, 1994). Also, we noted earlier that stress hormones released during hypothalamic-pituitary-adrenal (HPA) axis activation can adversely impact immune function. One way they do this is by inhibiting the production of lymphocytes, white blood cells that circulate in the body's fluids that are important in the immune response (Everly & Lating, 2002).

Some of the more dramatic examples demonstrating the link between stress and impaired immune function involve studies in which volunteers were exposed to viruses. The rationale behind this research is that because stress weakens the immune system, people with high stress levels should be more likely to develop an illness compared to those under little stress. In one memorable experiment using this method, researchers interviewed 276 healthy volunteers about recent stressful experiences (Cohen et al., 1998). Following the interview, these participants were given nasal drops containing the cold virus (in case you are wondering why anybody would ever want to participate in a study in which they are subjected to such treatment, the participants were paid $800 for their trouble). When examined later, participants who reported experiencing chronic stressors for more than one month—especially enduring difficulties involving work or relationships—were considerably more likely to have developed colds than were participants who reported no chronic stressors (Figure 2.10.4.1).

Figure 2.10.4.1



This graph shows the percentages of participants who developed colds (after receiving the cold virus) after reporting having experienced chronic stressors lasting at least one month, three months, and six months. Source: adapted from Cohen et al., 1998.

In another study, older volunteers were given an influenza virus vaccination. Compared to controls, those who were caring for a spouse with Alzheimer's disease (and thus were under chronic stress) showed poorer antibody response following the vaccination (Kiecolt-Glaser, Glaser, Gravenstein, Malarkey, & Sheridan, 1996).

Other studies have demonstrated that stress slows down wound healing by impairing immune responses important to wound repair (Glaser & Kiecolt-Glaser, 2005). In one study, for example, skin blisters were induced on the forearm. Subjects who reported higher levels of stress produced lower levels of immune proteins necessary for wound healing (Glaser et al., 1999). Stress, then, is not so much the sword that kills the knight, so to speak; rather, it's the sword that breaks the knight's shield, and your immune system is that shield.

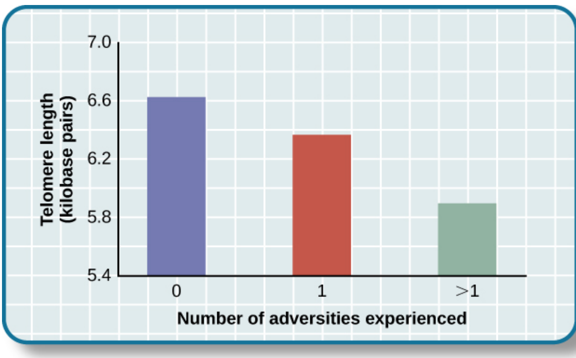
Stress and Aging: A Tale of Telomeres

Have you ever wondered why people who are stressed often seem to have a haggard look about them? A pioneering study from 2004 suggests that the reason is because stress can actually accelerate the cell biology of aging.

Stress, it seems, can shorten telomeres, which are segments of DNA that protect the ends of chromosomes. Shortened telomeres can inhibit or block cell division, which includes growth and proliferation of new cells, thereby leading to more rapid aging (Sapolsky, 2004). In the study, researchers compared telomere lengths in the white blood cells in mothers of chronically ill children to those of mothers of healthy children (Epel et al., 2004). Mothers of chronically ill children would be expected to experience more stress than would mothers of healthy children. The longer a mother had spent caring for her ill child, the shorter her telomeres (the correlation between years of caregiving and telomere length was $r= -.40$). In addition, higher levels of perceived stress were negatively correlated with telomere size ($r= -.31$). These researchers also found that the average telomere length of the most stressed mothers, compared to the least stressed, was similar to what you would find in people who were 9–17 years older than they were on average.

Numerous other studies since have continued to find associations between stress and eroded telomeres (Blackburn & Epel, 2012). Some studies have even demonstrated that stress can begin to erode telomeres in childhood and perhaps even before children are born. For example, childhood exposure to violence (e.g., maternal domestic violence, bullying victimization, and physical maltreatment) was found in one study to accelerate telomere erosion from ages 5 to 10 (Shalev et al., 2013). Another study reported that young adults whose mothers had experienced severe stress during their pregnancy had shorter telomeres than did those whose mothers had stress-free and uneventful pregnancies (Entringer et al., 2011). Further, the corrosive effects of childhood stress on telomeres can extend into young adulthood. In an investigation of over 4,000 U.K. women ages 41–80, adverse experiences during childhood (e.g., physical abuse, being sent away from home, and parent divorce) were associated with shortened telomere length (Surtees et al., 2010), and telomere size decreased as the amount of experienced adversity increased (Figure 2.10.4.2).

Figure 2.10.4.2



Telomeres are shorter in adults who experienced more trauma as children. Source: adapted from Blackburn & Epel, 2012.

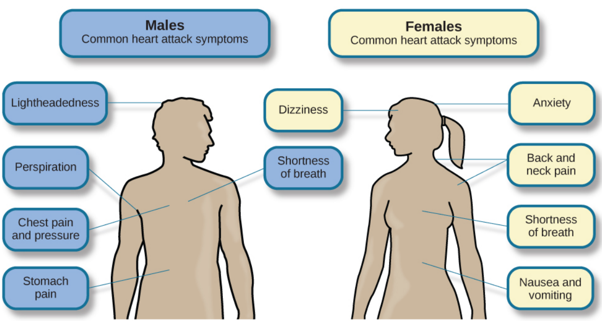
Efforts to dissect the precise cellular and physiological mechanisms linking short telomeres to stress and disease are currently underway. For the time being, telomeres provide us with yet another reminder that stress, especially during early life, can be just as harmful to our health as smoking or fast food (Blackburn & Epel, 2012).

Cardiovascular Disorders

The cardiovascular system is composed of the heart and blood circulation system. For many years, disorders that involve the cardiovascular system—known as cardiovascular disorders—have been a major focal point in the study of psychophysiological disorders because of the cardiovascular system's centrality in the stress response (Everly & Lating, 2002). **Heart disease** is one such condition. Each year, heart disease causes approximately one in three deaths in the United States, and it is the leading cause of death in the developed world (Centers for Disease Control and Prevention [CDC], 2011; Shapiro, 2005).

The symptoms of heart disease vary somewhat depending on the specific kind of heart disease one has, but they generally involve angina—chest pains or discomfort that occur when the heart does not receive enough blood (Office on Women's Health, 2009). The pain often feels like the chest is being pressed or squeezed; burning sensations in the chest and shortness of breath are also commonly reported. Such pain and discomfort can spread to the arms, neck, jaws, stomach (as nausea), and back (American Heart Association [AHA], 2012a) (Figure 2.10.4.3).

Figure 2.10.4.3



*Males and females often experience different symptoms of a heart attack. Source: [Psychology 14.3 Stress & Illness](). *

A major risk factor for heart disease is hypertension, which is high blood pressure. Hypertension forces a person's heart to pump harder, thus putting more physical strain on the heart. If left unchecked, hypertension can lead to a heart attack, stroke, or heart failure; it can also lead to kidney failure and blindness. Hypertension is a serious cardiovascular disorder, and it is sometimes called the silent killer because it has no symptoms—one who has high blood pressure may not even be aware of it (AHA, 2012b).

Many risk factors contributing to cardiovascular disorders have been identified. These risk factors include social determinants such as aging, income, education, and employment status, as well as behavioural risk factors that include unhealthy diet, tobacco use, physical inactivity, and excessive alcohol consumption; obesity and diabetes are additional risk factors (World Health Organization [WHO], 2013).

Over the past few decades, there has been much greater recognition and awareness of the importance of stress and other psychological factors in cardiovascular health (Nusair, Al-dadah, & Kumar, 2012). Indeed, exposure to stressors of many kinds has also been linked to cardiovascular problems; in the case of hypertension, some of these stressors include job strain (Trudel, Brisson, & Milot, 2010), natural disasters (Saito, Kim, Maekawa, Ikeda, & Yokoyama, 1997), marital conflict (Nealey-Moore, Smith, Uchino, Hawkins, & Olson-Cerny, 2007), and exposure to high traffic noise levels at one's home (de Kluizenaar, Gansevoort, Miedema, & de Jong, 2007). Perceived discrimination appears to be associated with hypertension among African Americans (Sims et al., 2012). In addition, laboratory-based stress tasks, such as performing mental arithmetic under time pressure, immersing one's hand into ice water (known as the cold pressor test), mirror tracing, and public speaking have all been shown to elevate blood pressure (Phillips, 2011).

Are You Type A or Type B?

Sometimes research ideas and theories emerge from seemingly trivial observations. In the 1950s, cardiologist Meyer Friedman was looking over his waiting room furniture, which consisted of upholstered chairs with armrests. Friedman decided to have these chairs reupholstered. When the man doing the reupholstering came to the office to do the work, he commented on how the chairs were worn in a unique manner—the front edges of the cushions were worn down, as were the front tips of the arm rests. It seemed like the cardiology patients were tapping or squeezing the front of the armrests, as well as literally sitting on the edge of their seats (Friedman & Rosenman, 1974). Were cardiology patients somehow different than other types of patients? If so, how?

After researching this matter, Friedman and his colleague, Ray Rosenman, came to understand that people who are prone to heart disease tend to think, feel, and act differently than those who are not. These individuals tend to be intensively driven workaholics who are preoccupied with deadlines and always seem to be in a rush. According to Friedman and Rosenman, these individuals exhibit Type A behaviour pattern; those who are more relaxed and laid-back were characterized as Type B (Figure 2.10.4.4). In a sample of Type As and Type Bs, Friedman and Rosenman were startled to discover that heart disease was over seven times more frequent among the Type As than the Type Bs (Friedman & Rosenman, 1959).

Figure 2.10.4.4

(a) (b)

(a) Type A individuals are characterized as intensely driven, (b) while Type B people are characterized as laid-back and relaxed. Source: *(a) modification of work by Greg Hernandez; (b) modification of work by Elvert Barnes.* Source: [Psychology 14.3 Stress & Illness](#).

The major components of the Type A pattern include an aggressive and chronic struggle to achieve more and more in less and less time (Friedman & Rosenman, 1974). Specific characteristics of the Type A pattern include an excessive competitive drive, chronic sense of time urgency, impatience, and hostility toward others (particularly those who get in the person's way).

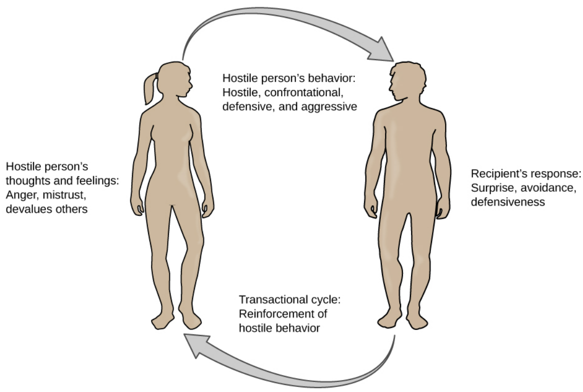
An example of a person who exhibits Type A behaviour pattern is Jeffrey. Even as a child, Jeffrey was intense and driven. He excelled at school, was captain of the swim team, and graduated with honors from an Ivy League college. Jeffrey never seems able to relax; he is always working on something, even on the weekends. However, Jeffrey always seems to feel as though there are not enough hours in the day to accomplish all he feels he should. He volunteers to take on extra tasks at work and often brings his work home with him; he often goes to bed angry late at night because he feels that he has not done enough. Jeffrey is quick tempered with his coworkers; he often becomes noticeably agitated when dealing with those coworkers he feels work too slowly or whose work does not meet his standards. He typically reacts with hostility when interrupted at work. He has experienced problems in his marriage over his lack of time spent with family. When caught in traffic during his commute to and from work, Jeffrey incessantly pounds on his horn and swears loudly at other drivers. When Jeffrey was 52, he suffered his first heart attack.

Extensive research clearly suggests that the anger/hostility dimension of Type A behaviour pattern may be one of the most important factors in the development of heart disease. This relationship was initially described in the Haynes et al. (1980) study mentioned above: Suppressed hostility was found to substantially elevate the risk of heart disease for both men and women. Also, one investigation followed over 1,000 male medical students from 32 to 48 years. At the beginning of the study, these men completed a questionnaire assessing how they react to pressure; some indicated that they respond with high levels of anger, whereas others indicated that they respond with less anger. Decades later, researchers found that those who earlier had indicated the highest levels of anger were over 6 times more likely than those who indicated less anger to have had a heart attack by age 55, and they were 3.5 times more likely to have experienced heart disease by the same age (Chang, Ford, Meoni, Wang, & Klag, 2002). From a health standpoint, it clearly does not pay to be an angry young person.

After reviewing and statistically summarizing 35 studies from 1983 to 2006, Chida and Steptoe (2009) concluded that the bulk of the evidence suggests that anger and hostility constitute serious long-term risk factors for adverse cardiovascular outcomes among both healthy individuals and those already suffering from heart disease. One reason angry and hostile moods might contribute to cardiovascular diseases is that such moods can create social strain, mainly in the form of antagonistic social encounters with others.

This strain could then lay the foundation for disease-promoting cardiovascular responses among hostile individuals (Vella, Kamarck, Flory, & Manuck, 2012). In this transactional model, hostility and social strain form a cycle (Figure 2.10.4.5).

Figure 2.10.4.5



According to the transactional model of hostility for predicting social interactions (Vella et al., 2012), the thoughts and feelings of a hostile person promote antagonistic behaviour toward others, which in turn reinforces complimentary reactions from others, thereby intensifying one's hostile disposition and intensifying the cyclical nature of this relationship. Source: Psychology 14.3 Stress & Illness.

For example, suppose Kaitlin has a hostile disposition; she has a cynical, distrustful attitude toward others and often thinks that other people are out to get her. She is very defensive around people, even those she has known for years, and she is always looking for signs that others are either disrespecting or belittling her. In the shower each morning before work, she often mentally rehearses what she would say to someone who said or did something that angered her, such as making a political statement that was counter to her own ideology. As Kaitlin goes through these mental rehearsals, she often grins and thinks about the retaliation on anyone who will irk her that day.

Socially, she is confrontational and tends to use a harsh tone with people, which often leads to very disagreeable and sometimes argumentative social interactions. As you might imagine, Kaitlin is not especially popular with others, including coworkers, neighbors, and even members of her own family. They either avoid her at all costs or snap back at her, which causes Kaitlin to become even more cynical and distrustful of others, making her disposition even more hostile. Kaitlin's hostility—through her own doing—has created an antagonistic environment that cyclically causes her to become even more hostile and angry, thereby potentially setting the stage for cardiovascular problems.

In addition to anger and hostility, a number of other negative emotional states have been linked with heart disease, including negative affectivity and depression (Suls & Bunde, 2005). Negative affectivity is a tendency to experience distressed emotional states involving anger, contempt, disgust, guilt, fear, and nervousness (Watson, Clark, & Tellegen, 1988). It has been linked with the development of both hypertension and heart disease. For example, over 3,000 initially healthy participants in one study were tracked longitudinally, up to 22 years. Those with higher levels of negative affectivity at the time the study began were substantially more likely to develop and be treated for hypertension during the ensuing years than were those with lower levels of negative affectivity (Jonas &

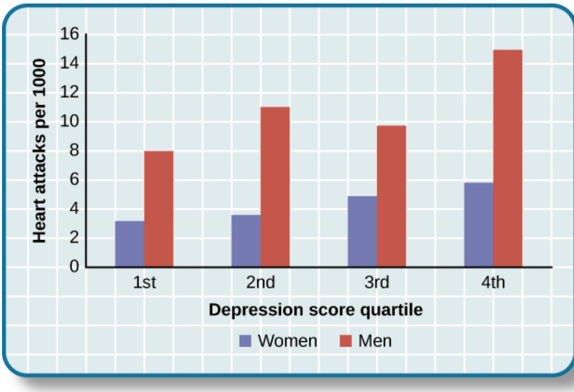
Lando, 2000). In addition, a study of over 10,000 middle-aged London-based civil servants who were followed an average of 12.5 years revealed that those who earlier had scored in the upper third on a test of negative affectivity were 32% more likely to have experienced heart disease, heart attack, or angina over a period of years than were those who scored in the lowest third (Nabi, Kivimaki, De Vogli, Marmot, & Singh-Manoux, 2008). Hence, negative affectivity appears to be a potentially vital risk factor for the development of cardiovascular disorders.

Depression and the Heart

For centuries, poets and folklore have asserted that there is a connection between moods and the heart (Glassman & Shapiro, 1998). You are no doubt familiar with the notion of a broken heart following a disappointing or depressing event and have encountered that notion in songs, films, and literature.

Perhaps the first to recognize the link between depression and heart disease was Benjamin Malzberg (1937), who found that the death rate among institutionalized patients with melancholia (an archaic term for depression) was six times higher than that of the population. A classic study in the late 1970s looked at over 8,000 manic-depressive persons in Denmark, finding a nearly 50% increase in deaths from heart disease among these patients compared with the general Danish population (Weeke, 1979). By the early 1990s, evidence began to accumulate showing that depressed individuals who were followed for long periods of time were at increased risk for heart disease and cardiac death (Glassman, 2007). In one investigation of over 700 Denmark residents, those with the highest depression scores were 71% more likely to have experienced a heart attack than were those with lower depression scores (Barefoot & Schroll, 1996). Figure 2.10.4.6 illustrates the gradation in risk of heart attacks for both men and women.

Figure 2.10.4.6



This graph shows the incidence of heart attacks among men and women by depression score quartile. Source: adapted from Barefoot & Schroll, 1996. Source: [Psychology 14.3 Stress & Illness](#).

After more than two decades of research, it is now clear that a relationship exists: Patients with heart disease have more depression than the general population, and people with depression are more likely to eventually develop heart disease and experience higher mortality than those who do not have depression (Hare, Toukhsati, Johansson, & Jaarsma, 2013); the more severe the depression, the higher the risk (Glassman, 2007). Consider the following:

- In one study, death rates from cardiovascular problems was substantially higher in depressed people; depressed men were 50% more likely to have died from cardiovascular problems, and depressed women were 70% more likely (Ösby, Brandt, Correia, Ekbom, & Sparén, 2001).
- A statistical review of 10 longitudinal studies involving initially healthy individuals revealed that those with elevated depressive symptoms have, on average, a 64% greater risk of developing heart disease than do those with fewer symptoms

(Wulsin & Singal, 2003).

- A study of over 63,000 registered nurses found that those with more depressed symptoms when the study began were 49% more likely to experience fatal heart disease over a 12-year period (Whang et al., 2009).

The American Heart Association, fully aware of the established importance of depression in cardiovascular diseases, several years ago recommended routine depression screening for all heart disease patients (Lichtman et al., 2008). Recently, they have recommended including depression as a risk factor for heart disease patients (AHA, 2014).

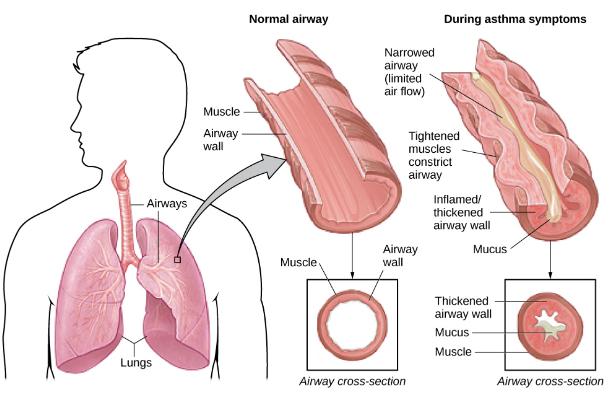
Although the exact mechanisms through which depression might produce heart problems have not been fully clarified, a recent investigation examining this connection in early life has shed some light. In an ongoing study of childhood depression, adolescents who had been diagnosed with depression as children were more likely to be obese, smoke, and be physically inactive than were those who had not received this diagnosis (Rottenberg et al., 2014). One implication of this study is that depression, especially if it occurs early in life, may increase the likelihood of living an unhealthy lifestyle, thereby predisposing people to an unfavorable cardiovascular disease risk profile.

It is important to point out that depression may be just one piece of the emotional puzzle in elevating the risk for heart disease, and that chronically experiencing several negative emotional states may be especially important. A longitudinal investigation of Vietnam War veterans found that depression, anxiety, hostility, and trait anger each independently predicted the onset of heart disease (Boyle, Michalek, & Suarez, 2006). However, when each of these negative psychological attributes was combined into a single variable, this new variable (which researchers called psychological risk factor) predicted heart disease more strongly than any of the individual variables. Thus, rather than examining the predictive power of isolated psychological risk factors, it seems crucial for future researchers to examine the effects of combined and more general negative emotional and psychological traits in the development of cardiovascular illnesses.

Asthma

Asthma is a chronic and serious disease in which the airways of the respiratory system become obstructed, leading to great difficulty expelling air from the lungs. The airway obstruction is caused by inflammation of the airways (leading to thickening of the airway walls) and a tightening of the muscles around them, resulting in a narrowing of the airways (Figure 2.10.4.7) (American Lung Association, 2010). Because airways become obstructed, a person with asthma will sometimes have great difficulty breathing and will experience repeated episodes of wheezing, chest tightness, shortness of breath, and coughing, the latter occurring mostly during the morning and night (CDC, 2006).

Figure 2.10.4.7



In asthma, the airways become inflamed and narrowed. Source: [*Psychology 14.3 Stress & Illness*](#).

Asthma attacks are acute episodes in which an asthma sufferer experiences the full range of symptoms. Asthma exacerbation is often triggered by environmental factors, such as air pollution, allergens (e.g., pollen, mold, and pet hairs), cigarette smoke, airway infections, cold air or a sudden change in temperature, and exercise (CDC, 2013b).

Psychological factors appear to play an important role in asthma (Wright, Rodriguez, & Cohen, 1998), although some believe that psychological factors serve as potential triggers in only a subset of asthma patients (Ritz, Steptoe, Bobb, Harris, & Edwards, 2006). Many studies over the years have demonstrated that some people with asthma will experience asthma-like symptoms if they expect to experience such symptoms, such as when breathing an inert substance that they (falsely) believe will lead to airway obstruction (Sodergren & Hyland, 1999). As stress and emotions directly affect immune and respiratory functions, psychological factors likely serve as one of the most common triggers of asthma exacerbation (Trueba & Ritz, 2013).

People with asthma tend to report and display a high level of negative emotions such as anxiety, and asthma attacks have been linked to periods of high emotionality (Lehrer, Isenberg, & Hochron, 1993). In addition, high levels of emotional distress during both laboratory tasks and daily life have been found to negatively affect airway function and can produce asthma-like symptoms in people with asthma (von Leupoldt, Ehnes, & Dahme, 2006). In one investigation, 20 adults with asthma wore preprogrammed wristwatches that signaled them to breathe into a portable device that measures airway function. Results showed that higher levels of negative emotions and stress were associated with increased airway obstruction and self-reported asthma symptoms (Smyth, Soefer, Hurewitz, Kliment, & Stone, 1999). In addition, D'Amato, Liccardi, Cecchi, Pellegrino, & D'Amato (2010) described a case study of an 18-year-old man with asthma whose girlfriend had broken up with him, leaving him in a depressed state. She had also unfriended him on Facebook , while friending other young males. Eventually, the young man was able to "friend" her once again and could monitor her activity through Facebook. Subsequently, he would experience asthma symptoms whenever he logged on and accessed her profile. When he later resigned not to use Facebook any longer, the asthma attacks stopped. This case suggests that the use of Facebook and other forms of social media may represent a new source of stress—it may be a triggering factor for asthma attacks, especially in depressed asthmatic individuals.

Exposure to stressful experiences, particularly those that involve parental or interpersonal conflicts, has been linked to the development of asthma throughout the lifespan. A longitudinal study of 145 children found that parenting difficulties during the first year of life increased the chances that the child developed asthma by 107% (Klinnert et al., 2001). In addition, a cross-sectional study of over 10,000 Finnish college students found that high rates of parent or personal conflicts (e.g., parental divorce, separation from spouse, or severe conflicts in other long-term relationships) increased the risk of asthma onset (Kilpeläinen, Koskenvuo, Helenius, & Terho, 2002). Further, a study of over 4,000 middle-aged men who were interviewed in the early 1990s and again a decade later found that breaking off an important life partnership (e.g., divorce or breaking off relationship from parents) increased the risk of developing asthma by 124% over the time of the study (Loerbroks, Apfelbacher, Thayer, Debling, & Stürmer, 2009).

Tension Headaches

A headache is a continuous pain anywhere in the head and neck region. Migraine headaches are a type of headache thought to be caused by blood vessel swelling and increased blood flow (McIntosh, 2013). Migraines are characterized by severe pain on one or both sides of the head, an upset stomach, and disturbed vision. They are more frequently experienced by women than by men (American

Academy of Neurology, 2014). Tension headaches are triggered by tightening/tensing of facial and neck muscles; they are the most commonly experienced kind of headache, accounting for about 42% of all headaches worldwide (Stovner et al., 2007). In the United States, well over one-third of the population experiences tension headaches each year, and 2–3% of the population suffers from chronic tension headaches (Schwartz, Stewart, Simon, & Lipton, 1998).

A number of factors can contribute to tension headaches, including sleep deprivation, skipping meals, eye strain, overexertion, muscular tension caused by poor posture, and stress (MedicineNet, 2013). Although there is uncertainty regarding the exact mechanisms through which stress can produce tension headaches, stress has been demonstrated to increase sensitivity to pain (Caceres & Burns, 1997; Logan et al., 2001). In general, tension headache sufferers, compared to non-sufferers, have a lower threshold for and greater sensitivity to pain (Ukestad & Wittrock, 1996), and they report greater levels of subjective stress when faced with a stressor (Myers, Wittrock, & Foreman, 1998). Thus, stress may contribute to tension headaches by increasing pain sensitivity in already-sensitive pain pathways in tension headache sufferers (Cathcart, Petkov, & Pritchard, 2008).

2.10.5. Reducing Stress

Introduction

As we learned in the previous section, stress—especially if it is chronic—takes a toll on our bodies and can have enormously negative health implications. When we experience events in our lives that we appraise as stressful, it is essential that we use effective coping strategies to manage our stress. Coping refers to mental and behavioural efforts that we use to deal with problems relating to stress, including its presumed cause and the unpleasant feelings and emotions it produces.

Coping Styles

Lazarus and Folkman (1984) distinguished two fundamental kinds of coping: **problem-focused coping** and **emotion-focused coping**. In problem-focused coping, one attempts to manage or alter the problem that is causing one to experience stress (i.e., the stressor). Problem-focused coping strategies are similar to strategies used in everyday problem-solving: they typically involve identifying the problem, considering possible solutions, weighing the costs and benefits of these solutions, and then selecting an alternative (Lazarus & Folkman, 1984). As an example, suppose Bradford receives a midterm notice that he is failing statistics class. If Bradford adopts a problem-focused coping approach to managing his stress, he would be proactive in trying to alleviate the source of the stress. He might contact his professor to discuss what must be done to raise his grade, he might also decide to set aside two hours daily to study statistics assignments, and he may seek tutoring assistance. A problem-focused approach to managing stress means we actively try to do things to address the problem.

Emotion-focused coping, in contrast, consists of efforts to change or reduce the negative emotions associated with stress. These efforts may include avoiding, minimizing, or distancing oneself from the problem, or positive comparisons with others ("I'm not as bad off as she is"), or seeking something positive in a negative event ("Now that I've been fired, I can sleep in for a few days"). In some cases, emotion-focused coping strategies involve reappraisal, whereby the stressor is construed differently (and somewhat self-deceptively) without changing its objective level of threat (Lazarus & Folkman, 1984). For example, a person sentenced to federal prison who thinks, "This will give me a great chance to network with others," is using reappraisal. If Bradford adopted an emotion-focused approach to managing his midterm deficiency stress, he might watch a comedy movie, play video games, or spend hours on Twitter to take his mind off the situation. In a certain sense, emotion-focused coping can be thought of as treating the symptoms rather than the actual cause.

While many stressors elicit both kinds of coping strategies, problem-focused coping is more likely to occur when encountering stressors we perceive as controllable, while emotion-focused coping is more likely to predominate when faced with stressors that we believe we are powerless to change (Folkman & Lazarus, 1980). Clearly, emotion-focused coping is more effective in dealing with uncontrollable stressors. For example, if at midnight you are stressing over a 40-page paper due in the morning that you have not yet started, you are probably better off recognizing the hopelessness of the situation and doing something to take your mind off it; taking a problem-focused approach by trying to accomplish this task would only lead to frustration, anxiety, and even more stress.

Fortunately, most stressors we encounter can be modified and are, to varying degrees, controllable. A person who cannot stand her job can quit and look for work elsewhere; a middle-aged divorcee can find another potential partner; the freshman who fails an exam can study harder next time, and a breast lump does not necessarily mean that one is fated to die of breast cancer.

Control and Stress

The desire and ability to predict events, make decisions, and affect outcomes—that is, to enact control in our lives—is a basic tenet of human behaviour (Everly & Lating, 2002). Albert Bandura (1997) stated that "the intensity and chronicity of human stress is governed largely by perceived control over the demands of one's life" (p. 262). As cogently described in his statement, our reaction to potential stressors depends to a large extent on how much control we feel we have over such things. Perceived controlis our beliefs about our personal capacity to exert influence over and shape outcomes, and it has major implications for our health and happiness (Infurna & Gerstorf, 2014). Extensive research has demonstrated that perceptions of personal control are associated with a variety of favorable outcomes, such as better physical and mental health and greater psychological well-being (Diehl & Hay, 2010). Greater personal control is also associated with lower reactivity to stressors in daily life. For example, researchers in one investigation found that higher levels of perceived control at one point in time were later associated with lower emotional and physical reactivity to interpersonal stressors (Neupert, Almeida, & Charles, 2007). Further, a daily diary study with 34 older widows found that their stress and anxiety levels were significantly reduced on days during which the widows felt greater perceived control (Ong, Bergeman, & Bisconti, 2005).

Seligman speculated that acquiring a sense of learned helplessness might be an important cause of depression in humans: Humans who experience negative life events that they believe they are unable to control may become helpless. As a result, they give up trying to control or change the situation and some may become depressed and show lack of initiative in future situations in which they can control the outcomes (Seligman, Maier, & Geer, 1968).

Seligman and colleagues later reformulated the original learned helplessness model of depression (Abramson, Seligman, & Teasdale, 1978). In their reformulation, they emphasized attributions (i.e., a mental explanation for why something occurred) that lead to the perception that one lacks control over negative outcomes are important in fostering a sense of learned helplessness. For example, suppose a coworker shows up late to work; your belief as to what caused the coworker's tardiness would be an attribution (e.g., too much traffic, slept too late, or just doesn't care about being on time).

The reformulated version of Seligman's study holds that the attributions made for negative life events contribute to depression. Consider the example of a student who performs poorly on a midterm exam. This model suggests that the student will make three kinds of attributions for this outcome: internal vs. external (believing the outcome was caused by his own personal inadequacies or by environmental factors), stable vs. unstable (believing the cause can be changed or is permanent), and global vs. specific (believing the outcome is a sign of inadequacy in most everything versus just this area). Assume that the student makes an internal ("I'm just not smart"), stable ("Nothing can be done to change the fact that I'm not smart") and global ("This is another example of how lousy I am at everything") attribution for the poor performance. The reformulated theory predicts that the student would perceive a lack of control over this stressful event and thus be especially prone to developing depression. Indeed, research has demonstrated that people who have a tendency to make internal, global, and stable attributions for bad outcomes tend to develop symptoms of depression when faced with negative life experiences (Peterson & Seligman, 1984).

Seligman's learned helplessness model has emerged over the years as a leading theoretical explanation for the onset of major depressive disorder. When you study psychological disorders, you will learn more about the latest reformulation of this model—now called hopelessness theory.

People who report higher levels of perceived control view their health as controllable, thereby making it more likely that they will better manage their health and engage in behaviours conducive to good health (Bandura, 2004). Not surprisingly, greater perceived control has been linked to lower risk of physical health problems, including declines in physical functioning (Infurna, Gerstorf, Ram, Schupp, & Wagner, 2011), heart attacks (Rosengren et al., 2004), and both cardiovascular disease incidence (Stürmer, Hasselbach, & Amelang, 2006) and mortality from cardiac disease (Surtees et al., 2010). In addition, longitudinal studies of British civil servants have found that those in low-status jobs (e.g., clerical and office support staff) in which the degree of control over the job is minimal are considerably more likely to develop heart disease than those with high-status jobs or considerable control over their jobs (Marmot, Bosma, Hemingway, & Stansfeld, 1997).

The link between perceived control and health may provide an explanation for the frequently observed relationship between social class and health outcomes (Kraus, Piff, Mendoza-Denton, Rheinschmidt, & Keltner, 2012). In general, research has found that more affluent individuals experience better health mainly because they tend to believe that they can personally control and manage their reactions to life's stressors (Johnson & Krueger, 2006). Perhaps buoyed by the perceived level of control, individuals of higher social class may be prone to overestimating the degree of influence they have over particular outcomes. For example, those of higher social class tend to believe that their votes have greater sway on election outcomes than do those of lower social class, which may explain higher rates of voting in more affluent communities (Krosnick, 1990). Other research has found that a sense of perceived control can protect less affluent individuals from poorer health, depression, and reduced life-satisfaction—all of which tend to accompany lower social standing (Lachman & Weaver, 1998).

Taken together, findings from these and many other studies clearly suggest that perceptions of control and coping abilities are important in managing and coping with the stressors we encounter throughout life.

Social Support

The need to form and maintain strong, stable relationships with others is a powerful, pervasive, and fundamental human motive (Baumeister & Leary, 1995). Building strong interpersonal relationships with others helps us establish a network of close, caring individuals who can provide social support in times of distress, sorrow, and fear. Social support can be thought of as the soothing impact of friends, family, and acquaintances (Baron & Kerr, 2003). Social support can take many forms, including advice, guidance, encouragement, acceptance, emotional comfort, and tangible assistance (such as financial help). Thus, other people can be very comforting to us when we are faced with a wide range of life stressors, and they can be extremely helpful in our efforts to manage these challenges. Even in nonhuman animals, species mates can offer social support during times of stress. For example, elephants seem to be able to sense when other elephants are stressed and will often comfort them with physical contact—such as a trunk touch—or an empathetic vocal response (Krumboltz, 2014).

Scientific interest in the importance of social support first emerged in the 1970s when health researchers developed an interest in the health consequences of being socially integrated (Stroebe & Stroebe, 1996). Interest was further fueled by longitudinal studies showing that social connectedness reduced mortality. In one classic study, nearly 7,000 Alameda County, California, residents were followed over 9 years. Those who had previously indicated that they lacked social and community ties were more likely to die during the follow-up period than those with more extensive social networks. Compared to those with the most social contacts, isolated men and women were, respectively, 2.3 and 2.8 times more likely to die. These trends persisted even after controlling for a variety of health-related variables, such as smoking, alcohol consumption, self-reported health at the beginning of the study, and physical activity (Berkman & Syme, 1979).

Since the time of that study, social support has emerged as one of the well-documented psychosocial factors affecting health outcomes (Uchino, 2009). A statistical review of 148 studies conducted between 1982 and 2007 involving over 300,000 participants concluded that individuals with stronger social relationships have a 50% greater likelihood of survival compared to those with weak or insufficient social relationships (Holt-Lunstad, Smith, & Layton, 2010). According to the researchers, the magnitude of the effect of social support observed in this study is comparable with quitting smoking and exceeded many well-known risk factors for mortality, such as obesity and physical inactivity (Figure 2.10.5.1).

Figure 2.10.5.1

(a) (b)

Close relationships with others, whether that's (a) a group of friends or (b) a family circle, provide more than happiness and fulfillment—they can help foster good health. Source: (a) modification of work by Nattachai Noogure; (b) modification of work by Christian Haugen. Source: [Regulation of Stress](#)

A number of large-scale studies have found that individuals with low levels of social support are at greater risk of mortality, especially from cardiovascular disorders (Brummett et al., 2001). Further, higher levels of social supported have been linked to better survival rates following breast cancer (Falagas et al., 2007) and infectious diseases, especially HIV infection (Lee & Rotheram-Borus, 2001). In fact, a person with high levels of social support is less likely to contract a common cold. In one study, 334 participants completed questionnaires assessing their sociability; these individuals were subsequently exposed to a virus that causes a common cold and monitored for several weeks to see who became ill. Results showed that increased sociability was linearly associated with a decreased probability of developing a cold (Cohen, Doyle, Turner, Alper, & Skoner, 2003).

For many of us, friends are a vital source of social support. But what if you found yourself in a situation in which you lacked friends or companions? For example, suppose a popular high school student attends a far-away college, does not know anyone, and has trouble making friends and meaningful connections with others during the first semester. What can be done? If real life social support is lacking, access to distant friends via social media may help compensate. In a study of college freshmen, those with few face-to-face friends on campus but who communicated electronically with distant friends were less distressed that those who did not (Raney & Troop-Gordon, 2012). Also, for some people, our families—especially our parents—are a major source of social support.

Social support appears to work by boosting the immune system, especially among people who are experiencing stress (Uchino, Vaughn, Carlisle, & Birmingham, 2012). In a pioneering study, spouses of cancer patients who reported high levels of social support showed indications of better immune functioning on two out of three immune functioning measures, compared to spouses who were below the median on reported social support (Baron, Cutrona, Hicklin, Russell, & Lubaroff, 1990). Studies of other populations have produced similar results, including those of spousal caregivers of dementia sufferers, medical students, elderly adults, and cancer patients (Cohen & Herbert, 1996; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002).

In addition, social support has been shown to reduce blood pressure for people performing stressful tasks, such as giving a speech or performing mental arithmetic (Lepore, 1998). In these kinds of studies, participants are usually asked to perform a stressful task either alone, with a stranger present (who may be either supportive or unsupportive), or with a friend present. Those tested with a friend present generally exhibit lower blood pressure than those tested alone or with a stranger (Fontana, Diegnan, Villeneuve, & Lepore, 1999). In one study, 112 female participants who performed stressful mental arithmetic exhibited lower blood pressure when they received support from a friend rather than a stranger, but only if the friend was a male (Phillips, Gallagher, & Carroll, 2009). Although these findings are somewhat difficult to interpret, the authors mention that it is possible that females feel less supported and more evaluated by other females, particularly females whose opinions they value.

Taken together, the findings above suggest one of the reasons social support is connected to favorable health outcomes is because it has several beneficial physiological effects in stressful situations. However, it is also important to consider the possibility that social support may lead to better health behaviours, such as a healthy diet, exercising, smoking cessation, and cooperation with medical regimens (Uchino, 2009).

Coping with Prejudice and Discrimination

While having social support is quite beneficial, being the recipient of prejudicial attitudes and discriminatory behaviours is associated with a number of negative outcomes. In their literature review, Brondolo, Brady, Pencille, Beatty, and Contrada (2009) describe how racial prejudice and discrimination serve as unique, significant stressors for those who are the targets of such attitudes and behaviour. Being the target of racism is associated with increased rates of depression, lowered self-esteem, hypertension, and cardiovascular disease.

Given the complex and pervasive nature of racism as a stressor, Brondolo et al. (2009) point out the importance of coping with this specific stressor. Their review is aimed at determining which coping strategies are most effective at offsetting negative health outcomes associated with racism-related stress. The authors examine the effectiveness of three coping strategies: focusing on racial identity to handle race-related stress, anger expression/suppression, and seeking social support. You've learned a bit about social support, so we'll focus the remainder of this discussion on the potential coping strategies of focusing on racial identity and anger expression/suppression.

Focusing on racial identity refers to the process by which a person comes to feel as if he belongs to a given racial group; this may increase a sense of pride associated with group membership. Brondolo et al. (2009) suggest that a strong sense of racial identity might help an individual who is the target of racism differentiate between prejudicial attitudes/behaviours that are directed toward his group as a whole rather than at him as a person. Furthermore, the sense of belonging to his group might alleviate the distress of being ostracized by others. However, the research literature on the effectiveness of this technique has produced mixed results.

Anger expression/suppression refers to the options available as a function of the anger evoked by racial prejudice and discrimination. Put simply, a target of racist attitudes and behaviours can act upon her anger or suppress her anger. As discussed by Brondolo et al. (2009), there has been very little research on the effectiveness of either approach; the results are quite mixed with some showing anger expression and others showing anger suppression as the healthier option.

In the end, racism-related stress is a complex issue and each of the coping strategies discussed here has strengths and weaknesses. Brondolo et al. (2009) argue that it is imperative that additional research be conducted to ascertain the most effective strategies for coping with the negative outcomes that are experienced by the targets of racism.

2.10.6. Stress Reduction Techniques

Beyond having a sense of control and establishing social support networks, there are numerous other means by which we can manage stress (Figure 2.10.6.1). A common technique people use to combat stress is exercise(Salmon, 2001). It is well-established that exercise, both of long (aerobic) and short (anaerobic) duration, is beneficial for both physical and mental health (Everly & Lating, 2002). There is considerable evidence that physically fit individuals are more resistant to the adverse effects of stress and recover more quickly from stress than less physically fit individuals (Cotton, 1990). In a study of more than 500 Swiss police officers and emergency service personnel, increased physical fitness was associated with reduced stress, and regular exercise was reported to protect against stress-related health problems (Gerber, Kellman, Hartman, & Pühse, 2010).

Figure 2.10.6.1

Stress reduction techniques may include (a) exercise, (b) meditation and relaxation, or (c) biofeedback. Source: (a) modification of work by "UNE Photos"/Flickr; (b) modification of work by Caleb Roenigk; (c) modification of work by Dr. Carmen Russoniello. Source: Regulation of Stress

One reason exercise may be beneficial is because it might buffer some of the deleterious physiological mechanisms of stress. One study found rats that exercised for six weeks showed a decrease in hypothalamic-pituitary-adrenal responsiveness to mild stressors (Campeau et al., 2010). In high-stress humans, exercise has been shown to prevent telomere shortening, which may explain the common observation of a youthful appearance among those who exercise regularly (Puterman et al., 2010). Further, exercise in later adulthood appears to minimize the detrimental effects of stress on the hippocampus and memory (Head, Singh, & Bugg, 2012). Among cancer survivors, exercise has been shown to reduce anxiety (Speck, Courneya, Masse, Duval, & Schmitz, 2010) and depressive symptoms

(Craft, VanIterson, Helenowski, Rademaker, & Courneya, 2012). Clearly, exercise is a highly effective tool for regulating stress.

In the 1970s, Herbert Benson, a cardiologist, developed a stress reduction method called the relaxation response technique(Greenberg, 2006). The relaxation response technique combines relaxation with transcendental meditation, and consists of four components (Stein, 2001):

- sitting upright on a comfortable chair with feet on the ground and body in a relaxed position
- being in a quiet environment with eyes closed
- repeating a word or a phrase—a mantra—to oneself, such as "alert mind, calm body"
- passively allowing the mind to focus on pleasant thoughts, such as nature or the warmth of your blood nourishing your body

The relaxation response approach is conceptualized as a general approach to stress reduction that reduces sympathetic arousal, and it has been used effectively to treat people with high blood pressure (Benson & Proctor, 1994).

Another technique to combat stress, biofeedback, was developed by Gary Schwartz at Harvard University in the early 1970s. Biofeedback is a technique that uses electronic equipment to accurately measure a person's neuromuscular and autonomic activity—feedback is provided in the form of visual or auditory signals. The main assumption of this approach is that providing somebody biofeedback will enable the individual to develop strategies that help gain some level of voluntary control over what are normally involuntary bodily processes (Schwartz & Schwartz, 1995). A number of different bodily measures have been used in biofeedback research, including facial muscle movement, brain activity, and skin temperature, and it has been applied successfully with individuals experiencing tension headaches, high blood pressure, asthma, and phobias (Stein, 2001).

2.10.7. Choosing Optimism

Happiness

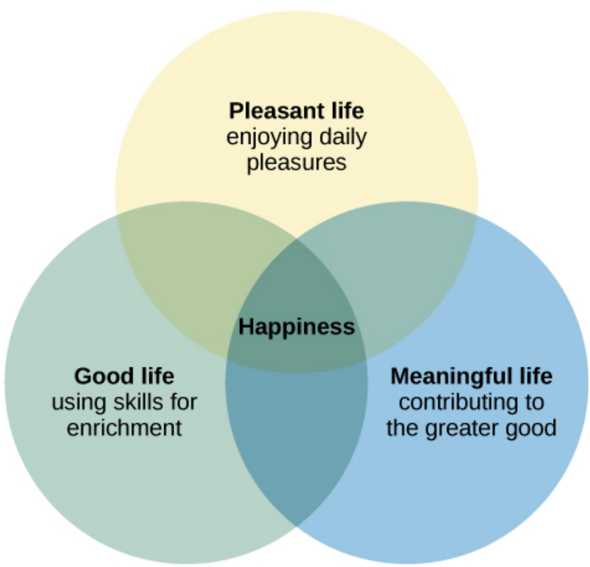
Although the study of stress and how it affects us physically and psychologically is fascinating, it is—admittedly—somewhat of a grim topic. Psychology is also interested in the study of a more upbeat and encouraging approach to human affairs—the quest for happiness.

