Clinical Nutrition

Clinical Nutrition

FAMN 4106 / 4401

KENDRA RIGGS

Nova Scotia Community College
Nova Scotia Canada

Contents

About the Book

Clinical Nutrition is a remixed adapted open textbook created with content from the following open textbooks:

- Consumer Nutrition by Megan Grimsley and Susan Kazen published in 2021 under a CC BY-NC-SA license.
- Nutrition: Science and Everyday Application by Alice Callahan, Heather Leonard, and Tamberly Powell; Lane Community College, published in 2021 under a CC BY-NC license.
- Human Nutrition in a Canadian Context by Karine Hamm published by BCcampus in 2021 under a CC BY License.
- Nutrition Through the Lifecycle by Sabine Zempleni
- Food Studies: Matter, Meaning, Movement by David Szanto, Amanda Di Battista, and Irena Knezevic published by ecampus Ontario in 2022 under a CC BY-NC-SA license.

See version history chapter for more information about how this edition was created.

INTRODUCTION

Defining Nutrition, Health, and Disease

Learning Objectives

1. Define health, nutrition, and disease.
2. List and describe the characteristics used to assess your health status.
3. Differentiate among risk factors, signs, and symptoms.
4. Define the word "nutrient" and differentiate among the six classes of nutrients essential for health.
5. Explain how energy values of food are determined, and list the three energy-yielding nutrients and their energy contribution.
6. Describe measures of food quality and be able to calculate and compare energy densities of foods.
7. Describe the importance of research and scientific methods to understanding nutrition.
8. Analyze sources of nutrition information for reliability and credibility.

Life depends on nourishment and the quality of life depends greatly on the foods you choose to eat. Any discussion of nutrition must begin with an understanding of nutrition, nutrients, and their overall relationship to health and well-being.

DEFINING NUTRITION, HEALTH, AND DISEASE

The word nutrition first appeared in 1551 and comes from the Latin word nutrire, meaning "to nourish." Today, we define **nutrition** as the sum of all processes involved in how organisms obtain nutrients, metabolize them, and use them to support all of life's processes. **Nutritional science** is the investigation of how an organism is nourished, and incorporates the study of how nourishment affects personal health, population health, and planetary health. Nutritional science covers a wide spectrum of disciplines. As a result, nutritional scientists can specialize in particular aspects of nutrition such as biology, physiology, immunology, biochemistry, education, psychology, sustainability, and sociology.

Without adequate nutrition the human body does not function optimally, and severe nutritional inadequacy can lead to disease and even death. The typical Canadian diet contains adequate calories, but is lacking in many ways, from not containing the proper amounts of essential nutrients, to being too speedily consumed, to being only meagerly satisfying.

Nutrition and Health and Disease

Your ability to wake up, to think clearly, to communicate, to hope, to dream, to go to school, to gain knowledge, to go to work, to earn a living, and to do all of the things that you like to do are dependent upon one factor—your health. Good health means you are able to function normally and work hard to achieve your goals in life. In 1946, the World Health Organization (WHO) defined **health** as "a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity."[1] This definition was adopted into the WHO constitution in 1948 and remains to this day. A triangle is often used to depict the equal influences of physical, mental, and social well-being on health.

Disease is defined as any abnormal condition affecting the health of organisms and typically characterized by specific signs and symptoms. Diseases are broadly categorized as resulting from pathogens (i.e., bacteria, viruses, fungi, and parasites), deficiencies, genetics, and/or physiological dysfunction. Diseases that primarily affect physical health are those that impair body structure (as is the case with osteoporosis), or functioning (as is the case with cardiovascular disease). Mental illnesses primarily affect mental and social well-being.

The foods we eat affect multiple aspects of our health. For example, a teen with type 2 diabetes (a disease often brought on by poor diet and lack of physical activity) is first diagnosed by physical signs and symptoms such as increased urination, excessive thirstiness, and unexplained weight loss. But research has also found that teens with uncontrolled type 2 diabetes often have impaired thinking and may not interact well with others in school, thereby affecting mental and social well-being. This is just one example of a physiological disease that can affect physical, mental, and social aspects of health.

In the early twentieth century, most nutrition-related diseases and conditions were related to inadequate calorie consumption or deficiency of nutrients. In the latter part of the twentieth century nutrition scientists, public health organizations, and the Canadian public increasingly recognized that eating too much of certain foods is linked to chronic diseases.

The table below shows the top ten causes of death in Canada. As you can see, many of these causes are related to nutrition. We now know that diet-related conditions and diseases include but are not limited to cardiovascular (heart) diseases including hypertension (high blood pressure) and stroke, obesity, type 2 diabetes, several forms of cancer, and osteoporosis.

1. World Health Organization. (1946). Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference. Official Records of the World Health Organization. https://www.who.int/about/who-we-are/constitution

Canada: Top 10 Leading Causes of Death (2019 to 2022)[2]

	2019	2020	2021	2022	2019	2020	2021	2022
	Number of Deaths	Number of Deaths	Number of Deaths	Number of Deaths	Rank	Rank	Rank	Rank
Malignant neoplasms(cancer)	80372	81242	82822	82412	1	1	1	1
Diseases of heart	53364	54430	55271	57357	2	2	2	2
COVID-19	...	15890	14466	19716	...	4	4	3
Accidents (unintentional injuries)	15527	16818	19257	18365	3	3	3	4
Cerebrovascular diseases	13717	13761	13491	13915	4	5	5	5
Chronic lower respiratory diseases	12902	11844	11018	12462	5	6	6	6
Diabetes mellitus	6987	7654	7472	7557	6	7	7	7
Influenza and pneumonia	6945	6037	4115	5985	7	8	10	8
Alzheimer's disease	6181	5788	5471	5413	8	9	8	9
Chronic liver disease and cirrhosis	3708	4199	4617	4530	11	10	9	10
Nephritis, nephrotic syndrome and nephrosis	3770	4065	3978	4234	10	12	11	11
Intentional self-harm (suicide)	4581	4152	3769	3593	9	11	12	13
Other ill-defined and unspecified causes of mortality	3378	6841	9471	16043	...	...	...	...
Total, all causes of death	285301	308412	311640	334081				

REFERENCES

Chapter 1, section 1.1 from Consumer Nutrition by Megan Grimsley and Susan Kazen published in 2021 under a CC BY-NC-SA license.

Author Notes

Portions of this chapter were taken from OER Sources listed below:

Tharalson, J. (2019). *Nutri300:Nutrition.* https://med.libretexts.org/Courses/Sacremento_City_College/SSC%3A_Nutri_300_(Tharalson)

Titchenal, A., Calabrese, A., Gibby, C., Revilla, M.K.F., 7 Meinke, W. (2018). *Human Nutrition. University of Hawai'i at Manoa Food Science and Human Nutrition Program Open Textbook.* https://pressbooks.oer.hawaii.edu

Zimmerman, M., & Snow, B. (2012). *An Introduction to Nutrition, v. 1.0.* https://2012books.lardbucket.org/books/an-introduction-to-nutrition/

2. Statitics Canada. (2023, November 27). Top 10 leading causes of death (2019 to 2022). https://www150.statcan.gc.ca/n1/daily-quotidien/231127/t001b-eng.htm

Assessing Your Health

There are many factors that determine whether you are "healthy." Although the WHO definition describes **health** as not just the absence of disease, but also encompassing psychological, emotional, and social well-being, most of Western medicine is focused on a person's physical health. As we have discussed previously, and will continue to discuss throughout this course, nutrition plays an enormous role in determining our overall health. Assessing one's nutritional status can help us determine whether nutritional intake (or lack of) is affecting the development or continuance of nutrition-related health conditions. No one eats 100% healthy foods 100% of the time, but with assessment we look at the overall eating pattern and how it affects overall health. **Nutrition assessment** uses many tools to help determine whether a person is well-nourished or malnourished (referring to either undernourished or overnourished).

There are six areas to consider when assessing health through a nutrition lens. An easy way to remember these areas is using the letters ABCDEF:

A. anthropometric
B. biochemical
C. clinical
D. dietary
E. environmental
F. family history

A: ANTHROPOMETRIC ASSESSMENT

The word anthropometric comes from two terms: anthropo meaning "human" and metric meaning "measure." There are many different measures used to assess growth in humans including height, weight, body mass index (BMI), head circumference, girth measurements of limbs, waist, hip, and body composition measures such as skinfold/fat fold thickness or bioelectrical impedance analysis. We then compare those measures to known health standards. Often these types of measurements are used to assess the growth of children and adolescents. However, some of these measures such as height and weight are used throughout our lifetimes, comparing measurements over time, or comparing one person to another.

B: BIOCHEMICAL ASSESSMENT

Biochemical assessment includes laboratory tests that can measure a nutrient or its metabolites in the blood, urine, feces, or other bodily secretions. We can learn quite a bit about a person's health by looking at these tests and they are routinely collected and examined as part of a general physical by your doctor. In nutrition, for example, we look at the levels of glucose in the blood and in the urine to determine if a person has or is at risk for diabetes. We look at blood cholesterol profiles to help determine risk for some forms of cardiovascular disease. The amount of iron in the blood can indicate a person's risk for anemia. It is recommended that you keep copies of your lab tests so that you can look at trends over time.

C: CLINICAL ASSESSMENT

In addition to anthropometric and biochemical measures, clinical signs and symptoms are used to assess nutritional status such as a potential nutrient deficiency or toxicity. **Signs** are those things that can be easily seen such as bleeding, vomiting, or fainting. **Symptoms** are those things that a patient may be experiencing that cannot easily be seen and must be described such as a headache, nausea, dizziness, or pain. Special attention is given to a person's organs such as skin, eyes, tongue, ears, mouth, hair, nails, and gums. Clinical methods of assessing nutritional status involve checking signs at specific points on the body, or asking patients about any symptoms that may indicate a nutrient deficiency. Often other clinical measures such as temperature and blood pressure are also taken.

If a nutrient deficiency is suspected based on signs or symptoms, often a biochemical test is completed to help identify the exact nutrient that may be inadequate or missing. There are two types of nutrient deficiencies a person may develop. A **primary nutrient deficiency** occurs when a person does not consume enough of an essential nutrient. A **secondary nutrient deficiency** occurs when enough of the nutrient is consumed, but for some reason the body is unable to use that nutrient effectively. Secondary nutrient deficiencies can occur because of functional problems in the digestive tract, medications that may be interfering with the body's absorption or metabolism of a particular nutrient, the body's natural aging process, and many other reasons.

D: DIETARY ASSESSMENT

Dietary methods of assessment include looking at past and current intake of nutrients from food by individuals or a group to help determine their nutritional status. Completing a dietary assessment is crucial when trying to determine whether or not your intake is related to a disease or condition. There are several methods that may be used to do this:

- *24-hour dietary recall.* A trained professional asks a person to recall all food or drink consumed in the previous 24-hours. This is a quick and easy method. However, it is dependent upon the person's short-term memory and may not be very accurate. It also looks at just one day, which may not be a "typical" day of intake for the individual.
- *Food Frequency Questionnaire*. The person is given a list of foods and asked to indicate average intake per day, per week, and per month. This method is inexpensive and easy to administer, however it often lacks detail and may not be very accurate. It can still provide a broad overview of one's overall eating pattern.
- *Food Diary*. Food intake is recorded at the time of eating. This is also known as a food journal or food record. These diaries can be done with paper and pencil, but are more likely to be recorded using apps on a phone or other electronic device. This method is generally reliable but is difficult to accurately maintain for more than a few days, and portion sizes can be difficult to estimate.
- *Observed Food Consumption.* This method requires food to be weighed and the nutrient content exactly calculated. It is very accurate, but time consuming and expensive, and is usually done only for research purposes.

E: ENVIRONMENTAL ASSESSMENT (LIFESTYLE)

Where and how you live can have a profound effect on your health and nutritional status. Many environmental factors play a role including your living situation (alone, with a family, with friends, etc.), geographic location (urban vs rural, north vs south, etc.), socioeconomic position, access to healthy foods, your ability to prepare food, and other lifestyle factors such as exercise and sleep patterns, emotional health, and work-life balance.

An assessment of your environment includes evaluating not only your nutrition, but also your personal habits. Many diseases are preventable by simply staying away from certain behaviors (smoking, excessive alcohol use, risky sexual activity, etc.). Instead adopt healthful measures like participating in regular physical activity, wearing seat belts in the car and helmets while cycling, and finding healthy ways to minimize your response to stressors like meditation or spending time outdoors. As stated earlier, health is more than just physical. Emotional health is often hard to talk about; however, a person's quality of life is highly affected by emotional stability. Finding balance between work and life is a difficult and continuous process involving keeping track of your time, taking advantage of job flexibility options, saying no, and finding support when you need it. Work-life balance can influence what you eat too.

F: FAMILY MEDICAL HISTORY

Everyone starts out in life with the genes handed down to them from their mother and father. Genes are responsible for your many traits as an individual and are defined as the sequences of DNA that code for all the proteins in your body. The expression of different genes can determine the color of your hair, skin, and eyes, and even if you are more likely to be fat or thin and if you have an increased risk for a certain disease. The sequence of DNA that makes up your genes and determines your genetic makeup is called your **genome**. In 2003, the Human Genome Project was completed and now the entire sequence of DNA in humans is known. It consists of about three billion individual units and contains between 25,000 and 30,000 genes. The human genome that was sequenced was taken from a small population of donors and is used as a reference DNA sequence for the entire population. Each of us has a similar but unique DNA sequence. Only identical twins and cloned animals have the exact same DNA sequence.

Epigenetics is the study of how your behaviors and your environment may turn genes "on" or "off," causing changes that can affect how your genes work. In recent years scientists have been studying the possible epigenetic links between genes and nutrients. Initial studies looked at **nutrigenomics**, the study of the intake of nutrients and their effects on genetic expression in an individual. Not all epigenetic changes are permanent. A beneficial change in nutrient intake, increased physical activity, or quitting smoking can reverse some epigenetic modifications and improve health.

A second way to look at the interplay between nutrients and genes is to identify genetic markers in individuals that may modify their need for or use of various nutrients which may influence health outcomes. This is called **nutrigenetics**. Genetic differences may help explain why some people achieve weight loss with certain diets and others do not. Or whether a person may benefit more from a low sodium diet than someone else might. You may see internet sites touting personalized nutrition, their ability to help you (for a hefty fee), "eat right for your genes." Although this is an exciting area of research, the science is complicated. Be sure that if you access these services, that there is a health professional such as an RD/RDN who can help you interpret your individual results.

Because genetics play a large role in defining your health it is a good idea to learn whether there are some diseases and conditions that may be more likely to affect you based on your inherited genes. To do this, record your family's medical history. Start by drawing a chart that lists your immediate family and relatives. The next time you attend a family event or see extended family members, start filling in the blanks. What did people die from? What country did Grandpa come from? While this may be an interesting project historically, it can also provide you with a practical tool to determine to what diseases you might be more susceptible. This will allow you to make better dietary and lifestyle changes early on to help prevent a disease from being handed down from your family to you. It is good to compile your information from multiple relatives.

Risk Factors

Assessing your current health status based on these six categories can help you identify some of your risk factors. A **risk factor** is something that makes you more likely to develop adverse health conditions. Some risk factors are inherited through your genes as discussed previously. These risk factors are part of your DNA, but may be affected by your health behaviors, either positively or negatively. However, scientists consider them non-modifiable because they are part of your genetic code which cannot be altered. Other risk factors such as biological sex, age, and race are also non-modifiable. Some risk factors are modifiable because they are choices an individual makes each day. For example, if you smoke you are more likely to develop lung cancer than someone who does not smoke. Thus smoking is a risk factor for lung cancer. Some people can smoke for years and never develop lung cancer, while others may develop lung cancer and never smoke. However, the chances that you will develop lung cancer if you're a smoker are much higher than if you never smoked. If you quit smoking, you may reduce your risk of developing this terrible disease. Obesity, physical inactivity, and dietary factors such as low fiber intake and high saturated fat intake are risk factors for many different health conditions including heart disease, type 2 diabetes, and some forms of cancer. Choosing healthier meals and exercising regularly can go a long way to reducing the chances that you will develop one of these debilitating health conditions. The more risk factors you have for a health condition the more likely you are to eventually suffer from it. Assessing your health using ABCDEF allows you to identify your current risk factors and to take steps to modify those you can.

Risk Factors vs Signs or Symptoms

Many people confuse risk factors with signs or symptoms of disease, but they are different. Risk factors occur prior to development of a disease. They make you more likely to develop the disease, but not everyone with a risk factor will. You will experience signs and symptoms when you have a condition. Common signs and symptoms of type 2 diabetes, for example, include frequent urination, excessive thirst, frequent hunger, tingling in the extremities, and others. These occur during and after the development of the disease. To reiterate, risk factors occur prior to disease development. The more risk factors you have for a health condition (both modifiable and non-modifiable) the more likely you are to develop that condition. Signs and symptoms are experienced once you develop the condition.

REFERENCES

Chapter 1, section 1.2 from [Consumer Nutrition] by Megan Grimsley and Susan Kazen published in 2021 under a [CC BY-NC-SA] license.

Nutrients

Our bodies require dozens of different chemicals found in food to help us maintain optimal health. These chemicals are called **nutrients** , and the study of how these chemicals interact with each other and with our bodies is called **nutrition**. Nutrients are substances required by the body to perform its basic functions. We consume our favorite foods and beverages (and sometimes our not so favorites) in an attempt to gain all of the necessary nutrients to achieve or maintain our health. Sometimes we also consume supplements in addition to foods to be sure we are getting all of the required nutrients.

Although all nutrients are important, scientists categorize some as **essential**. The word essential means we have to have it, however, in nutrition the word essential also means we have to obtain it from an outside source, from foods or beverages. In other words, an essential nutrient is one we need that we have to consume. **Non-essential** nutrients are also necessary and vital for good health, but these nutrients can be made by the body in sufficient amounts as long as adequate essential nutrients are consumed, and don't necessarily need to be a part of our daily dietary intake. Sometimes a formerly non-essential nutrient may become **conditionally essential**. This means that under normal circumstances a person could manufacture what they need, but if, for example, they are taking a certain medication or have a medical condition that modifies their ability to make the nutrient, then they must consume it.

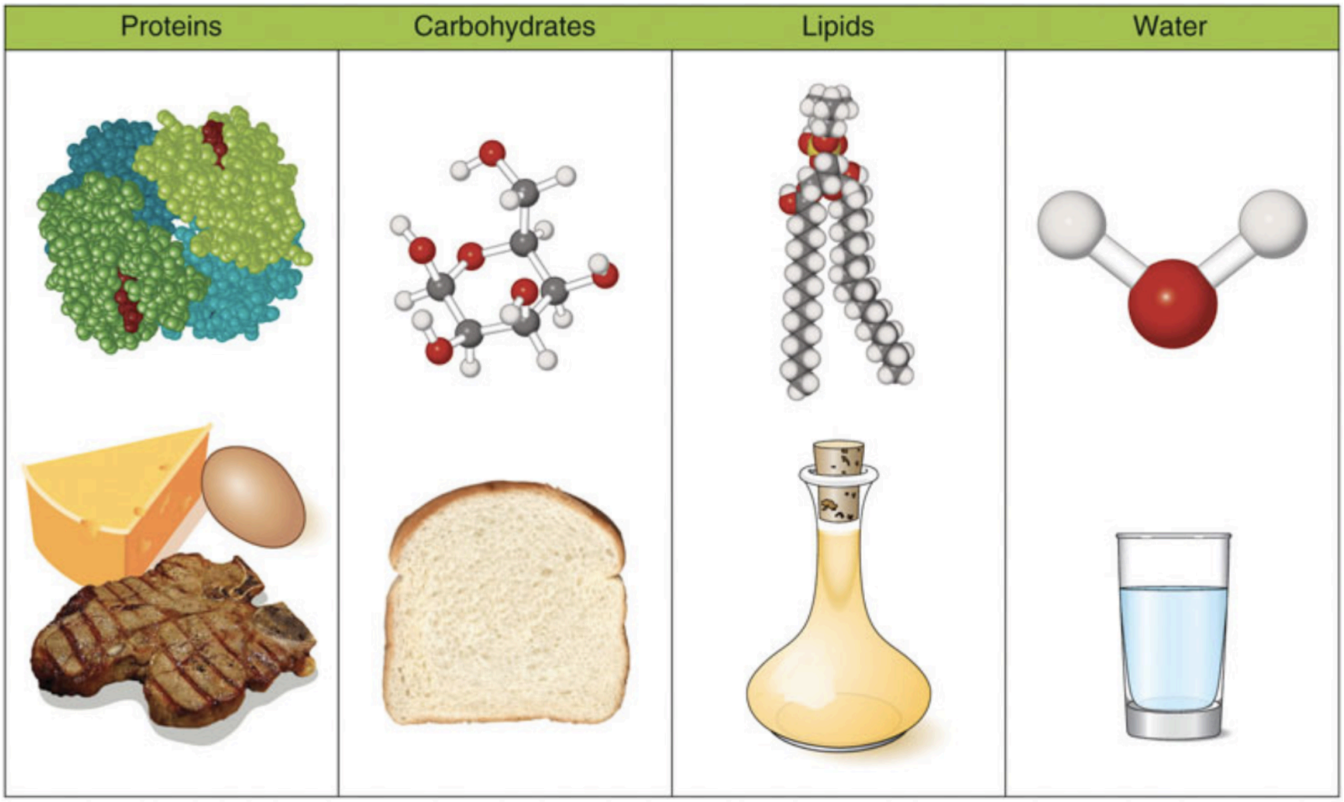
Nutrients are used to help us produce energy, detect and respond to environmental surroundings, move, excrete wastes, respire (breathe), grow, and reproduce. To make it easier to study nutrients, we combine those that have similar properties or functions into groups or "classes." There are six classes of nutrients required for the body to function and maintain overall health. These classes are carbohydrates, protein, lipids, water, vitamins, and minerals.

Classes of Nutrients and their Basic Functions

Nutrient Class	Basic Functions
Carbohydrates	Provide a ready source of energy for the body and provide structural constituents for the formation of cells.
Protein	Necessary for tissue formation, cell repair, production of hormones/enzymes/neurotransmitters. Essential for building muscle and a healthy immune system.
Lipids	Provide stored energy for the body, functions as structural components of cells, and also as signaling molecules for proper cellular communication. 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, 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.

MACRONUTRIENTS

Nutrients that are needed in large amounts are called **macronutrients**. There are four classes of macronutrients: carbohydrates, protein, lipids, and water. Of these macronutrients, three (carbohydrate, protein, and lipids) can be metabolically processed into cellular energy and thus are called **energy nutrients**. The energy from macronutrients comes from their chemical bonds. This chemical energy is converted into cellular energy in the form of **adenosine triphosphate (ATP)** that is then utilized to perform work, allowing our bodies to conduct their basic functions. 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.



The Macronutrients: Proteins, Carbohydrates, Lipids, and Water. This figure illustrates each nutrient's chemical structure and examples of food sources. Credit: [Basic Concepts in Nutrition Introduction] in [Human Nutrition] by University of Hawai'i at Mānoa Food Science and Human Nutrition Program, [CC BY License].

A unit of measurement of food energy is the **calorie** (denoted with a small "c"). A calorie is the amount of energy required to raise 1 gram of water 1° Celsius. On nutrition food labels and in the field of nutrition the amount given for "Calories" is actually equivalent to each calorie multiplied by one thousand. A **kilocalorie** or kcal (one thousand calories, denoted with a small "c") is synonymous with the "Calorie" (with a capital "C"). When you see Calories on nutrition food labels it is equal to kcal (Calorie = kcal). Therefore you can use "kcal" to denote amounts of energy from food (as we have done throughout this text).

Carbohydrates

Carbohydrates are molecules composed of carbon, hydrogen, and oxygen. Any molecule that contains carbon atoms is considered an **organic molecule**. This use of the term organic refers only to the molecule's chemical composition and is different from the use of the term organic in relation to how foods are grown. The main function of carbohydrates is to provide energy. The major food sources of carbohydrates are grains, milk, fruits, and starchy vegetables like potatoes. Non-starchy vegetables like broccoli or kale also contain carbohydrates, but in lesser quantities. Carbohydrates are almost exclusively found in plant-based foods. Carbohydrates are broadly classified into two forms based on their chemical structure: simple and complex.

One gram (g) of carbohydrates yields 4 kcal 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.

All carbohydrates are made up of building blocks called monosaccharides, the most common monosaccharide is glucose. Some carbohydrates such as table sugar or honey are made of just two monosaccharides, so are called simple carbohydrates. Other carbohydrates are made up of hundreds or thousands of monosaccharides, and are called complex. **Glucose** can be stored for future use. In animals including humans, the storage molecule of carbohydrates is called **glycogen** and in plants it is known as **starch**. Glycogen and starches are complex carbohydrates, as is dietary fiber.

Proteins

Proteins are organic molecules composed of chains of amino acids. **Amino acids** are simple sub-units composed of carbon, oxygen, hydrogen, and nitrogen. The food sources of proteins are 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 4 kcal of energy per g; however providing energy is not protein's most important function. Proteins provide structure to bones, muscles and skin, they make up hormones, enzymes, neurotransmitters, and molecules important in immunity, and play a role in conducting most of the chemical reactions that take place in the body. Scientists estimate that greater than 20,000 different proteins exist within the human body.

Lipids

Lipids are also a family of organic 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 (or triacylglycerols), phospholipids, and sterols. The main job of lipids is to store energy. Lipids provide more energy per g than carbohydrates or protein (9 kcal per g of lipids versus 4 kcal per g of carbohydrates/protein). In addition to energy storage, lipids serve as components of cell membranes, surround and protect organs, aid in temperature regulation, and regulate many other functions in the body.

Water

There is one other nutrient that we must consume in large quantities: water. Water does not contain carbon, making it an inorganic molecule. It is composed of two hydrogen (H_2) and one oxygen (O) per one molecule of water. More than 60% 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. According to the "rule of threes," a generalization supported by survival experts, a person can survive three minutes without oxygen, three days without water, and three weeks without food. Since water is so critical for life's basic processes, the amount of water input and output is supremely important. However, water does not provide any kcal. So it is considered a macronutrient, but not an energy nutrient.

Alcohol is not considered a nutrient, although it is a source of kcal. Remember that a nutrient is something that is necessary for body functioning and overall health. Alcohol does not meet that definition of a nutrient. Alcohol itself provides approximately 7 kcal for every g consumed. In addition to alcohol, many alcoholic drinks contain additional kcal from other nutrient classes—especially carbohydrates.

MICRONUTRIENTS

Micronutrients are nutrients required by the body in very small amounts, but are still essential for carrying out bodily functions. Micronutrients include all the essential minerals and vitamins. There are 13 essential vitamins and 16 minerals (see Table 1.3.2 and Table 1.3.3 for a complete list and their major functions). In contrast to carbohydrates, protein, and lipids, micronutrients are not directly used for making energy and do not contain kcal, but they assist in the process of energy production as part 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 roles in the body.

Vitamins

The 13 vitamins are categorized as either water-soluble or fat-soluble. The water-soluble vitamins are vitamin C and all the B vitamins, which include thiamin, riboflavin, niacin, pantothenic acid, B_6, biotin, folate and B_{12}. 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.

Vitamin deficiencies can cause severe health problems. 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 in asylums awaiting death. The deficiency of other vitamins was found to cause other disorders and diseases such as scurvy (vitamin C), night blindness (vitamin A), and rickets (vitamin D).

Vitamins and Their Major Functions

Vitamins	Major Functions
Water-soluble	
Thiamin (B_1)	Coenzyme, energy metabolism assistance
Riboflavin (B_2)	Coenzyme, energy metabolism assistance
Niacin (B_3)	Coenzyme, energy metabolism assistance
Pantothenic acid (B_5)	Coenzyme, energy metabolism assistance
B_6 (Pyroxidine)	Coenzyme, amino acid synthesis assistance
Biotin (B_7)	Coenzyme
Folate (B_9)	Coenzyme, essential for growth
B_{12} (Cobalamin)	Coenzyme, red blood cell synthesis
C	Collagen synthesis, antioxidant
Fat-soluble	
A	Vision, reproduction, immune system function, antioxidant
D	Bone and teeth health maintenance, immune system function
E	Antioxidant, cell membrane protection
K	Blood clotting, bone and teeth health maintenance

Minerals

Minerals are solid inorganic substances that form crystals and are classified depending on how much of them we need. Trace (minor) minerals such as molybdenum, selenium, zinc, iron, and iodine, are only required in a few milligrams (mg) or less per day while major minerals such as calcium, magnesium, potassium, sodium, and phosphorus, are required in hundreds of mg. Like vitamins, minerals do not contain kcal. 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.

Minerals and Their Major Functions

Minerals	Major Functions
Major	
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/Minor	
Iron	Carries oxygen, assists in energy production
Zinc	Protein and DNA production, wound healing, growth, immune system function
Iodine	Thyroid hormone production, growth, metabolism
Copper	Coenzyme, iron metabolism
Selenium	Antioxidant
Chromium	Assists insulin in glucose metabolism
Manganese	Coenzyme
Molybdenum	Coenzyme
Fluoride	Bone and teeth health maintenance, tooth decay prevention

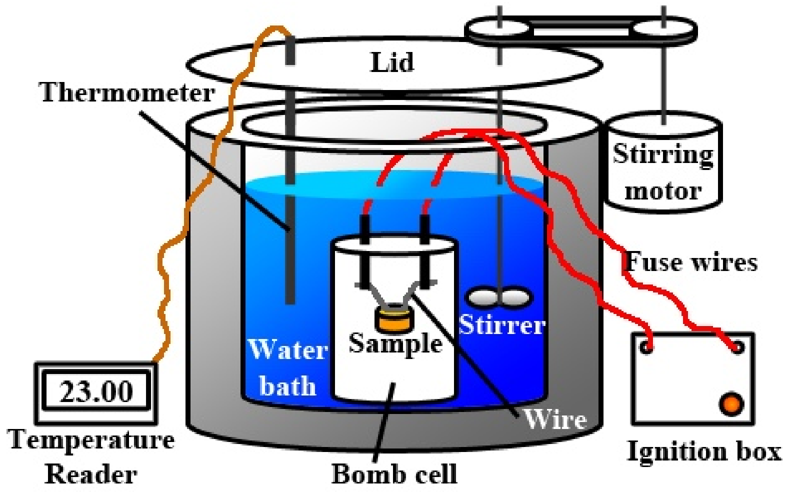
To review, the dozens of nutrients that the body requires are grouped into six classes based on form and function. Below is a summary of the characteristics of the six nutrient classes.

Summary of Nutrient Class Characteristics

Class of Nutrient	Macro- or Micronutrient	Organic Nutrient (contains carbon)	Energy Nutrients
Carbohydrates	Macro	Yes	Yes – 4 kcal/g
Protein	Macro	Yes	Yes – 4 kcal/g
Lipids	Macro	Yes	Yes – 9 kcal/g
Vitamins	Micro	Yes	No
Minerals	Micro	No	No
Water	Macro	No	No

FOOD ENERGY

As discussed previously, food energy is measured in Calories and commonly referred to as kcal. Though this is only the first chapter you have already seen the words “kcal” and “energy” used several times. In everyday life you have probably heard people talk about how many calories (kcal) they burned on the treadmill or how many calories are listed on a bag of chips. Kcal are a measure of energy. It takes quite a lot of kcal (energy) to keep us alive. Even if a person is in a coma, they still burn approximately 1000 kcal of energy every day in order for their heart to beat, their blood to circulate, their lungs to breathe, etc. We burn even more kcal when we exercise. A food’s kcal are determined by putting the food into a bomb calorimeter, heating it, and measuring the energy output (energy = heat produced). The carbohydrates, proteins, and fats we eat and drink provide these kcal for us (and alcohol as well if we choose to consume it).



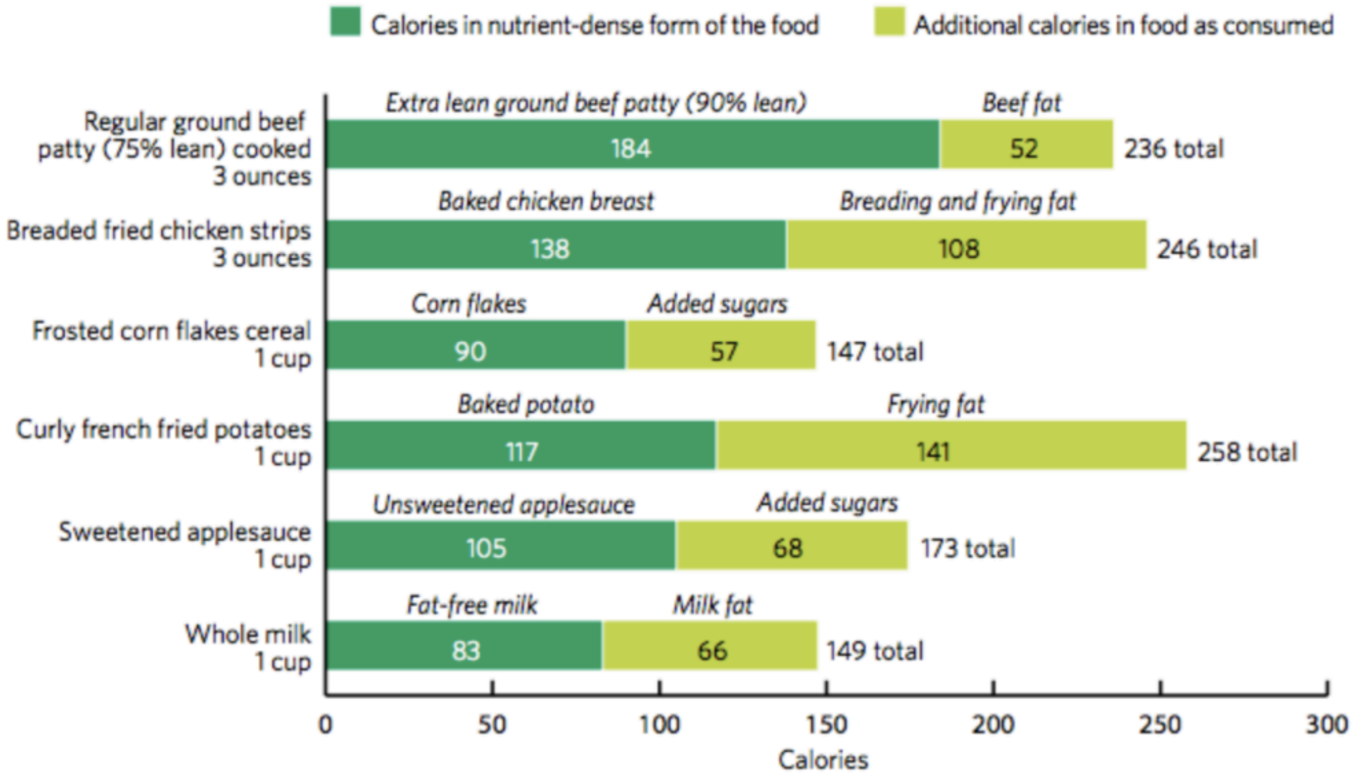
A bomb calorimeter. A sample is placed in the center and heated until it burns. The heat is transferred to the surrounding water, and the temperature rise of the water corresponds with the amount of heat calories generated by the sample. [Bomb calorimeter](#) by Lisdavid89, via [CC BY-SA 3.0](#)

FOOD QUALITY

Typical versus nutrient-dense foods. The Dietary Guidelines for Americans 2010, by U.S. Department of Agriculture, via Public Domain

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 many nutrients relative to the amount of calories they provide. A food with high nutrient density would have a large amount of various beneficial nutrients in each "bite" of that particular food. Because "bites" are different for everyone, we use common measures such as gram (g), ounce (oz), cup (c), pound (lb), liter (L), tablespoon (tbs), etc. to help us compare different foods. (See common measures used in Appendix 1). Determining nutrient density of a food is not straightforward. One must consider the nutrient profile of a food as a whole, and it can be quite subjective. However, it is generally agreed that whole fruits and vegetables, 100% whole grains, nuts, and legumes tend to have high nutrient density. Food quality is additionally associated with its taste, texture, appearance, microbial content, and how much consumers like it.

Another measure of food quality is to examine the number of kcals in a food relative to the size of each "bite." The term used to describe this is **energy density** or calorie density. Foods high in fats and sugars, like fast food burgers, pizza, candy bars, etc. would be considered energy dense since they provide many calories per bite but are typically lacking several essential vitamins, minerals, and other beneficial nutrients like fiber. We can compare the energy density of different foods if we know the number of kcals and the size of a serving for each.



Examples of the calories found in nutrient-dense food choices compared with calories found in less nutrient-dense forms of these foods . The Dietary Guidelines for Americans 2010, by U.S. Department of Agriculture, via Public Domain

A third term often used to describe food quality is "**empty calorie**." Foods such as carbonated sugary soft drinks provide many calories, but very few, if any, beneficial nutrients, making the calories "empty."

We can compare meals to examine food quality:

Let's say we have a choice between two different breakfasts depicted in the images below. Each breakfast contains 500 kcal. But breakfast #2 provides many more nutrients inthose 500 kcal than do the donuts. There are several different vitamins and minerals in the two types of berries and in the spinach. These fruits and vegetable also contain fiber, and there is lean protein in the eggs. The donuts in breakfast #1 contain 500 kcal as well, but those kcals are primarily fat and sugar. There are very few vitamins or minerals in the donuts, and almost no fiber or protein. Therefore, breakfast #2 is more nutrient dense.

We can also compare the energy density of the two breakfasts. Because we know the weights of the two (in grams) and that both contain 500 kcal, we can calculate the energy density of each breakfast.

Energy density of breakfast #1: 500 kcal/135 g = 3.7 kcal per gram of food

Energy density of breakfast #2: 500 kcal/350 g = 1.4 kcal per gram of food

Breakfast #1 has more than 2.5 times as many kcal per gram of food than breakfast #2. Therefore breakfast #1 has higher energy density.

Breakfast #1 is three powdered sugar donuts. This breakfast weights 135 g and is 500 kcal. Donuts by Salim Virji, via CC BY-SA 4.0

Breakfast #2 with two scrambled eggs with 1/2 cup of fresh spinach and 1 tablespoon of fresh parmesan cheese, 1 cup blackberries, and 1 cup strawberries. This breakfast is 350 g and has 500 kcal. Image by 3025332, via Pixabay License

Super Foods

Often you see lists of "Super Foods" on the internet or in magazines. These superfoods (also called "functional foods") are generally understood to be a food, or a food ingredient, that may provide a health benefit beyond the traditional nutrients it contains.[1] These functional foods tend to be whole (not processed) vegetables and fruits like kale or Swiss chard, legumes, or berries, or animal foods like cold water fish. They are considered highly nutritious because they contain not only beneficial nutrients, but also additional beneficial chemical compound(s) that are not nutrients (also called non-nutritive).Phytochemicals are non-nutritive chemical compounds found in plants (phyto) that provide characteristics to the plant like color, taste, smell. They are found in the edible parts of plants, especially the skin or peel. However, these plant chemicals are also believed to provide health benefits beyond the traditional nutrients. According to the Harvard Medical School, it is estimated that about 5,000 have been identified so far, but we don't yet know what they all do.[2] General categories of phytochemicals include (but are not limited to) carotenoids, flavonoids, and phenols.

Diets rich in fruits and vegetables have been associated with decreased risk of chronic diseases. Many fruits and vegetables are rich in phytochemicals, especially when consumed whole, leading some to hypothesize that phytochemicals are responsible for the decreased risk of chronic diseases. The role that phytochemicals play in health is still in the early stages of research. But you may be able to reduce your risk of chronic disease by consuming high amounts of whole fruits and vegetables to raise your intake of these phytochemicals. However, benefits seem to only come from the plant itself, and not from dietary supplements containing the phytochemical.

REFERENCES

1. Klemm, S. (2019, July 15). Functional foods. Academy of Nutrition and Dietetics. https://www.eatright.org/food/nutrition/healthy-eating/functional-foods
2. Harvard Health Letter. (2019, February). Fill up on phytochemicals. Harvard Medical School. https://www.health.harvard.edu/staying-healthy/fill-up-on-phytochemicals

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. There are a few websites that can be consistently relied upon for accurate material that is updated regularly.

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."
> "Stack your snacks to add three pounds of muscle."

How do you react when you read news of this nature? Do you boycott margarine and coffee? Change your snacking habits? Nutrition-related hyperbolic headlines and advertisements have been around for decades. In the 1930s there were ads recommending a "reducing soap" that would wash away fat and years of age. In the 1950s and 60s you could reduce your weight by listening to certain music, or by rubbing an "electric spot reducer" over your abdomen. We still see similar types of advertisements on food packaging, and in print and social media. Advertisers use authority figures like actors dressed in white lab coats to convince consumers that a product is healthful. They often use anecdotal evidence (stories) like before and after pictures or warped statistics or single research studies that may contain bias to exaggerate the benefits of a weight loss plan, "health" food, or dietary supplement. But this type of advertising and these sorts of headlines seem to work. Consumers spend billions of dollars each year on special health foods and beverages or dietary supplements even though the scientific evidence that these substances live up to their hype is sorely lacking.

So what should we as consumers believe? When reading nutrition-related claims, articles, websites, or advertisements always remember that one study does not substantiate a fact. One study neither proves or 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 the Academy of Nutrition and Dietetics. Question studies that come from less trustworthy sources (such as non peer-reviewed journals, popular magazines, or websites) or that are not published.
2. The report should disclose the methods used by the researcher(s). Did the study last for 3 or 30 weeks? What was the "*n*" (number of subjects)? The longer the study and the higher the number of subjects, the more robust and credible are the results. What did the participants actually do? Did the researcher(s) observe the results themselves or did they rely on self reports from study participants? Was there a control group who did not receive the treatment so that scientists can compare one group to another?
3. Who were the subjects of this study? Humans or animals? If human, are any traits/characteristics noted?

Were confounding variables assessed? How were subjects assigned to groups (randomness)? For example, the results of a study of the effects of a dietary supplement on the hearts of cardiac patients should not be used to convince an athlete to take a dietary supplement to improve their own heart's ability to exercise. These two types of people are quite different. 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 (age, biological sex, fitness level, underlying medical conditions, geographical location, etc.)

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 gives you more confidence in it.
5. Peer-reviewed articles published in well-respected scientific journals deliver a broad perspective and are inclusive of findings of many studies on the exact same subject. By providing a list of previously published articles related to the topic, one can see how a particular study fits into the totality of the research.
6. When reading 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.

There are thousands of websites that contain nutrition information. When reading information on websites, Johns Hopkins University recommends that you remember the following criteria for discerning if a site is valid and the information credible:[1]

Accuracy. Does the website use reliable research? Check many sources for the same information—are the results the same?

Authority. Websites that end in .gov or .edu (and sometimes .org), are usually the most reliable websites for health facts. Make sure the website is written by doctors, dietitians, or other experts in the health field.

Bias. Who pays for the website? If a company supports a website (usually through advertising) they may have control over the website and encourage inaccurate or misleading information that promotes a need for their product or service.

Currency. When were the facts last updated? Medical research never stops. Make sure the information is no older than 3 years.

Some non-profit, non-governmental organizations like Health on the Net (HON), affiliated with the WHO, promote transparency and reliable health information on the internet. For a fee, health-related websites can have their content checked by medical experts from these organizations for accuracy and reliability. If a website becomes certified, it will be allowed to post the organization's logo on their site for a specified time period (usually 5 years).[2] Other organizations like the Utilization Review Accreditation Commission (URAC) have a Health Website accreditation program that looks at both content and security settings for these sites. While these certifications do not guarantee that everything on the website is accurate or reliable, it does provide some level of assurance that the information has some validity.[3]

1. Johns Hopkins University. (2018). Reliable health information on the internet. https://www.hopkinsmedicine.org/johns_hopkins_bayview/_docs/patient_visitor_amenities/libraries/reliable_health_information_fall_2018.pdf
2. Health on the Net. (2020, March). https://www.hon.ch/en/
3. Utilization Review Accreditation Commission. (2020). Health website accreditation. https://www.urac.org/programs/health-web-site-accreditation

Beware of a website that is trying to sell you something (a program or product), charge a fee, or asks you to "sign up" for something like a free newsletter (they may be selling your information to a third party).

TRUSTWORTHY SOURCES

For a list of reliable sources that advocate good nutrition to promote health and prevent disease using evidence-based science see Table "Web Resources for Nutrition and Health", we will further discuss nutrition recommendations for Canadians.

Web Resources for Nutrition and Health

Organization	**Website**
Governmental	
USDA	http://www.usda.gov/wps/portal/usda/usdahome
USDA Center for Nutrition Policy and Promotion	http://www.cnpp.usda.gov/
US Department of Health and Human Services	http://www.hhs.gov/
Centers for Disease Control and Prevention	http://www.cdc.gov/
Food and Drug Administration	http://www.fda.gov/
Healthy People	http://www.healthypeople.gov/2020/default.aspx
Office of Disease Prevention and Health Promotion	http://odphp.osophs.dhhs.gov/
International	
World Health Organization	http://www.who.int/en/
Food and Agricultural Organization of the United Nations	http://www.fao.org/
Nongovernmental	
Harvard School of Public Health	http://www.hsph.harvard.edu/nutritionsource/index.html
Mayo Clinic	http://www.mayoclinic.com/
Linus Pauling Institute	http://lpi.oregonstate.edu/
American Society for Nutrition	http://www.nutrition.org/
American Medical Association	http://www.ama-assn.org/
American Diabetes Association	http://www.diabetes.org/
The Academy of Nutrition and Dietetics	http://www.eatright.org/
National Academy of Medicine: Food and Nutrition Board	https://www.nationalacademies.org/fnb/food-and-nutrition-board

REFERENCES

Chapter 1, section 1.5 from Consumer Nutrition by Megan Grimsley and Susan Kazen published in 2021 under a CC BY-NC-SA license.

DESIGNING A HEALTHY DIET

Introduction to Designing a Healthy Diet

Learning Objectives

After completing this unit, you should be able to:

1. Define nutrition, food, and nutrients, and describe how nutrition is related to health, including risk of chronic disease.
2. Describe the different factors that impact food choices.
3. Explain the basic structure of molecules and that all nutrients are also chemical molecules.
4. Describe the 6 types of nutrients and the various ways they are classified.
5. Explain how the Dietary Reference Intakes (DRI) are determined, what each type of DRI value means, and how they are used.
6. Use the information in a Nutrition Facts label to understand the nutritional qualities of a food.
7. Describe concepts that are helpful in planning a healthful diet, including adequacy, balance, moderation, variety, nutrient density, and empty calories.
8. Use tools for planning a healthful diet, including MyPlate, Harvard Healthy Eating Plate, and the Dietary Guidelines for Americans.

What makes a diet "healthy"? What does the word "healthy" even mean? Each of us might picture something different when we think of a healthy diet, and if you travel around the world, you'll find even more variation in how people define this term.

Person cooking at a table by Marcus Winkler via Unsplash license.

Indeed, humans are incredibly flexible when it comes to food. We are omnivores, and we can survive and thrive on a wide variety of different foods. The foods that nourish our bodies are often the same foods that nourish our souls, bringing us together with friends and family, celebrating traditions and conjuring memories of meals past.

We'll begin our study of nutrition by zooming in on nutrients—the molecules in food that nourish us—to begin to understand what each gives us. Then, we'll zoom back out to consider some tools for choosing foods that will together provide us with all the nutrients we need. Because whatever the deep and complex meanings that food brings to our lives and our culture, we also want to choose foods that will enable us to be well, to fuel our activities, to prevent disease, and to live long, healthy lives.

CHAPTER ATTRIBUTION

Nutrition and Health

WHAT IS NUTRITION?

Simply put, **food** is the plants and animals that we eat, and **nutrition** is how food affects the health of the body. According to the Academy of Nutrition and Dietetics, "Food is essential—it provides vital nutrients for survival, and helps the body function and stay healthy. Food is comprised of macronutrients including protein, carbohydrate and fat that not only offer calories to fuel the body and give it energy but play specific roles in maintaining health. Food also supplies micronutrients (vitamins and minerals) and phytochemicals that don't provide calories but serve a variety of critical functions to ensure the body operates optimally."[1] (**Phytochemicals** are compounds found in plants that give them their smell, taste, and color. They are not technically nutrients, but many have been shown to affect human health.)

Salad bowl by Anna Pelzer, via Unsplash License

The **study of nutrition** goes beyond just a discussion of food and the nutrients needed by the body. It includes how those nutrients are digested, absorbed, and used by the cells of the body. It examines how food provides energy for daily activities and how our food intake and choices impact body weight and risk for chronic diseases such as heart disease and type 2 diabetes. It also provides insight on behavioral, social, and environmental factors that influence what, how, when, and why we eat.[2] Thus, nutrition is an important part of the overall discussion of health and wellness.

1. Academy of Nutrition and Dietetics. (2019). How to Explain Basic Nutrition Concepts. https://www.eatrightpro.org/practice/practice-resources/international-nutrition-pilot-project/how-to-explain-basic-nutrition-concepts
2. Medline Plus. (2019). Definitions of Health Terms. https://medlineplus.gov/definitions/nutritiondefinitions.html

HOW NUTRITION AFFECTS HEALTH

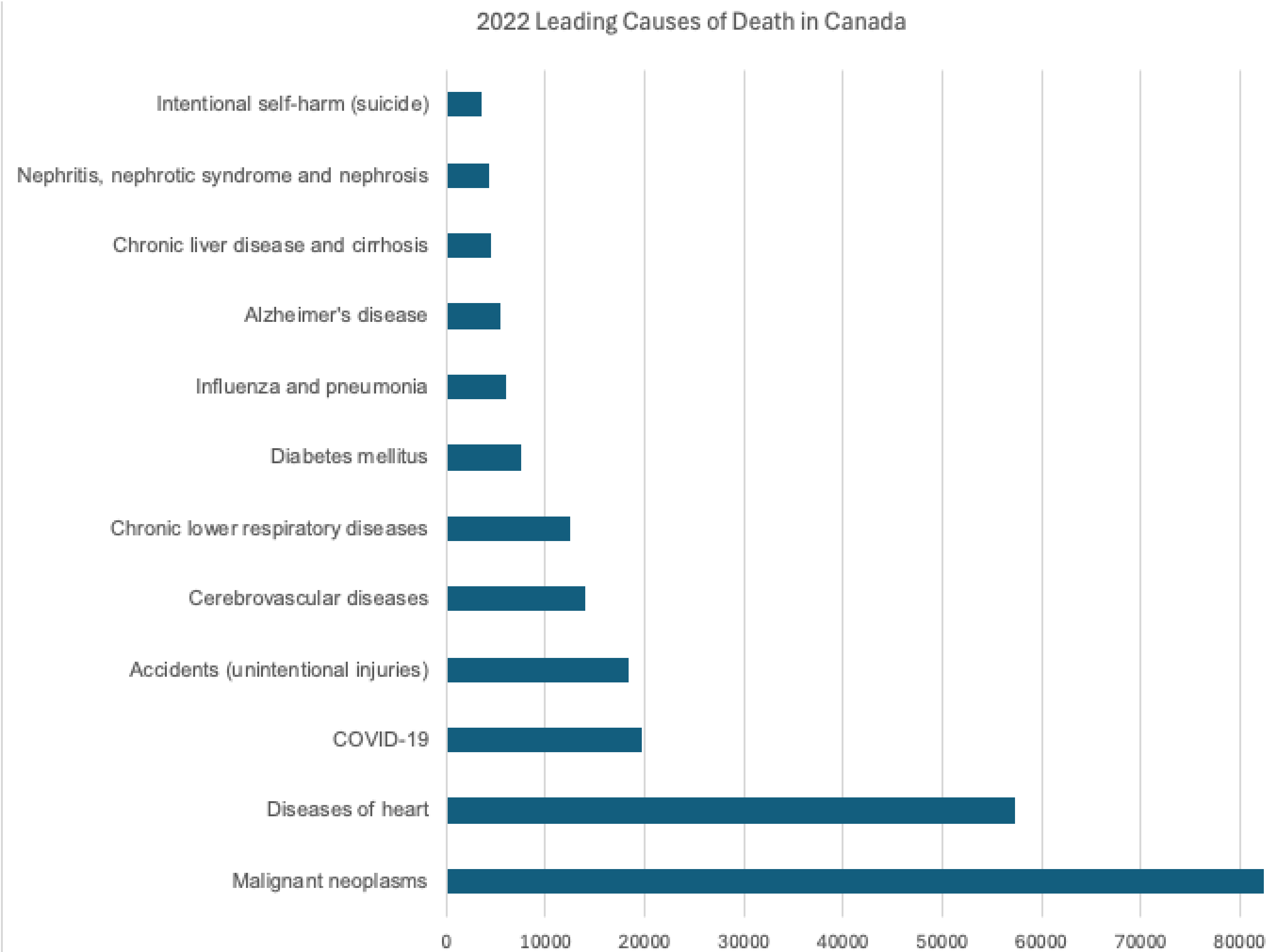
The World Health Organization (WHO) defines **health** as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.”[3] The WHO recognizes nutrition as a critical part of health and development, noting that better nutrition is related to:[4]

- improved infant, child and maternal health
- stronger immune systems
- safer pregnancy and childbirth
- lower risk of non-communicable diseases (such as type 2 diabetes and cardiovascular disease)
- greater longevity
- greater productivity, creating opportunities to break cycles of poverty and hunger

Malnutrition, including both undernutrition and over nutrition, is a significant threat to human health. In fact, nutrition is associated with many of the top ten leading causes of death in Canada. For example heart disease, cancer(malignant neoplasms), diabetes, and stroke.

Cancer and heart disease remained the two leading causes of death in Canada, accounting for 41.8% of deaths in 2022. In 2021, cancer and heart disease accounted for 44.3% of all deaths.[5]

3. World Health Organization. (n.d.) Constitution. https://www.who.int/about/who-we-are/constitution
4. World Health Organization. (2018, February 22). Nutrition. https://www.who.int/news-room/facts-in-pictures/detail/nutrition
5. Statitics Canada. (2023, November 27). Deaths. The Daily. https://www150.statcan.gc.ca/n1/daily-quotidien/231127/dq231127b-eng.htm



Data Source: Statistics Canada. Statitics Canada. (2023, November 27). Top 10 leading causes of death (2019 to 2022). https://www150.statcan.gc.ca/n1/daily-quotidien/231127/t001b-eng.htm

Nutrition can affect the health of the mind as well as the body. For example, some research suggests that the foods people eat can influence their mood. A 2019 study[6] of moderately-depressed people aged 17 to 35 years old found that when half of them shifted towards a Mediterranean-style eating pattern for 3 weeks—emphasizing more fruits and vegetables, whole grains, lean protein sources, unsweetened dairy, fish, nuts and seeds, olive oil, and spices—their depression levels decreased compared to participants who continued their usual eating habits. Some (but not all) other studies have also found links between healthier diets and decreased risk of depression. It's not clear why this might be, but researchers speculate that decreased inflammation or changes in the body's microbiome caused by these dietary patterns may play a role in brain functioning and mental health.[7] This is an area that requires much more research, but as you're thinking about dietary choices, it's worth thinking about how foods make you feel.

In addition to nutrition, **health is affected by genetics, the environment, life cycle, and lifestyle**. One

6. Francis HM, Stevenson RJ, Chambers JR, Gupta D, Newey B, Lim CK (2019) A brief diet intervention can reduce symptoms of depression in young adults – A randomised controlled trial. PLoS ONE 14(10): e0222768. https://doi.org/10.1371/journal.pone.0222768
7. Aubrey, A. & Chatterjee, R. (2019, October 19). Changing Your Diet Can Help Tamp Down Depression, Boost Mood. https://www.npr.org/sections/thesalt/2019/10/09/768665411/changing-your-diet-can-help-tamp-down-depression-boost-mood

important facet of lifestyle is personal 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 food choices and nutrition status. Following a healthy lifestyle improves your overall health and well-being.

VIDEO: LITTLE CHANGES[8]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=687#oembed-1

PERSONAL CHOICE: THE CHALLENGE OF CHOOSING FOODS[9]

There are other factors besides environment and lifestyle that influence the foods you choose to eat. Food itself can regulate 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 (also called **satiety**). Making food choices that maximize nutrient intake and satiety can help manage how much you eat and how long before you eat again.

Food also has social, cultural, and religious significance, all of which impact the foods we choose to eat. The social meanings of food affect what people eat, as well as how and when. Special events in our lives—from birthdays to funerals—are commemorated with equally special foods. Cultural influences and upbringing can also shape an individual's food habits. Being aware of these factors can help people make healthier food choices, and still honor the traditions and ties they hold dear.