America's founders declared that its citizens have an unalienable right to pursue happiness. But what is happiness? When asked to define the term, people emphasize different aspects of this elusive state. Indeed, happiness is somewhat ambiguous and can be defined from different perspectives (Martin, 2012). Some people, especially those who are highly committed to their religious faith, view happiness in ways that emphasize virtuosity, reverence, and enlightened spirituality. Others see happiness as primarily contentment—the inner peace and joy that come from deep satisfaction with one's surroundings, relationships with others, accomplishments, and oneself. Still others view happiness mainly as pleasurable engagement with their personal environment—having a career and hobbies that are engaging, meaningful, rewarding, and exciting. These differences, of course, are merely differences in emphasis. Most people would probably agree that each of these views, in some respects, captures the essence of happiness.

Elements of Happiness

Some psychologists have suggested that happiness consists of three distinct elements: the pleasant life, the good life, and the meaningful life, as shown in Figure 2.10.7.1 (Seligman, 2002; Seligman, Steen, Park, & Peterson, 2005). The pleasant life is realized through the attainment of day-to-day pleasures that add fun, joy, and excitement to our lives. For example, evening walks along the beach and a fulfilling sex life can enhance our daily pleasure and contribute to the pleasant life. The good life is achieved through identifying our unique skills and abilities and engaging these talents to enrich our lives; those who achieve the good life often find themselves absorbed in their work or their recreational pursuits. The meaningful life involves a deep sense of fulfillment that comes from using our talents in the service of the greater good: in ways that benefit the lives of others or that make the world a better place. In general, the happiest people tend to be those who pursue the full life—they orient their pursuits toward all three elements (Seligman et al., 2005).

Figure 2.10.7.1



Happiness is an enduring state of well-being involving satisfaction in the pleasant, good, and meaningful aspects of life.

Source: The Pursuit of Happiness
For practical purposes, a precise definition of happiness might incorporate each of these elements: an enduring state of mind consisting of joy, contentment, and other positive emotions, plus the sense that one's life has meaning and value (Lyubomirsky, 2001). The definition implies that happiness is a long-term state—what is often characterized as subjective well-being—rather than merely a transient positive mood we all experience from time to time. It is this enduring happiness that has captured the interests of psychologists and other social scientists.

The study of happiness has grown dramatically in the last three decades (Diener, 2013). One of the most basic questions that happiness investigators routinely examine is this: How happy are people in general? The average person in the world tends to be relatively happy and tends to indicate experiencing more positive feelings than negative feelings (Diener, Ng, Harter, & Arora, 2010). When asked to evaluate their current lives on a scale ranging from 0 to 10 (with 0 representing "worst possible life" and 10 representing "best possible life"), people in more than 150 countries surveyed from 2010–2012 reported an average score of 5.2. People who live in North America, Australia, and New Zealand reported the highest average score at 7.1, whereas those living Sub-Saharan Africa reported the lowest average score at 4.6 (Helliwell, Layard, & Sachs, 2013). Worldwide, the five happiest countries are Denmark, Norway, Switzerland, the Netherlands, and Sweden; the United States is ranked 17th happiest (Figure 2.10.7.2) (Helliwell et al., 2013).

Figure 2.10.7.2

(a)

(b)

a) Surveys of residents in over 150 countries indicate that Denmark has the happiest citizens in the world. (b) Americans ranked the United States as the 17th happiest country in which to live. Source: (a) modification of work by "JamesZ_Flickr"/Flickr; (b) modification of work by Ryan Swindell. Source: [The Pursuit of Happiness]

Several years ago, a Gallup survey of more than 1,000 U.S. adults found that 52% reported that they were "very happy." In addition, more than 8 in 10 indicated that they were "very satisfied" with their lives (Carroll, 2007). However, a recent poll of 2,345 U.S. adults surprisingly revealed that only one-third reported they are "very happy." The poll also revealed that the happiness levels of certain groups, including minorities, recent college graduates, and the disabled, have trended downward in recent years (Gregoire, 2013). Although it is difficult to explain this apparent decline in happiness, it may be connected to the challenging economic conditions the United States has endured over the last several years. Of course, this presumption would imply that happiness is closely tied to one's finances. But, is it? This question brings us to the next important issue: What factors influence happiness?

Factors Connected to Happiness

What really makes people happy? What factors contribute to sustained joy and contentment? Is it money, attractiveness, material possessions, a rewarding occupation, a satisfying relationship? Extensive research over the years has examined this question. One finding is that age is related to happiness: Life satisfaction usually increases the older people get, but there do not appear to be gender differences in happiness (Diener, Suh, Lucas, & Smith, 1999). Although it is important to point out that much of this work has been correlational, many of the key findings (some of which may surprise you) are summarized below.

Family and other social relationships appear to be key factors correlated with happiness. Studies show that married people report being happier than those who are single, divorced, or widowed (Diener et al., 1999). Happy individuals also report that their marriages are fulfilling (Lyubomirsky, King, & Diener, 2005). In fact, some have suggested that satisfaction with marriage and family life is the strongest predictor of happiness (Myers, 2000). Happy people tend to have more friends, more high-quality social relationships, and stronger social support networks than less happy people (Lyubomirsky et al., 2005). Happy people also have a high frequency of contact with friends (Pinquart & Sörensen, 2000).

Can money buy happiness? In general, extensive research suggests that the answer is yes, but with several caveats. While a nation's per capita gross domestic product (GDP) is associated with happiness levels (Helliwell et al., 2013), changes in GDP (which is a less certain index of household income) bear little relationship to changes in happiness (Diener, Tay, & Oishi, 2013). On the whole, residents of affluent countries tend to be happier than residents of poor countries; within countries, wealthy individuals are happier than poor individuals, but the association is much weaker (Diener & Biswas-Diener, 2002). To the extent that it leads to increases in purchasing power, increases in income are associated with increases in happiness (Diener, Oishi, & Ryan, 2013). However, income within societies appears to correlate with happiness only up to a point. In a study of over 450,000 U.S. residents surveyed by the Gallup Organization, Kahneman and Deaton (2010) found that well-being rises with annual income, but only up to $75,000. The average increase in reported well-being for people with incomes greater than $75,000 was null. As implausible as these findings might seem—after all, higher incomes would enable people to indulge in Hawaiian vacations, prime seats as sporting events, expensive automobiles, and expansive new homes—higher incomes may impair people's ability to savor and enjoy the small pleasures of life (Kahneman, 2011). Indeed, researchers in one study found that participants exposed to a subliminal reminder of wealth spent less time savoring a chocolate candy bar and exhibited less enjoyment of this experience than did participants who were not reminded of wealth (Quoidbach, Dunn, Petrides, & Mikolajczak, 2010).

What about education and employment? Happy people, compared to those who are less happy, are more likely to graduate from college and secure more meaningful and engaging jobs. Once they obtain a job, they are also more likely to succeed (Lyubomirsky et al., 2005). While education shows a positive (but weak) correlation with happiness, intelligence is not appreciably related to happiness (Diener et al., 1999).

Does religiosity correlate with happiness? In general, the answer is yes (Hackney & Sanders, 2003). However, the relationship between religiosity and happiness depends on societal circumstances. Nations and states with more difficult living conditions (e.g., widespread hunger and low life expectancy) tend to be more highly religious than societies with more favorable living conditions. Among those who live in nations with difficult living conditions, religiosity is associated with greater well-being; in nations with more favorable living conditions, religious and nonreligious individuals report similar levels of well-being (Diener, Tay, & Myers, 2011).

Clearly the living conditions of one's nation can influence factors related to happiness. What about the influence of one's culture? To the extent that people possess characteristics that are highly valued by their culture, they tend to be happier (Diener, 2012). For example, self-esteem is a stronger predictor of life satisfaction in individualistic cultures than in collectivistic cultures (Diener, Diener, & Diener, 1995), and extraverted people tend to be happier in extraverted cultures than in introverted cultures (Fulmer et al., 2010).

So we've identified many factors that exhibit some correlation to happiness. What factors don't show a correlation? Researchers have studied both parenthood and physical attractiveness as potential contributors to happiness, but no link has been identified. Although people tend to believe that parenthood is central to a meaningful and fulfilling life, aggregate findings from a range of countries indicate that people who do not have children are generally happier than those who do (Hansen, 2012). And although one's perceived level of attractiveness seems to predict happiness, a person's objective physical attractiveness is only weakly correlated with her happiness (Diener, Wolsic, & Fujita, 1995).

Life Events and Happiness

An important point should be considered regarding happiness. People are often poor at affective forecasting: predicting the intensity and duration of their future emotions (Wilson & Gilbert, 2003). In one study, nearly all newlywed spouses predicted their marital satisfaction would remain stable or improve over the following four years; despite this high level of initial optimism, their marital satisfaction actually declined during this period (Lavner, Karner, & Bradbury, 2013). In addition, we are often incorrect when estimating how our long-term happiness would change for the better or worse in response to certain life events. For example, it is easy for many of us to imagine how euphoric we would feel if we won the lottery, were asked on a date by an attractive celebrity, or were offered our dream job. It is also easy to understand how long-suffering fans of the Chicago Cubs baseball team, which has not won a World Series championship since 1908, think they would feel permanently elated if their team would finally win another World Series. Likewise, it easy to predict that we would feel permanently miserable if we suffered a crippling accident or if a romantic relationship ended.

However, something similar to sensory adaptation often occurs when people experience emotional reactions to life events. In much the same way our senses adapt to changes in stimulation (e.g., our eyes adapting to bright light after walking out of the darkness of a movie theater into the bright afternoon sun), we eventually adapt to changing emotional circumstances in our lives (Brickman & Campbell, 1971; Helson, 1964). When an event that provokes positive or negative emotions occurs, at first we tend to experience its emotional impact at full intensity. We feel a burst of pleasure following such things as a marriage proposal, birth of a child, acceptance to law school, an inheritance, and the like; as you might imagine, lottery winners experience a surge of happiness after hitting the jackpot (Lutter, 2007). Likewise, we experience a surge of misery following widowhood, a divorce, or a layoff from work. In the long run, however, we eventually adjust to the emotional new normal; the emotional impact of the event tends to erode, and we eventually revert to our original baseline happiness levels. Thus, what was at first a thrilling lottery windfall or World Series championship eventually loses its luster and becomes the status quo (Figure 2.10.7.3). Indeed, dramatic life events have much less long-lasting impact on happiness than might be expected (Brickman, Coats, & Janoff-Bulman, 1978).

Figure 2.10.7.3

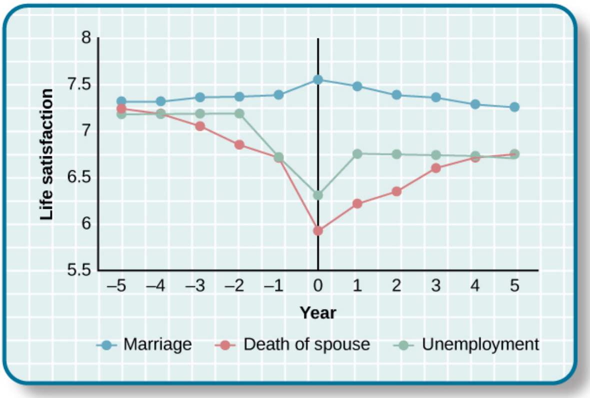
(a) (b)

(a) Long-suffering Chicago Cub fans would no doubt feel elated if their team won a World Series championship, a feat that has not been accomplished by that franchise in over a century. (b) In ways that are similar, those who play the lottery rightfully think that choosing the correct numbers and winning millions would lead to a surge in happiness. However, the initial burst of elation following such elusive events would most likely erode with time. Source: (a) modification of work by Phil Roeder; (b) modification of work by Robert S. Donovan.

Source: [The Pursuit of Happiness]()

Recently, some have raised questions concerning the extent to which important life events can permanently alter people's happiness set points (Diener, Lucas, & Scollon, 2006). Evidence from a number of investigations suggests that, in some circumstances, happiness levels do not revert to their original positions. For example, although people generally tend to adapt to marriage so that it no longer makes them happier or unhappier than before, they often do not fully adapt to unemployment or severe disabilities (Diener, 2012). Figure 2.10.7.4, which is based on longitudinal data from a sample of over 3,000 German respondents, shows life satisfaction scores several years before, during, and after various life events, and it illustrates how people adapt (or fail to adapt) to these events. German respondents did not get lasting emotional boosts from marriage; instead, they reported brief increases in happiness, followed by quick adaptation. In contrast, widows and those who had been laid off experienced sizeable decreases in happiness that appeared to result in long-term changes in life satisfaction (Diener et al., 2006). Further, longitudinal data from the same sample showed that happiness levels changed significantly over time for nearly a quarter of respondents, with 9% showing major changes (Fujita & Diener, 2005). Thus, long-term happiness levels can and do change for some people.

Figure 2.10.7.4



This graph shows life satisfaction scores several years before and after three significant life events (0 represents the year the event happened) (Diener et al., 2006). Source: [The Pursuit of Happiness]

Increasing Happiness

Some recent findings about happiness provide an optimistic picture, suggesting that real changes in happiness are possible. For example, thoughtfully developed well-being interventions designed to augment people's baseline levels of happiness may increase happiness in ways that are permanent and long-lasting, not just temporary. These changes in happiness may be targeted at individual, organizational, and societal levels (Diener et al., 2006). Researchers in one study found that a series of happiness interventions involving such exercises as writing down three good things that occurred each day led to increases in happiness that lasted over six months (Seligman et al., 2005).

Measuring happiness and well-being at the societal level over time may assist policy makers in determining if people are generally happy or miserable, as well as when and why they might feel the way they do. Studies show that average national happiness scores (over time and across countries) relate strongly to six key variables: per capita gross domestic product (GDP, which reflects a nation's economic standard of living), social support, freedom to make important life choices, healthy life expectancy, freedom from perceived corruption in government and business, and generosity (Helliwell et al., 2013). Investigating why people are happy or unhappy might help policymakers develop programs that increase happiness and well-being within a society (Diener et al., 2006). Resolutions about contemporary political and social issues that are frequent topics of debate—such as poverty, taxation, affordable health care and housing, clean air and water, and income inequality—might be best considered with people's happiness in mind.

Positive Psychology

In 1998, Seligman (the same person who conducted the learned helplessness experiments mentioned earlier), who was then president of the American Psychological Association, urged psychologists to focus more on understanding how to build human strength and psychological well-being. In deliberately setting out to create a new direction and new orientation for psychology, Seligman helped establish a growing movement and field of research called positive psychology (Compton, 2005). In a very general sense, positive psychology can be thought of as the science of happiness; it is an area of study that seeks to identify and promote those qualities that lead to greater fulfillment in our lives. This field looks at people's strengths and what helps individuals to lead happy, contented lives, and it moves away from focusing on people's pathology, faults, and problems. According to Seligman and Csikszentmihalyi (2000), positive psychology, at the subjective level is about valued subjective experiences: well-being, contentment, and satisfaction (in the past); hope and optimism (for the future); and… happiness (in the present). At the individual level, it is about positive individual traits: the capacity for love and vocation, courage, interpersonal skill, aesthetic sensibility, perseverance, forgiveness, originality, future mindedness, spirituality, high talent, and wisdom. (p. 5)

Some of the topics studied by positive psychologists include altruism and empathy, creativity, forgiveness and compassion, the importance of positive emotions, enhancement of immune system functioning, savoring the fleeting moments of life, and strengthening virtues as a way to increase authentic happiness (Compton, 2005). Recent efforts in the field of positive psychology have focused on extending its principles toward peace and well-being at the level of the global community. In a war-torn world in which conflict, hatred, and distrust are common, such an extended "positive peace psychology" could have important implications for understanding how to overcome oppression and work toward global peace (Cohrs, Christie, White, & Das, 2013).

The Center for Investigating Healthy Minds

On the campus of the University of Wisconsin–Madison, the Center for Investigating Healthy Minds at the Waisman Center conducts rigorous scientific research on healthy aspects of the mind, such as kindness, forgiveness, compassion, and mindfulness. Established in 2008 and led by renowned neuroscientist Dr. Richard J. Davidson, the Center examines a wide range of ideas, including such things as a kindness curriculum in schools, neural correlates of prosocial behaviour, psychological effects of Tai Chi training, digital games to foster prosocial behaviour in children, and the effectiveness of yoga and breathing exercises in reducing symptoms of post-traumatic stress disorder.

According to its website, the Center was founded after Dr. Davidson was challenged by His Holiness, the 14th Dalai Lama, "to apply the rigors of science to study positive qualities of mind" (Center for Investigating Health Minds, 2013). The Center continues to conduct scientific research with the aim of developing mental health training approaches that help people to live happier, healthier lives).

Positive Affect and Optimism

Taking a cue from positive psychology, extensive research over the last 10-15 years has examined the importance of positive psychological attributes in physical well-being. Qualities that help promote psychological well-being (e.g., having meaning and purpose in life, a sense of autonomy, positive emotions, and satisfaction with life) are linked with a range of favorable health outcomes (especially improved cardiovascular health) mainly through their relationships with biological functions and health behaviours (such as diet, physical activity, and sleep quality) (Boehm & Kubzansky, 2012). The quality that has received attention is positive affect, which refers to pleasurable engagement with the environment, such as happiness, joy, enthusiasm, alertness, and excitement (Watson, Clark, & Tellegen, 1988). The characteristics of positive affect, as with negative affect (discussed earlier), can be brief, long-lasting, or trait-like (Pressman & Cohen, 2005). Independent of age, gender, and income, positive affect is associated with greater social connectedness, emotional and practical support, adaptive coping efforts, and lower depression; it is also associated with longevity and favorable physiological functioning (Steptoe, O'Donnell, Marmot, & Wardle, 2008).

Positive affect also serves as a protective factor against heart disease. In a 10-year study of Nova Scotians, the rate of heart disease was 22% lower for each one-point increase on the measure of positive affect, from 1 (no positive affect expressed) to 5 (extreme positive affect) (Davidson, Mostofsky, & Whang, 2010). In terms of our health, the expression, “don’t worry, be happy” is helpful advice indeed. There has also been much work suggesting that optimism—the general tendency to look on the bright side of things—is also a significant predictor of positive health outcomes.

Although positive affect and optimism are related in some ways, they are not the same (Pressman & Cohen, 2005). Whereas positive affect is mostly concerned with positive feeling states, optimism has been regarded as a generalized tendency to expect that good things will happen (Chang, 2001). It has also been conceptualized as a tendency to view life’s stressors and difficulties as temporary and external to oneself (Peterson & Steen, 2002). Numerous studies over the years have consistently shown that optimism is linked to longevity, healthier behaviours, fewer postsurgical complications, better immune functioning among men with prostate cancer, and better treatment adherence (Rasmussen & Wallio, 2008). Further, optimistic people report fewer physical symptoms, less pain, better physical functioning, and are less likely to be rehospitalized following heart surgery (Rasmussen, Scheier, & Greenhouse, 2009).

Flow

Another factor that seems to be important in fostering a deep sense of well-being is the ability to derive flow from the things we do in life. Flow is described as a particular experience that is so engaging and engrossing that it becomes worth doing for its own sake (Csikszentmihalyi, 1997). It is usually related to creative endeavors and leisure activities, but it can also be experienced by workers who like their jobs or students who love studying (Csikszentmihalyi, 1999). Many of us instantly recognize the notion of flow. In fact, the term derived from respondents' spontaneous use of the term when asked to describe how it felt when what they were doing was going well. When people experience flow, they become involved in an activity to the point where they feel they lose themselves in the activity. They effortlessly maintain their concentration and focus, they feel as though they have complete control of their actions, and time seems to pass more quickly than usual (Csikszentmihalyi, 1997). Flow is considered a pleasurable experience, and it typically occurs when people are engaged in challenging activities that require skills and knowledge they know they possess. For example, people would be more likely report flow experiences in relation to their work or hobbies than in relation to eating. When asked the question, "Do you ever get involved in something so deeply that nothing else seems to matter, and you lose track of time?" about 20% of Americans and Europeans report having these flow-like experiences regularly (Csikszentmihalyi, 1997).

Although wealth and material possessions are nice to have, the notion of flow suggests that neither are prerequisites for a happy and fulfilling life. Finding an activity that you are truly enthusiastic about, something so absorbing that doing it is reward itself (whether it be playing tennis, studying Arabic, writing children's novels, or cooking lavish meals) is perhaps the real key. According to Csikszentmihalyi (1999), creating conditions that make flow experiences possible should be a top social and political priority. How might this goal be achieved? How might flow be promoted in school systems? In the workplace? What potential benefits might be accrued from such efforts?

In an ideal world, scientific research endeavors should inform us on how to bring about a better world for all people. The field of positive psychology promises to be instrumental in helping us understand what truly builds hope, optimism, happiness, healthy relationships, flow, and genuine personal fulfillment.

2.10.8. Summary

What Is Stress?

Stress is a process whereby an individual perceives and responds to events appraised as overwhelming or threatening to one's well-being. The scientific study of how stress and emotional factors impact health and well-being is called health psychology, a field devoted to studying the general impact of psychological factors on health. The body's primary physiological response during stress, the fight-or-flight response, was first identified in the early 20th century by Walter Cannon. The fight-or-flight response involves the coordinated activity of both the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis. Hans Selye, a noted endocrinologist, referred to these physiological reactions to stress as part of general adaptation syndrome, which occurs in three stages: alarm reaction (fight-or-flight reactions begin), resistance (the body begins to adapt to continuing stress), and exhaustion (adaptive energy is depleted, and stress begins to take a physical toll).

Stressors

Stressors can be chronic (long term) or acute (short term), and can include traumatic events, significant life changes, daily hassles, and situations in which people are frequently exposed to challenging and unpleasant events. Many potential stressors include events or situations that require us to make changes in our lives, such as a divorce or moving to a new residence. Thomas Holmes and Richard Rahe developed the Social Readjustment Rating Scale (SRRS) to measure stress by assigning a number of life change units to life events that typically require some adjustment, including positive events. Although the SRRS has been criticized on a number of grounds, extensive research has shown that the accumulation of many LCUs is associated with increased risk of illness. Many potential stressors also include daily hassles, which are minor irritations and annoyances that can build up over time. In addition, jobs that are especially demanding, offer little control over one's working environment, or involve unfavorable working conditions can lead to job strain, thereby setting the stage for job burnout.

Stress and Illness

Psychophysiological disorders are physical diseases that are either brought about or worsened by stress and other emotional factors. One of the mechanisms through which stress and emotional factors can influence the development of these diseases is by adversely affecting the body's immune system. A number of studies have demonstrated that stress weakens the functioning of the immune system. Cardiovascular disorders are serious medical conditions that have been consistently shown to be influenced by stress and negative emotions, such as anger, negative affectivity, and depression. Other psychophysiological disorders that are known to be influenced by stress and emotional factors include asthma and tension headaches.

Regulation of Stress

When faced with stress, people must attempt to manage or cope with it. In general, there are two basic forms of coping: problem-focused coping and emotion-focused coping. Those who use problem-focused coping strategies tend to cope better with stress because these strategies address the source of stress rather than the resulting symptoms. To a large extent, perceived control greatly impacts reaction to stressors and is associated with greater physical and mental well-being. Social support has been demonstrated to be a highly effective buffer against the adverse effects of stress. Extensive research has shown that social support has beneficial physiological effects for people, and it seems to influence immune functioning. However, the beneficial effects of social support may be related to its influence on promoting healthy behaviours.

The Pursuit of Happiness

Happiness is conceptualized as an enduring state of mind that consists of the capacity to experience pleasure in daily life, as well as the ability to engage one's skills and talents to enrich one's life and the lives of others. Although people around the world generally report that they are happy, there are differences in average happiness levels across nations. Although people have a tendency to overestimate the extent to which their happiness set points would change for the better or for the worse following certain life events, researchers have identified a number of factors that are consistently related to happiness. In recent years, positive psychology has emerged as an area of study seeking to identify and promote qualities that lead to greater happiness and fulfillment in our lives. These components include positive affect, optimism, and flow.

Personal Application Questions

- Think of a time in which you and others you know (family members, friends, and classmates) experienced an event that some viewed as threatening and others viewed as challenging. What were some of the differences in the reactions of those who experienced the event as threatening compared to those who viewed the event as challenging? Why do you think there were differences in how these individuals judged the same event?
- Suppose you want to design a study to examine the relationship between stress and illness, but you cannot use the Social Readjustment Rating Scale. How would you go about measuring stress? How would you measure illness? What would you need to do in order to tell if there is a cause-effect relationship between stress and illness?
- If a family member or friend of yours has asthma, talk to that person (if he or she is willing) about their symptom triggers. Does this person mention stress or emotional states? If so, are there any commonalities in these asthma triggers?
- Try to think of an example in which you coped with a particular stressor by using problem-focused coping. What was the stressor? What did your problem-focused efforts involve? Were they effective?
- Think of an activity you participate in that you find engaging and absorbing. For example, this might be something like playing video games, reading, or a hobby. What are your experiences typically like while engaging in this activity? Do your experiences conform to the notion of flow? If so, how? Do you think these experiences have enriched your life? Why or why not?

2.10.9 References

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2.10.10. Test Your Knowledge

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2.11. SUBSTANCE USE

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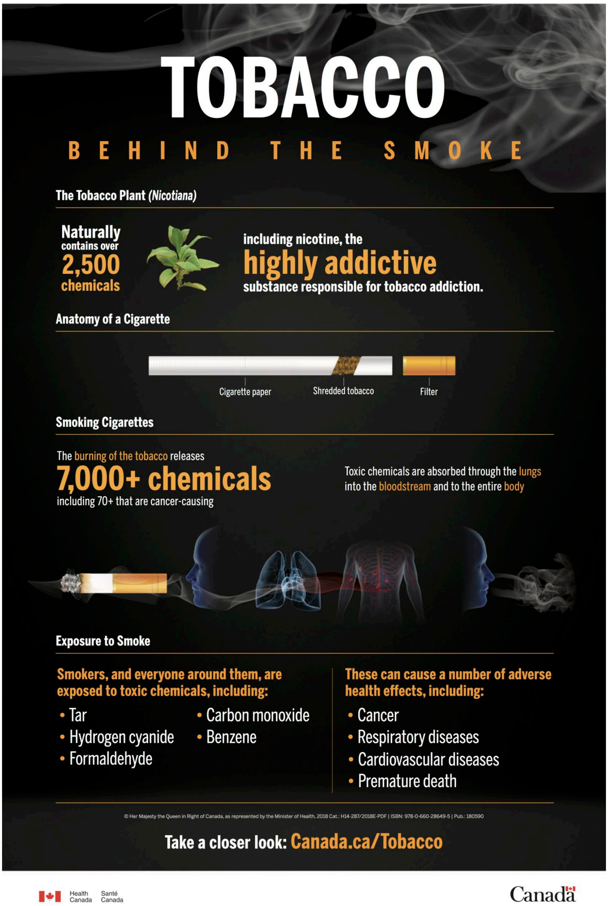
2.11.1. Smoking, Vaping and Tobacco

Effects of Smoking

Tobacco smoke is considered an environmental toxicant containing more than 4000 chemicals. More than 70 of these chemicals are known to cause, initiate and promote cancer.[1] Smoking is linked to more than two dozen diseases and conditions. **Most of smoking adverse effects can start to reverse once you quit. Sometimes these effects will occur in a matter of hours.**

Figure 2.11.1.1 *Tobacco: Behind the Smoke*

1. Biomarkers of Exposure. Government of Canada. https://www.canada.ca/en/health-canada/services/publications/healthy-living/biomarkers-exposure.html. Updated on May 13, 2014. Accessed on February 2, 2020.



Source: © All rights reserved. Tobacco Behind The Smoke. Health Canada. Adapted and reproduced with permission from the Minister of Health, 2020.

Health risks for people who smoke include the following:[2]

2. Risks of Smoking. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/effects-smoking/smoking-your-

- problems with their heart and blood vessels
- stroke
- certain types of cancers
- lung and respiratory problems
- premature death

Female smokers are also at increased risk for the following conditions:

- cancer of the cervix
- problems with periods (menstrual problems)
- problems getting pregnant (fertility problems)
- premature delivery
- having a low birth weight baby

Male smokers are also at increased risk for problems with erections (impotence/erectile dysfunction).

Health Risks From Second-Hand Smoke

Second-hand smoke includes both the smoke coming from the burning tobacco and the smoke that is exhaled by the person smoking. Children are especially at risk from second-hand smoke because their respiratory and immune systems are still developing.[3]

body/risks-smoking.html. Updated on May 17, 2016. Accessed on February 2, 2020

3. Risks of Smoking. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/effects-smoking/smoking-your-

People exposed to second-hand smoke are at increased risk for

- heart problems,
- lung cancer,
- breathing problems (like more severe asthma),
- excessive coughing,
- throat irritation, and
- premature death.

Children exposed to second-hand smoke are at increased risk for

- respiratory illnesses,
- more frequent and more severe asthma attacks (among children with asthma),
- ear infections,
- phlegm, wheezing, and breathlessness, and
- decreased level of lung function.

Consider the Consequences of Vaping

Even though vaping may be less harmful than smoking, there are still several consequences that must be considered. Vaping still exposes you to chemicals that can be harmful for your health and can still lead to nicotine addiction.[4] Vaping still exposes the

body/risks-smoking.html. Updated on May 17, 2016. Accessed on February 2, 2020

4. Consider the Consequences of Vaping. Government of Canada. https://www.canada.ca/en/services/health/campaigns/vaping.html. Updated on November 11, 2019. Accessed on February 2, 2020.

individual to dangerous chemicals such as formaldehyde, acrolein and metals such as nickel, tin and aluminum. Moreover, **the long term consequences of vaping and inhaling liquids like vegetable glycerine and propylene glycol is unknown.**

Health Risks of Vaping With Nicotine

Nicotine is not known to cause cancer however it is a highly addictive substance that can lead to dependence especially in populations that were not smokers. Children and youth are at risk for nicotine addiction becoming dependent on nicotine levels at lower levels of exposure than adults. Nicotine can affect memory and alter brain development in teens. In teens, nicotine can also reduce impulse control and cause cognitive behavioural problems.[5]

Second-Hand Vapour

Second-hand vapour is not harmless but does contain far fewer chemicals than second-hand smoke. However, the health effects of second-hand vapour are still unknown. There is evidence that e-cigarette use increases the level of nicotine and other chemicals on indoor surfaces. Although the health effects of second-hand vapour are believed to be lower than that of second-hand smoke, it is still

5. Risks of vaping. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/vaping/risks.html. Updated on July 31, 2019. Accessed on February 2, 2020.

recommend that user be aware of their surroundings and not vape near children or other non-vapours.[6]

Vaping Versus Smoking

Quitting smoking is the best thing you can do to improve your health. However replacing smoking with vaping will reduce your exposure to harmful chemicals.[7] Vaping typically contains a fraction of the 7000 chemicals found in cigarette smoke, does not involve burning or produce smoke. However, a vaping dependance can easily replace a smoking dependance because both of these contain nicotine which is highly addictive.

Nicotine Addiction

Nicotine is the chemical that makes tobacco and some vaping products so addictive. Once you introduce nicotine into your body it craves more. Nicotine is naturally found in the tobacco leaf. When you smoke tobacco nicotine is absorbed in the lungs and then

6. Risks of vaping. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/vaping/risks.html. Updated on July 31, 2019. Accessed on February 2, 2020.
7. Vaping and Quitting Smoking. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/vaping/smokers.html. Updated on December 21, 2018. Accessed on February 3, 2020.

moves into the blood stream where it can access the brain and other body organs. This can all happen within 10 seconds. Several reactions ensue such as increased heart rate and blood pressure, blood vessel constriction and muscle relaxation.[8]

Withdrawal Symptoms

Stopping smoking causes nicotine levels within the body to drop resulting in withdrawal symptoms. **These symptoms are temporary** and are often signs that the body is healing. Knowing what to expect can increase your chances of quitting. Most withdrawal symptoms will happen in the first week. They include the following:[9]

- dizziness and shaking
- headaches
- anxiety and irritability
- difficulty concentrating and sleeping
- increased appetite
- slight depression or feeing down

8. Nicotine Addiction. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/effects-smoking/smoking-your-body/nicotine-addiction.html. Updated on March 7, 2013.
9. Nicotine Addiction. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/effects-smoking/smoking-your-body/nicotine-addiction.html. Updated on March 7, 2013.

- craving for a smoke

Craving cigarettes can last for months even after the withdrawal symptoms are gone. This desire can be amplified in situations of stress, boredom or social exposure to other smokers. During these times it is important to remember your reasons for quitting and remember that these cravings are only temporary.[10]

Quitting Smoking or Vaping

There are several ways you can ease the process of quitting smoking or vaping. There are several commercially available products which help an individual tapper off their nicotine addiction. These products include patches, gums and lozenges. Additionally an individual can seek the help of a counselor to get over their addictive patterns. You can also talk to your doctor for advise and possible prescriptions that can help you quit smoking. Help can also be found online at the Government of Canada's Quit Smoking Webpage. Quitting the use of highly addictive nicotine is a challenge however with the right support and plan anyone can quit smoking or vaping.

10. Nicotine Addiction. Government of Canada. https://www.canada.ca/en/health-canada/services/smoking-tobacco/effects-smoking/smoking-your-body/nicotine-addiction.html. Updated on March 7, 2013.

Smoking or Vaping During Pregnancy

Women who smoke or vape during their pregnancy are at a higher risk of still birth and preterm deliveries. Their babies are also at an increased risk of low birth weight and death in the first year.[11] Women are encouraged to quit smoking before coming pregnant and to abstain from smoking for the entire length of their pregnancy. Additionally women should not smoke while breastfeeding as the harmful chemicals that are inhaled can enter the breast milk.

11. Smoking Cessation During Pregnancy and Relapse After Childbirth in Canada. Government of Canada. https://www.canada.ca/en/public-health/services/publications/healthy-living/smoking-cessation-during-pregnancy-relapse-after-childbirth-canada.html. Updated on July 7, 2016. Accessed on February 3, 2020

2.11.2. Cannabis

Cannabis and Its Components

Cannabis contains hundreds of chemical substances. Over 100 of these are known as cannabinoids which have effects on the cell receptors in the brain and body altering how they behave and communicate. Two of the most common cannabinoids are THC and CBD.

THC

THC is the most researched cannabinoid. THC is responsible for the high and intoxication you will feel from cannabis. THC content can be as low as 0.3% and as high as 30%. The greater the percentage the more potent the cannabis is.[1]

1. About Cannabis. Government of Canada. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/about.html. Updated on August 13, 2019. Accessed on February 3, 2020.

CBD

Unlike THC, CBD does not produce a high or intoxication and is the cannabinoid that is mostly studied for its therapeutic effects.[2]

Cannabis Impairment and Safety Risk

The THC in cannabis can affect your

- coordination,
- reaction time,
- ability to pay attention,
- decision-making abilities, and
- ability to judge distances.

Side effects from cannabis can endure for weeks after last use. Combining cannabis with alcohol greatly increases the risk of injury and death from accidents. Additionally combining cannabis with other psychoactive substances can increase the effects of the drug.

Addiction to Cannabis

Contrary to popular belief people **can** become addicted to cannabis

2. About Cannabis. Government of Canada. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/about.html. Updated on August 13, 2019. Accessed on February 3, 2020.

when use is frequent and heavy. Additionally, frequent use can cause a tolerance to develop causing the individual to consume more to get the same high. Addiction can develop at any age however youth are especially vulnerable because their brains are still developing.[3]

Problematic cannabis use can result in

- failing to fulfill major duties at work, school or home;
- giving up important social, occupational or recreational activities because of cannabis use;
- consuming it often and in larger amounts or over a longer period than intended; or
- being unable to cut down on or control cannabis use.

Health Effects of Cannabis[4]

Short-term health effects of cannabis include

- feeling high;
- a sense of well-being;

3. Addictions to Cannabis. Government of Canada. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/health-effects/addiction.html. Updated on January 11, 2019. Accessed on February 3, 2020.
4. Health effects of cannabis. Government of Canada. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/health-effects/effects.html. Updated on October 17, 2018. Accessed on February 3, 2020

- relaxation;
- heightened sight, taste, smell, or sound;
- confusion or sleepiness;
- impaired ability to remember, concentrate, pay attention, or react quickly; and
- anxiety, fear, and panic.

Cannabis can also lead to

- damage to blood vessels (if smoking),
- decreased blood pressure, or
- increased heart rate.

Psychotic episodes may also occur, characterized by

- paranoia,
- delusions, and
- hallucinations.

Long-term health effects of cannabis include

- poor memory,
- poor concentration, and
- decreased ability to make decisions.

The long-term effects on the body of smoking cannabis are similar to those of tobacco, and include

- bronchitis,
- lung infections,
- chronic cough, and
- increased mucus in the chest.

Cannabis and Mental Health

Cannabis has been found to increase the risk of mental illnesses such as psychosis or schizophrenia. Frequent use of cannabis has also been associated with and increased risk of suicide, depression, and anxiety disorders. Combining tobacco with cannabis can increase the strength of some psychoactive effects.[5]

Cannabis and Pregnancy

Click here for information on how cannabis can affect pregnancy.

5. Cannabis and Mental Health. The Government of Canada. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/health-effects/mental-health.html. Updated on March 6, 2018. Accessed on February 3, 2020.

2.11.3. Alcohol

Alcohol is an adaptation of the chapter "Alcohol" from *Human Nutrition*, by the University of Hawai'i at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. New material has been incorporated that includes the following: Canadian statistics and Canadian drinking guidelines and information on risks of alcohol consumption during pregnancy. Additionally, information that is not relevant to this course has been removed.

Introduction

Alcohol is a psychoactive drug. A psychoactive drug is any substance that crosses the blood-brain barrier primarily affecting the functioning of the brain, be it altering mood, thinking, memory, motor control, or behaviour. Alcohols in chemistry refer to a group of similar organic compounds, but in beverages the only alcohol consumed is ethanol.

It is estimated that 4 to 5 million Canadians engage in high risk drinking.[1] Depending on how much you drink there can be chronic

1. Alcohol. Government of Canada. https://www.canada.ca/en/health-canada/services/

or acute consequences. Chronic conditions include liver disease and cancer whereas acute consequences include alcohol poisoning, fights and accidents.

Alcohol in excess is detrimental to health; however since its beginnings it has been suspected and promoted as a benefit to the body and mind when consumed in moderation. Canadian Low Risk Drinking guidelines define moderate alcohol intake as no more than **two drinks per day for women and no more than three drinks per day for men**.[2] Drinking above these recommendations increases health risks associated with cancer, etc. Although drunkenness has pervaded many cultures, drinking in moderation has long been a mantra of multiple cultures with access to alcohol. More than 90 percent of ingested alcohol is metabolized in the liver. The remaining amount stays in the blood and is eventually excreted through exhaled breath, urine, saliva, and sweat. The blood alcohol concentration (BAC) is measured in milligrams percent, comparing units of alcohol to units of blood. BAC is a measurement used legally to assess intoxication and the impairment and ability to perform certain activities, as in driving a car. As a general rule, the liver can metabolize one standard drink (defined as 12 ounces of beer, 5 ounces of wine, or 1 ½ ounces of hard liquor) per hour. Drinking more than this, or more quickly, will cause BAC to rise to potentially unsafe levels. Table 2.11.3.1 "Mental and Physical Effects of Different BAC Levels" summarizes the mental and physical effects associated with different BAC levels.

health-concerns/alcohol-health-concerns.html. Accessed on Jun 17, 2014. Accessed on January 27, 2020.

2. Canada's Low Risk Guidelines. CAMH.https://www.canada.ca/en/health-canada/services/health-concerns/alcohol-health-concerns.html. Updated in 2013. Accessed on January 27, 2020.

Table 2.11.3.1 *Mental and Physical Effects of Different BAC Levels*

BAC percent	Typical effects
0.02	Some loss of judgment, altered mood, relaxation, increased body warmth
0.05	Exaggerated behaviour, impaired judgment, may have some loss of muscle control (focusing eyes), usually good feeling, lowered alertness, release of inhibition
0.08	Poor muscle coordination (balance, speech, vision, reaction time), difficulty detecting danger, and impaired judgment, self-control, reasoning, and memory
0.10	Clear deterioration of muscle control and reaction time, slurred speech, poor coordination, slowed thinking
0.15	Far less muscle control than normal, major loss of balance, vomiting

Source: Blood Alcohol Level & Effects on the Body. https://www.alcohol.org/effects/blood-alcohol-concentration/. Sourced: Dec 22, 2020.

Increasing blood alcohol content (BAC) comes with increases in physical and metal impairments.

In addition to the one drink per hour guideline, the rate at which an individual's BAC rises is affected by the following factors:

- sex (a woman's BAC will rise more quickly than a man's.)
- weight (BAC will rise more slowly for heavier people.)
- genetics
- length of time as a heavy drinker
- type of alcohol consumed
- amount of alcohol consumed
- consumption rate
- consumption before or after a meal (food in the stomach slows absorption)
- mixture (carbonated mixers speed absorption)
- medications may increase the bioavailability of alcohol

Alcohol Metabolism

Image by Serge Esteve on unsplash.com / [CC0](#)

Giving the liver enough time to fully metabolize the ingested alcohol is the only effective way to avoid alcohol toxicity. Drinking coffee or taking a shower will not help. The legal limit for intoxication is a BAC of 0.08. Taking into account the rate at which the liver metabolizes alcohol after drinking stops, and the alcohol excretion rate, it takes at least five hours for a legally intoxicated person to achieve sobriety.

Ethanol Consumption

Distilled spirits have exceptionally few nutrients, but beer and wine do provide some nutrients, vitamins, minerals, and beneficial plant chemicals along with calories. A typical beer is 150 kilocalories, a glass of wine contains approximately 80 kilocalories, and an ounce of hard liquor (without mixer) is around 65 kilocalories.

As a person starts drinking alcohol, up to 5% of the ingested ethanol is directly absorbed and metabolized by some of cells of the gastrointestinal tract (the mouth, tongue, esophagus and stomach). Up to 100% of the remaining ethanol travels in circulation. This is one reason why blood tests are more accurate in measuring alcohol levels.

The lungs and kidneys will excrete about 2% to 10% of this circulatory ethanol. The more you drink the more quick trips to the restroom. The human body dehydrates as a result of these frequent trips to the restroom. This dehydration affects every single cell in your body, including your brain cells. This is the cause of the so-called "morning hangover". Do not take Tylenol (acetaminophen). Alcohol metabolism activates an enzyme that transforms acetaminophen into a toxic metabolite that causes liver inflammation and damage. The resulting liver damage may not be reversible. Instead, drink water with electrolytes or sport drinks to rehydrate the body's cells.

Alcohol is a volatile (flammable) organic substance and can be converted to a gas. The lungs exhale alcohol as a gas. The more alcohol consumed, the stronger the smell of alcohol in a person's breathe. Breathalyzer tests measure the exhaled alcohol levels in the lungs to determine the state of inebriation.

Health Consequences of Alcohol Abuse

Alcoholic drinks in excess can contribute to weight gain by substantially increasing caloric intake. When alcohol is drunk in excess, it reduces the secretion of pancreatic juice and damages the lining of the gastrointestinal system, impairing nutrient digestion and absorption. The impaired digestion and absorption of nutrients in alcoholics contributes to their characteristic "skinniness" and multiple associated micronutrient deficiencies. The most common macronutrient deficiency among alcoholics is water, as it is excreted in excess. Commonly associated micronutrient deficiencies include thiamine, pyridoxine, folate, vitamin A, magnesium, calcium, and zinc. Furthermore, alcoholics typically replace calories from nutritious foods with alcohol, sometimes getting 50 percent or more of their daily caloric intake from alcoholic beverages.

Alcohol is a diuretic that results in dehydration. It suppresses the release of antidiuretic hormone and less water is reabsorbed and more is excreted. Drinking alcohol in excess can lead to a "hangover," of which the majority of symptoms are the direct result of dehydration.

Effects of Alcohol Abuse on the Brain

A small amount (up to 10%) of the liver acetaldehyde may accumulate inside the liver cells and diffuse into the blood circulation. In circulation, high levels of acetaldehyde cause nausea and vomiting. Vomiting causes more body dehydration and loss of electrolytes. If the dehydration becomes severe enough, this can impair brain function and a person may lose consciousness.

Alcohol can adversely affect nearly every area of the brain. When BAC rises, the central nervous system is depressed. Alcohol disrupts the way nerve cells communicate with each other by interfering with receptors on certain cells. The immediate impact of alcohol on the brain can be seen in the awkwardly displayed symptoms of confusion, blurred vision, slurred speech, and other signs of intoxication. These symptoms will go away once drinking stops, but abusive alcohol consumption over time can lead to long-lasting damage to the brain and nervous system. This is because alcohol and its metabolic byproducts kill brain cells.

Effects of Excessive Alcohol on the Liver

The increased accumulation of both stored triglycerides and very low density lipoprotein (VLDL). particles inside the liver cells causes a condition called fatty liver or hepatic steatosis. This can impair normal liver function. The more alcohol consumed, the more lipids produced and stored inside the liver cells. These effects are cumulative over time.

Although not every alcoholic or heavy drinker will die from liver problems, the liver is one of the body's main filtering organs and is severely stressed by alcohol abuse. The term alcoholic liver disease (ALD) is used to describe liver problems linked to excessive alcohol intake. ALD can be progressive, with individuals first suffering from a fatty liver and going on to develop cirrhosis. It is also possible to have different forms of ALD at the same time.