Factors that Drive Food Choices[10]

A number of other factors affect the dietary choices individuals make, including:

- **Taste, texture, and appearance**. Individuals have a wide range of taste preferences, which influence their food choices. For example, some people dislike milk and others hate raw vegetables. Foods that may be unappealing at first to some people, like vegetables or tofu, can often be adapted to meet most taste preferences, and people can learn to like foods over time with repeated exposures.
- **Economics**. Access to fresh fruits and vegetables may be limited, particularly for those who live in economically disadvantaged or remote areas, where affordable food options are limited to convenience stores and fast food.

8. Mustain, P. (May 22, 2014). Little Changes. https://vimeo.com/62954951
9. Adapted from Lifestyles and Nutrition in Human Nutrition by University of Hawai'i at Mānoa Food Science and Human Nutrition Program, published with a CC BY-NC 4.0 license.
10. Adapted from Lifestyles and Nutrition in Human Nutrition by University of Hawai'i at Mānoa Food Science and Human Nutrition Program, published with a CC BY-NC 4.0 license.

- **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 or experience food aversions as adults. On the other hand, those exposed to a variety of foods in the setting of pleasant family meals, are more likely to maintain those same eating habits in adulthood.
- **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 choices by persuading consumers to eat certain foods.
- **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 food allergies or intolerances and need to avoid certain 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 to change their weight.
- **Emotions**. There is a wide range in how emotional issues affect eating habits. Food can be a source of comfort, such as the taste of a favorite dish from childhood. Or, for people with a history of disordered eating, it may also be a source of anxiety. 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 consider animal welfare and sustainability in their choices. Purchasing local and organic food products and items grown through sustainable products can help to shrink the environmental impact of one's food choices.

SELF-CHECK:

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.nscc.ca/clinicalnutrition/?p=687#h5p-1

CHAPTER ATTRIBUTION

Classification of Nutrients

Food is one of life's greatest pleasures. It offers amazing flavors, aromas, and textures. Food also provides our body with essential nutrients and non-nutrients like phytochemicals, both of which are vital to health. This section will discuss the six classes of nutrients and how these nutrients can be classified.

WHAT ARE NUTRIENTS?

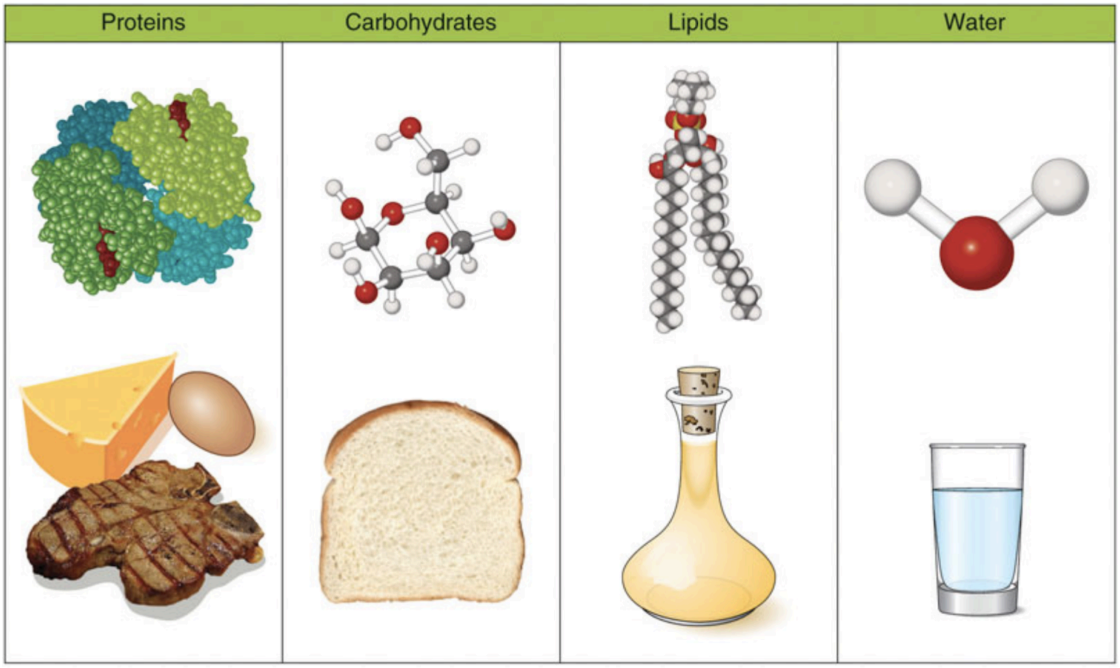
Nutrients are chemical substances found in food that are required by the body to provide energy, give the body structure, and help regulate chemical processes. **There are six classes of nutrients:**

1. carbohydrates
2. lipids
3. proteins
4. water
5. vitamins
6. minerals

Nutrients can be further classified as either **macronutrients** or **micronutrients** and either **organic** or **inorganic**, as well as whether or not they provide energy to the body (**energy-yielding**). We'll discuss these different ways of classifying nutrients in the following sections.

MACRONUTRIENTS

Nutrients that are needed in large amounts are called **macronutrients**. There are three classes of macronutrients: carbohydrates, lipids, and proteins. 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 energy.



The Macronutrients: Proteins, Carbohydrates, Lipids, and Water. This figure illustrates each nutrient's chemical structure and examples of food sources. Credit: Basic Concepts in Nutrition Introduction in Human Nutrition by University of Hawai'i at Mānoa Food Science and Human Nutrition Program, CC BY License.

Carbohydrates

Carbohydrates are molecules composed of carbon, hydrogen, and oxygen. The major food sources of carbohydrates are grains, dairy products, fruits, legumes, and starchy vegetables, like potatoes. Non-starchy vegetables, like carrots, also contain carbohydrates, but in lesser quantities.

Carbohydrates are broadly classified into two groups based on their chemical structure: simple carbohydrates (often called simple sugars) and complex carbohydrates, which include fiber, starch, and glycogen. Carbohydrates are a major fuel source for all cells of the body, and certain cells, like cells of the central nervous system and red blood cells, rely solely on carbohydrates for energy.

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, phospholipids, and sterols. The main job of lipids is to provide or store energy. In addition to energy storage, lipids serve as major components of cell membranes, surround and protect organs, provide insulation to aid in temperature regulation, and regulate many other functions in the body.

Proteins

Proteins are large molecules composed of chains of amino acids, which are simple subunits made of carbon, oxygen, hydrogen, and nitrogen. Food sources of proteins include meats, dairy products, seafood, and a variety of plant-based foods, like beans, nuts, and seeds. The word protein comes from a Greek word meaning "of primary importance," which is an apt description of these macronutrients as they are also known as the "workhorses" of life. Proteins provide structure to bones, muscles, and skin, and they play a role in conducting most of the chemical reactions occurring in the body. Scientists estimate that more than 100,000 different proteins exist within the human body. Proteins can also provide energy, though this is a relatively minor function, as carbohydrates and fat are preferred energy sources.

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, we can only survive a few days without it, making it one of the most vital nutrients.

MICRONUTRIENTS

Micronutrients are nutrients required by the body in smaller amounts, but they're still essential for carrying out bodily functions. Micronutrients include all of the essential minerals and vitamins. There are 16 essential minerals and 13 essential vitamins (Table 1.1 and Table 1.2). In contrast to carbohydrates, lipids, and proteins, micronutrients are not a source of energy, but they assist in the process of energy metabolism as cofactors or components of enzymes (known as coenzymes). **Enzymes** are proteins that catalyze (or accelerate) chemical reactions in the body; they're involved in all aspects of body functions, including producing energy, digesting nutrients, and building macromolecules.

Minerals

Minerals are inorganic substances that are classified depending on how much the body requires. **Trace minerals**, such as molybdenum, selenium, zinc, iron, and iodine, are only required in amounts of a few milligrams or less per day. **Major minerals**, such as calcium, magnesium, potassium, sodium, and phosphorus, are required in amounts of hundreds of milligrams or more per day. Many minerals are critical for enzyme function, and 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. To give you an appreciation of the many functions of minerals, the table below has a complete list of all the minerals and their major functions. (Note: There is no need to memorize these minerals and functions at this point in the course.)

Minerals and their major functions[1]

Major Minerals	Major Function
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 Minerals	**Function**
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

Vitamins

Vitamins are organic nutrients that are categorized based on their solubility in water. The **water-soluble vitamins** are vitamin C and all of the B vitamins. The **fat-soluble vitamins** are vitamins 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 function. To give you an appreciation of the many functions of vitamins, the table below lists the 13 essential vitamins and their major functions. (Note: There is no need to memorize these vitamins and functions at this point in the course.)

1. University of Hawaiʻi at Mānoa Food Science and Human Nutrition Program, Introduction. [CC BY-NC 4.0]

Vitamins and their major functions[2]

Water-Soluble Vitamins	Major Functions
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, energy metabolism 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 Vitamins	**Major Functions**
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

As you might suspect based on the major functions of vitamins listed above, 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 the United States. The common signs and symptoms of pellagra are known as the "4D's—diarrhea, dermatitis, dementia, and death." Until scientists discovered that better diets relieved the signs and symptoms of pellagra, many people with the disease ended up hospitalized and in asylums awaiting death. The following video gives an overview of pellagra and how its cure was discovered through a change in diet.

VIDEO: PELLAGRA VIDEO[3]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=700#oembed-1

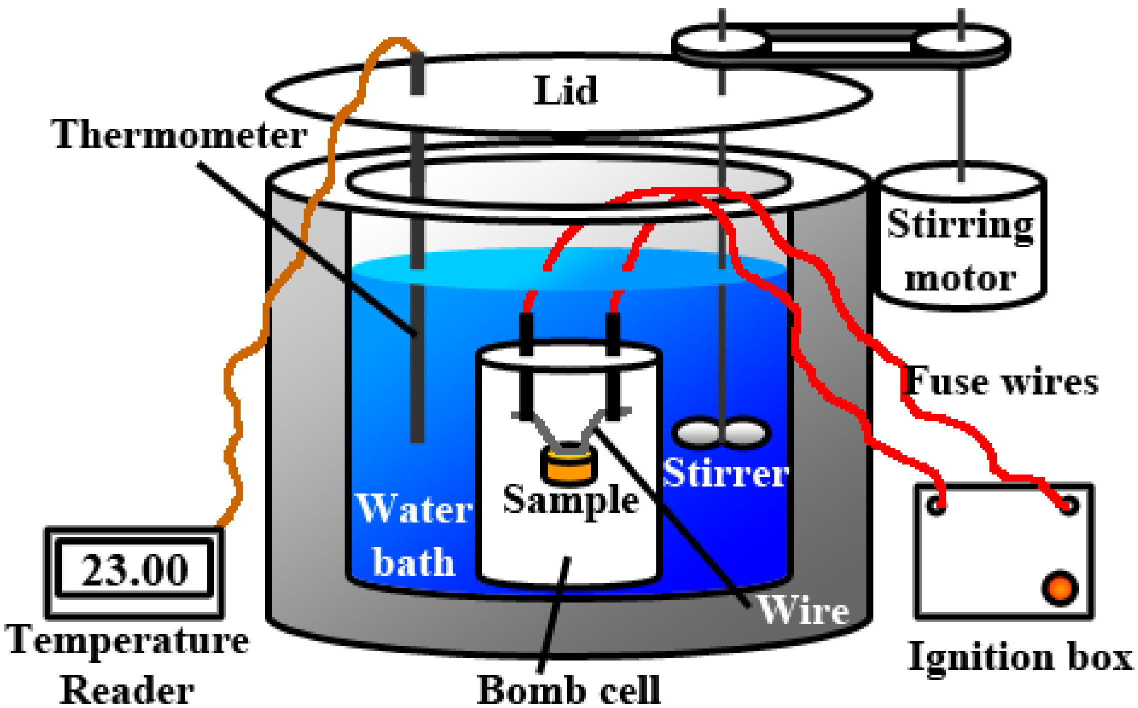
ENERGY-YIELDING NUTRIENTS

The macronutrients—carbohydrate, protein, and fat—are the only nutrients that provide energy to the body. The energy from macronutrients comes from their chemical bonds. This chemical energy is converted into

2. University of Hawaiʻi at Mānoa Food Science and Human Nutrition Program, Introduction. CC BY-NC 4.0
3. Johnson, T. (June 20, 2012). YouTube. https://youtu.be/ewz1INLpy6I?si=ajblO6t-UnqQSfjM

cellular energy that can be utilized to perform work, allowing cells to conduct their basic functions. **Although vitamins also have energy in their chemical bonds, our bodies do not make the enzymes to break these bonds and release this energy.** (This is fortunate, as we need vitamins for their specific functions, and breaking them down to use for energy would be a waste.)

Food energy is measured in kilocalories (kcals). A kilocalorie is the amount of energy needed to raise 1 kilogram of water by 1 degree Celsius. The kilocalories stored in food can be determined by putting the food into a bomb calorimeter and measuring the energy output (energy = heat produced).



Bomb calorimeter by Lisdavid89, via CC BY-SA 3.0

VIDEO: Bomb Calorimetry[4]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=700#oembed-2

The kilocalorie (kcal) is the most commonly used unit of energy 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." For the sake of simplicity, we'll use the terms "calories" and "kilocalories" interchangeably in this book.

Below is a list of energy sources in the diet from lowest to highest calories per gram (a gram is about the weight

4. Read, D. (September 16, 2008). YouTube. https://youtu.be/ohyA9amFfsc?si=huKzAGjdmaed0wii

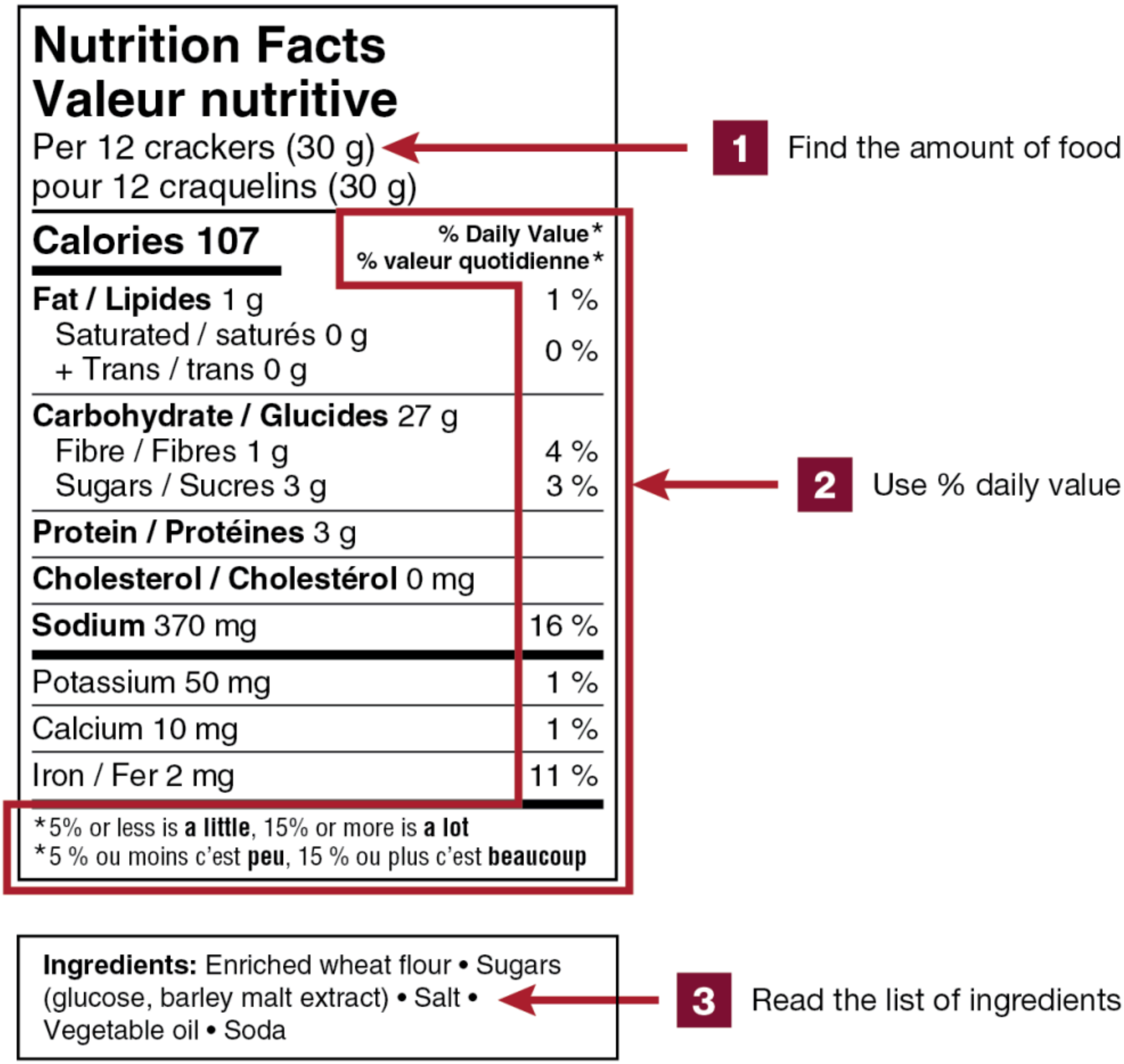
of a paperclip). Notice the addition of alcohol. Although alcohol does provide energy, it isn't a nutrient, because it isn't required as a source of nourishment to the body.

Energy Sources (kcal/g)

- Carbohydrates 4
- Protein 4
- Alcohol 7
- Lipids 9

Carbohydrates and proteins provide 4 calories per gram, and fats provide 9 calories per gram. Fat is the most energy-dense nutrient, because it provides the most calories per gram (more than double carbohydrates and protein).

NUTRITION FACTS LABEL



Three steps to understand food labels. Credit: Government of Canada. (2023). How to use food labels to make healthier choices. Canada's Food Guide. https://food-guide.canada.ca/en/tips-for-healthy-eating/use-food-labels-make-healthier-choices/

When you look at the Nutrition Facts panel on a food label, you'll see that it lists calories, as well as grams of total fat, total carbohydrates, and protein per serving. From these values, you can estimate the amount of calories coming from the different macronutrients.

Looking at the values in the Nutrition Facts label, you can convert grams into calories by doing the following calculations:

- 8 grams of fat x 9 kcal/g = 72 kcals
- 37 grams of carbohydrate x 4 kcal/g = 148 kcals
- 3 grams of protein x 4 kcal/g = 12 kcals

You can double check your math by adding the calories per serving provided from fat, carbohydrate, and protein (232 calories for the example above). This number should come close to the total calories per serving listed on the Nutrition Facts. It will not always match up exactly (like in the example above) due to rounding.

CHAPTER ATTRIBUTION

Defining Nutrient Requirements: Dietary Reference Intakes

How do we know how much of a given nutrient people should eat, or how much is too much? For this information, we can turn to the **Dietary Reference Intakes (DRI)**—a set of recommendations developed by the National Academies of Sciences, Engineering, and Medicine to describe the amounts of specific nutrients and energy that people should consume in order to stay healthy. They are developed by groups of nutrition scientists, who together evaluate the research to determine how much of a nutrient is required to prevent deficiencies and chronic disease, as well as how much is excessive and could cause toxicity. The DRI standards are specific to people living in the United States and Canada, and they're meant to be used by people who are generally healthy, because those with specific health conditions may have different nutrient requirements.

The DRI standards can be divided into two main categories:

- **Recommendations for energy intake** – How many calories are required, and how much energy should proportionately come from carbohydrate, fat, and protein?
- **Recommendations for nutrient intake** – How much of each nutrient should be consumed, and how much is excessive?

We'll discuss each of these categories, and then we'll discuss some of the ways that the DRI standards are used. Be prepared to learn a lot of acronyms!

DRI RECOMMENDATIONS FOR ENERGY INTAKE

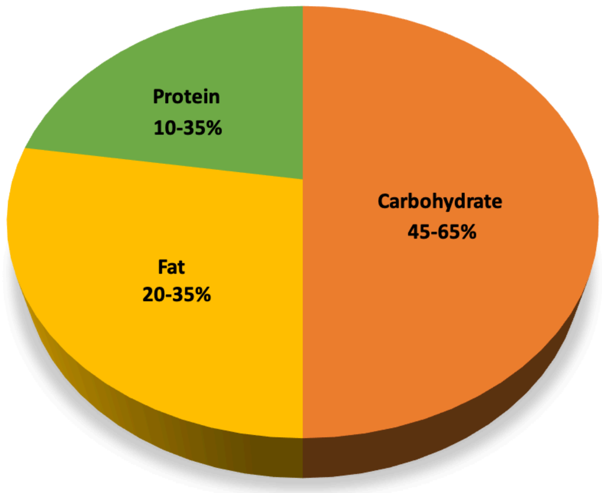
The DRIs include two types of recommendations related to energy intake:

People eating a meal around a table by Priscilla Du Preez, via Unsplash License

1. **Estimated Energy Requirement (EER)*.* The EER is an estimate of how many calories a person needs to consume, on average, each day to stay healthy, based on their age, sex, height, weight, and physical activity level.** For adults, the EER is meant to be a caloric intake that maintains energy balance, meaning that it won't cause weight loss or gain. For children, the EER includes the energy needed for normal growth. For pregnant or lactating women, it includes energy needed for development of the fetus and other pregnancy requirements or for milk production. Different EER values were also developed for different physical activity levels, because greater physical activity requires more energy.[1] The EER should be considered a "ballpark" estimate of a person's caloric needs. As we'll learn later in the term, the way that people process and utilize energy is highly variable, and two people can have the same sex, weight, height, and level of physical activity but different caloric needs.

2. **Acceptable Macronutrient Distribution Ranges (AMDR). The AMDR is the calculated range of how much energy from carbohydrate, fat, and protein is recommended for a healthy diet.** People who do not meet the AMDR may have increased risk of developing health complications—although these are also ballpark recommendations, not absolute requirements for health. Keep in mind that the percentage of daily caloric intake from the three energy-yielding macronutrients will add up to 100 percent, so the proportion of each influences the other two. For example, someone consuming a very low carbohydrate diet, with just 5 to 10 percent of calories coming from carbohydrates would not only fall short of the AMDR for carbohydrate but also exceed the recommended amounts of fat and/or protein, because the rest of daily calories must come from these macronutrients. The AMDR recommendations are based on balancing carbohydrate, fat, and protein to allow for adequate amounts of all three, and they are wide enough ranges that many different types of diets can fit within them.

1. Institute of Medicine, Food and Nutrition Board. (2005). Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). The National Academies Press.



Acceptable Macronutrient Distribution Ranges (AMDR) for the three energy-yielding macronutrients. AMDR by Callahan, A., CC BY 4.0.

DAILY RECOMMENDATIONS FOR NUTRIENT INTAKE

There are four different types of DRI values used to describe recommendations for intake of individual nutrients:

- Estimated Average Requirements (EAR)
- Recommended Dietary Allowances (RDA)
- Adequate Intakes (AI)
- Tolerable Upper Intake Levels (UL)

DRI values are summarized in tables to make it easy to find a specific value for a person based on their life stage and sex. For example, part of a table of EAR values for macronutrients and vitamins is shown below.

Dietary Reference Intakes (DRIs): Estimated Average Requirements
Food and Nutrition Board, Institute of Medicine, National Academies

Life Stage Group	CHO (g/d)	Protein (g/kg/d)	Vit A (μg/d)[a]	Vit C (mg/d)	Vit E (mg/d)[b]	Thiamin (mg/d)	Ribo-flavin (mg/d)	Niacin (mg/d)[c]	Vit B_6 (mg/d)
Infants									
7–12 mo		1.0							
Children									
1–3 y	100	0.87	210	13	5	0.4	0.4	5	0.4
4–8 y	100	0.76	275	22	6	0.5	0.5	6	0.5
Males									
9–13 y	100	0.76	445	39	9	0.7	0.8	9	0.8
14–18 y	100	0.73	630	63	12	1.0	1.1	12	1.1
19–30 y	100	0.66	625	75	12	1.0	1.1	12	1.1
31–50 y	100	0.66	625	75	12	1.0	1.1	12	1.1
51–70 y	100	0.66	625	75	12	1.0	1.1	12	1.4
> 70 y	100	0.66	625	75	12	1.0	1.1	12	1.4
Females									
9–13 y	100	0.76	420	39	9	0.7	0.8	9	0.8
14–18 y	100	0.71	485	56	12	0.9	0.9	11	1.0
19–30 y	100	0.66	500	60	12	0.9	0.9	11	1.1
31–50 y	100	0.66	500	60	12	0.9	0.9	11	1.1
51–70 y	100	0.66	500	60	12	0.9	0.9	11	1.3
> 70 y	100	0.66	500	60	12	0.9	0.9	11	1.3
Pregnancy									
14–18 y	135	0.88	530	66	12	1.2	1.2	14	1.6
19–30 y	135	0.88	550	70	12	1.2	1.2	14	1.6
31–50 y	135	0.88	550	70	12	1.2	1.2	14	1.6
Lactation									
14–18 y	160	1.05	885	96	16	1.2	1.3	13	1.7
19–30 y	160	1.05	900	100	16	1.2	1.3	13	1.7
31–50 y	160	1.05	900	100	16	1.2	1.3	13	1.7

Dietary Reference Intake (DRI), Nutrient Recommendations and Databases by National Institutes of Health Office of Dietary Supplements, via Public Domain

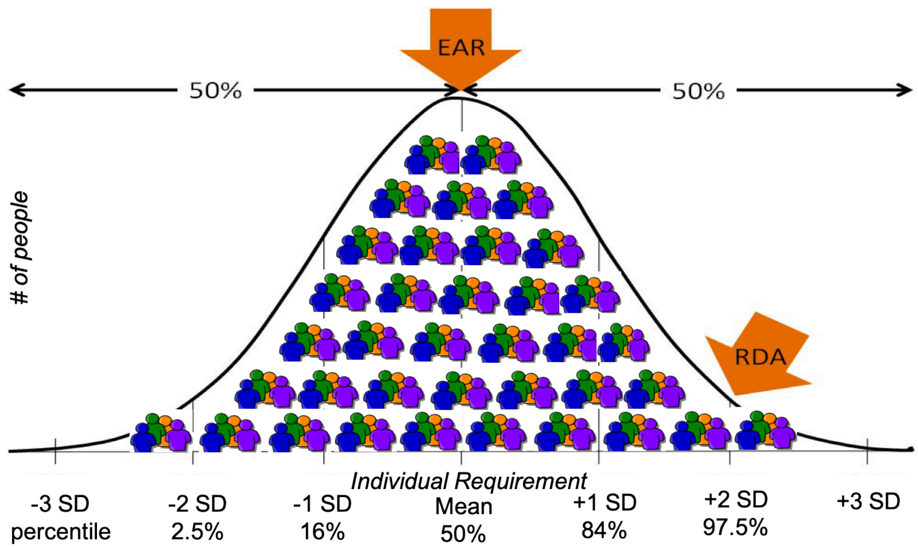
Let's look at how each of these DRI values is determined, what they mean, and how they are used.

Estimated Average Requirement

The Estimated Average Requirement (EAR) is the amount of a nutrient that meets the requirements of 50 percent of people within a group of the same life stage and sex. The requirements of half of the group will fall below the EAR, and the requirements of the other half will be above it. To understand the EAR, it's important to recognize that individuals have different nutrient requirements, depending on many factors beyond our life stage and sex (differences in genetics, metabolism, body weight, and physical activity, for example), and the EAR is like the midpoint in the range of different individual requirements.

To develop the EAR, a committee of scientists evaluates the research on that nutrient and chooses a specific bodily function as a criterion on which to base it. For example, the EAR for calcium is set using a criterion of maximizing bone health, because this is quantitatively one of the most important functions of calcium, and the effects of different levels of calcium intake on bone health can be measured. Thus, the EAR for calcium is set at a point that will meet the needs, with respect to bone health, of half of the population.

The EAR for a given nutrient is shown in the graph below, with the individual requirement on the x-axis. Imagine this graph is depicting individual calcium requirements. The people on the left side of the graph have lower calcium requirements, and the people on the right side of the graph have higher calcium requirements. If everyone was eating the EAR for calcium, half would be getting enough calcium and half would not. Therefore, it wouldn't be wise to recommend that everyone only consume the EAR, because about half of the population would fall short in calcium if this was set as the recommendation. **EAR values are most important because they are used to calculate the Recommended Daily Allowance (RDA) values, which are commonly used as population-wide recommendations for nutrient intake.**



EAR and RDA relative to individual requirements for a given nutrient by Callahan, A., CC BY 4.0

Recommended Daily Allowances

Once the EAR of a nutrient has been established, the**Recommended Daily Allowances (RDA)** value 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**. You can see this in the graph above. The RDA is a better recommendation for the population, because we can assume that if a person is consuming the RDA of a given nutrient, they are most likely meeting their nutritional needs for that nutrient.

This also explains why the RDA is not the same thing as an individual nutritional requirement. You may be consuming less than the RDA for calcium, but this does not automatically mean that your body is deficient in calcium and that you'll definitely end up with osteoporosis, because your *individual* calcium requirement may be less than the RDA. However, since you probably don't know your individual calcium requirement, the RDA is a good target amount for consumption, and the more your intake drops below the RDA, the greater your risk of later developing osteoporosis. 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.

It's interesting to compare and contrast the EER (for energy or calorie intake) and the RDA (for nutrient intake). In practice, both types of recommendations serve as a daily target for intake. However, the EER is set to meet the average caloric needs of a person, while the RDA is set to meet the needs of the vast majority of the population. Imagine if the EER was set to ensure that it met the caloric needs of the vast majority of a population. It would end up being a dramatic overestimate of caloric needs for most people. If everyone actually followed this recommendation, the majority of them would consume far more calories than they actually needed, resulting in weight gain. For nutrients, we have more flexibility in our intake, because we have ways of storing or metabolizing and excreting excess nutrients, so consuming somewhat more than our body needs is just fine.

Adequate Intake

When there is insufficient scientific evidence to set an EAR and RDA for the entire population, then the National Academies committee can decide to set an**Adequate Intake (AI)** level instead. **The AI is based on observing healthy people and seeing how much of the nutrient in question they are consuming**. An AI is less precise than an RDA, but in the absence of an RDA, the AI is our best guess of how much of a given nutrient is needed. If there is not an RDA for a nutrient, than the AI is used as the nutrient-intake goal.

For example, there has not been sufficient scientific research into the exact 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 young 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.

Tolerable Upper Intake Levels

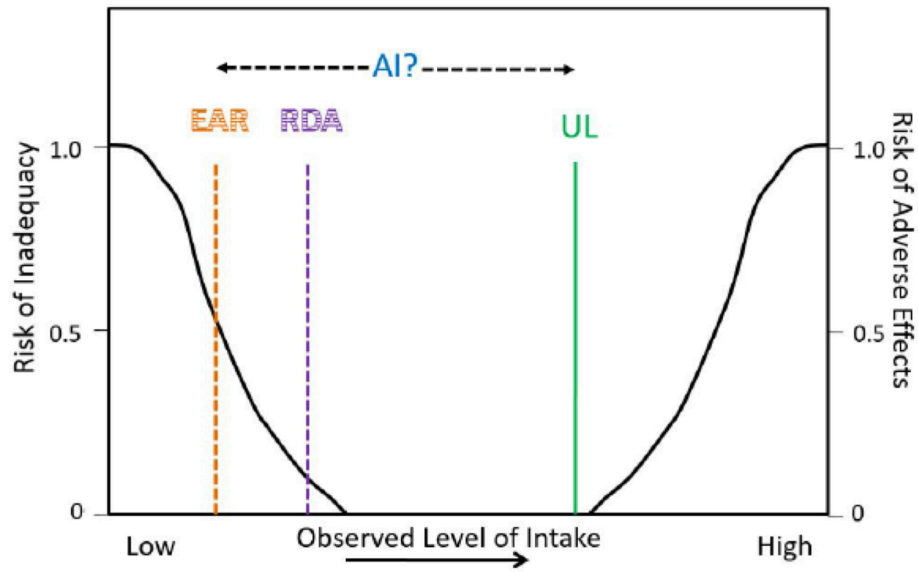
Consuming inadequate amount of nutrients can cause health problems, and we use the RDA or AI values as targets to ensure that we're getting enough. However, consuming too much of many nutrients can also cause health problems. This is where the**Tolerable Upper Intake Level (UL)** is helpful. **ULs indicate the highest level of continuous intake of a particular nutrient that may be taken without causing health problems.**

It's rare to find amounts of a nutrient exceeding the UL in a balanced diet based on whole foods. However, a person who consumes dietary supplements, foods fortified with high levels of additional nutrients (protein bars, for example) or a diet based on only a few foods, might exceed the UL, and this could cause problems with nutrient toxicity. If you're selecting a supplement, be sure to choose one that does not exceed the UL for any nutrient, unless this is under specific instructions from your doctor or a registered dietitian.

When a nutrient does not have any *known* issue if taken in excessive doses, it is not assigned a UL. However, if a nutrient does not have a UL, that doesn't necessarily mean that it is safe to consume in large amounts—only that there isn't currently evidence that large amounts will cause problems. Science is an ongoing process, and the toxicity of many nutrients hasn't yet been studied.

PUTTING IT ALL TOGETHER

The graph below summarizes the meaning of the 4 DRI values for nutrient intake.



The EAR, RDA, AI, and UL are shown relative to the observed level of intake and risk of inadequacy and adverse effects. [DRI values for nutrient intake](#) by Lindshield, B., via [CC BY-NC-SA 4.0](#)

This graph shows 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 needs 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 AI is shown to exist somewhere between the EAR and UL, as it's an amount of the nutrient known to maintain health.

Note that there is a wide margin between the RDA and UL, showing that a person might safely eat much more than the RDA for a given nutrient without concerns of nutrient toxicity. However, be aware that the margin of safety varies depending on the nutrient. For example, fat-soluble vitamins have a smaller margin of safety between the RDA and the UL than water-soluble vitamins, meaning that it's easier to consume toxic levels of fat-soluble vitamins.

VIDEO: DIETARY REFERENCE INTAKES[2]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=707#oembed-1

2. Luetkemeier, M. (September 16, 2015). YouTube. https://youtu.be/UPsymcEobDk?si=E9cZw-zy84jfWrjw

HOW THE DRIS ARE USED

Individuals can use the DRIs to help assess and plan their diets. Keep in mind 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 the average intake over time; that is, you don't need to meet these recommendations every single day—meeting them over several days is sufficient.

SELF-CHECK:

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.nscc.ca/clinicalnutrition/?p=707#h5p-4

CHAPTER ATTRIBUTION

Understanding Food Labels

Not so long ago, food choices were limited to what could be grown or raised, hunted or gathered. Today, grocery stores offer seemingly infinite choices in foods, with entire aisles dedicated to breakfast cereals and cases filled with a multitude of different yogurts. Faced with so many choices, how can we decide? Taste matters, of course. But if a healthy diet is your goal, so does nutrition. Food labels are our window into the nutritional value of a given food. Let's examine what we can learn from food labels and how reading them can help us make smart choices to contribute to a healthy diet.

Grocery aisle by NeONBRAND, via Unsplash License

Health Canada regulates the labelling of food products in Canada through the Food and Drugs Act. Regulations published on January 1, 2003 :

- Make nutrition labelling mandatory on most food labels.
- Update requirements for nutrient content claims.
- Permit, for the first time in Canada, diet-related health claims for foods.

NUTRITION LABELLING[1]

Nutrition labelling is information included on labels of packaged foods about nutrient content. Considering the health impact of foods and effects related to obesity, cardiovascular diseases, diabetes, and other conditions, there has been a shift in many countries to mandate and regulate nutrition labelling.[2]

The Canadian government has made efforts to create labels that provide necessary information for consumers. However, it is important to be aware that nutrition labelling is often poorly understood by consumers. Health professionals are expected to be knowledgeable about how to read and interpret nutrition labels (including **nutrition facts tables [NFT]** and the ingredients list). Such knowledge will allow health professionals to help clients read nutrition labels, like that which is illustrated in **Figure 2.1**, and to make informed choices about healthy and safe eating that meets the dietary needs of each individual.

Figure 2.1: Reading nutrition labels

Health Canada is responsible for constructing policies to meet the standards set by the Food and Drugs Act (FDA). The Food Directorate of Health Canada is responsible for the "development of policies, regulations and standards that relate to the use of health claims on food".[3] Other governing bodies, such as the Canadian Food Inspection Agency (CFIA), have responsibilities for administering and enforcing food labelling policies as well as managing the Consumer Packaging and Labelling Act. Under this legislation, food producers must meet governmental labelling requirements.

Most prepackaged food labels (e.g., can of soup, bag of chips, bag of frozen peas) must include:

- the NFT,
- a list of ingredients,

1. *Nutrition and Labelling for the Canadian Baker* by go2HR and is used under a Creative Commons Attribution 4.0 International License.
2. (Viola, Bianchi, Croce, & Ceretti, 2016).
3. Government of Canada, 2016, 3rd para).

- allergen statements,
- and best before dates.

The NFT is mandatory on prepackaged foods with the exception of some items such as alcoholic beverages and products that have few nutrients (e.g., coffee and spices). The Government of Canada[4] does not require nutritional labelling on foods such as fresh fruits and vegetables and foods sold at farmers' markets. In general, it is mandatory to show both official languages of Canada (French and English) on labels, with some exceptions (e.g., specialty foods, local foods, test market foods, and shipping containers) as long as the products are not resold to consumers.

THE NUTRITION FACTS TABLE AND INGREDIENT LIST

Under Government of Canada[5] regulations, the NFT must provide information about:

- serving size
- calories
- **percent daily value (% DV) of nutrients**
- core nutrients

Currently, the requirements for nutrient information are changing and industry has five years to make changes so that NFT include: fat, saturated fat, trans fat, cholesterol, sodium, carbohydrate, fibre, sugars, protein, potassium, calcium, and iron (Government of Canada, 2019a; Government of Canada, 2017).

Figure 2.2 illustrates the new NFT as compared with the original (i.e., the previous version).

4. (2019a)
5. (2019a)

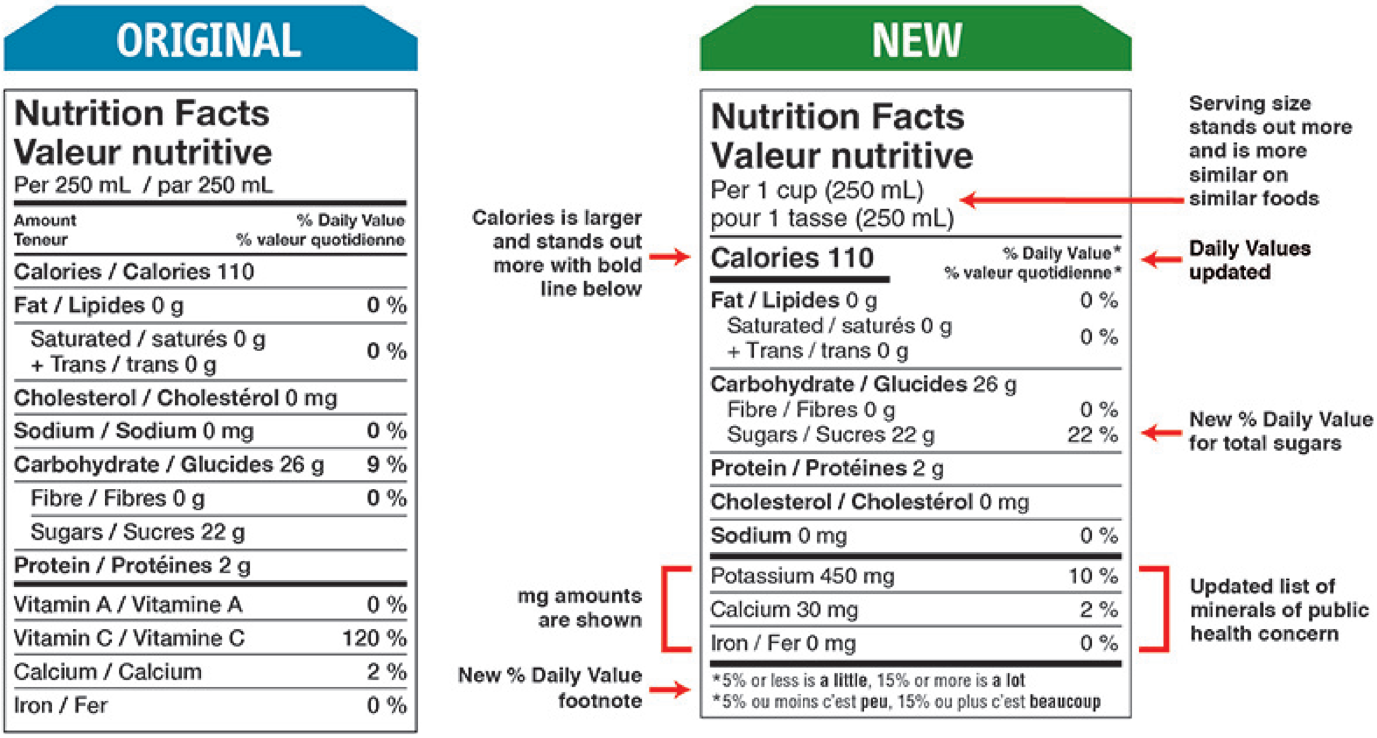


Figure 2.2: Comparison of the original NFT and the new NFT

The NFT displays the % DV so consumers can determine the amount of a certain nutrient in one serving. For example, the Government of Canada[6] indicates that 5% of the DV or less of a nutrient is considered “a little” while 15% of the DV or more of a nutrient is considered “a lot.” You should be aware that the % DV is not used to identify whether a person has had sufficient nutrients in a day, particularly considering that many foods do not require the NFT.[7] Rather, it is best to talk with your clients about using the % DV to compare and make choices between different types of food that are higher in healthy nutrients (e.g., fibre) and lower in nutrients that are not healthy (e.g., sodium and trans fat)[8]

The list of ingredients (as illustrated in **Figure 2.3**) is mandatory on most packaged foods that contain more than one ingredient, and ingredients are listed in order of weight. The weight of ingredients listed will be an important aspect of your conversation with a client. You may choose to draw their attention to that aspect of food labelling and discuss with them how it might impact their food choices. In addition, caffeinated energy drinks require that the amount of caffeine is included with a statement that the product is a “high source of caffeine” and “not recommended for children, pregnant/breastfeeding women” [9]

6. (2019b)
7. Government of Canada, 2019b
8. (Government of Canada, 2019b).
9. (Canadian Food Inspection Agency, 2015).

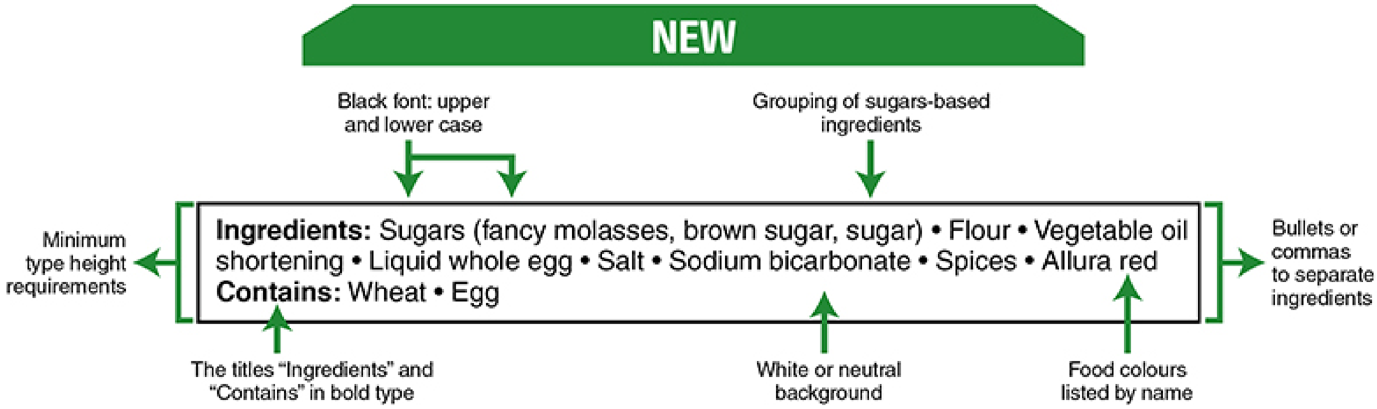


Figure 2.3: List of ingredients

READING LABELS

1. Statement of identity *(what type of food is it?)*
2. Net contents of the package *(how much is in there?)*
3. Name and address of manufacturer (*where was it produced?*)
4. Ingredients list *(what ingredients are included in the food?)*
5. Nutrition information (*what is the amount of nutrients included in a serving of food?*)

Statement of Identity

The statement of identity and net contents of the package tell you what type of food you're purchasing and how much is in the package. The name and address of the manufacturer are important if there's a food recall due to an outbreak of foodborne illness or other contamination issue. Given the size of our food system and the fact that one manufacturer may make products packaged under multiple brand names, being able to trace a food's origin is critical.

The last two types of required information—the ingredients list and the nutrition information—are a bit more complex and provide valuable information to consumers, so let's look more closely at each of these parts of a food label.

By law, food manufacturers must also list major allergens, which include milk, egg, fish, crustacean shellfish, tree nuts, wheat, peanuts, and soybeans.[2] Allergens may be listed in a separate statement, as on the corn muffin mix label, which lists "Contains: Wheat" on the label. Alternatively, allergens can be listed in parentheses within the ingredient list, such as "lecithin (soy)." Some labels include an optional "may contain" or "made in shared equipment with…" statement that lists additional allergens that could be present, not as ingredients in the food, but in trace amounts from equipment contamination. For people with food allergies, having this information clearly and accurately displayed on food packages is vital for their safety.

VIDEO: READING FOOD LABELS[10]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=717#oembed-1

Health Claims

Health claims are statements on food packaging that link the food or a component in the food to reducing the risk of a disease. Health claims can be "authorized" or "qualified." **Authorized health claims** have stronger scientific evidence to back them than qualified health claims.

As an example of an authorized health claim, a food that is low in sodium (per the FDA's definition of less than 140 mg per serving) can include the following claim on their packaging: "Diets low in sodium may reduce the risk of high blood pressure, a disease associated with many factors."

For an authorized health claim to be approved by the FDA, the agency says "there must be significant scientific agreement (SSA) among qualified experts that the claim is supported by the totality of publicly available scientific evidence for a substance/disease relationship. The SSA standard is intended to be a strong standard that provides a high level of confidence in the validity of the substance/disease relationship."[11] In other words, the FDA requires a great deal of evidence before allowing food manufacturers to claim that their products can reduce the risk of a disease. As is evident in the low sodium claim, they also require careful language, such as "*may* reduce" (not definitely!) and "a disease associated with many factors" (as in, there are many other factors besides sodium that influence blood pressure, so a low sodium diet isn't a guaranteed way to prevent high blood pressure).

Qualified health claims have some evidence to support them, but not as much, so there's less certainty that these claims are true. The FDA reviews the evidence for a qualified claim and determines how it should be worded to convey the level of scientific certainty for it. Here's an example of a qualified health claim: "Scientific evidence suggests but does not prove that eating 1.5 ounces per day of most nuts (such as name of specific nut) as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease."

Structure-Function Claims

Health claims are very specific and precise in their language, and they convey the level of scientific certainty supporting them. In contrast, **structure-function claims**are intentionally vague statements about nutrients playing some role in health processes. Examples of structure-function claims are "calcium builds strong bones" and "fiber maintains bowel regularity." Note that these statements make no claims to prevent osteoporosis or treat constipation, because structure-function claims are not allowed to say that a food or nutrient will treat, cure, or prevent any disease.[12] They're allowed by the FDA, but not specifically approved or regulated, as long as their language stays within those rules.

10. Cincinnati Children's. (May 9, 2019). YouTube. https://youtu.be/tB7BgszxLs8?si=KpLeRlrA16n_mU5o
11. U.S. Food and Drug Administration. (2018). Questions and Answers on Health Claims in Food Labeling. FDA. http://www.fda.gov/food/food-labeling-nutrition/questions-and-answers-health-claims-food-labeling
12. U.S. Food and Drug Administration. (2018). Structure/Function Claims. FDA. Retrieved from http://www.fda.gov/food/food-labeling-nutrition/structurefunction-claims

Structure-function claims were originally designed to be used on dietary supplements, but they can also be used on foods, and they're usually found on foods that are fortified with specific nutrients. They are marketing language, and because nutrients are involved in so many processes, they really don't mean much.

As you look at food labels, pay attention to what's shown on the front of the package compared with the back and side of the package. Nutrient and health claims are usually placed strategically on the front of the package, in large, colorful displays with other marketing messages, designed to sell you the product. But for consumers trying to decide which product to buy, you'll find the most useful information by turning the package around to read the Nutrition Facts panel and ingredients list. These parts of the label may appear more mundane, but if you understand how to read them, you'll find that they're rich in information.

SELF-CHECK:

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.nscc.ca/clinicalnutrition/?p=717#h5p-5

CHAPTER ATTRIBUTION

Unit 1, *Understanding Food Labels* in Nutrition: Science and Everyday Application by Alice Callahan, Heather Leonard, and Tamberly Powell; Lane Community College, published in 2021 under a CC BY-NC license.

Tools for Achieving a Healthy Diet

Good nutrition means eating the right foods, in the right amounts, to receive enough (but not too much) of the essential nutrients so that the body can remain free from disease, grow properly, work effectively, and feel its best. The phrase "you are what you eat" refers to the fact that the food you eat has cumulative effects on the body. And many of the nutrients obtained from food do become a part of us. For example, the protein and calcium found in milk can be used in the formation of bone. The foods we eat also impact how we feel—both today and in the future. Below we will discuss the key components of a healthy diet that will help prevent chronic disease (like heart disease and diabetes), maintain a healthy weight, and promote overall health.

ACHIEVING A HEALTHY DIET

Achieving a healthy diet is a matter of balancing the quality and quantity of food that you eat to provide an appropriate combination of energy and nutrients. There are four key characteristics that make up a healthful diet:

1. Adequacy
2. Balance
3. Moderation
4. Variety

Adequacy[1]

A diet is **adequate** when it provides sufficient amounts of calories and each essential nutrient, as well as fiber. In Canada:

- 5 in 10 women and 7 in 10 men have energy intakes that exceed their energy needs.
- 25% of males and 23% of females, 19 years and older, have fat intakes above the Acceptable Macronutrient Distribution Range.
- 32% of males and 21% of females, 19 years and older, have carbohydrate intakes below the Acceptable Macronutrient Distribution Range.
- Many adults have inadequate intakes of magnesium, calcium, vitamin A and vitamin D (see Box 1 below). For nutrients with an Adequate Intake (AI), there is concern that Canadian adults may not be meeting their needs for potassium and fibre – although the interpretation of the adequacy of nutrients with an AI

1. Health Canada. (2012). Do Canadian Adults Meet Their Nutrient Requirements Through Food Intake Alone? https://www.canada.ca/en/health-canada/services/food-nutrition/food-nutrition-surveillance/health-nutrition-surveys/canadian-community-health-survey-cchs/canadian-adults-meet-their-nutrient-requirements-through-food-intake-alone-health-canada-2012.html#a6

is limited.

- Canadian adults' sodium intakes are associated with an increased risk of adverse health effects.

Balance

A **balanced** diet means eating a combination of foods from the different food groups, and because these food groups provide different nutrients, a balanced diet is likely to be adequate in nutrients. For example, vegetables are an important source of potassium, dietary fiber, folate, vitamin A, and vitamin C, whereas grains provide B vitamins (thiamin, riboflavin, niacin, and folate) and minerals (iron, magnesium, and selenium). No one food is more important than the other. It is the combination of all the different food groups (fruit, vegetables, grains, dairy, protein and fats/oils) that will ensure an adequate diet.

Four Days of Bento. Image by Blairwang, CC BY 2.0

Moderation

Moderation means not eating to the extremes, neither too much nor too little of any one food or nutrient. Moderation means that small portions of higher-calorie, lower-nutrient foods like chips and candy can fit within a healthy diet. Including these types of foods can make healthy eating more enjoyable and also more sustainable. When eating becomes too extreme—where many foods are forbidden—this eating pattern is often short-lived until forbidden foods are overeaten. Too many food rules can lead to a cycle of restriction-deprivation-overeating-guilt. For sustainable, long-term health benefits, it is important to give yourself permission to eat all foods.

Colours of Health by Promois, A., CC BY-NC 2.0

Variety

Variety refers to consuming different foods within each of the food groups on a regular basis. Eating a varied diet helps to ensure that you consume adequate amounts of all essential nutrients required for health. One of the major drawbacks of a monotonous diet is the risk of consuming too much of some nutrients and not enough of others. Trying new foods can also be a source of pleasure—you never know what foods you might like until you try them.

DIETARY GUIDELINES FOR CANADIANS[2]

Canada's first food guide, the official food rules, was developed in 1942 to help prevent nutritional deficiencies and improve the health of Canadians during wartime food rationing. Since that time, it was been transformed many times to adapt to the current situations and demands. The current version, released in 2019, provides a less prescriptive approach. The new food guide has moved away from recommendations based on the number and size of servings. The new approach:

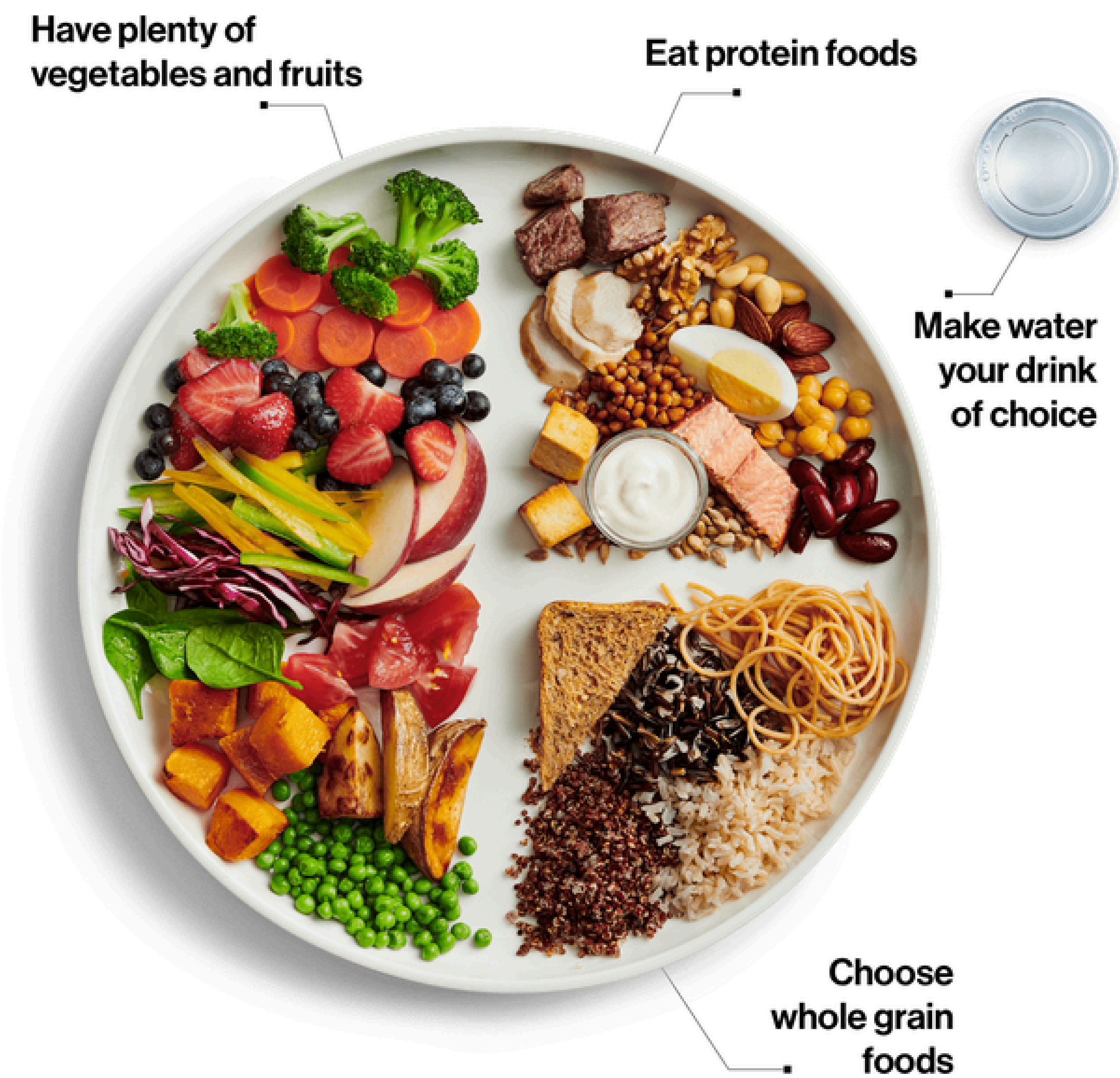
- is designed to be flexible
- includes tips for healthy eating habits
- recommends a variety of healthy food choices

The 2019 Canada Food Guide recommends the following:

1. Eat plenty of vegetables and fruits, whole grain foods and protein foods. Choose protein foods that come from plants more often. Select mono and poly-unsaturated fats over saturated fats.