Figure 2.11.3.1 *Liver Cirrhosis*

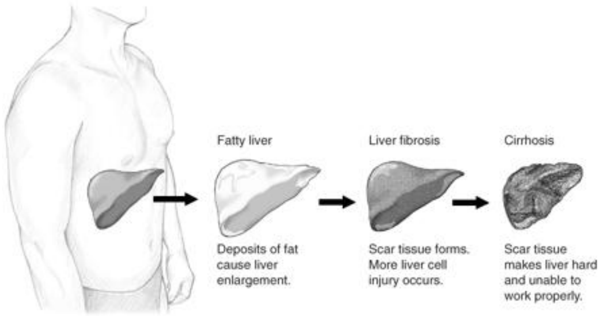
A liver that has cirrhosis due to the excessive consumption of alcohol. Source: "Cirrosi Micronodular" by [Amanda Alvarez](#)/ [CC BY SY 4.0](#).

Excessive alcohol consumption causes the destruction of liver cells. In an attempt to repair itself, the liver initiates an inflammatory and reparation process causing scar tissue to form. In the liver's attempt to replace the dead cells, surviving liver cells multiply. The result is clusters of newly formed liver cells, also called regenerative nodules, within the scar tissue. This state is called cirrhosis of the liver.

There are three common forms of ALD:

- **fatty liver:** A rather benign disorder that develops after excessive alcohol consumption; however it can progress to more fatal diseases. Fatty liver is reversible if alcohol use is brought under control.
- **alcoholic hepatitis:** The symptoms of this alcohol-induced liver inflammation are a swollen liver, abdominal pain, nausea, fever, jaundice, and vomiting. Although linked to alcohol use, even people who drink moderately can sometimes develop this condition, and not all alcohol abusers do. If a person stops drinking alcohol, the liver damage can be reversed. But if they continue, cirrhosis may develop and death can result.
- **cirrhosis:** This serious and sometimes fatal form of ALD develops when liver cells die and form scar tissue, which blocks blood flow and causes wastes and toxins to build up in the system. Strictly speaking, cirrhosis cannot be cured. It can, however, be stopped with medical treatment and complications can be managed if the individual stops drinking, and many do survive. Not all cases of cirrhosis are strictly due to alcoholism, and not all alcoholics develop the disease. Symptoms of cirrhosis include the buildup of abdominal fluid (ascites), abdominal pain, fever, thirst, confusion, and fatigue.

Figure 2.11.3.2 *The Progression of ALD*



Source: "Stages of Liver Damage" by National Digestive Diseases Information Clearinghouse/ Public Domain

As the liver cells release VLDL particles into circulation, this increases the levels of VLDL particles in blood. As VLDL particles continue to accumulate in blood, this cause a condition called hyperlipidemia. In their journey through circulation, VLDL particles are eventually degraded to low density lipoproteins (LDL) particles. LDL particles are also known as "bad cholesterol". Higher levels of LDL particles in circulation lead to the build-up of cholesterol deposition plaques inside the walls of the blood vessels (known as atherosclerosis). These plaques can impair or stop blood flow to the cells. If an artery is blocked, the cells cannot make enough energy and eventually stop working. If the artery remains blocked for more than a few minutes, the cells may die. When a cardiac artery is blocked, this causes a heart attack (acute myocardial infarction). Depending on the length and severity of the blockage, damage to the cardiac cells may be permanent and irreversible. Once the heart structure and function is compromised, the more susceptible a patient would be to suffer a second heart attack.

Effects of Alcohol in Pregnancy

The more alcohol that is consumed during a pregnancy the greater risk there will be damage to the baby. There is no safe amount of alcohol that can be drank during pregnancy. There is also no safe type of alcohol that can be drank during pregnancy. The safest thing to do is not drink alcohol when you are pregnant or planning on becoming pregnant. Alcohol use during pregnancy can cause life long disabilities to the baby. Fetal alcohol syndrome is a term that describes a range of health and behavioural problems that affect babies whose mothers drank during pregnancy.[3] These problems include but are not limited to the following traits:

- abnormal facial features
- small head size
- shorter than average height
- low body weight
- poor coordination
- hyperactive behaviour
- difficulty with attention
- poor memory
- learning disabilities
- speech and language delays
- poor reasoning and judgement
- vision or hearing problems
- problems with the heart, kidney or bones

3. Pregnancy and Alcohol Use. Health Link BC. https://tophat.com/marketplace/social-science/psychology/textbooks/oer-openstax-psychology-openstax-content/85/4057/. Updated December 2017. Accessed on February 3, 2020.

Health Benefits of Moderate Alcohol Intake

In contrast to excessive alcohol intake, moderate alcohol intake has been shown to provide health benefits to some segments of the population. The data is most convincing for preventing heart disease in middle-aged and older people. A review of twenty-nine studies concluded that moderate alcohol intake reduces the risk of coronary heart disease by about 30 percent in comparison to those who do not consume alcohol.[4] Health Canada notes that alcohol raises cancer risk for many people, particularly those with elevated cancer risk (previous occurrence, family history, related conditions, etc).

Several studies demonstrate that moderate alcohol consumption reduces the incidences of stroke and heart attack, and also death caused by cardiovascular and heart disease. The drop in risk for these adverse events ranges between percent. Moreover, there is some scientific evidence that moderate alcohol intake reduces the risk for metabolic syndrome, Type 2 diabetes, and gallstones. In addition to providing some health benefits, moderate alcohol intake also serves as a digestive aid, a source of comfort and relaxation, and inducing social interactions, thereby benefiting all aspects of the health triangle. It has not been clearly demonstrated that moderate alcohol consumption benefits younger populations, and the risks of any alcohol consumption do not outweigh the benefits for pregnant women, those who are taking medications that interact with alcohol, and those who are unable to drink in moderation.

4. Ronksley PE, et al. Association of Alcohol Consumption with Selected Cardiovascular Disease Outcomes: A Systematic Review and Meta-Analysis. BMJ. 2011; 342, d671. http://www.bmj.com/content/342/bmj.d671. Accessed October 5, 2017.

2.11.4. Test Your Knowledge

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2.12. SEXUALLY TRANSMITTED INFECTIONS

2.12.1. What Are STIs

What Are STIs?

The following information about STDs is published by the Office of Disease Prevention and Health Promotion on the website Healthy People.gov., and is found on the page "Sexually Transmitted Diseases."

STIs, previously known as sexual transmitted diseases (STDs), refers to more than 25 infectious organisms that are transmitted primarily through sexual activity. STI prevention is an essential primary care strategy for improving reproductive health.[1]

Despite their burdens, costs, and complications, and the fact that they are largely preventable, STIs remain a significant public health problem in the United States. This problem is largely unrecognized by the public, policymakers, and health care professionals because of the social taboo that surrounds them. STIs cause many harmful, often irreversible, and costly clinical complications, such as

- reproductive health problems,
- fetal and perinatal health problems,
- cancer, and
- facilitation of the sexual transmission of HIV infection.[2]

1. Centers for Disease Control and Prevention. (2012, February 8). Chlamydia-CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/chlamydia/STDFact- Chlamydia.htm
2. Centers for Disease Control and Prevention. (2012, April

How Are STIs Transmitted?

Ejaculation does not have to occur for an STI to be passed from person to person. Sharing contaminated needles used to inject drugs or using contaminated body piercing and tattooing equipment also can transmit some infections, such as HIV or hepatitis B and C.

Anyone who has had or is having sexual intercourse or oral sex, or who has participated or is participating in sex play, is at risk for acquiring an STI.

Fortunately, it is possible for a person to decrease his or her risk by having protected sex and knowing his or her STI status and that of his or her partner.

Still, the Centers for Disease Control and Prevention (CDC) estimates nearly 20 million new cases of these reportable STIs (gonorrhea, chlamydia, syphilis) occur each year in the United States– almost half of them among young people 15 to 24 years of age.[3]

While not the most common STI, HIV/AIDS is one of the most devastating and most well known. Recent data from the CDC indicate that 1.1 million Americans have HIV.[4]

11). Basic Information about HIV and AIDS. Retrieved July 11, 2012, from http://www.cdc.gov/hiv/basics/index.html
3. Centers for Disease Control and Prevention. (2012, February 8). Chlamydia-CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/chlamydia/STDFact- Chlamydia.htm
4. Centers for Disease Control and Prevention. (2012, April 11). Basic Information about HIV and AIDS. Retrieved July

- One in five is unaware that they have the virus.
- Approximately 50,000 Americans become infected with HIV each year.
- 15,529 people with AIDS died in 2010.

Click on the following link to learn more about reported STIs in the United States:

[CDC Fact Sheet]

11, 2012, from http://www.cdc.gov/hiv/basics/index.html

2.12.2. Common STIs

What Are the Most Common Types of STIs?

The following information about the most common STIs is published by the US Department of Health and Human Services and found on the NIH's website on the page "Sexually Transmitted Diseases."

Approximately 20 different infections are known to be transmitted through sexual contact. Here are descriptions of some of the most common and well known.

Chlamydia

Chlamydia[1] (pronounced kla-MID-ee-uh) is a common STI caused by the bacterium Chlamydia trachomatis. Chlamydia can be transmitted during vaginal, oral, or anal sexual contact with an infected partner. While many individuals will not experience symptoms, chlamydia can cause fever, abdominal pain, and unusual discharge of the penis or vagina.

1. Centers for Disease Control and Prevention. (2012, February 8). Chlamydia-CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/chlamydia/STDFact- Chlamydia.htm

In women, whether or not they are having symptoms and know about their infection, chlamydia can cause pelvic inflammatory disease (PID). In PID, the untreated STI progresses and involves other parts of the woman's reproductive system, including the uterus and fallopian tubes. This progression can lead to permanent damage to the woman's reproductive organs. This damage may lead to ectopic pregnancy (in which the fetus develops in abnormal places outside of the womb, a condition that can be life-threatening) and infertility.

Additionally, if the woman is pregnant, her developing fetus is at risk, because chlamydia can be passed on during her pregnancy or delivery and could lead to eye infections or pneumonia in the infant. If chlamydia is detected early, it can be treated easily with an antibiotic taken by mouth.

Gonorrhea

Gonorrhea[2] (pronounced gon-uh-REE-uh) is caused by the bacterium Neisseria gonorrhoeae, which can grow rapidly and multiply easily in the warm, moist areas of the reproductive tract. The most common symptoms of gonorrheal infection are a discharge from the vagina or penis and painful or difficult urination.

As with chlamydial infection, the most common and serious complications of gonorrhea occur in women and include pelvic inflammatory disease (PID), ectopic pregnancy, infertility, and the potential spread to the developing fetus if acquired during

2. Centers for Disease Control and Prevention. (2012, June 4). Gonorrhea-CDC Fact Sheet.Retrieved July 11, 2012, from http://www.cdc.gov/std/gonorrhea/STDFact-gonorrhea.htm

pregnancy. Gonorrhea also can infect the mouth, throat, eyes, and rectum and can spread to the blood and joints, where it can become a life-threatening illness.

In addition, people with gonorrhea can more easily contract HIV, the virus that causes AIDS. HIV-infected people with gonorrhea are also more likely to transmit the virus to someone else.[3]

Genital Herpes

Genital herpes[4] is a contagious infection caused by the herpes simplex virus (HSV). There are two different strains, or types, of HSV: herpes simplex virus type 1 (HSV-1) and type 2 (HSV-2). Both can cause genital herpes, although most cases of genital herpes are caused by HSV-2.5 When symptomatic, HSV-1 usually appears as fever blisters or cold sores on the lips, but it can also infect the genital region through oral-genital or genital-genital contact. Symptomatic HSV-2 typically causes painful, watery skin blisters on or around the genitals or anus. However, substantial numbers of people who carry these viruses have no or only minimal signs or symptoms. Neither HSV-1 nor HSV-2 can be cured, and even during

3. Centers for Disease Control and Prevention. (2012, April 11). Basic Information about HIV and AIDS. Retrieved July 11, 2012, from http://www.cdc.gov/hiv/basics/index.html
4. Centers for Disease Control and Prevention. (2012, January 31). Genital Herpes-CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/herpes/STDFact- Herpes.htm

times when an infected person has no symptoms, the virus can be found in the body's nerve cells. Periodically, some people will experience outbreaks in which new blisters form on the skin in the genital area; at those times, the virus is more likely to be passed on to other people.

Pregnant women, especially those who acquire genital herpes for the first time during pregnancy, may pass the infection to their newborns, causing life-threatening neonatal HSV, an infection affecting the infant's skin, brain, and other organs.[5]

HIV/AIDS

HIV, or the human immunodeficiency virus, is the virus that causes AIDS (acquired immunodeficiency syndrome). HIV destroys the body's immune system by killing the blood cells that fight infection. Once HIV destroys a substantial proportion of these cells, the body's ability to fight off and recover from infections is compromised. This advanced stage of HIV infection is known as AIDS.

People whose HIV has progressed to AIDS are very susceptible to opportunistic infections that do not normally make people sick and to certain forms of cancer. AIDS can be prevented by early initiation of antiretroviral therapy in those with HIV infection. Transmission of the virus primarily occurs during unprotected sexual activity and by sharing needles used to inject intravenous drugs, although the virus also can spread from mother to infant during pregnancy, delivery, and breastfeeding.

5. Marquez, L., Levy, M. L., Munoz, F. M., & Palazzi, D. L. (2011). A report of three cases and review of intrauterine herpes simplex virus infection. The Pediatric Infectious Disease Journal, 30, 153-157. PMID 20811312

In 2013, NIH-supported researchers reported that a 2-year-old child who was born with HIV and was treated starting in the first few days of life has had her HIV infection go into remission. This appears to be the first case of functional cure of HIV.

Human Papillomavirus (HPV)

HPV[6] is the most common STD/STI. More than 40 HPV types exist, and all of them can infect both men and women. The types of HPVs vary in their ability to cause genital warts; infect other regions of the body, including the mouth and throat; and cause cancers of the cervix, vulva, penis, and mouth.

Although no cure exists for HPV infection once it occurs, regular screening with a Pap smear test can prevent or detect at an early stage most cases of HPV-caused cervical cancer. (A Pap smear test involves a health care provider taking samples of cells from the cervix during a standard gynecologic exam; these cells are examined under a microscope for signs of developing cancer). A newly available vaccine protects against most (but not all) HPV types that cause cervical cancer. The American Academy of Pediatrics recommends this vaccine for school-aged boys and girls.[7]

6. Committee on Infectious Diseases. (2012). HPV vaccine recommendations. Pediatrics, 129, 602-605.
7. Centers for Disease Control and Prevention. (2011, November 17). 2010 Sexually Transmitted Diseases Surveillance: Syphilis. Retrieved June 7, 2012, fromhttp://www.cdc.gov/std/stats10/syphilis.htm

Syphilis

Syphilis infections, caused by the bacterium Treponema pallidum, are passed from person to person during vaginal, anal, or oral sex through direct contact with sores, called chancres. Between 2001 and 2009, the Centers for Disease Control and Prevention (CDC) data show that the syphilis rate increased each year. Those people at highest risk for syphilis include men having sex with both men and women and people residing in the south.[8] The first sign of syphilis is a chancre, a painless genital sore that most often appears on the penis or in and around the vagina. Beyond being the first sign of a syphilis infection, chancres make a person two to five times more likely to contract an HIV infection. If the person is already infected with HIV, chancres also increase the likelihood that the virus will be passed on to a sexual partner.[9] These sores typically resolve on their own, even without treatment. However, the body does not clear the infection on its own, and, over time, syphilis may involve other organs, including the skin, heart, blood vessels, liver, bones, and joints in secondary syphilis. If the illness is still not treated, tertiary syphilis can develop over a period of years and involve the nerves, eyes, and brain and can potentially cause death.

Expectant mothers harboring the bacterium are at an increased risk

8. 10. Centers for Disease Control and Prevention. (2011, November 17). 2010 Sexually Transmitted Diseases Surveillance: Syphilis. Retrieved June 7, 2012, from http://www.cdc.gov/std/stats10/syphilis.htm
9. Centers for Disease Control and Prevention. (2012, April 11). Basic Information about HIV and AIDS. Retrieved July 11, 2012, from http://www.cdc.gov/hiv/basics/index.html

of miscarriage and stillbirth, and they can pass the infection on to their fetuses during pregnancy and delivery. Infants that acquire congenital syphilis during pregnancy may suffer from skeletal deformity, difficulty with speech and motor development, seizure, anemia, liver disease, and neurologic problems.

Bacterial Vaginosis

Bacterial vaginosis[10] is a common, possibly sexually transmitted, vaginal infection in women of reproductive age. While it is healthy and normal for a vagina to have bacteria, just like the skin, mouth, or gastrointestinal (GI) tract, sometimes changes in the balance of different types of bacteria can cause problems.

Bacterial vaginosis occurs when problematic bacteria that are normally present only in small amounts increase in number, replace normal vaginal lactobacilli bacteria, and upset the usual balance. This situation becomes more likely if a woman douches frequently or has new or multiple sexual partners. The most common sign of a bacterial vaginosis infection is a thin, milky discharge that is often described as having a "fishy" odor. However, some women will have no symptoms at all.

Regardless of symptoms, having bacterial vaginosis increases the risk of getting other STIs and is also associated with pelvic inflammatory disease (PID), an infection of the female reproductive organs, including the uterus and the fallopian tubes (which carry

10. Centers for Disease Control and Prevention. (2010, September 1). Bacterial Vaginosis- CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/bv/STDFact- Bacterial-Vaginosis.htm

eggs to the uterus), and postoperative infections. Preterm labor and birth are also possibly more common in women with bacterial vaginosis.

Trichomoniasis

Trichomoniasis[11] (pronounced trik-uh-muh- NAHY-uh-sis) infection is caused by the single-celled protozoan parasite Trichomonas vaginalis and is common in young, sexually active women. The parasite also infects men, though less frequently. The parasite can be transmitted between men and women as well as between women whenever physical contact occurs between the genital areas. Although Trichomonas infections do not always cause symptoms, they can cause frequent, painful, or burning urination in men and women as well as vaginal discharge, genital soreness, redness, or itching in women. Because the infection can occur without symptoms, a person may be unaware that he or she is infected and continue to re- infect a sexual partner who is having recurrent signs of infection. As with bacterial STIs, all sexual partners should be treated at the same time to avoid re-infection.

NICHD-sponsored research has shown that during pregnancy, Trichomonas infection is associated with an increased risk of premature birth and infants with low birth weight. Moreover, infants born to mothers with Trichomonas infection are more than

11. Centers for Disease Control and Prevention. (2011, November 30). Trichomoniasis-CDC Fact Sheet. Retrieved July 11, 2012, fromhttp://www.cdc.gov/std/trichomonas/STDFact-Trichomoniasis.htm

twice as likely as infants born to uninfected women to be stillborn or to die as newborns.[12]

Viral Hepatitis

Viral hepatitis is a serious liver disease that can be caused by several different viruses, which can be transmitted through sexual contact.

Hepatitis A virus (HAV) causes a short-term or self-limited liver infection that can be quite serious, although it does not result in chronic infection. While there are other ways the virus can be transmitted, HAV can be spread from person to person during sexual activity through oral-rectal contact. Vaccination can prevent HAV infection.[13]

12. Klebanoff, M. A., Carey, J. C., Hauth, J. C., Hillier, S. L., Nugent, R. P., Thom, E. A., et al.; National Institute of Child Health and Human Development Network of Maternal-Fetal Medicine Units. (2001). Failure of metronidazole to prevent preterm delivery among pregnant women with asymptomatic Trichomonas vaginalis infection. New England Journal of Medicine, 345, 487-493.
13. Klebanoff, M. A., Carey, J. C., Hauth, J. C., Hillier, S. L., Nugent, R. P., Thom, E. A., et al.; National Institute of Child Health and Human Development Network of Maternal-Fetal Medicine Units. (2001). Failure of metronidazole to prevent preterm delivery among pregnant women with asymptomatic Trichomonas

Hepatitis B virus (HBV) causes a serious liver disease that can result in both immediate illness and lifelong infection leading to permanent liver scarring (cirrhosis), cancer, liver failure, and death. HBV spreads through both heterosexual and homosexual contact as well as through contact with other bodily fluids, such as blood, through shared contaminated needles used for injecting intravenous (IV) drugs, tattooing, and piercing. Pregnant women with HBV can transmit the virus to their infants during delivery. HBV infection is preventable through vaccination.[14]

Hepatitis C virus (HCV) can cause an immediate illness affecting the liver, but it more commonly becomes a silent, chronic infection that leads to liver scarring (cirrhosis), cancer, liver failure, and death. HCV is most commonly transmitted through sharing needles or exposure to infected blood. However, it can spread through sexual contact or from mother to fetus during pregnancy and delivery. There is no vaccine for HCV, and treatments are not always effective.[15]

vaginalis infection. New England Journal of Medicine, 345, 487-493.

14. Centers for Disease Control and Prevention. (2012, February 8). Chlamydia-CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/chlamydia/STDFact- Chlamydia.htm
15. Centers for Disease Control and Prevention. (2011, January 28). Sexually transmitted diseases (STDs). Sexually transmitted diseases treatment guidelines, 2010. Hepatitis C.Retrieved June 3, 2012, from http://www.cdc.gov/std/treatment/2010/hepC.htm

Rate Your Risk[16]

Various sexual activities and the possible STIs that can be transmitted through them are listed in Table 2.12.2.1 "Sexual Activities, Potential STIs and Methods of Prevention." It is important to know your risk of catching and STI and to know how your risk can me minimized.

Table 2.12.1.1 *Sexual Activities, Potential STIs and Methods of Prevention*

16. Sexually Transmitted Infections. Government of Canada. https://www.canada.ca/en/public-health/services/infectious-diseases/sexual-health-sexually-transmitted-infections/reports-publications/infections.html#t2. Updated on June 1, 2015. Accessed on February 2, 2020.

Activity	STI risk	Prevention methods
Kissing	Herpes, hepatitis B	Avoid kissing when cuts or sores are present in or around the mouth.
Skin to skin touching	Syphilis, HPV, genital herpes, public lice and scabies	Abstinence, condoms (male or female), dental dam, gloves
Giving oral sex	Chlamydia, gonorrhoea, syphilis, HPV, herpes, hepatitis B, HIV	Abstinence, condoms (male or female), dental dam
Receiving oral sex	Chlamydia, gonorrhoea, syphilis, genital herpes, HIV	Abstinence, condoms (male or female), dental dam
Vaginal sex	Chlamydia, gonorrhoea, syphilis, HPV, genital herpes, hepatitis B, HIV, pubic lice	Abstinence, condoms (male or female)
Anal sex	Chlamydia, gonorrhoea, syphilis, HPV, genital herpes, hepatitis B, HIV, pubic lice	Abstinence, condoms (male or female)
Exposure to infected needles	Hepatitis B & C, HIV	Abstinence

Source: Sexually Transmitted Infections. Government of Canada. https://www.canada.ca/en/public-health/services/infectious-diseases/sexual-health-sexually-transmitted-infections/reports-publications/infections.html#t2. Updated on June 1, 2015. Accessed on February 2, 2020.

2.12.3. STI Prevention

If You Choose To Have Sex, There Are Several Ways You Can Protect Yourself

If you choose to have penetrative sex, use a condom.
A condom should be used during

- vaginal sex,
- anal sex, and
- when using a sex toy that has not been cleaned.

Tips

- Use lubricated latex or polyurethane condoms.
- Keep condoms nearby so that they are easy to access when you need them.
- Store your condoms in a dry place away from heat or light.
- Check the expiry date on the package or condom box.
- Never use two condoms together.
- Never use a condom more than once.

How to use a male condom

Open Carefully. Rough tearing or long fingernails can damage the condom.

Place & Pinch. Put the condom at the end of the penis and pinch out the air in the tip.

Roll It On. Unroll the condom right down to the base of the penis.

Afterwards. Whoever is wearing the condom should pull out right after they ejaculate and while their penis is still hard. Remember to hold the base of the condom when pulling out so that is does not come off.

Throw the Used Condom Into the Garbage. Never use a condom twice.

How to use a female condom

Do not use a male condom with a female condom as this can cause tearing.

Open Carefully. Rough tearing or long fingernails can damage the condom.

Placement. The think ring is to be placed inside the condom. Find a comfortable position. Squeeze the walls of the ring together and insert into the vagina. Using the fingers push the inner ring as far up as it will go. Be sure the condom is not twisted. The thin outer ring should remain outside the vagina.

Afterwards. Twist the outer ring and pull out of the vagina.

Throw the Used Condom Into the Garbage. Never use a condom twice.

When having oral sex you can be protected from STIs by using

- **a condom** (see above) or
- **a dental dam** (a sheet of material that is placed between the mouth and the vagina or anus).

How to use a dental dam

Open Carefully. Rough tearing or long fingernails can damage the dental dam.

Placement. The dental dam is placed over the area where oral sex is being performed.

Afterwards. The dental dam is discarded.

A dental dam can be created out of a condom by cutting it lengthwise.

You Can Choose Not To Have Sex

You may *not* be ready for sex if

- you cannot talk to your partner about STI testing or using condoms,
- you do not have condoms to protect yourself,
- you feel pressured,
- you are not sure about it,
- you need to get drunk or stoned to do it,
- your partner is not ready, or
- your partner wants to get drunk or stoned to do it.

If You Choose To Have Sex, Get Tested

When To Get Tested

- before you have sex with a new partner
- if you or your partner have been sexually active and have not

been tested or do not know your results
- if you know your current or past, partner has or had an STI
- if the condom breaks or you have sex without one
- if you or your partner have shared needles for drugs, tattooing or piercing
- if you or your partner have any STI symptoms

What Should You Know About Getting Tested?

You should always feel comfortable with the person who is giving you the exam and with any other health care professionals that are in the room. If you are uncomfortable or if you would feel more comfortable with someone you know in the room, tell your healthcare provider.

Everything you discuss with your healthcare provider is confidential. Anything you discuss with them cannot be shared unless they

- have your permission,
- are making a referral that you have agreed to,
- feel you are not able to understand medical advice or the results of your decisions, or
- suspect abuse and they are required to report to a child protection agency.

Tests that are positive for chlamydia, gonorrhoea, syphilis, hepatitis B and HIV are reported to your local healthcare department. A nurse will contact you and provide help with telling current and past partners that they need to be tested. Your personal information is not shared with anyone and no one will know except you, your healthcare provider and the public health nurse.

What To Expect During an Exam

Male Exam. There will be several questions about your sex life. Some or all of the following tests will be performed:

- ask for a urine sample
- check the external parts of the genitals including the testicles and penis for lumps or pain
- use a cotton swab to take samples from the throat, anus, and/or urethra (the opening of the penis)
- take a blood sample

Female Exam. There will be several questions about your sex life. They will also ask you to undress from the waist down and will give you a drape to cover yourself. Some or all of the following tests will be performed:

- ask for a urine sample
- check the external parts of the genitals
- use a speculum to look at the inside of the vagina and at the cervix [the opening to the uterus]
- use a cotton swab to take samples from the throat, vagina, anus and/or cervix
- do a Pap test to check for changes in the cells of the cervix
- do a bimanual exam (the healthcare provider places one or two fingers inside the vagina and their other hand on the lower abdomen in order to feel the ovaries and uterus)
- take a blood sample

Telling Your Partners

If you are diagnosed with an STI it is important to tell your partner(s) to be tested as well so the infection does not spread further. There are many ways to tell your partner(s) that they need to be tested for STIs. Canada has programs and tools to help people tell their partners anonymously that they need to get tested. Contact your local health department for more information.

STI exams are not a part of a routine check-up. Therefore you need to tell your healthcare provider that you would like to be tested for STIs so they can order the appropriate blood and urine tests in addition to your routine tests.

Where To Go for Help

If you have questions about STIs or when to be tested for STIs, you can go to your local healthcare provider or local public health unit. You can also read Health Canada's information booklet on STIs.

Additionally the following link provides a work sheet to create an individualize plan for preventing STIs.

2.12.4. STI Treatment

STIs caused by bacteria, yeast, or parasites can be treated with antibiotics. These antibiotics are most often given by mouth (orally). However, sometimes they are injected or applied directly to the affected area. Whatever the infection, and regardless of how quickly the symptoms resolve after beginning treatment, the infected person must take all of the medicine prescribed by the health care provider to ensure that the STI is completely treated.

Although treatments, complications, and outcomes vary among viral STIs depending on the particular virus (HIV, genital herpes, human papillomavirus, hepatitis, or cytomegalovirus), health care providers can provide treatments to reduce the symptoms and the progression of most of these illnesses. For example, medications are available to limit the frequency and severity of genital herpes outbreaks while reducing the risk that the virus will be passed on to other people.

Individuals with HIV need to take special antiretroviral drugs that control the amount of virus they carry. These drugs, called highly active antiretroviral therapy, or HAART,[1] can help people live longer, healthier lives. If a woman with HIV becomes pregnant, these medicines also can reduce the chance that her fetus or infant will get the infection.

Being tested and treated for STIs is especially important for pregnant women because some STIs may be passed on to their infants during pregnancy or delivery. Testing women for these STIs

1. Centers for Disease Control and Prevention. (2012, February 8). Chlamydia-CDC Fact Sheet. Retrieved July 11, 2012, from http://www.cdc.gov/std/chlamydia/STDFact- Chlamydia.htm

early in their pregnancy is important, so that steps can be taken to help ensure delivery of a healthy infant. The necessary treatment will depend on the type of STI involved.

2.12.5. Test Your Knowledge

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https://opentextbooks.concordia.ca/fundamentalsofhealthandphysicalactivity/?p=868

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3.1. BASIC FITNESS PRINCIPLES AND EXERCISE HABITS

3.1.1. Physical Activity and Exercise

Introduction

From Ancient History to Modern Times

Mounting research supports historical assertions that exercise is vital to sustaining health and quality of life. Culturally, sports play a huge role in growth and development of youth and adults. Physically, there is indisputable evidence that regular exercise promotes healthy functioning of the brain, heart, and the skeletal and muscular systems. Exercise also reduces risk for chronic diseases, such as cancer, diabetes, and obesity. Regular exercise can even improve emotional health and overall wellbeing.

What Are Physical Activity and Exercise?

Physical activity is defined as any movement carried out by skeletal muscle that requires energy and affects health. Health benefits include improved blood pressure, blood-lipid profile, and heart health. Recommended physical activity includes yard work, house cleaning, walking the dog, or taking the stairs instead of the elevator. Physical activity does not have to be done all it once. It can be accumulated through various activities throughout the day. Although typing on a phone or laptop or playing video games does involve skeletal muscle and requires a minimal amount of energy, the amount required is not sufficient to improve health.

Despite the common knowledge that physical activity is tremendously beneficial to one's health, rates of activity among North Americans continue to be below what is needed. According to Statistics Canada almost half (48%) of Canadians over the age of 12 did the equivalent of less than half an hour of walking a day. In this report 25% of Canadians also claimed that they sit the majority of the day. Moreover, 2011 accelerometer data found that only 15% of Canadian adults were meeting the current recommendations for moderate-to-vigorous physical activity.

The word exercise, although often used interchangeably with the phrase physical activity, denotes a sub-category of physical activity. Exercise is a planned, structured, and repetitive movement pattern intended to improve fitness. As a positive side-effect, it significantly improves health as well. Fitness improvements include the heart's ability to pump blood, increased muscle, strength, and improved flexibility.

Activity Guidelines

Below are links to the physical activity guidelines provided by the US Department of Health and Human Services and the American College of Sports Medicine (ACSM). As you review these recommendations, notice how closely they follow the FITT pattern described earlier in the chapter.

NIH Recommendations for Physical Activity

Canadian Society for Exercise Physiology (CSEP) Recommendations on Quantity and Quality of Exercise

Fitness Guidelines

The recommendations linked above pertain to physical activity only. While they can be applied to fitness, more specific guidelines have been set to develop fitness. As stated previously, physical activity is aimed at improving health; exercise is aimed at improving health and fitness. These guidelines will be referenced often as each health-related component of fitness is discussed.

Components of Health-Related Fitness

In order to carry out daily activities without being physically overwhelmed, a minimal level of fitness is required. To perform daily activities without fatigue, it is necessary to maintain health in five areas: cardiorespiratory endurance, muscular strength and endurance, flexibility, and body composition. These five areas are called the components of health- related fitness. Development of these areas will improve your quality of life, reduce your risk of chronic disease, and optimize your health and well-being. Each of these 5 areas will be explored in depth at a later time. Below is a brief description of each:

- **Cardiorespiratory endurance** is the ability to carry out prolonged, large muscle, dynamic movements at a moderate to high level of intensity. This relates to your heart's ability to pump blood and your lungs' ability to take in oxygen.
- **Muscular strength** is the ability of the muscles to exert force over a single or maximal effort.
- **Muscular endurance** is the ability to exert a force over a period of time or repetitions.
- **Flexibility** is the ability to move your joints through a full range of motion.

- **Body composition** is the relative amount of fat mass to fat-free mass.

As previously stated, these areas are significant in that they influence your quality of life and overall health and wellness.

Skill-Related Components of Fitness

In addition to the 5 health-related components, there are 6 skill-related components that assist in developing optimal fitness: speed, agility, coordination, balance, power, and reaction time. Although important, these areas do not directly affect a person's health. A person's ability to perform ladder drills (also known as agility drills) is not related to his/her heart health. However, coordination of muscle movements may be helpful in developing muscular strength through resistance training. As such, they may indirectly affect the 5 areas associated with health-related fitness. Skill-related components are more often associated with sports performance and skill development.

Principles of Adaptation to Stress

The human body adapts well when exposed to stress. The term stress, within the context of exercise, is defined as an exertion above the normal, everyday functioning. The specific activities that result in stress vary for each individual and depend on a person's level of fitness. For example, a secretary who sits at a desk all day may push his/her cardiorespiratory system to its limits simply by walking up several flights of stairs. For an avid runner, resistance training may expose the runner's muscles to muscular contractions the athlete is not accustomed to feeling. Although stress is relative to each individual, there are guiding principles in exercise that can help individuals manage how much stress they experience to avoid injury and optimize their body's capacity to adapt. Knowing a little about these principles provides valuable insights needed for organizing an effective fitness plan.

Overload Principle

Consider the old saying, "No pain, no gain." Does exercise really have to be painful, as this adage implies, to be beneficial? Absolutely not. If that were true, exercise would be a lot less enjoyable. Perhaps a better way to relay the same message would be to say that improvements are driven by stress. Physical stress, such as walking at a brisk pace or jogging, places increased stress on the regulatory systems that manage increased heart rate and blood pressure, increased energy production, increased breathing, and even increased sweating for temperature regulation. As these subsequent adaptations occur, the stress previously experienced during the same activity, feels less stressful in future sessions. As a result of the adaptation, more stress must be applied to the system in order to stimulate improvements, a principle known as the overload principle.

For example, a beginning weightlifter performs squats with 10 repetitions at 150 pounds. After 2 weeks of lifting this weight, the lifter notices the 150 pounds feels easier during the lift and afterwards causes less fatigue. The lifter adds 20 pounds and continues with the newly established stress of 170 pounds. The lifter will continue to get stronger until his/her maximum capacity has been reached, or the stress stays the same, at which point the lifter's strength will simply plateau. This same principle can be applied, not only to gain muscular strength, but also to gain flexibility, muscular endurance, and cardiorespiratory endurance.

FITT

In exercise, the amount of stress placed on the body can be controlled by four variables: Frequency, Intensity, Time (duration), and Type, better known as FITT. The FITT principle, as outlined by the American College of Sports Medicine (ACSM) falls under the larger principle of overload.

Frequency and Time

Each variable can be used independently or in combination with other variables to impose new stress and stimulate adaptation. Such is the case for frequency and time.

Frequency relates to how often exercises are performed over a period of time. In most cases, the number of walking or jogging sessions would be determined over the course of a week. A beginner may determine that 2–3 exercise sessions a week are sufficient enough to stimulate improvements. On the other hand, a seasoned veteran may find that 2–3 days is not enough to adequately stress the system. According to the overload principle, as fitness improves, so must the stress to ensure continued gains and to avoid plateauing.

The duration of exercise, or time, also contributes to the amount of stress experienced during a workout. Certainly, a 30-minute brisk walk is less stressful on the body than a 4-hour marathon.

Although independent of one another, frequency and time are often combined into the blanket term, volume. The idea is that volume more accurately reflects the amount of stress experienced. This can be connected to the progression principle. For example, when attempting to create a jogging plan, you may organize 2 weeks like this:

- week 1: three days a week at 30 minutes per session

- week 2: four days a week at 45 minutes per session

At first glance, this might appear to be a good progression of frequency and time. However, when calculated in terms of volume, the aggressive nature of the progression is revealed. In week 1, three days at 30 minutes per session equals 90 minutes of total exercise. In week two, this amount was doubled with four days at 45 minutes, equaling 180 minutes of total exercise. Doing too much, too soon, will almost certainly lead to burnout, severe fatigue, and injury. The progression principle relates to an optimal overload of the body by finding an amount that will drive adaptation without compromising safety.

Type of Exercise

Simply put, the type of exercise performed should reflect a person's goals. In cardiorespiratory fitness, the objective of the exercise is to stimulate the cardiorespiratory system. Other activities that accomplish the same objective include swimming, biking, dancing, cross country skiing, aerobic classes, and much more. As such, these activities can be used to build lung capacity and improve cellular and heart function.

However, the more specific the exercise, the better. While vigorous ballroom dancing will certainly help develop the cardiorespiratory system, it will unlikely improve a person's 10k time. To improve performance in a 10k, athletes spend the majority of their time training by running, as they will have to do in the actual 10k. Cyclists training for the Tour de France, spend up to six hours a day in the saddle, peddling feverishly. These athletes know the importance of training the way they want their body to adapt. This concept, called the principle of specificity, should be taken into consideration when creating a training plan.

In this discussion of type and the principle of specificity, a few additional items should be considered. Stress, as it relates to exercise, is very specific. There are multiple types of stress. The three main stressors are metabolic stress, force stress, and environmental stress. Keep in mind, the body will adapt based on the type of stress being placed on it.

Metabolic stress results from exercise sessions when the energy systems of the body are taxed. For example, sprinting short distances requires near maximum intensity and requires energy (ATP) to be produced primarily through anaerobic pathways, that is, pathways not requiring oxygen to produce ATP. Anaerobic energy production can only be supported for a very limited time (10 seconds to 2 minutes). However, distance running at steady paces requires aerobic energy production, which can last for hours. As a result, the training strategy for the distance runner must be different than the training plan of a sprinter, so the energy systems will adequately adapt.

Likewise, force stress accounts for the amount of force required during an activity. In weightlifting, significant force production is required to lift heavy loads. The type of muscles being developed, fast-twitch muscle fibers, must be recruited to support the activity. In walking and jogging, the forces being absorbed come from the body weight combined with forward momentum. Slow twitch fibers, which are unable to generate as much force as the fast twitch fibers, are the type of muscle fibers primarily recruited in this activity. Because the force requirements differ, the training strategies must also vary to develop the right kind of musculature.

Environmental stress, such as exercising in the heat, places a tremendous amount of stress on the thermoregulatory systems. As an adaptation to the heat, the amount of sweating increases as does plasma volume, making it much easier to keep the body at a normal temperature during exercise. The only way to adapt is through heat exposure, which can take days to weeks to properly adapt.

In summary, to improve performance, being specific in your training, or training the way you want to adapt, is paramount.

Intensity

Intensity, the degree of difficulty at which the exercise is carried out, is the most important variable of FITT. More than any of the other components, intensity drives adaptation. Because of its importance, it is imperative for those beginning a fitness program to quantify intensity, as opposed to estimating it as hard, easy, or somewhere in between. Not only will this numeric value provide a better understanding of the effort level during the exercise session, but it will also help in designing sessions that accommodate individual goals.

How then can intensity be measured? Heart rate is one of the best ways to measure a person's effort level for cardiorespiratory fitness. Using a percentage of maximum lifting capacity would be the measure used for resistance training.

Rest, Recovery, and Periodization

For hundreds of years, athletes have been challenged to balance their exercise efforts with performance improvements and adequate rest. The principle of rest and recovery (or principle of recuperation) suggests that rest and recovery from the stress of exercise must take place in proportionate amounts to avoid too much stress. One systematic approach to rest and recovery has led exercise scientists and athletes alike to divide the progressive fitness training phases into blocks, or periods. As a result, optimal rest and recovery can be achieved without over-stressing the athlete. This training principle, called periodization, is especially important to serious athletes but can be applied to most exercise plans as well. The principle of periodization suggests that training plans incorporate phases of stress followed by phases of rest.

Training phases can be organized on a daily, weekly, monthly, and even multi-annual cycles, called micro-, meso-, and macrocycles, respectively.

An example of this might be:

Week	Frequency	Intensity	Time	Type
1	3 days	40% HRR	25 min	walk
2	4 days	40% HRR	30 min	walk
3	4 days	50% HRR	35 min	walk
4	2 days	30% HRR	30 min	other

As this table shows, the volume and intensity changes from week 1 to week 3. But, in week 4, the volume and intensity drops significantly to accommodate a designated rest week. If the chart were continued, weeks 5-7 would be "stress" weeks and week 8 would be another rest week. This pattern could be followed for several months.

Without periodization, the stress from exercise would continue indefinitely eventually leading to fatigue, possible injury, and even a condition known asovertraining syndrome. Overtraining syndrome is not well understood. However, experts agree that a decline in performance resulting from psychological and physiological factors cannot be fixed by a few days' rest. Instead, weeks, months, and sometimes even years are required to overcome the symptoms of overtraining syndrome. Symptoms include the following:

- weight loss
- loss of motivation
- inability to concentrate or focus
- feelings of depression
- lack of enjoyment in activities normally considered enjoyable
- sleep disturbances
- change in appetite

Reversibility

Chronic adaptations are not permanent. As the saying goes, “Use it or lose it.”
The principle of reversibility suggests that activity must continue at the same level to keep the same level of adaptation. As activity declines, called detraining, adaptations will recede.

In cardiorespiratory endurance, key areas, such as VO2max, stroke volume, and cardiac output all declined with detraining while submaximal heat rate increased. In one study, trained subjects were given bed rest for 20 days. At the end of the bed rest phase, VO2max had fallen by 27% and stroke volume and cardiac output had fallen by 25%. The most well-trained subjects in the study had to train for nearly 40 days following bed rest to get back into pre-rest condition. In a study of collegiate swimmers, lactic acid in the blood after a 2-minute swim more than doubled after 4 weeks of detraining, showing the ability to buffer lactic acid was dramatically affected.[1]

Not only is endurance training affected, but muscular strength, muscular endurance, and flexibility all show similar results after a period of detraining.

Individual Differences

While the principles of adaptation to stress can be applied to

1. Saltin, B., Blomqvist, G., Mitchell, J.H., Johnson, R.L., Jr., Wildenthal, K., Chapman, C.B. Response to submaximal and maximal exercise after bed rest and training. 1968 Nov, Vol. 38 (Suppl. 5)

everyone, not everyone responds to stress in the same way. In the HERITAGE Family study, families of 5 (father, mother, and 3 children) participated in a training program for 20 weeks. They exercised 3 times per week, at 75% of their VO_{2max}, increasing their time to 50 minutes by the end of week 14. By the end of the study, a wide variation in responses to the same exercise regimen was seen by individuals and families. Those who saw the most improvements saw similar percentage improvements across the family and vice versa. Along with other studies, this has led researchers to believe individual differences in exercise response are genetic. Some experts estimate genes to contribute as much as 47% to the outcome of training.

In addition to genes, other factors can affect the degree of adaptation, such as a person's age, gender, and training status at the start of a program. As one might expect, rapid improvement is experienced by those with a background that includes less training, whereas those who are well trained improve at a slower rate.

3.1.2. Creating a Fitness Plan

What Is a Successful Fitness Plan?

Often, the hardest step in beginning a new routine is simply starting the new routine. Old habits, insufficient motivation, lack of support, and time constraints all represent common challenges when attempting to begin a new exercise program. Success, in this case, is measured by a person's ability to consistently participate in a fitness program and reap the fitness benefits associated with a long-term commitment.

Think Lifestyle

Beginning a fitness program is a daunting task. To illustrate the concept of lifestyle, consider attendance at fitness centers during the month of January. Attendance increases dramatically, driven by the number 1 New Year's resolution in America: losing weight. Unfortunately, as time marches on, most of these new converts do not. By some estimates, as many as 80% have stopped coming by the second week in February. As February and March approach, attendance continues to decline, eventually falling back to pre-January levels.

Why does this occur? Why aren't these new customers able to persist and achieve their goal of a healthier, leaner body? One possible explanation: patrons fail to view their fitness program as a lifestyle. The beginning of a new year inspires people to make resolutions, set goals, as they envision a new and improved version of themselves. Unfortunately, most of them expect this transformation to occur in a short period of time. When this does not happen, they become discouraged and give up.

Returning to teen level weight and/or fitness may be an alluring, well-intended goal, but one that is simply unrealistic for most adults. The physical demands and time constraints of adulthood must be taken into consideration for any fitness program to be successful. Otherwise, any new fitness program will soon be abandoned and dreams of physical perfection fade, at least until next January.

Like any other lifestyle habit, optimal health and fitness do not occur overnight. Time and, more importantly, consistency, drive successful health and fitness outcomes. The very term lifestyle refers to changes that are long term and become incorporated into a person's daily routine. Unlike many fad diets and quick fixes advertised on television, successful lifestyle changes are also balanced and reasonable. They do not leave you feeling depressed and deprived after a few days. Find a balance between what you want to achieve and what you are realistically able to do. Finally, you must do more than simply change your behaviours. You must also modify your mental perception to promote long-term health. Find a compelling reason for incorporating healthier behaviours into your daily routine.

The steps below will guide you through this process. Before beginning a fitness program, you should understand the safety concerns associated with exercise.

Safety First: Assessing Your Risk

The physical challenges of beginning a new exercise program increase the risk of injury, illness, or even death. Results from various studies suggest vigorous activity increases the risk of acute cardiac heart attacks and/or sudden cardiac death.[1] While that cautionary information appears contradictory to the previously identified benefits of exercise, the long-term benefits of exercise unequivocally outweigh its risks. In active young adults (younger than 35), incidence of cardiac events are still rare, affecting 1 in 133,000 in men and 1 in 769,000 in women. In older individuals, 1 in 18,000 experience a cardiac event.[2]

Of those rare cardiac incidents that do occur, the presence of preexisting heart disease is the common thread, specifically, atherosclerosis. Atherosclerosis causes arteries to harden and become clogged with plaque, which can break apart, move to other parts of the body, and clog smaller blood vessels. As such, it is important to screen individuals for risk factors associated with heart disease before they begin an exercise program.

The American College of Sports Medicine recommends a thorough pre-screening to identify any risk of heart disease. The 7 major risk factors associated with increased risk of heart disease are identified below:[3]

- **family history:** Having a father or first-degree male relative who has experienced a cardiac event before the age of 55, or a

1. Noakes, Timothy D.; Sudden Death and Exercise, Sportscience, 1998, retrieved Dec. 2017, http://www.sportsci.org/jour/9804/tdn.html
2. Van Camp SP, Boor CM, Mueller FO, et al. Non-traumatic Sports Death in High School and college Athletes, Medicine and Science of Sports and Exercise 1995; 27:641-647
3. American College of Sports Medicine, 7th Edition, ACSM's Guidelines for Exercise Testing and Prescription, Philadelphia, PA, Lippincott, Williams and Wilkins, p. 10

mother or first-degree female relative who has experienced a cardiac event before age 65, could indicate a genetic predisposition to heart disease.

- **cigarette smoking:** The risk of heart disease is increased for those who smoke or have quit in the past 6 months.
- **hypertension:** Having blood pressure at or above 140 mm/HG systolic, 90 mm/Hg diastolic is associated with increased risk of heart disease.
- **dyslipidemia:** Having cholesterol levels that exceed recommendations (130 mg/dL, HDL below 40 mg/dL), or total cholesterol of greater than 200 mg/dL increases risk.
- **impaired fasting glucose (diabetes):** Blood sugar should be within the recommended ranges.
- **obesity:** Body mass index greater than 30, waist circumference of larger than 102 cm for men and larger than 88 cm for women, or waist to hip ratio of less than 0.95 men, or less than 0.86 women increases risk of heart disease.
- **sedentary lifestyle:** Persons not meeting physical activity guidelines set by US Surgeon General's Report have an increased risk of heart disease.

In addition to identifying your risk factors, you should also complete a Physical Activity Readiness Questionnaire (PAR-Q) before beginning an exercise program. The PAR-Q asks yes or no questions about symptoms associated with heart disease. Based on your responses on the PAR-Q, you will be placed into the low, moderate, or high risk category:

- **Low risk** persons include men younger than 45, and women younger than 55, who answer no to all of the PAR-Q questions and have one or no risk factors. Although further screening is a good idea, such as getting physician's approval, it isn't necessary.
- **Moderate risk** persons are men of or greater than 45, women 55 or those who have two or more risk factors. Because of the

connection between cardiac disease, the seven risk factors, and risk during exercise, it is recommended you get a physician's approval before beginning an exercise program.

- **High risk** persons answer yes to one or more of the questions on the PAR-Q. Physician's approval is required before beginning a program.

The Four Steps Toward Creating A Successful Fitness Plan

Once you have determined your ability to safely exercise, you are ready to take the next steps in beginning your program. Additional safety concerns, such as where you walk and jog, how to be safe during your workout, and environmental conditions, will be addressed at a later time.

As you review the remaining steps, a simple analogy may help to better conceptualize the process.

Imagine you are looking at a map because you are traveling to a particular location and you would like to determine the best route for your journey. To get there, you must first determine your current location and then find the roads that will take you to your desired location. You must also consider roads that will present the least amount of resistance, provide a reasonably direct route, and do not contain any safety hazards along the way. Of course, planning the trip, while extremely important, is only the first step. To arrive at your destination, you must actually drive the route, monitoring your car for fuel and/or malfunction, and be prepared to reroute should obstacles arise.

Preparing yourself for an exercise program and ultimately, adopting a healthier lifestyle, requires similar preparation. You will need to complete the following steps:

- **assess your current fitness**: Where are you on the map?
- **set goals**: What is your destination's location?
- **create a plan**: What route will you choose?
- **follow through**: Start driving!

Assess Your Condition

To adequately prepare, you will need to take a hard look at your current level of fitness. With multiple methods of assessing your fitness, you should select the one that most closely applies to you. Obtaining a good estimate will provide you a one-time glance at your baseline fitness and health and provide a baseline measurement for gauging the efficacy of your fitness program in subsequent reassessments.

Assessments are specific to each health-related component of fitness. You will have the opportunity to assess each one in the near future.

Set Goals

Using the map analogy, now that you know your current location, you must determine your destination and the best route for getting there. You can start by setting goals. In his bestselling book, The 7 Habits of Highly Effective People, author Stephen Covey suggests you should "Begin with the end in mind."[footnote]7 Habits of Highly Effective People,2003, Covey, Stephen R. Habit 2, New York, Franklin Covey Co. p. 40-61[/footnote]While Covey's words may not be directly aimed at those seeking to complete a fitness program, his advice is useful to anyone making a significant lifestyle change. To be successful, you must develop a clear vision of your destination. Setting specific goals about how you want to feel and look, increases your chances of success. Without specific goals to measure the success of your efforts, you could possibly exceed your target and believe you failed.

The art of setting goals includes stating them in a clearly defined and measurable way. Consider exactly what you would like to accomplish, make certain your goals can be measured, and establish a reasonable timeframe in which to achieve your goals.

Goals that meet these guidelines are referred to as **S.M.A.R.T. goals**.

- **specific:** Be as specific and detailed as possible in creating your goal.
- **measurable:**: If your goal cannot be measured, you will not know when you have successfully completed the goal.
- **attainable:** Consider whether you have the resources—such as time, family support, and financial means—to obtain your goal.
- **realistic:** While your goal should be challenging, it should not exceed reasonable expectations.
- **timeframe:** Set a deadline to accomplish your goal.

A well-stated goal contains all of the SMART components listed above. Take a look at the well-stated example below:

"I will improve my 12-minute distance by 10% within 2 months of the first assessment."

Note, all the ingredients of a well-stated goal are present. It is specific (improve 12-minute distance by 10%), measurable (10% improvement), attainable and realistic (the degree of improvement is reasonable in that time frame), and includes a time frame (a clear deadline of 2 months).

Less effective goals would be stated like this:

- "I will run farther next time I assess my fitness."
- "I want to jog faster."
- "I will lose weight."
- "I will exercise 3 days a week at 60% max heart rate for 45 minutes per session for 2 months."

At a closer glance, none of these examples contain all of the ingredients of a well-stated goal. How can “faster” be measured? “Farther” is not specific enough, nor is “lose weight.” In the last example, this is not a goal at all. It is a plan to achieve a goal that has not been stated.

In the end, setting up well-stated goals will give you the best chance to convert good intentions into a healthier lifestyle.

To complete this step, write down 2-3 personal goals, stated in the SMART format, and put them in a place you will see them frequently.

Create a Plan

Once you know exactly what you want to achieve, generate a strategy that will help you reach your goals. As you strategize, your goal is to determine the frequency, the intensity, and the duration of your exercise sessions. While doing this, it is imperative to keep in mind a few key principles.

First, use your goals as the foundation for your program. If your goal is related to weight loss, this should drive the frequency, duration, and intensity of your daily workouts as these variables will influence your body’s use of fat for fuel and the number of calories burned. If you feel more interested in improving your speed, you will need to dedicate more workout time to achieving those results.

Another key principle is the importance of safety. The importance of designing a program that is safe and effective cannot be overstated. You can minimize any risks by relying on the expert recommendations of the US Department of Health and Human Services and the American College of Sports Medicine previously outlined and linkedhere. These highly reputable organizations have conducted extensive research to discover the optimal frequency, intensity, and duration for exercise.

Follow Through

Once you have assessed your current fitness levels, set goals using the SMART guidelines, and created your personalized fitness plan, you should feel very proud of yourself! You have made significant progress toward achieving a healthier lifestyle. Now is when the "rubber hits the road." (Literally so, if your plan includes walking or jogging.) Now that you have invested time and energy to develop a thoughtful, well-designed fitness program, it is time to reap the returns of good execution. The assessment, planning and preparation are really the hardest parts. Once you know what to do and how to do it, success is simply a matter of doing it.

Unfortunately, the ability to stick with a program proves difficult for most. To prevent getting derailed from your program, identify barriers that may prevent you from consistently following through. One of the most common challenges cited is a shortage of time. Work schedules, school, child care, and the activities of daily living can leave you with little time to pursue your goals. Make a list of the items that prevent you from regularly exercising and then analyze your schedule and find a time for squeezing in your exercise routine. Regardless of when you schedule your exercise, be certain to exercise consistently. Below are a few additional tips for achieving consistency in your daily fitness program:

- **Think long term; think lifestyle:** The goal is to make exercise an activity you enjoy every day throughout your life. Cultivating a love for exercise will not occur overnight and developing your ideal routine will take time. Begin with this knowledge in mind and be patient as you work through the challenges of making exercise a consistent part of your life.
- **Start out slowly:** Again, you are in this for the long haul. No need to overdo it in the first week. Plan for low intensity activity, for 2–3 days per week, and for realistic periods of time (20–30 minutes per session).

- **Begin with low intensity/low volume:** As fitness improves, you will want to gradually increase your efforts in terms of quantity and quality. You can do this with more time and frequency (called volume) or you can increase your intensity. In beginning a program, do not change both at the same time.
- **Keep track:** Results from a program often occur slowly, subtly, and in a very anti-climactic way. As a result, participants become discouraged when immediate improvements are not visible. Keeping track of your consistent efforts, body composition, and fitness test results and seeing those subtle improvements will encourage and motivate you to continue.
- **Seek support:** Look for friends, family members, clubs, or even virtual support using apps and other online forums. Support is imperative as it provides motivation, accountability, encouragement, and people who share a common interest, all of which are factors in your ability to persist in your fitness program.
- **Vary your activities from time to time:** Your overall goals are to be consistent, build your fitness, and reap the health benefits associated with your fitness program. Varying your activities occasionally will prevent boredom. Instead of walking, play basketball or ride a bike. Vary the location of your workout by discovering new hiking trails, parks or walking paths.
- **Have fun:** If you enjoy your activities, you are far more likely to achieve a lasting lifestyle change. While you cannot expect to be exhilarated about exercising every day, you should not dread your daily exercise regimen. If you do, consider varying your activities more, or finding a new routine you find more enjoyable.
- **Eat healthier:** Nothing can be more frustrating than being consistent in your efforts without seeing the results on the scale. Eating a balanced diet will accelerate your results and allow you to feel more successful throughout your activities.

3.1.3. Safety Concerns

Staying Safe While Being Active

As activity rates among Americans increase, specifically outdoor activities, safety concerns also rise. Unfortunately, the physical infrastructure of many American cities does not accommodate active lifestyles. Limited financial resources and de-emphasis on public health means local and state governments are unlikely to allocate funds for building roads with sidewalks, creating walking trails that surround parks, or adding bike lanes. In addition, time constraints and inconvenience make it challenging for participants to travel to areas where these amenities are available. As a result, exercise participants share roads and use isolated trails/pathways, inherently increasing the safety risks of being active.

A key principle in outdoor safety is to recognize and avoid the extremes. For example, avoid roads that experience heavy traffic or are extremely isolated. Avoid heavy populated areas as well as places where no one is around. Do not exercise in the early morning or late at night, during extreme cold or extreme heat. To minimize safety risks during these types of environmental conditions, do not use headphones that could prevent you from hearing well and remaining alert, do not exercise alone, prepare for adequate hydration in the heat, and use warm clothing in extreme cold to avoid frostbite. Extreme conditions require extra vigilance on your part.

A second key principle, whether outdoor or indoor, is to simply use common sense. While this caveat seems obvious, it gets ignored far too often. Always remember the purpose of your exercise is for enjoyment and improved health. If these objectives could be compromised by going for a run at noon in 35-degree-Celsius heat, or lifting large amounts of weight without a spotter, you should reconsider your plan. Before exercising in what could be risky conditions, ask yourself, “Is there a safer option available?”

Lastly, be aware of the terrain and weather conditions. Walking or jogging on trails is a wonderful way to enjoy nature, but exposed roots and rocks present a hazard for staying upright. Wet, muddy, or icy conditions are additional variables to avoid in order to complete your exercise session without an accident.

The following safety tips that will help you stay safe in your activities.

Environmental Conditions

When exercising outdoors, you must consider the elements and other factors that could place you at increased risk of injury or illness.

Heat-Related Illness

Heat-related illnesses, such as heat cramps, heat exhaustion, and heat stroke, contributed to 7,233 deaths in the United States between 1999 and 2009. A 2013 report released by the Center for Disease Control stated that about 658 deaths from heat-related illnesses occurred every year which account for more deaths than tornadoes, hurricanes, and lightning combined. Of those deaths, most were male, older adults.[1]

1. Center for Disease Control and Prevention, Retrieved April 2017, CDC: Quick Stats: Number of Heat-related Deaths, by Sex-National Vital Statistics System-United

The number one risk factor associated with heat-related illness is hydration, the starting point of all heat-related illness. Unfortunately, sweat loss can occur at a faster rate than a person can replace with fluids during exercise, especially at high intensities. Even when trying to hydrate, ingestion of large amounts of fluids during exercise can lead to stomach discomfort. What does this mean? Hydration must begin before exercise and must become part of your daily routine.

Several practical methods of monitoring hydration levels can assist in preventing illness. One simple method, while not full proof, is to simply monitor the color of your urine. In a hydrated state, urination will occur frequently (every 2–3 hours) and urine will have very little color. In a dehydrated state, urination occurs infrequently in low volume and will become more yellow in color.

Another simple method involves weighing yourself before and after a workout. This is a great way to see firsthand how much water weight is lost during an exercise session primarily as a result of sweat. Your goal is to maintain your pre- and post-body weight by drinking fluids during and after the workout to restore what was lost. This method, when combined with urine-monitoring, can provide a fairly accurate assessment of hydration levels.

The best preventative measure for maintaining a hydrated state is simply drinking plenty of water throughout the day. In previous years, recommendations for the amount of water to drink were a one size fits all of about 48–64 oz. per day, per person. In an effort to individualize hydration, experts now recommend basing fluid intake on individual size, gender, activity levels, and climate. Generally, half an ounce (fluid ounces) to 1 ounce per pound of body weight is recommended.[2] For a 150-pound individual, this

States, 1999-2010, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6136a6.htm

2. Mayo Clinic, retrieved April 2017, Water: How Much

would mean 75–150 ounces of water per day! While there is still considerable debate over the exact amounts, no one disputes the importance of continually monitoring your hydration using one of the techniques described previously. Insufficient hydration leads to poor performance, poor health, and potentially serious illness.

It should be noted that electrolyte "sport" drinks, such as Gatorade and PowerAde, are often used to maintain hydration. While they can be effective, these types of drinks were designed to replace electrolytes (potassium, sodium, chloride) that are lost through sweating during physical activity. In addition, they contain carbohydrates to assist in maintaining energy during activities of long duration. If the activity planned is shorter than 60 minutes in duration, water is still the recommended fluid. For activities beyond 60 minutes, a sports drink should be used.

Cold-Related Illness

Much like extremely hot environmental conditions, cold weather can create conditions equally as dangerous if you fail to take proper precautions. To minimize the risk of cold-related illness, you must prevent the loss of too much body heat. The three major concerns related to cold- related illnesses are hypothermia, frost-nip, and frost bite.

As with heat-related illness, the objective of preventing cold-related illness is to maintain the proper body temperature around 37 degrees Celsius. If body temperature falls below 37 degrees Celsius, multiple symptoms may appear, indicating the need to take action. Some of those symptoms include:

Should You Drink Each Day? http://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/in- depth/water/art-20044256

- shivering
- numbness and stiffness of joints and appendages
- loss of dexterity and/or poor coordination
- peeling or blistering of skin, especially to exposed areas
- discoloration of the skin in the extremities

When walking or jogging in the cold, it is important to take the necessary steps to avoid problems that can arise from the environmental conditions.

First, **hydration is key**. Cold air is usually drier air, which leads to moisture loss through breathing and evaporation. Staying hydrated is key in maintaining blood flow and regulating temperature.

Next, **stay dry**: Heat loss occurs 25x faster in water than on dry land. As such, keeping shoes and socks dry and clothing from accumulating too much sweat will allow for more effective body temperature regulation.

Finally, **dress appropriately**. Because of the movement involved, the body will produce heat during the exercise session. Therefore, the key point is to direct moisture (sweat) away from the skin. This is controlled most effectively by layering your clothing. A base layer of moisture-wicking fabric should be used against the skin while additional layers should be breathable. This will channel moisture away from the skin, and any additional layers of clothing, without it becoming saturated in sweat. If exercising on a windy day, use clothing that protects from the wind and is adjustable so you can breathe.

To dress appropriately, you must also remember to **cover the extremities**. Those parts of the body farthest away from the heart (toes, fingers, and ears) tend to get coldest first. Take the appropriate steps to cover those areas by using gloves, moisture-wicking socks, and a winter cap to cover your head.

Terminology Checklist

Physical activity: any activity that requires skeletal muscle and requires energy aimed at improving health.

Exercise: a subset of physical activity that is planned and structured aimed at improving fitness.

Health related components of fitness: types of activities dedicated to improving physical fitness categorized as cardiorespiratory endurance, muscular strength and endurance, flexibility, and body composition.

Skills related components of fitness: types of activities dedicated to improving physical skills categorized as speed, agility, coordination, balance, power, and reaction time.

Principles of adaptations to stress: guidelines related to managing the application of stress during physical activity/exercise.

Overload principle: a principle of adaptation to stress suggesting the amount of stress applied during exercise must exceed a threshold level to stimulate adaptation.

Volume: the term used to describe "how much" stress is being applied by combining the duration and frequency of exercise.

Progression principle: a principle relating to how much additional stress that can safely be introduced to gradually improve fitness without risking injury or overuse.

Specificity: the principle of stress suggesting activities should be closely centered around the primary outcome goal, i.e. train the way you want to adapt.

Reversibility: the principle that adaptations to stress can be lost over time if training is modified or stopped.

Principle of rest and recovery: the concept that adaptation not only requires overload but also requires rest to avoid overstressing the body.

Periodization: a method of organizing workouts into blocks or periods. These cycles consist of work/stress periods and rest periods.

Overtraining syndrome: a condition of chronic stress from physical activity affecting the physical and psychological states of an individual or athlete.

Detraining: the act of no longer training at all or decreasing the amount of training.

3.1.4. Test Your Knowledge

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3.2. PHYSICAL FITNESS

“Physical Fitness” is an adaptation of “Performance Nutrition” from *Human Nutrition*, by the University of Hawai‘i at Mānoa Food Science and Human Nutrition Program, which is licensed under a CC BY 4.0 license. New material has been incorporated that includes Canadian content. Information that is not relevant to this course has been removed.

3.2.1. Physical Fitness and Energy

Image by Chris McCormack on flickr.com / CC BY-ND 2.0

Introduction

Becoming and staying physically fit is an important part of achieving optimal health. A well-rounded exercise program is crucial to becoming and remaining healthy. Physical activity improves your health in a number of ways. It promotes weight loss, strengthens muscles and bones, keeps the heart and lungs strong, and helps to protect against chronic disease. There are four essential elements of physical fitness: cardiorespiratory, muscular strength, flexibility, and maintaining a healthful body composition. Some enthusiasts might argue the relative importance of each, but optimal health requires some degree of balance between all four. For example, the Hawai'i Ironman is a vigorous race that consists of a 2.4 mile swim, 112 mile bike, and a 26 mile run. All four elements of physical fitness are vital in order to complete each leg of the race. To learn more about the Hawai'i Ironman, visit their website at http://www.ironman.com.Some forms of exercise confer multiple benefits, which can help you to balance the different elements of physical fitness. For example, riding a bicycle for thirty minutes or more not only builds cardiorespiratory endurance, it also improves muscle strength and muscle endurance. Some forms of yoga can also build muscle strength and endurance, along with flexibility. However, addressing fitness standards in all four categories generally requires incorporating a range of activities into your regular routine. If you exercise regularly, your body will begin to change and you will notice that you are able to continue your activity longer. This is due to the overload principle that our bodies will adapt to with continuous repetition. For example, if you run a mile everyday for a week, in a few weeks you would be able to run further and likely faster.

The Essential Elements of Physical Fitness

Cardiorespiratory Endurance

Cardiorespiratory endurance is enhanced by aerobic training which involves activities that increase your heart rate and breathing such as walking, jogging, or biking. Building cardiorespiratory endurance through aerobic exercise is an excellent way to maintain a healthy weight. Working on this element of physical fitness also improves your circulatory system. It boosts your ability to supply the body's cells with oxygen and nutrients, and to remove carbon dioxide and metabolic waste. Aerobic exercise is continuous exercise (lasting more than 2 minutes) that can range from low to high levels of intensity. In addition, aerobic exercise increases heart and breathing rates to meet increased demands for oxygen in working muscles. Regular, moderate aerobic activity, about thirty minutes at a time for five days per week, trains the body to deliver oxygen more efficiently, which strengthens the heart and lungs, and reduces the risk of cardiovascular disease.[1][2] Strengthening your heart muscle and increasing the blood volume pumped each heartbeat will lead to a lower resting heart rate for healthy individuals. Aerobic exercise increases the ability of muscles to use oxygen for energy metabolism therefore creating ATP.

Aerobic capacity, or $VO_2$is the most common standard for evaluating cardiorespiratory endurance. VO_2max is your maximal oxygen uptake, and the VO_2max test measures the amount of oxygen (in relation to body weight) that you can use per minute. A test subject usually walks or runs on a treadmill or rides a stationary bicycle while the volume and oxygen content of exhaled air is measured to determine oxygen consumption as exercise intensity increases. At some point, the amount of oxygen consumed no longer increases despite an increase in exercise intensity. This value of oxygen consumption is referred to as VO_2max, 'V' meaning volume, and 'max' meaning the maximum amount of oxygen (O2) an individual is capable of utilizing. The higher the number, the more oxygen you can consume, and the faster or longer you can walk, run,

1. The American Heart Association Recommendations for Physical Activity in Adults. American Heart Association. Heart.org. http://www.heart.org/HEARTORG/HealthyLiving/PhysicalActivity/FitnessBasics/American-Heart-Association-Recommendations-for-Physical-Activity-Infographic_UCM_450754_SubHomePage.jsp. Accessed March 10, 2018.
2. [3]
3.

bike, or swim, among other aerobic activities. VO_2max can increase over time with training.[4]

Figure 3.2.1.1 VO_2 *Max Test*

The VO_2 Max Test is conducted here on a treadmill. It can also be completed on a regular bike or an arm bike. It consists of incremental stages until the participant reaches exhaustion. Data from this tests informs on one's physical fitness. Source: *image by* Cosmed/ [CC BY-SA 3.0](CC BY-SA 3.0)

4. Ed Eyestone. How to Improve Your VO2 Max. RunnersWorld.com. http://www.runnersworld.com/article/0,7120,s6-238-244--12408-0,00.html. Published January 9, 2008.

Muscle Strength

Muscle strength is developed and maintained by weight or resistance training that often is called anaerobic exercise. Anaerobic exercise consists of short duration, high intensity movements that rely on immediately available energy sources and require little or no oxygen during the activity. This type of high intensity training is used to build muscle strength by short, high intensity activities. Building muscle mass is not just crucial for athletes and bodybuilders—building muscle strength and endurance is important for children, seniors, and everyone in between. The support that your muscles provide allows you to work, play, and live more efficiently. Strength training involves the use of resistance machines, resistance bands, free weights, or other tools. However, you do not need to pay for a gym membership or expensive equipment to strengthen your muscles. Homemade weights, such as plastic bottles filled with sand, can work just as well. You can also use your own body weight and do push-ups, leg squats, abdominal crunches, and other exercises to build your muscles. If strength training is performed at least twice a week, it can help to improve muscle strength and to increase bone strength. Strength training can also help you to maintain muscle mass during a weight-loss program.[5]

5. American College of Sports Medicine. Resistance Training for Health and Fitness. Acsm.org. https://www.acsm.org/docs/brochures/resistance-training.pdf. Accessed March 11, 2018.

Flexibility

Flexibility is the range of motion available to your joints. Yoga, tai chi, Pilates, and stretching exercises work to improve this element of fitness. Stretching not only improves your range of motion, it also promotes better posture, and helps you perform activities that can require greater flexibility, such as chores around the house. In addition to working on flexibility, older adults should include balance exercises in their regular routine. Balance tends to deteriorate with age, which can result in falls and fractures.[6]

Body Composition

Body composition is the proportion of fat and fat-free mass (which includes bones, muscles and organs) in your body. A healthy and physically fit individual has a greater proportion of muscle and smaller proportion of fat than an unfit individual of the same weight. Although habitual physical activity can promote a more healthful body composition, other factors like age, gender, genetics, and diet contribute to an individual's body composition. Women have a higher healthy fat percentage than men. For adult women, a healthy amount of body fat ranges from 20 to 32 percent. Adult males on the other hand range from 10 to 22 percent of body fat.[7]

6. Fitness Training: Elements of a Well-Rounded Routine. MayoClinic.com. http://www.mayoclinic.com/health/fitness-training/HQ01305. Updated August 10, 2017.
7. Measuring and Evaluating Body Composition. ACSM.org. http://www.acsm.org/public-information/articles/

Metabolic Fitness

Being fit also includes metabolic fitness. It relates to the number of calories you require to survive and the number of calories you burn during physical activity. Recall that metabolism is the sum of all chemical reactions that occur in the human body to conduct life's processes. Some are catabolic reactions that break down nutrients to supply the body with cellular energy. The rate at which a person burns calories depends on body composition, gender, age, nutritional status, physical activity, and genetics.

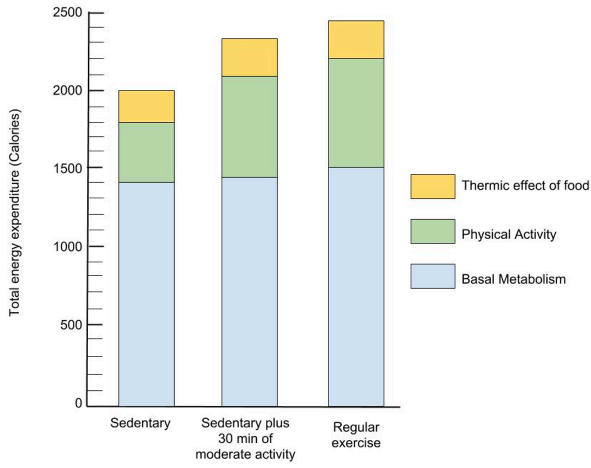
Increasing your daily activity and shedding excess body fat helps to improve metabolic fitness. Physical activity also makes weight management easier because it increases energy needs and lean body mass. During moderate to vigorous activity, energy expenditure raises well above the resting rate. With continuous exercise over time, regular exercise increases lean body mass as well. At rest, lean tissues use more energy than fat tissue therefore increasing basal metabolism. The combination of increased energy output, energy expenditure and basal needs over a long period of time can have a major impact on total energy expenditure. The more energy you expend, the more foods you are able to consume while maintaining a healthy weight. Any improvement to metabolic fitness is beneficial and means a decrease in the risk for developing diabetes, or other chronic conditions.

One measurement of metabolic fitness is basal metabolic rate, or BMR, which is a measurement of the amount of energy required for the body to maintain its basic functions while at rest, i.e. breathing, heart beats, liver and kidney function, and so on. On average, BMR accounts for between 50 and 70 percent of a person's total daily energy expenditure. Different factors can affect the BMR. For

2016/10/07/measuring-and-evaluating-body-composition example, a slender person who is tall has more body surface area and therefore has a higher RMR relative to their body mass (weight). Also, muscle utilizes more energy at rest than fat, so a person with more muscle mass has a higher BMR.

A second measurement of metabolic fitness is the number of calories burned during physical activity. The amount of calories burned depends on how much oxygen is delivered to tissues, and how efficiently metabolic reactions consume oxygen and, therefore, expend calories. One of the best estimates of energy expenditure during exercise is how much oxygen a person consumes. Recall that VO2 max is a measure of the maximum cardiorespiratory capacity to deliver oxygen to the body, especially to working muscles during exercise. Greater VO_2 max is indicative of better cardiovascular fitness. In contrast to RMR, VO_2 max increases significantly with exercise training due to training adaptations that increase the body's ability to deliver oxygen to working tissues and an increased capacity of muscles to take up and utilize oxygen.

Figure 3.2.1.2 *The Effect of Physical Activity on Energy Expenditure*



Physical activity increases basal metabolism and energy expenditure that occurs from physical activity. The thermic effect of food is not affected by physical activity. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Physical Activity Recommendations

The CDC along with the American College of Sports Medicine (ACSM) have evidence based recommendations and guidelines for individuals to follow in order to obtain or maintain a healthy lifestyle. Adults should get at least 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous-intensity aerobic physical activity each week. In addition to aerobic physical activity, it is recommended that adults do muscle strengthening activities on each major muscle group two or three times each week. Adults also are recommended by the ACSM to do flexibility exercises at least two to three times a week to improve range of motion. To learn more about these guidelines visit the CDC website at https://health.gov/paguidelines/guidelines/adults.aspx and the ACSM website at http://www.acsm.org/about-acsm/media-room/news-releases/2011/08/01/acsm-issues-new-recommendations-on-quantity-and-quality-of-exercise.

The Benefits of Physical Activity

Regular physical activity is one of the best things you can do to achieve optimal health. Individuals who are physically active for about seven hours per week lower the risk of dying early by 40 percent compared to those who are active for less than thirty minutes per week.[8] Improving your overall fitness involves sticking

8. Physical Activity and Health: The Benefits of Physical Activity. CDC.org. http://www.cdc.gov/physicalactivity/everyone/health/index.html. Last updated February 16, 2011.

with an exercise program on a regular basis. If you are nervous or unsure about becoming more active, the good news is that moderate-intensity activity, such as brisk walking, is safe for most people. Also, the health advantages of becoming active far outweigh the risks. Physical activity not only helps to maintain your weight, it also provides a wealth of benefits—physical, mental, and emotional.

Physical Benefits

Getting the recommended amount of physical activity each week, about 150 minutes of moderate, aerobic exercise, such as power walking or bicycling, does not require joining a gym, or taking expensive, complicated classes. If you can't commit to a formal workout four to five days per week, you can become more active in simple ways—by taking the stairs instead of the elevator, by walking more instead of driving, by going out dancing with your friends, or by doing your household chores at a faster pace. It is not necessary to perform at the level of a professional dancer or athlete, or to work out for several hours every day, to see real gains from exercise. Even slightly increased activity can lead to physical benefits, such as the following:

- **longer life:** A regular exercise program can reduce your risk of dying early from heart disease, certain cancers, and other leading causes of death.
- **healthier weight:** Exercise, along with a healthy, balanced eating plan, can help you lose extra weight, maintain weight loss, or prevent excessive weight gain.
- **cardiovascular disease prevention:** Being active boosts HDL cholesterol and decreases unhealthy triglycerides, which reduces the risk of cardiovascular diseases.
- **management of chronic conditions:** A regular routine can help to prevent or manage a wide range of conditions and concerns,

such as metabolic syndrome, type 2 diabetes, depression, arthritis, and certain types of cancer.

- **energy boosts:** Regular physical activity can improve muscle tone and strength and provide a boost to your cardiovascular system. When the heart and lungs work more efficiently, you have more energy.
- **strong bones:** Research shows that aerobic activity and strength training can slow the loss of bone density that typically accompanies aging.

Mental and Emotional Benefits

The benefits of an exercise program are not just physical, they are mental and emotional as well. Anyone who has gone for a walk to clear their head knows the mental benefits of exercise firsthand. Also, you do not have to be a marathoner on a “runner’s high” to enjoy the emotional benefits of becoming active. The mental and emotional benefits of physical activity include the following:

- **mood improvement:** Aerobic activity, strength-training, and more contemplative activities such as yoga, all help break cycles of worry, absorption, and distraction, effectively draining tension from the body.
- **reduced risk of depression or reduced symptoms:** Some people have called exercise “nature’s antidepressant,” and studies have shown that physical activity reduces the risk of and helps people cope with the symptoms of depression.
- **cognitive skills retention:** Regular physical activity can help people maintain thinking, learning, and judgement as they age.
- **better sleep:** A good night’s sleep is essential for clear thinking, and regular exercise promotes healthy, sound sleep. It can also help you fall asleep faster and deepen your rest.

Changing to a More Active Lifestyle

A physically active lifestyle yields so many health benefits that it is recommended for everyone. Change is not always easy, but even small changes such as taking the stairs instead of the elevator, or parking farther away from a store to add a bit more walking into your day can lead to a more active lifestyle and set you on the road to optimal health. When people go one step further by walking or biking on a regular basis, or becoming active by growing and maintaining a garden, they do more than promote their own health—they safeguard the health of the planet, too.

As you change to a more active lifestyle, select an activity that you can integrate into your schedule smoothly, so you can maintain it. For example, instead of making time to get coffee with friends, you might suggest a walk, rollerblading, or going for a swim in the campus pool. Also, find an activity that you will be motivated to do. Some people decide to participate in team sports, such as local soccer or softball leagues, because they enjoy being active with others or like knowing that a team relies on them. Others prefer to take a class, such as spinning or yoga, that is led by an instructor who will motivate them. Still others prefer more solitary pursuits, such as taking a jog alone in their neighborhood. No matter what your preference, you are more likely to stick to a workout program if you enjoy it.

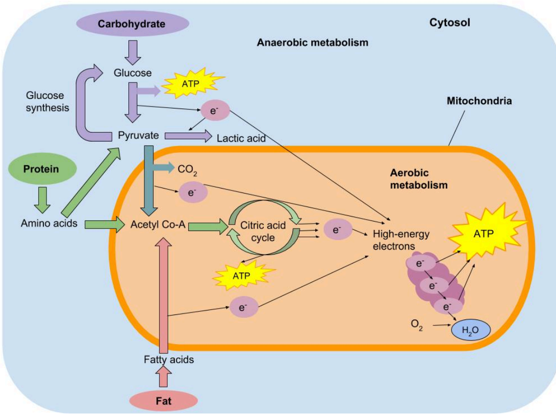
Fuel Sources

The human body uses carbohydrate, fat and protein in food and from body stores as energy. These essential nutrients are needed regardless of the intensity of activity you are doing. If you are lying down reading a book or running the the Honolulu Marathon, these macronutrients are always needed in the body. However, in order for these nutrients to be used as fuel for the body, their energy must be transferred into the high energy molecule known as Adenosine Triphosphate (ATP). ATP is the body's immediate fuel source of energy that can be generated either with the presences of oxygen known as aerobic metabolism or without the presence of oxygen by anaerobic metabolism. The type of metabolism that is predominately used during physical activity is determined by the availability of oxygen and how much carbohydrate, fat, and protein are used.

Anaerobic and Aerobic Metabolism

Anaerobic metabolism occurs in the cytosol of the muscle cells. As seen in Figure 3.2.1.3 "Anaerobic Versus Aerobic Metabolism", a small amount of ATP is produced in the cytosol without the presence of oxygen. Anaerobic metabolism uses glucose as its only source of fuel and produces pyruvate and lactic acid. Pyruvate can then be used as fuel for aerobic metabolism. Aerobic metabolism takes place in the mitochondria of the cell and is able to use carbohydrates, protein or fat as its fuel source. Aerobic metabolism is a much slower process than anaerobic metabolism but produces majority of the ATP.

Figure 3.2.1.3 *Anaerobic Versus Aerobic Metabolism*



The pathways of glycolysis (anaerobic metabolism; shown in purple) and oxidative phosphorylation (aerobic metabolism; shown in green). Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Physical Activity Duration and Fuel Use

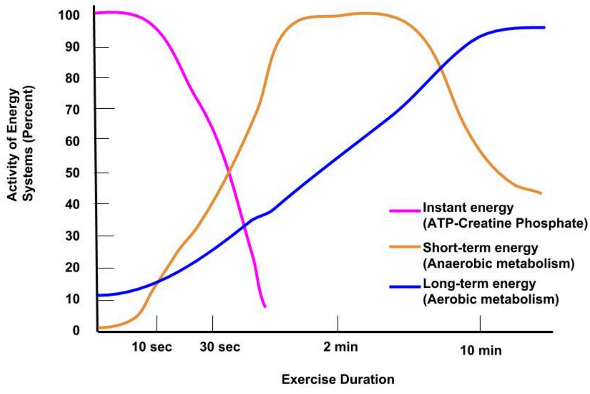
The respiratory system plays a vital role in the uptake and delivery of oxygen to muscle cells throughout the body. Oxygen is inhaled by the lungs and transferred from the lungs to the blood where the cardiovascular system circulates the oxygen-rich blood to the muscles. The oxygen is then taken up by the muscles and can be used to generate ATP. When the body is at rest, the heart and lungs are able to supply the muscles with adequate amounts of oxygen to meet the aerobic metabolism energy needs. However, during physical activity your muscles energy and oxygen needs are increased. In order to provide more oxygen to the muscle cells, your heart rate and breathing rate will increase. The amount of oxygen that is delivered to the tissues via the cardiovascular and respiratory systems during exercise depend on the duration, intensity and physical conditioning of the individual.

During the first few steps of exercise, your muscles are the first to respond to the change in activity level. Your lungs and heart however do not react as quickly and during those beginning steps they do not begin to increase the delivery of oxygen. In order for our bodies to get the energy that is needed in these beginning steps, the muscles rely on a small amount of ATP that is stored in resting muscles. The stored ATP is able to provide energy for only a few seconds before it is depleted. Once the stored ATP is just about used up, the body resorts to another high-energy molecule known as creatine phosphate to convert ADP (adenosine diphosphate) to ATP. After about 10 seconds, the stored creatine phosphate in the muscle cells are also depleted as well.

About 15 seconds into exercise, the stored ATP and creatine phosphate are used up in the muscles. The heart and lungs have still not adapted to the increase need of oxygen so the muscles must begin to produce ATP by anaerobic metabolism (without oxygen). Anaerobic metabolism can produce ATP at a rapid pace but only uses glucose as its fuel source. The glucose is obtained from the blood of muscle glycogen. At around 30 seconds, anaerobic pathways are operating at their full capacity but because the availability of glucose is limited, it cannot continue for a long period of time.

As your exercise reaches two to three minutes, your heart rate and breathing rate have increased to supply more oxygen to your muscles. Aerobic metabolism is the most efficient way of producing ATP by producing 18 times more ATP for each molecule of glucose than anaerobic metabolism. Although the primary source of ATP in aerobic metabolism is carbohydrates, fatty acids and protein can also be used as fuel to generate ATP.

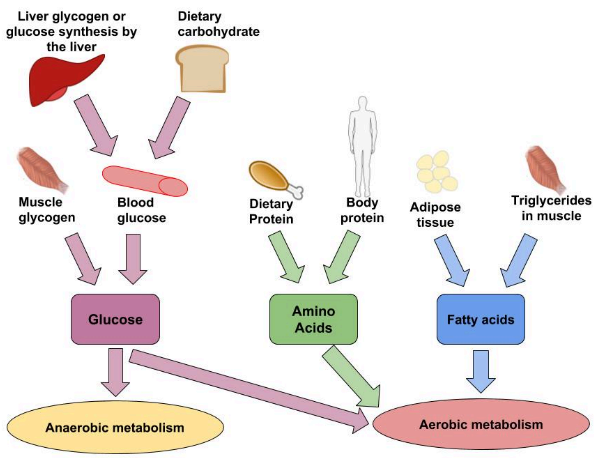
Figure 3.2.1.4 *The Effect of Exercise Duration on Energy Systems*



Short duration exercise utilizes the ATP-creatine phosphate system. As this system is depleted, the anaerobic energy system kicks in. Throughout exercise the contribution of the aerobic system increases. After ~10 minutes the aerobic energy system is the dominating system in play. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

The fuel sources for anaerobic and aerobic metabolism will change depending on the amount of nutrients available and the type of metabolism. Glucose may come from blood glucose (which is from dietary carbohydrates or liver glycogen and glucose synthesis) or muscle glycogen. Glucose is the primary energy source for both anaerobic and aerobic metabolism. Fatty acids are stored as triglycerides in muscles but about 90% of stored energy is found in adipose tissue. As low to moderate intensity exercise continues using aerobic metabolism, fatty acids become the predominant fuel source for the exercising muscles. Although protein is not considered a major energy source, small amounts of amino acids are used while resting or doing an activity. The amount of amino acids used for energy metabolism increase if the total energy intake from your diet does not meet the nutrient needs or if you are involved in long endurance exercises. When amino acids are broken down removing the nitrogen-containing amino acid, that remaining carbon molecule can be broken down into ATP via aerobic metabolism or used to make glucose. When exercise continues for many hours, amino acid use will increase as an energy source and for glucose synthesis.

Figure 3.2.1.5 *Fuel Sources for Anaerobic and Aerobic Metabolism*



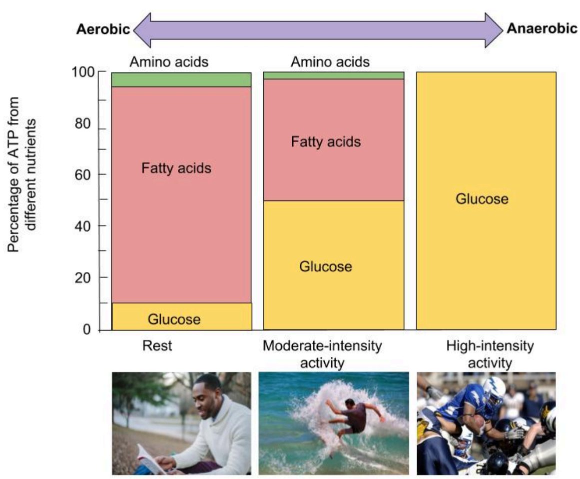
The different sources of fuel for anaerobic metabolism and aerobic metabolism and how these fuel sources are broken down. Source: image by Allison Calabrese /

Physical Activity Intensity and Fuel Use

The exercise intensity determines the contribution of the type of fuel source used for ATP production(see Figure 3.2.1.6 "The Effect of Exercise Intensity on Fuel Sources"). Both anaerobic and aerobic metabolism combine during exercise to ensure that the muscles are equipped with enough ATP to carry out the demands placed on them. The amount of contribution from each type of metabolism will depend on the intensity of an activity. When low-intensity activities are performed, aerobic metabolism is used to supply enough ATP to muscles. However, during high-intensity activities more ATP is needed so the muscles must rely on both anaerobic and aerobic metabolism to meet the body's demands.

During low-intensity activities, the body will use aerobic metabolism over anaerobic metabolism because it is more efficient by producing larger amounts of ATP. Fatty acids are the primary energy source during low-intensity activity. With fat reserves in the body being almost unlimited, low-intensity activities are able to continue for a long time. Along with fatty acids, a small amount of glucose is used as well. Glucose differs from fatty acids where glycogen storages can be depleted. As glycogen stores are depleted, fatigue will eventually set in.

Figure 3.2.1.6 *The Effect of Exercise Intensity on Fuel Sources*



Restful activities use mainly fatty acids to fuel their energy demands. As exercise intensity increases, there is a switch to glucose being the primary energy source. Amino acids are the least used source for energy. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

The Fat-Burning Zone

The fat-burning zone is a low intensity aerobic activity that keeps your heart rate between 60 and 69% of your maximum heart rate. The cardio zone on the other hand is a high intensity aerobic activity that keeps the heart rate between about 70 to 85% of your maximum heart rate. So which zone do you burn the most fat in? Technically, your body burns a higher percentage of of calories from fat during a low intensity aerobic activity but there's more to it than just that. When you begin a low intensity activity, about 50% of the calories burned comes from fat whereas in the cardio zone only 40% comes from fat. However, when looking at the actual numbers of calories burned, higher intensity activity burns just as much fat and a much greater total calories overall.