2. Government of Canada. (2020). Healthy eating recommendations. Canada's Food Guide. https://food-guide.canada.ca/en/healthy-eating-recommendations/

2. Limit highly processed foods. Prepare meals with little to no sodium, sugars or saturated fats.
3. Make water your drink of choice.
4. Use food labels
5. Be aware that marketing can influence your choices.



Eat a variety of healthy foods each day. Credit: Canada's Food Guide.

The guide outlines a set of recommendations to develop healthy eating habits:

1. Be mindful of your eating habits. Take time to eat and notice when you are hungry and full.
2. Cook more often. Plan what you eat, involve others in planning and prepare meals.
3. Enjoy your food. Culture and food traditions can be part of healthy eating.

4. Eat meals with others.

Purposeibid.

Canada's Food Guide offers guidance on what to eat, as well as where, when, why and how we eat. It helps develop food skills that can help people in Canada navigate the complex food environment and promote health and well-being. Its goal is to help:

- meet nutrient needs
- improve nutritional health
- lower the risk of nutrition-related chronic diseases and conditions

Canada is not the only country that develops nutritional guidelines. The Food and Agriculture Organization of the United Nations has a website where you can search for dietary guidelines for different countries, such as Sweden's guidelines, illustrated below.

Sweden's one-minute advice by Food and Agriculture Organization of the United Nations (FAO). CC BY 3.0

The Swedish National Food Agency also has a great resource, "Find Your Way To Eat Greener, Not Too Much and Be Active" on how to put these guidelines into practice.

CHAPTER ATTRIBUTION

Canadian content added from the Government of Canada. (2020). Healthy eating recommendations. Canada's Food Guide. https://food-guide.canada.ca/en/healthy-eating-recommendations/

Adapted from Unit 1, *Tools for Achieving a Healthy Diet* in Nutrition: Science and Everyday Application by Alice Callahan, Heather Leonard, and Tamberly Powell; Lane Community College, published in 2021 under a CC BY-NC license.

Creation notes in Nutrition: Science and Everyday Application include attribution for unspecified content from:

- University of Hawai'i at Mānoa Food Science and Human Nutrition Program, "Achieving a Healthy Diet," CC BY-NC 4.0
- "Recommendations for Optimal Heath," section 2.5 from the book An Introduction to Nutrition (v. 1.0), CC BY-NC-SA 3.0

Finding Accurate Sources of Nutrition Information

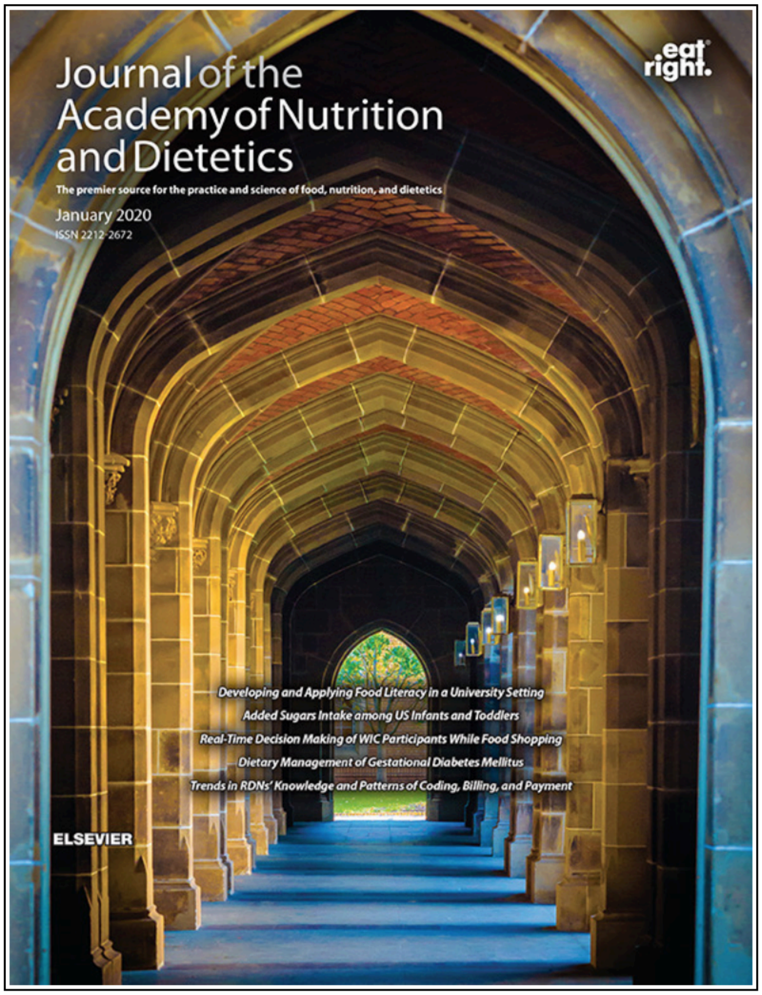
As we discussed in the previous section, science is always evolving, albeit sometimes slowly. One study is not enough to make a guideline or recommendation or to cure a disease. Science is a stepwise process that continuously builds on past evidence and develops towards a well-accepted consensus, although even that can be questioned as new evidence emerges. Unfortunately, the way scientific findings are communicated to the general public can sometimes be inaccurate or confusing. In today's world, where instant Internet access is just a click away, it's easy to be overwhelmed or misled if you don't know where to go for reliable nutrition information. Therefore, it's important to know how to find accurate sources of nutrition information and how to interpret nutrition-related stories when you see them.

DECIPHERING NUTRITION INFORMATION

> "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 headlines like this? Do you boycott margarine and coffee? When reading nutrition-related claims, articles, websites, or advertisements, always remember that one study neither proves or disproves anything. Readers who may be looking for answers to complex nutrition questions can quickly misconstrue such statements and be led down a path of misinformation, especially if the information is coming from a source that isn't credible. Listed below are ways that you can develop a discerning eye when reading news highlighting nutrition science and research.

- **The scientific study under discussion should be published in a peer-reviewed journal.** Having gone through the peer review process, these studies have been checked by other experts in the field to ensure that their methods and analysis were rigorous and appropriate. Peer-reviewed articles also include a review of previous research findings on the topic of study and examine how their current findings relate to, support, or are in contrast to previous research. Question studies that come from less trustworthy sources (such as non peer-reviewed journals or websites) or that are not formally published.



An example of a peer-reviewed journal, the Journal of the Academy of Nutrition and Dietetics, which publishes research findings of nutrition scientists. Nutrition research is also frequently published in journals like the Journal of Nutrition, American Journal of Clinical Nutrition, and Journal of Nutrition Education and Behavior, as well as medical and behavioral journals. Journal photo by Leonard, H. CC BY 4

- **The report should disclose the methods used by the researcher(s).**
  - Identify the type of study and where it sits on the hierarchy of evidence. Keep in mind that a study in humans is likely more meaningful than one that's in vitro or in animals; an intervention study is usually more meaningful than an observational study; and systematic reviews and meta-analyses often give you the best synthesis of the science to date.
  - If it's an intervention study, check for some of the attributes of high-quality research already discussed: randomization, placebo control, and blinding. If it's missing any of those, what questions does that raise for you?
  - Did the study last for three weeks or three years? Depending on the research question, studies that are short may not be long enough to establish a true relationship with the issues being examined.

  - Were there ten or two hundred participants? If the study was conducted on only a few participants, it's less likely that the results would be valid for a larger population.
  - What did the participants actually do? It's important to know if the study included conditions that people rarely experience or if the conditions replicated real-life scenarios. For example, a study that claims to find a health benefit of drinking tea but required participants to drink 15 cups per day may have little relevance in the real world.
  - Did the researcher(s) observe the results themselves, or did they rely on self reports from program participants? Self-reported data and results can be easily skewed by participants, either intentionally or by accident.
- **The article should include details on the subjects (or participants) in the study.** Did the study include humans or animals? If human, are any traits/characteristics noted? You may realize you have more in common with certain study participants and can use that as a basis to gauge if the study applies to you.
- **Statistical significance is not the same as real-world significance.** A statistically significant result is likely to have not occurred by chance, but rather to be a real difference. However, this doesn't automatically mean that the difference is relevant in the real world. For example, imagine a study reporting that a new vitamin supplement causes a statistically significant reduction in the duration of the common cold. Colds can be miserable, so that sounds great, right? But what if you look closer and see that the supplement only shortened study subjects' colds by half a day? You might decide that it isn't worth taking a supplement just to shorten a cold by half a day. In other words, it's not a real-world benefit to you.
- **Credible reports should 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 (previously published studies) supports a finding, it adds credibility to the study. A news story about a new scientific finding should also include comments from outside experts (people who work in the same field of research but weren't involved in the new study) to provide some context for what the study adds to the field, as well as its limitations.
- **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 it could also be a sensationalized 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.

THE CRAAPP TEST[FOOTNOTE]BLAKESLEE, SARAH (2004). THE CRAAP TEST, LOEX QUARTERLY, 31(3)6-7. HTTPS://COMMONS.EMICH.EDU/LOEXQUARTERLY/VOL31/ISS3/4[/FOOTNOTE][1]

The CRAAPP Test is a six-letter mnemonic device for evaluating the credibility and validity of information found through various sources, including websites and social media channels. The CRAAPP Test can be particularly useful in evaluating nutrition related news and articles.

While there is a wealth of information about nutrition on the internet and in books and magazines, it can be challenging to separate the accurate information from the hype and half-truths. You can use the CRAAPP Test to help you determine the validity of the resources you encounter and the information they provide. By applying

1. Lumen Learning. (n.d.) The CRAAPP Test. Introduction to College Research. https://courses.lumenlearning.com/atd-fscj-introtoresearch/chapter/the-craapp-test/

the following principles, you can be confident that the information is credible. We've added several notes to the traditional CRAAPP Test to help you expand your analysis[2] and apply it to nutrition information.

Currency

- When was it written or published? Has the website been updated recently?
- Do you need current information, or will older sources meet your research need?
- Where is your topic in the information cycle?
- Note: In general, newer articles are more likely to provide up-to-date perspectives on nutrition science, so as a starting point, look for those published in the last 5-7 years. However, it depends on the question that you're researching. In some areas, nutrition science hasn't changed much in recent years, or you may be interested in historical background on the question. In either case, an older article would be appropriate.

Relevance

- Does it meet stated requirements of your assignment?
- Does it meet your information needs/answer your research question?
- Is the information at an appropriate level or for your intended audience?

Authority

- Who is the creator/author/publisher/source/sponsor? Are they reputable?
- What are the author's credentials and their affiliations to groups, organizations, agencies or universities?
- What type of authority does the creator have? For example, do they have subject expertise (scholar), social position (public office, title), or special experience?
- Note: The authority on nutrition information would be a registered dietitian nutritionist (RDN), a professional with advanced degree(s) in nutrition (MS or PhD), or a physician with appropriate education and expertise in nutrition. (This will be discussed in more detail on the next page). Look for sources authored or reviewed by experts with this level of authority or written by people who seek out and include their expertise in the article.

Accuracy

- Is the information reliable, truthful, and correct?
- Does the creator cite sources for data or quotations? Who did they cite?
- Are they cherry-picking facts to support their argument?
- Is the source peer-reviewed, or reviewed by an editor? Do other sources support the information presented?
- Are there spelling, grammar, and typo errors that demonstrate inaccuracy?

2. Fielding, J.A. (2019). Rethinking CRAAP: Getting students thinking like fact-checkers in evaluating web sources. C&RL News, December: 620-622.

- Note: Oftentimes, checking the accuracy of information in a given article or website means opening a new internet tab and doing some additional sleuthing to check the claims against other sources.

Purpose

- Is the intent of the website to inform, persuade, entertain, or sell something?
- Does the point of view seem impartial or biased?
- Is the content primarily opinion? Is it balanced with other viewpoints?
- Who is the intended audience?
- Note: Particularly if you're looking at an organization's website, do some background research on the organization to see who funds it and what is the purpose of the group. That information can help you determine if their point-of-view is likely to be biased.

Process

    - What kind of effort was put into the creation and delivery of this information?
    - Is it a Tweet? A blog post? A YouTube video? A press release?
- Was it researched, revised, or reviewed by others before published?
- How does this format fit your information needs or requirements of assignment?

RED FLAGS OF JUNK SCIENCE

When it comes to nutrition advice, the adage holds true that "if it sounds too good to be true, it probably is." There are several tell-tale signs of **junk science**—untested or unproven claims or ideas usually meant to push an agenda or promote special interests. In addition to using the CRAAPP Test to decipher nutrition information, you can also use these simple guidelines to spot red flags of junk science. When you see one or more of these red flags in an article or resource, it's safe to say you should at least take the information with a grain of salt, if not avoid it altogether.

Red Flags of Junk Science[3]

- Promise a quick fix
- Dire warnings of danger
- Claims that sound to good to be true
- Simple conclusions drawn from a complex study
- Recommendations based on a single study
- Dramatic statements that are refuted by reputable scientific organizations
- List of good and bad foods
- Recommendations aim to sell a product

3. Adapted from: Position of the American Dietetic Association: Food and Nutrition Misinformation. (2002). Journal of the American Dietetic Association, Volume 106, Issue 4, 601 - 607 DOI: https://doi.org/10.1016/j.jada.2006.02.019

- Recommendations based on unpublished studies or studies published. by unreliable sources
- Recommendations from studies that ignore individual or group differences

With the mass quantities of nutrition articles and stories circulating in media outlets each week, it's easy to feel overwhelmed and unsure of what to believe. But by using the tips outlined above, you'll be armed with the tools needed to decipher every story you read and decide for yourself how it applies to your own nutrition and health goals.

HOW TO USE THE CRAAP TEST VIDEO[4]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=759

SELF-CHECK:

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.nscc.ca/clinicalnutrition/?p=759#h5p-10

CHAPTER ATTRIBUTION

4. Hodges University Library. (2016, December 12). How to use the CRAAP test [Video]. YouTube. https://youtu.be/tVqnamWs91I

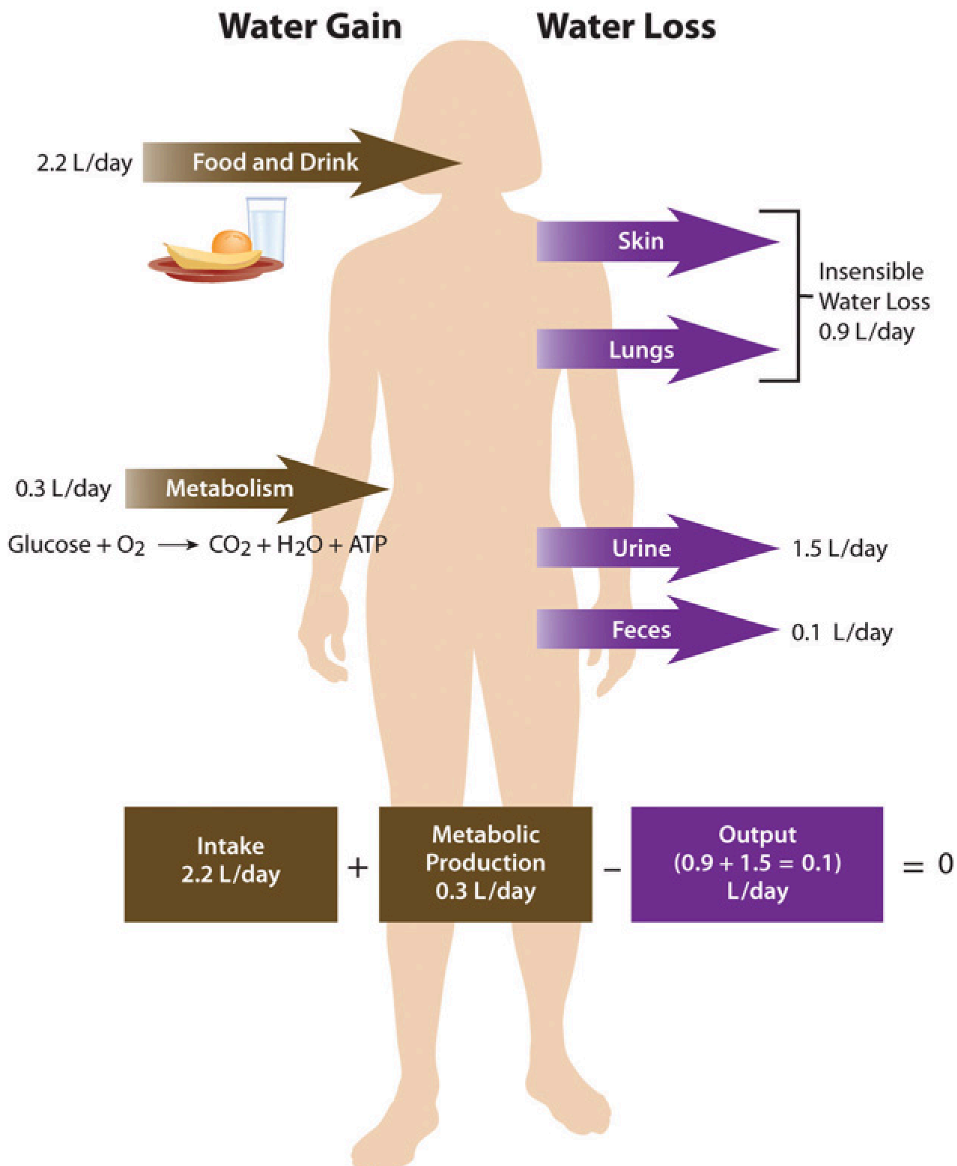
WATER AND ELECTROLYTES

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.



[Daily Fluid Loss and Gain](#) by lardbucket, via [CC BY-NC-SA 4.0](#)

DIETARY GAIN OF WATER

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. Approximately 20 percent of dietary water comes from solid foods. See Table "Water Content in Foods" for the range of water contents for selected food items. Beverages includes water, tea, coffee, sodas, and juices.

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.

Water Content in Foods[2]

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

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?

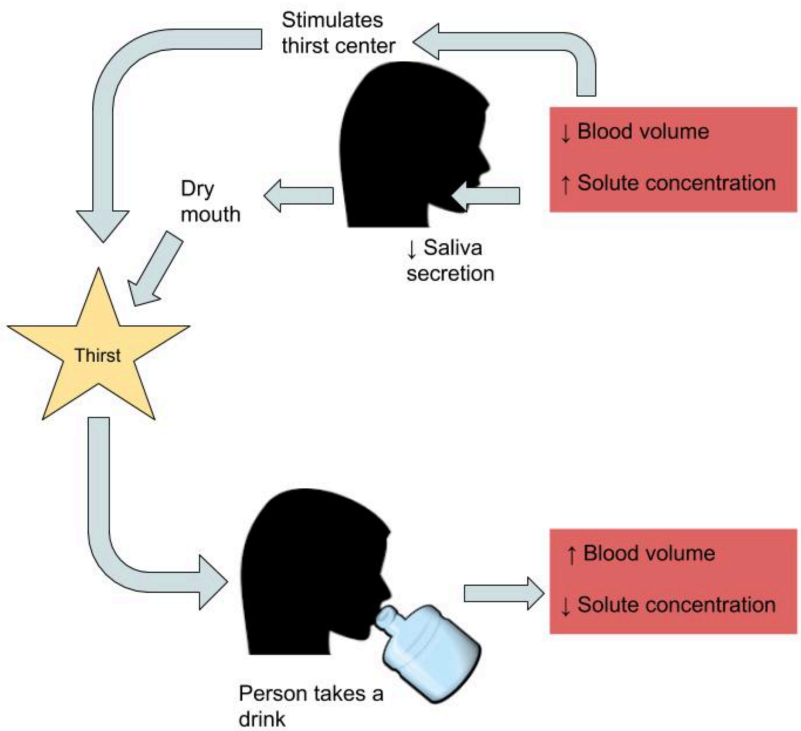
Thirst is an osmoregulatory mechanism to increase water input. The thirst mechanism is activated in response to changes in water volume in the blood, but is even more sensitive to changes in blood osmolality. Blood osmolality is primarily driven by the concentration of sodium cations. The urge to drink results from a complex interplay of hormones and neuronal responses that coordinate to increase water input and contribute toward fluid balance and composition in the body. 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. Thirst happens in the following sequence of physiological events:

1. Receptor proteins in the kidney, heart, and hypothalamus detect decreased fluid volume or increased sodium concentration in the blood.
2. Hormonal and neural messages are relayed to the brain's thirst center in the hypothalamus. The hypothalamus sends neural signals to higher sensory areas in the cortex of the brain, stimulating the conscious thought to drink.
3. Fluids are consumed.
4. Receptors in the mouth and stomach detect mechanical movements involved with fluid ingestion.
5. Neural signals are sent to the brain and the thirst mechanism is shut off.

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

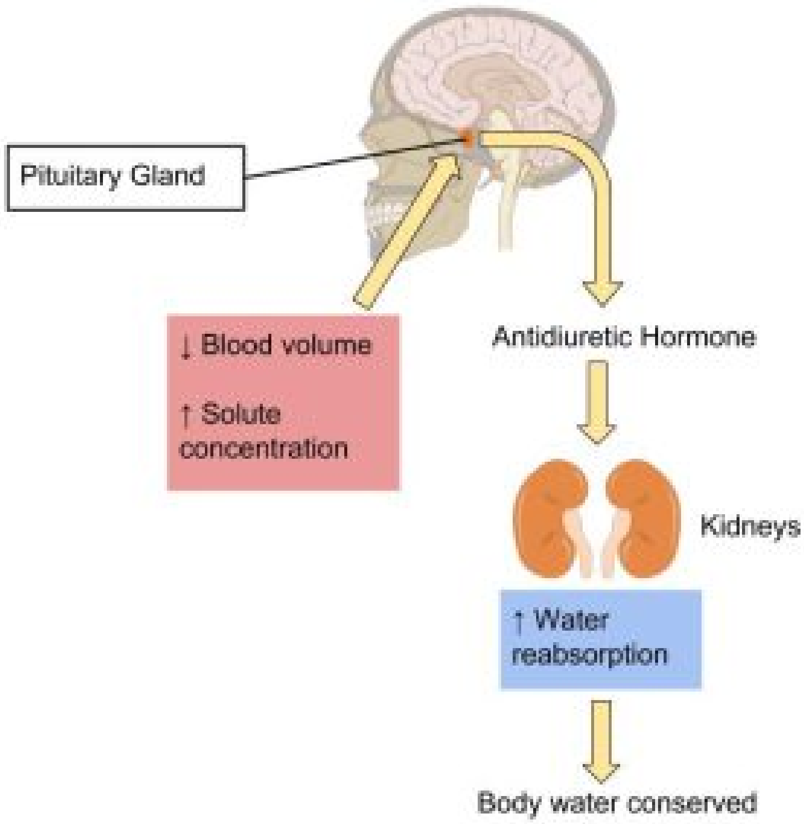
2. Department of Agriculture, Agricultural Research Service. (2010). National Nutrient Database for Standard Reference, Release 23. http://www.ars.usda.gov/ba/bhnrc/ndl.

might have a habit of drinking a glass of orange juice and eating a bowl of cereal every morning before school or work.



Regulating Water Intake by Calabrese, A. CC BY 4.0

REGULATION OF DAILY WATER OUTPUTAs stated, daily water output averages 2.5 liters. There are two types of outputs. The first type is insensible water loss, meaning we are unaware of it. The body loses about 400 milliliters of its daily water output through exhalation. Another 500 milliliters is lost through our skin. The second type of output is sensible water loss, meaning we are aware of it. Urine accounts for about 1,500 milliliters of water output, and feces account for roughly 100 milliliters of water output. Regulating urine output is a primary function of the kidneys, and involves communication with the brain and endocrine system.



Regulating Water Output by Calabrese, A. CC BY 4.0

THE KIDNEYS DETECT BLOOD VOLUME

The kidneys are two bean-shaped organs, each about the size of a fist and located on either side of the spine just below the rib cage. The kidneys filter about 190 liters of blood and produce (on average) 1.5 liters of urine per day. Urine is mostly water, but it also contains electrolytes and waste products, such as urea. The amount of water filtered from the blood and excreted as urine is dependent on the amount of water in, and the electrolyte composition in the blood.

Kidneys have protein sensors that detect blood volume from the pressure, or stretch, in the blood vessels of the kidneys. When blood volume is low, kidney cells detect decreased pressure and secrete the enzyme, renin. Renin travels in the blood and cleaves another protein into the active hormone, angiotensin. Angiotensin targets three different organs (the adrenal glands, the hypothalamus, and the muscle tissue surrounding the arteries) to rapidly restore blood volume and, consequently, pressure.

THE HYPOTHALAMUS DETECTS BLOOD OSMOLALITY

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. Thus, it is not only kidneys that stimulate antidiuretic- hormone release, but also the hypothalamus. This dual control of antidiuretic hormone release allows for the body to respond to both decreased blood volume and increased blood osmolality.

THE ADRENAL GLANDS DETECT BLOOD OSMOLALITY

Cells in the adrenal glands sense when sodium levels are low and potassium levels are high in the blood. In response to either stimulus, they release aldosterone. Aldosterone is released in response to angiotensin stimulation and is controlled by blood electrolyte concentrations. In either case, aldosterone communicates the same message, to increase sodium reabsorption and consequently water reabsorption. In exchange, for the reabsorption of sodium and water, potassium is excreted.

CHAPTER ATTRIBUTION

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.

OTHER FUNCTIONS OF SODIUM IN THE BODY

The second notable function of sodium is in nerve impulse transmission. Nerve impulse transmission results from the transport of sodium cations into a nerve cell, which creates a charge difference (or voltage) between the nerve cell and its extracellular environment. 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 must make their way from the small intestine to the blood. To do so, they pass through intestinal cells on their way 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 are the following:

1. Excessive sodium loss and/or water intake.

2. Sodium levels fall in blood and in the fluid between cells.
3. Water moves to where solutes are more concentrated (i.e. into cells).
4. Cells swell.
5. Symptoms, including nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death result.

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 AI level for sodium for healthy adults between the ages of nineteen and fifty at 1,500 milligrams (Table "Dietary Reference Intakes for Sodium"). 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. 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.The Tolerable Upper Intake Level (UL) for sodium is 2,300 milligrams per day for adults. (Just over 1 teaspoon of salt contains the 2,300 milligrams of sodium recommended). The UL is considered appropriate for healthy individuals but not those with hypertension (high blood pressure). 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. People over fifty, individuals of African descent, diabetics, and those with chronic kidney disease should consume no more than 1,500 milligrams of sodium per day. All adults, not just those listed, should consume less than 1,500 milligrams of sodium per day to prevent cardiovascular disease because millions of people have risk factors for hypertension and there is scientific evidence supporting that lower-sodium diets are preventive against hypertension.

1. Convertino VA, et al. American College of Sports Medicine Position Stand. (1996). Exercise and Fluid Replacement. Medicine and Science in Sports and Exercise. 28(1) i–vii. http://www.ncbi.nlm.nih.gov/pubmed/9303999.

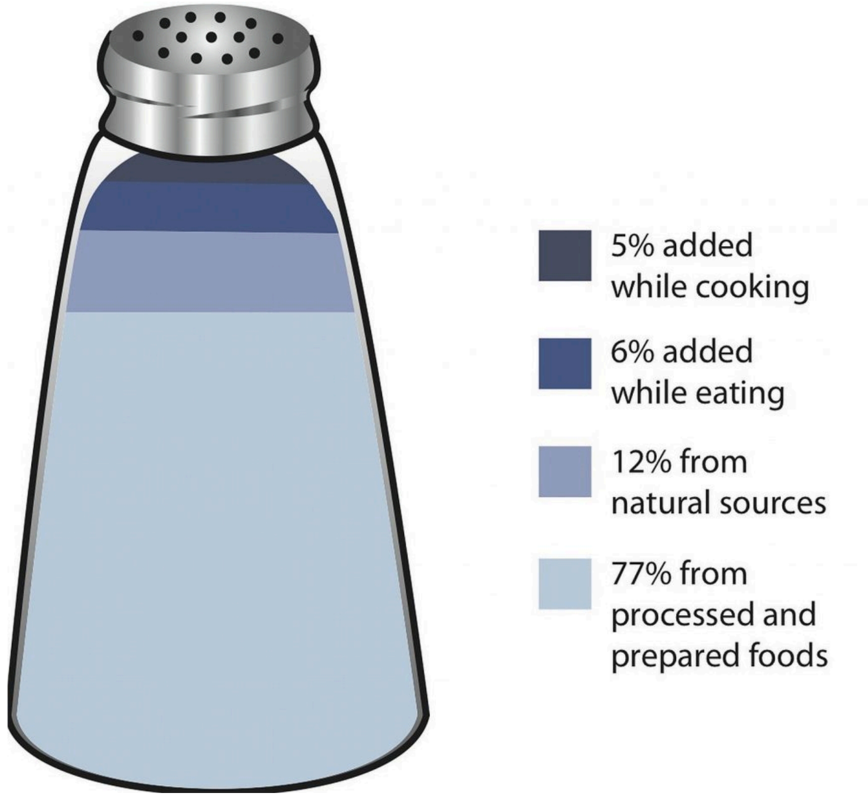
Dietary Reference Intakes for Sodium[2]

Age Group	Adequate Intake (mg/day)	Tolerable Upper Intake Level (mg/day)
Infants (0–6 months)	120	ND
Infants (6–12 months)	370	ND
Children (1–3 years)	1,000	1,500
Children (4–8 years)	1,200	1,900
Children (9–13 years)	1,500	2,200
Adolescents (14–18 years)	1,500	2,300
Adults (19–50 years)	1,500	2,300
Adults (50–70 years)	1,300	2,300
Adults (> 70 years)	1,200	2,300
ND = not determined		

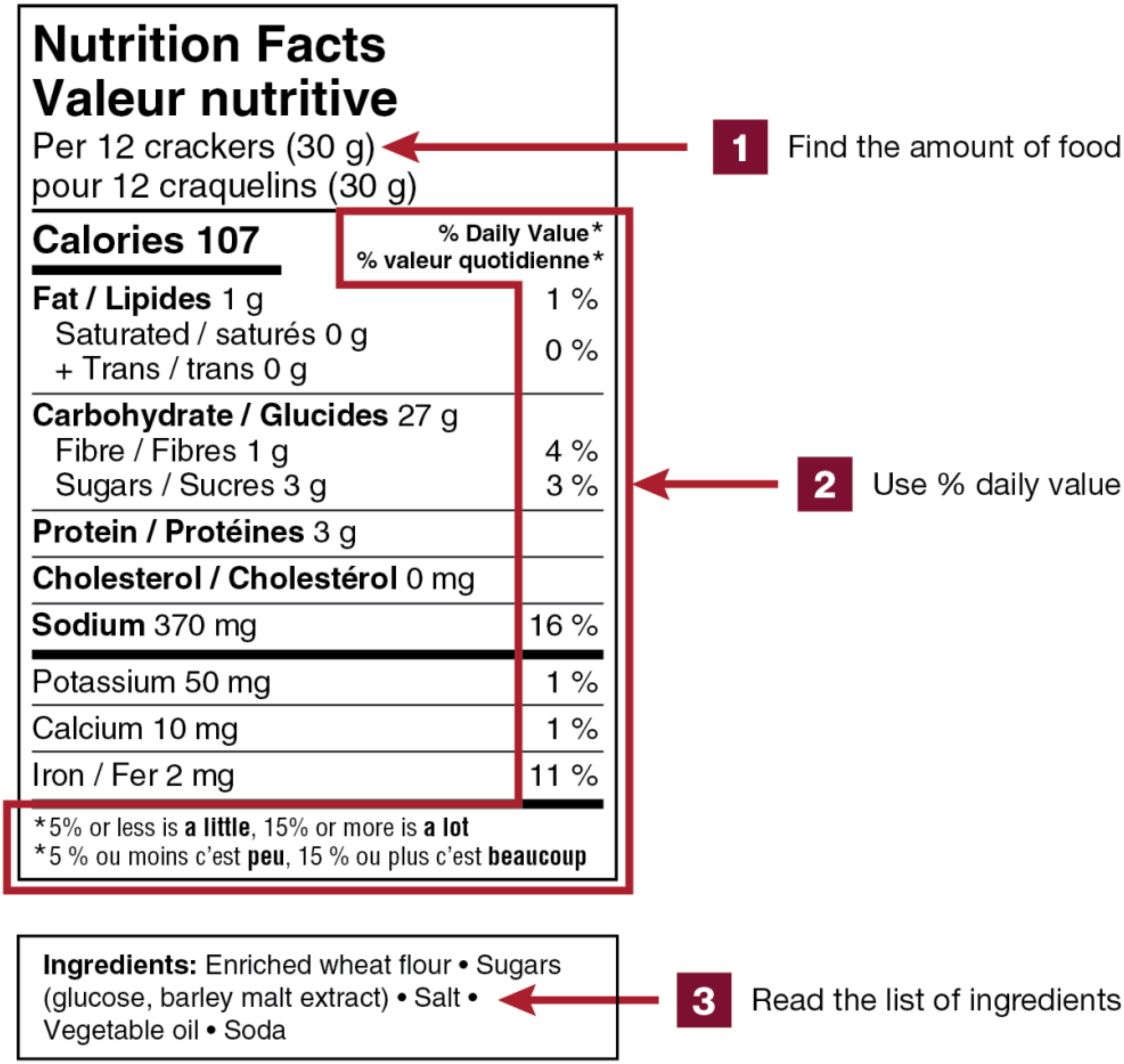
Food Sources for Sodium

Most sodium in the typical Canadian 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 "Sodium Contents of Selected Foods".

2. Institute of Medicine. (2004). Water, Potassium, Sodium, Chloride, and Sulfate. http://www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.



Dietary Sources of Sodium by lardbucket, via CC BY-NC-SA 4.0



Three steps to understand food labels. Credit: Government of Canada. (2023). How to use food labels to make healthier choices. Canada's Food Guide. https://food-guide.canada.ca/en/tips-for-healthy-eating/use-food-labels-make-healthier-choices/

SODIUM CONTENTS OF SELECTED FOODS

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

Sodium on the Nutrition Facts Panel

The Nutrition Facts panel displays the amount of sodium (in milligrams) per serving of the food in question. Food additives are often high in sodium, for example, monosodium glutamate (MSG) contains 12 percent sodium. Additionally, baking soda, baking powder, disodium phosphate, sodium alginate, and sodium nitrate or nitrite contain a significant proportion of sodium as well. When you see a food's Nutrition Facts label, you can check the ingredients list to identify the source of the added sodium.

Food Packaging Claims Regarding Sodium[3]

Claim	Meaning
"Light in Sodium" or "Low in Sodium"	Sodium is reduced by at least 50 percent
"No Salt Added" or "Unsalted"	No salt added during preparation and processing*
"Lightly Salted"	50 percent less sodium than that added to similar food
"Sodium Free" or "Salt Free"	Contains less than 5 mg sodium per serving
"Very Low Salt"	Contains less than 35 mg sodium per serving
"Low Salt"	Contains less than 140 mg sodium per serving
*Must also declare on package "This is not a sodium-free food" if food is not sodium-free	

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. Table "Salt Substitutes" displays the sodium and potassium amounts in some salt substitutes.

3. US Food and Drug Administration. (2009). Food Labeling Guide. http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064911.htm.

Salt Substitutes[4]

Product	Serving Size	Sodium (mg)	Potassium (mg)
Salt	1 tsp.	2,300	0
Mrs. Dash	1 tsp.	0	40
Spike (Salt-Free)	1 tsp.	0	96
Veg-It	1 tsp.	<65	<65
Accent Low-Sodium Seasoning	1 tsp.	600	0
Salt Sense	1 tsp.	1,560	0
Pleasoning Mini-Mini Salt	1 tsp.	440	0
Morton Lite Salt	1 tsp.	1,100	1,500
Estee Salt-It	1 tsp.	0	3,520
Morton Nature's Seasons	1 tsp.	1,300	2,800
Morton Salt Substitute	1 tsp.	0	2,730
No Salt	1 tsp.	5	2,500
Nu-Salt	1 tsp.	0	529

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 "Salt Alternatives" for a list of alternative food seasonings.

4. University of Wisconsin Hospitals and Clinics Authority. (2011). Health Facts for You: Guidelines for a Low Sodium Diet. http://www.uhs.wisc.edu/health-topics/nutrition-fitness-and-heart-health/documents/Sodium.pdf.

Salt Alternatives[5]

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

CHAPTER ATTRIBUTION

5. American Heart Association. (2012). Shaking the Salt Habit. http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Shaking-the-Salt-Habit_UCM_303241_Article.jsp.

Consequences of Deficiency or Excess

As with all nutrients, having too much or too little water has health consequences. Excessive water intake can dilute the levels of critical electrolytes in the blood. Water intoxication is rare, however when it does happen, it can be deadly. On the other hand, having too little water in the body is common. In fact, diarrhea-induced dehydration is the number-one cause of early-childhood death worldwide. In this section we will discuss subtle changes in electrolytes that compromise health on a chronic basis.

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.

HYPERTENSION

Blood pressure is the force of moving blood against arterial walls. It is reported as the systolic pressure over the diastolic pressure, which is the greatest and least pressure on an artery that occurs with each heartbeat. The force of blood against an artery is measured with a device called a sphygmomanometer. The results are recorded in millimeters of mercury, or mmHg. A desirable blood pressure ranges between 90/60 and 120/80 mmHg. Hypertension is the scientific term for high blood pressure and defined as a sustained blood pressure of 140/90 mmHg or greater. Hypertension is a risk factor for cardiovascular disease, and reducing blood pressure has been found to decrease the risk of dying from a heart attack or stroke.

Measuring Blood Pressure. Testing a GIs blood pressure at Guantanamo by Charlie Helmholt, via Public Domain

There has been much debate about the role sodium plays in hypertension. In the latter 1980s and early 1990s the largest epidemiological study evaluating the relationship of dietary sodium intake with blood pressure, called INTERSALT, was completed and then went through further analyses.[12]

More than ten thousand men and women from thirty-two countries participated in the study. The study concluded that a higher sodium intake is linked to an increase in blood pressure. A more recent study, involving over twelve thousand US citizens, concluded that a higher sodium-to-potassium intake is linked to higher cardiovascular mortality and all-causes mortality.[3]

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.[4]

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.

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. People of African descent, 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. Because reducing dietary salt intake will not work for everyone with hypertension or a risk for developing the condition, there are many opponents of reducing dietary salt intake at the national level. Among such opponents is the Salt Institute, a nonprofit trade organization that states, "No evidence demonstrates that current salt intake levels lead to worse health outcomes such as more heart attacks or higher cardiovascular mortality."[5]

CHAPTER ATTRIBUTION

1. Intersalt Cooperative Research Group. Intersalt: An International Study of Electrolyte Excretion and Blood Pressure. Results for 24 Hour Urinary Sodium and Potassium Excretion. BMJ. 1988; 297(6644), 319–28. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1834069/.
2. Elliott P, Stamler J, et al. Intersalt Revisited: Further Analyses of 24 Hour Sodium Excretion and Blood Pressure within and across Populations. BMJ. 1996; 312(7041), 1249–53. http://www.ncbi.nlm.nih.gov/pubmed/8634612.
3. Yang Q, Liu T, et al. Sodium and Potassium Intake and Mortality among US Adults: Prospective Data from the Third National Health and Nutrition Examination Survey. Arch Intern Med. 2011; 171(13), 1183–91. https://www.ncbi.nlm.nih.gov/pubmed/21747015.
4. 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.
5. Salt and Health. (2011). The Salt Institute. http://www.saltinstitute.org/Issues-in-focus/Food-salt-health.

Water Concerns

At this point you have learned how critical water is to support human life, how it is distributed and moved in the body, how fluid balance and composition is maintained, and the recommended amount of fluids a person should consume daily. In Canada you have a choice of thousands of different beverages. Which should you choose to receive the most health benefit and achieve your recommended fluid intake?

READING THE LABEL

Most beverages marketed in Canada 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 "Calories in Various Beverages".

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

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. Soft drinks and fruit drinks, increase energy intake, are not satiating, and that there is little if any reduction in other foods to compensate for the excess calories. All of these factors contribute to increased energy intake and obesity.

Recommendations[1]

Beverage	Servings per day*
Water	≥ 4 (women), ≥ 6 (men)
Unsweetened coffee and tea	≤ 8 for tea, ≤ 4 for coffee
Nonfat and low-fat milk; fortified soy drinks	≤ 2
Diet beverages with sugar substitutes	≤ 4
100 percent fruit juices, whole milk, sports drinks	≤ 1
Calorie-rich beverages without nutrients	≤ 1, less if trying to lose weight
*One serving is eight ounces.	

SOURCES OF DRINKING WATER

Women should drink at least 32 ounces and men drink at least 48 ounces of water daily. Producing water safe for drinking involves some or all of the following processes: screening out large objects, removing excess calcium carbonate from hard water sources, flocculation, which adds a precipitating agent to remove solid particles, clarification, sedimentation, filtration, and disinfection. These processes aim to remove unhealthy substances and produce high-quality, colorless, odorless, good-tasting water.

Most drinking water is disinfected by the process of chlorination, which involves adding chlorine compounds to the water. Chlorination is cheap and effective at killing bacteria. However, it is less effective at removing protozoa, such as Giardia lamblia. Chlorine-resistant protozoa and viruses are instead removed by extensive filtration methods. In the decades immediately following the implementation of water chlorination and disinfection methods in this country, waterborne illnesses, such as cholera and typhoid fever, essentially disappeared. In fact, the treatment of drinking water is touted as one of the top public-health achievements of the last century.

CHAPTER ATTRIBUTION

1. University of North Carolina (2012). US Beverage Guidance Council: Beverage Panel Recommendations and Analysis. http://www.cpc.unc.edu/projects/nutrans/policy/beverage/us-beverage-panel.

CARBOHYDRATES

Introduction

Learning Objectives

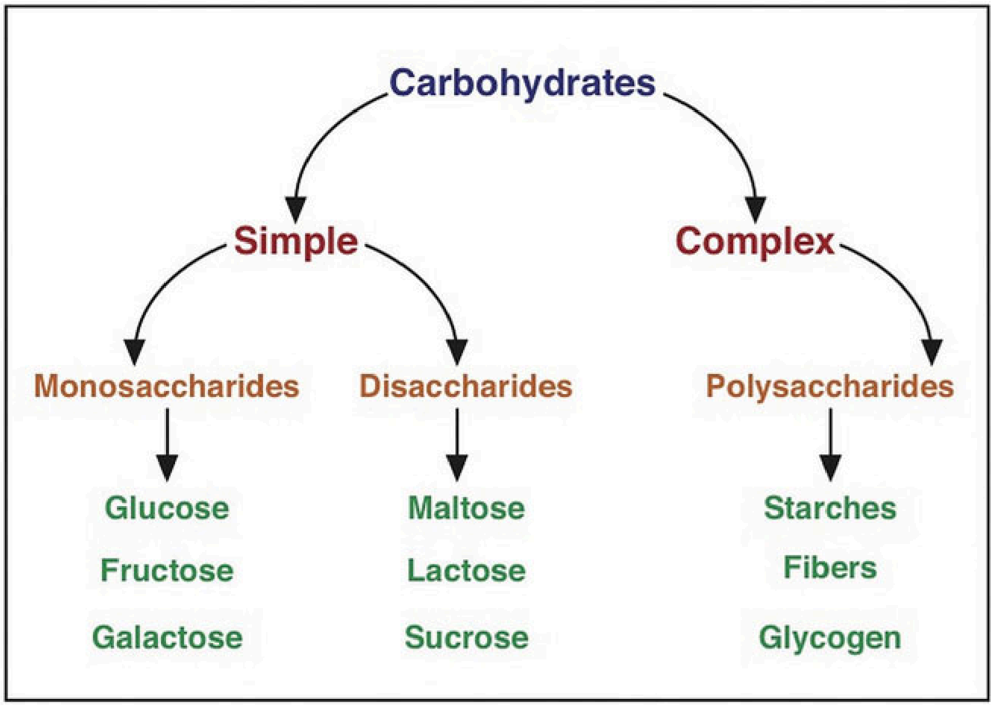
By the end of this chapter, you will be able to:

- Describe the different types of simple and complex carbohydrates
- Describe the process of carbohydrate digestion and absorption
- Describe the functions of carbohydrates in the body
- Describe the body's carbohydrate needs and how personal choices can lead to health benefits or consequences

Two Breadfruit by Michael Coghlan, via CC BY-SA 2.0

Throughout history, carbohydrates have and continue to be a major source of people's diets worldwide. 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.



Carbohydrates are broken down into the subgroups simple and complex carbohydrates. These subgroups are further categorized into mono-, di-, and polysaccharides. Carbohydrate Classification Scheme by lardbucket, CC BY-NC-SA 3.0

Carbohydrates are a group of organic compounds containing a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Basically, they are hydrated carbons. The word "carbo" means carbon and "hydrate" means water. Glucose, the most abundant carbohydrate in the human body, has six carbon atoms, twelve hydrogen atoms, and six oxygen atoms. The chemical formula for glucose is written as $C_6H_{12}O_6$. Synonymous with the term carbohydrate is the Greek word "saccharide," which means sugar. 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.

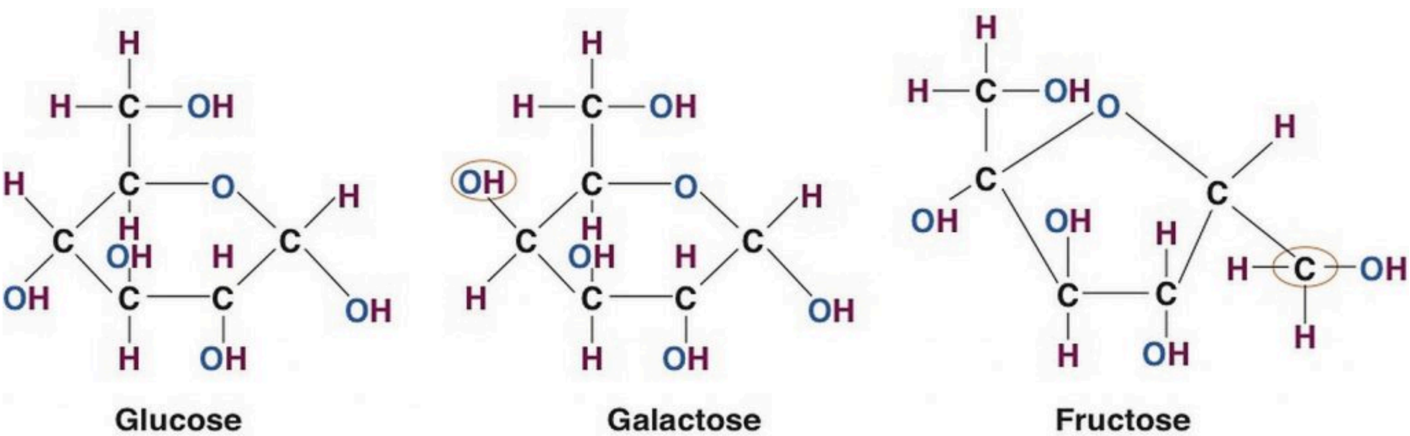
Simple carbohydrates stimulate the sweetness taste sensation, which is the most sensitive of all taste sensations. Even extremely low concentrations of sugars in foods will stimulate the sweetness taste sensation.

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). The monosaccharide galactose differs from glucose only in that a hydroxyl (−OH) group faces in a different direction on the number four carbon. This small structural alteration causes galactose to be less stable than glucose. As a result, the liver rapidly converts it to glucose. 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.)

Fructose also has the same chemical formula as glucose but differs in its chemical structure, as the ring structure contains only five carbons and not six. Fructose, in contrast to glucose, is not an energy source for other cells in the body. 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.



Structures of the Three Most Common Monosaccharides: Glucose, Galactose, and Fructose. Circles indicate the structural differences between the three. Image by lardbucket, CC BY-NC-SA 3.0

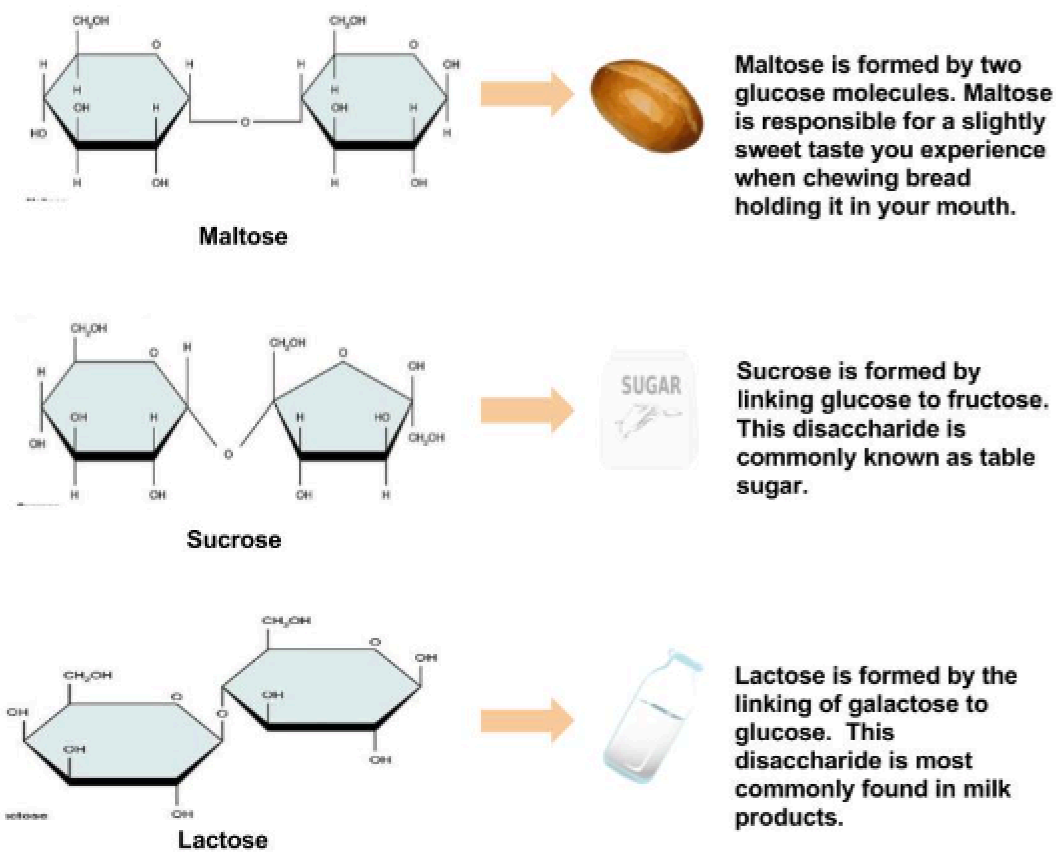
Pentoses are less common monosaccharides which have only five carbons and not six. The pentoses are abundant in the nucleic acids RNA and DNA, and also as components of fiber.

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

Disaccharides are composed of pairs of two monosaccharides linked together. Disaccharides include sucrose, lactose, and maltose. All of the disaccharides contain at least one glucose molecule.

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.



The Most Common Disaccharides by Calabrese, A., CC BY 4.0

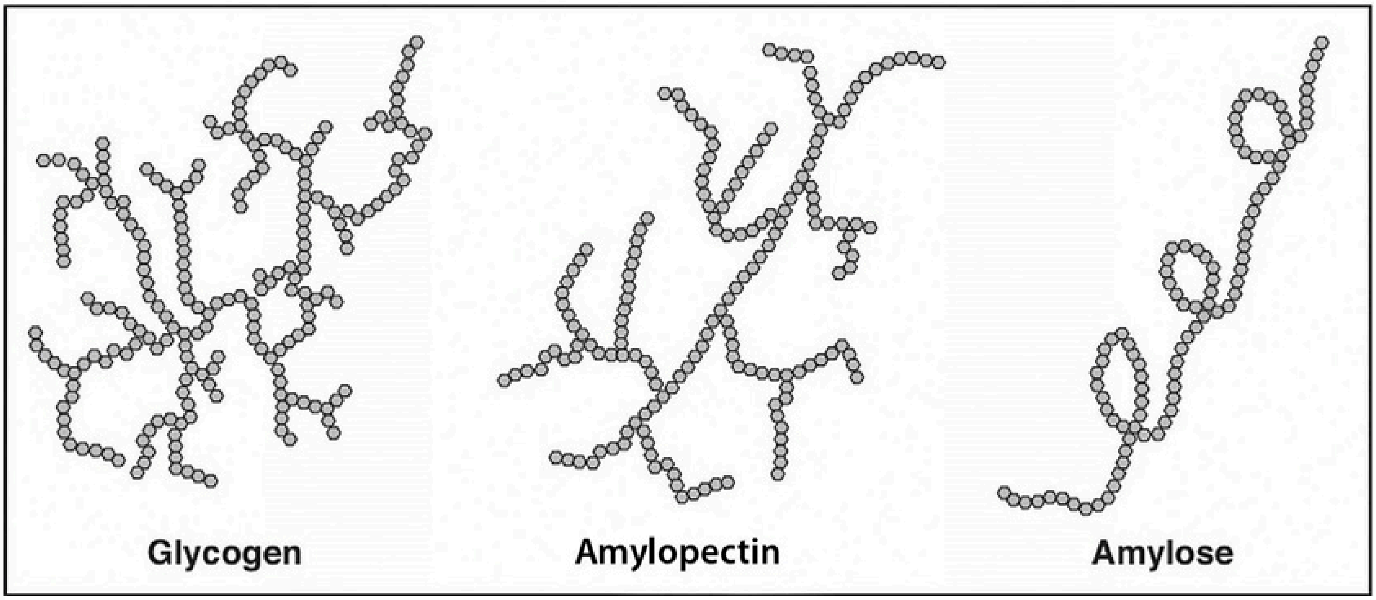
COMPLEX/SLOW-RELEASING CARBOHYDRATES

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. Amylose, a plant starch, is a linear chain containing hundreds of glucose units. Amylopectin, another plant starch, is a branched chain containing thousands of glucose units. These large starch molecules form crystals and are the energy-storing molecules of plants. These two starch molecules (amylose and amylopectin) are contained together in foods, but the smaller one, amylose, is less abundant. 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.



Structures of the Plant Starches and Glycogen by lardbucket, CC BY-NC-SA 3.0

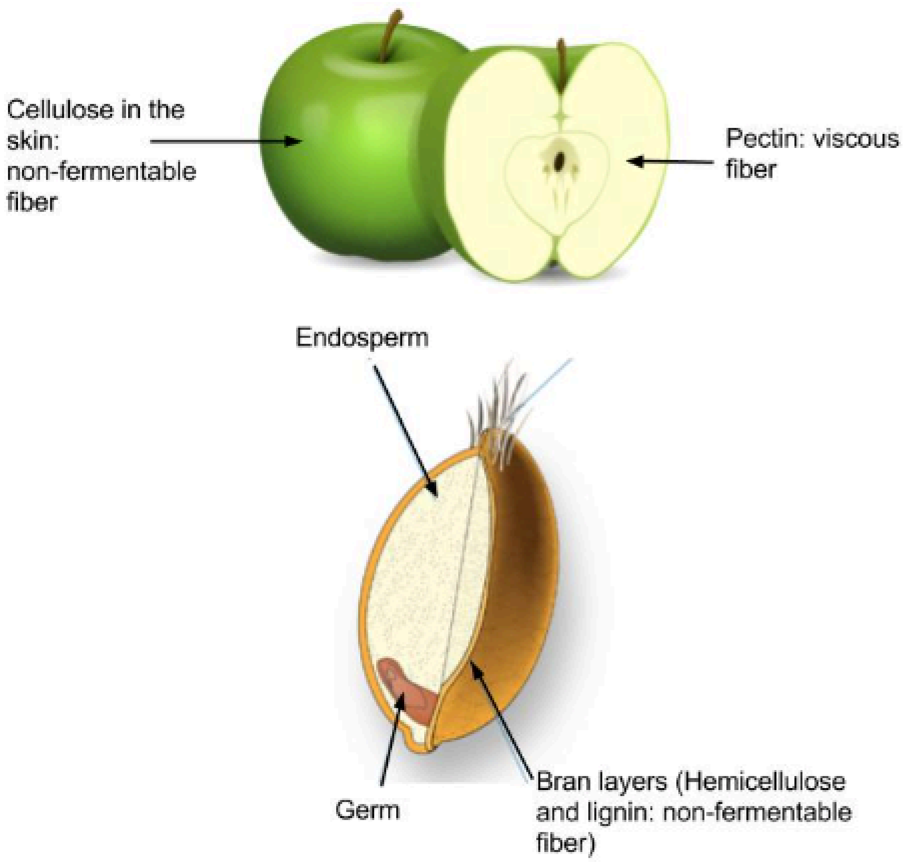
DIETARY FIBERS

Dietary fibers are polysaccharides that are highly branched and cross-linked. Some dietary fibers are pectin, gums, cellulose, hemicellulose, and lignin. Lignin, however, is not composed of carbohydrate units. 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. 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. Total dietary fiber intake is the sum of dietary fiber and functional fiber consumed.