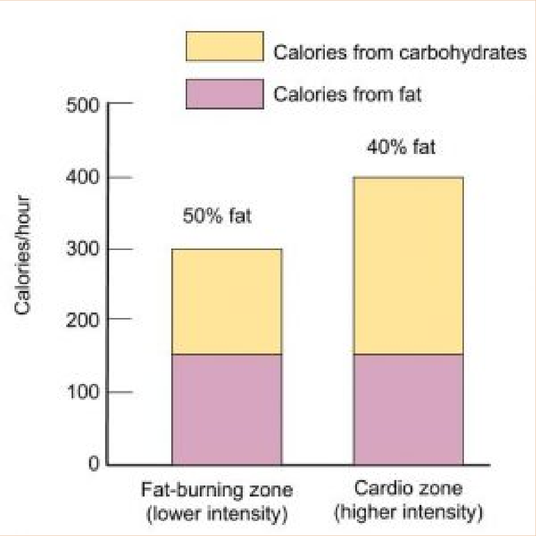


Image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

"Hitting the Wall" or "Bonking"

If you are familiar with endurance sports, you may have heard of "hitting the wall" or "bonking." These colloquial terms refer to the extreme fatigue that sets in after about 120 minutes of performing an endurance sport, such as marathon running or long-distance cycling. The physiology underlying "hitting the wall" means that muscles have used up all their stored glycogen and are therefore dependent on other nutrients to support their energy needs. Fatty acids are transported from fat-storing cells to the muscle to rectify the nutrient deficit. However, fatty acids take more time to convert to energy than glucose, thus decreasing performance levels. To avoid “hitting the wall” or “bonking,” endurance athletes load up on carbohydrates for a few days before the event, known as carbohydrate loading. This will maximize an athlete’s amount of glycogen stored in their liver and muscle tissues. It is important not to assume that carbohydrate loading works for everyone. Without accompanied endurance training you will not increase the amount of stored glucose. If you plan on running a five-mile race for fun with your friend and decide to eat a large amount of carbohydrates in the form of a big spaghetti dinner the night before, the excess carbohydrates will be stored as fat. Therefore, if you are not an endurance athlete exercising for more than 90 minutes, carbohydrate loading will provide no benefit, and can even have some disadvantages. Another way for athletes to avoid “hitting the wall” is to consume carbohydrate-containing drinks and foods during an endurance event. In fact, throughout the Tour de France—a twenty-two-day, twenty-four-hundred-mile race—the average cyclist consumes greater than 60 grams of carbohydrates per hour.

3.2.2. Sports Nutrition

Nutrient Needs for Athletes

Nutrition is essential to your performance during all types of exercise. The foods consumed in your diet are used to provide the body with enough energy to fuel an activity regardless of the intensity of activity. Athletes have different nutritional needs to support the vigorous level they compete and practice at.

Energy Needs

To determine an athletes nutritional needs, it is important to revisit the concept of energy metabolism. Energy intake is the foundation of an athlete's diet because it supports optimal body functions, determines the amount of intake of macronutrients and micronutrients, and assists in the maintaining of body composition. Energy needs for athletes increase depending on their energy expenditure. The energy expended during physical activity are contingent on the intensity, duration, and frequency of the exercise. Competitive athletes may need 3,000 to over 5,000 calories daily compared to a typical inactive individual who needs about 2,000 calories per day. Energy needs are also affected by an individual's gender, age, and weight. Weight-bearing exercises, such as running, burn more calories per hour than non-weight bearing exercises, such as swimming. Weight-bearing exercises requires your body to move against gravity which requires more energy. Men are also able to burn more calories than women for the same activity because they have more muscle mass which requires more energy to support and move around.[1]

Body weight and composition can have a tremendous impact on exercise performance. Body weight and composition are considered the focal points of physique for athletes because they are the able to be manipulated the most. Energy intake can play a role in manipulating the physiques for athletes. For individuals competing in sports such as football and weight lifting, having a large amount of muscle mass and increased body weight may be beneficial. This can be obtained through a combination of increased energy intake, and protein. Although certain physiques are more advantageous for specific sports, it is important to remember that a single and rigid "optimal" body composition is not recommended for any group of athletes.[2]

1. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.
2. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

Macronutrient Needs

The composition of macronutrients in the diet is a key factor in maximizing performance for athletes. Carbohydrates are an important fuel source for the brain and muscle during exercise. Carbohydrate storage in the liver and muscle cells are relatively limited and therefore it is important for athletes to consume enough carbohydrates from their diet. Carbohydrate needs should increase about 3-10 g/kg/day depending on the type of training or competition.[3] See Table 3.2.2.1 "Daily Needs for Carbohydrate Fuel" for carbohydrate needs for athletes depending on the intensity of the exercise.

Table 3.2.2.1 *Daily Needs for Carbohydrate Fuel*

3. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

Activity level	Example of exercise	Increase of carbohydrate (g/kg of athlete's body weight/ day)
Light	Low intensity or skill based activities	3-5
Moderate	Moderate exercise program (about 1 hour per day)	5-7
High	Endurance program (about 1-3 hours per day of moderate to high intensity exercise)	6-10
Very high	Extreme commitment (4-5 hours per day of moderate to high intensity exercise)	8-12

Note: Daily need for carbohydrates increases with the intensity of activity level. *Source:* Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition__and__Athletic__Performance.25.aspx. Accessed March 17, 2018.

Fat is a necessary component of a healthy diet to provide energy, essential fatty acids and to facilitate the absorption of fat-soluble vitamins. Athletes are recommended to consume the same amount of fat in the diet as the general population, 20-35% of their energy intake. Although these recommendations are in accordance with public health guidelines, athletes should individualize their needs based on their training level and body composition goals. Athletes who choose to excessively restrict their fat intake in an effort to lose body weight or improve body composition should ensure they are still getting the minimum recommended amount of fat. Fat intakes below 20% of energy intake will reduce the intake of fat-soluble vitamins and essential fatty acids, especially omega 3's.[4]

4. Nutrition and Athletic Performance. American College of

Although protein accounts for only about 5% of energy expended, dietary protein is necessary to support metabolic reactions (that generate ATP), and to help muscles with maintenance, growth, and repair. During exercise, these metabolic reactions for generating ATP rely heavily on proteins such as enzymes and transport proteins. It is recommended that athletes consume 1.2 to 2.0 g/kg/day of proteins in order to support these functions. Higher intakes may also be needed for short periods of intense training or when reducing energy intake.[5] See Table 3.2.2.2 "Recommended Daily Protein Intakes for Athletes" below for a better representation of protein needs depending on extent of training and dietary sources.

Table 3.2.2.2 *Recommended Protein Intakes for Individuals*

Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

5. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

Group	Daily protein intake (g per kg body weight)
Most adults	0.8
Endurance athletes	1.2 to 1.4
Vegetarian endurance athletes	1.3 to 1.5
Strength athletes	1.6 to 1.7
Vegetarian strength athletes	1.7 to 1.8

Note: Amount of protein intake increases for endurance and strength athletes. Vegetarian athletes require the highest amounts of protein. *Source*: Dietary Reference Intakes, 2002 ACSM/ADA/Dietitians of Canada Position Statement: Nutrition & Athletic Performance, 2001. Accessed March 17, 2018.

It is important to consume adequate amounts of protein and to understand that the quality of the protein consumed affects the amount needed. High protein foods such as meats, dairy, and eggs contain all of the essential amino acids in relative amounts that most efficiently meet the body's needs for growth, maintenance and repair of muscles. Vegetarian diets contain protein that has lower digestibility and amino acid patterns that do not match human needs as closely as most animal proteins. To compensate for this as well as the fact that plant food protein sources also contain higher amounts of fiber, higher protein intakes are recommended for vegetarian athletes. (See Table 3.2.2.2 "Recommended Daily Protein Intakes for Individuals")

Micronutrient Needs

Vitamins and minerals are essential for energy metabolism, the delivery of oxygen, protection against oxidative damage, and the repair of body structures. When exercise increases, the amount of many vitamins and minerals needed are also increased due to the excess loss in nutrients. Currently, there is not special micronutrient recommendations made for athletes but most athletes will meet their needs by consuming a balanced diet that meets their energy needs. Because the energy needs of athletes increase, they often consume extra vitamins and minerals. The major micronutrients of concern for athletes include iron, calcium, vitamin D, and some antioxidants.[6]

Common Nutrient Deficiencies for Athletes

Energy deficiency

For athletes, consuming sufficient amounts of calories to support their energy expenditure is vital to maintain health and body functions. When the energy intake for athletes does not meet the high demands of exercise, a syndrome referred to as relative energy deficiency in sport (RED-S) occurs. RED-S has a negative effect on performance and health in both male and female athletes as shown in "Relative Energy Deficiency in Sport Effects". Athletes in sports with weight classes, such as wrestling, may put their health at risk by rapid weight loss in order to hit a specific weight for a match.

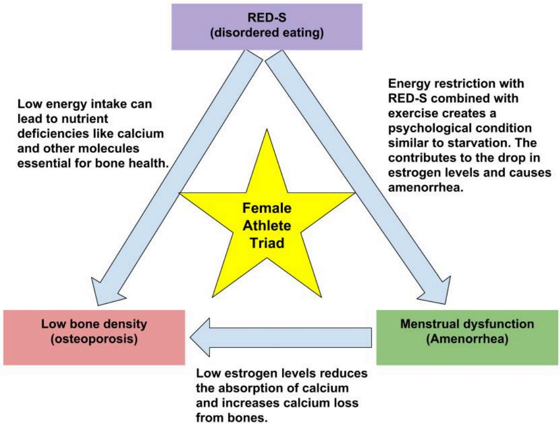
6. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

These athletes are vulnerable to eating disorders due to sporadic dieting (several of which will restrict energy intake). The long term effects of these practices can not only impair performance but also have serious repercussions such as heart and kidney function, temperature regulation and electrolyte balance problems.

Of the RED-S consequences that occur from an energy intake deficiency, the two health effects that are of the greatest concern to female athletes are menstrual dysfunction and decreased bone density. Menstrual dysfunction and low bone density symptoms of RED-S can create hormonal imbalances that are described in Figure 3.3.2.1 “The Female Athlete Triad”. In today’s society, there is increasing pressure to be extremely thin that some females take exercise too far. The low energy intakes will lead to the female athlete triad that causes bone loss, stoppage of menstrual periods, and eating disorders.[7]

Figure 3.3.2.1 *The Female Athlete Triad*

7. The Female Athlete Triad. American College of Sports Medicine. http://www.acsm.org/public-information/articles/2016/10/07/the-female-athlete-triad. Published October 7, 2016. Accessed March 16, 2018.



The female triad includes low bone density, central dysfunction and disordered eating. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Iron

Iron deficiency is very common in athletes. During exercise, iron-containing proteins like hemoglobin and myoglobin are needed in great amounts. An iron deficiency can impair muscle function to limit work capacity leading to compromised training performance. Some athletes in intense training may have an increase in iron losses through sweat, urine, and feces. Iron losses are greater in females than males due to the iron lost in blood every menstrual cycle. Female athletes, distance runners and vegetarians are at the greatest risk for developing iron deficiency.[8] See Table 3.2.2.3. "The Potential Iron Loss in Endurance Athletes" for the potential amounts of iron loss each day in male and female athletes. An increased

8. Beard J, Tobin B. Iron Status and Exercise. The American Journal of Clinical Nutrition. 2000; 72(2), 594S–597S. https://academic.oup.com/ajcn/article/72/2/594S/4729672. Accessed March 16, 2018.

recommendation for both genders are shown below. These recommendations are based on the assumption that iron has a 10% absorption efficiency. As noted above, women athletes have a greater iron loss due to menstruation and therefore must increase their dietary needs more than male athletes.

Table 3.2.2.3 *The Potential Iron Loss in Endurance Athletes*

Approximate daily iron losses in endurance athletes (mg/day) and increased dietary need		
	Male	**Female**
Sedentary	1	1.5
Athlete	1.8	2.5

Note: Iron loss is greatest in endurance athletes, particularly in females, increasing their daily needs. *Source*: Weaver CM, Rajaram S.Exercise and iron status. J Nutr. 1992 Mar;122(3 Suppl):782-7. https://www.ncbi.nlm.nih.gov/pubmed/1542048. Accessed March 23, 2018.

Sports anemia, which is different from iron deficiency anemia is an adaptation to training for athletes. Excessive training causes the blood volume to expand in order to increase the amount of oxygen delivered to the muscles. During sports anemia, the synthesis of red blood cells lags behind the increase in blood volume which results in a decreased percentage of blood volume that is red blood cells. The total amount of red blood cells remains the same or may increase slightly to continue the transport of oxygen. Eventually as training progresses, the amount of red blood cells will increase to catch up with the total blood volume.

Vitamin D and Calcium

Vitamin D regulates the calcium and phosphorus absorption and metabolism and plays a key role in maintaining optimal bone health.

There is also growing evidence that vitamin D is important for other aspect of athletic performance such as injury prevention, rehabilitation, and muscle metabolism. Individuals who primarily practice indoors are at a larger risk for a vitamin D deficiency and should ensure they are consuming foods high in vitamin D to maintain sufficient vitamin D status.[9]

Calcium is especially important for the growth, maintenance, and repair of bone tissue. Low calcium intake occurs in athletes with RED-S, menstrual dysfunction, and those who avoid dairy products. A diet inadequate in calcium increases the risk for low bone mineral density which ultimately leads to stress fractures.

Antioxidant Nutrients

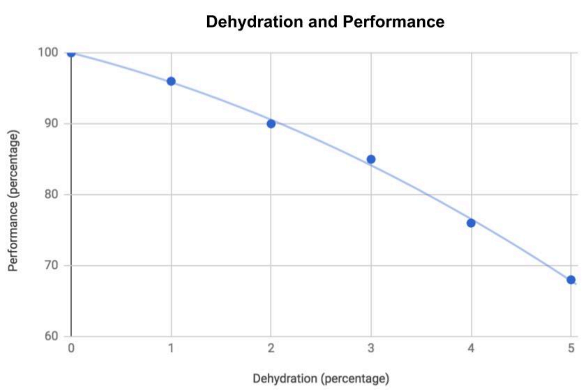
Antioxidant nutrients play an important role in protecting cell membranes from oxidative damage. During exercise, the amount of oxygen used by the muscles increases and can produce free radicals which causes an increase in antioxidant systems in the the body. These antioxidant systems rely on the dietary antioxidants such as beta-carotene, vitamin C, vitamin E, and selenium that can be obtained through a nutrient dense diet.

9. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

Water and Electrolyte Needs

During exercise, being appropriately hydrated contributes to performance. Water is needed to cool the body, transport oxygen and nutrients, and remove waste products from the muscles. Water needs are increased during exercise due to the extra water losses through evaporation and sweat. Dehydration can occur when there is inadequate water levels in the body and can be very hazardous to the health of an individual. As the severity of dehydration increases, the exercise performance of an individual will begin to decline (see Figure 3.3.2.2 "Dehydration Effect on Exercise Performance"). It is important to continue to consume water before, during and after exercise to avoid dehydration as much as possible.

Figure 3.3.2.2 *Dehydration Effect on Exercise Performance*



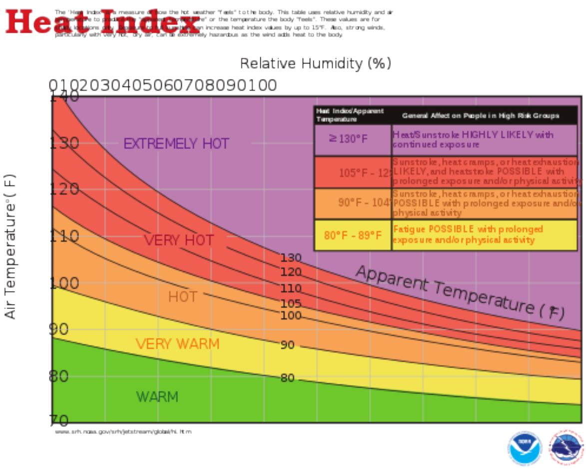
Performance decreases significantly with dehydration. Source: image by Allison Calabrese / [CC BY 4.0]

During exercise, thirst is not a reliable short term indicator of the body's needs as it typically is not enough to replace the water loss. Even with the constant replenishing of water throughout an exercise, it may not be possible to drink enough water to compensate for the losses. Dehydration occurs when the total loss of water is so significant that the total blood volume decreases which leads to the reduction of oxygen and nutrients transported to the muscle cells. A decreased blood volume also reduces the blood flow to the skin and the production of sweat which can increase the body temperature. As a result, the risk of heat related illnesses increases.

Heat cramps are one of the heat related illnesses that can occur during or after exercise. Heat cramps are involuntary muscle spasms that usually involve the muscle being exercised, which causes by an imbalance of electrolytes, usually sodium. Heat exhaustion is caused by the loss of water decreasing the blood volume so much that it is not possible to cool the body as well as provide oxygen and nutrients to the active muscles. Symptoms that arise from heat exhaustion may include low blood pressure, disorientation, profuse sweating, and fainting. Heat exhaustion can progress further if exercise continues into a heat stroke. A heat stroke is the most serious form of heat related illnesses that can occur. During a heat stroke, the internal body temperature rises above 105F which causes the brain's temperature-regulatory center to shut down. When the brain's temperature regulatory center shuts down, an individual is unable to sweat regardless of their internal body temperature rising. Other symptoms that arise are dry skin, extreme confusion, and unconsciousness. A heat stroke requires immediate medical attention.

The external temperature during exercise can also play a role in the risk of heat related illnesses. As the external temperature increases, it becomes more difficult for the body to dissipate heat. As humidity also increases, the body is unable to cool itself through evaporation. The Heat Index is a measure of how hot the body feels when humidity is added to the air temperature (see Figure 3.3.2.3 "The Heat Index").

Figure 3.3.2.3 *The Heat Index*



Being physically active during "warm" and "very warm" weather is mostly safe; however, being physically active at temperature above these put you at risk of heat stroke, cramps and dehydration. Source: "Heat Index" by [National Weather Service, Southern Region Headquarters]/ Public Domain

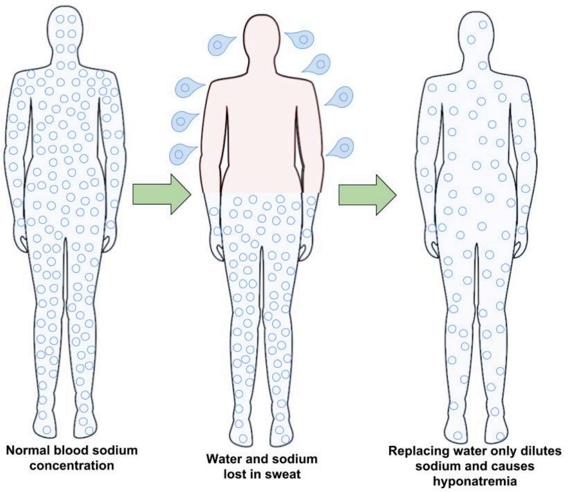
Hyponatremia

Sweating during exercise helps our bodies to stay cool. Sweat consists of mostly water but it also causes losses of sodium, potassium, calcium and magnesium. During most exercises, the amount of sodium lost is very small. Drinking water after completing an exercise will replenish the sodium in the body. However, during long endurance exercises such as a marathon or triathlon, sodium losses are larger and must be replenished as well. If water is replenished without sodium the sodium already in the body will become diluted. These low levels of sodium in the blood will cause a condition known as hyponatremia (see Figure 3.3.2.4

"The Effect of Exercise on Sodium Levels"). When sodium levels in the blood are decreased, water moves into the cell through osmosis which causes swelling. Accumulation of fluid in the lungs and the brain can cause serious life threatening conditions such as a seizure, coma and death.

In order to avoid hyponatremia, athletes should increase their consumption of sodium in the days leading up to an event and consume sodium-containing sports drinks during their race or game. The early signs of hyponatremia include nausea, muscle cramps, disorientation, and slurred speech. To learn more about the sports drinks that can optimize your performance, refer back to Chapter 3, Water and Electrolytes.

Figure 3.3.2.4 *The Effect of Exercise on Sodium Levels*



Exercise causes a loss in sodium, which is excreted through sweat. When hydration is only done with water this can further dilute sodium concentrations, leading to hyponatremia. Source: image by Allison Calabrese /CC BY 4.0

Food Supplements and Food Replacements

Current trends also include the use of supplementation to promote health and wellness. Vitamins, minerals, herbal remedies, and supplements of all kinds constitute big business and many of their advertising claims suggest that optimal health and eternal youth are just a pill away. Dietary supplements can be macronutrient (amino acids, proteins, essential fatty acids), micronutrient (vitamins and minerals that promote healthy body functions), probiotic (beneficial bacteria such as the kind found in the intestines), and herbally (often target a specific body part, such as bones) based.

Some public health officials recommend a daily multivitamin due to the poor diet of most North Americans. The US Preventive Task Force also recommends a level of folate intake which can be easier to achieve with a supplement. In addition, the following people may benefit from taking daily vitamin and mineral supplements:[10]

- women who are pregnant or breastfeeding
- premenopausal women who may need extra calcium and iron
- older adults
- people with health issues that affect their ability to eat
- vegetarians, vegans, and others avoiding certain food groups

However, before you begin using dietary supplementation, consider that the word supplement denotes something being added.

10. Nutrition and Athletic Performance. American College of Sports Medicine.Medicine & Science in Sports & Exercise. 2016; 48(3), 543- 568. https://journals.lww.com/acsm-msse/Fulltext/2016/03000/Nutrition_and_Athletic_Performance.25.aspx. Accessed March 17, 2018.

Vitamins, minerals, and other assorted remedies should be considered as extras. They are add-ons—not replacements—for a healthy diet. As food naturally contains nutrients in its proper package, remember that **food should always be your primary source of nutrients**. When considering taking supplements, it is important to recognize possible drawbacks that are specific to each kind:[11]

- **micronutrient supplements:** Some vitamins and minerals are toxic at high doses. Therefore, it is vital to adhere to the Tolerable Upper Intake Levels (UL) so as not to consume too much of any vitamin. For example, too much vitamin A is toxic to the liver. Symptoms of vitamin A toxicity can include tinnitus (ringing in the ears), blurred vision, hair loss, and skin rash. Too much niacin can cause a peptic ulcer, hyperglycemia, dizziness, and gout.
- **herbal supplements:** Some herbs cause side effects, such as heart palpitations and high blood pressure, and must be taken very carefully. Also, some herbs have contraindications with certain medicines. For example, Valerian and St. John's Wort negatively interact with certain prescription medications such as oral contraceptives, and most notably antidepressants. Additionally, there is a real risk of overdosing on herbs because they do not come with warning labels or package inserts.
- **amino acid supplements:** Certain amino acid supplements, which are often taken by bodybuilders among others, can increase the risk of consuming too much protein. An occasional amino acid drink in the place of a meal is not a

11. Choosing a Vitamin and Mineral Supplement—Topic Overview. WebMD.com. http://www.webmd.com/food-recipes/tc/choosing-a-vitamin -and-mineral-supplement-topic-overview. Last revised March 11, 2018.

problem. However, problems may arise if you add the supplement to your existing diet. Most North Americans receive two to three times the amount of protein required on a daily basis from their existing diets—taking amino acid supplements just adds to the excess. Also, certain amino acids share the same transport systems in the absorption process; therefore, a concentrated excess of one amino acid obtained from a supplement may increase the probability of decreased absorption of another amino acid that uses the same transport system. This could lead to deficiency in the competing amino acid.

Supplement Claims and Restrictions

The Food and Drug Administration (FDA) regulates supplements, but it treats them like food rather than pharmaceuticals. Dietary supplements must meet the FDA's Good Manufacturing Standards, but are not required to meet the standards for drugs, although some companies do so voluntarily. Also, although supplement manufacturers are allowed to say a particular ingredient may reduce the risk of a disease or disorder, or that it might specifically target certain body systems, these **claims are not approved by the FDA**. This is why labels that make structural and functional claims are required to carry a **disclaimer** saying the product is not intended "to diagnose, treat, cure, or prevent any disease." In addition, in the United States, supplements are taken off the market only after the FDA has proven that they are hazardous.[12]

12. Watson S. How to Evaluate Vitamins and Supplements. WebMD.com. http://www.webmd.com/vitamins-and-

Before Taking Supplements

The phrase caveat emptor means "buyer beware," and it is important to keep the term in mind when considering supplementation. Just because a product is "natural" does not mean it can't be harmful or dangerous, particularly if used inappropriately. The following are helpful questions to explore before deciding to take a supplement:

- Does the scientific community understand how this supplement works and are all its effects well known?
- Is there proof that the supplement actually performs in the manner that it claims?
- Does this supplement interact with food or medication?
- Is taking this supplement necessary for my health?
- Is the supplement affordable?
- Is the supplement safe and free from contaminants?

Lastly, please remember that a supplement is only as good as the diet that accompanies it. We cannot overstate the importance of eating a healthy, well-balanced diet designed to provide all of the necessary nutrients. **Food contains many more beneficial substances, such as phytochemicals and fiber, that promote good health and cannot be duplicated with a pill or a regimen of supplements**. Therefore, vitamins and other dietary supplements should never be a substitute for food. Nutrients should always be derived from food first.

supplements/lifestyle-guide -11/how-to-evaluate-vitamins-supplements. Accessed March 11, 2018.

Food: The Best Medicine

Poor dietary choices and a sedentary lifestyle account for about 300–600 thousand deaths every year according to the US Department of Health and Human Services. That number is thirteen times higher than the deaths due to gun violence.[13] The typical North American diet is too high in saturated fat, sodium, and sugar, and too low in fiber in the form of whole fruits, vegetables, and whole grains to keep people healthy. With so many threats to optimal health it is vital to address those factors that are under your control, namely dietary and lifestyle choices. A diet that supplies your body with the needed energy and nutrients daily will result in efficient body functioning and in protection from disease. Making sound nutritional choices can also provide support for individuals undergoing treatment for short-term or chronic conditions. Finding a balance between nutritional needs with concerns about drug interactions can hasten recovery, improve quality of life, and minimize the side effects from treatment protocols.

13. Why Good Nutrition Is Important. CSPINET.org. http://www.cspinet.org/nutritionpolicy/nutrition_policy.html. Accessed March 9, 2018.

3.2.3. Test Your Knowledge

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3.3. CARDIOVASCULAR HEALTH/FITNESS

3.3.1. The Cardiovascular and Respiratory System

What Is the Cardiovascular and Respiratory System?

Imagine for a moment climbing to the top of Mt. Everest, a challenging feat very few have accomplished. In the process, you gradually ascend from base camp, which sits at about 17,500 feet above sea level, to the peak at over 29,000 feet. At this elevation, the pressure of oxygen is so low, you struggle to take in a satisfying breath. Although you strive to breathe deeply, you are unable to get enough air. Your heart rate increases and you might even develop nausea and a headache. Unless your body has a chance to acclimate itself to higher elevations or you gain access to supplemental oxygen, your symptoms will persist or worsen.

These are the sensations many people with cardiovascular or respiratory illnesses, such as asthma, chronic bronchitis, or mild cardiovascular disease, experience on a daily basis. Climbing up a flight of steps may leave them gasping for air, as would walking briskly or even breathing in cold air. Regardless of the cause, being unable to take in sufficient air can create a sense of panic and cause serious physical discomfort.

From this simple example, hopefully, you feel an appreciation for the simple act of breathing and ensuing satisfaction that comes with each life-sustaining breath. For most people, unless they engage in strenuous physical activity sufficient to get them breathing hard, their cardiovascular and respiratory system (heart, blood vessels, and lungs) operates efficiently enough to go relatively unnoticed. However, does that mean their cardiorespiratory (CR) system is functioning at optimal capacity? Or, could it be operating at a minimum level and experiencing problems that go undetected? This chapter defines cardiorespiratory fitness, examines the benefits of a healthy CR system, and explores how to effectively assess and improve the CR system.

The Benefits of Good Cardiorespiratory Health

The link below provides a list of specific benefits:

List of Benefits

The article linked below describes how exercise protects against Cardiovascular Disease (CVD):

Preventing CVD

How the Cardiorespiratory System Works

The cardiorespiratory system operates to obtain and circulate vital compounds throughout the body—specifically, oxygen and nutrients, such as food energy, vitamins, and minerals. Both oxygen and nutrients, which are imperative for cellular energy production, must be taken in from the lungs and digestive system. Because the heart and lungs are so interlocked in this process, the two systems are often labeled together as the cardiorespiratory system. Without a healthy respiratory system, the body would struggle to bring in enough oxygen, release carbon dioxide (the chemical waste product of cellular metabolism) and eliminate unwanted particles that enter the respiratory tract when inhaling. Without a healthy heart, transporting oxygen from the lungs and nutrients from the digestive system to the body's cells would be impossible. If the health of the CR system were compromised enough, survival would be impossible. Additionally, both must be healthy or the function of one or the other will be compromised.

Below are three videos explaining how the cardiovascular and respiratory systems operate and function together:

The CR System and Exercise

How the Cardiovascular System Works

Respiratory System Explained in Detail

The Cardiorespiratory System and Energy Production

Clearly the cardiovascular and respiratory systems function as one, but why is the CR system so important? What makes the distribution of oxygen throughout the body so vital to existence? The answer is simple: ENERGY. While oxygen in and of itself does not contain any energy (calories), it does combine with fuel extracted from food once it has been introduced into the cell to help produce adenosine triphosphate (ATP). ATP is the basic form of cellular energy found in the body. Because the body stores very little ATP, it must constantly be regenerated. For this reason, people must continue eating and breathing to live.

Within the context of fitness, the purpose of the cardiorespiratory system is not only to produce energy but to also adapt in a way so that energy production can be optimized. For example, a high school cross country runner wants to be fit enough to compete in the state cross country meet. Unfortunately, this athlete's current mile times are 6 minutes per mile. In other words, that is the maximum work rate possible for this athlete. However, the goal is to improve to 5 minutes per mile, or improve the maximum work rate. To do so, more energy must be produced. According to the principles of adaptation, it is possible for this athlete to become more efficient at producing energy, enabling him to run a mile in less time. An example of this adaptation comes from the world record mile time of 3 minutes and 43 seconds. The world record marathon time (26.2 miles) is 2 hours, 2 minutes, and 52 seconds. That equates to 4 minutes and 41 seconds per mile over the 26-mile course. That is some serious ATP production!

Oxidative Energy System (Aerobic)

As oxygen and nutrients are delivered to the cells, they are utilized to produce ATP. The workhorses of the cell for oxidative metabolism are the mitochondria. This form of energy production is contingent on the ability of the CR system to deliver oxygen and nutrients and the cell's ability to process that oxygen. Because of the importance of oxygen in this particular energy-producing pathway, it is called the oxidative energy system, or aerobic system.

Oxidative energy production is the primary means of ATP production during rest and for activities that last for 2 minutes or longer. Although other forms of energy production assist in ATP production at any given time, long duration exercise sessions rely on this aerobic pathway. Also, in contrast to other forms of ATP production, the oxidative energy system uses both carbohydrates and fats for fuel sources.

To consider: What activities would emphasize development of this energy pathway?

Immediate/Explosive Energy System

While the oxidative system is the primary source of ATP production, it does require a few minutes for the system to begin operating at full capacity during exercise. How then could the body immediately produce enough energy to perform a strenuous activity, such as sprinting 50 meters? Clearly, another energy system must drive ATP production. The immediate or explosive energy system utilizes the storage of creatine phosphate (CP) and the storage of adenosine diphosphate, which is stored in very small amounts, to generate ATP. When needed, this energy system provides enough ATP to sustain a short- duration, explosive activity, approximately 10–20 seconds or less. Once CP is depleted, other energy systems must assist in the ATP generating process.

Non-Oxidative or Anaerobic Energy System

As the name implies, the non-oxidative energy system does not require oxygen to generate ATP. Instead, the cells where the ATP is produced require glucose(carbohydrates that have been broken down) as the fuel source. Like the immediate energy system, this system is associated with high intensity and short duration movements. While it is possible for some elite athletes to maintain exercise at "anaerobic" levels for several minutes, even they will eventually fatigue as a result of the non-oxidative system's ability to sustain ATP production for events lasting longer than approximately 2 minutes.

As glucose is processed to produce ATP, the natural byproduct of this process, lactic acid, also begins to accumulate. The result of excessive lactic acid accumulation contributes to muscle fatigue, making it impossible to continue exercise at a high intensity.

Energy Systems Combine

It is important to understand that energy systems do not operate in a compartmental fashion, but rather operate simultaneously, each carrying some of the burden of ATP production. For example, a professional soccer player would spend most of the match "cruising" at a light/moderate intensity level, thus primarily utilizing the oxidative energy system. However, during the match, he or she may sprint for several hundred meters, utilizing the explosive and non-oxidative system, or he or she may jump, requiring use of the explosive system. Thus, both energy systems are utilized simultaneously throughout the match. To improve performance, this player would need to develop the energy system which is utilized the most during the match.

Changes in the Cardiorespiratory System

An improvement in CR functioning, or fitness level, requires adaptation of the system. Remember, the point is to more effectively generate ATP so more work can be accomplished. In order to process more oxygen and deliver more oxygenated blood to the cells, the overall system must undergo changes to make this possible. Here is a list of adaptations that occur to the CR system as a result of consistent aerobic exercise:

- **Resting heart rate may decrease.** The average resting heart rate hovers around 70–75 beats per minute. Elite athletes may have resting heart rates in the high 30s. Generally, resting heart rate may decrease by approximately 10 beats per minute with chronic exercise.
- **Pulmonary adaptations**, such as increased tidal volume (the amount of oxygen entering the lungs with each breath) and increased diffusion capacity (the amount of oxygen that enters the blood stream from the lungs). This allows for more oxygen to enter the pulmonary circulation en route to the left side of the heart.
- **The heart muscles**, specifically the left side of the heart, increase in size making it possible to contract more forcefully. As a result, more blood can be pumped with each beat meaning

more oxygen can be routed to the systemic circulation.

- **More oxygen** is delivered and transported into the cells where ATP production can occur. This is called the arterial-vein difference (a-VO2diff).

These changes in the system are not permanent because of a process known as the principle of reversibility. Following a period of inactivity, the benefits from chronic aerobic exercise will be reversed.

3.3.2. Assessing and Developing Cardiorespiratory Fitness

Assessing Cardiorespiratory Fitness

To adequately prepare for starting a personal fitness program, it is important to first assess your current level of fitness. There are multiple methods for assessing a person's level of fitness. Each of the walking/jogging assessments discussed here attempts to estimate a key physiological marker of the heart's and lungs' functioning capacity and maximal oxygen consumption. Maximal oxygen consumption, or VO_2max, measures the body's maximum ability to take in and utilize oxygen, which directly correlates to overall health and fitness. A good estimate of VO_2max provides a one- time glance at a person's health and fitness level and a baseline measurement for reassessment at future dates to gauge improvements.

Some of the most common walking/jogging assessments used to estimate VO_2max include the 12-Minute Walk, 1.5-Mile Run/Walk Test, 3-Minute Step Test, and 1- Mile Walk Test. Unfortunately, these field assessments, although practical and inexpensive, only provide estimations. More accurate assessments require a lab-based VO2max test using equipment that measures the volume of oxygen and carbon dioxide being moved in and out of the air passages during exercise. Although this test is more accurate, the expense and availability make it impractical for most. Unlike the lab test, the field assessments are relatively cost free, user-friendly and require very little expertise to conduct or perform. In addition, the key point of the assessment is measuring differences rather than absolute values, and the field tests accurately meet that objective.

Information on how to safely perform these assessments will be provided at the end of this chapter.

Measuring Heart Rate

Those starting the VO_2max assessments must first measure their heart rate, an important component used in the calculations.

Here is a video describing how to determine heart rate:

How to check your pulse

Creating a Plan To Develop Cardiorespiratory Fitness

Once the assessments have been completed, the next step is to develop a plan for maintaining or improving your current level of fitness. This fitness plan should include activities that are safe and adapted to meet your personal goals. Once these fitness goals have been identified, the principles of adaptation to change can be utilized to achieve those goals. These principles include specificity, targeting specific areas in a workout, and overload, the practice of increasing exertion as the body adapts to ensure continued gains in fitness levels. Specifically, you need to apply the FITT principle (Fitness, Intensity, Time, and Type) described in detail in the previous chapter, "Basic Fitness Principles and Exercise Habits":

- **frequency**: 3–5 days per week for healthy adults.
- **intensity**: moderate to vigorous intensity, which equals 40–85% of heart rate reserve, or 55–90% of percentage of max

heart rate. (More information about intensity will be provided later.)

- **time/duration**: 20–60 minutes per session or accumulation of 150 minutes per week. Sessions must be continuous for 10 minutes or more.
- **type/mode**: Use large muscle groups and exercises specific to cardiorespiratory exercise.

Click on the link below for ACSM's latest recommendations on the quantity and quality of exercise for adults:

ACSM's Official News Release

Measuring Intensity

Intensity may be the most important aspect of the FITT principle. Engaging in a "cardio" program that does not stress the CR system to the recommended levels will be ineffective. Engaging in a program that overstresses the system can lead to injury and pose unnecessary risks. So how do you know if you are in the right range?

Heart rate is one of the best ways to measure effort level. Walking and jogging increase a person's heart rate. Based on the function of the heart, this is no surprise. The heart rate directly correlates with the amount of oxygen being taken in by the lungs. As activity increases in intensity, oxygen demands increase and so does heart rate.

Because of this relationship, heart rate can be used in the design of an effective walking and jogging program by creating target heart rate zones. Heart rate zones represent an intensity range—a low end heart rate and a high end rate—within which a person's heart rate would fall during a walking or jogging session.

The first step in determining your target heart rate (THR), is to determine your maximum heart rate (MHR), both measured in beats per minute (bpm). Generally, MHR is estimated to be your age subtracted from 220 beats per minute. In other words, your heart rate should theoretically stop increasing once it reaches the calculated maximum. While helpful, it is not uncommon to see variances in the laboratory tested maximum heart rate versus the calculated method.

The next step in calculating THR is to calculate a specific percentage of your MHR. This is done using two different methods. Keep in mind, finding the THR is the objective in both methods, even though slightly different numbers are used.

The first method, called Max Heart Rate Method, is more commonly used.

Max Heart Rate Method

1. Calculate MHR; MHR = 220 – age.
2. Calculate high and low THR by plugging in a percentage range. In this example, 60 and 80% are being used.
   $MHR \times .60 = THR_{Low}$
   $MHR \times .80 = THR_{High}$
3. The resulting low and high THR numbers represent the range, or target intensity.

The target intensity signifies an optimal training zone for that particular walking or jogging session. By keeping the heart rate within that range, you will drive adaptation specific to that intensity. By using real, but random numbers, and plugging them into the above equation this becomes apparent.

Female, aged 20:
MHR = 220 -20
MHR = 200 bpm;

$THR_{low} = 200 \times .60$
$THR_{low} = 120$ bpm

THR_{high}=200 x .80
THR_{high}= 160 bpm
THR=120-160bpm

To achieve her self-established goals, the female in the example above will need to stay within the range of 120 and 160 bpm. If her efforts are intense enough that she begins to exceed 160 bpm during her session, or easy enough that her heart rate falls below 120 bpm, she would need to change her intensity mid-session to get the optimal results.

The Karvonen Formula or Heart Rate Reserve Method

1. Calculate MHR; MHR = 220 – age.
2. Determine your resting heart rate (RHR).
3. Find the heart rate reserve (HRR); HRR = MHR – RHR
4. Calculate high and low THR by plugging in a percentage range and then adding in the RHR. In this example, 60 and 80% are being used. THR_{low}= HRR x .60 + RHR, THR_{high}= HRR x .80 + RHR
5. The resulting low and high THR numbers represent the range, or target intensity.

Clearly, the Karvonen formula requires a few more steps, specifically, the incorporation of the resting heart rate. Using the same female in the example above, along with a randomly selected RHR, the THR looks like this:
MHR=220−20 MHR = 200
RHR = 72 bpm (randomly selected)
HRR=MHR−RHR
HRR=200−72

$HRR = 128$

$THR_{low} = HRR \times 0.60 + RHR$

$THR_{low} = 128 \times 0.60 + 72$

$THR_{low} = 149$ bpm

$THR_{high} = HRR \times 0.80 + RHR$

$THR_{high} = 128 \times 0.80 + 72$

$THR_{high} = 174$ bpm

$THR = 149 - 174$bpm

A comparison of the two methods, reveals that the low and high end of the Karvonen formula is much higher than the Max Heart Rate method, even though the exact same percentages have been used. If the female in this example used the Karvonen Formula, she would find herself at a much higher intensity, especially at the low end of the range (120 vs. 149 bpm). How can this be? Aren't these formulas supposed to have the same objective?

While it is true that both equations are used to estimate a target heart rate range, only the Karvonen Formula takes into account the RHR, the lowest possible heart rate that can be measured for that individual. The Max Heart Rate method assumes the lowest heart rate possible is "0," a number to be avoided if at all possible! Because of the difference between 0 and the maximum heart rate, the calculated percentages result in a much lower number. In terms of accuracy, the Karvonen method is superior. It simply is a better representation of true target ranges.

Other Ways To Determine Intensity

Since not everyone owns a heart rate monitor, other methods of determining exercise intensity have been developed. One particular method, called the rating of perceived exertion (RPE), uses subjective measurement to determine intensity. The method is as simple as asking the question, Overall, how hard do I feel I am working? The answer is given based on a scale of 6 to 20 with 6 being almost no effort and 20 being maximum effort. Studies have indicated that when subjects are asked to exercise at a moderate or heavy intensity level, subjects can accurately do so, even without seeing their heart rate. As a result, using the RPE scale can be an effective way of managing intensity.

The original RPE scale or Borg Scale, designed by Dr. Gunnar Borg, was developed to mimic generalized heart rate patterns. The starting and ending point of the scale are less intuitive than a typical scale of 1-10. By design, the 6 represents a resting heart rate of 60 bpm and the 20 an exercise heart rate of 200 bpm, a beat count someone might experience at maximum effort. Over time, a modified Borg Scale was developed using a simple 1– 10 scale, with 1 being resting effort and 10 being maximum effort. Even though the modified scale is more intuitive, the traditional scale is still used more frequently.

Walking and jogging not only benefit physical health, but many enjoy the social benefits realized by exercising with friends. When walking or jogging with friends, intensity can easily be measured by monitoring your ability to carry on a conversation. With the Talk Test, if you are only able to say short phrases or give one word responses when attempting to converse during an exercise session, this would suggest you are working at a high enough intensity that your breathing rate makes conversation difficult. Certainly, if you can speak in full sentences without getting winded, the intensity would be very light. Just like RPE, the Talk Test is yet another way to subjectively measure intensity, which can then be correlated with heart rates.

Terminology Checklist

Cardiorespiratory system: the term used to describe the relationship between the cardiovascular system (heart and blood vessels) and respiratory system (lungs).

Calorie: a term used to describe food energy. Scientifically, it is the amount of energy needed to raise one kilogram of water, 1 degree Celsius. More accurately, it is one kilocalorie.

Adenosine triphosphate (ATP): the basic unit of energy used by the cells.

Aerobic energy system: the term used to describe the way cells produce ATP. In this case, the cells require oxygen to assist in ATP production.

Mitochondria: the area (organelle) of the cell where ATP is produced.

Creatine phosphate: a compound found in the cells and used by the immediate energy system that can be used to produce ATP.

Non-oxidative energy system: a term used to describe the way cells produce ATP. In this case, cells do not require oxygen to produce ATP.

Glucose: the simplest form of sugars found in the blood.

Tidal volume: the amount of air measured during inspiration or expiration.

Diffusion capacity: the amount of air that is transferred from the lungs to the blood.

Arterial-vein difference (aVO2diff): the difference between the oxygen found in arterial blood and venous blood.

Principle of reversibility: the fitness principle describing how fitness is lost while detraining.

Maximal oxygen consumption (VO2max): the maximum amount of oxygen the body can take in and utilize.

Specificity: a fitness principle describing how fitness improvements or adaptations to exercise stress are specific to the type of training that is performed.

Overload: the fitness principle describing how adaption to exercise stress is driven by progressively increasing the workload during training.

Target heart rate (THR): a term describing heart rate zones that represent an intensity range—a low end heart rate and a high end rate—used as a guide for exercise intensity.

Max heart rate (MHR): the maximum number of beats per minute the heart can contract.

Resting Heart Rate (RHR): the minimum number of beats per minute the heart contracts.

Heart Rate Reserve (HRR): the difference between the maximum heart rate and the resting heart rate. This term is also used to describe a method for calculating target heart rate.

Rating of perceived exertion (RPE): a self-assessment used during exercise used to estimate the intensity of the work being performed. The scale used, called the Borg Scale, ranges from 6 to 20.

Talk-test: a self-assessment used during exercise to estimate the intensity of the work being performed. The assessment is based on the degree of breathlessness observed while attempting to talk during exercise.

3.3.3. Test Your Knowledge

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3.4. MUSCLE TRAINING

"Muscle Training" is an adaptation of material from *Concepts of Biology*, by Samantha Fowler, Rebecca Roush, and James Wise, and *Anatomy and Physiology*, by J. Gordon Betts, Kelly A. Young, James A. Wise, Eddie Johnson, Brandon Poe, Dean H. Kruse, Oksana Korol, Jody E. Johnson, Mark Womble, and Peter DeSaix, both of which are published by OpenStax under a CC BY 4.0 license, as well as *Concepts of Fitness and Wellness*, by Scott Flynn, Lisa Jellum, Althea Moser, Jonathan Howard, Sharryse Henderson, Christin Collins, Amanda West, and David Mathis, which is licensed under a CC BY 4.0 license. Specific attribution statements can be found in each chapter. Information that is not relevant to this course has been removed.

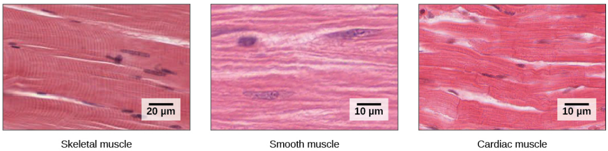
3.4.1. Muscle Function

“Muscle Function” is an adaptation of the chapter “Musculoskeletal System” from *Concepts of Biology*, by Samantha Fowler, Rebecca Roush, and James Wise, and the chapters “Overview of Muscle Tissues” and “Types of Muscle Fibers” from *Anatomy and Physiology*, by J. Gordon Betts, Kelly A. Young, James A. Wise, Eddie Johnson, Brandon Poe, Dean H. Kruse, Oksana Korol, Jody E. Johnson, Mark Womble, and Peter DeSaix. Both texts are published by OpenStax under a CC BY 4.0 license. Information that is not relevant to this course has been removed.

Muscles

Muscles allow for movement such as walking, and they also facilitate bodily processes such as respiration and digestion. The body contains three types of muscle tissue: skeletal muscle, cardiac muscle, and smooth muscle (Figure 3.4.1.1).

Figure 3.4.1.1



The body contains three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle. Notice that skeletal muscle cells are long and cylindrical, they have multiple nuclei, and the small, dark nuclei are pushed to the periphery of the cell. Smooth muscle cells are short, tapered at each end, and have only one nucleus each. Cardiac muscle cells are also cylindrical, but short. The cytoplasm may branch, and they have one or two nuclei in the center of the cell. Source: modification of work by NCI, NIH; scale-bar *data from Matt Russell. Source: [Overview of Muscle Tissue]*

Skeletal muscle tissue forms skeletal muscles, which attach to bones and sometimes the skin and control locomotion and any other movement that can be consciously controlled. Because it can be controlled intentionally, skeletal muscle is also called voluntary muscle. When viewed under a microscope, skeletal muscle tissue has a striped or striated appearance. This appearance results from the arrangement of the proteins inside the cell that are responsible for contraction. The cells of skeletal muscle are long and tapered and have multiple nuclei on the periphery of each cell.

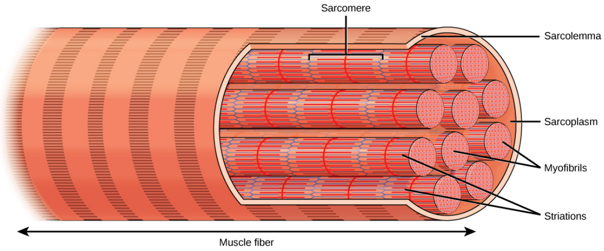
Smooth muscle tissue occurs in the walls of hollow organs such as the intestines, stomach, and urinary bladder, and around passages such as in the respiratory tract and blood vessels. Smooth muscle has no striations, is not under voluntary control, and is called involuntary muscle. Smooth muscle cells have a single nucleus.

Cardiac muscle tissue is only found in the heart. The contractions of cardiac muscle tissue pump blood throughout the body and maintain blood pressure. Like skeletal muscle, cardiac muscle is striated, but unlike skeletal muscle, cardiac muscle cannot be consciously controlled and is called involuntary muscle. The cells of cardiac muscle tissue are connected to each other through intercalated disks and usually have just one nucleus per cell.

Skeletal Muscle Fiber Structure and Function

Each skeletal muscle fiber is a skeletal muscle cell. Within each muscle fiber are **myofibrils**, long cylindrical structures that lie parallel to the muscle fiber. Myofibrils run the entire length of the muscle fiber. They attach to the plasma membrane, called the **sarcolemma**, at their ends, so that as myofibrils shorten, the entire muscle cell contracts (Figure 3.4.1.2).

Figure 3.4.1.2



A skeletal muscle fiber is surrounded by a plasma membrane called the sarcolemma, with a cytoplasm called the sarcoplasm. A muscle fiber is composed of many fibrils packaged into orderly units. The orderly arrangement of the proteins in each unit, shown as red and blue lines, gives the cell its striated appearance.

The striated appearance of skeletal muscle tissue is a result of repeating bands of the proteins **actin** and **myosin** that occur along the length of **myofibrils**.

Myofibrils are composed of smaller structures called **myofilaments**. There are two main types of myofilaments: thick filaments and thin filaments. Thick filaments are composed of the protein myosin. The primary component of thin filaments is the protein actin.

The thick and thin filaments alternate with each other in a structure called a **sarcomere**. The sarcomere is the unit of contraction in a muscle cell. Contraction is stimulated by an electrochemical signal from a nerve cell associated with the muscle fiber. For a muscle cell to contract, the sarcomere must shorten. However, thick and thin filaments do not shorten. Instead, they slide by one another, causing the sarcomere to shorten while the filaments remain the same length. The sliding is accomplished when a molecular extension of myosin, called the myosin head, temporarily binds to an actin filament next to it and through a change in conformation, bends, dragging the two filaments in opposite directions. The myosin head then releases its actin filament, relaxes, and then repeats the process, dragging the two filaments further along each other. The combined activity of many binding sites and repeated movements within the sarcomere causes it to contract. The coordinated contractions of many sarcomeres in a myofibril leads to contraction of the entire muscle cell and ultimately the muscle itself. The movement of the myosin head requires ATP, which provides the energy for the contraction.

Muscle Contraction

Muscle is one of the four primary tissue types of the body. All three muscle tissues have some properties in common; they all exhibit a quality called **excitability** as their plasma membranes can change their electrical states (from polarized to depolarized) and send an electrical wave called an **action potential** along the entire length of the membrane. While the nervous system can influence the excitability of cardiac and smooth muscle to some degree, skeletal muscle completely depends on signaling from the nervous system to work properly. On the other hand, both cardiac muscle and smooth muscle can respond to other stimuli, such as hormones and local stimuli.

The muscles all begin the actual process of contracting (shortening) when a protein called actin is pulled by a protein called myosin. This occurs in striated muscle (skeletal and cardiac) after specific binding sites on the actin have been exposed in response to the interaction between calcium ions (Ca^{2}) and proteins (troponin and tropomyosin) that "shield" the actin-binding sites. Ca^{2} also is required for the contraction of smooth muscle, although its role is different: here Ca^{2} activates enzymes, which in turn activate myosin heads. All muscles require adenosine triphosphate (ATP) to continue the process of contracting, and they all relax when the Ca^{2} is removed and the actin-binding sites are re-shielded.

A muscle can return to its original length when relaxed due to a quality of muscle tissue called **elasticity**. It can recoil back to its original length due to elastic fibers. Muscle tissue also has the quality of **extensibility**; it can stretch or extend. Contractility allows muscle tissue to pull on its attachment points and shorten with force.

Differences among the three muscle types include the microscopic organization of their contractile proteins—actin and myosin. The actin and myosin proteins are arranged very regularly in the cytoplasm of individual muscle cells (referred to as fibers) in both skeletal muscle and cardiac muscle, which creates a pattern, or stripes, called striations. The striations are visible with a light microscope under high magnification. Skeletal muscle fibers are multi-nucleated structures that compose the skeletal muscle. Cardiac muscle fibers each have one to two nuclei and are physically and electrically connected to each other so that the entire heart contracts as one unit (called a syncytium).

Because the actin and myosin are not arranged in such regular fashion in smooth muscle, the cytoplasm of a smooth muscle fiber (which has only a single nucleus) has a uniform, non-striated appearance (resulting in the name smooth muscle). However, the less organized appearance of smooth muscle should not be interpreted as less efficient. Smooth muscle in the walls of arteries is a critical component that regulates blood pressure necessary to push blood through the circulatory system; and smooth muscle in the skin, visceral organs, and internal passageways is essential for moving all materials through the body.

Muscle Types

Two criteria to consider when classifying the types of muscle fibers are how fast some fibers contract relative to others, and how fibers produce ATP. Using these criteria, there are three main types of skeletal muscle fibers. **Slow oxidative (SO) fibres** contract relatively slowly and use aerobic respiration (oxygen and glucose) to produce ATP. **Fast oxidative (FO) fibres** have fast contractions and primarily use aerobic respiration, but because they may switch to anaerobic respiration (glycolysis), can fatigue more quickly than SO fibers. Lastly, **fast glycolytic (FG) fibres** have fast contractions and primarily use anaerobic glycolysis. The FG fibers fatigue more quickly than the others. Most skeletal muscles in a human contain(s) all three types, although in varying proportions.

The speed of contraction is dependent on how quickly myosin's ATPase hydrolyzes ATP to produce cross-bridge action. Fast fibers hydrolyze ATP approximately twice as quickly as slow fibers, resulting in much quicker cross-bridge cycling (which pulls the thin filaments toward the center of the sarcomeres at a faster rate). The primary metabolic pathway used by a muscle fiber determines whether the fiber is classified as oxidative or glycolytic. If a fiber primarily produces ATP through aerobic pathways it is oxidative. More ATP can be produced during each metabolic cycle, making the fiber more resistant to fatigue. Glycolytic fibers primarily create ATP through anaerobic glycolysis, which produces less ATP per cycle. As a result, glycolytic fibers fatigue at a quicker rate.

The oxidative fibers contain many more mitochondria than the glycolytic fibers, because aerobic metabolism, which uses oxygen (O_2) in the metabolic pathway, occurs in the mitochondria. The SO fibers possess a large number of mitochondria and are capable of contracting for longer periods because of the large amount of ATP they can produce, but they have a relatively small diameter and do not produce a large amount of tension. SO fibers are extensively supplied with blood capillaries to supply O_2 from the red blood cells in the bloodstream. The SO fibers also possess myoglobin, an O_2-carrying molecule similar to O_2-carrying hemoglobin in the red blood cells. The myoglobin stores some of the needed O_2 within the fibers themselves (and gives SO fibers their red color). All of these features allow SO fibers to produce large quantities of ATP, which can sustain muscle activity without fatiguing for long periods of time.

The fact that SO fibers can function for long periods without fatiguing makes them useful in maintaining posture, producing isometric contractions, stabilizing bones and joints, and making small movements that happen often but do not require large amounts of energy. They do not produce high tension, and thus they are not used for powerful, fast movements that require high amounts of energy and rapid cross-bridge cycling.

FO fibers are sometimes called intermediate fibres because they possess characteristics that are intermediate between fast fibers and slow fibers. They produce ATP relatively quickly, more quickly than SO fibers, and thus can produce relatively high amounts of tension. They are oxidative because they produce ATP aerobically, possess high amounts of mitochondria, and do not fatigue quickly. However, FO fibers do not possess significant myoglobin, giving them a lighter color than the red SO fibers. FO fibers are used primarily for movements, such as walking, that require more energy than postural control but less energy than an explosive movement, such as sprinting. FO fibers are useful for this type of movement because they produce more tension than SO fibers but they are more fatigue-resistant than FG fibers.

FG fibers primarily use anaerobic glycolysis as their ATP source.

They have a large diameter and possess high amounts of glycogen, which is used in glycolysis to generate ATP quickly to produce high levels of tension. Because they do not primarily use aerobic metabolism, they do not possess substantial numbers of mitochondria or significant amounts of myoglobin and therefore have a white color. FG fibers are used to produce rapid, forceful contractions to make quick, powerful movements. These fibers fatigue quickly, permitting them to only be used for short periods. Most muscles possess a mixture of each fiber type. The predominant fiber type in a muscle is determined by the primary function of the muscle.

Physical Activity

Physical training alters the appearance of skeletal muscles and can produce changes in muscle performance. Conversely, a lack of use can result in decreased performance and muscle appearance. Although muscle cells can change in size, new cells are not formed when muscles grow. Instead, structural proteins are added to muscle fibers in a process called **hypertrophy**, so cell diameter increases. The reverse, when structural proteins are lost and muscle mass decreases, is called atrophy. Age-related muscle atrophy is called **sarcopenia**. Cellular components of muscles can also undergo changes in response to changes in muscle use.

Endurance Exercise

Slow fibers are predominantly used in endurance exercises that require little force but involve numerous repetitions. The aerobic metabolism used by slow-twitch fibers allows them to maintain contractions over long periods. Endurance training modifies these slow fibers to make them even more efficient by producing more mitochondria to enable more aerobic metabolism and more ATP production. Endurance exercise can also increase the amount of myoglobin in a cell, as increased aerobic respiration increases the need for oxygen. **Myoglobin** is found in the sarcoplasm and acts as an oxygen storage supply for the mitochondria.

The training can trigger the formation of more extensive capillary networks around the fiber, a process called **angiogenesis**, to supply oxygen and remove metabolic waste. To allow these capillary networks to supply the deep portions of the muscle, muscle mass does not greatly increase in order to maintain a smaller area for the diffusion of nutrients and gases. All of these cellular changes result in the ability to sustain low levels of muscle contractions for greater periods without fatiguing.

The proportion of SO muscle fibers in muscle determines the suitability of that muscle for endurance, and may benefit those participating in endurance activities. Postural muscles have a large number of SO fibers and relatively few FO and FG fibers, to keep the back straight. Endurance athletes, like marathon-runners also would benefit from a larger proportion of SO fibers, but it is unclear if the most-successful marathoners are those with naturally high numbers of SO fibers, or whether the most successful marathon runners develop high numbers of SO fibers with repetitive training. Endurance training can result in overuse injuries such as stress fractures and joint and tendon inflammation.

Resistance Exercise

Resistance exercises, as opposed to endurance exercise, require large amounts of FG fibers to produce short, powerful movements that are not repeated over long periods. The high rates of ATP hydrolysis and cross-bridge formation in FG fibers result in powerful muscle contractions. Muscles used for power have a higher ratio of FG to SO/FO fibers, and trained athletes possess even higher levels of FG fibers in their muscles. Resistance exercise affects muscles by increasing the formation of myofibrils, thereby increasing the thickness of muscle fibers. This added structure causes hypertrophy, or the enlargement of muscles, exemplified by the large skeletal muscles seen in body builders and other athletes. Because this muscular enlargement is achieved by the addition of structural proteins, athletes trying to build muscle mass often ingest large amounts of protein.

Except for the hypertrophy that follows an increase in the number of sarcomeres and myofibrils in a skeletal muscle, the cellular changes observed during endurance training do not usually occur with resistance training. There is usually no significant increase in mitochondria or capillary density. However, resistance training does increase the development of connective tissue, which adds to the overall mass of the muscle and helps to contain muscles as they produce increasingly powerful contractions. Tendons also become stronger to prevent tendon damage, as the force produced by muscles is transferred to tendons that attach the muscle to bone.

For effective strength training, the intensity of the exercise must continually be increased. For instance, continued weight lifting without increasing the weight of the load does not increase muscle size. To produce ever-greater results, the weights lifted must become increasingly heavier, making it more difficult for muscles to move the load. The muscle then adapts to this heavier load, and an even heavier load must be used if even greater muscle mass is desired.

If done improperly, resistance training can lead to overuse injuries of the muscle, tendon, or bone. These injuries can occur if the load is too heavy or if the muscles are not given sufficient time between workouts to recover or if joints are not aligned properly during the exercises. Cellular damage to muscle fibers that occurs after intense exercise includes damage to the sarcolemma and myofibrils. This muscle damage contributes to the feeling of soreness after strenuous exercise, but muscles gain mass as this damage is repaired, and additional structural proteins are added to replace the damaged ones. Overworking skeletal muscles can also lead to tendon damage and even skeletal damage if the load is too great for the muscles to bear.

Performance-Enhancing Substances

Some athletes attempt to boost their performance by using various agents that may enhance muscle performance. Anabolic steroids are one of the more widely known agents used to boost muscle mass and increase power output. **Anabolic steroids** are a form of testosterone, a male sex hormone that stimulates muscle formation, leading to increased muscle mass.

Endurance athletes may also try to boost the availability of oxygen to muscles to increase aerobic respiration by using substances such as erythropoietin (EPO), a hormone normally produced in the kidneys, which triggers the production of red blood cells. The extra oxygen carried by these blood cells can then be used by muscles for aerobic respiration. Human growth hormone (hGH) is another supplement, and although it can facilitate building muscle mass, its main role is to promote the healing of muscle and other tissues after strenuous exercise. Increased hGH may allow for faster recovery after muscle damage, reducing the rest required after exercise, and allowing for more sustained high-level performance.

Although performance-enhancing substances often do improve performance, most are banned by governing bodies in sports and are illegal for non-medical purposes. Their use to enhance performance raises ethical issues of cheating because they give users an unfair advantage over nonusers. A greater concern, however, is that their use carries serious health risks. The side effects of these substances are often significant, non-reversible, and in some cases fatal. The physiological strain caused by these substances is often greater than what the body can handle, leading to effects that are unpredictable and dangerous. Anabolic steroid use has been linked to infertility, aggressive behaviour, cardiovascular disease, and brain cancer.

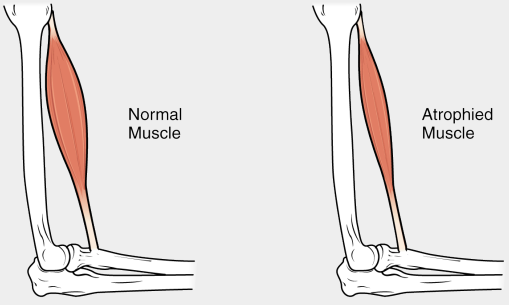
Similarly, some athletes have used creatine to increase power output. Creatine phosphate provides quick bursts of ATP to muscles in the initial stages of contraction. Increasing the amount of creatine available to cells is thought to produce more ATP and therefore increase explosive power output, although its effectiveness as a supplement has been questioned.

EVERYDAY CONNECTION

Aging and Muscle Tissue

Although atrophy due to disuse can often be reversed with exercise, muscle atrophy with age, referred to as sarcopenia, is irreversible. This is a primary reason why even highly trained athletes succumb to declining performance with age. This decline is noticeable in athletes whose sports require strength and powerful movements, such as sprinting, whereas the effects of age are less noticeable in endurance athletes such as marathon runners or long-distance cyclists. As muscles age, muscle fibers die, and they are replaced by connective tissue and adipose tissue (Figure 3.4.1.3 "Atrophy"). Because those tissues cannot contract and generate force as muscle can, muscles lose the ability to produce powerful contractions. The decline in muscle mass causes a loss of strength, including the strength required for posture and mobility. This may be caused by a reduction in FG fibers that hydrolyze ATP quickly to produce short, powerful contractions. Muscles in older people sometimes possess greater numbers of SO fibers, which are responsible for longer contractions and do not produce powerful movements. There may also be a reduction in the size of motor units, resulting in fewer fibers being stimulated and less muscle tension being produced.

Figure 3.4.1.3 Atrophy



Muscle mass is reduced as muscles atrophy with disuse.

Sarcopenia can be delayed to some extent by exercise, as training adds structural proteins and causes cellular changes that can offset the effects of atrophy. Increased exercise can produce greater numbers of cellular mitochondria, increase capillary density, and increase the mass and strength of connective tissue. The effects of age-related atrophy are especially pronounced in people who are sedentary, as the loss of muscle cells is displayed as functional impairments such as trouble with locomotion, balance, and posture. This can lead to a decrease in quality of life and medical problems, such as joint problems because the muscles that stabilize bones and joints are weakened. Problems with locomotion and balance can also cause various injuries due to falls.

Source: Exercise and Muscle Performance

3.4.2. Muscular Strength and Endurance

"Muscular Strength and Endurance" is an adaptation of the chapter "Muscular Strength and Endurance" from *Concepts of Fitness and Wellness*, by Scott Flynn, Lisa Jellum, Althea Moser, Jonathan Howard, Sharryse Henderson, Christin Collins, Amanda West, and David Mathis, which is licensed under a CC BY 4.0 license, and the chapter "Nervous Control of Muscle Tension" from *Anatomy and Physiology*, by J. Gordon Betts, Kelly A. Young, James A. Wise, Eddie Johnson, Brandon Poe, Dean H. Kruse, Oksana Korol, Jody E. Johnson, Mark Womble, and Peter DeSaix, which is published by OpenStax under a CC BY 4.0 license. New material has been incorporated that includes Canadian guidelines. Additionally, information that is not relevant to this course has been removed.

Muscular Physiology

Muscles are used for movement in the body. The largest portion of energy expenditure in the body happens in muscles while helping us perform daily activities with ease and improving our wellness. **Muscular strength** is the amount of force that a muscle can produce one time at a maximal effort, and **muscular endurance** is the ability to repeat a movement over an extended period of time.

Resistance training is the method of developing muscular strength and muscular endurance, which in turns improves wellness. This chapter explores many ways to resistance train. However, achieving the best muscular performance often requires the assistance of a trained professional.

Muscles are highly specialized to contract forcefully. Muscles are powered by muscle cells, which contract individually within a muscle to generate force. This force is needed to create movement.

There are over 600 muscles in the human body; they are responsible for every movement we make, from pumping blood through the heart and moving food through the digestive system, to blinking and chewing. Without muscle cells, we would be unable to stand, walk, talk, or perform everyday tasks.

There are three types of muscle:

- **skeletal muscle:** responsible for body movement
- **cardiac muscle:** responsible for the contraction of the heart
- **smooth muscle:** responsible for many tasks, including
    - movement of food along intestines,
    - enlargement and contraction of blood vessels,
    - size of pupils, and
    - many other contractions

Skeletal Muscle Structure and Function

Skeletal muscles are attached to the skeleton and are responsible for the movement of our limbs, torso, and head. They are under conscious control, which means that we can consciously choose to contract a muscle and can regulate how strong the contraction actually is. Skeletal muscles are made up of a number of muscle fibers. Each muscle fiber is an individual muscle cell and may be anywhere from 1 mm to 4 cm in length. When we choose to contract a muscle fiber—for instance we contract our bicep to bend our arm upwards—a signal is sent from our brain via the spinal cord to the muscle. This signals the muscle fibers to contract. Each nerve will control a certain number of muscle fibers. The nerve and the fibers it controls are called a **motor unit**. Only a small number of muscle fibers will contract to bend one of our limbs, but if we wish to lift a heavy weight then many more muscles fibers will be recruited to perform the action. This is called **muscle fiber recruitment**.

Each muscle fiber is surrounded by **connective tissue** called an external lamina. A group of muscle fibers are encased within more connective tissue called the endomysium. The group of muscle fibers and the endomysium are surrounded by more connective tissue called the perimysium. A group of muscle fibers surrounded by the perimysium is called a muscle fasciculus. A muscle is made up of many muscle fasciculi, which are surrounded by a thick collagenous layer of connective tissue called the epimysium. The epimysium covers the whole surface of the muscle.

Muscle fibers also contain many **mitochondria,** which are energy powerhouses that are responsible for the aerobic production of energy molecules, or ATP molecules. Muscle fibers also contain glycogen granules as a stored energy source, and **myofibrils**, which are threadlike structures running the length of the muscle fiber. Myofibrils are made up of two types of protein: 1) **Actin myofilaments,** and 2) **myosin myofilaments.** The actin and myosin filaments form the contractile part of the muscle, which is called the **sarcomere**. Myosin filaments are thick and dark when compared with actin filaments, which are much thinner and lighter in appearance. The actin and myosin filaments lie on top of one another; it is this arrangement of the filaments that gives muscle its striated or striped appearance. When groups of actin and myosin filaments are bound together by connective tissue they make the **myofibrils**. When groups of myofibrils are bound together by connective tissue, they make up **muscle fibers**.

The ends of the muscle connect to bone through a **tendon**. The muscle is connected to two bones in order to allow movement to occur through a joint. When a muscle contracts, only one of these bones will move. The point where the muscle is attached to a bone that moves is called the **insertion**. The point where the muscle is attached to a bone that remains in a fixed position is called the **origin**.

How Muscles Contract

Muscles are believed to contract through a process called the **Sliding Filament Theory**. In this theory, the muscles contract when actin filaments slide over myosin filaments resulting in a shortening of the length of the sarcomeres, and hence, a shortening of the muscle fibers. During this process the actin and myosin filaments do not change length when muscles contract, but instead they slide past each other.

During this process the muscle fiber becomes shorter and fatter in appearance. As a number of muscle fibers shorten at the same time, the whole muscle contracts and causes the tendon to pull on the bone it attaches to. This creates movement that occurs at the point of insertion.

For the muscle to return to normal (i.e., to lengthen), a force must be applied to the muscle to cause the muscle fibers to lengthen. This force can be due to gravity or due to the contraction of an opposing muscle group.

Skeletal muscles contract in response to an electric signal called an **action potential**. Action potentials are conducted along nerve cells before reaching the muscle fibers. The nerve cells regulate the function of skeletal muscles by controlling the number of action potentials that are produced. The action potentials trigger a series of chemical reactions that result in the contraction of a muscle.

When a nerve impulse stimulates a motor unit within a muscle, all of the muscle fibers controlled by that motor unit will contract. When stimulated, these muscle fibers contract on an all-or-nothing basis. The **all-or-nothing principle** means that muscle fibers either contract maximally along their length or not at all. Therefore, when stimulated, muscle fibers contract to their maximum level and when not stimulated there is no contraction. In this way, the force generated by a muscle is not regulated by the level of contraction by individual fibers, but rather it is due to the number of muscle fibers that are recruited to contract. This is called **muscle fiber recruitment**. When lifting a light object, such as a book, only a small number of muscle fibers will be recruited. However, those that are recruited will contract to their maximum level. When lifting a heavier weight, many more muscle fibers will be recruited to contract maximally.

When one muscle contracts, another opposing muscle will relax. In this way, muscles are arranged in pairs. An example is when you bend your arm at the elbow: you contract your bicep muscle and relax your tricep muscle. This is the same for every movement in the body. There will always be one contracting muscle and one relaxing muscle. If you take a moment to think about these simple movements, it will soon become obvious that unless the opposing muscle is relaxed, it will have a negative effect on the force generated by the contracting muscle.

A muscle that contracts, and is the main muscle group responsible for the movement, is called the **agonist** or prime mover. The muscle that relaxes is called the **antagonist**. One of the effects that regular strength training has is an improvement in the level of relaxation that occurs in the opposing muscle group. Although the agonist/antagonist relationship changes, depending on which muscle is responsible for the movement, every muscle group has an opposing muscle group.

Below are examples of agonist and antagonist muscle group pairings:

Agonist (prime mover)	Antagonist
Latiissimuss dorsi (upper back)	Deltoids (shoulder)
Rectus Abdominus (stomach)	Erector Spinae (back muscles)
Quadriceps (top of thigh)	Hamstrings (back of thigh)
Gastrocnemius (calf)	Tibialis Anterior (front of lower leg)
Soleus (below calf)	Tibialis Anterior (front of lower leg)

Smaller muscles may also assist the agonist during a particular movement. The smaller muscle is called the **synergist**. An example of a synergist would be the deltoid (shoulder) muscle during a press-up. The front of the deltoid provides additional force during the press-up; however, most of the force is applied by the pectoralis major (chest). Other muscle groups may also assist the movement by helping to maintain a fixed posture and prevent unwanted movement. These muscle groups are called **fixators**. An example of a fixator is the shoulder muscle during a bicep curl or tricep extension.

Types of Muscular Contraction

Isometric

This is a static contraction where the length of the muscle, or the joint angle, does not change. An example is pushing against a stationary object such as a wall. This type of contraction is known to lead to rapid rises in blood pressure.

Isotonic

This is a moving contraction, also known as dynamic contraction.

During this contraction the muscle fattens, and there is movement at the joint.

Types of Isotonic Contraction

- **concentric:** This is when the muscle contracts and shortens against a
resistance. This may be referred to as the lifting or positive phase. An example would be the lifting phase of the bicep curl.
- **eccentric:** This occurs when the muscle is still contracting and lengthening at the same time. This may be referred to as the lowering or negative phase.

Muscle Fiber Types

Not all muscle fibers are the same. In fact, there are two main types of muscle fiber:

- **Type I; also called SO (slow-oxidative):** often called slow-twitch or highly-oxidative muscle fibers
- **Type II; also called FG (fast-glycolitic):** often called fast-twitch or low-oxidative muscle fibers

Additionally, Type II muscle fibers can be further split into **Type IIa** and **Type IIb**. Type IIb fibers are the truly fast twitch fibers, whereas Type IIa are in between slow and fast twitch. Surprisingly, the characteristics of Type IIa fibers can be strongly influenced by the type of training undertaken. Following a period of endurance training, they will start to strongly resemble Type I fibers, but following a period of strength training they will start to strongly resemble Type IIb fibers. In fact, following several years of endurance training they may end up being almost identical to slow-twitch muscle fibers.

Type I (Slow-Twitch Muscle Fibers)

Slow-twitch muscle fibers contain more mitochondria, the organelles that produce aerobic energy. They are also smaller, have better blood supply, contract more slowly, and are more fatigue resistant than their fast-twitch brothers. Slow-twitch muscle fibers produce energy, primarily, through aerobic metabolism of fats and carbohydrates. The accelerated rate of aerobic metabolism is enhanced by the large numbers of mitochondria and the enhanced blood supply. They also contain large amounts of **myoglobin**, a pigment similar to hemoglobin that also stores oxygen. The myoglobin provides an additional store of oxygen for when oxygen supply is limited. This extra oxygen, along with the slow-twitch muscle fibers' slow rate of contraction, increases their endurance capacity and enhances their fatigue resistance. Slow-twitch muscle fibers are recruited during continuous exercise at low to moderate levels.

Type IIb (Fast-Twitch Low-Oxidative Muscle Fibers)

These fibers are larger in size, have a decreased blood supply, have smaller mitochondria and less of them, contract more rapidly, and are more adapted to produce energy anaerobically (without the need for oxygen) than slow-twitch muscle fibers. Their reduced rate of blood supply, together with their larger size and fewer mitochondria, makes them less able to produce energy aerobically, and are therefore, not well suited to prolonged exercise. However, their faster rate of contraction, greater levels of glycogen, and ability to produce much greater amounts of energy anaerobically make them much more suited to short bursts of energy. Because of their greater speed of contraction and reduced blood supply, they are far less fatigue resistant than slow- twitch fibers, and they tire quickly during exercise.

Numbers of Slow and Fast-Twitch Fibers

The number of slow and fast-twitch fibers contained in the body varies greatly between individuals and is determined by a person's genetics. People who do well at endurance sports tend to have a higher number of slow-twitch fibers, whereas people who are better at sprint events tend to have higher numbers of fast-twitch muscle fibers. Both the slow twitch and fast-twitch fibers can be influenced by training. It is possible through sprint training to improve the power generated by slow twitch fibers, and through endurance training, it is possible to increase the endurance level of fast-twitch fibers. The level of improvement varies, depending on the individual, and training can never make slow-twitch fibers as powerful as fast- twitch, nor can training make fast-twitch fibers as fatigue resistant as slow-twitch fibers.

Cardiac Muscle Structure and Function

Cardiac muscle cells are only found in the heart. They are elongated and contain actin and myosin filaments, which form sarcomeres; these join end to end to form myofibrils. The actin and myosin filaments give cardiac muscle a striated appearance. The striations are less numerous than in skeletal muscle. Cardiac muscles contain high numbers of mitochondria, which produce energy through aerobic metabolism. An extensive capillary network of tiny blood vessels supply oxygen to the cardiac muscle cells. Unlike the skeletal muscle cells, the **cardiac cells all work as one unit, all contracting**

at the same time. In short, the **sinoatrial node** at the top of the heart sends an impulse to the **atrio-ventricular node**, which sends a wave of polarization that travels from one heart cell to another causing them all to contract at the same time.

Smooth Muscle Structure and Function

Smooth muscle cells are variable in function and perform numerous roles within the body. They are spindle shaped and smaller than skeletal muscle and contain fewer actin and myosin filaments. The actin and myosin filaments are not organized into sarcomeres, so smooth muscles do not have a striated appearance. Unlike other muscle types, smooth muscle can apply a constant tension. This is called **smooth muscle tone**. Smooth muscle cells have a similar metabolism to skeletal muscle, producing most of their energy aerobically. As such, they are not well adapted to producing energy anaerobically.

Resistance Exercise Programming

Designing a resistance exercise program can seem like a daunting task. However, the basics are very simple. The next sections provide instructions for designing an effective resistance exercise program.

Recommendations for Resistance Training Exercise

- Perform a minimum of 8 to 10 exercises that train the major

muscle groups. Workouts should not be too long. Programs longer than one hour are associated with higher dropout rates. Choose more compound, or multi-joint exercises, which involve more muscles with fewer exercises.
- Perform one set of 8 to 12 repetitions to the point of volitional fatigue. More sets may elicit slightly greater strength gains, but additional improvement is relatively small.
- Perform exercises at least 2 days per week. More frequent training may elicit slightly greater strength gains, but additional improvement is relatively small since progress is made during the recuperation between workouts.
- Adhere as closely as possible to the specific exercise techniques.
- Perform exercises through a full range of motion. Elderly trainees should perform the exercises in the maximum range of motion that does not elicit pain or discomfort.
- Perform exercises in a controlled manner.
- Maintain a normal breathing pattern.
- If possible, exercise with a training partner. Partners can provide feedback, assistance, and motivation.

Position Stand on Progression Models in Resistance Training for Healthy Adults

- both concentric and eccentric muscle actions
- both single and multiple joint exercises
- exercise sequence:
  - large before small muscle group exercises
  - multiple-joint exercises before single-joint exercises
  - higher intensity before lower intensity exercises
- when training at a specific RM load 2-10% increase in load if one to two repetitions over the desired number

- training frequency: 2-3 days per week for novice and intermediate training; 4-5 days per week for advanced training.

- novice training: 8-12 repetition maximum (RM)

- intermediate to advanced training:
  - 1-12 RM using **periodization*** (strategic implementation of specific training phases alternating between phases of stress and phases of rest)
  - eventual emphasis on heavy loading (1-6 RM)
  - at least 3-min rest periods between sets
  - moderate contraction velocity
  - 1-2 s concentric, 1-2 s eccentric

*For more information on using periodization for weight training, click on the link below:
[Periodization for Weight Training]

- **hypertrophy training**
  - 1-12 RM in periodized fashion, with emphasis on the 6-12 RM zone
  - 1- to 2-min rest periods between sets
  - moderate contraction velocity, higher volume, multiple-set programs
- **power training** (two general loading strategies):
  - strength training
    - use of light loads
    - 30-60% of 1 RM
    - fast contraction velocity
    - 2-3 min of rest between sets for multiple sets per exercise
    - emphasize multiple-joint exercises especially those involving the total body
  - local muscular endurance training

- light to moderate loads
- 40-60% of 1 RM
- high repetitions (> 15)
- short rest periods (< 90 seconds)

Recommendations should be viewed within the context of an individual's target goals, physical capacity, and training status.

Six Types of Resistance Training

Each type of resistance training benefits muscles in a different way. While these types of resistance training are not new, they could be unique sources of resistance that you have not considered in your quest to add muscle to your frame. Using these forms of resistance alone, in combination with one another, or in combination with the more traditional resistance apparatus, can enable you to diversify your efforts to produce valuable and improved results.

In each type of training, you may use an apparatus to create an environment for resistance. The uniqueness of these sources is found in the way they are implemented. You might use a dumbbell for a particular exercise in some of these alternative resistance methods, but the way you use the resistance through a range of motion may be altogether different.

Dynamic Constant Training. As the name suggests, the most distinctive feature of dynamic constant training (DCT) is that the resistance is constant. A good example of DCT occurs when you use free weights or machines that do not alter resistance, but redirect it instead. The emphasis shifts to different planes along the muscle group being worked. When you work on a shoulder-press machine, for example, the resistance remains constant over the entire range of motion. It is identical from the bottom of the movement to the top and back down again. Only the direction of the resistance varies. The resistance redirects itself through the arc and then redirects itself again when the shoulders let the weight come back down to the starting position.

Dynamic Progressive Training. In dynamic progressive training (DPT), resistance increases progressively as you continue to exercise. DPT is often used as a rehabilitative measure and offers the sort of resistance that builds gradually while remaining completely within the control of the person using it. Equipment includes rubber bands and tubing, springs, and an apparatus controlled by spring-loaded parts. They are low- cost items that are easily accessible and can be used anywhere. Though commonly employed for rehabilitation of torn ligaments, joints, muscles, and broken bones, it is also convenient for travelers on either vacation or business trips. When combined with traditional forms of resistance, this training creates a better-balanced program and provides the muscles with a welcome alternative from time to time.

Dynamic Variable Training. This form of resistance exercise takes up where dynamic constant training leaves off. Whereas DCT employs constant resistance, never varying to accommodate the body's mechanics, DVT can be adapted to the varying degrees of strength of a muscle group throughout a range of motion. Though very few machines succeed in this goal, a few have come close.

Isokinetic Training. In isokinetic training (IKT), the muscle is contracted at a constant tempo. Speed determines the nature of this resistance training, not the resistance itself; however, the training is based on movement carried out during a condition of resistance. IKT can be performed with the body's own weight. In isokinetic training, resistance is steady while velocity remains constant. For example, isokinetics are at work with any machine that is hydraulically operated. The opposing forces mirror each other throughout the range of motion. A good example would be pressing down for triceps on a hydraulic machine and having to immediately pull up (the resistance is constant in both directions) into a biceps curl while maintaining the same speed. IKT often involves opposing body parts. Trainers can use a variety of apparatus with their clients to achieve isokinetic stasis between muscle groups.

Isometric Training. Familiar to most people, isometric training (IMT) is an excellent way to build strength with little adverse effect on joints and tendons commonly associated with strength training and lifting heavy weights. Though it appears simple in comparison to traditional resistance training, IMT should not be underrated in its effectiveness. IMT is a method in which the force of contraction is equal to the force of resistance. The muscle neither lengthens nor shortens. You may be wondering how any training occurs without lengthening and shortening the muscles. In IMT, the muscles act against each other or against an immovable object. Isometric training is what you see swimmers do when they press their hands against a solid wall, forcing all their bodyweight into the wall. Another common IMT exercise is pressing the hands together to strengthen the pectorals and biceps. Pressing against the wall can involve muscles in the front deltoid, chest and biceps. Isometric training has been proven very effective for gaining strength, but this method usually strengthens only the muscles at the point of the isometric contraction. If the greatest resistance and force are acting upon the mid-portion of the biceps, that is where most of the benefit will occur. A comprehensive isometric routine can serve to increase strength in certain body parts.

Isotonic Training. This method demands constant tension, typically with free weights. Though this approach may sound a lot like dynamic constant training, it differs because it does not necessarily redirect the resistance through a range of motion, but rather, keeps tension constant as in the negative portion of an exercise. Complete immobility of the muscle being worked is required. For example, in the preacher curl, the biceps are fixed against the bench. They lift (positive), then release the weight slowly downward (negative), keeping the same tension on the muscles in both directions. This is one reason that free-weight exercise is considered the best form of isotonic training. Merely lifting a dumbbell or barbell, however, is not necessarily enough to qualify as isotonic. The true essence of isotonic training is keeping resistance constant in both the positive and negative portions of each repetition.

Exercise Order for Resistance Training

The general guidelines for exercise order when training all major muscle groups in a workout is as follows:

- Large muscle group exercises (i.e., squat) should be performed before smaller muscle group exercises (i.e., shoulder press).
- Multiple-joint exercises should be performed before single-joint exercises.
- For power training, total body exercises (from most to least complex) should be performed before basic strength exercises. For example, the most complex exercises are the snatch (because the bar must be moved the greatest distance) and related lifts, followed by cleans and presses. These take precedence over exercises such as the bench press and squat
- Alternating between upper and lower body exercises or opposing (agonist–antagonist relationship) exercises can allow some muscles to rest while the opposite muscle groups are trained. This sequencing strategy is beneficial for maintaining high training intensities and targeting repetition numbers.
- Some exercises that target different muscle groups can be staggered between sets of other exercises to increase workout efficiency. For example, a trunk exercise can be performed between sets of the bench press. Because different muscle groups are stressed, no additional fatigue would be induced prior to performing the bench press. This is especially effective when long rest intervals are used.[1]

Resistance Training Conclusion

The most effective type of resistance- training routine employs a variety of techniques to create a workout program that is complete and runs the gamut, from basic to specialized. Learning different methods of training, different types of resistance, and the recommended order can help you acquire a balanced, complete physique. That does not mean that these training methods will help everybody to win competitions, but they will help you learn how to tune in to your body and understand its functions through resistance and movement. This knowledge and understanding develops a valuable skill, allowing you to become more adept at finding what works best for you on any given day.

Types of Contraction

To move an object, referred to as load, the sarcomeres in the muscle fibers of the skeletal muscle must shorten. The force generated by the contraction of the muscle (or shortening of the sarcomeres) is called muscle tension. However, muscle tension also is generated when the muscle is contracting against a load that does not move, resulting in two main types of skeletal muscle contractions: isotonic contractions and isometric contractions.

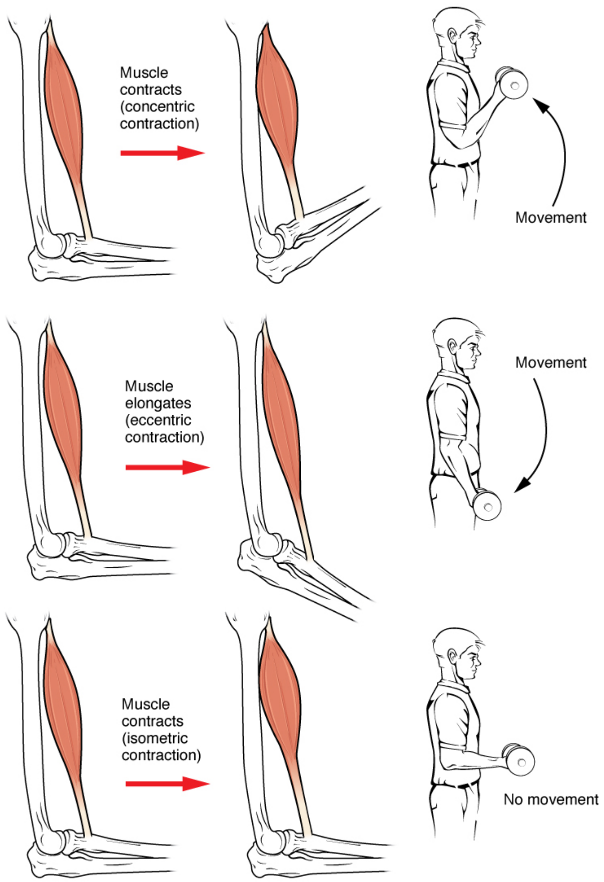
In isotonic contractions, where the tension in the muscle stays constant, a load is moved as the length of the muscle changes (shortens). There are two types of isotonic contractions: concentric and eccentric. A concentric contraction involves the muscle shortening to move a load. An example of this is the biceps brachii

1. Information is from the National Strength and Conditioning Association and LiveStrong.org

muscle contracting when a hand weight is brought upward with increasing muscle tension. As the biceps brachii contract, the angle of the elbow joint decreases as the forearm is brought toward the body. Here, the biceps brachii contracts as sarcomeres in its muscle fibers are shortening and cross-bridges form; the myosin heads pull the actin. An eccentric contraction occurs as the muscle tension diminishes and the muscle lengthens. In this case, the hand weight is lowered in a slow and controlled manner as the amount of cross-bridges being activated by nervous system stimulation decreases. In this case, as tension is released from the biceps brachii, the angle of the elbow joint increases. Eccentric contractions are also used for movement and balance of the body.

An isometric contraction occurs as the muscle produces tension without changing the angle of a skeletal joint. Isometric contractions involve sarcomere shortening and increasing muscle tension, but do not move a load, as the force produced cannot overcome the resistance provided by the load. For example, if one attempts to lift a hand weight that is too heavy, there will be sarcomere activation and shortening to a point, and ever-increasing muscle tension, but no change in the angle of the elbow joint. In everyday living, isometric contractions are active in maintaining posture and maintaining bone and joint stability. However, holding your head in an upright position occurs not because the muscles cannot move the head, but because the goal is to remain stationary and not produce movement. Most actions of the body are the result of a combination of isotonic and isometric contractions working together to produce a wide range of outcomes (Figure 3.4.2.1 “Types of Muscle Contractions”).

Figure 3.4.2.1 *Types of Muscle Contractions*



During isotonic contractions, muscle length changes to move a load. During isometric contractions, muscle length does not change, because the load exceeds the tension the muscle can generate.

Source: [Nervous System Control of Muscle Tension]

All of these muscle activities are under the exquisite control of the nervous system. Neural control regulates concentric, eccentric and isometric contractions, muscle fiber recruitment, and muscle tone. A crucial aspect of nervous system control of skeletal muscles is the role of motor units.

Motor Units

As you have learned, every skeletal muscle fiber must be innervated by the axon terminal of a motor neuron in order to contract. Each muscle fiber is innervated by only one motor neuron. The actual group of muscle fibers in a muscle innervated by a single motor neuron is called a motor unit. The size of a motor unit is variable depending on the nature of the muscle.

A small motor unit is an arrangement where a single motor neuron supplies a small number of muscle fibers in a muscle. Small motor units permit very fine motor control of the muscle. The best example in humans is the small motor units of the extraocular eye muscles that move the eyeballs. There are thousands of muscle fibers in each muscle, but every six or so fibers are supplied by a single motor neuron, as the axons branch to form synaptic connections at their individual NMJs. This allows for exquisite control of eye movements so that both eyes can quickly focus on the same object. Small motor units are also involved in the many fine movements of the fingers and thumb of the hand for grasping, texting, etc.

A large motor unit is an arrangement where a single motor neuron supplies a large number of muscle fibers in a muscle. Large motor units are concerned with simple, or "gross," movements, such as powerfully extending the knee joint. The best example is the large motor units of the thigh muscles or back muscles, where a single motor neuron will supply thousands of muscle fibers in a muscle, as its axon splits into thousands of branches.

There is a wide range of motor units within many skeletal muscles, which gives the nervous system a wide range of control over the muscle. The small motor units in the muscle will have smaller, lower-threshold motor neurons that are more excitable, firing first to their skeletal muscle fibers, which also tend to be the smallest. Activation of these smaller motor units, results in a relatively small degree of contractile strength (tension) generated in the muscle. As more strength is needed, larger motor units, with bigger, higher-threshold motor neurons are enlisted to activate larger muscle fibers. This increasing activation of motor units produces an increase in muscle contraction known as recruitment. As more motor units are recruited, the muscle contraction grows progressively stronger. In some muscles, the largest motor units may generate a contractile force of 50 times more than the smallest motor units in the muscle. This allows a feather to be picked up using the biceps brachii arm muscle with minimal force, and a heavy weight to be lifted by the same muscle by recruiting the largest motor units.