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



Dietary Fiber by Calabrese, A., CC BY 4.0

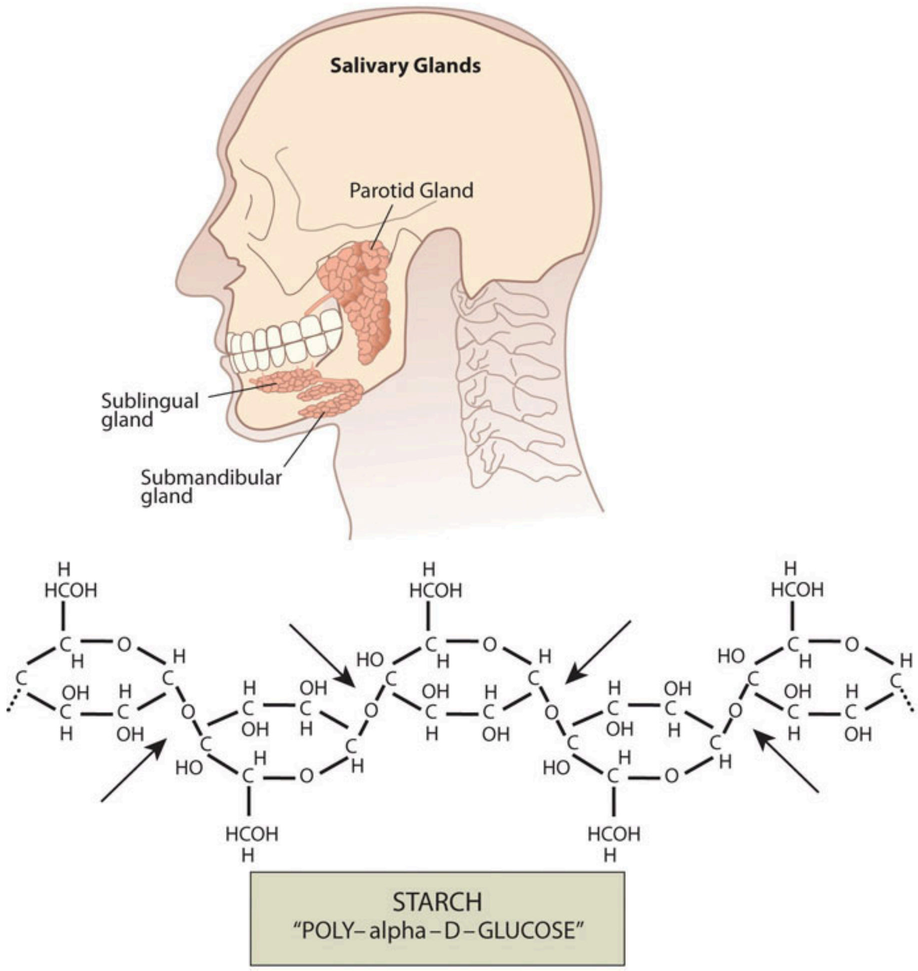
CHAPTER ATTRIBUTION

Chapter 5 Introduction in Human Nutrition in a Canadian Context by Karine Hamm published by BCcampus in 2021 under a CC BY License.

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. Saliva contains the enzyme, salivary amylase. This enzyme breaks the bonds between the monomeric sugar units of disaccharides, oligosaccharides, and starches. The salivary amylase breaks down amylose and amylopectin into smaller chains of glucose, called dextrins and maltose. The increased concentration of maltose in the mouth that results from the mechanical and chemical breakdown of starches in whole grains is what enhances their sweetness. 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 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.



Salivary glands secrete salivary amylase, which begins the chemical breakdown of carbohydrates by breaking the bonds between monomeric sugar units. [Salivary Glands in the Mouth](#) by lardbucket, [CC BY-NC-SA 3.0](#)

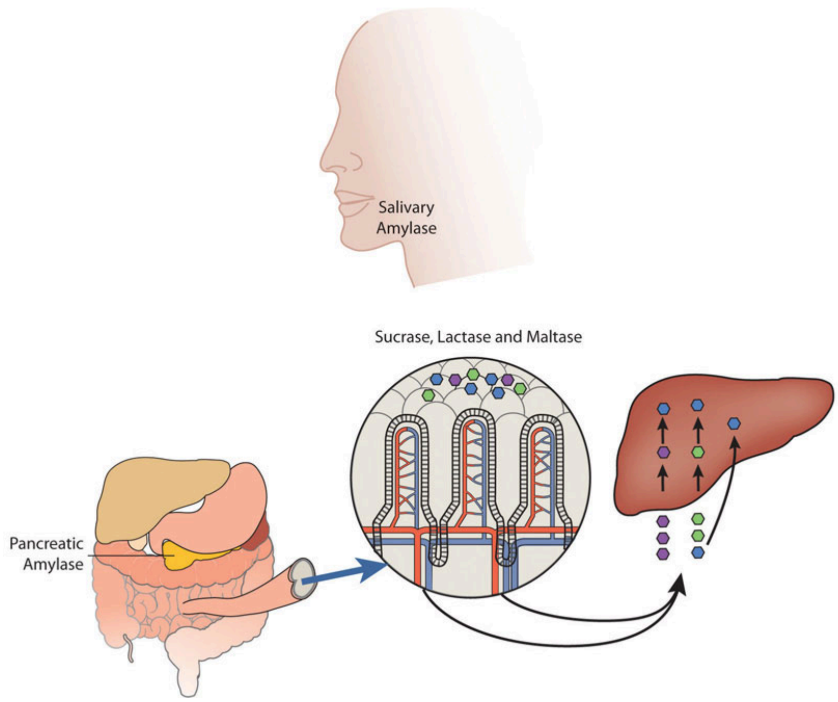
FROM THE STOMACH TO THE SMALL INTESTINE

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. This pancreatic juice contains the enzyme, pancreatic amylase, which starts again the breakdown of dextrins into shorter and shorter carbohydrate chains. Additionally, enzymes are secreted by the intestinal cells that line the villi. These enzymes, known collectively as disaccharidase, are sucrase, maltase, and lactase. Sucrase breaks sucrose into glucose and fructose molecules. Maltase breaks the bond between the two glucose units of maltose, and lactase breaks the bond between galactose and glucose. 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. 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.

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.

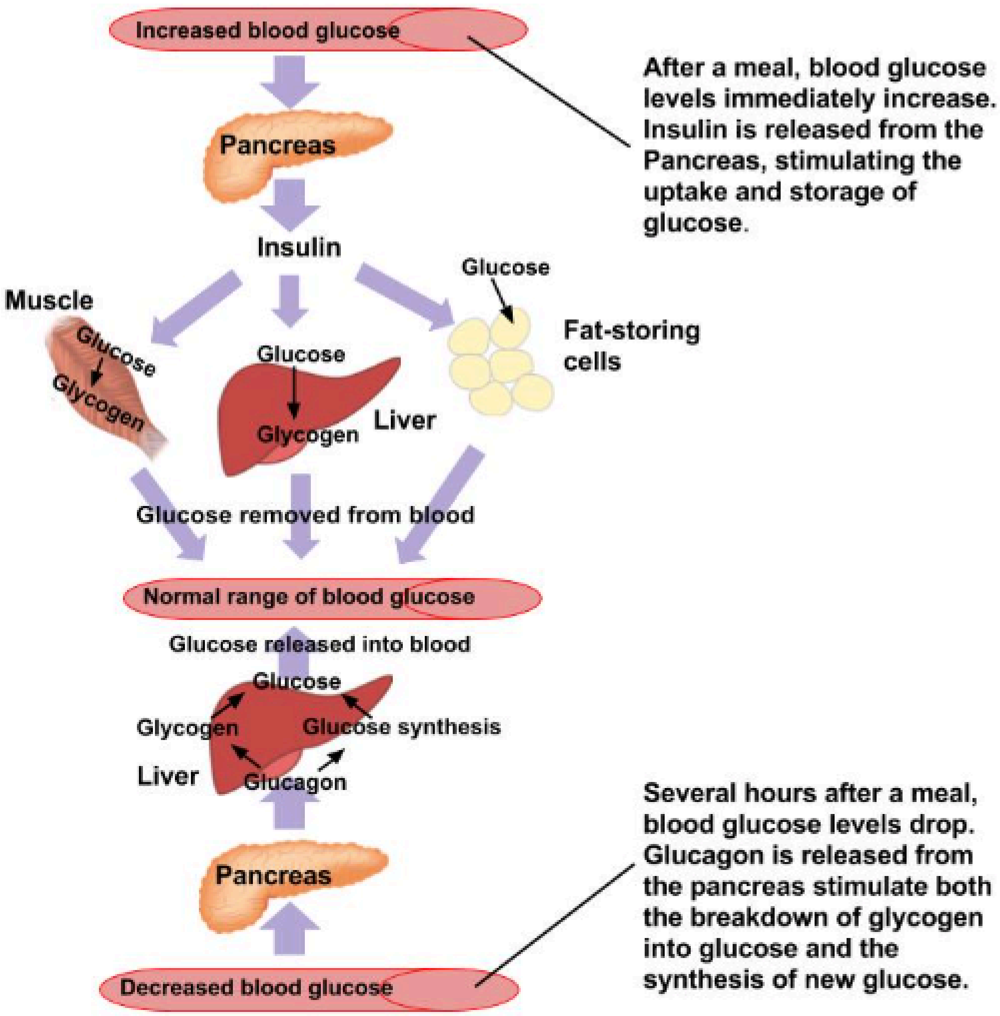


Carbohydrate digestion begins in the mouth and is most extensive in the small intestine. The resultant monosaccharides are absorbed into the bloodstream and transported to the liver. Carbohydrate Digestion by lardbucket, CC BY-NC-SA 3.0

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 health consequences. Glucose regulates its levels in the blood via a process called negative feedback. An everyday example of negative feedback is in your oven because it contains a thermostat. When you set the temperature to cook a delicious homemade noodle casserole at 375°F the thermostat senses the temperature and sends an electrical signal to turn the elements on and heat up the oven. When the temperature reaches 375°F the thermostat senses the temperature and sends a signal to turn the element off. Similarly, your body senses blood glucose levels and maintains the glucose "temperature" in the target range. The 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.

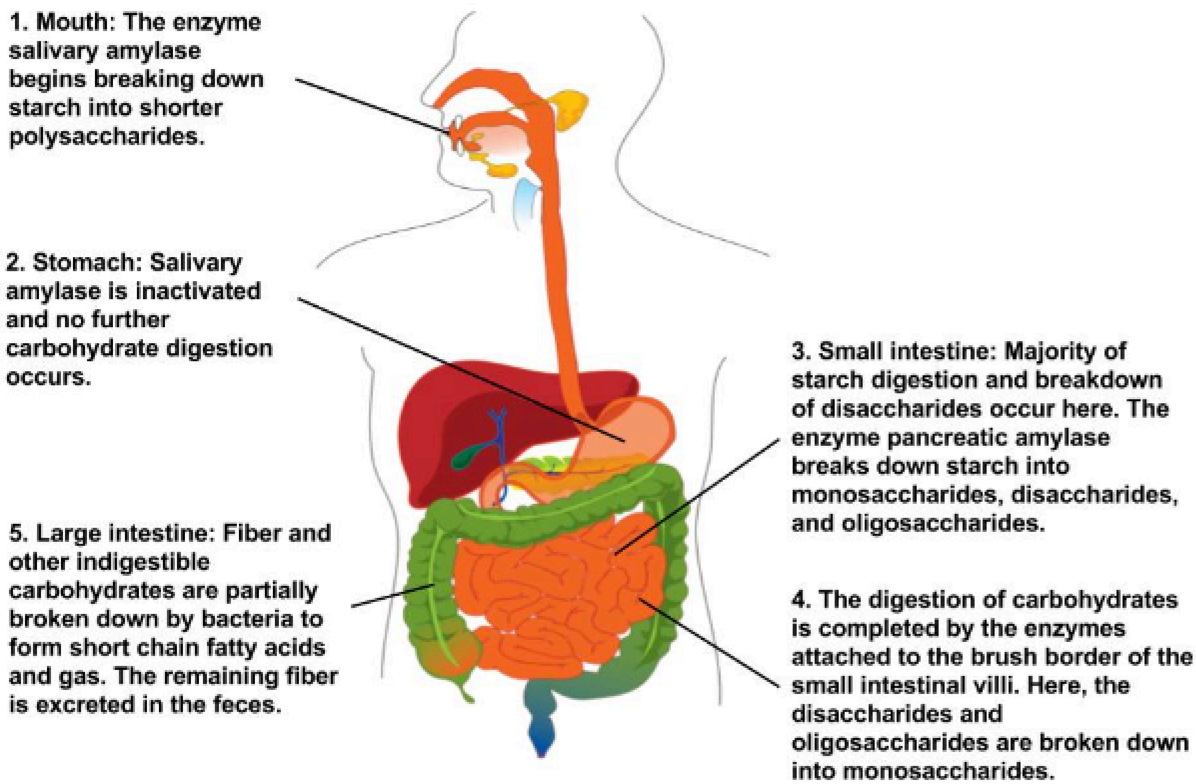


The Regulation of Glucose by Calabrese, A., CC BY 4.0

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 short-chain fatty acids are either used by the bacteria to make energy and grow, are eliminated in the feces, or are absorbed into cells of the colon, with a small amount being transported to the liver. Colonic cells use the short-chain fatty acids to support some of their functions. The liver can also metabolize the short-chain fatty acids into cellular energy. The yield of energy from dietary fiber is about

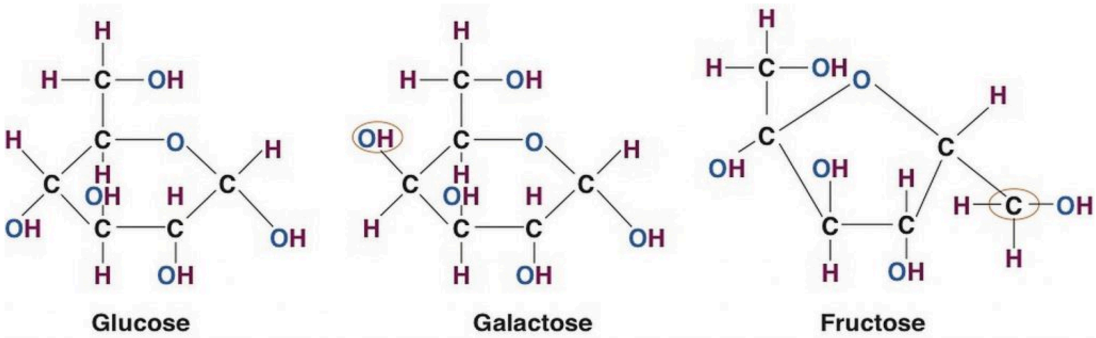
2 kilocalories per gram for humans, but is highly dependent upon the fiber type, with soluble fibers and resistant starches yielding more energy than insoluble fibers. Since dietary fiber is digested much less in the gastrointestinal tract than other carbohydrate types (simple sugars, many starches) 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.



Overview of Carbohydrate Digestion by Calabrese, A., CC BY 4.0

A Carbohydrate Feast

You are at a your grandma's house for family dinner and you just consumed ham, white rice, sweet potatoes, mac salad, chicken long rice and a hot sweet bread roll dripping with butter. Less than an hour later you top it off with a slice of apple pie and then lie down on the couch to watch TV. The "hormone of plenty," insulin, answers the nutrient call. Insulin sends out the physiological message that glucose is abundant in the blood, so that cells can absorb it and either use it or store it. The result of this hormone message is maximization of glycogen stores and all the excess glucose, protein, and lipids are stored as fat.



[Image](#) by Calabrese, A. [CC BY 4.0](#)

A typical 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.

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]

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.

The Glycemic Index: Foods In Comparison To Glucose

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

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 Canada 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. The first is GI does not take into account the amount of carbohydrates in a portion of food, only the type of carbohydrate. Another is that combining low- and high-GI foods changes the GI for the meal. Also, 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.) Lastly, meats and fats do not have a GI since they do not contain carbohydrates.

MORE RESOURCES

Visit this online databases to discover the glycemic indices of foods. Foods are listed by category and also by low, medium, or high glycemic index:

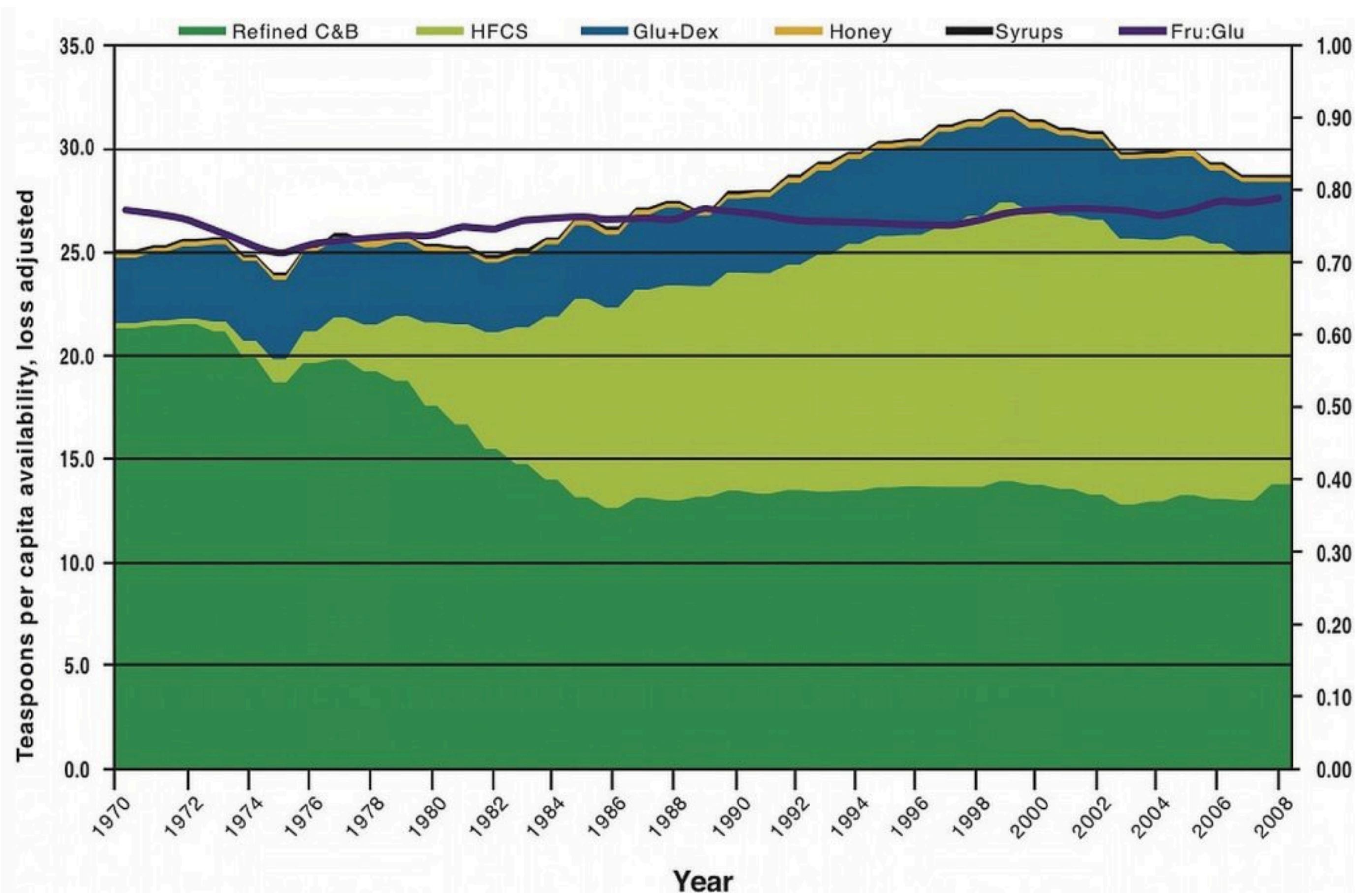
- Glycemic Index listing
- Revised International Table of Glycemic Index (GI) and Glycemic Load (GL) Values

CHAPTER ATTRIBUTION

Health Consequences and Benefits of High-Carbohydrate Diets

Can we blame the obesity epidemic on the higher consumption of added sugars and refined grains? This is a hotly debated topic by both the scientific community and the general public. In this section, we will give a brief overview of the scientific evidence.

ADDED SUGARS



Sugar Consumption (in teaspoons, from various sources) by Calabrese, A.

Added sugars are defined as “sugars and syrups that are added to foods during processing or preparation. 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). Results from a survey of forty-two thousand Americans reports that in 2008 the average intake of added sugars is 15 percent of total calories, a drop from 18 percent of total calories in 2000.[1] The numbers in Canada are similar.

OBESITY, DIABETES, AND HEART DISEASE AND THEIR HYPOTHESIZED LINK TO EXCESSIVE SUGAR AND REFINED CARBOHYDRATE CONSUMPTION

The obesity epidemic has reached young adults and children and will markedly affect the prevalence of serious health consequences in adulthood. Health consequences linked to being overweight or obese include Type 2 diabetes, cardiovascular disease, arthritis, depression, and some cancers. An infatuation with sugary foods and refined grains likely contributes to the epidemic proportion of people who are overweight or obese in this country, but so do the consumption of high-calorie foods that contain too much saturated fat and the sedentary lifestyle of most Canadians. There is much disagreement over whether high-carbohydrate diets increase weight-gain and disease risk, especially when calories are not significantly higher between compared diets. Many scientific studies demonstrate positive correlations between diets high in added sugars with weight gain and disease risk, but some others do not show a significant relationship. In regard to refined grains, there are no studies that show consumption of refined grains increases weight gain or disease risk. What is clear, however, is that getting more of your carbohydrates from dietary sources containing whole grains instead of refined grains stimulates weight loss and reduces disease risk.

A major source of added sugars in the Canadian diet is soft drinks. There is consistent scientific evidence that consuming sugary soft drinks increases weight gain and disease risk. An analysis of over thirty studies in the American Journal of Clinical Nutrition concluded that there is much evidence to indicate higher consumption of sugar-sweetened beverages is linked with weight gain and obesity.[2] A study at the Harvard School of Public Health linked the consumption of sugary soft drinks to an increased risk for heart disease.[3]

While the sugar and refined grains and weight debate rages on, the results of all of these studies has led some public health organizations like the Canadian Heart and Stroke Foundation to recommend even a lower intake of sugar per day (fewer than 9 teaspoons per day for men and fewer than 6 teaspoons for women) than what used to be deemed acceptable. The following recommendations were made:

- First, know the number of total calories you should eat each day.
- Consume an overall healthy diet and get the most nutrients for the calories, using foods high in added sugars as discretionary calories (those left over after getting all recommended nutrients subtracted from the calories used).
- Lower sugar intake, especially when the sugars in foods are not tied to positive nutrients such as in sugary drinks, candies, cakes, and cookies.
- Focus on calories in certain food categories such as beverages and confections, and encourage consumption of positive nutrients and foods such as cereals and low-fat or fat-free dairy products.

1. Welsh JA, Sharma AJ, et al. Consumption of Added Sugars Is Decreasing in the United States. Am J Clin Nutr. 2011; 94(3), 726–34. http://www.ncbi.nlm.nih.gov/pubmed/21753067.
2. Malik VS, Schulze MB, Hu FB. Intake of Sugar-Sweetened Beverages and Weight Gain: A Systematic Review. Am J Clin Nutr. 2006; 84(2), 274–88. http://www.ajcn.org/content/84/2/274.long.
3. Public Health Takes Aim at Sugar and Salt. Harvard School of Public Health. https://www.hsph.harvard.edu/news/magazine/sugar-and-salt/. Published 2009.

THE MOST NOTORIOUS SUGAR

Before high-fructose corn syrup (HFCS) was marketed as the best food and beverage sweetener, sucrose (table sugar) was the number-one sweetener in North America. (Recall that sucrose, or table sugar, is a disaccharide consisting of one glucose unit and one fructose unit.) HFCS also contains the simple sugars fructose and glucose, but with fructose at a slightly higher concentration. In the production of HFCS, corn starch is broken down to glucose, and some of the glucose is then converted to fructose. Fructose is sweeter than glucose; hence many food manufacturers choose to sweeten foods with HFCS. HFCS is used as a sweetener for carbonated beverages, condiments, cereals, and a great variety of other processed foods.

Some scientists, public health personnel, and healthcare providers believe that fructose is the cause of the obesity epidemic and its associated health consequences. The majority of their evidence stems from the observation that since the early 1970s the number of overweight or obese North Americans has dramatically increased and so has the consumption of foods containing HFCS. However, as discussed, so has the consumption of added sugars in general. Animal studies that fuel the fructose opponents show fructose is not used to produce energy in the body; instead it is mostly converted to fat in the liver—potentially contributing to insulin resistance and the development of Type 2 diabetes. Additionally, fructose does not stimulate the release of certain appetite-suppressing hormones, like insulin, as glucose does. Thus, a diet high in fructose could potentially stimulate fat deposition and weight gain.

In human studies, excessive fructose intake has sometimes been associated with weight gain, but results are inconsistent. Moderate fructose intake is not associated with weight gain at all. Moreover, other studies show that some fructose in the diet actually improves glucose metabolism especially in people with Type 2 diabetes.[4]

In fact, people with diabetes were once advised to use fructose as an alternative sweetener to table sugar. Overall, there is no good evidence that moderate fructose consumption contributes to weight gain and chronic disease. At this time conclusive evidence is not available on whether fructose is any worse than any other added sugar in increasing the risk for obesity, Type 2 diabetes, and cardiovascular disease.

DO LOW-CARBOHYDRATE DIETS AFFECT HEALTH?

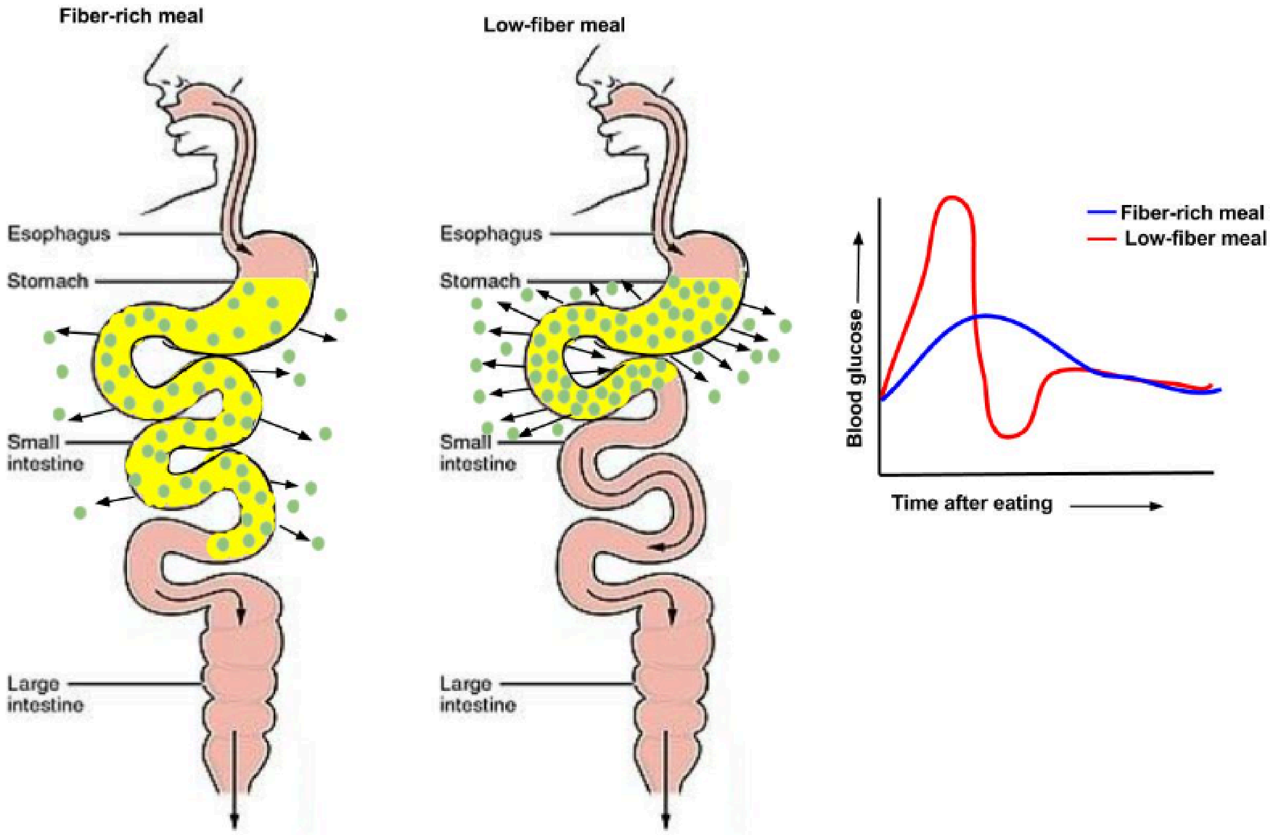
Since the early 1990s, marketers of low-carbohydrate diets have bombarded us with the idea that eating fewer carbohydrates promotes weight loss and that these diets are superior to others in their effects on weight loss and overall health. The most famous of these low-carbohydrate diets is the Atkins 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.[5]

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.

4. Elliott SS, Keim NL, et al. Fructose, Weight Gain, and the Insulin Resistance Syndrome. Am J Clin Nutr. 2002; 76(5),911–22. http://www.ajcn.org/content/76/5/911.full.
5. Kerksick CM, Wismann-Bunn J, 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/

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 5.14 "Fibers Role in Carbohydrate Digestion and Absorption") can significantly slow down the absorption process therefore affecting blood glucose levels. Canadians typically do not consume the recommended amount of whole grains, which is 50 percent or more of grains from whole grains.



Fibers Role in Carbohydrate Digestion and Absorption by Calabrese, A. CC BY 4.0

Diets high in whole grains have repeatedly been shown to decrease weight. A large group of studies all support that consuming more than two servings of whole grains per day reduces one's chances of getting Type 2 diabetes by 21 percent.[6] A study found that women who consumed two to three servings of whole grain products daily were 30 percent less likely to have a heart attack.[7]

Regarding while grains:

- "Dietary fiber from whole grains, as part of an overall healthy diet, helps reduce blood cholesterol levels and may lower risk of heart disease."

6. de Munter JS, Hu FB, et al. Whole Grain, Bran, and Germ Intake and Risk of Type 2 Diabetes: A Prospective Cohort Study and Systematic Review. PLoS Medicine. 2007; 4(8), e261. https://www.ncbi.nlm.nih.gov/pubmed/17760498.
7. Liu S, Stampfer MJ, et al. Whole-Grain Consumption and Risk of Coronary Heart Disease: Results from the Nurses' Health Study. Am J Clin Nutr. 1999; 70(3), 412–19. http://www.ajcn.org/content/70/3/412.long.

- "Fiber-containing foods, such as whole grains, help provide a feeling of fullness with fewer calories and may help with weight management."

CHAPTER ATTRIBUTION

Carbohydrates and Personal Diet Choices

In this chapter, you learned what carbohydrates are, the different types of carbohydrates in your diet, and that excess consumption of some types of carbohydrates cause disease while others decrease disease risk. Now that we know the benefits of eating the right carbohydrate, we will examine exactly how much should be eaten to promote health and prevent disease.

HOW MANY CARBOHYDRATES DOES A PERSON NEED?

The Recommended Dietary Allowance (RDA) of carbohydrates for children and adults at 130 grams per day. This is the average minimum amount the brain requires to function properly. The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrates is between 45 and 65 percent of your total caloric daily intake. This means that on a 2,000 kilocalorie diet, a person should consume between 225 and 325 grams of carbohydrate each day. No more than 25 percent of total calories consumed should come from added sugars. The World Health Organization recommends much lower intakes of added sugars—10 percent or less of total calories consumed. The Adequate Intakes for dietary fiber, are 38 and 25 grams for men and women, respectively. The recommendations for dietary fiber are based upon the intake levels known to prevent against heart disease.

Dietary Reference Intakes For Carbohydrates And Fiber[1]

Carbohydrate Type	RDA (g/day)	AMDR (% calories)
Total Carbohydrates	130	45–65
Added Sugars		< 25
Fiber	38 (men),* 25 (women)*	
* denotes Adequate Intake		

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 "Carbohydrates in Foods (grams/serving)" gives the specific amounts of carbohydrates, fiber, and added sugar of various foods.

1. US Department of Agriculture. (2011). National Nutrient Database for Standard Reference. http://www.nal.usda.gov/fnic/foodcomp/search/.

Carbohydrates in Foods (grams/serving)[2]

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

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.

UNDERSTANDING CARBOHYDRATES FROM PRODUCT INFORMATION

While nutrition facts labels aid in determining the amount of carbohydrates you eat, they do not help in determining whether a food is refined or not. The ingredients list provides some help in this regard. It identifies all of the food's ingredients in order of concentration, with the most concentrated ingredient first. When choosing between two breads, pick the one that lists whole wheat (not wheat flour) as the first ingredient, and avoid those with other flour ingredients, such as white flour or corn flour. (Enriched wheat flour refers to white flour with added vitamins.) Eat less of products that list HFCS and other sugars such as sucrose, honey, dextrose, and cane sugar in the first five ingredients. If you want to eat less processed foods then, in general, stay away from products with long ingredient lists. On the front of food and beverages the manufacturers may include claims such as "sugar-free," "reduced sugar," "high fiber," etc.

2. US Department of Agriculture. (2006). Database for the Added Sugars Content of Selected Foods. http://www.nal.usda.gov/fnic/foodcomp/search/.

Food Labels Pertaining to Carbohydrates.[3]

Label	Meaning
Sugar-free	Contains less than 0.5 grams of sugar per serving
Reduced sugar	Contains 25 percent less sugar than similar product
Less sugar	Contains 25 percent less sugar than similar product, and was not altered by processing to become so
No sugars added	No sugars added during processing
High fiber	Contains at least 20 percent of daily value of fiber in each serving
A good source of fiber	Contains between 10 and 19 percent of the daily value of fiber per serving
More fiber	Contains 10 percent or more of the daily value of fiber per serving

Although the information above is based on American guidelines, The U.S. Food and Drug Administration (FDA) signed an arrangement with the Canadian Food Inspection Agency (CFIA) and the Department of Health Canada (Health Canada) recognizing each other's food safety systems as comparable to each other. References to guidelines made by the FDA is this textbook applies to guidelines that are similar in Canada.

PERSONAL CHOICES

Carbohydrates are in most foods so you have a great variety of choices with which to meet the carbohydrates recommendations for a healthy diet. Health Canada recommends eating more unrefined carbohydrates and more fiber, and reducing consumption of foods that are high in added sugars. To accomplish these recommendations use some or all of the following suggestions:

- Get more daily carbohydrate servings from whole grains by eating a whole-grain cereal for breakfast, using whole-grain bread to make a sandwich for lunch, and eating a serving of beans and/or nuts with dinner.
- Make sure to get at least three servings (or more) of all the grains you eat as whole grains every day. A serving of whole grains is equal to one slice of whole-wheat bread, one ounce of whole-grain cereal, and one-half cup of cooked cereal, brown rice, or whole-wheat pasta.
  Food products made with cornmeal use the whole grain so choose tortillas, corn cereals, and corn breads with cornmeal listed as the first ingredient.
- When baking, substitute whole-wheat flour or other whole-grain flour for some of the refined white flour.
- If you like bread at dinner, choose a whole-grain muffin over a Kaiser roll or baguette.
  Add beans, nuts, or seeds to salad—they add texture and taste.
- Choose whole-grain pastas and brown rice, cook al dente, and add some beans and vegetables in equal portions.
- Change it up a bit and experience the taste and satisfaction of other whole grains such as barley, quinoa, and bulgur.
- Eat snacks high in fiber, such as almonds, pistachios, raisins, and air-popped popcorn.
  Add an artichoke and green peas to your dinner plate more often.
- Calm your "sweet tooth" by eating fruits, such as berries or an apple.

3. US Food and Drug Administration. (2009). Appendix A: Definitions of Nutrient Claims. Guidance for Industry: A Food Labeling Guide. http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064911.htm.

- Replace sugary soft drinks with seltzer water, tea, or a small amount of 100 percent fruit juice added to water or soda water.

THE FOOD INDUSTRY: FUNCTIONAL ATTRIBUTES OF CARBOHYDRATES AND THE USE OF SUGAR SUBSTITUTES

In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes, including increased sweetness, viscosity, bulk, coating ability, solubility, consistency, texture, body, and browning capacity. The differences in chemical structure between the different carbohydrates confer their varied functional uses in foods. Starches, gums, and pectins are used as thickening agents in making jam, cakes, cookies, noodles, canned products, imitation cheeses, and a variety of other foods. Molecular gastronomists use slow-releasing carbohydrates, such as alginate, to give shape and texture to their fascinating food creations. Adding fiber to foods increases bulk. Simple sugars are used not only for adding sweetness, but also to add texture, consistency, and browning. In ice cream, the combination of sucrose and corn syrup imparts sweetness as well as a glossy appearance and smooth texture.

Due to the potential health consequences of consuming too many added sugars, sugar substitutes have replaced them in many foods and beverages. Sugar substitutes may be from natural sources or artificially made. Those that are artificially made are called artificial sweeteners and must be approved by the FDA for use in foods and beverages. The artificial sweeteners approved by the FDA are saccharin, aspartame, acesulfame potassium, neotame, advantame, and sucralose. Stevia is an example of a naturally derived sugar substitute. It comes from a plant commonly known as sugarleaf and does not require FDA approval. Sugar alcohols, such as xylitol, sorbitol, erythritol, and mannitol, are sugar alcohols that occur naturally in some fruits and vegetables. However, they are industrially synthesized with yeast and other microbes for use as food additives. The FDA requires that foods disclose the fact that they contain sugar alcohols, but does not require scientific testing of it. (Though many of them have undergone studies anyway.) In comparison to sucrose, artificial sweeteners are significantly sweeter (in fact, by several hundred times), but sugar alcohols are more often less sweet than sucrose (see Table 5.5 “Relative Sweetness of Sugar Substitutes”). Artificial sweeteners and Stevia are not digested or absorbed in significant amounts and therefore are not a significant source of calories in the diet. Sugar alcohols are somewhat digested and absorbed and, on average, contribute about half of the calories as sucrose (4 kilocalories/gram). These attributes make sugar substitutes attractive for many people—especially those who want to lose weight and/or better manage their blood-glucose levels.

Relative Sweetness Of Sugar Substitutes

Sweetener	Trade Names	Sweeter than Sucrose (times)
Saccharine	“Sweet-N-Lo”	300.0
Aspartame	“NutraSweet,” “Equal”	80-200.0
Acesulfame-K	“Sunette”	200.0
Neotame		7,000.0–13,000.0
Advantame		20,000
Sucralose	“Splenda”	600.0
Stevia		250.0–300.0
Xylitol		0.8
Mannitol		0.5
Sorbitol		0.6
Erythritol		1.0

BENEFITS OF SUGAR SUBSTITUTES

Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. Artificial sweeteners are basically non-nutrients though not all are completely calorie-free. However, because they are so intense in sweetness they are added in very small amounts to foods and beverages. Artificial sweeteners and sugar alcohols are not "fermentable sugars" and therefore they do not cause tooth decay. Chewing gum with artificial sweeteners is the only proven way that artificial sweeteners promote oral health. The Canadian Dental Association (CDA) allows manufacturers of chewing gum to label packages with a CDA seal if they have convincing scientific evidence demonstrating their product either reduces plaque acids, cavities, or gum disease, or promotes tooth remineralization.

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.

In the early 1970s scientific studies were published that demonstrated that high doses of saccharin caused bladder tumors in rats. This information fueled the still-ongoing debate of the health consequences of all artificial sweeteners. In actuality, the results from the early studies were completely irrelevant to humans. The large doses (2.5 percent of diet) of saccharine caused a pellet to form in the rat's bladder. That pellet chronically irritated the bladder wall, eventually resulting in tumor development. Since this study, scientific investigation in rats, monkeys, and humans have not found any relationship between saccharine consumption and bladder cancer. In 2000, saccharin was removed from the US National Toxicology Program's list of potential carcinogens.[4]

There have been health concerns over other artificial sweeteners, most notably aspartame (sold under the trade names of NutraSweet and Equal). The first misconception regarding aspartame was that it was linked with an increase in the incidence of brain tumors in the United States. It was subsequently discovered that the increase in brain tumors started eight years prior to the introduction of aspartame to the market. Today, aspartame is accused of causing brain damage, autism, emotional disorders, and a myriad of other disorders and diseases. Some even believe aspartame is part of a governmental conspiracy to make people dumber. The reality is there is no good scientific evidence backing any of these accusations, and that aspartame has been the most scientifically tested food additive. It is approved for use as an artificial sweetener in over ninety countries.

Aspartame is made by joining aspartic acid and phenylalanine to a dipeptide (with a methyl ester). When digested, it is broken down to aspartic acid, phenylalanine, and methanol. People who have the rare genetic disorder phenylketonuria (PKU) have to avoid products containing aspartame. Individuals who have PKU do not have a functional enzyme that converts phenylalanine to the amino acid tyrosine. This causes a buildup of phenylalanine and its metabolic products in the body. If PKU is not treated, the buildup of phenylalanine causes progressive brain damage and seizures. The FDA requires products that contain aspartame to state on the product

4. National Cancer Institute. (2009). Artificial Sweeteners and Cancer. http://www.cancer.gov/cancertopics/factsheet/Risk/artificial-sweeteners. Updated August 5, 2009.

label, "Phenylketonurics: Contains Phenylalanine." For more details on sugar substitutes please refer to Table "Sweeteners".

Sweeteners

Sweeteners with Trade Name	Calories	Source/Origin	Consumer Recommendations	Controversial Issues	Product Uses
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.	Beverages, gelatin desserts, gums, fruit spreads.
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	General purpose sweetener in all foods and beverages. Sold as Sweet 'n' Low in United States; also found in cosmetics and pharmaceutical products.
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.		Chewing gum, powdered beverage mixes, nondairy creamers, gelatins, puddings, instant teas and coffees.
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.	Recommended as a substitute for table sugar for diabetics in 1950s, baked goods.
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.		General purpose sweetener, baked goods, beverages, gelatin desserts, frozen dairy desserts, canned fruits, salad dressings, dietary supplements; currently recommended as a replacement for table sugar and additive for diabetics.
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.	Sold in health food stores as a dietary supplement.

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.	Biscuits, cookies, cakes, pies, candy canes, ice cream, sorbets, and as a food preservative.
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.		Sweeteners in various foods and beverages such as sodas, teas, alcoholic beverages, and baked goods.
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.	Soft drinks, desserts, candies, jellies.
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.	Provide bulk and sweetness in the following sugar-free items: cookies, jams, jellies, chewing gum, candies, mints, pharmaceutical and oral health products.

LIPIDS

Introduction

Learning Objectives

By the end of this chapter, you will be able to:

- Describe the function and role of lipids in the body
- Describe the process of lipid digestion and absorption
- Describe tools and methods for balancing your diet with lipids

Coconut and coconut oil by Phu Thinh Co, via CC BY-SA 2.0

The coconut provided a valuable source of fat to a diet that was generally low in fat as the major nutrient found in the mature coconut is fat. As you read further, you will learn the different types of fats, their essential roles in the body, and the potential health consequences and benefits of diets rich in particular lipids. You will be better equipped to decide the best way to get your nutritional punch from various fats in your diet.

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.

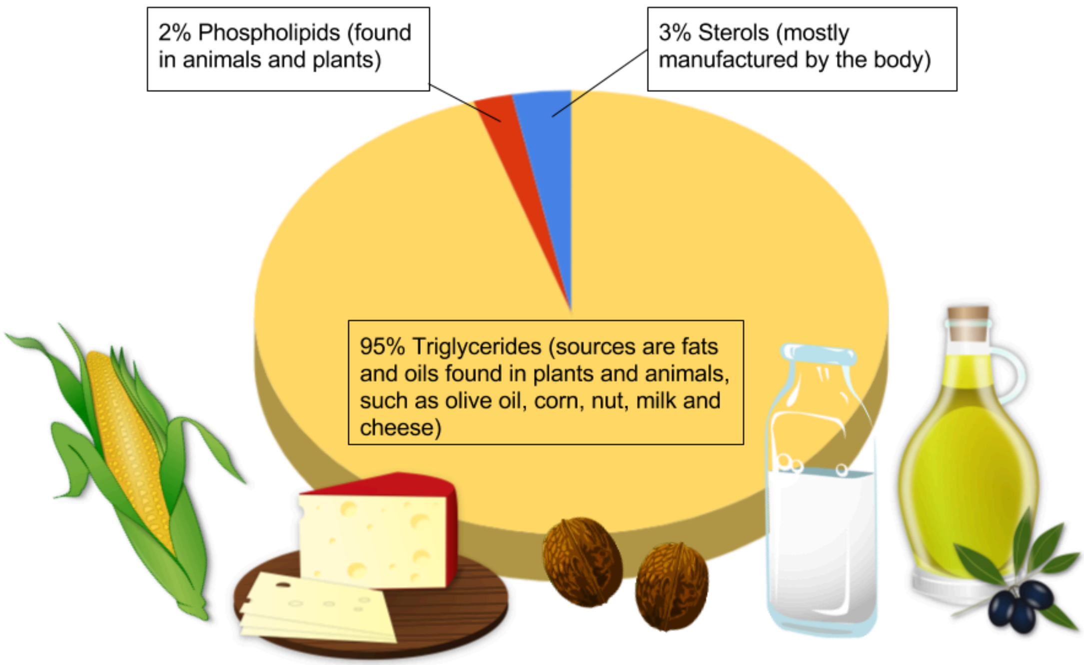
Lipids are a family of organic compounds that are mostly insoluble in water. Composed of fats and oils, lipids are molecules that yield high energy and have a chemical composition mainly of carbon, hydrogen, and oxygen. Lipids perform three primary biological functions within the body: they serve as 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.

Later in this chapter, we will examine each of these lipids in more detail and discover how their different structures function to keep your body working.



Types of Lipids by Calabrese, A., via CC BY 4.0

CHAPTER ATTRIBUTION

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

Did you know that up to 30 percent of body weight is comprised of fat tissue? 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.

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.

CHAPTER ATTRIBUTION

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, 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

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.

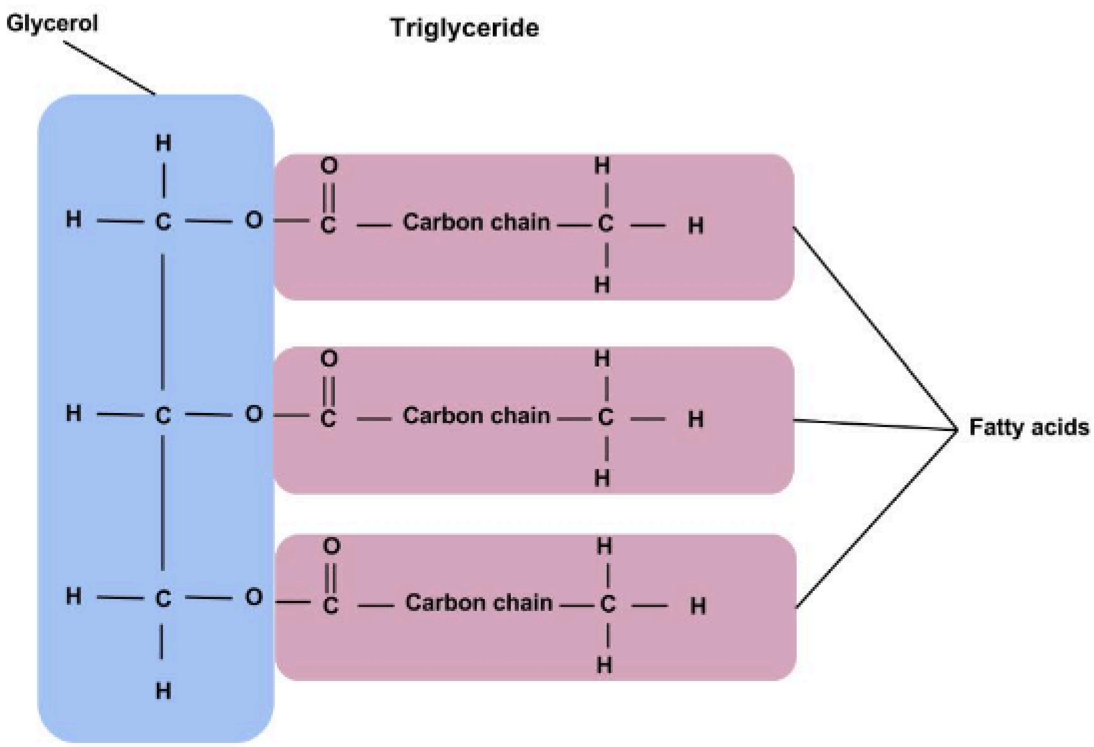
CHAPTER ATTRIBUTION

How Lipids Work

Lipids are unique organic compounds, each serving key roles and performing specific functions within the body. As we discuss the various types of lipids (triglycerides, phospholipids, and sterols) in further detail, we will compare their structures and functions and examine their impact on human health.

TRIGLYCERIDES STRUCTURE AND FUNCTIONS

Triglycerides are the main form of lipid found in the body and in the diet. Fatty acids and glycerol are the building blocks of triglycerides. Glycerol is a thick, smooth, syrupy compound that is often used in the food industry. To form a triglyceride, a glycerol molecule is joined by three fatty acid chains. triglycerides contain varying mixtures of fatty acids.



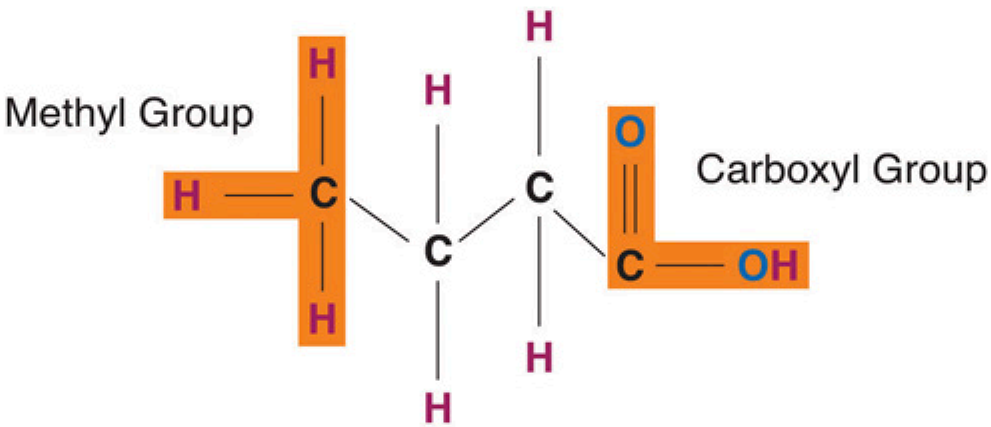
The Structure of a Triglycerides by Calabrese, A., via CC BY 4.0

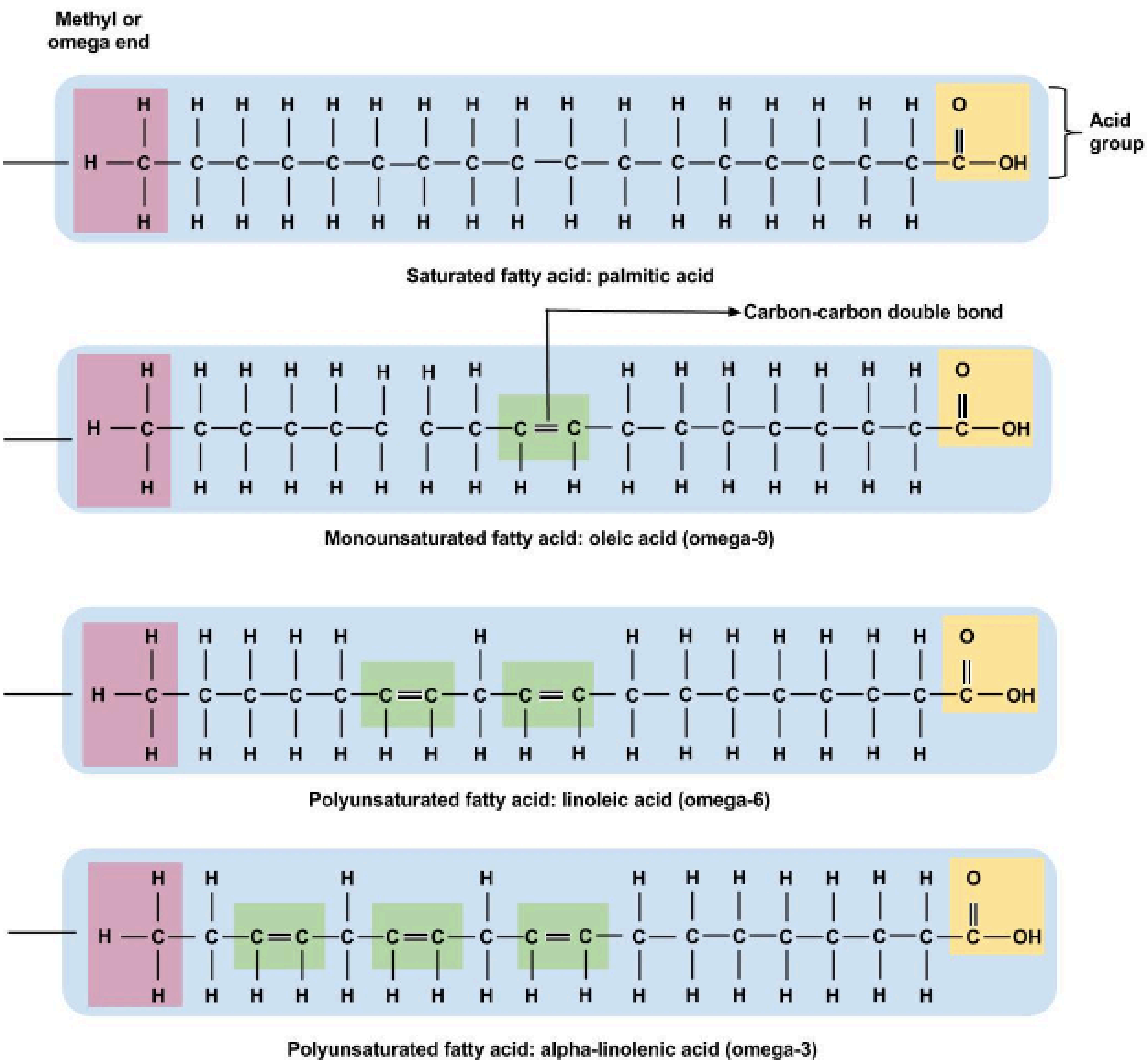
FATTY ACIDS

Fatty acids determine if the compound is solid or liquid at room temperature. Fatty acids consist of a carboxylic acid (−COOH) group on one end of a carbon chain and a methyl group (−CH3) on the other end. Fatty acids can differ from one another in two important ways—carbon chain length and degree of saturation.

IT'S ALL IN THE CHAIN

Fatty acids have different chain lengths and different compositions. Foods have fatty acids with chain lengths between four and twenty-four carbons and most of them contain an even number of carbon atoms. When the carbon chain length is shorter, the melting point of the fatty acid becomes lower—and the fatty acid becomes more liquid.