When necessary, the maximal number of motor units in a muscle can be recruited simultaneously, producing the maximum force of contraction for that muscle, but this cannot last for very long because of the energy requirements to sustain the contraction. To prevent complete muscle fatigue, motor units are generally not all simultaneously active, but instead some motor units rest while others are active, which allows for longer muscle contractions. The nervous system uses recruitment as a mechanism to efficiently utilize a skeletal muscle.

Terminology Checklist

Muscles: organ in the body that causes movement
Skeletal muscle: responsible for body movement
Cardiac muscle: responsible for the contraction of the heart
Muscle fiber: individual muscle cell
Motor unit: a nerve controlling a group of muscle fibers
Myofibrils: which are threadlike structures running the length of the muscle fiber

Insertion: point where the muscle is attached to a bone that moves
Origin: point where the muscle is attached to a bone that remains in a fixed position

Action potential: the electrical current that cause a muscle to contract
Sliding filament theory: the theory of how our muscles move
Dynamic contraction: muscle movements that cause bodily movements

Repetition: one movement pattern
Set: a group of repetitions
Periodization: breaking resistance training into different training phases
Strength: the maximal amount a force that can produced one time
Hypertrophy: muscle fibers getting bigger
Atrophy: muscle fibers getting smaller
Isokinetic: muscle is contracted at a constant tempo
Isometric: muscle contraction cause no bodily movement

3.4.3. Test Your Knowledge

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https://opentextbooks.concordia.ca/fundamentalsofhealthandphysicalactivity/?p=731

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3.5. WATER AND ELECTROLYTES

3.5.1. Fluid and Electrolyte Balance

Fluid and Electrolyte Balance

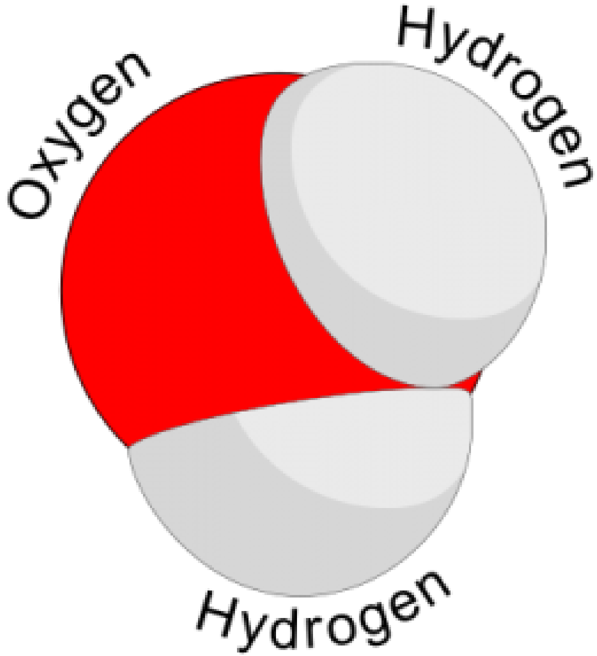
Maintaining the right level of water in your body is crucial to survival, as either too little or too much water in your body will result in less-than-optimal functioning. One mechanism to help ensure the body maintains water balance is thirst. Thirst is the result of your body's physiology telling your brain to initiate the thought to take a drink. Sensory proteins detect when your mouth is dry, your blood volume too low, or blood electrolyte concentrations too high and send signals to the brain stimulating the conscious feeling to drink. In the summer of 1965, the assistant football coach of the University of Florida Gators requested scientists affiliated with the university study why the withering heat of Florida caused so many heat-related illnesses in football players and provide a solution to increase athletic performance and recovery post-training or game. The discovery was that inadequate replenishment of fluids, carbohydrates, and electrolytes was the reason for the "wilting" of their football players. Based on their research, the scientists concocted a drink for the football players containing water, carbohydrates, and electrolytes and called it "Gatorade." In the next football season the Gators were nine and two and won the Orange Bowl. The Gators' success launched the sports-drink industry, which is now a multibillion-dollar industry that is still dominated by Gatorade. Excess consumption of sugary soft drinks is common and has been scientifically proven to increase the risk for dental caries, obesity, Type 2 diabetes, and cardiovascular disease. In addition to sugary soft drinks, beverages containing added sugars include fruit drinks, sports drinks, energy drinks and sweetened bottled waters. Sports drinks are designed to rehydrate the body after excessive fluid depletion, a problem for high-intensity athletes performing prolonged workouts in hot, humid climates. Electrolytes in particular promote normal rehydration to prevent fatigue during physical exertion. Are they a good choice for achieving the recommended fluid intake? Are they performance and endurance enhancers like they claim? Who should drink them?Typically, eight ounces of a sports drink provides extra calories and carbohydrate, mostly in the form of simple sugars. Sodium and potassium are the most commonly included electrolytes in sports drinks, with the levels of these in sports drinks being highly variable. The American College of Sports Medicine says a sports drink should contain 125 milligrams of sodium per 8 ounces as it is helpful in replenishing some of the sodium lost in sweat and promotes fluid uptake in the small intestine, improving hydration. Health agencies and dieticians recommend water for most active people as sports drinks are suited to high-energy performance. In this chapter we will discuss the importance and functions of fluid and electrolyte balance in the human body, the consequences of getting too much or too little of water and electrolytes, the best dietary sources of these nutrients, and healthier beverage choices.

Overview of Fluid and Electrolyte Balance

Water is made up of 2 hydrogen atoms and 1 oxygen atom (Figure 3.5.1.1 “The Water Molecule”). Adult males typically are composed of about 60 percent water and females are about 55 percent water. (This gender difference reflects the differences in body-fat content, since body fat is practically water-free. This also means that if a person gains weight in the form of fat the percentage of total body water content declines.) As we age, total body water content also diminishes so that by the time we are in our eighties the percent of water in our bodies has decreased to around 45 percent. Does the loss in body water play a role in the aging process? Alas, no one knows. But, we do know that dehydration accelerates the aging process whereas keeping hydrated decreases headaches, muscle aches, and kidney stones. Additionally a study conducted at the Fred Hutchinson Cancer Research Center in Seattle found that women who drank more than five glasses of water each day had a significantly decreased risk for developing colon cancer.[1]

Figure 3.5.1.1 *The Water Molecule*

1. Shannon JE, et al. Relationship of Food Groups and Water Intake to Colon Cancer Risk. Cancer Epidemiol Biomarkers Prev. 1996; 5(7), 495–502. http://cebp.aacrjournals.org/content/5/7/495.long. Accessed September 22, 2017.

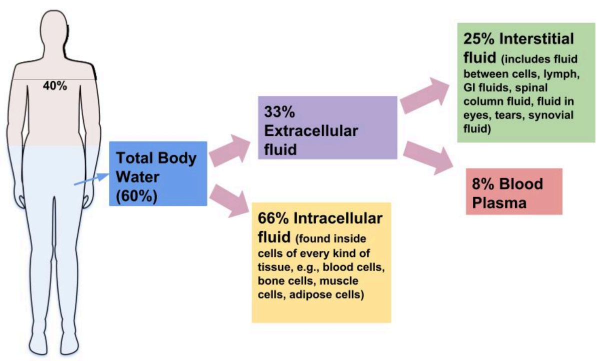


The water molecule is made up of two hydrogen atoms and one oxygen atom. Source: "Water Molecule" by [Chris Martin](#) / [Public Domain](#)

Fluid and Electrolyte Balance

Although water makes up the largest percentage of body volume, it is not actually pure water but rather a mixture of cells, proteins, glucose, lipoproteins, electrolytes, and other substances. **Electrolytes are substances that, when dissolved in water, dissociate into charged ions**. Positively charged electrolytes are called cations and negatively charged electrolytes are called anions. For example, in water sodium chloride (the chemical name for table salt) dissociates into sodium cations ($Na+$) and chloride anions ($Cl–$). Solutes refers to all dissolved substances in a fluid, which may be charged, such as sodium ($Na+$), or uncharged, such as glucose. In the human body, water and solutes are distributed into two compartments: inside cells, called **intracellular**, and outside cells, called extracellular. The **extracellular** water compartment is subdivided into the spaces between cells also known as **interstitial**, blood plasma, and other bodily fluids such as the cerebrospinal fluid which surrounds and protects the brain and spinal cord (Figure 3.5.1.2 "Distribution of Body Water"). The composition of solutes differs between the fluid compartments. For instance, more protein is inside cells than outside and more chloride anions exist outside of cells than inside.

Figure 3.5.1.2 *Distribution of Body Water*



Our bodies are made up of ~60% water. This water consists of intracellular fluid and extracellular fluid. Extracellular fluid is composed of interstitial fluid and plasma. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Osmoregulation

One of the essential homeostatic functions of the body is to maintain fluid balance and the differences in solute composition between cells and their surrounding environment. Osmoregulation is the control of fluid balance and composition in the body. The processes involved keep fluids from becoming too dilute or too concentrated. Fluid compartments are separated by selectively permeable membranes, which allow some things, such as water, to move through while other substances require special transport proteins, channels, and often energy. Water is never transported actively; that is, it never takes energy for water to move between compartments. Although cells do not directly control water movement, they do control movement of electrolytes and other solutes and thus indirectly regulate water movement by controlling where there will be regions of high and low concentrations.

3.5.2. Water's Function

Water's Importance to Vitality

You get up in the morning, flush wastes down the toilet, take a shower, brush your teeth, drink, eat, drive, wash the grime from your windshield, get to work, and drink coffee. Next to a fountain you eat lunch and down it with a glass of water, you use the toilet again and again, drive home, prepare dinner, etc. Add all the ways you use water every day and you still will not come close to the countless uses water has in the human body. Of all the nutrients, water is the most critical as its absence proves lethal within a few days. Organisms have adapted numerous mechanisms for water conservation. Water uses in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/shock absorber, and temperature regulator.

Image by NASA *on unsplash.com* / CC0

Water is the foundation of all life—the surface of the earth is 70 percent water; the volume of water in humans is about 60 percent.

Water as a Transportation Vehicle

Water is called the "universal solvent" because more substances dissolve in it than any other fluid. Molecules dissolve in water because of the hydrogen and oxygen molecules ability to loosely bond with other molecules. Molecules of water (H_2O) surround substances, suspending them in a sea of water molecules. The solvent action of water allows for substances to be more readily transported. A pile of undissolved salt would be difficult to move throughout tissues, as would a bubble of gas or a glob of fat. Blood, the primary transport fluid in the body is about 78 percent water. Dissolved substances in blood include proteins, lipoproteins, glucose, electrolytes, and metabolic waste products, such as carbon dioxide and urea. These substances are either dissolved in the watery surrounding of blood to be transported to cells to support basic functions or are removed from cells to prevent waste build-up and toxicity. Blood is not just the primary vehicle of transport in the body, but also as a fluid tissue blood structurally supports blood vessels that would collapse in its absence. For example, the brain which consists of 75 percent water is used to provide structure.

Water as a Medium for Chemical Reactions

Water is required for even the most basic chemical reactions. Proteins fold into their functional shape based on how their amino-acid sequences react with water. These newly formed enzymes must conduct their specific chemical reactions in a medium, which in all organisms is water. Water is an ideal medium for chemical reactions as it can store a large amount of heat, is electrically neutral, and has a pH of 7.0, meaning it is not acidic or basic. Additionally, water is involved in many enzymatic reactions as an agent to break bonds or, by its removal from a molecule, to form bonds.

Water as a Lubricant/Shock Absorber

Many may view the slimy products of a sneeze as gross, but sneezing is essential for removing irritants and could not take place without water. Mucus, which is not only essential to discharge nasal irritants, is also required for breathing, transportation of nutrients along the gastrointestinal tract, and elimination of waste materials through the rectum. Mucus is composed of more than 90 percent water and a front-line defense against injury and foreign invaders. It protects tissues from irritants, entraps pathogens, and contains immune-system cells that destroy pathogens. Water is also the main component of the lubricating fluid between joints and eases the movement of articulated bones.

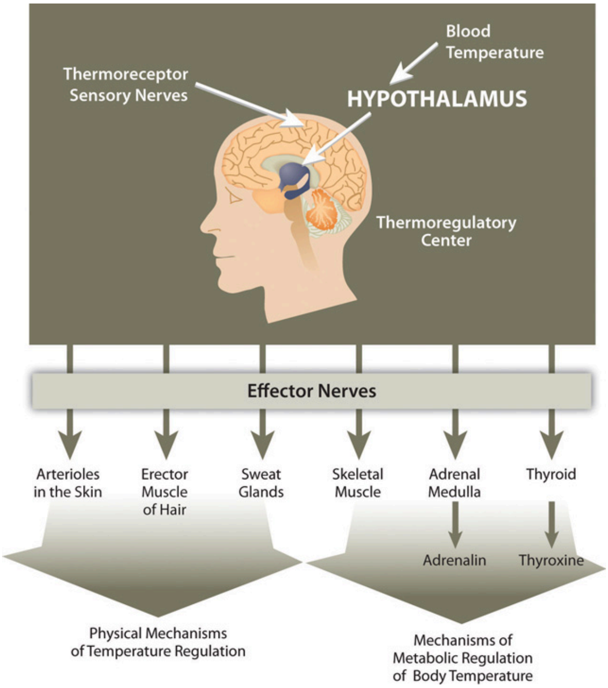
The aqueous and vitreous humors, which are fluids that fill the extra space in the eyes and the cerebrospinal fluid surrounding the brain and spinal cord, are primarily water and buffer these organs against sudden changes in the environment. Watery fluids surrounding organs provide both chemical and mechanical protection. Just two weeks after fertilization water fills the amniotic sac in a pregnant woman providing a cushion of protection for the developing embryo.

Water as a Temperature Regulator

Another homeostatic function of the body, termed thermoregulation is to balance heat gain with heat loss and body water plays an important role in accomplishing this. Human life is supported within a narrow range of temperature, with the temperature set point of the body being 98.6°F (37°C). Too low or too high of a temperature causes enzymes to stop functioning and metabolism is halted. At 82.4°F (28°C) muscle failure occurs and hypothermia sets in. At the opposite extreme of 111.2°F (44°C) the central nervous system fails and death results. Water is good at storing heat, an attribute referred to as heat capacity and thus helps maintain the temperature set point of the body despite changes in the surrounding environment.

There are several mechanisms in place that move body water from place to place as a method to distribute heat in the body and equalize body temperature (Figure 3.5.2.1 "Thermoregulatory Center"). The hypothalamus in the brain is the thermoregulatory center. The hypothalamus contains special protein sensors that detect blood temperature. The skin also contains temperature sensors that respond quickly to changes in immediate surroundings. In response to cold sensors in the skin, a neural signal is sent to the hypothalamus, which then sends a signal to smooth muscle tissue surrounding blood vessels causing them to constrict and reduce blood flow. This reduces heat lost to the environment. The hypothalamus also sends signals to muscles to erect hairs and shiver and to endocrine glands like the thyroid to secrete hormones capable of ramping up metabolism. These actions increase heat conservation and stimulate its production in the body in response to cooling temperatures.

Figure 3.5.2.1 *Thermoregulatory Center*



Thermoregulation is the ability of an organism to maintain body temperature despite changing environmental temperatures.

Source: [Water's Importance to Vitality]

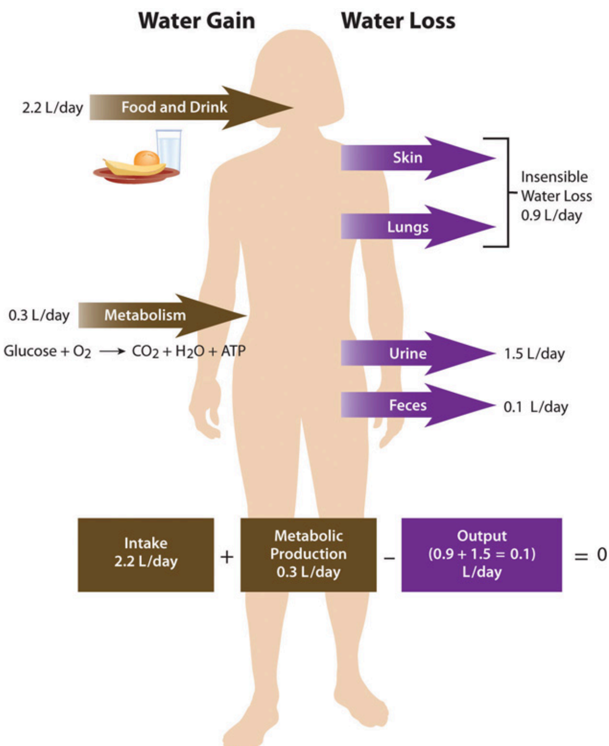
Regulation of Water Balance

As you eat a bite of food, the salivary glands secrete saliva. As the food enters your stomach, gastric juice is secreted. As it enters the small intestine, pancreatic juice is secreted. Each of these fluids contains a great deal of water. How is that water replaced in these organs? What happens to the water now in the intestines? In a day, there is an exchange of about 10 liters of water among the body's organs. The osmoregulation of this exchange involves complex communication between the brain, kidneys, and endocrine system. A homeostatic goal for a cell, a tissue, an organ, and an entire organism is to balance water output with water input.

Regulation of Daily Water Input

Total water output per day averages 2.5 liters. This must be balanced with water input. Our tissues produce around 300 milliliters of water per day through metabolic processes. The remainder of water output must be balanced by drinking fluids and eating solid foods. The average fluid consumption per day is 1.5 liters, and water gained from solid foods approximates 700 milliliters.

Figure 3.5.2.2 *Daily Fluid Loss and Gain*



Water is gained and lost in a variety of ways throughout the day.

Source: [Water's Importance to Vitality]

Dietary Gain of Water

The Food and Nutrition Board of the Institute of Medicine (IOM) has set the Adequate Intake (AI) for water for adult males at 3.7 liters (15.6 cups) and at 2.7 liters (11 cups) for adult females.[1] These intakes are higher than the average intake of 2.2 liters. It is important to note that the AI for water includes water from all dietary sources; that is, water coming from food as well as beverages. People are not expected to consume 15.6 or 11 cups of pure water per day. In America, approximately 20 percent of dietary water comes from solid foods. See Table 3.5.2.1 "Water Content in Foods" for the range of water contents for selected food items. Beverages includes water, tea, coffee, sodas, and juices.

Table 3.5.2.1 *Water Content in Foods*

1. Institute of Medicine Panel on Dietary Reference Intakes for Electrolytes and Water. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. The National Academies of Science, Engineering, and Medicine. Washington D.C; 2005: 73-185. http://www.nap.edu/openbook.php?record_id=10925&page=73. Accessed September 22, 2017.

Percentage	Food item
90–99	Nonfat milk, cantaloupe, strawberries, watermelon, lettuce, cabbage, celery, spinach, squash
80–89	Fruit juice, yogurt, apples, grapes, oranges, carrots, broccoli, pears, pineapple
70–79	Bananas, avocados, cottage cheese, ricotta cheese, baked potato, shrimp
60–69	Pasta, legumes, salmon, chicken breast
50–59	Ground beef, hot dogs, steak, feta cheese
40–49	Pizza
30–39	Cheddar cheese, bagels, bread
20–29	Pepperoni, cake, biscuits
10–19	Butter, margarine, raisins
1–9	Walnuts, dry-roasted peanuts, crackers, cereals, pretzels, peanut butter
0	Oils, sugars

Source: National Nutrient Database for Standard Reference, Release 23. US Department of Agriculture, Agricultural Research Service. http://www.ars.usda.gov/ba/bhnrc/ndl. Updated 2010. Accessed September 2017.

Different foods have different water contents. Oils and sugars do not contain any water however foods such as milk, strawberries and watermelon can be up to 99% water.

There is some debate over the amount of water required to maintain health because there is no consistent scientific evidence proving that drinking a particular amount of water improves health or reduces the risk of disease. In fact, kidney-stone prevention seems to be the only premise for water-consumption recommendations. You may be surprised to find out that the commonly held belief that people need to drink eight 8-ounce glasses of water per day isn't an official recommendation and isn't based on any scientific evidence! The amount of water/fluids a person should consume every day is actually variable and should be based on the climate a person lives in, as well as their age, physical activity level, and kidney function. No maximum for water intake has been set.

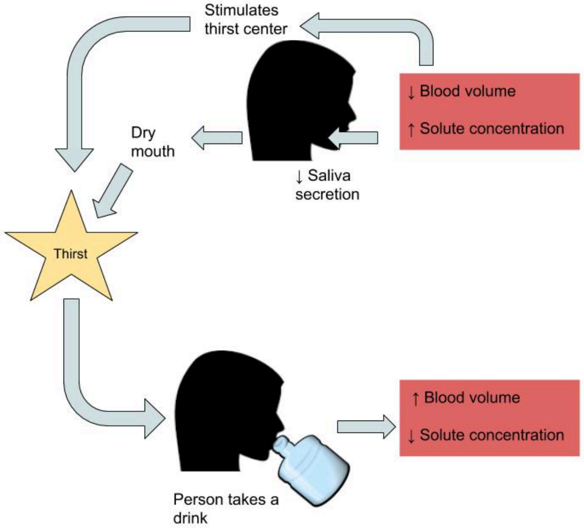
Thirst Mechanism: Why Do We Drink?

Thirst is an osmoregulatory mechanism to increase water input. The thirst mechanism is activated in response to changes in water volume in the blood, but is even more sensitive to changes in blood osmolality. The "thirst center" is contained within the hypothalamus, a portion of the brain that lies just above the brainstem. In older people the thirst mechanism is not as responsive and as we age there is a higher risk for dehydration.

Sodium and fluid balance are intertwined. Osmoreceptors (specialized protein receptors) in the hypothalamus detect sodium concentration in the blood. In response to a high sodium level, the hypothalamus activates the thirst mechanism and concurrently stimulates the release of antidiuretic hormone.

The physiological control of thirst is the backup mechanism to increase water input. Fluid intake is controlled primarily by conscious eating and drinking habits dependent on social and cultural influences. For example, you might have a habit of drinking a glass of orange juice and eating a bowl of cereal every morning before school or work.

Figure 3.5.2.3 *Regulating Water Intake*



Water intake is regulated by a variety of stimuli. When thirst develops and water is consumed, these stimuli subside. Source: image by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Water intake is regulated by a variety of stimuli. When thirst develops and water is consumed these stimuli subside.

3.5.3. Sodium, Chloride, and Potassium

Sodium

Sodium is vital not only for maintaining fluid balance but also for many other essential functions. In contrast to many minerals, sodium absorption in the small intestine is extremely efficient and in a healthy individual all excess sodium is excreted by the kidneys. In fact, very little sodium is required in the diet (about 200 milligrams) because the kidneys actively reabsorb sodium. Kidney reabsorption of sodium is hormonally controlled, allowing for a relatively constant sodium concentration in the blood.

A notable function of sodium is in nerve impulse transmission. Similar to how a current moves along a wire, a sodium current moves along a nerve cell. Stimulating a muscle contraction also involves the movement of sodium ions as well as other ion movements.

Sodium is essential for nutrient absorption in the small intestine and also for nutrient reabsorption in the kidney. Amino acids, glucose and water are aided by sodium as they make their way from the small intestine to the blood. The transport of nutrients through intestinal cells is facilitated by the sodium-potassium pump, which by moving sodium out of the cell, creates a higher sodium concentration outside of the cell (requiring ATP).

Sodium Imbalances

Sweating is a homeostatic mechanism for maintaining body temperature, which influences fluid and electrolyte balance. Sweat is mostly water but also contains some electrolytes, mostly sodium and chloride. Under normal environmental conditions (i.e., not hot, humid days) water and sodium loss through sweat is negligible, but is highly variable among individuals. It is estimated that sixty minutes of high-intensity physical activity, like playing a game of tennis, can produce approximately one liter of sweat; however the amount of sweat produced is highly dependent on environmental conditions. A liter of sweat typically contains between 1 and 2 grams of sodium and therefore exercising for multiple hours can result in a high amount of sodium loss in some people. Additionally, hard labor can produce substantial sodium loss through sweat. In either case, the lost sodium is easily replaced in the next snack or meal.

In athletes **hyponatremia**, or a low blood-sodium level, is not so much the result of excessive sodium loss in sweat, but rather drinking too much water. The excess water dilutes the sodium concentration in blood. Illnesses causing vomiting, sweating, and diarrhea may also cause hyponatremia. The symptoms of hyponatremia, also called water intoxication (since it is often the root cause) include nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death. The physiological events that occur in water intoxication proceed as follows:

- excessive sodium loss and/or water intake
- sodium levels fall in blood and in the fluid between cells
- water moves to where solutes are more concentrated (i.e. into cells)
- cells swell
- symptoms result, including nausea, muscle cramps, confusion, dizziness and, in severe cases, coma and death

Hyponatremia in endurance athletes (such as marathon runners) can be avoided by drinking the correct amount of water, which is about 1 cup every twenty minutes during the event. Sports drinks are better at restoring fluid and blood-glucose levels than replacing electrolytes. During an endurance event you would be better off drinking water and eating an energy bar that contains sugars, proteins, and electrolytes. The American College of Sports Medicine suggests if you are exercising for longer than one hour you eat one high carbohydrate (25–40 grams) per hour of exercise along with ample water.[1]

Watch out for the fat content, as sometimes energy bars contain a hefty dose. If you're not exercising over an hour at high intensity, you can skip the sports drinks, but not the water. For those who do not exercise or do so at low to moderate intensity, sports drinks are another source of extra calories, sugar, and salt.

Needs and Dietary Sources of Sodium

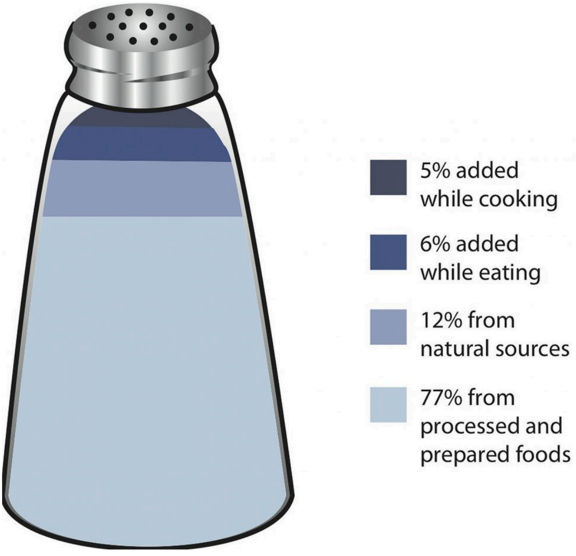
The IOM has set an AI (Adequate Intake)level for sodium for healthy adults between the ages of nineteen and fifty at 1,500 milligrams. Table salt is approximately 40 percent sodium and 60 percent chloride. As a reference point, **only ⅔ teaspoon of salt is needed in the diet to meet the AI for sodium and chloride.** The AI takes into account the amount of sodium lost in sweat during recommended physical activity levels and additionally provides for the sufficient intake of other nutrients, such as chloride. Many scientific studies demonstrate that reducing salt intake prevents hypertension, is helpful in reducing blood pressure after hypertension is diagnosed, and reduces the risk for cardiovascular disease.

1. Convertino VA, et al. American College of Sports Medicine Position Stand. Exercise and Fluid Replacement. Medicine and Science in Sports and Exercise. 1996; 28(1) i–vii. http://www.ncbi.nlm.nih.gov/pubmed/9303999. Accessed September 22, 2017.

Food Sources for Sodium

Most sodium in the typical North American diet comes from processed and prepared foods. Manufacturers add salt to foods to improve texture and flavor, and also as a preservative. The amount of salt in similar food products varies widely. Some foods, such as meat, poultry, and dairy foods, contain naturally-occurring sodium. For example, one cup of low-fat milk contains 107 milligrams of sodium. Naturally-occurring sodium accounts for less than 12 percent of dietary intake in a typical diet. For the sodium contents of various foods see Table 3.5.3.1 "Sodium Contents of Selected Foods."

Figure 3.5.3.1 *Dietary Sources of Sodium*



The majority of salt intake comes from processed and prepared foods. Source: [Sodium]

Table 3.5.3.1 *Sodium Contents of Selected Foods*

Food group	Serving size	Sodium (mg)
Breads, all types	1 oz.	95–210
Rice Chex cereal	1 ¼ c.	292
Raisin Bran cereal	1 c.	362
Frozen pizza, plain, cheese	4 oz.	450–1200
Frozen vegetables, all types	½ c.	2–160
Salad dressing, regular fat, all types	2 Tbsp.	110–505
Salsa	2 Tbsp.	150–240
Soup (tomato), reconstituted	8 oz.	700–1260
Potato chips	1 oz. (28.4 g)	120–180
Tortilla chips	1 oz. (28.4 g)	105–160
Pork	3 oz.	59
Chicken	(½ breast)	69
Chicken fast food dinner		2243
Chicken noodle soup	1 c.	1107
Dill pickle	1	928
Soy sauce	1 Tbsp.	1029
Canned corn	1 c.	384
Baked beans, canned	1 c.	856
Hot dog	1	639
Burger, fast-food	1	990
Steak	3 oz.	55
Canned tuna	3 oz.	384
Fresh tuna	3 oz.	50
Dry-roasted peanuts	1 c.	986
American cheese	1 oz.	406
Tap water	8 oz.	12

Source: [Sodium]

Foods vary in sodium content. Some sodium intake is necessary for health; however, large intakes of sodium should be avoided.

Tools for Change

To decrease your sodium intake, become a salt-savvy shopper by reading the labels and ingredients lists of processed foods and choosing those lower in salt. Even better, stay away from processed foods and control the seasoning of your foods. Eating a diet with less salty foods diminishes salt cravings so you may need to try a lower sodium diet for a week or two before you will be satisfied with the less salty food.

Salt Substitutes

For those with hypertension or those looking for a way to decrease salt use, using a salt substitute for food preparation is one option. However, many salt substitutes still contain sodium, just in lesser amounts than table salt. Also, remember that most salt in the diet is not from table-salt use, but from processed foods. Salt substitutes often replace the sodium with potassium. People with kidney disorders often have problems getting rid of excess potassium in the diet and are advised to avoid salt substitutes containing potassium. People with liver disorders should also avoid salt substitutes containing potassium because their treatment is often accompanied by potassium dysregulation.

Alternative Seasonings

Table salt may seem an essential ingredient of good food, but there are others that provide alternative taste and zest to your foods. See Table 3.5.3.2 "Salt Alternatives" for an AHA list of alternative food seasonings.

Table 3.5.3.2 *Salt Alternatives*

Seasoning	Foods
Allspice	Lean ground meats, stews, tomatoes, peaches, applesauce, cranberry sauce, gravies, lean meat
Almond extract	Puddings, fruits
Caraway seeds	Lean meats, stews, soups, salads, breads, cabbage, asparagus, noodles
Chives	Salads, sauces, soups, lean-meat dishes, vegetables
Cider vinegar	Salads, vegetables, sauces
Cinnamon	Fruits, breads, pie crusts
Curry powder	Lean meats (especially lamb), veal, chicken, fish, tomatoes, tomato soup, mayonnaise,
Dill	fish sauces, soups, tomatoes, cabbages, carrots, cauliflower, green beans, cucumbers, potatoes, salads, macaroni, lamb
Garlic (not garlic salt)	Lean meats, fish, soups, salads, vegetables, tomatoes, potatoes
Ginger	Chicken, fruits
Lemon juice	Lean meats, fish, poultry, salads, vegetables
Mace	Hot breads, apples, fruit salads, carrots, cauliflower, squash, potatoes, veal, lamb
Mustard (dry)	lean ground meats, lean meats, chicken, fish, salads, asparagus, broccoli, Brussels sprouts, cabbage, mayonnaise, sauces
Nutmeg	Fruits, pie crust, lemonade, potatoes, chicken, fish, lean meatloaf, toast, veal, pudding
Onion powder	Lean meats, stews, vegetables, salads, soups
Paprika	Lean meats, fish, soups, salads, sauces, vegetables
Parsley	Lean meats, fish, soups, salads, sauces, vegetables
Peppermint extract	Puddings, fruits
Pimiento	Salads, vegetables, casserole dishes
Rosemary	Chicken, veal, lean meatloaf, lean beef, lean pork, sauces, stuffings, potatoes, peas, lima beans

Sage	Lean meats, stews, biscuits, tomatoes, green beans, fish, lima beans, onions, lean pork
Savory	Salads, lean pork, lean ground meats, soups, green beans, squash, tomatoes, lima beans, peas
Thyme	Lean meats (especially veal and lean pork), sauces, soups, onions, peas, tomatoes, salads
Turmeric	Lean meats, fish, sauces, rice

Note: There are a wide variety of foods that can be substituted for salt. A lot of these options serve as healthier alternatives. *Source*: Shaking the Salt Habit. American Heart Association. http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Shaking-the-Salt-Habit_UCM_303241_Article.jsp. Updated June 6, 2012. Accessed September 22, 2017.

Chloride's Role in Fluid Balance

Chloride aids in fluid balance mainly because it follows sodium in order to maintain charge neutrality. Chloride channels also play a role in regulating fluid secretion, such as pancreatic juice into the small intestine and the flow of water into mucus. Fluid secretion and mucus are important for many of life's processes. Their importance is exemplified in the signs and symptoms of the genetic disease, cystic fibrosis (CF). CF's signs and symptoms include salty skin, poor digestion and absorption (leading to poor growth), sticky mucus accumulation in the lungs (causing increased susceptibility to respiratory infections), liver damage, and infertility.

Needs and Dietary Sources of Potassium

The IOM based their AIs for potassium on the levels associated with a decrease in blood pressure, a reduction in salt sensitivity, and a minimal risk of kidney stones. Signs and symptoms of low potassium include muscle weakness and cramps, respiratory distress, and constipation. Severe potassium depletion can cause the heart to have abnormal contractions and can even be fatal. High levels of potassium in the blood, also affects the heart.

3.5.4. Hydration Status

High-Hydration Status: Water Intoxication/ Hyponatremia

Water intoxication mainly affects athletes who overhydrate. Water intoxication is extremely rare, primarily because healthy kidneys are capable of excreting up to one liter of excess water per hour. Overhydration was unfortunately demonstrated in 2007 by Jennifer Strange, who drank six liters of water in three hours while competing in a "Hold Your Wee for a Wii" radio contest. Afterward she complained of a headache, vomited, and died.

Low-Hydration Status: Dehydration

Dehydration refers to water loss from the body without adequate replacement. It can result from either water loss or electrolyte imbalance, or, most commonly, both. Dehydration can be caused by prolonged physical activity without adequate water intake, heat exposure, excessive weight loss, vomiting, diarrhea, blood loss, infectious diseases, malnutrition, electrolyte imbalances, and very high glucose levels.

Physiologically, dehydration decreases blood volume. The water in cells moves into the blood to compensate for the low blood-volume, and cells shrink. Signs and symptoms of dehydration include thirst, dizziness, fainting, headaches, low blood-pressure, fatigue, low to no urine output, and, in extreme cases, loss of consciousness and death. Signs and symptoms are usually noticeable after about 2 percent of total body water is lost.

Chronic dehydration is linked to higher incidences of some diseases. There is strong evidence that low-hydration status increases the risk for kidney stones and exercise-induced asthma. There is also some scientific evidence that chronic dehydration increases the risk for kidney disease, heart disease, and the development of hyperglycemia in people with diabetes. Older people often suffer from chronic dehydration as their thirst mechanism is no longer as sensitive as it used to be.

Heat Stroke

Heat stroke is a life-threatening condition that occurs when the body temperature is greater than 105.1°F (40.6°C). It is the result of the body being unable to sufficiently cool itself by thermoregulatory mechanisms. Dehydration is a primary cause of heat stroke as there are not enough fluids in the body to maintain adequate sweat production, and cooling of the body is impaired. Signs and symptoms are dry skin (absence of sweating), dizziness, trouble breathing, rapid pulse, confusion, agitation, seizures, coma, and possibly death. Dehydration may be preceded by heat exhaustion, which is characterized by heavy sweating, rapid breathing, and fast pulse. The elderly, infants, and athletes are the most at risk for heat stroke.

DASH Diet (Regulating Dietary Sodium To Reduce Hypertension)

Figure 3.5.4.1 *Measuring Blood Pressure*

Source: "Testing a GI's blood pressure at Guantanamo" by Charlie Helmholt/ Public Domain

The DASH-Sodium trial was a clinical trial which evaluated the effects of a specified eating plan with or without reduced sodium intake. The DASH diet is an eating plan that is low in saturated fat, cholesterol, and total fat. Fruits, vegetables, low-fat dairy foods, whole-grain foods, fish, poultry, and nuts are emphasized while red meats, sweets, and sugar-containing beverages are mostly avoided. In this study, people on the low-sodium (1500 milligrams per day) DASH diet had mean systolic blood pressures that were 7.1 mmHg lower than people without hypertension not on the DASH diet. The effect on blood pressure was greatest in participants with hypertension at the beginning of the study who followed the DASH diet. Their systolic blood pressures were, on average, 11.5 mmHg lower than participants with hypertension on the control diet.[1]

Following the DASH diet not only reduces sodium intake, but also increases potassium, calcium, and magnesium intake. All of these electrolytes have a positive effect on blood pressure, although the mechanisms by which they reduce blood pressure are largely unknown.

Try for Yourself

The National Heart, Lung, and Blood Institute has prepared an informative fact sheet on the DASH diet: http://www.nhlbi.nih.gov/health/public/heart/hbp/dash/new_dash.pdf.
Use the food-group charts to help design a daily menu that follows the DASH eating plan.

1. Sacks, FM, Svetkey LP, et al. Effects on Blood Pressure of Reduced Dietary Sodium and the Dietary Approaches to Stop Hypertension (DASH) Diet. N Engl J Med. 2001; 344(1), 3–10. http://www.ncbi.nlm.nih.gov/pubmed/11136953. Accessed September 22, 2017.

3.5.5. Beverages

Reading the Label

Most beverages have a Nutrition Facts panel and ingredients list, but some, such as coffee (for home consumption), beer, and wine, do not. As with foods, beverages that are nutrient-dense are the better choices, with the exception of plain water, which contains few to no other nutrients. Beverages do not make you full; they satiate your thirst. Therefore, the fewer calories in a beverage the better it is for avoiding weight gain. For an estimate of kilocalories in various beverages see Table 3.5.5.1 "Calories in Various Beverages".

Table 3.5.5.1 *Calories in Various Beverages*

Beverage	Serving size (oz)	Kilocalories
Soda	12.0	124–189
Bottled sweet tea	12.0	129–143
Orange juice	12.0	157–168
Tomato/vegetable juice	12.0	80
Whole milk	12.0	220
Nonfat milk	12.0	125
Soy milk	12.0	147–191
Coffee, black	12.0	0–4
Coffee, with cream	12.0	39–43
Caffe latte, whole milk	12.0	200
Sports drink	12.0	94
Beer	12.0	153
White wine	5.0	122

Source: How Many Calories Are in Your Drink? https://www.webmd.com/diet/calories-in-drinks-and-popular-beverages. Created Nov 12, 2018. Sourced: Dec 22, 2020.

Beverages such as soda and alcohol contain a high amount of calories whereas beverages such as coffee contain less.

Beverage Consumption in the United States

In all age groups the consumption of total beverages provides, on average, 21 percent of daily caloric intake. This is 7 percent higher than the IOM acceptable caloric intake from beverages. Moreover, the high intakes of soft drinks and sugary beverages displace the intake of more nutrient-dense beverages, such as low-fat milk.

Scientific studies have demonstrated that while all beverages are capable of satisfying thirst they do not make you feel full, or satiated. This means that drinking a calorie-containing beverage with a meal only provides more calories, as it won't be offset by eating less food.

Popular Beverage Choices

Caffeine

Caffeine is a chemical called xanthine found in the seeds, leaves, and fruit of many plants, where it acts as a natural pesticide. It is the most widely consumed psychoactive substance and is such an important part of many people's lives that they might not even think of it as a drug. Up to 90 percent of adults around the world use it on a daily basis. According to both the FDA and the American Medical

Association the moderate use of caffeine is "generally recognized as safe." It is considered a legal psychoactive drug and, for the most part, is completely unregulated.

Typical Doses and Dietary Sources

What is a "moderate intake" of caffeine? Caffeine intakes are described in the following manner:

- **low–moderate intake:** 130–300 milligrams per day
- **moderate intake:** 200–300 milligrams per day
- **high intake:** 400 or more milligrams per day

The average caffeine consumption for American adults is considered moderate at 280 milligrams per day, although it is not uncommon for people to consume up to 600 milligrams per day. This works out to almost 4 ½ cups of coffee per day. The bitter taste of caffeine is palatable for many and coffee is the most readily available source of it, accounting for 70 percent of daily caffeine consumption. The second readily available source of caffeine is soft drinks, delivering 16 percent of daily caffeine. (In this case, the bitter caffeine taste is usually masked by a large amount of added sugar.) Tea is the third common source of caffeine, at 12 percent.

Just how much caffeine is there in a cup of coffee? It varies. The caffeine content of an average cup of coffee can range from 102 to 200 milligrams, and the range for tea is 40 to 120 milligrams. Table 3.5.5.2 "Caffeine Content in Various Beverages and Foods" provides useful information on the levels of caffeine found in common beverages. When estimating your total caffeine consumption remember it's not only in beverages, but also some foods and medicine.

Table 3.5.5.2 *Caffeine Content in Various Beverages and Foods*

Beverage/food	Caffeine (mg)
Starbucks Grande Coffee (16 oz.)	380
Plain brewed coffee (8 oz.)	102–200
Espresso (1 oz.)	30–90
Plain, decaffeinated coffee (8 oz.)	3–12
Tea, brewed (8 oz.)	40–120
Green tea (8 oz.)	25–40
Coca-Cola Classic (12 oz.)	35
Dr. Pepper (12 oz.)	44
Jolt Cola (12 oz.)	72
Mountain Dew (12 oz.)	54
Mountain Dew, MDX (12 oz.)	71
Pepsi-Cola (12 oz.)	38
Red Bull (8.5 oz.)	80
Full Throttle (16 oz.)	144
Monster Energy (16 oz.)	160
Spike Shooter (8.4 oz.)	300

Source: Caffeine.MedicineNet.com. http://www.medicinenet.com/caffeine/article.htm. Accessed October 2, 2011.

Large intakes of high caffeine beverages should be avoided.

Health Benefits

The most renowned effects of caffeine on the body are increased alertness and delay of fatigue and sleep. How does caffeine stimulate the brain? Caffeine is chemically similar to a chemical in our brains (adenosine). Caffeine interacts with adenosine's specific protein receptor. It blocks the actions of the adenosine, and affects the levels of signaling molecules in the brain, leading to an increase in energy metabolism. At the molecular level, caffeine stimulates the brain, increasing alertness and causing a delay of fatigue and sleep. At high doses caffeine stimulates the motor cortex of the brain and interferes with the sleep-wake cycle, causing side effects such as shakiness, anxiety, and insomnia. People's sensitivity to the adverse effects of caffeine varies and some people develop side effects at much lower doses. The many effects caffeine has on the brain do not diminish with habitual drinking of caffeinated beverages.

Tools for Change

Consuming caffeine in the evening and in the middle of the night will help keep you awake to study for an exam, but it will not enhance your performance on the next day's test if you do not get enough sleep. Drink caffeinated beverages in moderation at any time of the day or evening to increase alertness (if you are not sensitive to caffeine's adverse effects), but get the recommended amount of sleep.

It is important to note that caffeine has some effects on health that are either promoted or masked by the other beneficial chemicals found in coffee and tea. This means that when assessing the benefits and consequences of your caffeine intake, you must take into account how much caffeine in your diet comes from coffee and tea versus how much you obtain from soft drinks.

Photo by Jeremy Ricketts on unsplash.com / CC0

There is scientific evidence supporting that higher consumption of caffeine, mostly in the form of coffee, substantially reduces the risk for developing Type 2 diabetes and Parkinson's disease. There is a lesser amount of evidence suggesting increased coffee consumption lowers the risk of heart attacks in both men and women, and strokes in women. In smaller population studies, decaffeinated coffee sometimes performs as well as caffeinated coffee, bringing up the hypothesis that there are beneficial chemicals in coffee other than caffeine that play larger roles in the health benefits of coffee. A review of fifteen epidemiological studies in The Journal of the American Medical Association proposes that habitual coffee consumption reduces the risk of Type 2 diabetes.[1] The risk reduction was 35 percent for those who consumed greater than 6–7 cups of coffee per day and was 28 percent for those who consumed

1. van Dam R M, Hu FB. Coffee Consumption and Risk of Type 2 Diabetes: A Systematic Review. JAMA. 2005; 294(1), 97–104. http://jamanetwork.com/journals/jama/article-abstract/201177. Accessed September 22, 2017.

4–5 cups daily. These groups were compared with people who consumed less than 2 cups of coffee per day.