Structures of a Saturated, Monounsaturated, and Polyunsaturated Fat by Calabrese, A., via CC BY 4.0

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.[1]

DEGREES OF SATURATION

Fatty acid chains are held together by carbon atoms that attach to each other and to hydrogen atoms. The term saturation refers to whether or not a fatty acid chain is filled (or "saturated") to capacity with hydrogen atoms. If each available carbon bond holds a hydrogen atom we call this a saturated fatty acid chain. All carbon atoms in such a fatty acid chain are bonded with single bonds. Sometimes the chain has a place where hydrogen atoms are missing. This is referred to as the point of unsaturation.

When one or more bonds between carbon atoms are a double bond (C=C), that fatty acid is called an unsaturated fatty acid, as it has one or more points of unsaturation. Any fatty acid that has only one double bond is a monounsaturated fatty acid, an example of which is olive oil (75 percent of its fat is monounsaturated). Monounsaturated fats help regulate blood cholesterol levels, thereby reducing the risk for heart disease and stroke. A polyunsaturated fatty acid is a fatty acid with two or more double bonds or two or more points of unsaturation. Soybean oil contains high amounts of polyunsaturated fatty acids. Both monounsaturated fats and polyunsaturated fats provide nutrition that is essential for normal cell development and healthy skin.

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 (stearic acid, an eighteen-carbon saturated fatty acid is a primary component) and meat. Foods rich in unsaturated fatty acids, such as olive oil (oleic acid, an eighteen-carbon unsaturated fatty acid, is a major component) 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.

Knowing the connection between chain length, degree of saturation, and the state of the fatty acid (solid or liquid) is important for making food choices. 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.

CIS OR *TRANS* FATTY ACIDS?

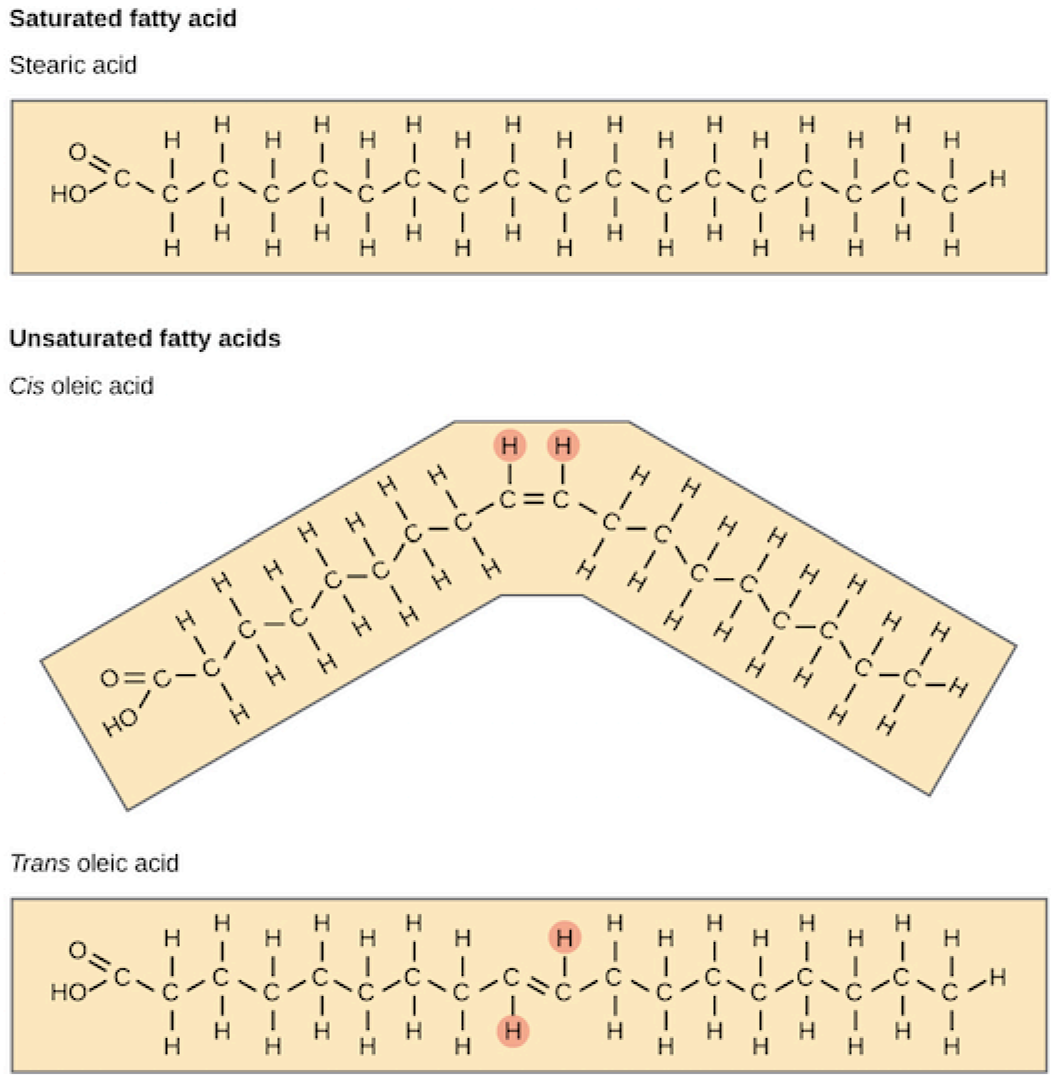
The introduction of a carbon double bond in a carbon chain, as in an unsaturated fatty acid, can result in different structures for the same fatty acid composition. When the hydrogen atoms are bonded to the same side of the carbon chain, it is called a cis fatty acid. Because the hydrogen atoms are on the same side, the carbon chain has a bent structure. Naturally occurring fatty acids usually have a cis configuration.

In a trans fatty acid, the hydrogen atoms are attached on opposite sides of the carbon chain. Unlike cis fatty

1. Mori T, Kondo H. Dietary fish oil upregulates intestinal lipid metabolism and reduces body weight gain in C57BL/6J mice. J Nutr. 2007;137(12):2629-34. http://www.ncbi.nlm.nih.gov/pubmed/18029475.

acids, most trans fatty acids are not found naturally in foods, but are a result of a process called hydrogenation. 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.[2]



Unsaturated, Cis and Trans fatty Acids. Structures of Saturated by OpenStax, via CC BY 4.0

Interestingly, some naturally occurring trans fats do not pose 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. 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

2. Introduction to "Fats and Cholesterol: Out with the Bad, In with the Good" The Nutrition Source. Harvard School of Public Health. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/fats-full-story/#references.

occurring trans fats have are counteracted by the presence of other fatty acid molecules in these animal products, which work to promote human health.

CHAPTER ATTRIBUTION

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, 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.)

The following total cholesterol values are used to target treatment[1]

- Desirable. Under 200 mg/dL
- Borderline high. 200–239 mg/dL
- High risk. 240 mg/dL and up

1. National Heart, Lung, and Blood Institute, National Institutes of Health. (2005). High Blood Cholesterol: What You Need to Know. NIH Publication. http://www.nhlbi.nih.gov/health/public/heart/chol/wyntk.htm.

The following desired values are used to measure an overall lipid profile:

- LDL. Less than 160 mg/dL (if you have heart disease or diabetes, less than 100 mg/dL)
- HDL. Greater than 40–60 mg/dL
- triglycerides. 10–150 mg/dL
- VLDL. 2–38 mg/dL

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.

RECOMMENDED FAT INTAKE

The acceptable macronutrient distribution range (AMDR) from the Dietary Reference Intake Committee for adult fat consumption is as follows:[2]

- Fat calories should be limited to 20–35 percent of total calories with most fats coming from polyunsaturated and monounsaturated fats, such as those found in fish, nuts, and vegetable oils.
- Consume fewer than 10 percent of calories from saturated fats. Some studies suggest that lowering the saturated fat content to less than 7 percent can further reduce the risk of heart disease.
- Keep the consumption of trans fats (any food label that reads hydrogenated or partially hydrogenated oil) to a minimum, less than 1 percent of calories.
- Think lean and low-fat when selecting meat, poultry, milk, and milk products.

The current AMDR for child and adolescent fat consumption (for children over four) are as follows:

- For children between ages four and eighteen years, between 25 and 35 percent of caloric intake should be from fat.
- For all age groups, most fats should come from polyunsaturated and monounsaturated fats such as fish, nuts, and vegetable oils.

IDENTIFYING SOURCES OF FAT

Population-based studies of 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 Heart and Stroke Foundation recommends choosing lean meats and vegetable alternatives, choosing dairy products with low fat content, and minimizing the intake of trans fats. The Heart and Stroke guidelines also recommend consuming fish, especially oily fish, at least twice per week.

2. Institute of Medicine. (2006). Dietary Reference Intakes: Macronutrients. https://www.nal.usda.gov/sites/default/files/fnic_uploads/DRIEssentialGuideNutReq.pdf.

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 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

Recall that 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.

- Omega-3 Fatty Acids. At the helm of the omega-3 fatty acid family is linolenic acid. From this fatty acid, the body can make eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Linolenic acid is found in nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed. EPA and DHA are found abundantly in fatty fish.
- Omega-6 Fatty Acids. At the helm of the omega-6 fatty acid family is linoleic acid. Like linolenic acid, the body uses linoleic acid to make other important substances such as arachidonic acid (ARA) that is used to make eicosanoids. Recall that eicosanoids perform critical roles in the body as they affect a broad spectrum of functions. The word eicosanoid originates from the Greek word eicosa, meaning twenty, because this hormone is derived from ARA that is twenty carbon atoms in length. Eicosanoids affect the synthesis of all other body hormones and control all body systems, such as the central nervous system and the immune system. Among the many functions eicosanoids serve in the body, their primary function is to regulate inflammation. Without these hormones the body would not be able to heal wounds, fight infections, or fight off illness each time a foreign germ presented itself. Eicosanoids work together with the body’s immune and inflammatory processes to play a major role in several important body functions, such as circulation, respiration, and muscle movement.

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.

CHAPTER ATTRIBUTION

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?

Food manufacturers are aware that fatty acids are susceptible to attack by oxygen molecules because their points of unsaturation render them vulnerable in this regard. When oxygen molecules attack these points of unsaturation the modified fatty acid becomes oxidized. The oxidation of fatty acids makes the oil rancid and gives the food prepared with it an unappetizing taste. Because oils can undergo oxidation when stored in open containers, they must be stored in airtight containers and possibly be refrigerated to minimize damage from oxidation. Hydrogenation poses a solution that food manufacturers prefer.

When lipids are subjected to hydrogenation, the molecular structure of the fat is altered. Hydrogenation is the process of adding hydrogen to unsaturated fatty-acid chains, so that the hydrogen atoms are connected to the points of saturation and results in a more saturated fatty acid. Liquid oils that once contained more unsaturated fatty acids become semisolid or solid (upon complete hydrogenation) and behave like saturated fats. Oils initially contain polyunsaturated fatty acids. When the process of hydrogenation is not complete, for example, not all carbon double bonds have been saturated the end result is a partially hydrogenated oil. The resulting oil is not fully solid. Total hydrogenation makes the oil very hard and virtually unusable. Some newer products are now using fully hydrogenated oil combined with nonhydrogenated vegetable oils to create a usable fat.

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. Like saturated fats, trans fats raise LDL "bad cholesterol," but unlike saturated fats, trans fats lower HDL "good cholesterol." You should limit 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.

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 such as partially or fractionated hydrogenated oil. 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.

CHAPTER ATTRIBUTION

Lipids and Disease

Because heart disease, cancer, and stroke are the three leading causes of death in the Canada, it is critical to address dietary and lifestyle choices that will ultimately decrease risk factors for these diseases. 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.[1] 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 Canada and other developed 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. The average Canadian female consumes 237 milligrams of dietary cholesterol per day and for males the figure is slightly higher—about 358 milligrams. 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. Limit saturated fats, thereby indirectly limiting dietary cholesterol since foods that are high in cholesterol tend to be high in saturated fats also.

1. Harvard School of Public Health. (2017). Fats and Cholesterol: Out with the Bad, In with the Good. http://www.hsph.harvard.edu/nutritionsource/what-should-you -eat/fats-full-story/

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:

- Cardiovascular disease. According to the Heart and Stroke foundation, 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 Canada, 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.
- Obesity has been linked to increased risks of developing diabetes and heart disease. 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 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.

CHAPTER ATTRIBUTION

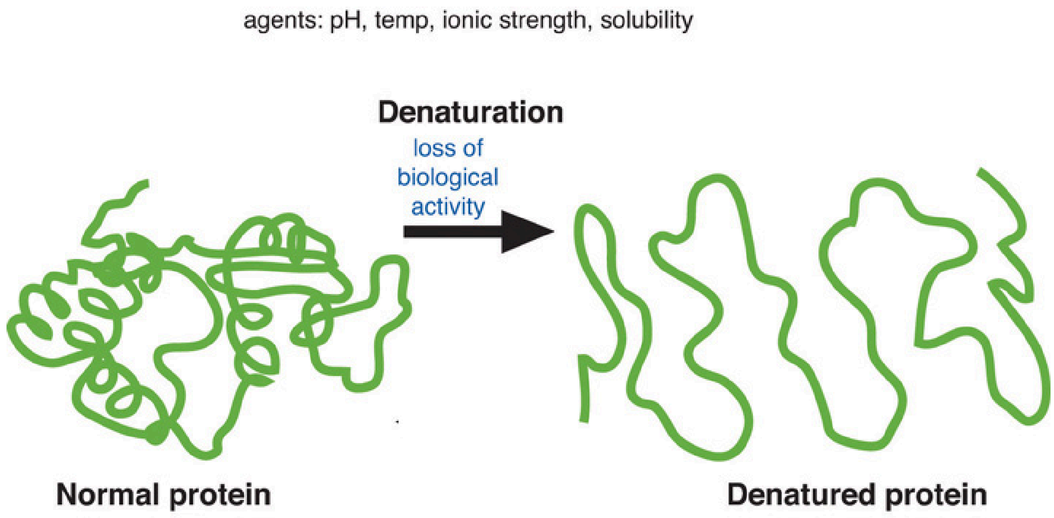
PROTEIN

The Role of Proteins in Foods: Cooking and Denaturation

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.

PROTEIN DENATURATION: UNRAVELING THE FOLD

When a cake is baked, the proteins are denatured. Denaturation refers to the physical changes that take place in a protein exposed to abnormal conditions in the environment. Heat, acid, high salt concentrations, alcohol, and mechanical agitation can cause proteins to denature. When a protein denatures, its complicated folded structure unravels, and it becomes just a long strand of amino acids again. Weak chemical forces that hold tertiary and secondary protein structures together are broken when a protein is exposed to unnatural conditions. Because proteins' function is dependent on their shape, denatured proteins are no longer functional. During cooking the applied heat causes proteins to vibrate. This destroys the weak bonds holding proteins in their complex shape (though this does not happen to the stronger peptide bonds). The unraveled protein strands then stick together, forming an aggregate (or network).



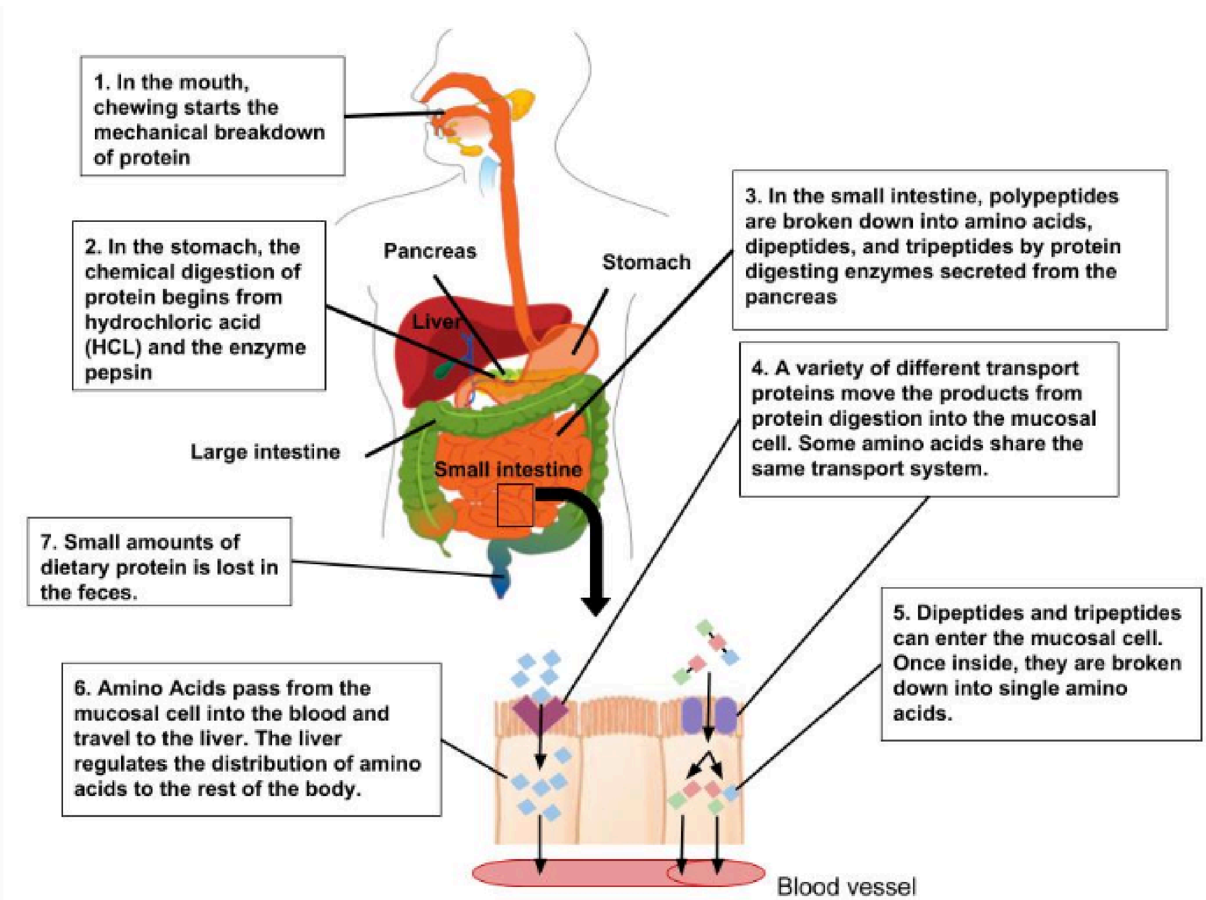
When a protein is exposed to a different environment, such as increased temperature, it unfolds into a single strand of amino acids. [Protein Denaturation](), by lardbucket, via [CC BY 4.0]()

CHAPTER ATTRIBUTION

Chapter 7.2 in [Human Nutrition in a Canadian Contex]()t by Karine Hamm published by BCcampus in 2021 under a [CC BY License.]()

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. 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.



Digestion and Absorption of Protein by Calabrese, A., via CC BY 4.0

FROM THE MOUTH TO THE STOMACH

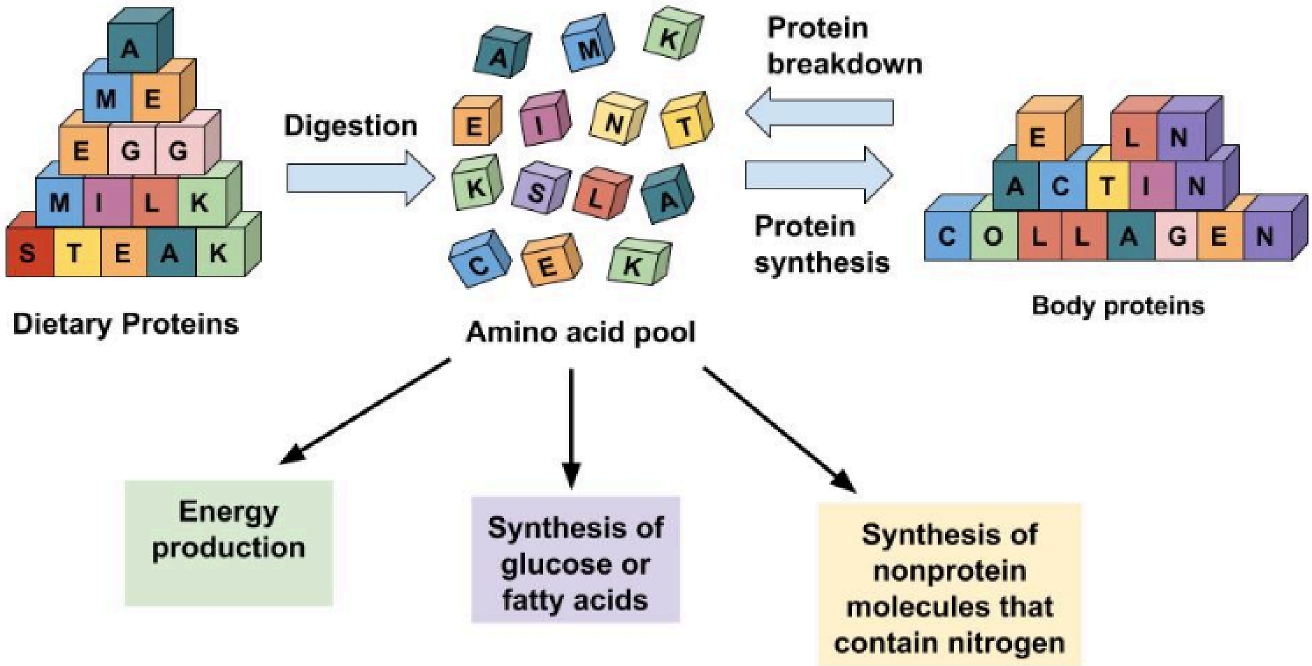
Unless you are eating it raw, the first step in egg digestion (or any other protein food) involves chewing. The teeth begin the mechanical breakdown of the large egg pieces into smaller pieces that can be swallowed. The salivary glands provide some saliva to aid swallowing and the passage of the partially 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 two major pancreatic enzymes that digest proteins are chymotrypsin and trypsin. 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).



Options For Amino Acid Use In The Human Body by Calabrese, A., via CC BY 4.0

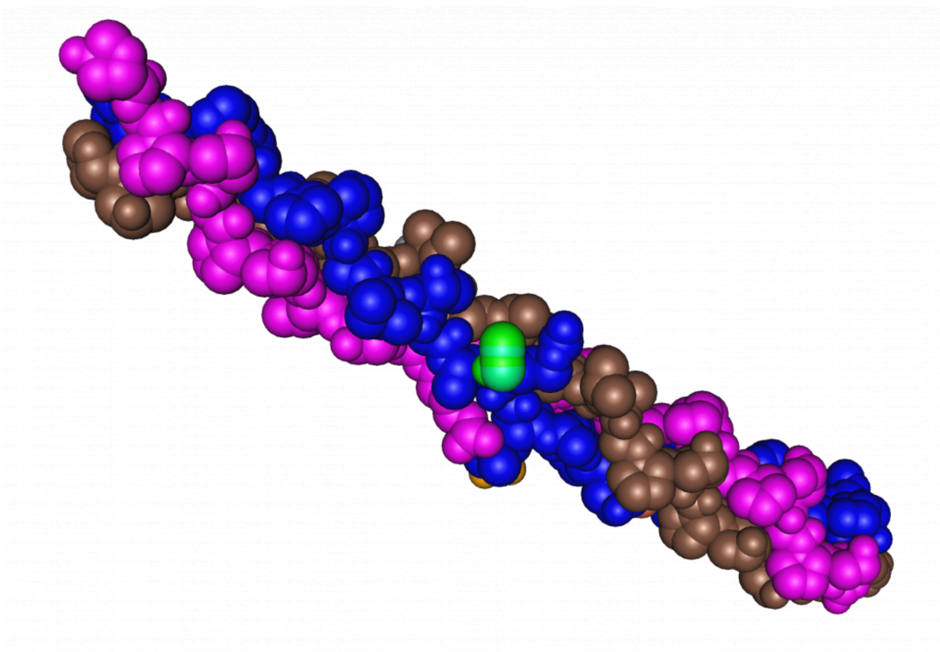
Amino acids in the cellular pool come from dietary protein and from the destruction of cellular proteins. The amino acids in this pool need to be replenished because amino acids are outsourced to make new proteins, energy, and other biological molecules.

CHAPTER ATTRIBUTION

Protein's Functions in the Body

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.

STRUCTURE AND MOTION

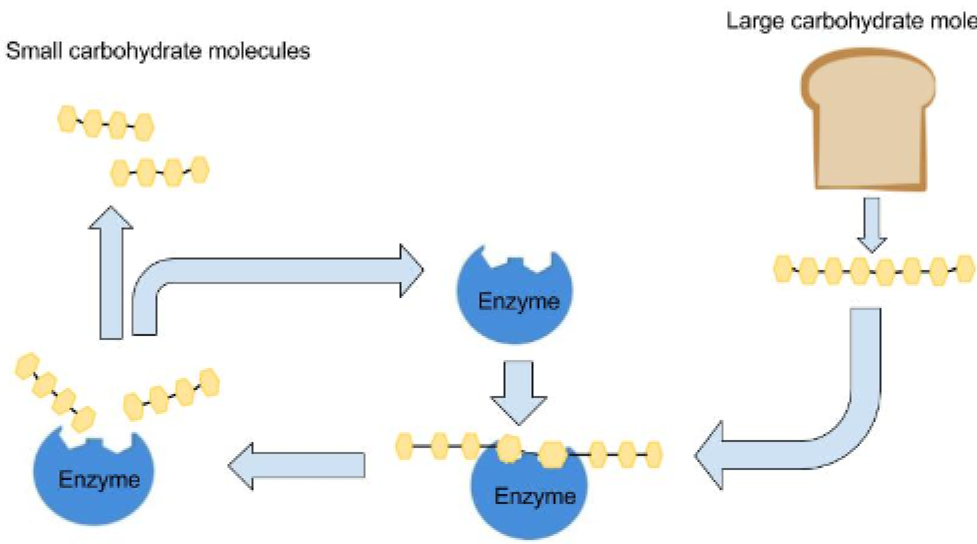


Collagen Structure. Collagen Triple Helix by Nevit Dilmen / CC BY-SA 3.0

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 made up of mostly glycine and proline. Within its quaternary structure three peptide strands twist around each other like a rope and then these collagen ropes overlap with others. This highly ordered structure is 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.



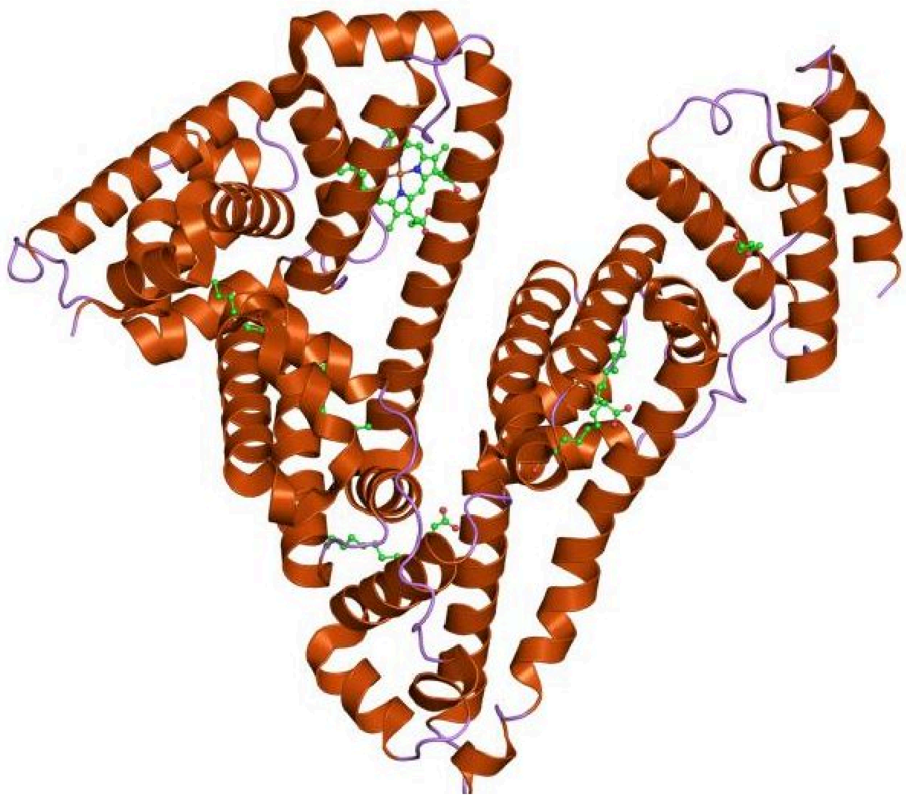
Enzymes Role in Carbohydrate Digestion by Calabrese, A., via CC BY 4.0

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.



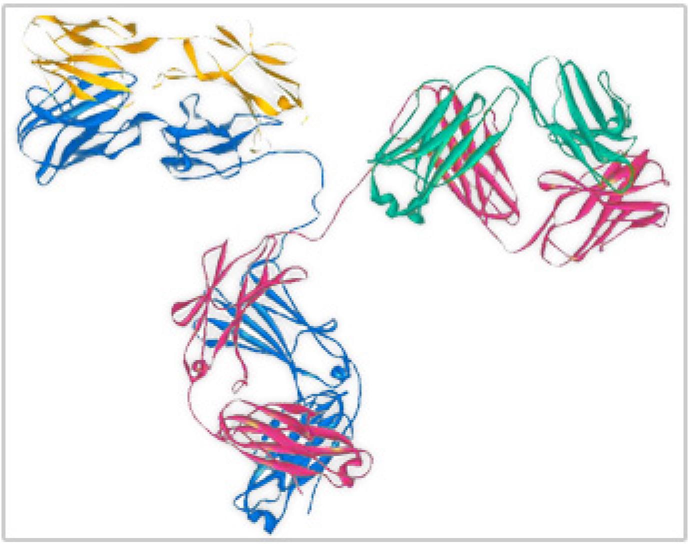
The butterfly-shaped protein, albumin, has many functions in the body including maintaining fluid and acid-base balance and transporting molecules. [PDB 1o9x EBI] by Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute, via [Public Domain.]

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. Recall that acidic conditions can cause protein denaturation, which stops proteins from functioning. The body has several systems that hold the blood pH within the normal range to prevent this from happening. One of these is the circulating albumin. Albumin is slightly acidic, and because it is negatively charged it balances the many positively charged molecules, such as protons (H+), calcium, potassium, and magnesium which are also circulating in the blood. Albumin acts as a buffer against abrupt changes in the concentrations of these molecules, thereby balancing blood pH and maintaining the status quo. The protein hemoglobin also participates in acid-base balance by binding and releasing protons.

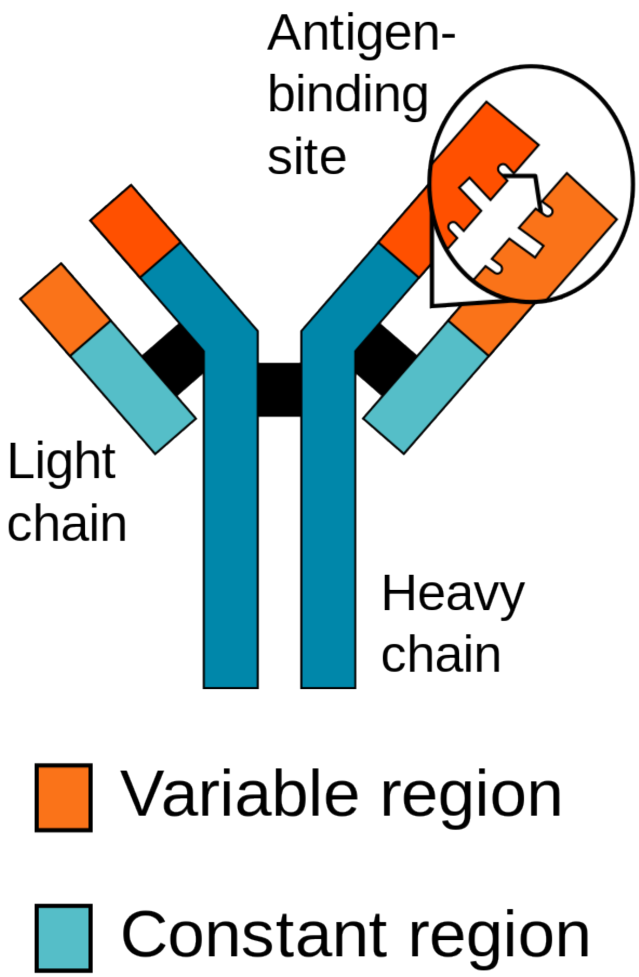
TRANSPORT

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



Antibody Proteins by Blake C., via CC BY-SA 3.0



Antigens. [Antibody chains] by Fred the Oyster, via [Public Domain.]

An antibody protein is made up of two heavy chains and two light chains. The variable region, which differs from one antibody to the next, allows an antibody to recognize its matching antigen.

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.

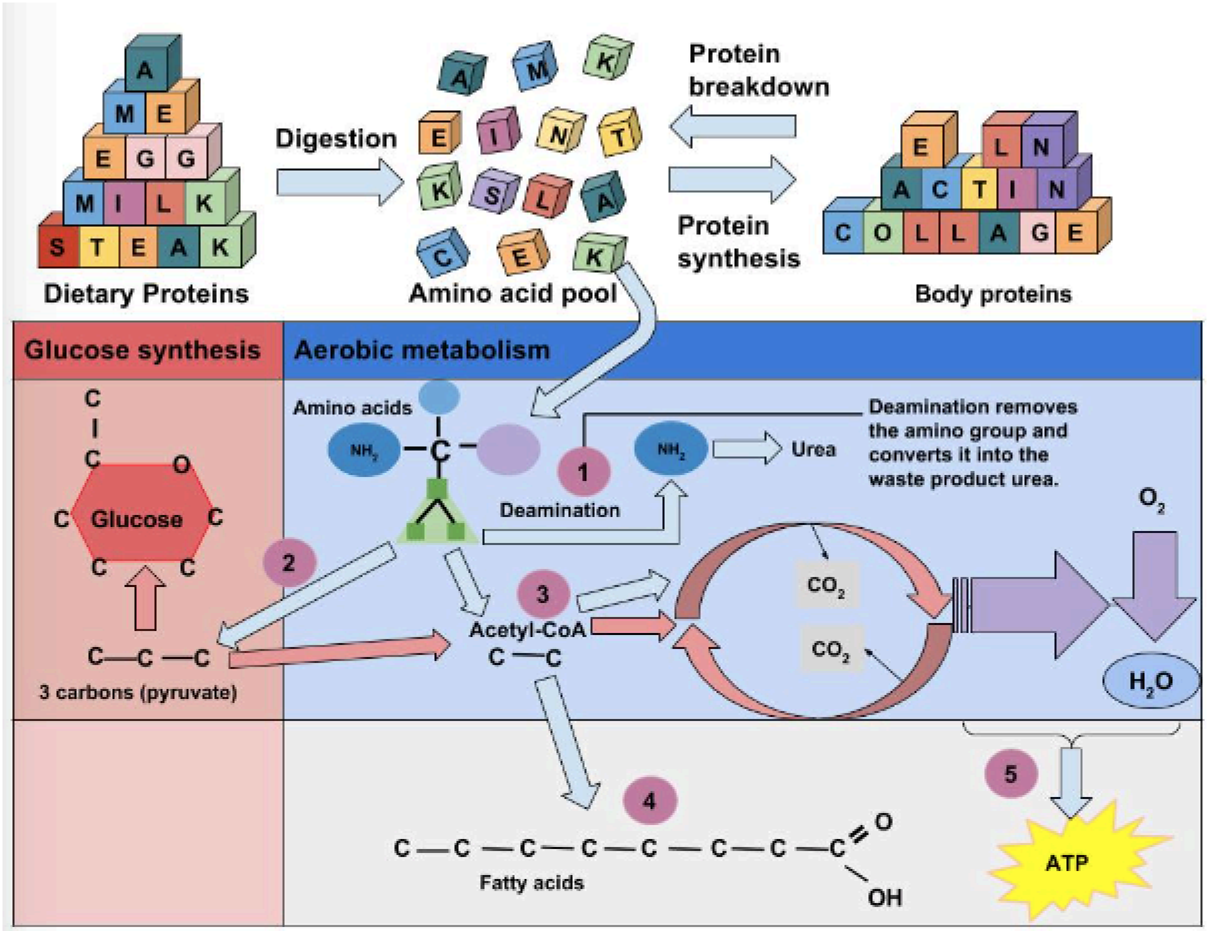
WOUND HEALING AND TISSUE REGENERATION

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 such as bradykinin, which dilate blood vessels at the site of injury. An additional protein called fibrin 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 7.14 "Amino Acids Used for Energy"). Only about 10 percent of dietary proteins are catabolized each day to make cellular energy. The liver is able to break down amino acids to the carbon skeleton, which can then be fed into the citric acid cycle. This is similar to the way that glucose is used to make ATP. 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.



[Amino Acids Used for Energy](#) *by Calabrese, A., via* [*CC BY 4.0*](#)

CHAPTER ATTRIBUTION

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. Severe protein deficiency is a rare occurrence in children and adults in Canada. 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. In this section we will discuss the health consequences of protein intake that is either too low to support life's processes or too high, thereby increasing the risk of chronic disease. In the last section of this chapter, we will discuss in more detail the personal choices you can make to optimize your health by consuming the right amount of high-quality protein.

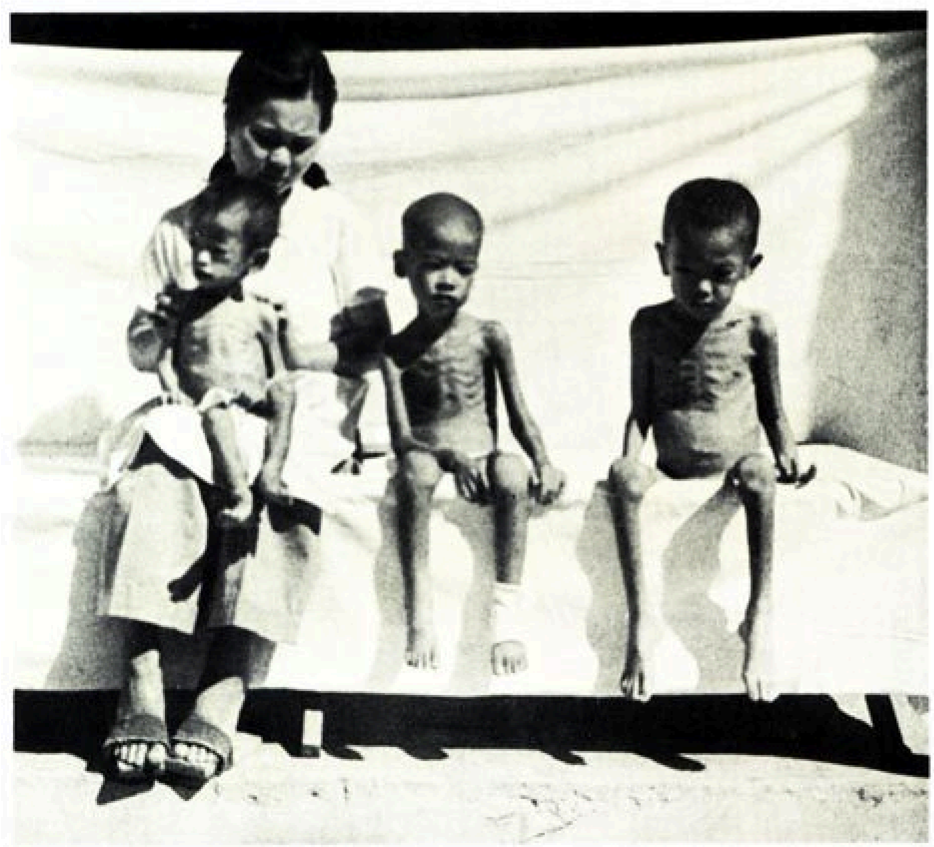
HEALTH CONSEQUENCES OF PROTEIN DEFICIENCY

Although severe protein deficiency is rare in the developed world, it is a leading cause of death in children in many poor, underdeveloped countries. There are two main syndromes associated with protein deficiencies: Kwashiorkor and Marasmus. Kwashiorkor affects millions of children worldwide. When it was first described in 1935, more than 90 percent of children with Kwashiorkor died. Although the associated mortality is slightly lower now, most children still die after the initiation of treatment. The name Kwashiorkor comes from a language in Ghana and means, "rejected one." The syndrome was named because it occurred most commonly in children who had recently been weaned from the breast, usually because another child had just been born. Subsequently the child was fed watery porridge made from low-protein grains, which accounts for the low protein intake. Kwashiorkor is characterized by swelling (edema) of the feet and abdomen, poor skin health, growth retardation, low muscle mass, and liver malfunction. 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. The primary symptoms of Kwashiorkor 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.

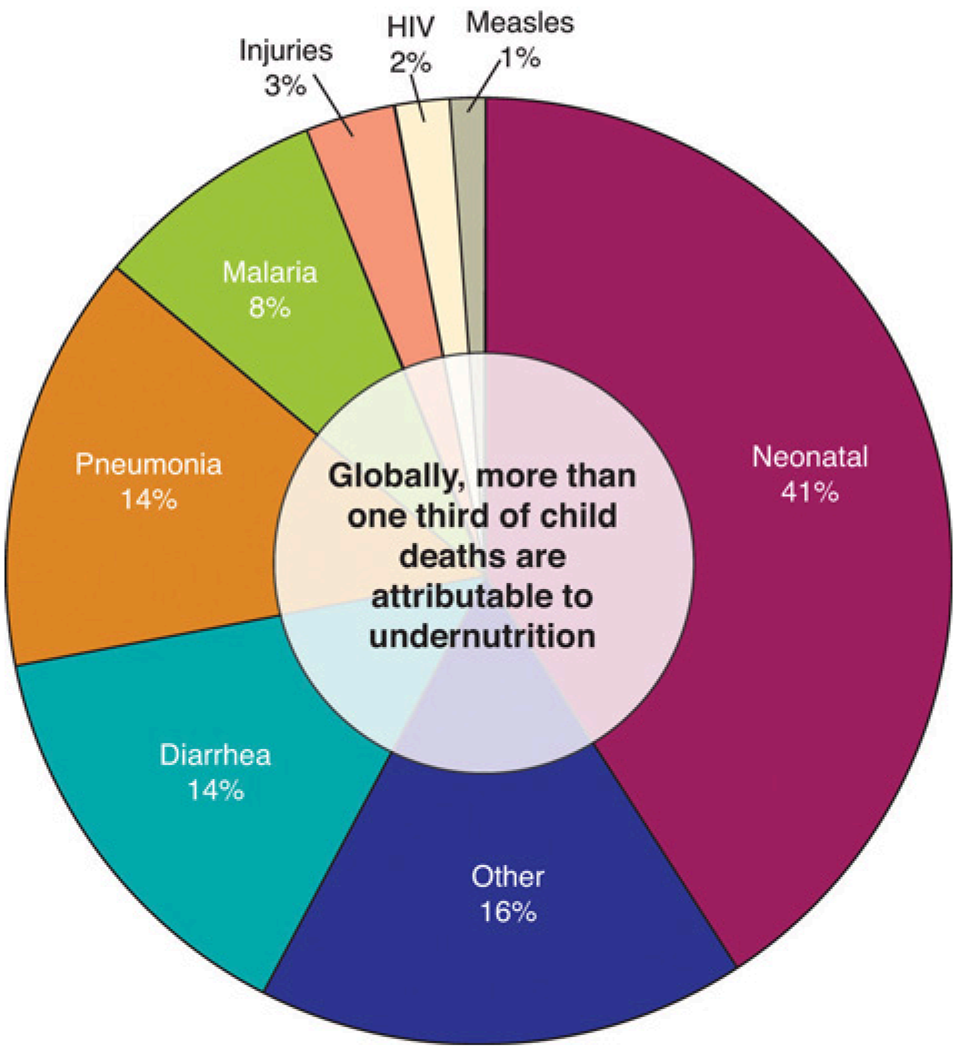
A Young Boy With Kwashiorkor by the Centers for Disease Control and Prevention (CDC), via Public Domain.

Kwashiorkor is a disease brought on by a severe dietary protein deficiency. Symptoms include edema of legs and feet, light-colored, thinning hair, anemia, a pot-belly, and shiny skin.

Children and adults with marasmus neither have enough protein in their diets nor do they take in enough calories. Marasmus affects mostly children below the age of one in poor countries. Body weights of children with Marasmus may be up to 80 percent less than that of a normal child of the same age. Marasmus is a Greek word, meaning “starvation.” The syndrome affects more than fifty million children under age five worldwide. It is characterized by an extreme emaciated appearance, poor skin health, and growth retardation. The symptoms are acute fatigue, hunger, and diarrhea.



Japanese nurse with dependent children having typical appearance of malnutrition, New Bilibid Prison, September-October 1945. [Children With Marasmus](#) by Unknown author, via [Public Domain.](#)



Causes Of Death For Children Under The Age Of Five, Worldwide.

Kwashiorkor and marasmus often coexist as a combined syndrome termed marasmic kwashiorkor. Children with the combined syndrome have variable amounts of edema and the characterizations and symptoms of marasmus. Although organ system function is compromised by undernutrition, the ultimate cause of death 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.

HEALTH CONSEQUENCES OF TOO MUCH PROTEIN IN THE DIET

An explicit definition of a high-protein diet has not yet been developed 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 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 underdiagnosed. 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 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][3]

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.[4]

High-protein diets can restrict other essential nutrients. 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 these diets are therefore at risk for compromised vitamin and mineral intake, as well as potential cardiac, renal, bone, and liver abnormalities overall. [5]

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. Read on to find out more about calculating your dietary protein recommendations, dietary protein sources, and personal choices about protein.

1. Chan DS, Lau R, 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.
2. The Nutrition Source. (2012). Protein: The Bottom Line. Harvard School of Public Health. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/protein/.
3. Barzel US, Massey LK. Excess Dietary Protein Can Adversely Affect Bone. J Nutr. 1998; 128(6), 1051–53. http://jn.nutrition.org/content/128/6/1051.long.
4. St. Jeor ST, 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
5. St. Jeor ST, 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.

CHAPTER ATTRIBUTION

VITAMINS

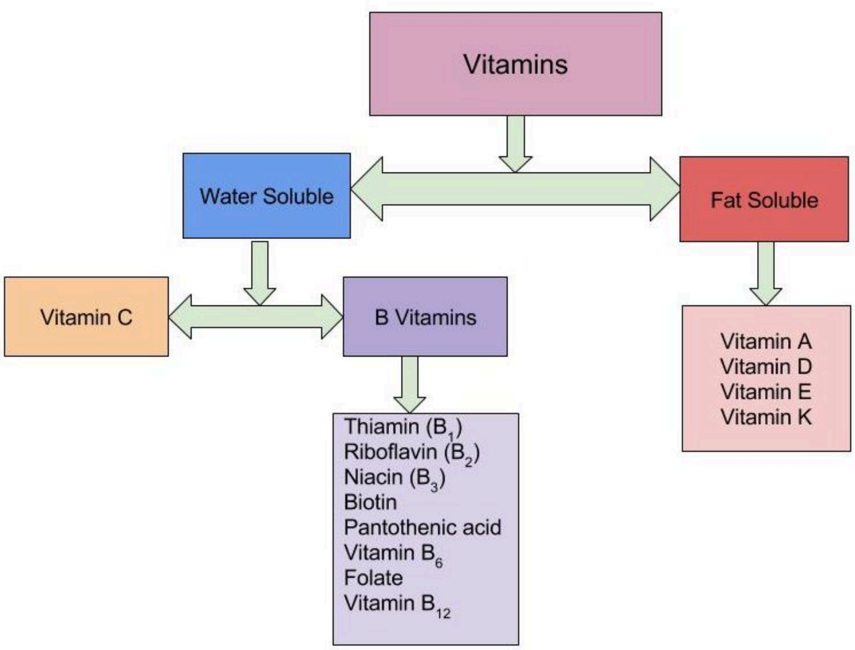
Introduction

Learning Objectives

By the end of this chapter, you will be able to:

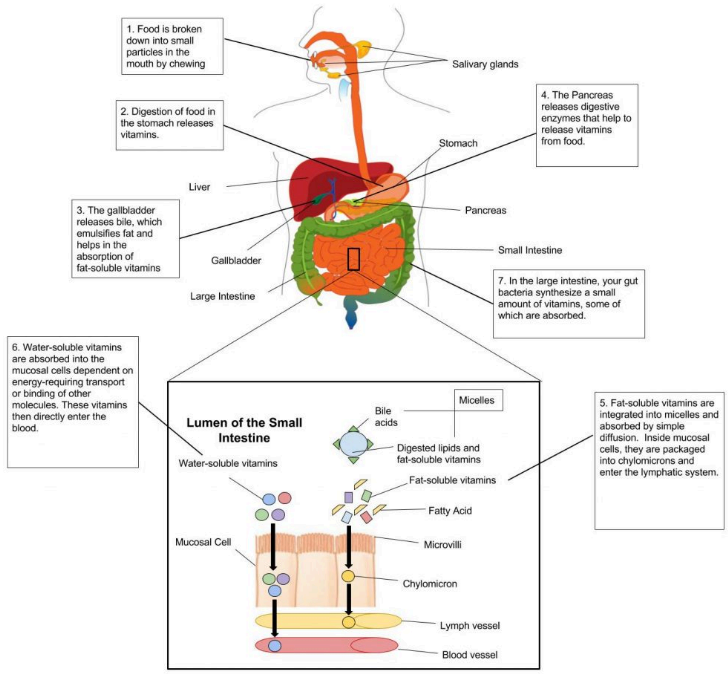
- Describe the role of vitamins as antioxidants in the body
- Describe the functions and sources of antioxidant micronutrients, phytochemicals, and antioxidant minerals
- Describe the functions of vitamins in catabolic pathways, anabolic pathways, and blog

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.



The Vitamins by Calabrese, A., via CC 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 into chylomicrons 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.



Absorption of Fat-Soluble and Water-Soluble Vitamins by Calabrese, A., via CC BY 4.0

CHAPTER ATTRIBUTION

Chapter 10 Introduction in Human Nutrition in a Canadian Context by Karine Hamm published by BCcampus in 2021 under a CC BY License.

Fat-Soluble Vitamins

VITAMIN A FUNCTIONS AND HEALTH BENEFITS

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. Beta-carotene, alpha-carotene, and beta-cryptoxanthin are converted to some extent to retinol in the body. The other carotenoids, such as lycopene, are not. Many biological actions of carotenoids are attributed to their antioxidant activity, but they likely act by other mechanisms, too.

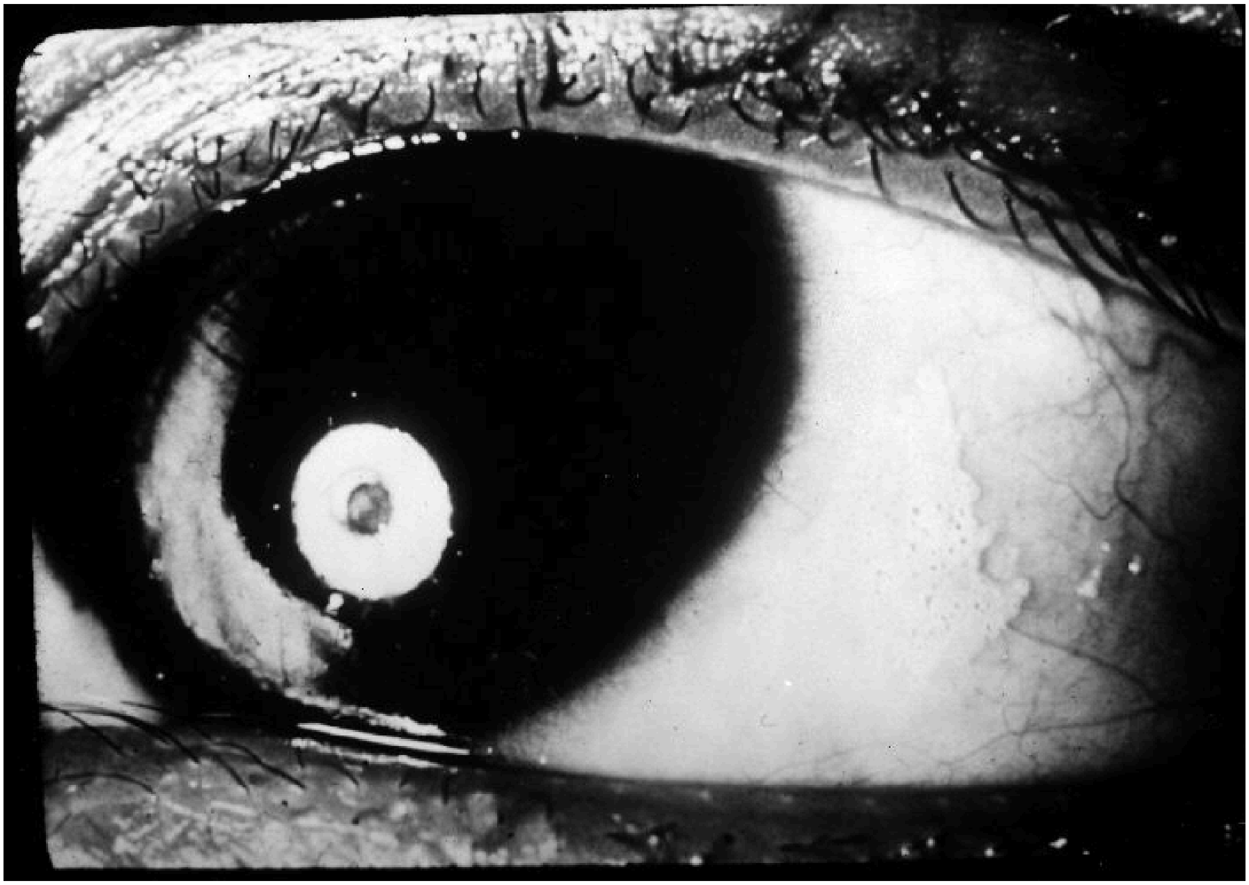
Vitamin A is fat-soluble and is packaged into chylomicrons in small intestine, and transported to the liver. The liver stores and exports vitamin A as needed; it is released into the blood bound to a retinol-binding protein, which transports it to cells. Carotenoids are not absorbed as well as vitamin 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.

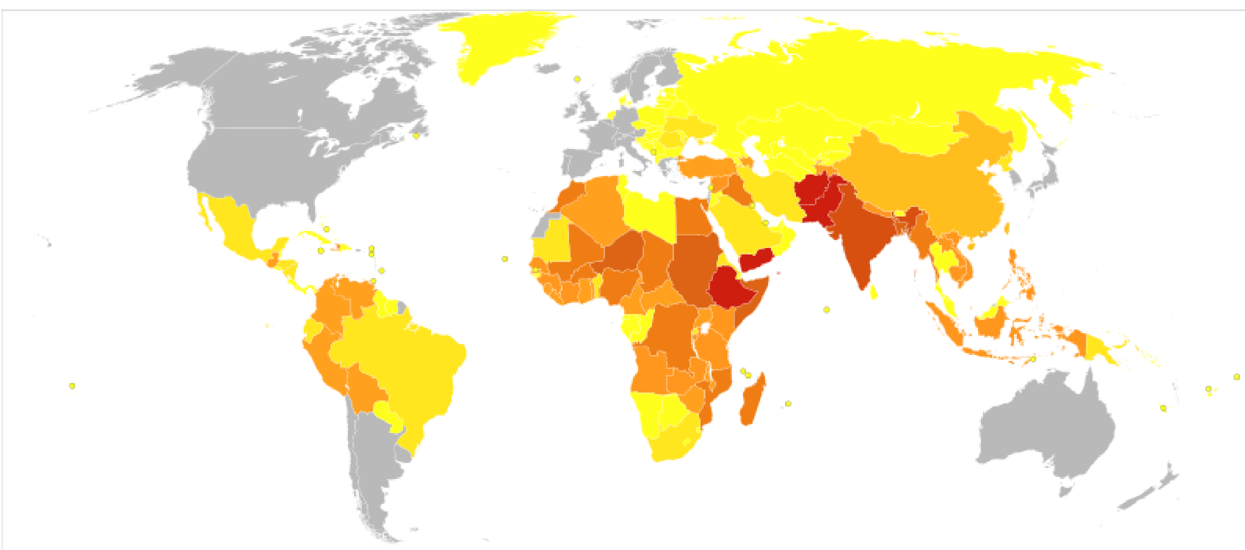
VISION

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.



Bitot Spot caused by vitamin A deficiency. Malnutrition-Bitot's Spots by CDC/Nutrition Program, via Public Domain.



Vitamin A Deficiency World Map by Chris55, via Public Domain.

Legend: Disability-adjusted life years (DALY) lost from Vitamin A deficiency in 2012 per million persons.

0-28	31-78	85-85	85-141	144-257	258-376	432-455	558-558	586-883

IMMUNITY

The common occurrence of advanced xerophthalmia in children who died from infectious diseases led scientists to hypothesize that supplementing vitamin A in the diet for children with xerophthalmia might reduce disease-related mortality. In Asia in the late 1980s, targeted populations of children were administered vitamin A supplements, and the death rates from measles and diarrhea declined by up to 50 percent. Vitamin A supplementation in these deficient populations did not reduce the number of children who contracted these diseases, but it did decrease the severity of the diseases so that they were no longer fatal. Soon after the results of these studies were communicated to the rest of the world, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) commenced worldwide campaigns against vitamin A deficiency. UNICEF estimates that the distribution of over half a billion vitamin A capsules prevents 350,000 childhood deaths annually.[1]

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.

CANCER

Vitamin A's role in regulating cell growth and death, especially in tissues that line and cover organs, suggests it may be effective in treating certain cancers of the lung, neck, and liver. It has been shown in some observational studies that vitamin A-deficient populations have a higher risk for some cancers. However, vitamin A supplements have actually been found to increase the risk of lung cancer in people who are at high risk for the disease (i.e., smokers, ex-smokers, workers exposed to asbestos). The Beta-Carotene and Retinol Efficacy Trial (CARET) involving over eighteen thousand participants who were at high risk for lung cancer found that people who took supplements containing very high doses of vitamin A (25,000 international units) and beta-carotene had a 28 percent higher incidence of lung cancer midway through the study, which was consequently stopped.[2]

1. Sommer A. Vitamin A Deficiency and Clinical Disease: An Historical Overview. J Nutr. 2008; 138, 1835–39. http://jn.nutrition.org/content/138/10/1835.long.
2. Goodman GE, et al. The Beta-Carotene and Retinol Efficacy Trial: Incidence of Lung Cancer and Cardiovascular Disease

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 Reference Intakes for Vitamin A

There is more than one source of vitamin A in the diet. There is preformed vitamin A, which is abundant in many animal-derived foods, and there are carotenoids, which are found in high concentrations in vibrantly colored fruits and vegetables and some oils.

Some carotenoids are converted to retinol in the body by intestinal cells and liver cells. However, only minuscule amounts of certain carotenoids are converted to retinol, meaning fruits and vegetables are not necessarily good sources of vitamin A.

The RDA for vitamin A includes all sources of vitamin A. The RDA for vitamin A is given in mcg of retinol activity requirements (RAE) to take into account the many different forms it is available in. The human body converts all dietary sources of vitamin A into retinol. Therefore, 1 mcg of retinol is equivalent to 12 mcg of beta-carotene, and 24 mcg of alpha-carotene or beta-cryptoxanthin. For example, 12 micrograms of fruit- or vegetable-based beta-carotene will yield 1 microgram of retinol. Currently vitamin A listed in food and on supplement labels use international units (IUs). The following conversions are listed below:[3]

- 1 IU retinol = 0.3 mcg RAE
- 1 IU beta-carotene from dietary supplements = 0.15 mcg RAE
- 1 IU beta-carotene from food = 0.6 mcg RAE
- 1 IU alpha-carotene or beta-cryptoxanthin = 0.025 mcg RAE

The RDA for vitamin A is considered sufficient to support growth and development, reproduction, vision, and immune system function while maintaining adequate stores (good for four months) in the liver.

Mortality During 6-year Follow-up after Stopping Beta-Carotene and Retinol Supplements. J Natl Cancer Inst. 2004; 96(23), 1743–50. http://jnci.oxfordjournals.org/content/96/23/1743.long.

3. Office of Dietary Supplements. (2012). Dietary Supplement Fact Sheet: Vitamin A. National Institutes of Health. http://ods.od.nih.gov/factsheets/VitaminA-QuickFacts/.

Dietary Reference Intakes for Vitamin A[4]

Age Group	RDA Males and Females mcg RAE/day	UL
Infants (0–6 months)	400*	600
Infants (7–12 months)	500*	600
Children (1–3 years)	300	600
Children (4–8 years)	400	900
Children (9–13 years)	600	1,700
Adolescents (14–18 years)	Males: 900	2,800
Adolescents (14–18 years)	Females: 700	2,800
Adults (> 19 years)	Males: 900	3,000
Adults (> 19 years)	Females: 700	3,000
*denotes Adequate Intake		

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 "Vitamin A Content of Various Foods"). The dietary sources of carotenoids will be given in the following text.

Vitamin A Content of Various Foods[5]

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

The most consumed carotenoids are alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, lutein, and zeaxanthin. See Table "Alpha- and Beta-Carotene Content of Various Foods for the carotenoid content of various foods".

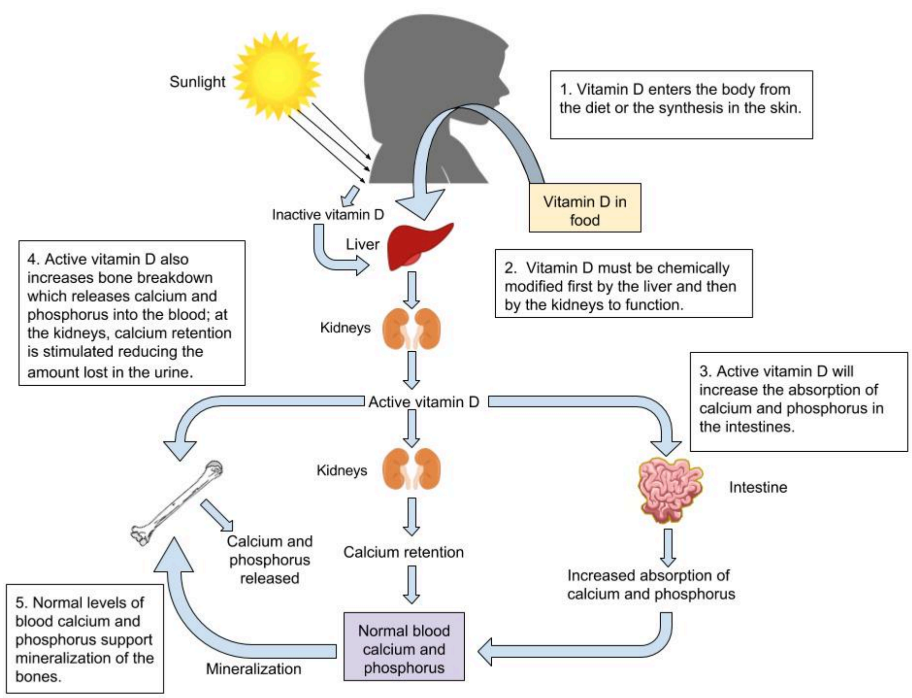
4. Dietary Supplement Fact Sheet: Vitamin A. National Institutes of Health. Office of Dietary Supplements. (2012). http://ods.od.nih.gov/factsheets/VitaminA-QuickFacts/.
5. Dietary Supplement Fact Sheet: Vitamin A. National Institutes of Health. Office of Dietary Supplements. (2012). http://ods.od.nih.gov/factsheets/VitaminA-QuickFacts/.

Alpha- and Beta-Carotene Content of Various Foods[6]

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

VITAMIN D FUNCTIONS AND HEALTH BENEFITS

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.



The Functions of Vitamin D by Calabrese, A. , via CC BY 4.0

6. 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.

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.

Rickets, stages of development for children by Wellcome Images, via 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.[7] 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 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.

DIETARY REFERENCE INTAKE FOR VITAMIN D

The Institute of Medicine RDAs for vitamin D for different age groups is listed in Table "Dietary Reference Intakes for Vitamin D". For adults, the RDA is 600 international units (IUs), which is equivalent to 15 micrograms of vitamin D. Slightly higher levels are recommended for adults fifty and older. It is recommended they get between 800 and 1,000 international units of vitamin D every day. The tolerable upper intake level (UL) for vitamin D is 4,000 international units per day. 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.

7. 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.

Dietary Reference Intakes for Vitamin D[8]

Age Group	RDA (mcg/day)	UL (mcg/day)
Infant (0–6 months)	10*	25
Infants (6–12 months)	10*	25
Children (1–3 years)	15	50
Children (4–8 years)	15	50
Children (9–13 years)	15	50
Adolescents (14–18 years)	15	50
Adults (19–71 years)	15	50
Adults (> 71 years)	20	50
* denotes Adequate Intake		

DIETARY SOURCES OF VITAMIN D

Vitamin D Content of Various Foods[9]

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

VITAMIN E FUNCTIONS AND HEALTH BENEFITS

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

8. Ross, A. C. et al. The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know. J Clin Endocrinol Metab. 2011; 96(1), 53–8. http://www.ncbi.nlm.nih.gov/pubmed/21118827.
9. National Institutes of Health, Office of Dietary Supplements. (2012). Dietary Supplement Fact Sheet: Vitamin D. https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/#h3.

studies do not support the idea that taking higher doses of this vitamin will increase its power to prevent or reduce disease risk.[10][11]

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.

CARDIOVASCULAR DISEASE

Vitamin E reduces the oxidation of LDLs, and it was therefore hypothesized that vitamin E supplements would protect against atherosclerosis. However, large clinical trials have not consistently found evidence to support this hypothesis. In fact, in the "Women's Angiographic Vitamin and Estrogen Study," postmenopausal women who took 400 international units (264 milligrams) of vitamin E and 500 milligrams of vitamin C twice per day had higher death rates from all causes.[12]

Other studies have not confirmed the association between increased vitamin E intake from supplements and increased mortality. There is more consistent evidence from observational studies that a higher intake of vitamin E from foods is linked to a decreased risk of dying from a heart attack.

CANCER

The large clinical trials that evaluated whether there was a link between vitamin E and cardiovascular disease risk also looked at cancer risk. These trials, called the HOPE-TOO Trial and Women's Health Study, did not find that vitamin E at doses of 400 international units (264 milligrams) per day or 600 international units (396 milligrams) every other day reduced the risk of developing any form of cancer.[13][14]

EYE CONDITIONS

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

10. 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.
11. 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
12. Waters DD, et al. Effects of Hormone Replacement Therapy and Antioxidant Vitamin Supplements on Coronary Atherosclerosis in Postmenopausal Women: A Randomized Controlled Trial. *JAMA. 2002; 288*(19), 2432–40. https://jamanetwork.com/journals/jama/fullarticle/195531.
13. HOPE and HOPE-TOO Trial Investigators. Effects of Long-Term Vitamin E Supplementation on Cardiovascular Events and Cancer. *JAMA. 2005; 293*, 1338–47. http://jama.ama-assn.org/content/293/11/1338.long.,
14. Lee IM, et al. Vitamin E in the Primary Prevention of Cardiovascular Disease and Cancer: The Women's Health Study. *JAMA.2005; 294*, 56–65. http://jama.ama-assn.org/content/294/1/56.long.

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.[15]

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.[16]

DIETARY REFERENCE INTAKES FOR VITAMIN E

The Recommended Dietary Allowances (RDAs) and Tolerable Upper Intake Levels (ULs) for different age groups for vitamin E are given in Table "Dietary Reference Intakes for Vitamin E".

Dietary Reference Intakes for Vitamin E[17]

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	4*	–
Infants (7–12 months)	5*	–
Children (1–3 years)	6	200
Children (4–8 years)	7	300
Children (9–13 years)	11	600
Adolescents (14–18 years)	15	800
Adults (> 19 years)	15	1,000
*denotes Adequate Intake		

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.

15. Devore EE, et al. Dietary Antioxidants and Long-Term Risk of Dementia. *Arch Neurol. 2010; 67*(7), 819–25. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923546/?tool=pubmed.
16. Dietary Supplement Fact Sheet: Vitamin E. National Institutes of Health. Office of Dietary Supplements. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/.
17. Office of Dietary Supplements. (2011). Dietary Supplement Fact Sheet: Vitamin E.National Institutes of Health. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/.

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.

Healthy dietary dose of vitamin E by Farhad Ibrahimzade, via Unsplash License.

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 "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.

Vitamin E Content of Various Foods[18]

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

18. Office of Dietary Supplements. (2011). Dietary Supplement Fact Sheet: Vitamin E.National Institutes of Health. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/.

VITAMIN K FUNCTIONS AND HEALTH BENEFITS

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 REFERENCE INTAKE AND FOOD SOURCES FOR VITAMIN K

The AI of vitamin K for adult females is 90 micrograms per day, and for males it is 120 micrograms per day. A UL for vitamin K has not been set. There is no UL for vitamin K because it has a low potential for toxicity. No adverse effects associated with vitamin K consumption from food or supplements have been reported in humans or animals.

Dietary Reference Intakes for Vitamin K[19]

Age Group	RDA (mcg/day)
Infants (0–6 months)	2.0*
Infants (6–12 months)	2.5*
Children (1–3 years)	30
Children (4–8 years)	55
Children (9–13 years)	60
Adolescents (14–18 years)	75
Adult Males (> 19 years)	120
Adult Females (> 19 years)	90
* denotes Adequate Intake	

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

19. Institute of Medicine. (2001). Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. http://www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

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.

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

SUMMARY OF FAT-SOLUBLE VITAMINS

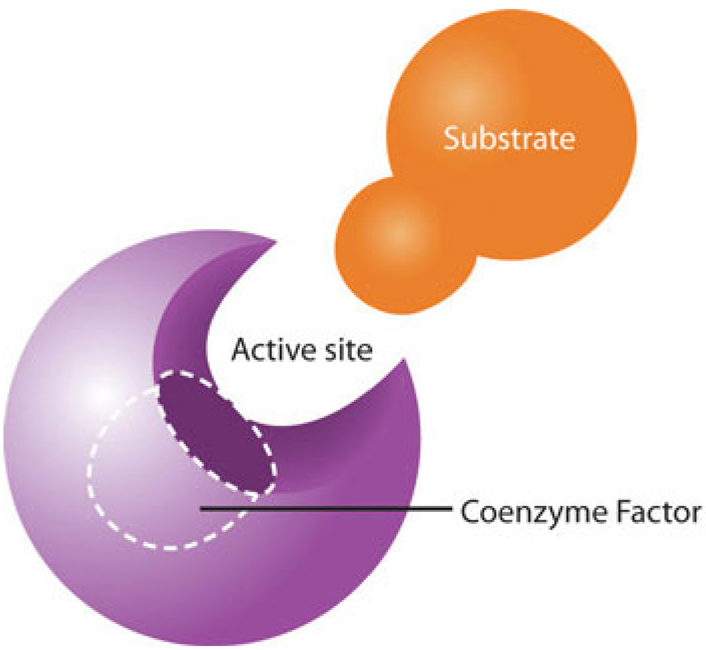
Fat-Soluble Vitamins

Vitamin	Sources	Recommended Intake for adults	Major functions	Deficiency diseases and symptoms	Groups at risk of deficiency	Toxicity	UL
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 in poverty (especially infants and children), premature infants, pregnant and lactating women people who consume low-fat or low-protein diets	Hypervitaminosis A: Dry, itchy skin, hair loss, liver damage, joint pain, fractures, birth defects, swelling of the brain	3000 mcg/day
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	Breastfed infants, older adults people with limited sun exposure, people with dark skin	Calcium deposits in soft tissues, damage to the heart, blood vessels, and kidneys	4000 IU/day (100 mcg/day)
Vitamin E	Sunflower seeds, almonds, hazelnuts,peanuts	15 mg/day	Antioxidant, protects cell membranes	Broken red blood cells, nerve damage	People with poor fat absorption, premature infants	Inhibition of vitamin K clotting factors	1000 mcg/day from supplemental sources
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	Newborns, people on long term antibiotics	Anemia, brain damage	ND

CHAPTER ATTRIBUTION

Water-Soluble Vitamins

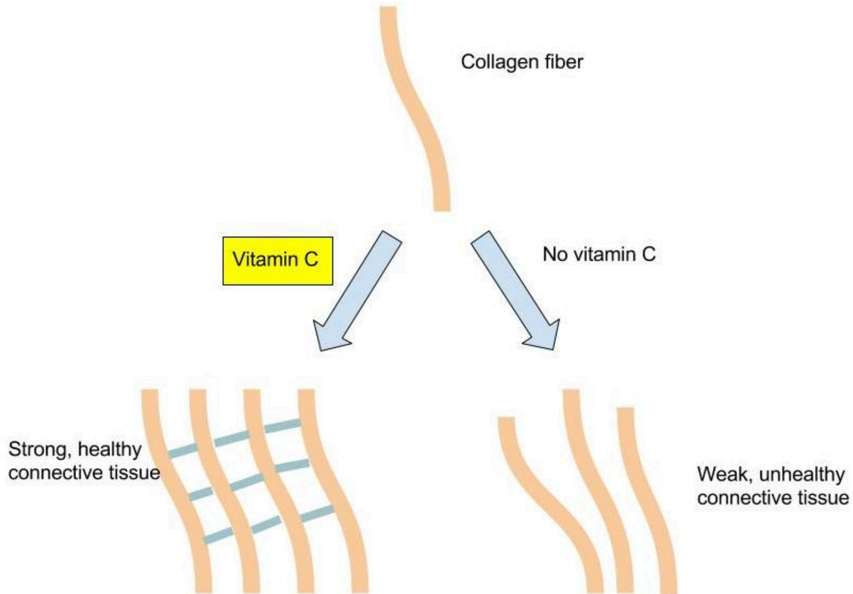
All water-soluble vitamins play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage. Vitamins and minerals that make up part of enzymes are referred to as coenzymes and cofactors, respectively. Coenzymes and cofactors 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, amongst its many other functions. In this section we will focus on the vitamins that take part in metabolism and blood function and renewal.



Coenzymes and cofactors are the particular vitamin or mineral required for enzymes to catalyze a specific reaction. [Enzyme Active Site for Cofactors](#) by Calabrese, A., via [CC BY 4.0](#)

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.



The Role of Vitamin C in Collagen Synthesis by Calabrese, A., via CC BY 4.0

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.

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.

Bleeding Gums Associated with Scurvy. [Scorbutic gums] by Centers for Disease Control and Prevention, via [Public Domain.]

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.[1] 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.[2]

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,

1. 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.
2. 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.

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.

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.[3]

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 the UL for adults is 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 Reference Intakes for Vitamin C

The RDAs and ULs for different age groups for vitamin C are listed in Table "Dietary Reference Intakes for Vitamin C". They are considered adequate to prevent scurvy. Vitamin C's effectiveness as a free radical scavenger motivated the Institute of Medicine (IOM) to increase the RDA for smokers by 35 milligrams, as tobacco smoke is an environmental and behavioral contributor to free radicals in the body.

Dietary Reference Intakes for Vitamin C[4]

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	40*	–
Infants (7–12 months)	50*	–
Children (1–3 years)	15	400
Children (4–8 years)	25	650
Children (9–13 years)	45	1200
Adolescents (14–18 years)	75 (males), 65 (females)	1800
Adults (> 19 years)	90 (males), 75 (females)	2000
*denotes Adequate Intake		

3. Douglas RM, et al. Vitamin C for Preventing and Treating the Common Cold. Cochrane Database of Systematic Reviews. 2004; 4. http://www.ncbi.nlm.nih.gov/pubmed/15495002?dopt=Abstract. Accessed October 5, 2017.
4. National Institutes of Health, Office of Dietary Supplements. (2011). Dietary Supplement Fact Sheet: Vitamin C. http://ods.od.nih.gov/factsheets/VitaminC-QuickFacts/

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 "Vitamin C Content of Various Foods".

Vitamin C Content of Various Foods[5]

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

THIAMIN (B_1)

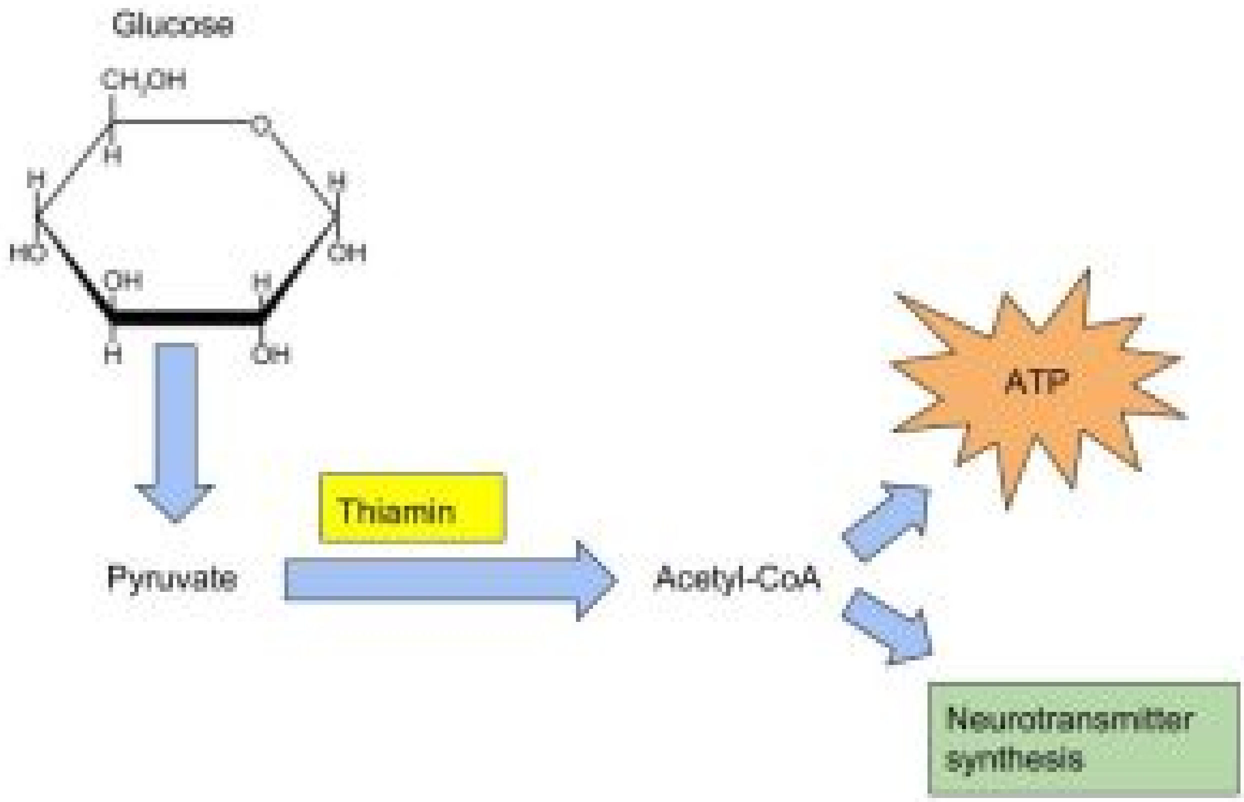
Thiamin is especially important in glucose metabolism. It acts as a cofactor for enzymes that break down glucose for energy production. Thiamin plays a key role in nerve cells as the glucose that is catabolized by thiamin is needed for an energy source. Additionally, thiamin plays a role in the synthesis 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. Dutch physician Dr. Christiaan Eijkman cured chickens of beriberi by feeding them unpolished rice bran in 1897. By 1912, Sir Frederick Gowland Hopkins determined from his experiments with animals that the "accessory factors," eventually renamed vitamins, are needed in the diet to support growth, since animals fed a diet of pure carbohydrates, proteins, fats, and minerals failed to grow.[6] Eijkman and Hopkins were awarded the Nobel Prize in Physiology (or Medicine) in 1929 for their discoveries in the emerging science of nutrition.

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

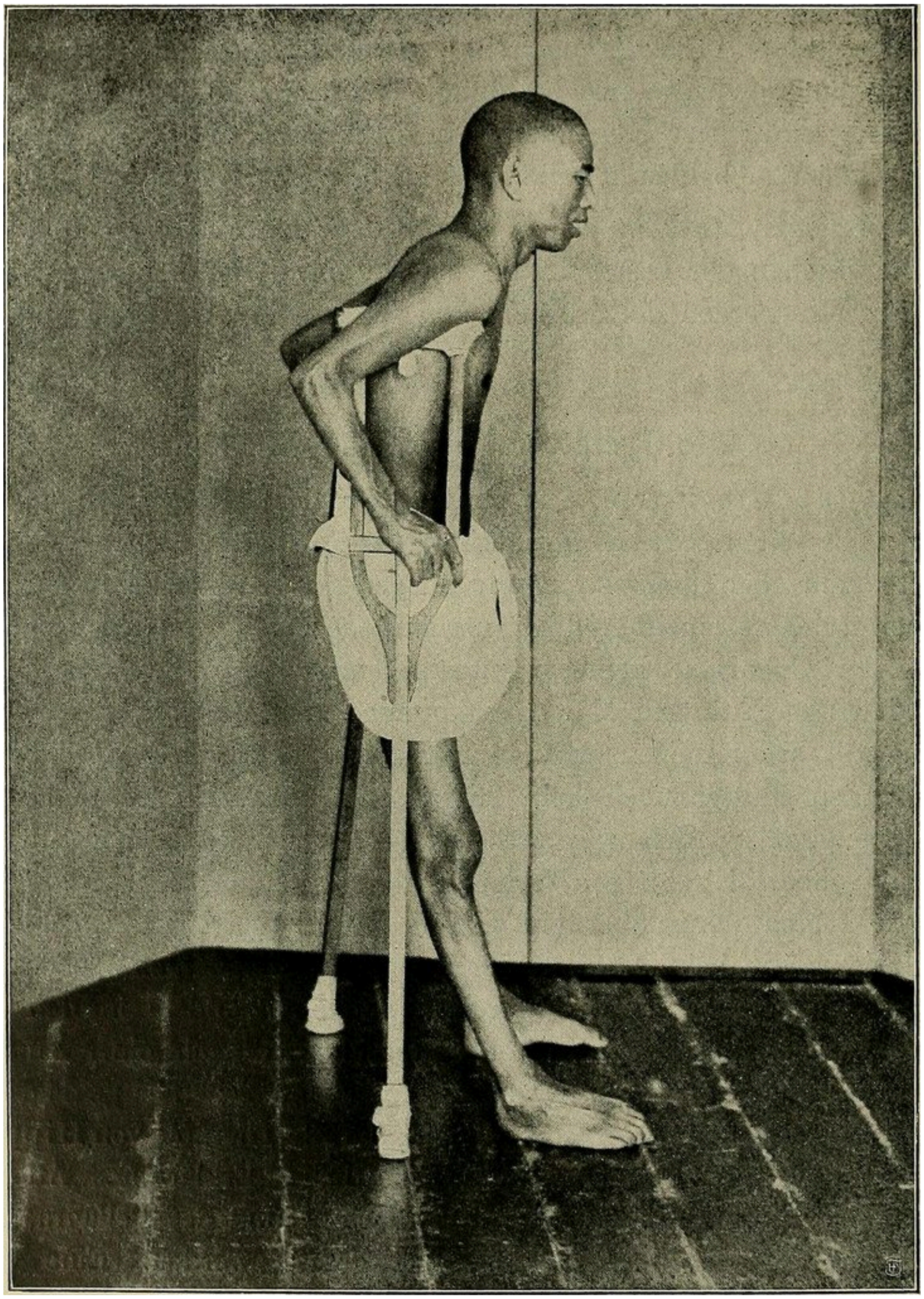
5. National Institutes of Health, Office of Dietary Supplements. (2011). Dietary Supplement Fact Sheet: Vitamin C. http://ods.od.nih.gov/factsheets/VitaminC-QuickFacts/
6. Frederick Gowland Hopkins and his Accessory Food Factors. (2011). *Encyclopedia Brittanica Blog.* http://www.britannica.com/blogs/2011/06/frederick-gowland-hopkins-accessory-food-factors/

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.[7]



The Role of Thiamin by Calabrese, A., via CC BY 4.0

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



[Beriberi, Thiamin Deficiency](#) by Casimir Funk, via [Public Domain.](#)

Dietary Reference Intakes of Thiamin (B_1)

The RDAs and ULs for different age groups for thiamin are listed in Table "Dietary Reference Intakes for Thiamin". There is no UL for thiamin because there has not been any reports on toxicity when excess amounts are consumed from food or supplements.

Dietary Reference Intakes for Thiamin[8]

Age Group	RDA Males and Females mg/day
Infants (0–6 months)	0.2 *
Infants (7–12 months)	0.3
Children (1–3 years)	0.5
Children (4–8 years)	0.6
Children (9–13 years)	0.9
Adolescents (14–18 years)	1.2 (males), 1.0 (females)
Adults (> 19 years)	1.2 (males), 1.1 (females)
*denotes Adequate Intake	

Dietary Sources for Thiamin (B_1)

Whole grains, meat and fish are great sources of thiamin. Canada fortifies their refined breads and cereals. For the thiamin content of various foods, see Table "Thiamin Content of Various Foods".

Thiamin Content of Various Foods[9]

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

RIBOFLAVIN (B_2)

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

8. National Institutes of Health, Office of Dietary Supplements. (2016). Health Professional Fact Sheet: Thiamin. https://ods.od.nih.gov/factsheets/Thiamin-HealthProfessional/
9. National Institutes of Health, Office of Dietary Supplements. (2016). Health Professional Fact Sheet: Thiamin. https://ods.od.nih.gov/factsheets/Thiamin-HealthProfessional/

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 Reference Intakes of Riboflavin (B_2)

The RDAs for different age groups for riboflavin are listed in Table "Dietary Reference Intakes for Riboflavin". There is no UL for riboflavin because no toxicity has been reported when an excess amount has been consumed through foods or supplements.

Dietary Reference Intakes for Riboflavin[10]

Age Group	RDA Males and Females mg/day
Infants (0–6 months)	0.3 *
Infants (7–12 months)	0.4*
Children (1–3 years)	0.5
Children (4–8 years)	0.6
Children (9–13 years)	0.9
Adolescents (14–18 years)	1.3 (males), 1.0 (females)
Adults (> 19 years)	1.3 (males), 1.1 (females)
*denotes Adequate Intake	

Dietary Sources for Riboflavin (B_2)

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 "Riboflavin Content of Various Foods".

10. National Institute of Health, Office of Dietary Supplements. (2016). Fact Sheet for Health Professionals, Riboflavin. https://ods.od.nih.gov/factsheets/Riboflavin-HealthProfessional/

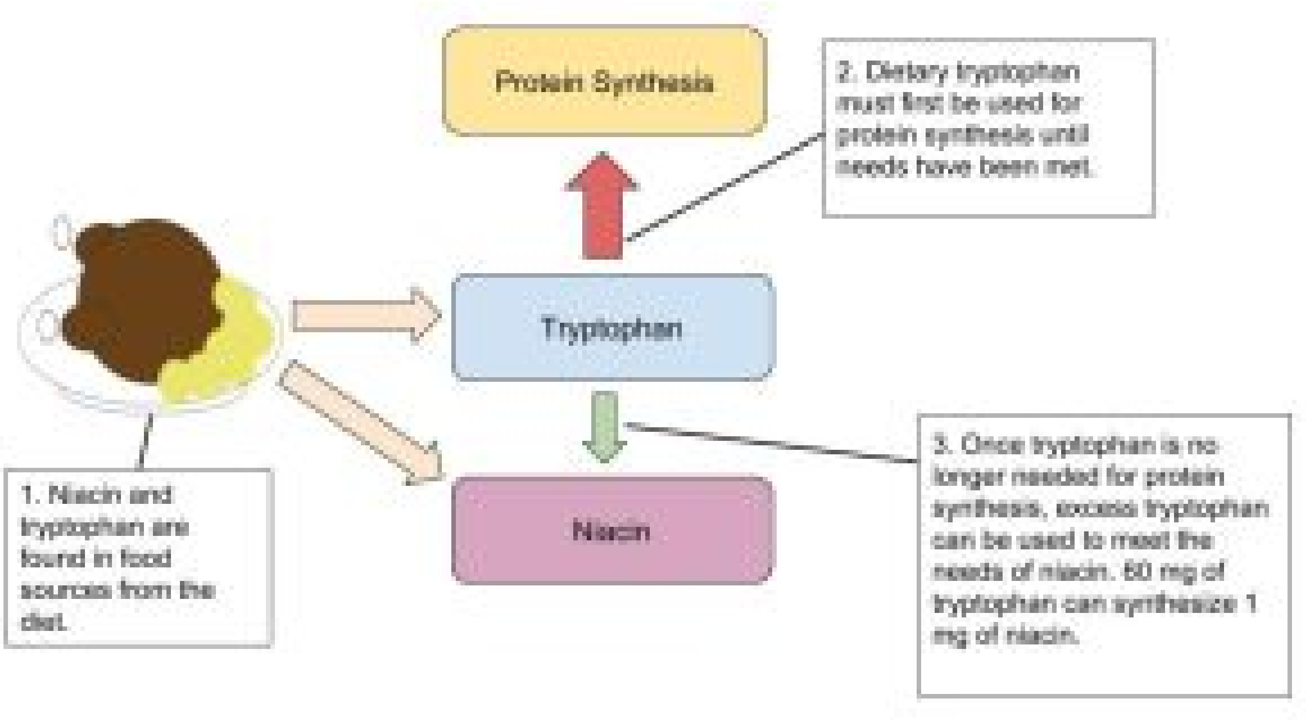
Riboflavin Content of Various Foods[11]

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

NIACIN (B_3)

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.

11. National Institute of Health, Office of Dietary Supplements. (2016). Fact Sheet for Health Professionals, Riboflavin. https://ods.od.nih.gov/factsheets/Riboflavin-HealthProfessional/



Conversion of Tryptophan to Niacin by Calabrese, A., via [CC BY 4.0](#)

[Niacin Deficiency, Pellagra](#) by Herbert L. Fred, MD, Hendrik A. van Dijk / [CC BY-SA 3.0](#)

Dietary Reference Intakes for Niacin (B_3)

The RDAs and ULs for different age groups for Niacin are listed in Table "Dietary Reference Intakes for Niacin ". Because Niacin needs can be met from tryptophan, The RDA is expressed in niacin equivalents (NEs). The conversions of NE, Niacin, and tryptophan are: 1 mg NE= 60 mg tryptophan= 1 mg niacin

Dietary Reference Intakes for Niacin[12]

Age Group	RDA Males and Females mg NE/day)	UL
Infants (0–6 months)	2 *	Not possible to establish
Infants (7–12 months)	4*	Not possible to establish
Children (1–3 years)	6	10
Children (4–8 years)	8	15
Children (9–13 years)	12	20
Adolescents (14–18 years)	16 (males), 14 (females)	30
Adults (> 19 years)	16 (males), 14 (females)	35
*denotes Adequate Intake		

12. Oregon State University, Linus Pauling Institute. (2013). Micronutrient Information Center: Niacin. http://lpi.oregonstate.edu/mic/vitamins/niacin.

Dietary Sources of Niacin (B_3)

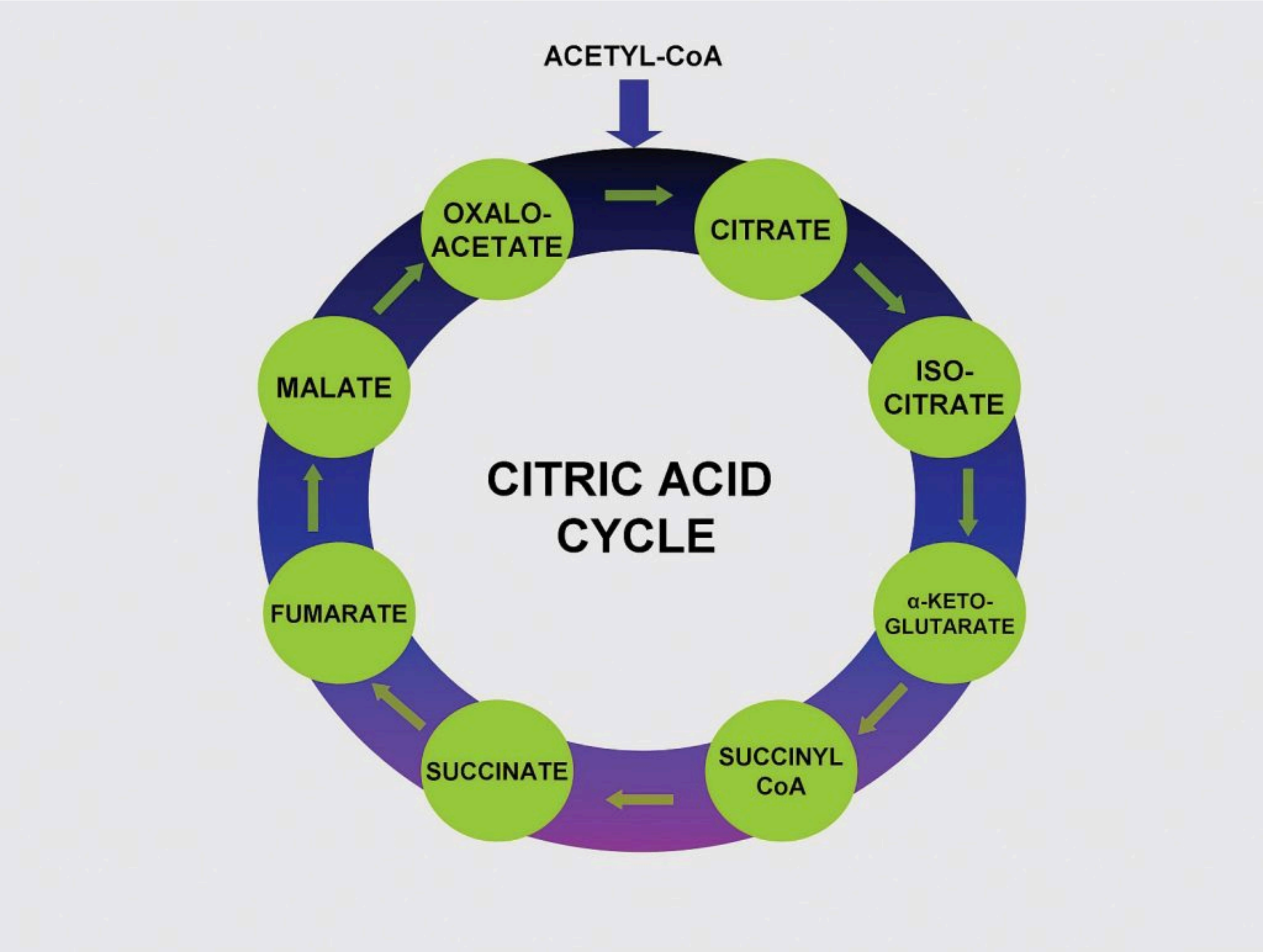
Niacin can be found in a variety of different foods such as yeast, meat, poultry, red fish, and cereal. In plants, especially mature grains, niacin can be bound to sugar molecules which can significantly decrease the niacin bioavailability. For the niacin content of various foods, see Table "Niacin Content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

Niacin Content of Various Foods[13]

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

13. Oregon State University, Linus Pauling Institute. (2013). Micronutrient Information Center: Niacin. http://lpi.oregonstate.edu/mic/vitamins/niacin.

PANTOTHENIC ACID (B5)



Pantothenic Acid (Vitamin B5) makes up coenzyme A, which carries the carbons of glucose, fatty acids, and amino acids into the citric acid cycle as Acetyl-CoA. Pantothenic Acid's Role in the Citric Acid Cycle by Calabrese, A., via CC BY 4.0

Pantothenic acid forms coenzyme A, which is the main carrier of carbon molecules in a cell. Acetyl-CoA is the carbon carrier of glucose, fatty acids, and amino acids into the citric acid cycle. 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 Reference Intakes for Pantothenic Acid (B5)

Because there is little information on the requirements for pantothenic acids, the Adequate Intakes (AI) is based on the observed dietary intakes in healthy population groups. The AI for different age groups for pantothenic acid are listed in Table "Dietary Reference Intakes for Pantothenic Acid".

Dietary Reference Intakes for Pantothenic Acid[14]

Age Group	AI Males and Females mg/day)
Infants (0–6 months)	1.7
Infants (7–12 months)	1.8
Children (1–3 years)	2
Children (4–8 years)	3
Children (9–13 years)	4
Adolescents (14–18 years)	5
Adults (> 19 years)	5

Dietary Sources of Pantothenic Acid (B_5)

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 "Pantothenic Acid Content of Various Foods".

Pantothenic Acid Content of Various Foods[15]

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

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

14. Oregon State University, Linus Pauling Institute. (2013). Micronutrient Information Center: Pantothenic Acid. http://lpi.oregonstate.edu/mic/vitamins/patothenic-acid
15. Oregon State University, Linus Pauling Institute. (2013). Micronutrient Information Center: Pantothenic Acid. http://lpi.oregonstate.edu/mic/vitamins/patothenic-acid

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 Reference Intakes for Biotin

Because there is little information on the requirements for biotin, the Adequate Intakes (AI) is based on the observed dietary intakes in healthy population groups. The AI for different age groups for biotin are listed in Table "Dietary Reference Intakes for Biotin".

Dietary Reference Intakes for Biotin[16]

Age Group	AI Males and Females mcg/day)
Infants (0–6 months)	5
Infants (7–12 months)	6
Children (1–3 years)	8
Children (4–8 years)	12
Children (9–13 years)	20
Adolescents (14–18 years)	25
Adults (> 19 years)	30

Dietary Sources of Biotin

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 "Biotin Content of Various Foods".

Biotin Content of Various Foods[17]

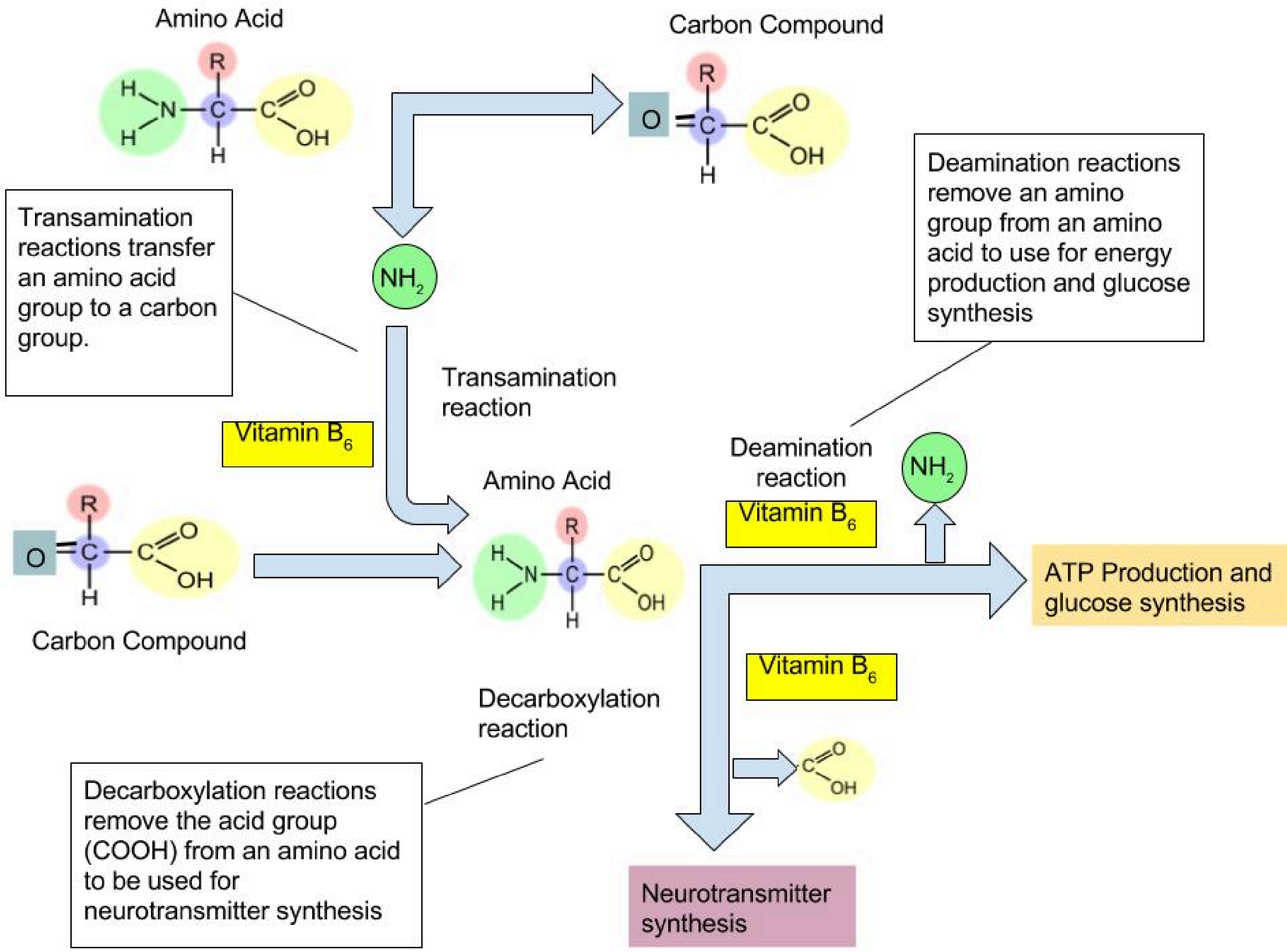
Food	Serving	Biotin (mcg)	Percent Daily Value*
Eggs	1 large	10	33.3
Salmon, canned	3 oz.	5	16.6
Pork chop	3 oz.	3.8	12.6
Sunflower seeds	¼ c.	2.6	8.6
Sweet potato	½ c.	2.4	8
Almonds	¼ c.	1.5	5
Tuna, canned	3 oz.	0.6	2
Broccoli	½ c.	0.4	1.3
Banana	½ c.	0.2	0.6
* Current AI used to determine Percent Daily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

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

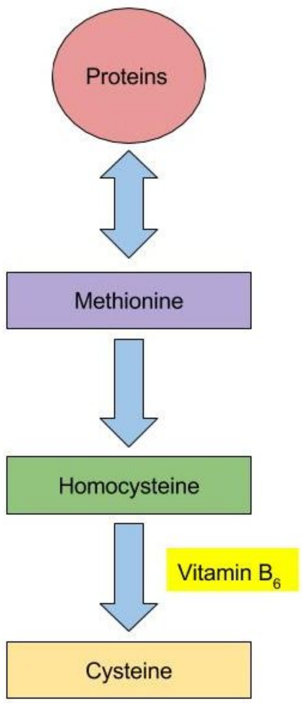
16. National Institute of Health, Office of Dietary Supplements. (2017). Fact Sheet for Health Professionals: Biotin. https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/
17. National Institute of Health, Office of Dietary Supplements. (2017). Fact Sheet for Health Professionals: Biotin. https://ods.od.nih.gov/factsheets/Biotin-HealthProfessional/

release glucose from glycogen in the catabolic pathway of glycogenolysis and is required by enzymes for the synthesis of multiple neurotransmitters and hemoglobin.



[The Function of Vitamin B6 in Amino Acid Metabolism](#) by Calabrese, A., via [CC BY 4.0](#)

Vitamin B_6 is also a required coenzyme for the synthesis of hemoglobin. A deficiency in vitamin B6 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.



Vitamin B6 Functional Coenzyme Role by Calabrese, A., via CC BY 4.0

The vitamin B_6 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 B_6 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 Reference Intakes for Vitamin B_6

The RDAs and ULs for different age groups for vitamin B_6 are listed in Table "Dietary Reference Intakes for Vitamin B_6".

Dietary Reference Intakes for Vitamin B6[18]

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	0.1*	Not possible to determine
Infants (7–12 months)	0.3*	Not possible to determine
Children (1–3 years)	0.5	30
Children (4–8 years)	0.6	40
Children (9–13 years)	1	60
Adolescents (14–18 years)	1.3 (males), 1.2 (females)	80
Adults (> 19 years)	1.3	100
*denotes Adequate Intake		

Dietary Sources of Vitamin B_6

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 "Vitamin B_6 Content of Various Foods".

18. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Supplement Fact Sheet: Vitamin B6. https://ods.od.nih.gov/factsheets/VitaminB6-HealthProfessional/

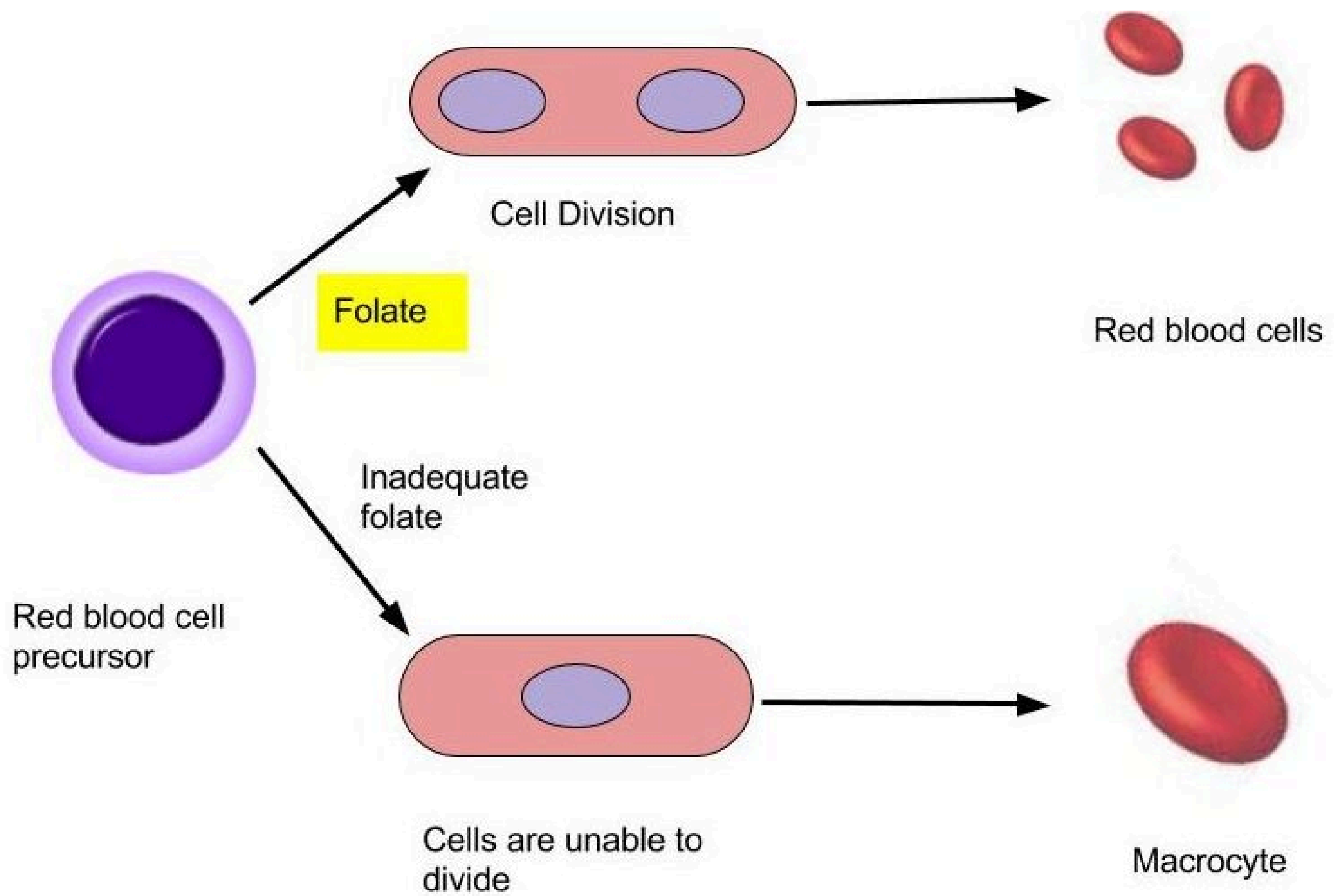
Vitamin B_6 Content of Various Foods[19]

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

FOLATE

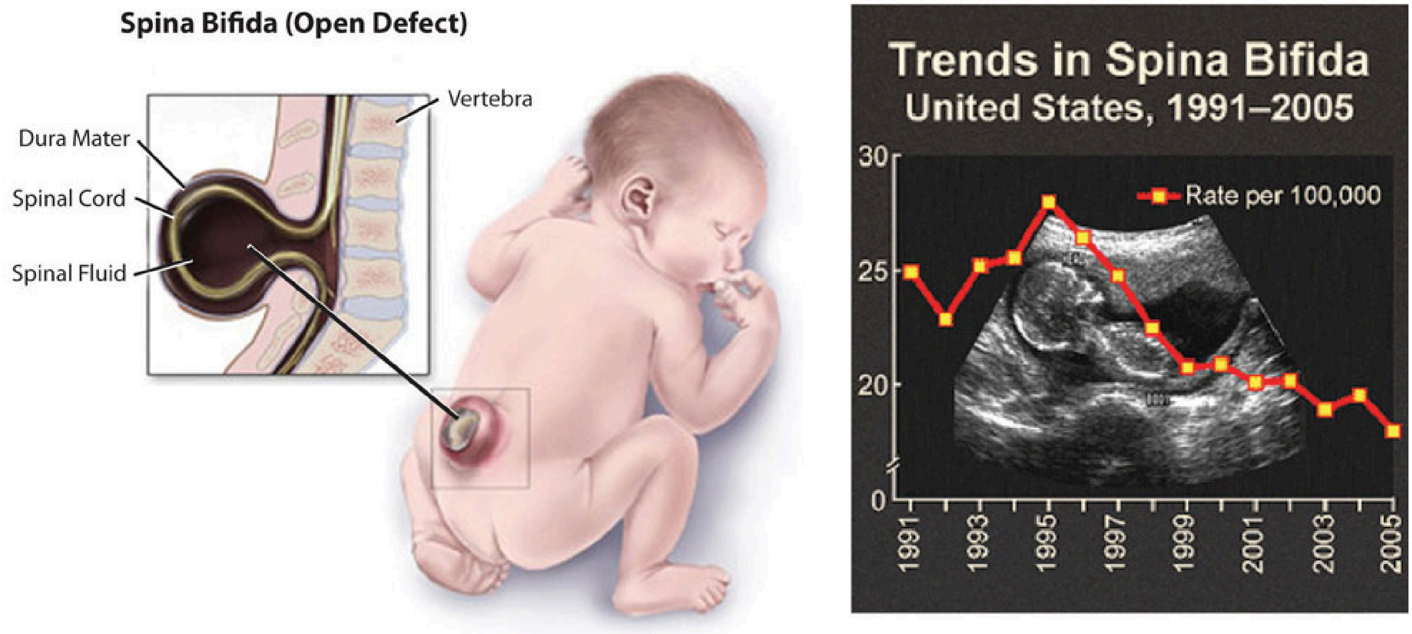
Folate is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem 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.

19. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Supplement Fact Sheet: Vitamin B6. https://ods.od.nih.gov/factsheets/VitaminB6-HealthProfessional/



Folate and the Formation of Macrocytic Anemia by Calabrese, A., via CC 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. Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 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. The RDA was raised 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.



Spina bifida is a neural-tube defect that can have severe health consequences. [Spina Bifida in Infants](#) by Calabrese, A., via [CC BY 4.0](#)

Dietary Reference Intakes for Folate

The RDAs and ULs for different age groups for folate are listed in Table "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 dietary folate equivalents (DFE) was developed 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

Dietary Reference Intakes for Folate[20]

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		

20. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Supplement Fact Sheet: Folate. https://ods.od.nih.gov/factsheets/Folate-HealthProfessional/

Dietary Sources of Folate

Folate is found naturally in a wide variety of food especially in dark leafy vegetables, fruits, and animal products. Manufacturers can fortify enriched breads, cereals, flours, and cornmeal to increase the consumption of folate by Canadians. For the folate content of various foods, see Table "Folate Content of Various Foods".

Folate Content of Various Foods[21]

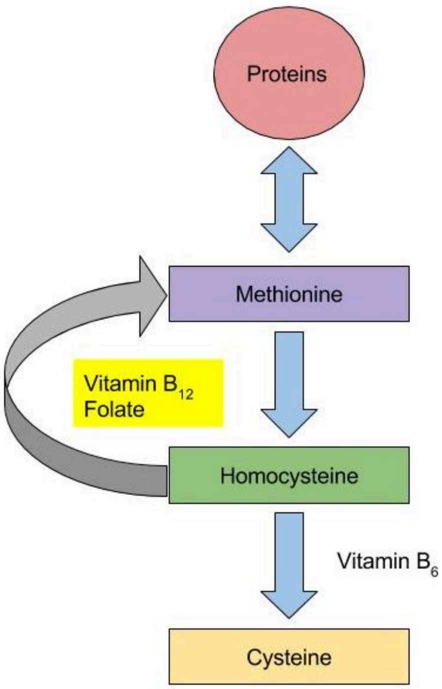
Food	Serving	Folate (mcg DFE)	Percent Daily Value
Beef Liver	3 oz.	215	54
Fortified breakfast cereals	¾ c.	400	100
Spinach	½ c.	131	33
White rice, enriched	½ c.	90	23
Asparagus	4 spears	85	20
White bread, enriched	1 slice	43	11
Broccoli	2 spears	45	10
Avocado	½ c.	59	15
Orange juice	6 oz.	35	9
Egg	1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

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.