Parkinson's disease is an illness of the central nervous system causing many disorders of movement. Research scientists in Hawai'i found an inverse relationship between caffeine intake and the incidence of Parkinson's disease. Men who did not consume coffee had a five times more likely chance of Parkinson's disease than men who consumed more than 3 cups of coffee daily.[2]

In this study other caffeine sources, such as soft drinks and tea, were also associated with a reduced risk of Parkinson's disease. A review of several studies, published in the Journal of Alzheimer's Disease, has reaffirmed that caffeine intake may reduce the risk of Parkinson's disease in both men and women.[3] This review also took into consideration caffeine obtained from dietary sources other than caffeine, though the data on these is not as extensive or as strong as for coffee. There is also some scientific evidence that drinking coffee is linked to a much lower risk for dementia and Alzheimer's disease.[4]

2. Ross GW, et al. Association of Coffee and Caffeine Intake with the Risk of Parkinson's Disease. JAMA. 2000; 283(20), 2674–79. http://jamanetwork.com/journals/jama/fullarticle/192731. Accessed September 22, 2017.
3. Costa J, et al. Caffeine Exposure and the Risk of Parkinson's Disease: A Systematic Review and Meta-Analysis of Observational Studies. J Alzheimers Dis. 2010; 20, S221–38. http://www.ncbi.nlm.nih.gov/pubmed/20182023. Accessed September 22, 2017.
4. Patil H, Lavie CJ, O'Keefe JH . Cuppa Joe: Friend or Foe? Effects of Chronic Coffee Consumption on Cardiovascular and Brain Health. Missouri Medical. 2011;

Health Consequences

The acute adverse health effects of caffeine ingestion are anxiety, shakiness, and sleep deprivation. On a more chronic basis, some scientific reports suggest that higher caffeine intake is linked to negative effects on heart health and increased cardiovascular disease; although at this point most data suggests caffeine does not significantly increase either. A comprehensive review published in the American Journal of Clinical Nutrition reports that caffeine induces a modest increase in blood pressure lasting less than three hours in people with hypertension, but there is no evidence that habitual coffee consumption increases blood pressure long-term or increases the risk for cardiovascular disease.[5]

There is no good evidence that chronic caffeine exposure increases blood pressure chronically in people without hypertension.

Some have hypothesized that caffeine elevates calcium excretion and therefore could potentially harm bones. The scientific consensus at this time is that caffeine minimally affects calcium levels and intake is not associated with any increased risk for osteoporosis or the incidence of fractures in most women. Although the effect of caffeine on calcium excretion is small, postmenopausal women with risk factors for osteoporosis may want to make sure their dietary caffeine intake is low or moderate and not excessive.

108(6), 431–8. http://www.ncbi.nlm.nih.gov/pubmed/22338737. Accessed September 22, 2017.

5. Mesas AE, et al. The Effect of Coffee on Blood Pressure and Cardiovascular Disease in Hypertensive Individuals: A Systematic Review and Meta-Analysis. Am J Clin Nutr. 2011; 94(4), 1113–26. http://www.ncbi.nlm.nih.gov/pubmed/21880846. Accessed September 22, 2017.

The Caffeine Myth

A diuretic refers to any substance that elevates the normal urine output above that of drinking water. Caffeinated beverages are commonly believed to be dehydrating due to their diuretic effect, but results from scientific studies do not support that caffeinated beverages increase urine output more so than water. This does not mean that consuming caffeinated beverages does not affect urine output, but rather that it does not increase urine output more than water does. Thus, caffeinated beverages are considered a source of hydration similar to water.

Sports Drinks

Scientific studies under certain circumstances show that consuming sports drinks (instead of plain water) during high-intensity exercise lasting longer than one hour significantly enhances endurance, and some evidence indicates it additionally enhances performance. There is no consistent evidence that drinking sports drinks instead of plain water enhances endurance or performance in individuals exercising less than one hour and at low to moderate intensities. A well-concocted sports drink contains sugar, water, and sodium in the correct proportions so that hydration is optimized. The sugar is helpful in maintaining blood-glucose levels needed to fuel muscles, the water keeps an athlete hydrated, and the sodium enhances fluid absorption and replaces some of that lost in sweat. The American College of Sports Medicine states that the goal of drinking fluids during exercise is to prevent dehydration, which compromises performance and endurance.

The primary source of water loss during intense physical activity is sweat. Perspiration rates are variable and dependent on many factors including body composition, humidity, temperature, and type of exercise. The hydration goal for obtaining optimal endurance and performance is to replace what is lost, not to over-hydrate. A person's sweating rate can be approximated by measuring weight before and after exercise—the difference in weight will be the amount of water weight you lost.

The primary electrolyte lost in sweat is sodium. One liter of sweat can contain between 1,000–2,000 milligrams of sodium. Potassium, magnesium, and calcium are also lost, but in much lower amounts. If you are exercising at high intensity for greater than ninety minutes, it is important to replace sodium as well as water. This can be partly accomplished by consuming a sports drink. The highest content of sodium in commercial sports drinks is approximately 450 milligrams per liter and thus will not replace all lost sodium unless a person drinks several liters. This is **NOT** recommended, as water intoxication not only compromises performance, but may also be deadly. The sodium in sports drinks enhances fluid absorption so that rehydration is more efficiently accomplished. If you are not exercising for more than ninety minutes at a high intensity, dietary intake of sodium and other electrolytes should be sufficient for replacing lost electrolytes.

Who Needs Sports Drinks?

Children and adult athletes exercising for more than one hour at high-intensity (tennis, rowing, rugby, soccer, etc.) may benefit endurance-wise and possibly performance-wise from consuming a sports drink rather than water. However, consuming sports drinks provides no benefit over water to endurance, performance, or exercise recovery for those exercising less than an hour. In fact, as with all other sugary drinks containing few to no nutrients, they are only another source of calories. Drinking sports drinks when you are doing no exercise at all is not recommended.

Sports Drink Alternatives

Instead of a sports drink, you can replenish lost fluids and obtain energy and electrolytes during exercise by drinking plain water and eating a sports bar or snack that contains carbohydrates, protein, and electrolytes. Post-exercise, low-fat milk has been scientifically shown to be just as effective as a sports drink as a rehydration beverage and it is more nutrient-dense, containing carbohydrates, protein, and electrolytes, in addition to other vitamins.

The Bottom Line

Sports drinks consumed in excess by athletes or used by non-athletes simply are another source of added sugars, and thus extra calories, in the diet and provide no performance, exercise recovery or health benefit.

3.5.6. Test Your Knowledge

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3.6. FLEXIBILITY

3.6.1. What is Flexibility?

Introduction

One of the five health-related components of fitness is flexibility. Flexibility relates to the ability to move a joint through its full range of motion (ROM). Developing a complete fitness program requires taking time to emphasize this component by stretching. Unfortunately, as the American Council on Exercise points out, "Most people neglect flexibility training, limiting freedom of movement, physical and mental relaxation, release of muscle tension and soreness, and injury prevention."

Perhaps the reason it is so easy for people to overlook flexibility is because its benefits, while significant, are felt more than seen. However, failing to address this component of fitness can have serious consequences, especially as a person ages. Without flexibility, everyday tasks, such as sweeping the floor or even getting out of bed, become difficult. A reduced mobility of joints increases the risk of injury during regular activities, sports, and exercise routines, as well as the risk of occasional and chronic back pain.

Types of Flexibility

Flexibility is classified into two types: static and dynamic.

Static Flexibility. This type of flexibility is a measure of the limits of a joint's overall range of motion. It is measured by stretching and holding a joint in the position of its maximum range while using a measuring instrument to quantify that range. To achieve the maximum range, passive forces, the force generated from an external source, are required.

Dynamic flexibility. This type of flexibility is a measure of overall joint stiffness during movement. Unlike static flexibility, dynamic flexibility requires active force production, or your own muscles contracting. Because quantifying "stiffness," is difficult, dynamic flexibility is measured more subjectively. Assessment is based on how easy or difficult it is to perform certain tasks, such as swinging a tennis racket, climbing steps, or getting in and out of a car.

The aim of any good stretching program is to improve both static and dynamic flexibility so that normal range of motion (ROM) can be achieved. The definition of normal in this context is one developed from population studies that measured various areas of the body and established an average degree of movement for a particular joint.

Benefits of Flexibility and Stretching

Regular stretching provides many benefits, the most important of which is simple: flexibility provides freedom of movement and the ability to complete activities with greater ease and lower risk of injury or discomfort.

Healthy Joints and Pain Management

Many adults report pain and stiffness in joints. The number increases dramatically with age, and women are more likely to develop joint symptoms.

For adults, arthritis is one of the most common conditions, with approximately half of people 75 years and older diagnosed with arthritis.

Regular exercise, including stretching, is essential for people with arthritis to maintain function and manage joint pain. Even for those not affected by joint conditions, stretching increases joint mobility and function, and decreases joint stiffness and pain.

Imbalances in the muscles can cause discomfort and pain. For example, if the front of a person's thighs and hips gets too tight from a lack of flexibility, the tension will pull on the hips, where the muscles are attached. The result is the pelvis may be pulled forward and cause greater sway in your lower back. This affects posture and can eventually lead to pain and stiffness in the neck, shoulders, and lower back. Stretching all major muscle groups and joint areas regularly promotes good alignment and balance.

Muscle Relaxation and Stress Relief

Staying in one position for long periods of time, repetitive movements, and other everyday stressors can result in stiff muscles and knots, also called trigger points. Regular stretching decreases anxiety, blood pressure, and breathing rate, which help to relax muscles and aches and pains related to neuromuscular tension (stress). Flexibility exercises have also been prescribed successfully to treat dysmenorrhea, which is painful menstruation. It also relieves muscle cramps that can occur during exercise or participation in sports.

Other Benefits

In addition to the benefits listed above, research has documented additional benefits that provide good reasons for maintaining a routine of stretching.

Increased Blood Flow. Blood carries vital nutrients and oxygen to muscles and tissues. Stretching increases blood flow to the muscles being stretched, which helps them recover from exercise faster.

Reduced Risk of Developing Future Lower Back Pain. Although research is still inconclusive, most experts agree that muscle fitness and stretching exercises reduce the risk of developing lower back pain by counteracting the natural loss in muscle and connective tissue elasticity that occurs with aging.

Flexibility and Aging

For many college students, maintaining long-term flexibility is not a concern. For young adults, bending over to tie their shoes is painless. Walking around campus with a backpack requires minimal effort. However, ROM declines with age. Simple activities like rotating the head and neck to glance over the shoulders, getting in and out of a vehicle, or carrying groceries can become painful. Therefore, flexibility is critical in maintaining a high quality of life throughout the aging process.

The Inactivity-Mobility Cycle

Anyone who has suffered an injury and had to wear a splint, cast, or brace to immobilize a joint knows how important mobility is to overall health. Unfortunately, when ROM becomes restricted by arthritis or other injuries, activity declines. As activity declines, ROM continues to diminish as a result of inactivity, and a vicious cycle ensues. A simple stretching program can help alleviate this problem and break the cycle.

Improving Range of Motion

Joint ROM results from a combination of factors, which are classified as either internal or external. Internal structures relate to the physical structures of body tissue. External factors are non-structural and include gender, age, excess fat mass, muscle mass, environmental temperature, and restrictions in clothing or equipment.

Internal factors include joint structure/joint mechanics and the connective and soft tissue surrounding the joint. Because muscular actions, such as muscular contractions and stretching, are controlled by the nervous system, another internal factor can be attributed to the neuromuscular system and how the stretching and tension is managed.

Joint Structure

A joint is defined as a location on the skeletal system where two or more bones intersect and interact. For example, the humerus (upper arm) intersects with the radius and ulna (lower arm) at the point of the elbow. The bony formation of each joint structurally limits its ROM. For example, the shoulder joint, which is structurally a ball-in-socket joint, can rotate in multiple directions, giving it a wide range of motion. However, the knee joint is a modified hinge joint, which is limited to essentially a forward-backward direction of movement.

Additionally, ROM may be limited by excessive fat mass or even large muscle mass surrounding a particular joint. Although the amount of muscle mass and fat mass surrounding a joint can be altered by diet and activity levels, joint structure is permanent. As a result, little can be done to improve flexibility in this area.

Not only is range of motion related to the joint structure, but flexibility exercises are joint-specific. Stretching the hamstring will not improve flexibility in the shoulders. Likewise, flexibility in the shoulders may be excellent while fingers or ankles remain "stiff." As such, a complete and effective stretching program includes multiple stretches for various joints.

Connective and Muscle Tissue

Joints are surrounded and connected by muscles, tendons, ligaments, and skin. The head of the humerus fits into a small cavity to create the shoulder joint. However, those bones cannot remain in that position without the muscles, tendons, and ligaments that keep the joint tight and hold it in place. In addition, muscle tissue is surrounded with connective tissue, primarily collagen and elastin. As a joint moves through its normal range of motion, all of this soft tissue must stretch to accommodate the movement. Therefore, static and dynamic flexibility is probably most limited by the flexibility of the surrounding soft tissue, specifically the connective tissue.

While the exact mechanisms of how flexibility is changed is not well understood, they do appear to be related to the elastic and plastic properties of the connective tissue. Elasticity is defined as the ability to return to resting length after passive stretching (i.e., elastic recoil). Like a spring, soft tissues stretch and then recoil to their resting position. Plasticity is the tendency to assume a greater length after passive stretching (i.e., plastic deformation). Stretching that spring composed of soft tissues will change its resting position to a new longer length. The goal of a flexibility program is to repeatedly overload the elastic properties of the muscle to elicit plastic deformation over time. Experts suggest that a slow, sustained stretch for 30–90 seconds is necessary to produce chronic plastic deformation.

Neuromuscular System

Modern cars come equipped with a central computer and sensors to troubleshoot problems with the vehicle. Sensors in the engine monitor temperature. Sensors on the wheels gauge tire pressure while sensors in the gas tank alert the driver when fuel is low. Much like a car, our bodies are equipped with sensors, called **proprioceptors**, that help us manage movement and prevent injury.

Muscles have two specific types of proprioceptors that determine the length and tension of the muscle. These proprioceptors are called muscle spindles and Golgi tendon organs (GTOs).

Muscles spindles lie parallel to the regular muscle and help determine the length of muscles when they are being stretched. When a muscle is stretched, it sends signals to the central nervous system causing the stretched muscle to contract. This resistance to the stretch, called **stretch reflex** is generated by the nervous system's reflexive stimulus sent to the stretching muscle. That same signal also causes the **antagonist**, or opposing muscle to relax, called **reciprocal inhibition**. As such, when the upper thigh (quadriceps) are stretched, the hamstrings (antagonist to the quadriceps) relax.

The **Golgi tendon organs** (GTOs) are located near the muscle-tendon junction, the end points of the muscle, and relay messages to the central nervous system regarding muscle lengthening and tension of the muscle. When activated, these signals will override the stretch reflex causing a sudden relaxation of the stretching muscle. This is called **autogenic inhibition** or the **inverse myotatic reflex**. This inhibitory reflex can only occur after the muscle has been stretched for 5 seconds or longer. This is why, to effectively stretch, movements must be sustained for long, slow increments of time. Otherwise, the resistance encountered from the stretch reflex will not be overridden and lengthening cannot occur. Whether signaling the muscles to contract or relax, the neuromuscular system manipulates the stretched muscle, presumably as a protective mechanism to prevent injury.

3.6.2. Improving Flexibility

Stretching Techniques

Research has identified multiple stretching techniques that aid in improving ROM. Regardless of the specific technique or specific mode used, each technique can be performed using either active or passive mode. **Active stretching**, also called unassisted stretching, is done individually without an external stimulus. **Passive stretching**, or assisted stretching, is when a partner or trainer is used as the stimulus in the stretching exercise. Both modes are effective and can be applied to each of the techniques described below.

Static Stretching

The technique most commonly prescribed and used to improve flexibility is the static stretch. A static stretch involves slow, gradual, and controlled movements. The muscle group is stretched toward the end of the joint's ROM until the point of mild discomfort is reached. Once that point is reached, the stretch is held in a "static" position for 30 to 90 seconds. After the prescribed time, the stretch can be repeated.

Some of the major advantages of static stretching are that it is

- generally considered safe (some common stretches are "contraindicated"),
- simple to perform, and
- effective at increasing ROM.

The only major disadvantage comes from stretching too much, which can reduce strength and may make joints unstable. Of course, this potential risk applies to all of the techniques.

Ballistic Stretching

Ballistic stretching involves forceful bouncing or ball-like movements that quickly exaggerate the joint's ROM without holding the position for any particular duration. This type of stretching involves dynamic movements somewhat like those done by athletes during sports events. In that regard, ballistic stretching is seen as being very specific to particular sports and athletes. However, one criticism of ballistic stretching is that because of the short duration of the stretch and the forceful nature of ballistic movements, the muscular contraction from the stretch reflex may cause muscle soreness or even injury. For that reason, many experts regard ballistic stretching as unsafe. Also, many researchers contend that it is less effective at improving ROM. Nonetheless, the American College of Sports Medicine (ACSM) still lists ballistic stretching as one method to effectively increase flexibility.

Dynamic Stretching

Ballistic stretching is a form of dynamic stretching. However, when referring to dynamic stretching routines, most fitness professionals are referring to dynamic movements that do not involve forceful bouncing motions. Instead, dynamic stretching, in this context, suggests performing exaggerated sports movements in a slower, more controlled manner. For example, a sprinter may use several exaggerated stride lengths before a race to improve hip ROM.

An advantage of dynamic stretching is its ability to target and improve dynamic flexibility, which in turn may improve performance. A disadvantage comes from the movements involved, which often require good balance and coordination. Since mastering the correct form requires time and a certain level of athleticism, dynamic stretching may not be suitable for certain populations.

Proprioceptive Neuromuscular Facilitation (PNF) Stretching

This type of exercise usually involves a partner. The cycle starts with a stretch. This movement is immediately followed by an isometric muscle contraction of the same muscles just stretched- they contract while pushing back against resistance (provided by the partner). This contraction is then followed by another passive stretch. This type of stretch is also named contract-relax stretch because of the sequence of movements involved. Other types of PNF stretching involve different sequences of stretching and contracting movements including additional steps.

As the name of the technique implies, PNF stretching emphasizes the natural interaction of the proprioceptors with the muscles to increase the ROM during the stretch. Remember that during the stretch, the muscle spindles cause two responses: the stretch reflex and the reciprocal inhibition (the relaxing of the antagonist muscle). After 5 seconds, the GTOs then override the muscle spindle's signals causing autogenic inhibition. Because the muscle is relaxed, it can be stretched more easily.

Creating an Effective Stretching Program

The ACSM has made specific recommendations on how to design a flexibility program. However, before examining these recommendations in depth, you should first evaluate your current flexibility status by assessing various joints' ROM. Specifically, performing the sit-and-reach test will assess your hamstring and lower back flexibility while using a goniometer can be used to assess your ankles, knees, hips, neck and shoulders.

Setting Goals

Once you determine which of your joints are the most and least flexible, you can set some realistic goals to improve or maintain your ROM. Be specific when you set goals. Instead of just saying, "I want to increase my flexibility," identify the specific area of the body you intend to improve. You will also want to make sure your goal can be measured. A better way to state your goal is, "I will improve my sit-and-reach score by 4 cm by the end of the semester." Notice this goal, as stated, includes a specific area, is measurable, and includes a deadline. By stating your goal properly, you will increase the likelihood of achieving it.

Applying the FITT Principle

As mentioned previously, the ACSM and CSEP have made recommendations for designing a flexibility program based on the FITT Principle (Frequency, Intensity, Time and Type). https://csep.ca/news.asp?a=view&id=140&pageToView=9

As the ACSM recommends, your flexibility program should include multiple stretching exercises that target all major joints, including the neck, shoulders, elbows, wrists, trunk, hips, knees, and ankles.

After selecting your exercises, follow the recommendations below when performing your routine:

- **frequency:** Stretch a minimum of 2-3 days per week, ideally 5-7 days per week.
- **intensity:** Stretch to the point of tightness or mild discomfort.
- **time (duration of each stretch):** Stretch for a minimum of 10 seconds for very tight muscles with an emphasis on progressing to 30-90 seconds. Complete 2-4 repetitions of each stretch.
- **type (mode):** Select the technique that best suits your circumstances: static, dynamic, ballistic, or proprioceptive neuromuscular facilitation.

When to Stretch

Although stretching can be done any time, the ACSM traditionally recommends that flexibility training be incorporated into the warm up or cool down phase of an exercise session. Recent studies suggests that stretching before an exercise session will compromise the force-producing capabilities of muscles and should be avoided. Therefore, it is recommended that stretching be restricted to after the warm- up or workout, when the temperature of the body and muscles has increased. Additional evidence pertaining to this concept shows that applying heat packs for 20 minutes to increase muscle temperature can increase hamstring flexibility more so than 30 seconds of static stretching. These findings confirm that temperature also plays a significant role in muscle ROM.

The link below offers guidelines about how certain types of

stretching before performing activities can affect strength and performance:
https://journals.lww.com/acsm-healthfitness/fulltext/2016/09000/flexibility_exercises_and_performance.4.aspx

Stretching Safely

In addition to warming up your muscles before performing stretching exercises, additional precautions can be taken to ensure the safety of your routine. When muscles are stretched quickly and forcefully, the stretch reflex can be activated. This creates significant tension because the muscle fibers will not only be stretching but also attempting to contract. As mentioned previously, this is one of the reasons ballistic stretching may not be suitable for everyone. To avoid this, stretch slowly and in a controlled fashion while holding the stretch for 10 seconds or more.

Stretches to Avoid

Research indicates that some stretches are contraindicated, which means they are not recommended because they provide little to no benefit and may cause injury. To avoid injury, it is important to consider personal limitations before performing a stretch exercise.

Assessing Your Flexibility

The first step in creating a successful flexibility program is to assess your own flexibility.

[Assessment Exercises]

Terminology Checklist

Static flexibility: the outermost limit of a stretched muscle measured while holding a stretch in place. This can also refer to a technique used to improve the outermost limit of a stretched muscle performed by holding stretches for 15-60 seconds.

Dynamic flexibility: the relative degree of ease a muscle can move through a normal range of motion. The can also refer to a technique used to improve static flexibility and ease of motion done by performing exaggerated movements.

Elasticity: the ability of the muscle to return to its resting length after being stretched.

Plasticity: the tendency of a muscle to assume a greater length after stretching.

Proprioceptors: sensors within muscles that send feedback to the central nervous system conveying muscular length and tension. The two primary sensors related to flexibility are Golgi Tendon Organs (GTO's) and muscle spindles.

Joint structure: the fixed arrangement of a joint that is a determining factor for range of motion. An example would be ball-in- socket joint or modified hinge joint.

Myotatic reflex: a reflexive stimulus of the muscle to contract as a muscle is being stretched.

Reciprocal inhibition: the principle that when one muscle is stimulated to contract the opposing muscle is will relax.

Autogenic inhibition: an inhibitory reflex that allows one sensor in the muscle to override the signals of another sensor. Also called the inverse myotatic reflex.

Active stretching: a mode for stretching that is unassisted or involves no internal stimulus.

Passive stretching: a mode for stretching that uses an external source such as a partner or gravity to assist in the movements.

Ballistic stretching: a technique used to improve range of motion performed by gently bouncing back and forth to stretch and relax the muscle.

Proprioceptive neuromuscular facilitation (PNF): a technique used to improve range of motion performed by a sequence of stretching and contracting muscles. These sequences target the neuromuscular structures to facilitate relaxation of reflexive activity.

3.6.3. Test Your Knowledge

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3.7. BODY COMPOSITION

"Body Composition" is an adaptation of the chapter "Body Composition" from *Concepts of Fitness and Wellness, 2nd Edition*, by Scott Flynn, Lisa Jellum, Jonathan Howard, Althea Moser, David Mathis, Christin Collins, Sharryse Henderson, and Connie Watjen, which is licensed under a CC BY NC SA 4.0 license. New material has been incorporated that includes Canadian guidelines. Information that is not relevant to this course has been removed.

3.7.1. Body Weight Versus Body Composition

Limitations of the BMI Calculation

Body composition measures the different tissues that make up our body. Normally tissues are grouped into three categories; fat mass, lean mass (including skeletal muscle and organs), and bone mass. There are several ways of measuring body composition, some being more accurate than others. The most common methods include DEXA scan, bio-electrical impedance and skin folds. Since these methods either require trained operating personal or expensive machinery, the body mass index (BMI) calculation is often used as an easy, inexpensive way of estimating body composition.

Body Mass Index = Weight (kg) / Height (m)^2

There are limitations to only considering body composition measures such as weight or BMI. In Table 3.7.1.1 "Variances in Body Composition Between Individuals With the Same Weight" you can see that the lean and obese males have the same weight but that because of their difference in height, one has a lean BMI and the other has an obese BMI. Furthermore, even though the obese male and bodybuilder have the same BMI, the obese male has a waist circumference that is classified as unhealthy where as the bodybuilder has a waist circumference that is classified as healthy.

Table 3.7.1.1 *Variances in Body Composition Between Individuals With the Same Weight*

	Lean male	Male with obesity	Bodybuilder male
Weight	75 kg	75 kg	75 kg
Height	1.8 m	1.5 m	1.5
BMI	23 kg/m^2	33 kg/m^2	33 kg/m^2
Waist circumference	85 cm	110 cm	80 cm

Individuals with the same body weight can vary drastically in BMI and waist circumference. Weight, height, BMI and waist circumference should all be considered when examining body composition.

The major limitation of the BMI calculation is that it does not differentiate between fat mass and lean mass. Therefore a muscular individual will be classified as obese even though they have minimal fat tissue. Ideally weight, height and waist circumference can be obtained to give a better representation of an individuals body composition. This discrepancy also exists when applying BMI to the senior population. As age increases, muscle mass declines. Seniors who have experienced years of muscle mass decline but increased body fat may maintain a constant weight despite having a very different body composition.

Other criticisms of using BMI as a health risk assessment tool include its failure to take age sex or gender into account. As discussed previously, females naturally have more body fat yet are classified in the same context as males. Because this measurement is so widely used by physicians, patients continue to express concerns about the validity of BMI as an indication of fatness.

Regardless of the criticisms, BMI as used for the general population, has been shown to be a reasonable predictor of health outcomes. At its core, it is not intended to be an estimate of body composition, i.e., measure FM and FFM. Instead, it is intended to be used as an estimate of healthy/unhealthy levels of body fat. When used as a means of tracking weight changes over time it can be a valuable tool in predicting health and for recommending lifestyle modifications.

How To Measure Body Composition

Multiple methods exist to estimate body composition. Remember, body composition is the ration of FM and FFM used to help determine health risks. Of the other methods already mentioned (waist, waist- to-hip ratio, and BMI), none provide estimates of body composition but do provide measurements of other weight- related health markers, such as abdominal fat. Experts have designed several methods to estimate body composition. While they are not flawless, they do provide a fairly accurate representation of body composition. We discuss the five most common methods here.

Hydrostatic Weighing (Underwater Weighing)

At one time, hydrostatic weighing (also and maybe more accurately called hydrodensitometry) was considered the criterion for measuring body composition. Many other methods are founded on this model, in one form or another. This method attempts to measure the density of the body by applying Archimedes' principle: density = mass/volume. The mass and volume components are measured by using dry weight and then weight while being submerged in a water tank. Since fat is less dense than muscle tissue, a person with more body fat will weigh less in the water than a similar person with more lean mass. Using the measurements, the density can be determined and converted into body fat percentage. With a small margin of error (around 1-2%) this method is very accurate. Unfortunately, the expense and practicality of building and maintaining a water tank limits access for most. Also, for those with a fear of water, this would obviously not be the preferred method.

Dual Energy X-Ray Absorptiometry (DEXA)

Replacing underwater weighing as the new "gold standard," is DEXA. While underwater weighing accurately compartmentalizes FM and FFM, DEXA adds a third compartment by using low-radiation X-rays to distinguish bone mineral. This addition slightly increases the accuracy of DEXA by eliminating some of the guess work associated with individual differences, such as total body water and bone mineral density.

Originally, DEXA scanners were designed to determine and help diagnose bone density diseases. As a result, they can be found in many physicians' offices. However, a full body scan, which takes only a few minutes, is all that is needed to also determine body fat percentage.

Major disadvantages to this method are its high cost and the need for a well-trained professional to operate the equipment and analyze the results.

Air Displacement (Plethysmography)

A good alternative to more expensive methods, air displacement determines body density using the same principle as underwater weighing, by measuring mass and volume. Clearly, the main difference is that mass and volume are being determined by air displacement rather than water displacement. Using a commercial device (the Bod Pod is most commonly referenced), a person sits in a chamber that varies the air pressure allowing for body volume to be assessed. Air displacement provides a viable alternative for those with a fear of water.

Like many other methods, the expense, availability, and training of personnel Air Displacement requires limit accessibility. Additionally, its accuracy is slightly less than underwater weighing.

Bio-electrical Impedance Analysis (BIA)

BIA takes a slightly different approach to measuring FFM. The premise behind BIA is that FFM will be proportional to the electrical conductivity of the body. Fat-tissue contains little water, making it a poor conductor of electricity; whereas, lean tissue contains mostly water and electrolytes, making it an excellent conductor. BIA devices emit a low-level electrical current through the body and measure the amount of resistance the current encounters. Based on the level of impedance, a pre-programed equation is used to estimate body fat percentage.

The most accurate BIA devices use electrodes on the feet and hands to administer the point-to-point electrical current. The margin of error for these devices falls in the range of 3–5%. Portable or handheld BIA devices that only measure lower or upper body conductivity have a higher margin of error (4–8%).

Because BIA devices primarily measure hydration, circumstances that may influence hydration status at the time of measurement must be taken into account. Recent exercise, bladder content, hydration habits, and meal timing can cause wide measurement variations and influence accuracy. However, this method is generally inexpensive, often portable, and requires limited training to use, making it a very practical option.

Skinfold Analysis

Skinfold analysis is a widely used method of assessing body composition because of its simplicity, portability, and affordability. It is also fairly accurate when administered properly. Margins of error are about 4–7%, depending on the quality of the skinfold calipers and skill of the administrator/technician. The assumption of skinfold measurement is that the amount of subcutaneous fat is proportionate to overall body fat. As such, a technician pinches the skin at various sites and uses calipers to measure and record the diameter of the skin folds. These numbers can then be plugged into an equation to generate an estimate of body fat percentage.

The proportionality of subcutaneous fat and overall body fat depends on age, gender, ethnicity, and activity rates. As such, technicians should use the skinfold technique specific to the equation that accounts for those variables to improve accuracy.

3.7.2. Risks of High Body Fat

Diseases Associated with Excessive Body Fat

According to the U.S. National Institute of Health (NIH), a wide array of diseases can be linked to excessive body fat.[1]

These diseases include the following:

- type II diabetes mellitus
- hypertension
- cancer
- cerebrovascular disease (stroke)
- cardiovascular disease
- metabolic syndrome
- lung disorders (such as sleep apnea and asthma)
- musculoskeletal diseases (such as osteoarthritis and gout)
- gallbladder disease
- pancreatitis
- non-alcohol fatty liver disease
- dementia
- psychological problems and quality of life issues
- kidney disease
- pregnancy problems

An explanation of how being overweight relates to each disease can be viewed by clicking on the following link.

NIH-Explanation of Disease Risk Associated with Overweight

1. https://www.niddk.nih.gov/health-information/weight-management/health-risks-overweight?dkrd=hispt0908

How Much Fat is Needed?

Fat is a necessary component of daily nutrition. It is needed for healthy cellular function, energy, cushioning for vital organs, insulation, and for food flavor.

Fat storage in the body consists of two types of fat: **essential** and **nonessential** fat. Essential fat is the minimal amount of fat necessary for normal physiological function. Fat above the minimal amount is referred to as nonessential fat. It is generally accepted that an overall range of (approximately) 11-20 percent for men and (approximately) 16-30 percent for women is considered good health. A body composition within the recommended range suggests a person has less risk of developing obesity-related diseases, such as diabetes, high blood pressure, and even some cancers.

A woman's essential fat range is naturally greater than a man's because of fat deposits in breasts, uterus and sex-specific sites. In both males and females, non-essential fat reserves can be healthy, especially in providing substantial amounts of energy.

Excessive body fat is categorized by the terms overweight and obesity. These terms do not implicate social status or physical attractiveness, but rather indicate health risks. Overweight is defined as the accumulation of non-essential body fat to the point that it adversely affects health. Overweight is classified as a BMI of 25-29.9 kg/m^2.

Obesity is characterized by excessive accumulation of body fat and can be defined as a more serious degree of being overweight. Classifications of obesity begin at a BMI of 30 kg/m^2 in both males and females.[2]

2. https://www.unm.edu/~lkravitz/Article%20folder/underbodycomp.html

Other Health Risks

Diseases are not the only concern with an unhealthy level of body fat. Several others are listed below.

Performance of Physical Activity. An important component of a healthy lifestyle and weight management is regular physical activity and exercise. To the contrary, those who live a sedentary lifestyle will find it more difficult to maintain a healthy body weight or develop adequate musculature, endurance, and flexibility. Unfortunately, additional body weight makes it more difficult to be active because it requires more energy and places a higher demand on weak muscles and the cardiovascular system. The result is a self-perpetuating cycle of inactivity leading to more body weight, which leads to more inactivity.

Emotional Wellness. Studies indicate obesity is associated with a 25% increase in anxiety and mood disorders, regardless of age or gender. Other studies suggest increases in BMI significantly increase the incidence of personality disorders and anxiety and mood disorders. Additional studies have been able to associate a higher incidence of psychological disorders and suicidal tendencies in obese females compared with obese males.[3]

Premature Death. The association between obesity and diseases, such as cancer, CVD, and diabetes, suggests that people with more body fat generally have shorter lifespans. The U.S. Center for Disease Control (CDC) estimated between 1997-2000 up to 365,000

3. Knight, J. Diseases and Disorders Associated with Excess Body Weight, Annals of Clinical Laboratory Science, Spring 2011, vol. 41 no.2 107-121, http://www.annclinlabsci.org/content/41/2/107.full

deaths each year can be linked with obesity, representing nearly 15% of all deaths. Other studies have tied the Years of Life Lost to body mass index measurements, estimating anywhere from 2 to 20 years can be lost, depending on ethnicity, age at time of obese classification, and gender.[4]

Economic Impact. The physical harm caused by obesity and overweight is mirrored by its economic impact on the health care system. Overweight and obesity also contribute to loss of productivity at work through absenteeism and presenteeism, defined as being less productive while working. The annual U.S. nationwide productivity costs fall within the range of from $3.38 to $6.38 billion.[5]

4. .Pollack, L. M., & Colditz, G. A. Life Years Lost Associated with Obesity-Related Diseases for U.S. Non-Smoking Adults, 2013, PLoS ONE, 8(6), e66550, http://doi.org/10.1371/journal.pone.0066550
5. Centers for Disease Control and Prevention, Retrieved Jan 2018, CDC: Adult Obesity Causes and Consequences https://www.cdc.gov/obesity/adult/causes.html

3.7.3. Body Fat Distribution

Body composition measurements can help determine health risks and assist in creating an exercise and nutrition plan to maintain a healthy weight. However, the presence of unwanted body fat is not the only concern associated with an unhealthy weight. Where the fat is stored, or fat distribution, also affects overall health risks.

Non-essential fat is primarily stored in adipose tissue, or fat cells, located on the surface of the body and surrounding the body's organs. Surface fat, located just below the skin, is called subcutaneous fat. Fat that lies deeper in the body surrounding the body's organs is called visceral fat. Unlike subcutaneous fat, visceral fat is more often associated with abdominal fat. Researchers have found that excessive belly fat decreases insulin sensitivity, making it easier to develop type 2 diabetes. It may also negatively impact blood lipid metabolism, contributing to more cases of cardiovascular disease and stroke in patients with excessive belly fat.[1]

Body fat distribution can easily be determined by simply looking in the mirror. The outline of the body, or body shape, would indicate the location of where body fat is stored. Abdominal fat storage patterns are generally compared to the shape of an apple, called the android shape. This shape is more commonly found in males and post- menopausal females. In terms of disease risk, this implies males and post- menopausal females are at greater risk of developing health issues associated with excessive visceral fat. Individuals who experience chronic stress tend to store fat in the abdominal region.

1. Doheny, K. The Truth About Fat, WebMD, July 2009, http://www.webmd.com/diet/features/the-truth-about-fat#4

A pear-shaped body fat distribution pattern, or gynoid shape, is more commonly found in pre-menopausal females. Gynoid shape is characterized by fat storage in the lower body such as the hips and buttocks. This shape may be connected to females' child- bearing abilities as enzymes associated with fat-storage and mobilization are activated during certain times of pregnancy and postpartum.

Besides looking in the mirror to determine body shape, people can use an inexpensive tape measure to measure the diameter of their hips and waist. Many leading organizations and experts currently believe a waist circumference of 88cm or greater for males and 102cm or greater for females significantly increases risk of disease.[2]

In addition to measuring was circumference, measuring the waist and the hips and using a waist-to-hip ratio (waist circumference divided by the hip circumference) is equally effective at predicting body fat-related health outcomes. According to the National Heart, Lung, and Blood Institute, a ratio of greater than 0.82 for females and 0.94 for males is associated with a higher risk of developing heart disease, diabetes, and hypertension.[3]

2. Harvard T.H. Chan School of Public Health, Retrieved March 2018, HSPH: Waist Size Matters https://www.hsph.harvard.edu/obesity-prevention-source/obesity- definition/abdominal-obesity/
3. National Heart, Lung, and Blood Institute, Retrieved Jan 2018, NIH: Classification of Overweight and Obesity by BMI, Waist Circumference, and Associated Disease Risks https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi_dis.htm

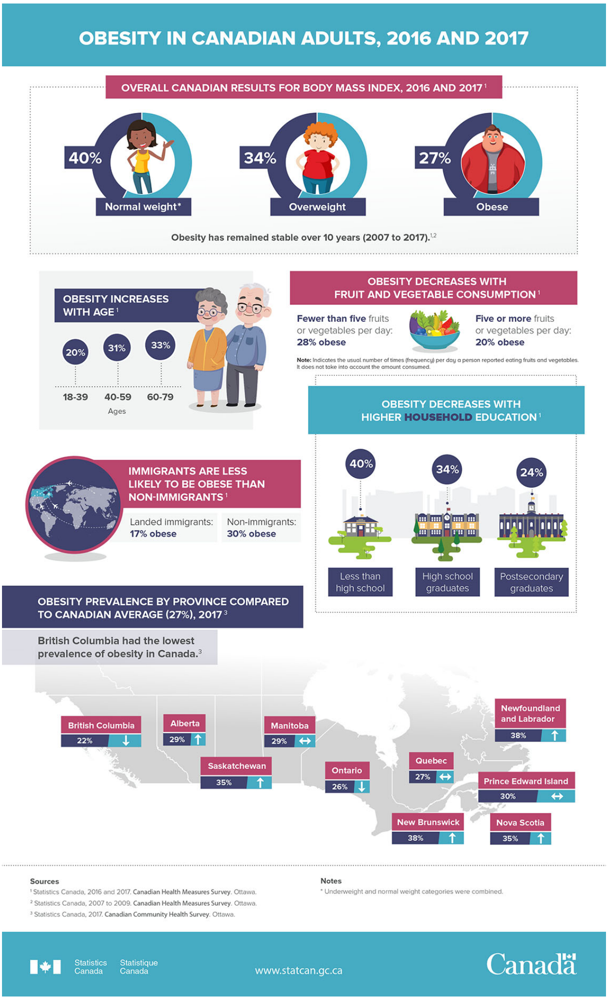
3.7.4. Weighing In on Canada

Weighing In on Canada

In 2018 an examination of Canadian BMIs revealed that 26.8% of Canadians were obese and 36.3% were overweight. These numbers increased between 2015 and 2018 by about 2%. Overall, males were more overweight and obese than females. [1]

Figure 3.7.4.1 *Obesity in Canadian Adults*

1. Overweight and obese adults. Statistics Canada. https://www150.statcan.gc.ca/n1/en/pub/82-625-x/2019001/article/00005-eng.pdf?st=U0H1ykqg. Updated on June 25, 2019. Accessed on March 10, 2020.



Source: Statistics Canada, Obesity in Canadian Adults, 2016 and 2017, March 10, 2020. Reproduced and distributed on an "as is" basis with the permission of Statistics Canada.

When examining the BMIs of Canadian children it was found that 1 in 7 children and youth are obese. However in the past decade, rates of excess weight have been relativity stable in Canadian children and youth. [2]

With such a diverse population in the U.S. and Canada and with an understanding of how BMI is calculated, it is only natural to question the high number of overweight and obese citizens based on BMI alone. However, it is generally believed this is an accurate portrayal of weight status. In a study attempting to compare BMI measurements to actual body fat percentage, it was determined that the total number of obese citizens may be underestimated, and its current prevalence may be worse than is currently being reported.

What Can Be Done?

With the available tools to identify health risks associated with body fat, anyone concerned about their health should gather as much data about body composition and body fat distribution as possible. Compiling multiple measurements and analyzing them provides a better idea of a person's current health status and will help determine the next course of action. For example, BMI alone can be beneficial. But when combined with waist circumference, a greater understanding of risk can be achieved. Likewise, when combining BMI and waist circumference with body fat percentage, an ideal conclusion of health status can be made.

The next course of action is to set goals and formulate a plan to get to a healthy range of weight and body fat percentage. Where

2. Rao, D. et al (2016). Childhood overweight and obesity trends in Canada. Health Promotion and Chronic Disease Prevention in Canada : Research, Policy and Practice, 36(9), 194–198.

weight loss is needed, the plan should include a balance of calorie restriction and physical activity/exercise. This might also include tracking your current eating and activity habits. More specific information on weight management strategies will be discussed in a later chapter.

Low Body Fat

Because more people experience excess body fat, the focus up to this point has been on health concerns related to overweight and obesity. However, fat is an essential component to a healthy body, and in rare cases, individuals have insufficient fat reserves, which can also be a health concern. The range of essential body fat for males is 3-5% and 8-12% for females. Attempting to, or intentionally staying in those ranges, through excessive exercise or calorie restriction is not recommended. Unfortunately, low body fat is often associated with individuals struggling with eating disorders, the majority of whom are females.

The main concern of low body fat relates to the number and quality of calories being consumed. Foods not only provide energy but also provide the necessary nutrients to facilitate vital body functions. For example, low amounts of iron from a poor diet can result in anemia. Potassium deficiencies can cause hypokalemia leading to cardiovascular irregularities. If adequate calcium is not being obtained from foods, bone deficiencies will result. Clearly, having low body fat, depending on the cause, can be equally as detrimental to health as having too much.

The health concerns most often linked to low body fat are:

- reproductive disorders
- infrequent or missing menstrual cycles
- respiratory disorders

- immune system disorders
- circulatory disorders
- premature death

In some cases, despite attempts to gain weight, individuals are unable to gain the pounds needed to maintain a healthy weight. In these cases, as in the case of excess fat, a holistic approach should be taken to determine if the low levels of body fat are adversely affecting health. These individuals should monitor their eating habits to assure they are getting adequate nutrition for their daily activity needs. Additionally, other lifestyle habits should be monitored or avoided, such as smoking, which may suppress hunger.

Additional reading on low body fat and its impact can be found on the Livestrong.com website, on this page: At what body fat percent do you start losing your period?

Terminology Checklist

Body composition: the measurement of the body's proportion of fat mass to fat free mass.

Fat mass: the amount of fat tissue in the body often expressed as a percentage of total body mass.

Fat free mass (FFM): non-fat tissue in the body such as bones, muscles, ligaments, and blood.

Essential fat: the amount of fat needed for vital body functions.

Non-essential fat: the amount of fat that exceeds the necessary fat needed for vital body functions. This fat is considered energy storage.

Overweight: the accumulation of non- essential body fat to the point that it adversely affects health.

Obesity: defined as excessive accumulation of body fat and can be defined as a more serious degree of being overweight.

Adipose tissue: another term for fat. More specifically it is loose connective tissue composed of adipocytes.

Subcutaneous fat: fat tissue stored below the skin's surface.

Visceral fat: fat tissue stored around central organs.

Android shape: a body shape used to help characterize body fat distribution in which fat is stored in the abdominal region. The android shape is also called the "apple" shape.

Gynoid shape: a body shape used to help characterize body fat distribution in which fat is stored in the hips, buttocks, and thighs. It is also called the pear shape.

Body mass index (BMI): an index based on concept that weight and height should be proportionate. It is calculated by dividing weight by the height squared (weight/height2).

Hydrodensitometry: this method attempts to measure the density of the body by using water displacement.

Dual energy X-ray absorptiometry (DEXA): a method of measuring body composition that uses low energy x-rays that also measure bone density.

Air displacement plethysmography: a method of measuring body composition that measures the density of the body by using air displacement.

Bio-electrical impedance analysis (BIA): a method of measuring body composition by emitting a small electrical current through the body and using the amount of resistance encountered by this current to predict body fat content.

Skinfold analysis: a method of measuring body composition by measuring the diameter of pinched skin at various sites on the body.

3.7.5. Test Your Knowledge

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Versioning History

This page provides a record of changes made to this open textbook since its initial publication. If the change is minor, the version number increases by 0.1. If the change involves substantial updates, the version number increases to the next full number.

Version	Date	Detail
1.0	Jan 2020	Pilot version released
1.1	Aug 2020	• Headings within each chapter were reorganized • “Test your knowledge” questions were added • DOI was added • Book cover was changed • 1.2.4. The New Canadian Food Guide was updated with content adapted and reproduced with permission from Health Canada
2.0	Jan 2021	Copyediting has been done, which includes: • Overall content levels and numbering • Formatting of figures, tables, and lists • Attribution statements
2.1	Sep 2021	All copyediting changes have been implemented