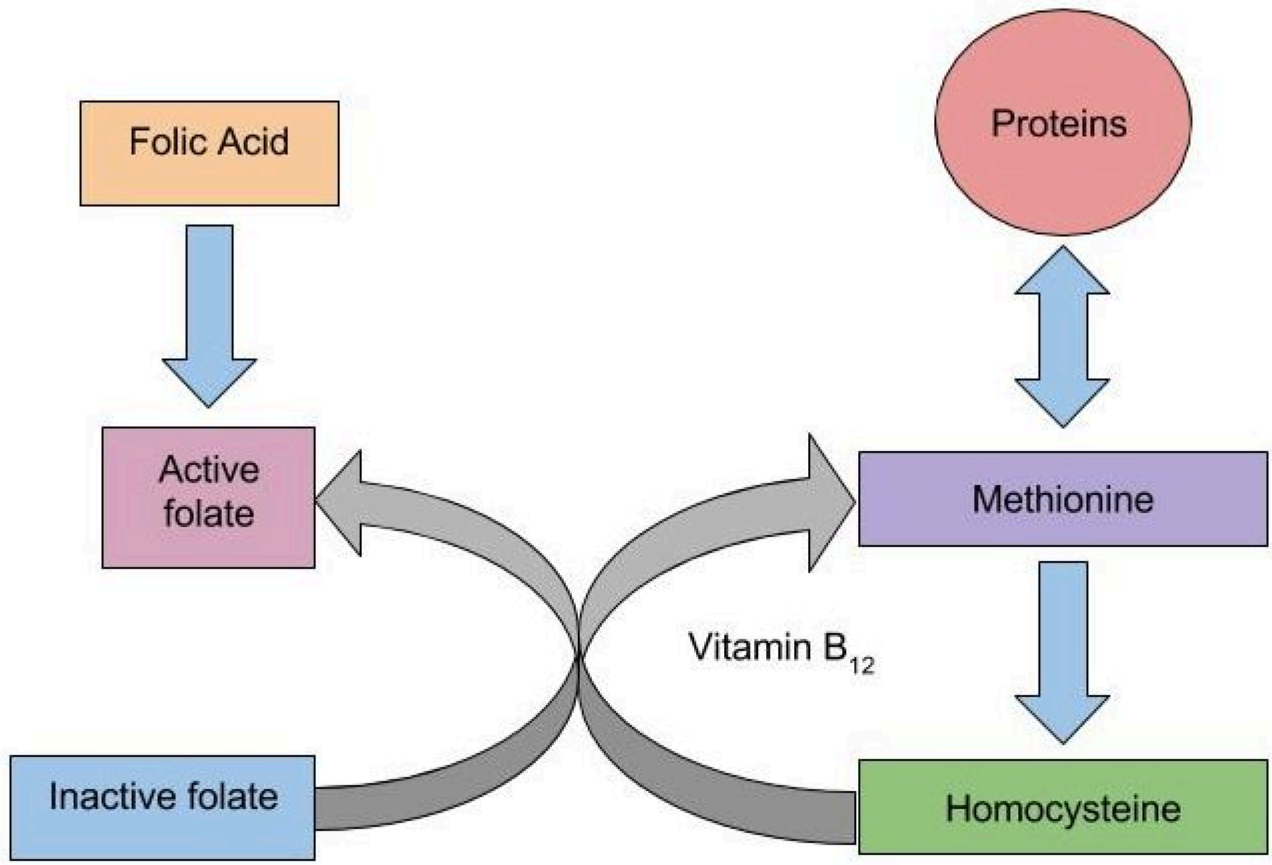
21. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Supplement Fact Sheet: Folate. https://ods.od.nih.gov/factsheets/Folate-HealthProfessional/

Vitamin B_{12} Relationship with Folate and Vitamin B_6



B Vitamins Coenzyme Roles by Calabrese, A, via. CC BY 4.0

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.



The Relationship Between Folate and Vitamin B12 by Calabrese, A., via CC BY 4.0

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 Reference Intakes for Vitamin B_{12}

The RDAs and ULs for different age groups for Vitamin B_{12} are listed in Table "Dietary Reference Intakes for Vitamin B_{12}".

Dietary Reference Intakes for Vitamin B_{12}[22]

Age Group	RDA Males and Females mcg/day
Infants (0–6 months)	0.4*
Infants (7–12 months)	0.5*
Children (1–3 years)	0.9
Children (4–8 years)	1.2
Children (9–13 years)	1.8
Adolescents (14–18 years)	2.4
Adults (> 19 years)	2.4
*denotes Adequate Intake	

Dietary Sources of Vitamin B_{12}

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 "Vitamin B_{12} Content of Various Foods".

Vitamin B_{12} Content of Various Foods[23]

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

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 Reference Intakes for Choline

There is insufficient data on choline so the FNB has developed AIs for all ages in order to prevent fatty liver disease. The AI and UL for different age groups for choline are listed in Table "Dietary Reference Intakes for Choline".

22. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Fact Sheet: Vitamin B12. https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/
23. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Fact Sheet: Vitamin B12. https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/

Dietary Reference Intakes for Choline[24]

Age Group	AI Males and Females mg/day)	UL
Infants (0–6 months)	125	–
Infants (7–12 months)	150	–
Children (1–3 years)	200	1000
Children (4–8 years)	250	1000
Children (9–13 years)	375	2000
Adolescents (14–18 years)	550 (males), 400 (females)	3000
Adults (> 19 years)	550 (males), 425 (females)	3500

Dietary Sources of Choline

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

Choline Content of Various Foods[25]

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

24. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Fact Sheet: Vitamin B12. https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/
25. National Institute of Health, Office of Dietary Supplements. (2016). Dietary Fact Sheet: Vitamin B12. https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/

SUMMARY OF WATER-SOLUBLE VITAMINS

Water-Soluble vitamins[26]

Vitamin	Sources	Recommended Intake for adults	Major Functions	Deficiency diseases and symptoms	Groups at risk of deficiency	Toxicity	UL
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,	Smokers, alcoholics, elderly	Kidney stones, GI distress, diarrhea	2000 mg/day
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	Alcoholics, older adults, eating disorders	None reported	ND
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	None reported	ND
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	Alcoholics	Nausea, rash, tingling extremities	35 mg/day from fortified foods and supplements
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	Alcoholics	Fatigue, rash	ND
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	Alcoholics	Nerve damage	100 mg/day
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	Those consuming raw egg whites	None reported	ND
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	Pregnant women, alcoholics	Masks B12 deficiency	1000 mcg/day from fortified foods and supplements
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	Vegans, elderly	None reported	ND
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	Liver damage, excessive sweating, hypotension	3500 mg/day

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

26. National Institute of Health, Office of Dietary Supplements. (2016). Water-Soluble vitamins. https://www.ncbi.nlm.nih.gov/books/NBK218756/

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 Canada, 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 North 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.

CHAPTER ATTRIBUTION

MAJOR MINERALS

Summary of Major Minerals

A Summary of the Major Minerals[1]

Micronutrient	Sources	Recommended Intakes for adults	Major functions	Deficiency diseases and symptoms	Groups at risk for deficiency	Toxicity	UL
Calcium	Yogurt, cheese, sardines, milk, orange juice, turnip	1,000 mg/day	Component of mineralized bone, provides structure and microarchitecture	Increased risk of osteoporosis	Postmenopausal women, those who are lactose intolerant, or vegan	Kidney stones	2,500 mg
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 adults, alcoholics	None	3,000 mg
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	Alcoholics, individuals with kidney and gastrointestinal disease	Nausea, vomiting, low blood pressure	350 mg/ day
Sulfur	Protein foods	None specified	Structure of some vitamins and amino acids, acid-base balance	None when protein needs are met	None	None	ND
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 consuming too much water, excessive sweating, those with vomiting or diarrhea	High blood pressure	2,300 mg/ day
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 consuming diets high in processed meats, those with vomiting or diarrhea	Abnormal heartbeat	ND
Chloride	Table salt, processed foods	<3600 mg/day; ideally 2300 mg/day	Major negative extracellular ion, fluid balance	Unlikely	none	None	3,600 mg/ day

CHAPTER ATTRIBUTION

1. National Institutes of Health, Office of Dietary Supplements. (2009). Dietary Supplement Sheets. https://ods.od.nih.gov/factsheets/list-all/

LIFE CYCLE

Nutrition Through the Lifecycle

Learning Objectives

1. Summarize prenatal nutritional requirements and dietary recommendations.
2. Discuss the most important nutritional concerns during pregnancy.
3. Describe the benefits and barriers related to breastfeeding.
4. Examine feeding problems that parents and caregivers may face with their infants.
5. Explain factors related to the introduction of solid foods into a toddler's diet.
6. Describe the most important nutrition-related concerns during childhood.
7. Describe the most important nutrition-related concerns during adolescence.
8. Explain how nutritional and lifestyle choices can affect current and future health.
9. Describe the most important nutrition-related concerns during middle and old age.

Human bodies change significantly over time, and food is the fuel for those changes. People of all ages need the same basic nutrients—amino acids, carbohydrates, fatty acids, vitamins and minerals, and water—to sustain life and health. However, the amounts of nutrients needed differ. Throughout the human life cycle, the body constantly changes and goes through different periods known as stages. In this chapter we will discuss the major changes that occur during each stage, focusing on the roles nutrition plays. The major stages of the human life cycle are defined as follows:

- Pregnancy. The development of a zygote into an embryo and then into a fetus in preparation for childbirth.
- Infancy. The earliest part of childhood. It is the period from birth through age 1.
- Toddler years. Occur during ages 2 and 3 and are the end of early childhood.
- Childhood. Takes place from ages 4 to 8.
- Puberty. The period from ages 9 to 13, which is the beginning of adolescence.
- Older adolescence. The stage that takes place between ages 14 and 18.
- Adulthood. The period from adolescence to the end of life. Begins at age 19.
- Middle age. The period of adulthood that stretches from age 31 to 50.
- Senior years, or old age. Extends from age 51 until the end of life.

PREGNANCY

Conception to the Early Days of Pregnancy

Women who are trying to conceive should make proper dietary choices and practice healthy habits to ensure the delivery of a healthy baby. Fathers-to-be should also consider their lifestyles. For both men and women, a sedentary lifestyle, excess body weight, and a diet low in fresh fruits and vegetables may affect fertility. Men who consume too much alcohol, use certain drugs, and/or smoke cigarettes/use tobacco may also damage the quantity and quality of their sperm.[1] For both men and women, adopting healthy habits also boosts general well-being and makes it possible to meet the demands of parenting.

Pregnancy is measured from the first day of a woman's last menstrual period until childbirth, and typically lasts about 40 weeks. Humans like to think of pregnancy in terms of equal time, so we divide pregnancy into three approximately equal sections or trimesters. The first trimester is the first 13 weeks of pregnancy, the second is weeks 14 through 27, and pregnancy ends with the third trimester, weeks 28 through birth.

However, trimesters do not reflect the actual stages of development through the pregnancy. The first trimester encompasses several stages of development. At conception, a sperm cell fertilizes an egg cell, creating a **zygote**. This first stage of pregnancy accounts for the first 2 weeks. The zygote rapidly divides into multiple cells to become an **embryo** and implants itself in the uterine wall. Major changes begin to occur in these earliest days after conception, often weeks before a woman even knows that she is pregnant. The embryonic stage lasts from week 3 through week 10. During this timethere are **critical periods** of development where the infrastructure for organ systems such as the nervous system, heart, limbs, ears, eyes, teeth, palate, and external genitalia is laid down. During these periods the developing embryo is very sensitive to damage caused by inadequate nutrition, medications, alcohol, or exposure to other harmful substances. Adequate nutrition supports cell division, tissue differentiation, and organ development, especially during these critical times. As each week passes, new milestones are reached. The end of the embryonic stage marks the start of the **fetal** stage which is week 11 through birth. During this stage the organ systems grow to maturity, and weight of the fetus increases from about 1 oz to about 7.5 lb. At the 20-week mark, physicians typically perform an ultrasound to acquire information about the fetus and check for abnormalities. By this time, it is possible to know the sex of the baby.

Good nutrition is vital for any pregnancy and not only helps an expectant mother remain healthy, but also impacts the development of the fetus and ensures that the baby thrives in infancy and beyond. During pregnancy, a woman's needs increase for certain nutrients more than for others. If these nutritional needs are not met, infants could suffer from low birth weight (a birth weight less than 5.5 lb, or 2,500 grams), among other developmental problems. Therefore, it is crucial to make careful dietary choices.

Weight Gain during Pregnancy

During pregnancy, a mother's body changes in many ways. One of the most notable and significant changes is weight gain. If a pregnant woman does not gain enough weight, her unborn baby will be at risk. Infant birth weight is one of the best indicators of a baby's future health. Poor weight gain by the mother, especially in the third trimester, could result not only in low birth weight, but also in infant intellectual disabilities or mortality. Therefore, it is vital for a pregnant woman to maintain a healthy weight, and her weight prior to pregnancy also has a major effect. Pregnant women at a healthy weight pre-pregnancy should gain between 25-35 lb in total through the entire pregnancy. The precise amount that a mother should gain usually depends on her beginning body mass index (BMI).

1. Centers for Disease Control and Prevention. (2020, February 26). *Before pregnancy. Information for men.* https://www.cdc.gov/preconception/men.html

Recommended Weight Gain During Pregnancy

Pre-Pregnancy BMI	Weight Category	Recommended Weight Gain
< 18.5	Underweight	28-40 lb
18.5-24.9	Healthy	25-35 lb
25.0-29.9	Overweight	15-25 lb
> 30.0	Obese (all classes)	11-20 lb

Starting weight below or above the healthy range can lead to different complications. Pregnant women with a pre-pregnancy BMI below 20 kg/m^2 are at a higher risk of a preterm delivery and an underweight infant. Pregnant women with a pre-pregnancy BMI above 30 kg/m^2 have an increased risk of the need for a cesarean section during delivery. Therefore, it is optimal to have a BMI in the normal range prior to pregnancy.

Generally, women gain 2 to 5 lb in the first trimester. After that, it is recommended to gain no more than one lb per week until birth. Some of the new weight is due to the growth of the fetus, while some is due to changes in the mother's body that support the pregnancy. Weight gain often breaks down in the following manner: 6 to 8 lb of fetus, 1 to 2 lb for the **placenta** (which supplies nutrients to the fetus and removes waste products), 2 to 3 lb for the amniotic sac (which contains fluids that surround and cushion the fetus), 1 to 2 lb in the breasts, 1 to 2 lb in the uterus, 3 to 4 lb of maternal blood, 3 to 4 lb maternal fluids, and 8 to 10 lb of extra maternal fat stores that will be needed for breastfeeding and delivery for a total of 25-35 lb. Women who are pregnant with more than one fetus are advised to gain even more weight to ensure the health of their unborn babies.

Weight Loss after Pregnancy

During labor, new mothers lose some of their gained weight (usually 9-13 lb) with the delivery of their child (weight of the baby, the placenta, and the amniotic fluid). In the following weeks, they continue to shed weight as they lose accumulated fluids and their blood volume returns to normal. Some studies have found that exclusive breastfeeding helps a new mother lose some of the extra weight when compared to non-exclusive breastfeeding.[2]

New mothers who gain the recommended amount of weight and participate in regular physical activity during their pregnancies have an easier time shedding weight post-pregnancy. However, women who gain more weight than needed for a pregnancy typically retain that excess weight as body fat. If that weight gain increases a new mother's BMI by a unit or more, that could lead to complications such as hypertension or type 2 diabetes in future pregnancies and later in life.

NUTRITIONAL REQUIREMENTS

As a mother's body changes, so do her nutritional needs. Pregnant women must consume more kcal and nutrients in the second and third trimesters than other adult women. However, the average recommended daily caloric intake can vary depending on activity level and the mother's normal weight. Also, pregnant women should choose a high quality, diverse diet, consume fresh foods, and nutrient-rich meals. It is also standard for pregnant women to take prenatal supplements to ensure adequate intake of necessary micronutrients.

Energy and Macronutrients

During the first trimester, a pregnant woman has the same energy requirements as normal and should consume the same number of kcal as usual. However, as the pregnancy progresses, a woman must increase her caloric

2. Jarlenski, M. P., Bennett, W. L., Bleich, S. H., Barry, C. L., & Stuart, E. A. (2014). *Effects of breastfeeding on postpartum weight loss among US women. Preventive Medicine, 69*, 146-50. https://doi:10.1016/j.ypmed.2014.09.018

intake. A pregnant woman should consume an additional 340 kcal per day during the second trimester, and an additional 450 kcal per day during the third trimester.[3] This is partly due to an increase in metabolism which rises during pregnancy. A woman can easily meet these increased needs by consuming more nutrient dense foods.

The recommended dietary allowance, or RDA, of carbohydrates during pregnancy is about 175 to 265 g per day to fuel fetal brain development. The best food sources for pregnant women include whole-grain breads and cereals, brown rice, whole vegetables, legumes, and fruits. These and other unrefined carbohydrates provide nutrients, phytochemicals, antioxidants, and the extra 3 mg/day of fiber that is recommended during pregnancy. These foods also help to build the placenta and supply energy for the growth of the unborn baby.

During pregnancy, extra protein is needed for the synthesis of new maternal and fetal tissues. Protein builds muscle and other tissues, enzymes, antibodies, and hormones in both the mother and the unborn baby. Additional protein also supports increased blood volume and the production of amniotic fluid. Protein should be derived from healthy sources, such as lean red meat, poultry, legumes, nuts, seeds, eggs, and fish. Low-fat milk and other dairy products also provide protein, along with calcium and other nutrients. To calculate protein needs during pregnancy, use pre-pregnancy weight in kg body weight times the RDA for protein (0.8 g/kg/day), and add 25 g. For example, if your pre-pregnancy weight was 150 lb:

1. Convert 150 lb to kg by dividing by 2.2: 150 lb ÷ 2.2 lb/kg = 68 kg
2. Multiply 68 kg by RDA: 68 kg x 0.8 g/kg/day = 54.5 g protein
3. Add 25 g during second and third trimester: 54.5 g + 25 g = ~80 g protein

There are no specific recommendations for fats in pregnancy, apart from following normal dietary guidelines. Although it is recommended to increase the amount of essential fatty acids (omega-3 and omega-6) because they are incorporated into the placenta and fetal tissues. Fats should make up 25-35% of daily kcal and should come from healthy sources, such as avocados, nuts and nut butters, and olives and olive oils. It is not recommended for pregnant women to be on a very low-fat diet, since it would be hard to meet the needs of essential fatty acids and fat soluble vitamins. Fatty acids are important during pregnancy because they support the baby's brain and eye development.

Fluids

Fluid intake must also be monitored. According to the National Academy of Medicine (NAM), pregnant women should drink at least 2.3 liters (about 10 cups) of liquids per day to provide enough fluid for blood production.[4] It is also important to drink additional liquids during physical activity or when it is hot and humid outside, to replace fluids lost via perspiration. The combination of a high fiber diet and lots of liquids also helps to eliminate waste.

Vitamins and Minerals

The daily requirements for non-pregnant women change with the onset of a pregnancy. Taking a daily prenatal supplement or multivitamin helps to meet many nutritional needs. However, most of these requirements should be fulfilled with a healthy diet. The following table compares the non-pregnant levels of required vitamins and minerals to the levels needed during pregnancy. For pregnant women, the RDA of nearly all vitamins and minerals increases.

3. Most, J., Dervis, S., Haman, F., Adamo, K. B., & Redman, L. M. (2019). Energy intake requirements in pregnancy. *Nutrients, 11*(8), 1812. https://doi:10.3390/nu11081812
4. Office on Women's Health. (2019, March 14). *Staying Healthy and Safe. United States Department of Health and Human Services.* https://www.womenshealth.gov/pregnancy/youre-pregnant-now-what/staying-healthy-and-safe/#1

Recommended Micronutrient Intakes during Pregnancy

Nutrient	Non-Pregnant Women	Pregnant Women
Vitamin A (mcg)	700.0	770.0
Thiamin (mg)	1.1	1.4
Riboflavin (mg)	1.1	1.4
Niacin (mg)	14.0	18.0
Vitamin B_6 (mg)	1.3	1.9
Folate (mcg)	400.0	600.0
Vitamin B_{12} (mcg)	2.4	2.6
Vitamin C (mg)	75.0	85.0
Vitamin D (mcg)	15.0	15.0
Vitamin E (mg)	15.0	15.0
Calcium (mg)	1000.0	1000.0
Iron (mg)	18.0	27.0
Magnesium (mg)	310.0 (19-30 yr)	350.0 (19-30 yr)
	320.0 (31-50 yr)	360.0 (31-50 yr)
Phosphorus (mg)	700.0	700.0
Zinc (mg)	8.0	11.0

The micronutrients involved with building the skeleton—vitamin D and calcium—are crucial during pregnancy to support fetal bone development. Although the recommended levels are the same as those for non-pregnant women, many women do not typically consume adequate amounts and should make an extra effort to meet those needs.

There is an increased need for all B vitamins during pregnancy. Adequate vitamin B_6 supports the metabolism of amino acids, while more vitamin B_{12} is needed for the synthesis of red blood cells and DNA. Additional zinc is crucial for cell development and protein synthesis. The need for vitamin A also increases, and extra iron intake is important because of the increase in blood supply during pregnancy and to support the fetus and placenta. Iron is the one micronutrient that is almost impossible to obtain in adequate amounts from food sources only. Therefore, even if a pregnant woman consumes a healthy diet, there still is a need to take an iron supplement, in the form of ferrous salts. Also remember that folate needs increase during pregnancy to 600 mcg per day to prevent neural tube defects (during the first 8 weeks of pregnancy). This micronutrient is also crucial because it helps produce the extra blood a woman's body requires during pregnancy.

For other micronutrients, recommended intakes are the same as those for non-pregnant women, although it is crucial for pregnant women to make sure to meet the RDAs to reduce the risk of birth defects. In addition, pregnant mothers should avoid exceeding any recommendations. Taking megadose supplements can lead to excessive amounts of certain micronutrients, such as vitamin A and zinc, which may produce toxic effects that can also result in birth defects.

GUIDE TO EATING DURING PREGNANCY

While pregnant women have an increased need for energy, vitamins, and minerals, energy increases are proportionally less than other macronutrient and micronutrient increases. So, nutrient dense foods, which are higher in proportion of macronutrients and micronutrients relative to kcal, are essential to a healthy diet. Examples of nutrient dense foods include fruits, vegetables, whole grains, peas, beans, reduced-fat dairy, and lean meats. Pregnant women should be able to meet almost all of their increased needs via a healthy diet. However, as discussed previously, expectant mothers should take a prenatal supplement to ensure an adequate intake of iron and folate. Here are some additional dietary guidelines for pregnant women:[5]

- Eat iron-rich or iron-fortified foods, including meat or meat alternatives, breads, and cereals, to help satisfy increased need for iron and prevent anemia. Include vitamin C-rich foods, such as orange juice, broccoli, or strawberries, or peppers to enhance iron absorption.
- Eat a well-balanced diet including fruits, vegetables, whole grains, calcium-rich foods, lean meats, and a variety of cooked seafood (excluding fish that are high in mercury, such as swordfish and shark).
- Drink additional fluids, especially water.

Foods to Avoid

A number of substances can harm a growing fetus. Therefore, it is vital for women to avoid them throughout a pregnancy. Some are so detrimental that a woman should avoid them even if she suspects that she might be pregnant. For example, consumption of alcoholic beverages results in a range of abnormalities that fall under the umbrella of Fetal Alcohol Spectrum Disorders. They include learning and attention deficits, heart defects, and abnormal facial features. Alcohol enters the unborn baby via the umbilical cord and can slow fetal growth, damage the brain, or even result in miscarriage. The effects of alcohol are most severe in the first trimester, when the organs are developing. As a result, there is no safe amount of alcohol that a pregnant woman should consume.

Caffeine is found in coffee, and also in tea, colas, cocoa, chocolate, and some over-the-counter painkillers. Caffeine is safe in small amounts. Pregnant women should try to keep caffeine intake below 300 mg a day, which is about two 8-oz (237 mL) cups of coffee.[6]

Some bacteria, such as Listeria can go through the placenta. So if a pregnant woman becomes sick, there is an increased risk for infection as the unborn baby's immune system is not developed enough to fight off harmful bacteria. Food poisoning during the first 3 months of pregnancy, can cause a miscarriage. If it happens later in the pregnancy, it can cause premature births. Food poisoning can also cause a stillbirth or a baby who is born very ill. [7]

Pregnant women can eat fish, ideally 8 to 12 oz of different types each week. Expectant mothers are able to eat cooked shellfish such as shrimp, farm-raised fish such as salmon, and a maximum of 6 oz of albacore or white, tuna. However, they should avoid fish with high methylmercury levels, such as shark, swordfish, and king mackerel. Pregnant women should also avoid consuming raw fish to avoid foodborne illness.

Food Cravings and Aversions

Food aversions and cravings can occur during pregnancy and often get a lot of attention. Fortunately most do not have a major impact unless food choices are extremely limited. For most women, it is not harmful to indulge in the occasional craving, such as a desire for pickles and ice cream. However, a medical disorder known as **pica**, the craving and willing consumption of substances with little or no nutritive value, such as dirt, clay, or laundry starch, can be harmful. Pica is most prevalent among pregnant women and young children. Although the etiology

5. Office on Women's Health. (2019, March 14). *Staying Healthy and Safe. United States Department of Health and Human Services.* https://www.womenshealth.gov/pregnancy/youre-pregnant-now-what/staying-healthy-and-safe/#1
6. Government of Canada. (2024, May 16). *Your Guide to a Healthy Pregnancy.* https://www.canada.ca/en/public-health/services/health-promotion/healthy-pregnancy/healthy-pregnancy-guide.html
7. Health Canada. (2015). *Safe food handling for pregnant women.* https://www.canada.ca/content/dam/hc-sc/documents/services/food-safety-vulnerable-populations/food-safety-vulnerable-populations/pregnant-enceintes-eng.pdf

(or cause) of pica is not completely understood, several studies have linked pica, particularly during pregnancy, to iron deficiency anemia.[8]

COMPLICATIONS DURING PREGNANCY

Expectant mothers may face different complications during the course of their pregnancy. They include certain medical conditions that could greatly impact a pregnancy if left untreated, such as gestational hypertension and gestational diabetes, which have diet and nutrition implications.

Gestational Hypertension

Gestational hypertension is a condition of high blood pressure during the second half of pregnancy. First time mothers are at a greater risk, along with women who have mothers or sisters who had gestational hypertension, women carrying multiple fetuses, women with a prior history of high blood pressure or kidney disease, and women who are overweight or obese when they become pregnant. Hypertension can prevent the placenta from getting enough blood, which would result in the baby getting less oxygen and nutrients. This can result in low birth weight, although most women with gestational hypertension can still deliver a healthy baby if the condition is detected and treated early.

Some risk factors can be controlled such as diet, while others cannot, such as family history. If left untreated, gestational hypertension can lead to a serious complication called preeclampsia, which is sometimes referred to as toxemia. This disorder is marked by elevated blood pressure, protein in the urine, and is associated with fluid retention and swelling. If preeclampsia worsens, a life-threatening condition for both the mother and the baby called eclampsia can occur.

Gestational Diabetes

About 8% of pregnant women suffer from a condition known as gestational diabetes, or abnormal glucose tolerance during pregnancy.[9] As discussed in Chapter 5, gestational diabetes is similar to type 2 diabetes. The mother's body becomes resistant to the hormone **insulin**, which enables cells to transport glucose from the blood and into cells. Gestational diabetes is typically diagnosed between 24-28 weeks, although it is possible for the condition to develop later into a pregnancy. Signs and symptoms include extreme hunger, thirst, or fatigue. The excess glucose in the mother's blood is transported to the placenta, and the fetus will take up this excess glucose from the mother. If blood sugar levels are not properly monitored and treated, the baby might gain too much weight, possibly causing a premature birth and/or a difficult delivery. Diet and regular physical activity can help to manage this condition. Some patients with gestational diabetes may require daily insulin injections to boost the absorption of glucose from the bloodstream and promote the storage of glucose in the form of glycogen in liver and muscle cells. Gestational diabetes usually resolves quickly after childbirth, however women who suffer from this condition have a 50% chance of eventually developing type 2 diabetes later in life, particularly if they are overweight.

BREASTFEEDING

After the birth of the baby, nutritional needs must be met to ensure that an infant not only survives, but thrives

8. Lumish, R. A., Young, S. L., Lee, S., Cooper, E., Presman, E., Guillet, R., & O'Brien, K. O. (2014). Gestation iron deficiency is associated with pica behavior in adolescents. *The Journal of Nutrition, 144*(10), 1533-1539. doi: 10.3945/jn.114.192070
9. Zhou, T., Sun, D., Li, X., Heianza, Y., Nisa, H., Hu, G., Pei, X., Shang, X., & Qi, L. (2018). Prevalence and trends in gestational diabetes mellitus among women in the United States, 2006-2016. *Diabetes, 67* (Suppl1). https://doi:10.2237/db18-121-OR

from infancy into childhood. Exclusive breastfeeding is one of the best ways a mother can support the growth and protect the health of her infant child.

Breast milk contains all of the nutrients that a newborn requires for rapid growth and development and gives a child the best start to a healthy life. New mothers must also pay careful consideration to their own nutritional requirements to help their bodies recover in the wake of the pregnancy and delivery. This is particularly true for women who breastfeed their babies, which calls for an increased intake of certain nutrients.

BENEFITS OF BREASTFEEDING

The importance of breastfeeding for the short- and long-term health of infants, young children and mothers is well established. Exclusive breastfeeding is recommended for the first six months, and continued for up to 2 years or longer along with age-appropriate complementary feeding.[10] Global targets set for breastfeeding include increasing the rate of exclusive breastfeeding for the first 6 months to at least 50% by 2025 and to 70% by 2030.[11][12]

Breastfeeding has a number of benefits, both for the mother and for the child. Breast milk contains immunoglobulins, enzymes, immune factors, and white blood cells. As a result, breastfeeding boosts the baby's immune system and lowers the incidence of diarrhea, along with respiratory diseases, gastrointestinal problems, and ear infections. Breastfed babies also are less likely to develop asthma and allergies, and breastfeeding lowers the risk of sudden infant death syndrome (SIDS). In addition, human milk encourages the growth of healthy bacteria in an infant's intestinal tract. All of these benefits remain in place after an infant has been weaned from breast milk. Some studies suggest other possible long-term effects. For example, breast milk may protect against type 1 diabetes and obesity, although research is ongoing in these areas.[13]

Breastfeeding has a number of other important benefits. It is easier for babies to digest breast milk than bottle formula, which often contains proteins made from cow's milk that require an adjustment period for infant digestive systems. Breastfed infants are sick less often than formula-fed infants. Breastfeeding is more sustainable and results in less plastic waste and other trash. Breastfeeding can also save families money because it does not incur the same cost as purchasing formula. Breast milk is always ready. It does not have to be mixed, heated, or prepared. Also, breast milk is sterile and always at the right temperature. In addition, the skin-to-skin contact of breastfeeding promotes a close bond between mother and baby, which provides important emotional and psychological benefits. The practice also provides health benefits for the mother. Studies have shown that breastfeeding reduces the risk of type 2 diabetes, and breast and ovarian cancers for the mother.[14]

The choice to breastfeed is one that all new mothers face. Although breast milk is ideal for almost all infants, there are some challenges that nursing mothers may face when starting and continuing to breastfeed their infants. These obstacles include painful engorgement or fullness in the breasts, sore and tender nipples, lack of comfort or confidence in public, and lack of accommodation to breastfeed or express milk in the workplace. Support from family members, friends, employers, and others can greatly help with both the decision making process during pregnancy and the practice of breastfeeding after the baby's birth.

10. Nutrition for healthy term infants: Recommendations from birth to six months. Health Canada, Canadian Paediatric Society, Dietitians of Canada, and Breastfeeding Committee for Canada, 2012.
11. Global Nutrition Targets 2025: Breastfeeding policy brief. World Health Organization, UNICEF
12. Public Health Agency of Canada. (2022). *Canada's breastfeeding progress report 2022.* https://health-infobase.canada.ca/src/data/breastfeeding/PHAC%20-%20Breastfeeding%20Report%202022.pdf
13. American Pregnancy Association. (n.d.). *Breastfeeding vs bottle feeding formula.* https://americanpregnancy.org/breastfeeding/breastfeeding-vs-bottle-feeding-formula/
14. American Pregnancy Association. (n.d.). *Breastfeeding vs bottle feeding formula.* https://americanpregnancy.org/breastfeeding/breastfeeding-vs-bottle-feeding-formula/

In Canada in 2022, about 91% of babies start out being breastfed and 62% of parents who breastfed did so for at least 6 months. [15]

International Board Certified Lactation Consultants are healthcare professionals (often a registered nurse or registered dietitian) certified in breastfeeding management that work with new mothers to solve problems and educate families about the benefits of this practice. Women who give birth in hospitals with lactation consultants are more likely to breastfeed. Once a new mother has left the hospital for home, she also needs access to a trained individual who can provide consistent information.[16] Lactation consultants can help new mothers learn proper technique, and help troubleshoot breastfeeding problems when they occur.

CONTRAINDICATIONS TO BREASTFEEDING

Although there are numerous benefits to breastfeeding, in some cases there are also risks that must be considered. A new mother with HIV should not breastfeed as the infection can be transmitted through breast milk. Breastfeeding is also not recommended for women undergoing radiation or chemotherapy treatment for cancer. Women actively using alcohol excessively and/or illicit drugs should also avoid breastfeeding.

LACTATION

Lactation (or lactogenesis) is the synthesis and secretion of breast milk. An infant suckling at the breast stimulates nerve endings which signal the pituitary gland to release two hormones, prolactin and oxytocin. **Prolactin** signals the growth of the milk duct system and initiates and maintains milk production in the alveoli of the breast.

Oxytocin is involved in milk ejection, also called milk letdown. It signals contraction of the alveoli cells, forcing milk into the ducts and out through the nipple. The nipple tissue becomes firmer with stimulation, which makes it more flexible and easier for the baby to grasp in the mouth. The release of oxytocin also has psychological benefits by inducing calm and enhancing feelings of affection or bonding between mother and baby.[17]

New mothers need to adjust their caloric and fluid intake to make breastfeeding possible. The RDA is 330 additional kcal during the first six months of lactation and 400 additional kcal during the second six months of lactation. The energy needed to support breastfeeding comes from both increased intake and from stored fat. For example, during the first six months after her baby is born, the daily caloric cost for a lactating mother is 500 kcal, with 330 kcal derived from increased intake and 170 kcal derived from maternal fat stores. This helps explain why breastfeeding may promote weight loss in new mothers. Lactating women should also drink approximately 13 cups of liquids per day to maintain milk production, according to the NAM. As is the case during pregnancy, the RDA of several vitamins and minerals increases for women who are breastfeeding their babies. The following table compares the recommended vitamins and minerals for lactating women to the levels for non-pregnant and pregnant women.

15. Government of Canada. (2022, November 4). *Canada's breastfeeding dashboard.* https://health-infobase.canada.ca/breastfeeding/#a2
16. United States Department of Health and Human Services. (2011, January 20). *Executive summary: The Surgeon General's call to action to support breastfeeding. Office of the Surgeon General.* https://www.hhs.gov/sites/default/files/breastfeeding-call-to-action-executive-summary.pdf
17. Pillay, J., & Davis, T. J. (2020, April 27). *Physiology, lactation. StatPearls.* https://www.ncbi.nlm.nih.gov/books/NBK499981/

Nutrient	Non-Pregnant Women	Pregnant Women	Lactating Women
Vitamin A (mcg)	700.0	770.0	1300.0
Thiamin (mg)	1.1	1.4	1.4
Riboflavin (mg)	1.1	1.4	1.6
Niacin (mg)	14.0	18.0	17.0
Vitamin B_6 (mg)	1.3	1.9	2.0
Folate (mcg)	400.0	600.0	500.0
Vitamin B_{12} (mcg)	2.4	2.6	2.8
Vitamin C (mg)	75.0	85.0	120.0
Vitamin D (mcg)	15.0	15.0	15.0
Vitamin E (mg)	15.0	15.0	19.0
Calcium (mg)	1000.0	1000.0	1000.0
Iron (mg)	18.0	27.0	9.0
Magnesium (mg)	310.0 (19-30 yr)	350.0 (19-30 yr)	310.0 (19-30 yr)
	320.0 (31-50 yr)	360.0 (31-50 yr)	320.0 (31-50 yr)
Phosphorus (mg)	700.0	700.0	700.0
Zinc (mg)	8.0	11.0	12.0

Calcium requirements do not change during breastfeeding because of more efficient absorption, which is the case during pregnancy, as well. However, the reasons for this differ. During pregnancy, there is enhanced absorption within the gastrointestinal tract. During lactation, there is enhanced retention by the kidneys. The RDA for phosphorus, vitamin D, and fluoride also remain the same. The RDA for iron is reduced significantly during lactation to half of the requirement for non-pregnant women. This is because, for most women, lactation significantly reduces or eliminates menstruation.

Components of Breast Milk

Human breast milk not only provides adequate and highly bioavailable nutrition for infants, it also helps to protect newborns from disease. Breast milk is rich in cholesterol, which is needed for brain development. **Colostrum** is produced immediately after birth, prior to the start of milk production, and lasts for several days after the arrival of the baby. Colostrum is thicker than breast milk, and is often yellowish in color. This protein-rich liquid fulfills an infant's nutrient needs during those early days. Although low in volume, colostrum is packed with concentrated nutrition for newborns. This special "milk" is high in fat-soluble vitamins, minerals, and immunoglobulins (antibodies) that pass from the mother to the baby. Immunoglobulins provide passive immunity for the newborn and protect the baby from bacterial and viral diseases.[18]

Two to four days after birth, colostrum is replaced by transitional milk. **Transitional milk** is a creamy liquid that lasts for approximately two weeks and includes high levels of fat, lactose, and water soluble vitamins. It also contains more kcal than colostrum.

Colostrum on the left, Mature milk on the right. [Colostrum vs breastmilk](#) by Tonicthebrown, via [CC BY 3.0](#).

Mature milk is the final fluid that a new mother produces. In most women, this begins by the end of the second week postpartum. There are two types of mature milk that appear during a feeding. **Foremilk** occurs at the beginning and includes more water, vitamins, and protein. **Hindmilk** occurs after the initial release of milk and contains higher levels of fat, which is necessary for weight gain. Combined, these two types of milk ensure that a baby receives adequate nutrients to grow and develop properly.[19]

About 90% of mature milk is water, which helps an infant remain hydrated. The remaining 10% contains carbohydrates, proteins, and fats, which support energy and growth. Similar to cow's milk, the main carbohydrate of mature breast milk is lactose. Breast milk contains vital essential fatty acids, such as docosahexaenoic acid (DHA) and arachidonic acid (ARA). In terms of protein, breast milk contains more whey than casein (which is the reverse of cow's milk). Whey is much easier for infants to digest than casein. Complete protein, which means all of the essential amino acids, is also present in breast milk, as well as lactoferrin, an iron-gathering compound that helps to absorb iron into an infant's bloodstream.

In addition, breast milk provides adequate vitamins and minerals. Although absolute amounts of some micronutrients are low, they are more efficiently absorbed by infants. Other essential components include digestive enzymes that help a baby digest the breast milk. Human milk also provides the hormones and growth factors that help a newborn to develop.

Diet and Milk Quality

A mother's diet can have a major impact on milk production and quality. As during pregnancy, lactating mothers should avoid harmful substances such as tobacco. Some legal drugs and herbal products can be harmful as well, so it is important to discuss them with a healthcare provider. Some mothers may need to avoid certain things, such as spicy foods, that can produce gas in sensitive infants. Avoiding alcohol completely is the safest option for a breastfeeding mother. However, consumption of up to one alcoholic drink a day (12 oz of beer, 5 oz of wine, or 1.5 oz of liquor) is not known to be harmful to the infant, particularly if the mother waits 2-3 hours after consumption to breastfeed.[20]

In terms of the mother's nutrient intake, there is limited research regarding the extent of its role on breast milk composition. A systematic review of 36 journal publications found that the concentration of fatty acids and

18. Ballard, O., & Morrow, A. L. (2013). *Human milk composition: Nutrients and bioactive factors. Pediatric Clinics of North America, 60*(1), 49-74. https://doi:10.1016.j.pcl.2012.10.002
19. American Pregnancy Association. (2020, June, 25). *Breastfeeding: Overview*. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.
20. Centers for Disease Control and Prevention. (2019, December 28). *Alcohol*. https://www.cdc.gov/breastfeeding/breastfeeding-special-circumstances/vaccinations-medications-drugs/alcohol.html

vitamins A, C, B_6, and B_{12} are reported to be most influenced by maternal diet, while mineral content is much less affected.[21] However, more research on this topic is needed.

BOTTLE FORMULA FEEDING

Most women can and should breastfeed when given sufficient education and support. However, as discussed, a small percentage of women are unable to breastfeed their infants, while others choose not to. While infant formula provides a balance of nutrients, not all formulas are the same and there are important considerations that parents and caregivers must weigh. Standard formulas use cow's milk as a base. They have 20 kcal per fl oz, similar to breast milk, with vitamins and minerals added. Cow's milk alone should never be given to babies under the age of one as young infants cannot fully digest it and it does not meet their nutrient needs. Soy-based formulas are usually given to infants who develop diarrhea, constipation, vomiting, colic, or abdominal pain, or to infants with a cow's milk protein allergy.

Hypoallergenic protein hydrolysate formulas are usually given to infants who are allergic to cow's milk and soy protein. This type of formula uses hydrolyzed protein, meaning that the protein is already broken down into amino acids and small peptides, which makes it easier to digest. Preterm infant formulas are given to low birth weight infants, if breast milk is unavailable. Preterm infant formulas have 24 kcal per fl oz and are given until the infant reaches a desired weight.

Infant formula comes in three basic types:

1. Powder that requires mixing with water. This is the least expensive type of formula.
2. Concentrates, which are liquids that must be diluted with water. This type is slightly more expensive.
3. Ready-to-use liquids that can be poured directly into bottles. This is the most expensive type of formula. However, it requires the least amount of preparation. Ready-to-use formulas are also convenient for traveling.

Most babies need about 2.5 oz of formula per lb of body weight each day. Therefore, the average infant should consume about 24 fl oz of breast milk or formula per day. When preparing formula, parents and caregivers should carefully follow the safety guidelines, since an infant has an immature immune system. All equipment used in formula preparation should be sterilized. Prepared, unused formula should be refrigerated to prevent bacterial growth. Parents should make sure not to use contaminated water to mix formula in order to prevent foodborne illnesses. Follow the instructions for powdered and concentrated formula carefully. Formula that is overly diluted would not provide adequate kcal and protein, while overly concentrated formula provides too much protein and too little water which can impair kidney function.

It is important to note again that the Public Health Agency of Canada, The Canadian Paediatric Society, and the World Health Organization (WHO) state that breast milk is far superior to infant formula. This table compares some of the advantages of giving a child breast milk to the disadvantages of using bottle formula.[22]

21. Bravi, F., Wiens, F., Decarli, A., Dal Pont, A., Agostoni, C., & Ferraroni, M. (2016). *Impact of maternal nutrition on breast-milk composition: a systematic review. The American Journal of Clinical Nutrition, 104*(3), 646-662. https://doi:10.3945/ajcn.115.120881
22. Public Health Agency of Canada. (2022). Canada's breastfeeding progress report 2022. https://health-infobase.canada.ca/src/data/breastfeeding/PHAC%20-%20Breastfeeding%20Report%202022.pdf

Breast Milk	Bottle Formula
Antibodies and lactoferrin in breast milk protect infants.	Formula does not contain immuno-protective factors.
The iron in breast milk is absorbed more easily.	Formula contains more iron than breast milk but it is less easily absorbed.
The feces that breastfed babies produce lacks smell due to different bacteria in the gut.	The feces that formula fed infants produce tends to have more of a foul odor.
Breast milk is always available and is always at the correct temperature.	Formula must be prepared, refrigerated for storage and warmed before given to an infant.
Breastfed babies are less likely to have constipation.	Formula fed babies tend to have more constipation.
Breastfeeding ostensibly is free, though purchasing a pump and bottles to express milk does require some expense.	Formula must be purchased and is expensive.
Breast milk contains the essential fatty acids, DHA and ARA, which are critical for brain and vision development.	Some formulas contain DHA and ARA.

INFANCY

Diet and nutrition have a major impact on a child's development from infancy into the adolescent years. A healthy diet not only affects growth, but also immunity, intellectual capabilities, and emotional well-being. One of the most important jobs of parenting is making sure that children receive an adequate amount of needed nutrients to provide a strong foundation for the rest of their lives.

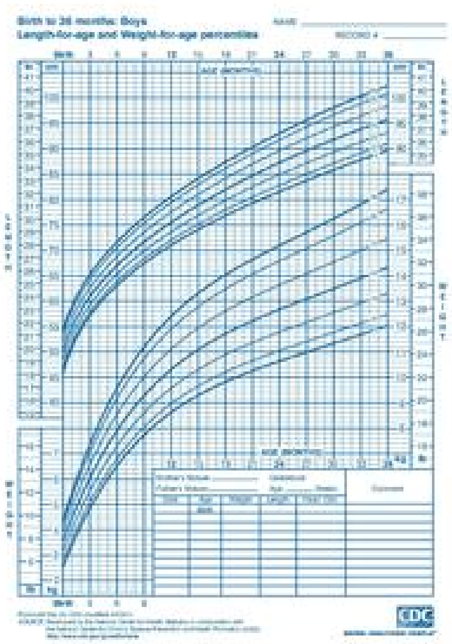
INFANT GROWTH AND DEVELOPMENT

A number of major physiological changes occur during infancy. The trunk of the body grows faster than the arms and legs, while the head becomes less prominent in comparison to the limbs. Organs and organ systems grow at a rapid rate. Also during this period, countless new synapses form to link brain neurons. Two soft spots on the baby's skull, known as fontanels, allow the skull to accommodate rapid brain growth. The posterior fontanel closes first, by eight weeks of age. The anterior fontanel closes about a year later, at 18 months on average. Developmental milestones include sitting up without support, learning to walk, teething, and vocalizing among many, many others. All of these changes require adequate nutrition to ensure development at the appropriate rate.[23]

Healthy infants grow steadily, but not always at an even pace. For example, during the first year of life, height increases by 50%, while weight triples. Physicians and other health professionals use growth charts to track a baby's development process. Because infants cannot stand, length is used instead of height to determine the rate of a child's growth. Other important developmental measurements include head circumference and weight. All of these must be tracked and compared against standard measurements for an infant's age.

Infant by meinmon, via *Pixabay Content License.*

23. McMillan, B. (2008). *Illustrated atlas of the human body.* Weldon Owen.



Sample growth chart for use with American boys from birth to age 36 months by NCHS. Image by Centers for Disease Control and Prevention, via Public Domain.

For infants and toddlers, the WHO growth charts are used to monitor growth. These standards represent optimal growth for children at this age and allow for tracking growth trends over time through percentile rankings. Growth charts may provide warnings that a child has a medical problem or is malnourished. Insufficient weight or height gain during infancy may indicate a condition known as failure-to-thrive, which is characterized by poor growth.

NUTRITIONAL REQUIREMENTS

Requirements for macronutrients and micronutrients on a per kg basis are higher during infancy than at any other stage in the human life cycle. These needs are affected by the rapid cell division that occurs during growth, which requires energy and protein, along with the nutrients that are involved in DNA synthesis. During this period, children are entirely dependent on their parents or other caregivers to meet these needs. For almost all infants, six months or younger, breast milk is the best source to fulfill nutritional requirements. An infant may require feedings 8-12 times a day or more in the beginning. After six months, infants can gradually begin to consume solid foods to help meet nutrient needs.

Energy and Macronutrients

Energy needs relative to size are much greater in an infant than an adult. A baby's resting metabolic rate is two times that of an adult. The RDA to meet energy needs changes as an infant matures and puts on more weight. Just as we calculate energy needs in adults using various equations, there are also equations to calculate total energy expenditure and resulting energy needs for infants and children. For example, the equation for the first three months of life is: (89 x weight [kg] − 100) + 175 kcal. However, the amount and frequency an infant wants to eat will also change over time due to growth spurts, which typically occur at about two and six weeks of age, and again at about three months and six months of age.

The dietary recommendations for infants are based on the nutritional content of human breast milk. Carbohydrates make up about 45-65% of the caloric content in breast milk, which amounts to an RDA of about 130 g. Almost all of the carbohydrate in human milk is lactose, which infants digest and tolerate well. In fact, lactose intolerance is practically nonexistent in infants (not to be confused with an allergy to the protein in cow's milk). Protein makes up about 5-20% of the caloric content of breast milk, which amounts to about 13 g per day. Infants need protein to support growth and development, though excess protein (which is only a concern with formula feeding) can cause dehydration, diarrhea, fever, and acidosis in premature infants. About 30-40% of the caloric content in breast milk is made up of fat. A high fat diet is necessary to encourage the development of neural pathways in the brain and other parts of the body. However, saturated fats and trans fatty acids inhibit this growth. Infants who are over the age of six months, which means they are no longer exclusively breastfed, should not consume foods that are high in these types of fats.

Micronutrients

Almost all of the nutrients that infants require can be met if they consume an adequate amount of breast milk.

Because of our northern latitude, Canadian infants are at risk of vitamin D deficiency. Since breast milk has only small amounts of vitamin D, babies who are breastfed should receive a daily supplement, which is available as drops[24]

The Canadian Paediatric Society also recommends a Vitamin D supplementation of 800 IU/day for breastfed northern Indigenous infants, and 400 IU/day for those being formula fed, due to their higher risk.[25]

Babies are born with a very small amount of vitamin K. Our bodies need vitamin K to form clots and to stop bleeding. We get vitamin K from the foods we eat, such as green leafy vegetables, fish, meat, and eggs. The Canadian Paediatric Society recommends that doctors give newborns vitamin K by injection.[26]

Breast milk is not high in iron, but the iron in breast milk is well absorbed by infants. Babies are born with about a six month supply of stored iron. After six months, however, an infant needs an additional source of iron other than breast milk. This is typically the time solid foods begin to be introduced, particularly iron-enriched cereals.[27]

Fluids

Infants have a high need for fluids, 1.5 ml per kcal consumed compared to 1.0 ml per kcal consumed for adults. This is because children have larger body surface area per unit of body weight and a reduced capacity for perspiration. Therefore, they are at greater risk of dehydration. However, parents or other caregivers can meet an infant's fluid needs with breast milk or formula. As solids are introduced, parents must make sure that young children continue to drink fluids throughout the day.

Introducing Solid Foods

The Canadian Paediatric Society and the WHO recommends exclusive breastfeeding for the first six months of life, followed by continued breastfeeding as complementary foods are introduced, with continuation of breastfeeding for one year or longer as mutually desired by mother and infant.[28]

A child may be ready to eat solids, once they can sit with little or no support, has good head control, and opens their mouth and leans toward food when it is offered. Infants should not exclusively consume solid foods prior to six months as these do not contain the right nutrient mix that infants need. If parents try to feed an infant who is too young or is not ready, their tongue will push the food out, which is called an **extrusion reflex**.

Solid baby foods can be bought commercially or prepared from regular food using a food processor, blender, food mill, or grinder at home. By nine months to a year, infants are able to chew soft foods and can eat solids that are well chopped or mashed. It is important to feed a young child only one new food at a time, to help identify allergic responses or food intolerances. An iron supplement or iron-fortified cereal is still recommended at this time.

TODDLER YEARS

Major physiological changes continue into the toddler years. Unlike in infancy, the limbs grow much faster than

24. Canadian Paediatric Society. (2018). Breastfeeding. Caring for Kids. https://caringforkids.cps.ca/handouts/pregnancy-and-babies/breastfeeding
25. Ibid.
26. Canadian Paediatric Society. (2018). Vitamin K for newborns. Caring for Kids. https://caringforkids.cps.ca/handouts/pregnancy-and-babies/vitamin-k-for-newborns
27. Centers for Disease Control and Prevention. (2019, October 17). *When, what, and how to introduce solid foods.* https://www.cdc.gov/nutrition/infantandtoddlernutrition/foods-and-drinks/when-to-introduce-solid-foods.html
28. Canadian Paediatric Society. (2022, August). Breastfeeding. Caring for Kids. https://caringforkids.cps.ca/handouts/pregnancy-and-babies/breastfeeding#who

the trunk, which gives the body a more proportionate appearance. By the end of the third year, a toddler is taller and more slender than an infant, with a more erect posture. As the child grows, bone density increases and bone tissue gradually replaces cartilage.

Developmental milestones include running, drawing, toilet training, and self-feeding. How a toddler acts, speaks, learns, and eats offers important clues about their development. By the age of two, children have advanced from infancy and are on their way to becoming school-aged children. Their physical growth and motor development slows compared to the progress they made as infants. However, toddlers experience enormous intellectual, emotional, and social changes. Of course, food and nutrition continue to play an important role in a child's development. During this stage, the diet completely shifts from breastfeeding or formula feeding to solid foods along with other liquids. Parents of toddlers also need to be mindful of certain nutrition-related issues that may crop up during this stage of the human life cycle. For example, fluid requirements relative to body size are higher in toddlers than in adults because children are at greater risk of dehydration.

Toddler by avitalchn, via Pixabay Content License.

The toddler years pose interesting challenges for parents or other caregivers, as children learn how to eat on their own and begin to develop personal preferences.

NUTRITIONAL REQUIREMENTS

A toddler's serving sizes should be approximately one-quarter that of an adult serving size. One way to estimate serving sizes for young children is one tablespoon for each year of life. For example, a 2 year old child would be served 2 tbsp of fruits or vegetables at a meal, while a 4 year old would be given 4 tbsp, or one-quarter cup. Here is an example of a toddler-sized meal:

- 1 oz of meat or chicken, or 2 to 3 tbsp of beans
- One-quarter slice of whole-grain bread
- 1 to 2 tbsp of cooked vegetable
- 1 to 2 tbsp of fruit

Energy

The energy requirements for ages two to three are about 1,000-1,400 kcal a day. In general, a toddler needs to consume about 40 kcal for every inch of height. For example, a young child who measures 32 inches should take in an average of 1,300 kcal a day. However, the recommended caloric intake varies with each child's level of activity. Toddlers require small, frequent, nutritious snacks and meals to satisfy energy requirements. The amount of food a toddler needs from each food group depends on daily kcal needs.

Food Group	2 Year olds	3 Year olds	What Counts as:
Fruit	1 c	1-1½ c	½ cup of fruit? • ½ c mashed, sliced, or chopped fruit • ½ small banana • 4-5 large strawberries
Vegetables	1 c	1-1½ c	½ cup of veggies? • ½ c mashed, sliced, or chopped veggies • 1 c raw leaf greens • 1 small ear corn
Grains	3 oz	3-5 oz	1 oz grain? • 1 slice bread • 1 c ready to eat flake cereal • ½ c oatmeal, rice, or pasta • 1 tortilla (6" across)
Protein Foods	2 oz	2-4 oz	1 oz protein food? • 1 oz cooked meat, poultry, or seafood • 1 egg • 1 tbsp peanut butter • ¼ c cooked beans or peas (kidney, pinto, lentils)
Dairy	2 c	2-2½ c	½ cup dairy? • ½ c milk • 4 oz yogurt • ¾ oz cheese

Macronutrients

Toddlers' needs increase to support their body and brain development. Toddlers' needs increase to support their body and brain development. For toddlers, the AMDR for carbohydrate intake is 45-65% of daily kcal. For protein, it's 5-20% and for fat it's 30-40% of daily kcal. Essential fatty acids are vital for the development of the eyes, along with nerves and other types of tissue. However, toddlers should not consume foods with high amounts of trans fats and saturated fats. Instead, young children require the equivalent of three teaspoons of healthy oils, such as olive oil, each day.

Micronutrients

As a child grows bigger, the demands for micronutrients increase. These needs for vitamins and minerals can be met with a balanced diet, with a few exceptions. According to Health Canada, people over the age of 2 need to eat foods that contain vitamin D every day or take a daily supplement containing 400 IU (10 μg) of vitamin D.[29] Pediatricians may also prescribe a fluoride supplement for toddlers who live in areas with fluoride-poor water. Iron deficiency is also a major concern for children between the ages of two and three.

Iron deficiency anemia (IDA) can cause a number of problems including weakness, pale skin, shortness of

29. Government of Canada. (2022, May 2). Vitamin D. Health Canada. https://www.canada.ca/en/health-canada/services/nutrients/vitamin-d.html

breath, fatigue, and irritability. It can also result in intellectual, behavioural, or motor problems. IDA can occur as young children are weaned from iron-rich foods, such as breast milk and iron-fortified formula. They begin to eat solid foods that may not provide enough of this nutrient. Therefore, it is important that parents and caregivers add more iron-rich foods to a child's diet, including lean meats, fish, poultry, eggs, legumes, and iron-enriched whole-grain breads and cereals. Children may also be given a daily supplement, such as ferrous sulfate drops.

Food-Related Problems in the Toddler Years

During the toddler years, parents may face a number of problems related to food and nutrition. Possible obstacles include difficulty helping a young child overcome a fear of new foods, or fights over messy habits at the dinner table. Even in the face of problems and confrontations, parents and other caregivers must make sure their preschooler has nutritious choices at every meal. For example, even if a child stubbornly resists eating vegetables, parents should continue to provide them. Before long, the child may change their mind, and develop a taste for foods once abhorred. It is important to remember this is the time to establish or reinforce healthy habits.

Registered Dietitian Ellyn Satter states that feeding is a responsibility that is split between parent and child. According to Satter and her Division of Responsibility in Feeding, parents are responsible for what their infants eat, while infants are responsible for how much they eat. In the toddler years and beyond, parents are responsible for what children eat, when they eat, and where they eat, while children are responsible for how much food they eat and whether they eat. Satter states that the role of a parent or a caregiver in feeding includes the following:[30]

- selecting and preparing food
- providing regular meals and snacks
- making mealtimes pleasant
- showing children what they must learn about mealtime behavior
- being considerate of children's lack of food experiences without catering to likes and dislikes

Picky Eaters

Children at this stage are often picky about what they want to eat. They may turn their heads away after eating just a few bites. Or they may resist coming to the table at mealtimes. They also can be unpredictable about what they want to consume for specific meals or at particular times of the day. Although it may seem as if toddlers should increase their food intake to match their level of activity, there may be a good reason for picky eating. A child's growth rate slows after infancy, and toddlers do not require as much food.

Some children may also go through a **food jag**, or period of time where they only want to eat the same few foods every day and for most, if not every, meal. While this can be a way for a child to begin to express some independence, which is a normal part of development, it can make for frustrating meal times. It's important not to force a child to eat foods they don't want as this can actually prolong the food jag. Instead, offer new foods or healthy foods that they like and allow them to eat the preferred food with remaining food on their plate. Remember to follow Ellyn Satter's Division of Responsibility in Feeding as stated above.

Choking

At this young age, children are still learning how to adequately chew and swallow, increasing the risk of choking. To minimize this risk, encourage children to sit when eating, chew thoroughly, play close attention to what they

30. The Ellyn Satter Institute. (n.d.). *Division of responsibility in feeding.* https://www.ellynsatterinstitute.org/how-to-feed/the-division-of-responsibility-in-feeding/

put in their mouths, and supervise older children who may give foods considered choking hazards to younger kids. Such foods include nuts, whole cherries or grapes, raw carrots or celery, hard candy, hot dogs, etc. Make sure to cut foods into smaller and/or mashed pieces.

Early Childhood Caries

Early childhood **caries** (dental issues such as cavities) remain a potential problem during the toddler years. The risk of early childhood caries increases with the consumption of foods with a higher sugar content. According to the National Health and Nutrition Examination Survey, children between ages of 2 and 5 consume slightly more than 200 kcal of added sugar per day or approximately 13% of their total kcal.[31] Therefore, parents with toddlers should avoid processed foods, such as snacks from vending machines, and sugary beverages, such as soda. Parents also need to instruct a child on brushing their teeth at this time to help a toddler develop healthy habits and avoid tooth decay.

Toddler Obesity

Another potential problem during the early childhood years is toddler obesity. According to the Public Health Agency of Canada, obesity rates among children and youth in Canada have nearly tripled in the last 30 years. Children and youth who are obese are at higher risk of developing a range of health problems, and weight issues in childhood are likely to persist into adulthood.[32]

Obesity during early childhood tends to linger as a child matures and can cause health problems later in life. Children undergo both hyperplasia and hypertrophy of adipose tissue, and the additional adipose cells created during childhood remain in adulthood. There are a number of reasons for the increases in obesity rates in toddlers. One is a lack of time. Parents and other caregivers who are constantly on the go may find it difficult to fit home-cooked meals into a busy schedule and may turn to fast food and other conveniences that are quick and easy, but not nutritionally sound. Another contributing factor is a lack of access to fresh fruits and vegetables. This is a problem particularly in low-income neighbourhoods where local stores and markets may not stock fresh produce or may have limited options. Physical inactivity is also a factor, as toddlers who live a sedentary lifestyle are more likely to be overweight or obese. Another contributor is a lack of breastfeeding support. Children who were breastfed as infants show lower rates of obesity than children who were formula-fed.

The Public Health Agency of Canada provides the following suggestions to prevent or address toddler obesity parents and caregivers.[33]

Tips for eating healthy

- By following the food guide, you and your family can make healthy food choices and develop healthy eating habits.
- Set a good example for your children by being a role model for healthy eating. Your children are more likely to try new foods if you eat them too.
- Eat meals together as a family as often as possible. Make food the focus. Turn off the TV and put away

31. Ervin, R. B., Kit, B. K., Carroll, M. D., & Ogden, C. L. (2012, February). Consumption of added sugar among US Children and Adolescents, 2005-2008. *National Center for Health Statistics. Data Brief, no. 87.* https://www.cdc.gov/nchs/products/databriefs/db87.htm
32. Government of Canada. (2023, January 13). C*hildhood obesity.* Public Health Agency of Canada. https://www.canada.ca/en/public-health/services/childhood-obesity/childhood-obesity.html
33. Ibid.

electronic devices during mealtime. Children often eat better without these distractions.

- Involve children in planning and preparing meals and snacks. This is a great way to teach kids healthy eating habits while connecting and spending quality time together as a family.

Tips for being physically active

- Children and teenagers should participate in at least 60 minutes of physical activity per day. This can include walking to and from school, playing sports, or riding a bike.
- Set a good example. Try to add physical activity to your daily routine and encourage your children to join you.
- Limit the amount of time children spend on sedentary activities like watching television, playing video games, and surfing the web.
- Be aware of the opportunities community resources offer. Are there bike paths nearby? What community programs are available throughout the year?[34]

Food for Thought

What would you recommend to help families prevent obesity among their children? What tips would you provide? What lifestyle changes might help?

CHILDHOOD

Nutritional needs change as children leave the toddler years. From ages four to eight, school-aged children grow consistently, but at a slower rate than infants and toddlers. They also experience the loss of deciduous, or "baby" teeth, and the arrival of permanent "adult" teeth, which typically begins at age six or seven. As new teeth come in, many children have some malocclusion, or malposition, of their teeth, which may affect their ability to chew food. Other changes that affect nutrition include the influence of peers on dietary choices and the kinds of foods offered by schools and after-school programs, which can make up a sizable part of a child's diet. Excessive weight gain early in life can lead to obesity into adolescence and adulthood.

At this life stage, a healthy diet facilitates physical and mental development and helps to maintain health and wellness. School-aged children experience steady, consistent growth, with an average growth rate of 2 to 3 inches in height and 4.5 to 6.5 lb in weight per year. In addition, the rate of growth for the extremities is faster than for the trunk, which results in more adult-like proportions.

34. Ibid.

NUTRITIONAL REQUIREMENTS

Energy

Children's energy needs vary depending on their growth and level of physical activity. Energy requirements may also vary according to gender. Girls ages 4 to 8 require 1,200-1,800 kcal a day, while boys need 1,200-2,000 kcal daily and, depending on their activity level, a child may require more. Also, recommended intakes of macronutrients and most micronutrients are higher relative to body size, compared with nutrient needs during adulthood.

Macronutrients

For carbohydrates, the AMDR remains 45-65% of daily kcal. Children also require 17-25 g of fiber per day. They have a high need for protein to support muscle growth and development, therefore the AMDR increases a bit to 10-30% of daily kcal. High levels of essential fatty acids are needed to support growth (although not as high as in infancy and toddler years). As a result, the AMDR for fat is 25-35% of daily kcal.

Micronutrients

Micronutrient needs should be met with foods first. Parents and caregivers should select a variety of foods from each food group to ensure that nutritional requirements are met. Because children grow rapidly, they require foods that are high in iron, such as lean meats, legumes, fish, poultry, and iron-enriched cereals. Adequate fluoride is crucial to support strong teeth. Two of the most important micronutrient requirements during childhood is adequate calcium and vitamin D intake. Both are needed to build dense bones and a strong skeleton. Children who do not consume adequate vitamin D should be given a supplement of 10 mcg per day. Table below shows the micronutrient recommendations for school-aged children. Note that the recommendations are the same for boys and girls. As we progress through the different stages of the human life cycle, there will be some differences between males and females regarding micronutrient needs.

Nutrient	4-8 Years	9-13 Years
Vitamin A (mcg)	400.0	600.0
Thiamin (mg)	0.6	0.9
Riboflavin (mg)	0.6	0.9
Niacin (mg)	8.0	12.0
Vitamin B_6 (mg)	0.6	1.0
Folate (mcg)	200.0	200.0
Vitamin B_{12} (mcg)	1.2	1.8
Vitamin C (mg)	25.0	45.0
Vitamin D (mcg)	15.0	15.0
Vitamin E (mg)	7.0	11.0
Vitamin K (mcg)	55.0	60.0
Calcium (mg)	1000.0	1300.0
Iron (mg)	10.0	8.0
Magnesium (mg)	130.0	240.0
Phosphorus (mg)	500.0	1250.0
Selenium (mcg)	30.0	40.0
Zinc (mg)	5.0	8.0

Factors Influencing Intake

A number of factors can influence children's eating habits and attitudes toward food. Family environment, societal trends, taste preferences, and messages in the media all impact the emotions that children develop in relation to their diet. Television commercials can entice children to consume sugary products, fatty fast foods, excess kcal, refined ingredients, and sodium. Therefore, it is critical that parents and caregivers direct children toward healthy choices.

One way to encourage children to eat healthy foods is to make meals and snacks fun and interesting. Parents should include children in food planning and preparation, for example selecting items while grocery shopping or helping to prepare part of a meal, such as making a salad. At this time, parents can also educate children about kitchen safety. It might be helpful to cut sandwiches, meats, or pancakes into small or interesting shapes. In addition, parents should offer nutritious desserts, such as fresh fruits, instead of calorie-laden cookies, cakes, salty snacks, and ice cream. Additionally, research has found that regularly eating dinner as a family is associated with greater consumption of fruits, vegetables, and less saturated and trans fat.[35]

ADOLESCENCE

The onset of puberty is the beginning of adolescence and is the bridge between the childhood years and young adulthood. According to the DRI recommendations, adolescence is divided into two age groups: 9 through 13 years, and 14 through 18 years. Some of the important physiological changes that take place during this stage include the development of the primary sex characteristics (the reproductive organs), along with the onset of menstruation in females. This life stage is also characterized by the appearance of secondary sex characteristics, such as the growth of facial and body hair, the development of breasts in girls, the deepening of the voice in boys,

35. Gillman, M. W., Rifas-Shiman, S. L., Frazier, L., Rockett, H. R., Camargo, C. A., Field, A. E., Berkey, C. S., & Colditz, G. A. (2000). Family dinner and diet quality among older children and adolescents. *Archives of Family Medicine 9*, 235-240.

and alterations in body proportions. All of these changes, as well as the accompanying mental and emotional adjustments, should be supported with sound nutrition.

THE ONSET OF PUBERTY (AGES 9 THROUGH 13 YEARS)

This period of physical development is divided into two phases. The first phase involves height increases from 20-25%. Puberty is second to the prenatal period in terms of rapid growth as the long bones stretch to their final, adult size. Girls grow 2 to 8 inches taller, while boys grow 4 to 12 inches taller. The second phase involves weight gain related to the development of bone, muscle, and fat tissue.

Energy and Macronutrients

The energy requirements for preteens differ according to biological sex, growth, and activity level. For ages 9 to 13, girls should consume about 1,400-2,200 kcal per day and boys should consume 1,600-2,600 kcal per day. Physically active preteens who regularly participate in sports or exercise need to eat a greater number of kcal to account for increased energy expenditures.

The AMDR recommendations remain 45-65% of total kcal from carbohydrates, 10-30% from protein, and 25-35% from fat. Foods that are high in fiber should make up the bulk of carbohydrate intake.

School lunch by U.S. Department of Agriculture, via Flickr Public Domain

Micronutrients

Key vitamins needed during puberty include vitamins B_{12}, D, and K. Adequate calcium intake is essential for building bone and preventing osteoporosis later in life. Young females need more iron beginning at the onset of menstruation, while young males need additional iron for the development of lean body mass. Almost all of these needs should be met with dietary choices, not supplements (although iron may be an exception).

LATE ADOLESCENCE (AGES 14 THROUGH 18 YEARS)

After puberty, the rate of physical growth slows down. Girls stop growing taller around age 16, while boys continue to grow until ages 18-20. One of the psychological and emotional changes that takes place during this life stage includes the desire for independence as adolescents develop individual identities apart from their families. As teenagers make more and more of their own dietary decisions, parents or other caregivers and authority figures should guide them toward appropriate, nutritious choices. One way that teenagers assert their independence is by choosing what to eat. They often have their own money to purchase food and tend to eat more meals away from home. Older adolescents also can be curious and open to new ideas, which includes trying new kinds of food and experimenting with their diet. For example, teens will sometimes skip a main meal and snack instead. That is not necessarily problematic. Their choice of food is more important than the time or place.

However, too many poor choices can make young people nutritionally vulnerable. Teens should be discouraged from eating fast food, which has a high fat, sugar, and sodium content, or frequenting convenience stores and using vending machines, which typically offer poor nutritional selections. Other challenges that teens may face include obesity and eating disorders. At this life stage, young people still need guidance from parents and other caregivers about nutrition-related matters. It can be helpful to explain to young people how healthy eating habits can support activities they enjoy, such as skateboarding or dancing, or connect to their desires or interests, such as athletic performance or improved cognition.

Eating Healthy Food by Tafadzwa Tarumbwa, via Public Domain.

As during puberty, growth and development during adolescence differs in males and females. Teenage girls experience a significant increase in body fat, while teenage boys often experience an increase in fat-free and skeletal mass, and a decrease in body fat.[36] For both males and females, primary and secondary sex characteristics have fully developed and the rate of growth slows with the end of puberty.

Energy and Macronutrients

Adolescents have increased appetites due to increased nutritional requirements. Nutrient needs are greater in adolescence than at any other time in the life cycle, except during pregnancy. The energy requirements for ages 14 to 18 are 1,800-2,400 kcal for girls and 2,000-3,200 kcal for boys, depending on activity level. The extra energy required for physical development during the teenage years should be obtained from foods that provide nutrients instead of "empty calories." Also, teens who participate in athletics must make sure to meet their increased energy needs.

Older adolescents are more responsible for their dietary choices than younger children, but parents and caregivers must make sure that teens continue to meet their nutrient needs. The AMDR for carbohydrates remains 45-65% of daily kcal and the adequate intake (AI) of fiber is 25-34 g per day (depending on daily kcal intake). Adolescents require more servings of grain than younger children, and should eat whole grains, such as wheat, oats, barley, and brown rice. The NAM recommends higher intakes of protein for growth in the adolescent population. The AMDR for protein remains 10-30% of daily kcal and lean proteins, such as meat, poultry, fish, beans, nuts, and seeds are excellent ways to meet those nutritional needs. The AMDR for fat remains 25-35% of daily kcal. It is also essential for young athletes and other physically active teens to intake enough fluids, because they are at a higher risk for becoming dehydrated.

Micronutrients

Micronutrient recommendations for adolescents are mostly the same as for adults, though children this age need more of certain minerals to promote bone growth (e.g., calcium and phosphorus, along with iron and zinc for girls). Again, vitamins and minerals should be obtained from food first, with supplementation for certain micronutrients only (such as iron).

The most important micronutrients for adolescents are calcium, vitamin D, vitamin A, and iron. Adequate calcium and vitamin D are essential for building bone mass. The recommendation for calcium is 1,300 mg for both boys and girls. Low-fat milk and cheeses are excellent sources of calcium and help young people avoid saturated fat and cholesterol. It can also be helpful for adolescents to consume products fortified with calcium, such as

36. Loomba-Albrecht, L.A., & Styne, D. M. (2009). Effect of puberty on body composition. Current Opinion in Endocrinology, *Diabetes and Obesity, 16*(1), 10-15. https://doi:10.3945/ajcn.115.120881

breakfast cereals and orange juice. Iron supports the growth of muscle and lean body mass. Adolescent girls also need to ensure sufficient iron intake as they start to menstruate. Girls ages 12 to 18 require 15 mg of iron per day. Increased amounts of vitamin C from orange juice and other sources can aid in iron absorption. Also, adequate fruit and vegetable intake allows for meeting vitamin A needs.

Nutrient	Females, 14-18 Years	Males, 14-18 Years
Vitamin A (mcg)	700.0	900.0
Thiamin (mg)	1.0	1.2
Riboflavin (mg)	1.0	1.3
Niacin (mg)	14	16
Vitamin B_6 (mg)	1.2	1.3
Folate (mcg)	400.0	300.0
Vitamin B_{12} (mcg)	2.4	2.4
Vitamin C (mg)	65.0	75.0
Vitamin D (mcg)	15.0	15.0
Vitamin E (mg)	15.0	15.0
Vitamin K (mcg)	75.0	75.0
Calcium (mg)	1300.0	1300.0
Iron (mg)	15.0	11.0
Magnesium (mg)	360.0	410.0
Phosphorus (mg)	1250.0	1250.0
Selenium (mcg)	55.0	55.0
Zinc (mg)	9.0	11.0

ADULTHOOD

Adulthood begins at the end of adolescence and continues until the end of one's life. Young adulthood is the period from ages 19 to 30 years. It is a stable time compared to childhood and adolescence. Physical growth has been completed and all of the organs and body systems are fully developed. Typically, a young adult who is active has reached his or her physical peak and is in prime health. During this life stage, it is important to continue to practice good nutrition. Healthy eating habits promote metabolic functioning, assist repair and regeneration, and prevent the development of chronic conditions. Proper nutrition and adequate physical activity at this stage not only promote wellness in the present, but also provide a solid foundation for the future.

With the onset of adulthood, good nutrition can help young adults enjoy an active lifestyle. The body of an adult does not need to devote its energy and resources to support the rapid growth and development that characterizes youth. However, the choices made during those formative years can have a lasting impact. Eating habits and preferences developed during childhood and adolescence influence health and fitness into adulthood. Some adults have gotten a healthy start and have established a sound diet and regular activity program, which helps them remain in good condition from young adulthood into their later years. Others carry childhood obesity into adulthood, which adversely affects their health. However, it is not too late to change course and develop healthier habits and lifestyle choices. Therefore, adults must monitor their dietary decisions and make sure their caloric intake provides the energy that they require, without going into excess.

Energy and Macronutrients

Young men typically have higher nutrient needs than young women. For ages 19-30, the energy requirements for women are 1,800-2,400 kcal, and 2,400-3,000 kcal for men, depending on activity level. These estimates do not include women who are pregnant or breastfeeding, who require a higher energy intake. For carbohydrates, the AMDR continues to be 45-65% of daily kcal. All adults, young and old, should eat fewer energy dense carbohydrates, especially refined, sugar dense sources, particularly for those who lead a more sedentary lifestyle. The AMDR for protein is 10-35% of total daily kcal, and should include a variety of lean meat and poultry, eggs, beans, peas, nuts, and seeds. The guidelines also recommend that adults eat at least two 4 oz servings of seafood per week.

It is also important to replace foods that are high in saturated fat with ones that are lower in solid fats and kcal. All adults should limit total fat to 20-35% of their daily kcal and keep saturated fatty acids to less than 10% of total kcal by replacing them with monounsaturated and polyunsaturated fatty acids. The adequate intake for fiber is 22-28 g per day for women and 28-34 g per day for men. Soluble fiber may help improve cholesterol and blood sugar levels, while insoluble fiber can help prevent constipation.

Micronutrients

Micronutrient needs in adults differ slightly according to sex. Young men and women who are very athletic and perspire a great deal may require extra sodium, potassium, and magnesium. Males require more of vitamins A, C, and K along with thiamin, riboflavin, and niacin. Females require extra iron due to menstruation. Therefore, it can be beneficial for some young adults to follow a daily multivitamin regimen to help meet nutrient needs. But as always, it is important to remember “food first, supplements second.”

Nutrient	Females, 19+ Years	Males, 19+ Years
Vitamin A (mcg)	700.0	900.0
Thiamin (mg)	1.1	1.2
Riboflavin (mg)	1.1	1.3
Niacin (mg)	14.0	16.0
Vitamin B_6 (mg)	1.3 (19-50 yr)	1.3 (19-50 yr)
	1.5 (51+ yr)	1.7 (51+ yr)
Folate (mcg)	400.0	400.0
Vitamin B_{12} (mcg)	2.4	2.4
Vitamin C (mg)	75.0	90.0
Vitamin D (mcg)	15.0 (19-70 yr)	15.0 (19-70 yr)
	20.0 (71+ yr)	20.0 (71+ yr)
Vitamin E (mg)	15.0	15.0
Vitamin K (mcg)	90.0	120.0
Calcium (mg)	1000.0 (19-50 yr)	1000.0 (19-70 yr)
	1200.0 (51+yr)	1200.0 (71+ yr)
Iron (mg)	18.0 (19-50 yr)	8.0
	8.0 (51+ yr)	
Magnesium (mg)	310.0 (19-30 yr)	400.0 (19-30 yr)
	320.0 (31+ yr)	420.0 (31+ yr)
Phosphorus (mg)	700.0	700.0
Selenium (mcg)	55.0	55.0
Zinc (mg)	8.0	11.0

MIDDLE AGE

Middle age is defined as the period from age 31 to 50. The early period of this stage is very different from the end. For example, during the early years of middle age, many women experience pregnancy, childbirth, and lactation. In the latter part of this life stage, women face perimenopause, which is a transition period that leads up to menopause, or the end of menstruation. A number of physical changes take place in the middle-aged years, including the loss of bone mass in women due to dropping levels of estrogen during menopause. In both men and women, visual acuity declines, and by age 40 there can be a decreased ability to see objects at a close distance.[37] All of these are signs of aging, as the human body begins to change in subtle and not-so-subtle ways. However, a middle aged person can remain vital, healthy, and near his or her physical peak with proper diet and adequate exercise.

During this stage of the human life cycle, adults begin to experience the first outward signs of aging. Wrinkles begin to appear, joints may ache after a highly active day, and body fat accumulates. There is also a loss of muscle tone and elasticity in the connective tissue.[38] Many people in this stage may also notice a decline in endurance, the onset of wear-and-tear injuries (such as osteoarthritis), and changes in the digestive system. Wounds and other injuries may also take longer to heal. Body composition changes due to fat deposits in the trunk. To maintain health and wellness during the middle-aged years and beyond, it is important to:

37. Poland, E.U., & Taylor, D.R. (2003). *Journey across the lifespan: Human development and health promotion.* Davis Company.
38. Poland, E.U., & Taylor, D.R. (2003). *Journey across the lifespan: Human development and health promotion.* Davis Company.

- maintain a healthy body weight
- consume nutrient dense foods
- drink alcohol moderately or not at all
- avoid tobacco products
- engage in moderate aerobic physical activity at least 150 minutes per week
- engage in muscle strengthening activity at least two days per week

Energy and Macronutrients

The energy requirements for ages 31 to 50 are 1,800-2,200 kcal for women and 2,200-3,000 kcal for men, depending on activity level. These estimates do not include women who are pregnant or breastfeeding. Middle-aged adults must rely on healthy food sources to meet these needs. Following the dietary guidelines in the middle-aged years provides adequate but not excessive energy, vitamins, and minerals.

The recommended intake for carbohydrates, protein, fat, fiber, and fluids remain the same from young adulthood into middle age. It is important to avoid putting on excess weight and limiting intake of saturated fats and added sugars to help avoid cardiovascular disease, diabetes, and other chronic conditions.

Micronutrients

There are some differences, however, regarding micronutrients. For men, the recommendation for magnesium increases to 420 mg daily, while middle-aged women should increase their intake of magnesium to 320 mg per day. Other key vitamins needed during the middle-aged years include vitamins $B_{6,}$ B_{12} and folate to prevent elevation of homocysteine, a byproduct of metabolism that can damage arterial walls and lead to atherosclerosis, a cardiovascular condition.

Preventive/Defensive Nutrition

During the middle-aged years, preventive nutrition can promote wellness and help organ systems to function optimally throughout aging. **Preventive nutrition** is defined as dietary practices directed toward reducing disease and promoting health and well-being. Healthy eating in general, such as eating unrefined carbohydrates instead of refined carbohydrates and avoiding trans fats and saturated fats, helps to promote wellness. However, there are also some things that people can do to target specific concerns. One example is consuming foods high in antioxidants, such as strawberries, blueberries, and other colorful fruits and vegetables, to reduce risk of cancer. Omega-3 fatty acids can help to prevent coronary artery disease. These crucial nutrients are found in oily fish, including salmon, mackerel, tuna, herring, cod, and halibut. Other beneficial fats that are vital for healthy functioning include monounsaturated fats, which are found in plant oils, avocados, and pecans.

MENOPAUSE

In the middle-aged years, women undergo a specific change that has a major effect on their health. They begin the process of menopause, typically in their late 40s or early 50s. The ovaries slowly cease to produce estrogen and progesterone, which results in the end of menstruation. Menopausal symptoms can vary, but often include hot flashes, night sweats, and mood changes. The hormonal changes that occur during menopause can lead to a number of physiological changes as well, including alterations in body composition, such as weight gain in the abdominal area. Bone loss is another common condition related to menopause due to the loss of female reproductive hormones. When one loses a significant amount of bone, they likely have osteoporosis, increasing their risk of fractures, which can affect mobility and the ability to complete everyday tasks.[39]

Recommendations for women experiencing menopause or perimenopause (the stage just prior to the end of the menstruation) include:[40]

- consuming a variety of whole, nutrient dense foods like vegetables, fruits, whole grains, and lean protein sources such as beans and lentils
- avoiding caffeine, spicy foods, and alcohol to help prevent hot flashes
- eating foods rich in calcium, or taking physician prescribed calcium and vitamin D supplements
- reducing sodium intake
- being physically active at least 30 minutes at moderate intensity most days of the week, include strength training activities, and stretching to improve balance and flexibility and reduce the risk of falls and fractures
- drinking plenty of water

OLDER AGE

Couple eating lunch by National Cancer Institute, via Public Domain.

The senior years are the period from age 51 until the end of life. A number of physiological and emotional changes take place during this life stage. For example, many older adults face serious health challenges, such as cancer, heart disease, diabetes, or dementia. Both men and women experience a loss of hormone production, muscle mass and strength, and undergo changes in body composition. Fat deposits build up in the abdominal area, which increases the risk for type 2 diabetes and cardiovascular disease. The skin becomes thinner and may take longer to heal after an injury. Also in the later years, the heart has to work harder because each pump is not as efficient as it used to be. Kidneys are not as effective in excreting metabolic products such as sodium and potassium, which can alter water balance and increase the risk for dehydration. In addition, immune function decreases and there is lower efficiency in the absorption of vitamins and minerals.

In addition, disorders of the nervous system can have profound effects. Dementia is the umbrella term for changes in the normal activity of the brain. Elderly adults who suffer from dementia may experience memory loss, agitation, and delusions. As of January 1, 2024, it is estimated that 733,040 people in Canada are living with dementia.[41] Neurological disorder and psychological conditions, such as depression, can influence attitudes toward food, along with the ability to prepare or ingest food. They might lead some adults to overindulge to compensate for stress or emotions that are difficult to handle. Other adults might eat less or pay less attention to

39. National Osteoporosis Foundation. (n.d.). What is osteoporosis and what causes it? https://www.nof.org/patients/what-is-osteoporosis/
40. Wolfram, T. (2019). *Eating right during menopause.* Academy of Nutrition and Dietetics. https://www.eatright.org/health/wellness/healthy-aging/eating-right-during-menopause
41. Alzheimer Society of Canada. (2024, July 10). Dementia numbers in Canada. https://alzheimer.ca/en/about-dementia/what-dementia/dementia-numbers-canada

their diet and nutritional needs. Older adults may also need guidance from dietitians and healthcare professionals to make the best dietary choices for this stage of life.

In older age, blood pressure rises and the immune system may have more difficulty battling invaders and infections. The skin becomes more wrinkled and hair has turned gray or white or fallen out, resulting in hair thinning. Older adults may gradually lose an inch or two in height. Also, short-term memory might not be as keen as it once was.

Being either underweight or overweight is a major concern for the elderly. However, many older adults remain in relatively good health and continue to be active into their golden years. Good nutrition is often the key to maintaining health later in life. In addition, the fitness and nutritional choices made earlier in life set the stage for continued health and happiness. Older adults should continue to consume nutrient dense foods and remain physically active. However, deficiencies are more common after age 60, primarily due to reduced intake or absorption. The loss of mobility among frail, home-bound elderly adults also impacts their access to healthy, diverse foods.

Energy and Macronutrients

Due to reductions in lean body mass and metabolic rate, older adults require less energy than younger adults. The energy requirements for people ages 51 and over are 1,600-2,200 kcal for women and 2,000-2,800 kcal for men, depending on activity level. The decrease in physical activity that is typical of older adults also influences nutritional requirements. The AMDRs for carbohydrates, protein, and fat remain the same from middle age into old age. However, it is recommended that the elderly consume 1.2-2.0 g of protein per kg body weight to help prevent significant muscle loss.[42] Older adults should choose more unrefined carbohydrates such as whole grains and brown rice instead of refined grains. Fiber is especially important in preventing constipation and diverticulitis, and may also reduce the risk of colon cancer. Protein should be lean and healthy fats, such as omega-3 fatty acids, are part of any good diet.

Micronutrients

An increase in certain micronutrients can help maintain health during this life stage. The recommendations for calcium increase to 1,200 mg per day for women beginning at age 51 and men at age 71 to slow bone loss. Also to help protect bones, vitamin D recommendations increase from 15 to 20 mcg per day for men and women. Vitamin B_6 recommendations rise to 1.7 mg per day for older men and 1.5 mg per day for older women to help lower levels of homocysteine and protect against cardiovascular disease. For elderly women, higher iron levels are no longer needed postmenopause and recommendations decrease to 8 mg per day. People over age 50 should eat foods rich with all of these micronutrients.

Nutritional Concerns for Older Adults

Dietary choices can help improve health during this life stage and address some of the nutritional concerns that many older adults face. In addition, there are specific concerns related to nutrition that affect adults in their later years. They include medical problems, such as disability and disease, which can impact diet and activity level. For example, dental problems can lead to difficulties with chewing and swallowing, which in turn can make it hard to maintain a healthy diet. The use of dentures or the preparation of chopped or pureed foods can help solve this problem. There also is a decreased thirst response in the elderly, and the kidneys have a decreased ability to concentrate urine, both of which can lead to dehydration.

42. Baum, J.I.,Kim, I-Y., & Wolfe, R.R. (2016). Protein consumption and the elderly. *Nutrients, 8*(6), 359. doi:10.3390%2Fnu8060359

Sensory Issues

At about age 60, taste buds begin to decrease in size and number. As a result, the taste threshold is higher in older adults, meaning that more of the same flavor must be present to detect the taste. Many elderly people lose the ability to distinguish between salty, sour, sweet, and bitter flavors. This can make food seem less appealing and decrease the appetite. An intake of foods high in sugar and sodium can increase due to an inability to discern those tastes. The sense of smell also decreases, which impacts attitudes toward food. Sensory issues may also affect the digestion because the taste and smell of food stimulates the secretion of digestive enzymes in the mouth, stomach, and pancreas.

Gastrointestinal Issues

A number of gastrointestinal issues can affect food intake and digestion among the elderly. Saliva production decreases with age, which affects chewing, swallowing, and taste. Other digestive secretions decline later in life as well, which can lead to atrophic gastritis (inflammation of the lining of the stomach). This interferes with the absorption of some vitamins and minerals. Reduction of the digestive enzyme lactase results in a decreased tolerance for dairy products. Slower gastrointestinal motility can result in more constipation, gas, and bloating, and can also be tied to low fluid intake, decreased physical activity, and a diet low in fiber, fruits, and vegetables.

Dysphagia

Some older adults have difficulty getting adequate nutrition because of the disorder **dysphagia**, which impairs the ability to swallow. Any damage to the parts of the brain that control swallowing can result in dysphagia, therefore having a cerebrovascular accident, more commonly called a stroke, is a common cause. Dysphagia is also associated with advanced dementia because of overall brain function impairment. To assist older adults suffering from dysphagia, it can be helpful to alter food consistency. For example, solid foods can be chopped, ground, or pureed to allow a more successful and safe swallow. This decreases the risk of aspiration, which occurs when food enters into the respiratory tract and can result in pneumonia. Typically, speech therapists, physicians, and dietitians work together to determine the appropriate diet for dysphagia patients.

Vision Problems

Many older people suffer from vision problems and a loss of vision. Age-related macular degeneration is the leading cause of blindness in Americans over age 60.[43] This disorder can make food planning and preparation extremely difficult and people who suffer from it often must depend on caregivers for their meals. Self-feeding may be difficult if an elderly person cannot see his or her food clearly. Friends and family members can help older adults with shopping and cooking. Food-assistance programs for older adults (such as Meals on Wheels) can also be helpful.

Diet may help to prevent macular degeneration. Consuming colorful fruits and vegetables increases the intake of lutein and zeaxanthin. Several studies have shown that these antioxidants provide protection for the eyes. Lutein and zeaxanthin are found in green, leafy vegetables such as spinach, kale, and collard greens, and also corn, peaches, squash, broccoli, Brussels sprouts, orange juice, and honeydew melon.[44]

43. National Eye Institute. (2019. July 17). *Age-related macular degeneration (AMD) data and statistics*. National Institutes of Health. https://www.nei.nih.gov/learn-about-eye-health/resources-for-health-educators/eye-health-data-and-statistics/age-related-macular-degeneration-amd-data-and-statistics
44. Eisenhauer, B., Natoli, S., Liew, G., & Flood, V. M. (2017). Lutein and zeaxanthin-food sources, bioavailability and dietary variety in age-related macular degeneration protection. *Nutrients, 9*(2), 120. https://doi.org/10.3390/nu9020120

Obesity in Old Age

In Canada, poor eating habits, physical inactivity and their contribution to obesity are critical public health challenges. Statistics Canada reports that two out of every three adults in Canada are overweight or obese.[45]

Obesity significantly increases the risk of several chronic diseases, including type 2 diabetes, some forms of cardiovascular disease, and certain types of cancer, and osteoarthritis.[46] Type 2 diabetes affects an estimated 1.8 million Canadians. In addition, from 2016 to 2019, 4% of Canadians aged 20 to 79 were living with prediabetes, and Canadians aged 60 to 79 (8%) were twice as likely to be living with prediabetes as those aged 40 to 59 (4%).[47]

For older adults who are overweight or obese, dietary changes to promote weight loss should be combined with an exercise program to protect muscle mass. This is because dieting reduces muscle as well as fat, which can exacerbate the loss of muscle mass due to aging. Although weight loss among the elderly can be beneficial, it is best to be cautious and consult with a healthcare professional before beginning a weight loss program.

The Anorexia of Aging

In addition to concerns about obesity among senior citizens, being underweight can be a major problem. A condition known as the anorexia of aging is characterized by poor food intake, which results in dangerous weight loss. This major health problem among the elderly leads to a higher risk for immune deficiency, frequent falls, muscle loss, and cognitive deficits. Reduced muscle mass (**sarcopenia**) and physical activity mean that older adults need fewer kcal per day to maintain a normal weight. It is important for health care providers to examine the causes for anorexia of aging among their patients, which can vary from one individual to another. Understanding why some elderly people eat less as they age can help healthcare professionals assess the risk factors associated with this condition. Decreased intake may be due to disability or the lack of a motivation to eat. Also, many older adults skip at least one meal each day, sometimes because of financial reasons. As a result, some elderly people are unable to meet even reduced energy needs.

Nutritional interventions should focus primarily on a healthy diet. Remedies can include increasing the frequency of meals and adding healthy, high-calorie foods (such as nuts, potatoes, whole-grain pasta, and avocados) to the diet. Liquid supplements between meals may help to improve caloric intake. Health care professionals should consider a patient's habits and preferences when developing a nutritional treatment plan. After a plan is in place, patients should be weighed on a weekly basis until they show improvement.

LONGEVITY AND NUTRITION

The foods you consume in your younger years influence your health as you age. Good nutrition and regular physical activity can help you live longer and healthier. Conversely, poor nutrition and a lack of exercise can shorten your life and lead to medical problems. The right foods provide numerous benefits at every stage of life. They help an infant grow, an adolescent develop mentally and physically, a young adult achieve his or her physical peak, and an older adult cope with aging. Nutritious foods form the foundation of a healthy life at every age.

Key Takeaways

45. Government of Canada. (2016). *Obesity*. Health Canada. https://www.canada.ca/en/health-canada/services/healthy-living/your-health/lifestyles/obesity.html
46. Government of Canada. (2011). *Obesity in Canada – Health and economic implications.* https://www.canada.ca/en/public-health/services/health-promotion/healthy-living/obesity-canada/health-economic-implications.html
47. Statistics Canada. (2023, November 29). *Diabetes among Canadian adults.* https://www.statcan.gc.ca/o1/en/plus/5103-diabetes-among-canadian-adults

- Starting BMI determines how much weight a woman needs to gain throughout her pregnancy. In an average pregnancy, a woman gains an extra 30 lb.
- During the second and third trimesters, a woman's energy requirements increase by 340 kcal per day for the second trimester and 450 kcal per day for the third trimester. For the first six months of life, children should consume breast milk exclusively.
- For the next six months, solid foods should be introduced gradually into an infant's diet as parents and caregivers continue to provide breast milk.
- Breast milk is ideal for infants and provides all of the nutrients they need to grow and develop. Breastfeeding provides numerous benefits for both a mother and her infant.
- By the toddler years, young children are able to self-feed and begin to develop eating habits and preferences.
- Some food- and nutrition-related problems that can occur during the toddler years include choking, picky eating and food jags, early childhood caries, and iron deficiency anemia.
- The recommended intakes of macronutrients and micronutrients for children are higher relative to body size compared with nutrient needs during adulthood. Children's daily energy needs vary depending on their level of physical activity.
- Beginning in adolescence, some micronutrient needs begin to differ by biological sex.
- Nutritional concerns for middle-aged adults relate to menopause and the prevention of chronic disease.
- Older adults are more susceptible to medical problems, such as disability and disease, which can impact appetite, the ability to plan and prepare food, chewing and swallowing, self-feeding, and general nutrient intake.

CHAPTER ATTRIBUTION

Creation notes in Nutrition: Science and Everyday Application include attribution for unspecified content from:

- Tharalson, J. (2019). Nutri300:Nutrition. https://med.libretexts.org/Courses/Sacremento_City_College/SSC%3A_Nutri_300_(Tharalson)
- Titchenal, A., Calabrese, A., Gibby, C., Revilla, M.K.F., & Meinke, W. (2018). Human Nutrition. University of Hawai'i at Manoa Food Science and Human Nutrition Program Open Textbook. https://pressbooks.oer.hawaii.edu

United States Department of Agriculture. (2016, October). Healthy eating for preschoolers. ChooseMyPlate. https://choosemyplate-prod.azureedge.net/sites/default/files/tentips/healthy_eating_for_preschoolers.pdf)

LONGEVITY

Sarcopenia and Frailty

Learning Objectives

Why the development of frailty impacts quality of life and longevity.

- Sarcopenia is the driving force for frailty.
- The development and progression of frailty is a dynamic process.
- Progressing frailty is connected to an array of geriatric symptoms.

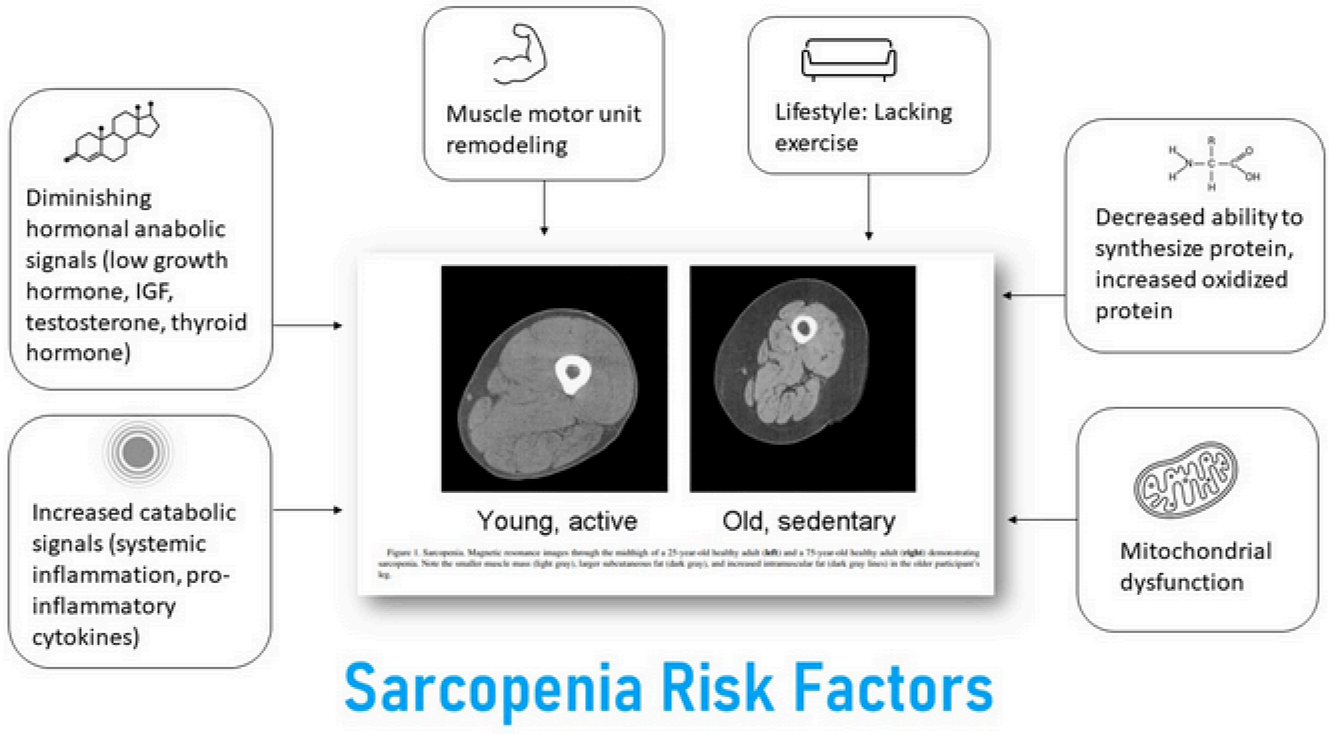
THE DEVELOPMENT OF FRAILTY IMPACTS QUALITY OF LIFE AND LONGEVITY

What are you picturing when I talk about a frail person? Most likely, you think of a very thin and delicate person that could be blown over by a strong wind. This is not necessarily the case.

Frailty can come with thinness or obesity. The main descriptor is having little strength and a decreased ability to cope with everyday stressors. Frail people are vulnerable for disability, diseases, physical and cognitive impairments and geriatric diseases such as falls, delirium and urinary incontinence. In fact, today we see an early onset of frailty—particularly in obese people living a sedentary lifestyle—and especially if they have developed chronic diseases.

The driving force behind frailty is sarcopenia, independent of weight.

RISK FACTORS FACTORS FOR DEVELOPING SARCOPENIA



[2] *Sarcopenia Risk Factors*

People can develop frailty at any point during their life. In younger people this is usually due to disease. Several risk factors that come with aging accelerate the risk for frailty.

A sedentary lifestyle leads to loss of muscle mass leading to a loss of strength over time. This is aggravated by age-associated anatomical changes leading to a remodeling of the **muscle motor unit**.

The anatomical changes limit communication between neuron and muscle fiber reducing the functionality of the muscle. Loss of muscle mass accelerates especially when the person leads a sedentary lifestyle.

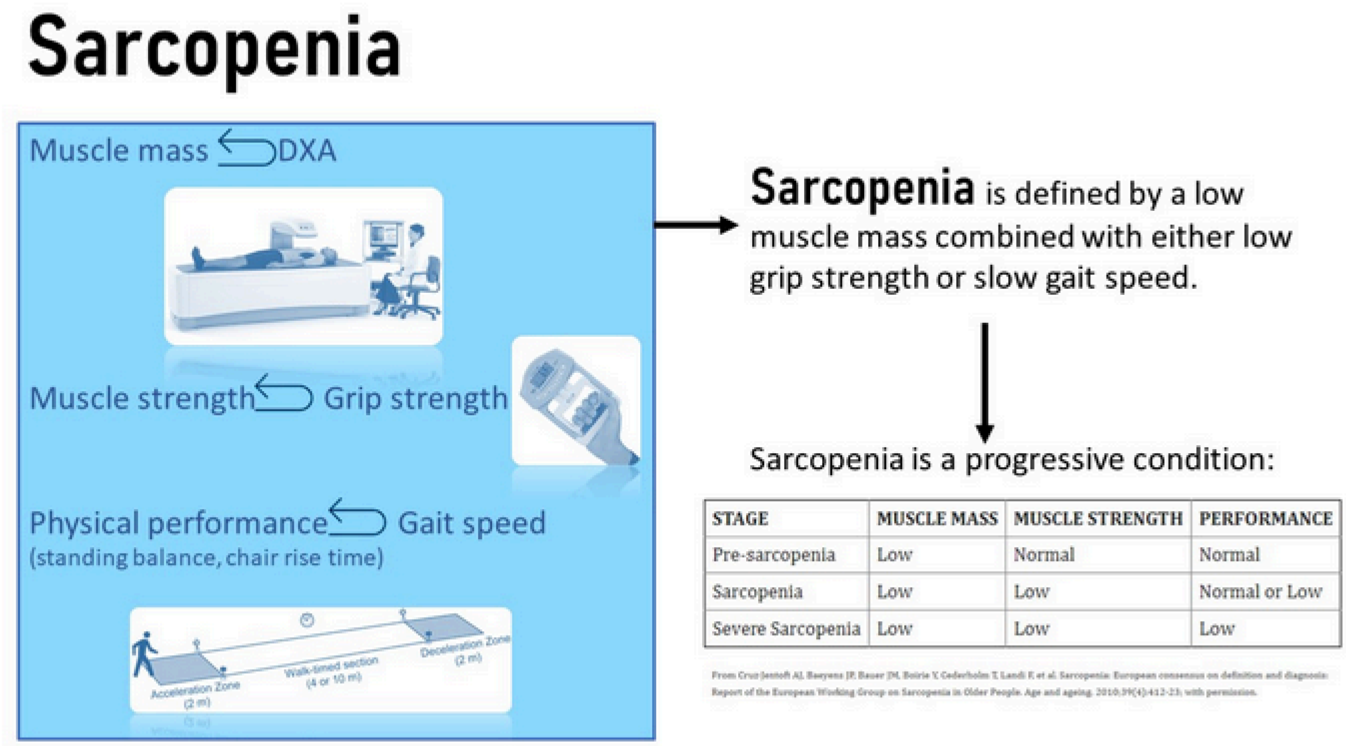
In high age metabolic changes make it harder to gain and maintain muscle. Protein synthesis becomes more inefficient (for example ER stress increases misfolding of proteins, chapter 30) and anabolic signals promoting muscle growth after physical activity such as growth hormone, IGF, testosterone and thyroid hormones decline.

Elderly people do not just lose muscle mass, they also see an increase in ectopic fat. Ectopic fat infiltrates muscles fiber and reduces muscle functionality and strength.

Increased inflammation changes muscle cell function and mitochondrial dysfunction (chapter 30) reduces available ATP in the muscle cell. The elderly person has less energy to be active, tires faster and becomes more sedentary.

These aging-associated processes increase the vulnerability for sarcopenia by themselves. In addition, obesity and chronic diseases accelerate those processes and people can develop sarcopenia earlier in life.

HOW TO DIAGNOSE SARCOPENIA



STAGE	MUSCLE MASS	MUSCLE STRENGTH	PERFORMANCE
Pre-sarcopenia	Low	Normal	Normal
Sarcopenia	Low	Low	Normal or Low
Severe Sarcopenia	Low	Low	Low

[3] *Sarcopenia diagnosis*

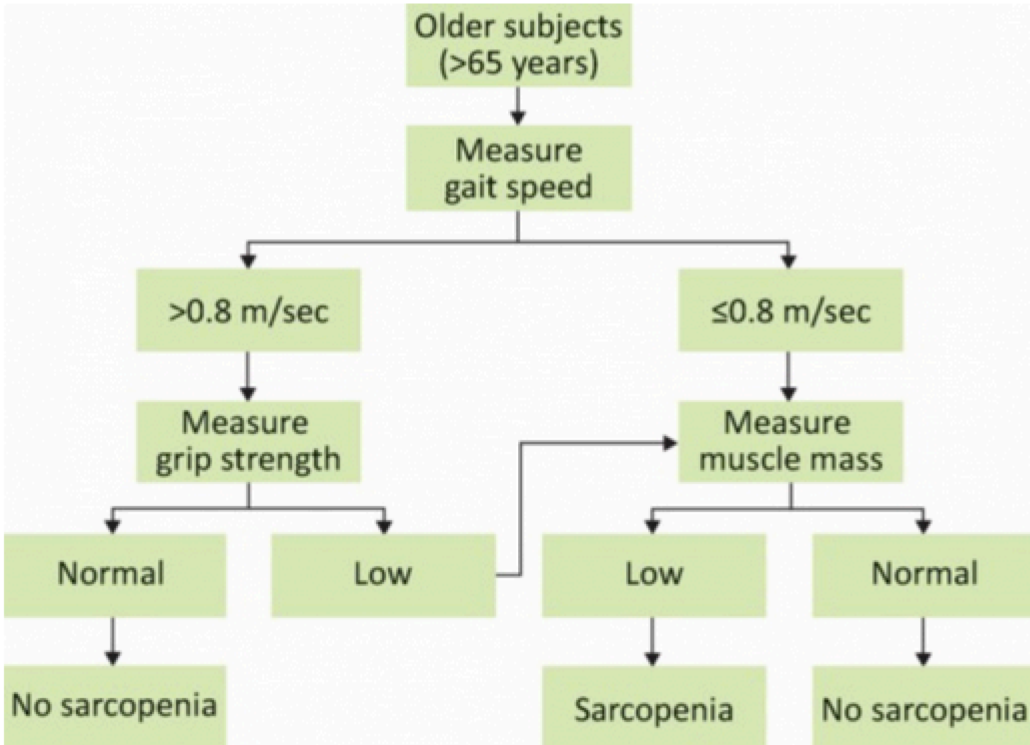
For the longest time, sarcopenia was defined as the loss of muscle mass due to inactivity or old age. However, recent studies did not find a direct connection between low muscle mass, disability, and mortality. Instead, those newer studies found a connection to disability, morbidity, cognitive decline, and lower survival times when *both* physical performance and muscle strength were impaired.

This led to a **new definition of sarcopenia** as low muscle mass combined with either low muscle strength and/ or low physical performance.

It is important to know the signs of and/or get tested for sarcopenia development. The European Working Group on Sarcopenia for Older People (EWGSOP) has developed standards for diagnostic testing, which is recommended for individuals aged 65 and older, across three parameters:

- **Physical performance:** This is usually the first test conducted and is done so by observing patient gait speed (walking speed). The standard for a normal gait speed is anything greater than 0.8 meters per second. The gait speed can be measured in a hallway and requires only a measuring tape and some masking tape to mark start and end points. The patient has 2 meters to accelerate, then walks between 4 and 10 meters at top speed. This stretch is timed and the gait speed calculated.
- **Muscle Strength:** This is tested through the use of a hand grip called a Dynamometer. Squeezing the grip will display the amount of strength in kilograms with the normal being about 28.0-44.0 kg and 15.0-27.0 kg for males and females respectively.
- **Muscle Mass:** This is usually the last test conducted, and is most commonly done through dual-energy X-ray absorptiometry (DXA). Among other mass tests, it is the most accurate at estimating the proportion of lean mass, fat, and bone density. The skeletal mass is divided by the individuals height to determine the amount of mass, while cut-offs are based on individual factors.

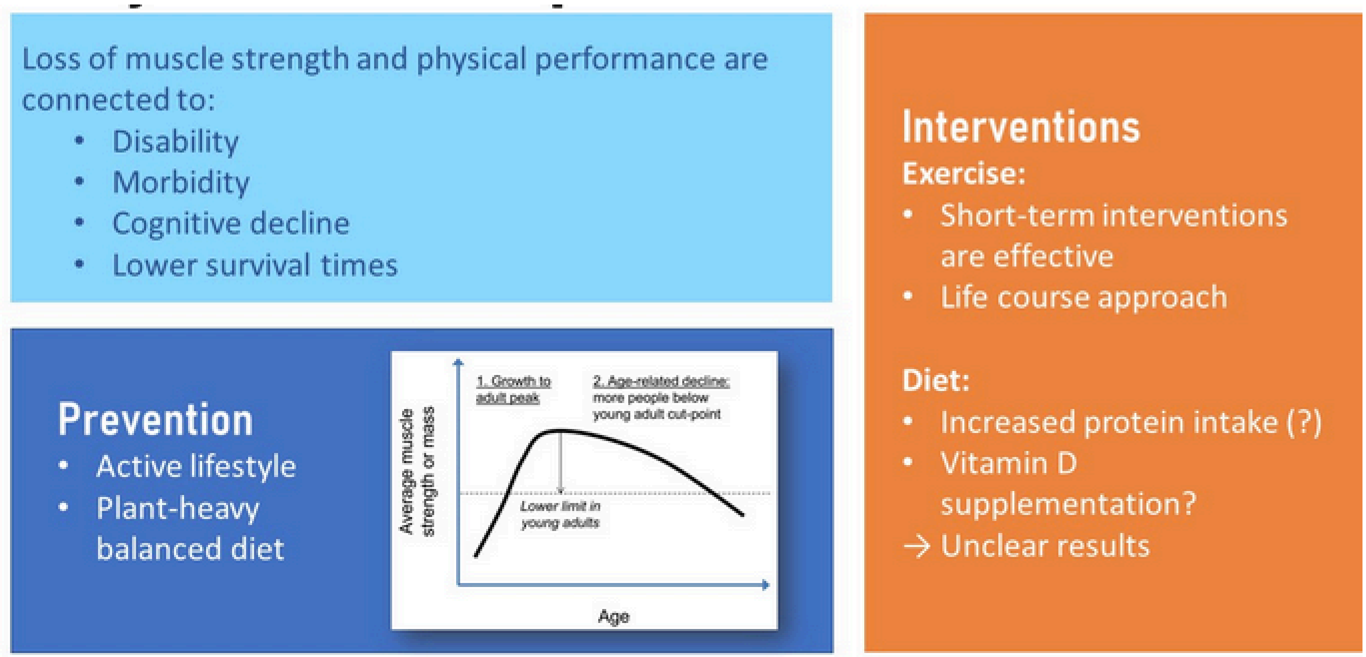
The final diagnosis of sarcopenia is done through a combination of these tests.



[Tests for diagnosis of sarcopenia](#) by Zempleni, S. and Hanzel, E., [CC BY-NC-ND 4.0](#)

PREVENTION AND TREATMENT OF SARCOPENIA

The best way to **prevent sarcopenia** is a having a healthy lifestyle in young and middle adulthood. It is similar to osteoporosis, in that developing optimal bone density will give you a reserve when bone loss naturally occurs during aging. Developing a healthy level of lean body mass and muscular strength will give you a reserve during age-related LBM decline.

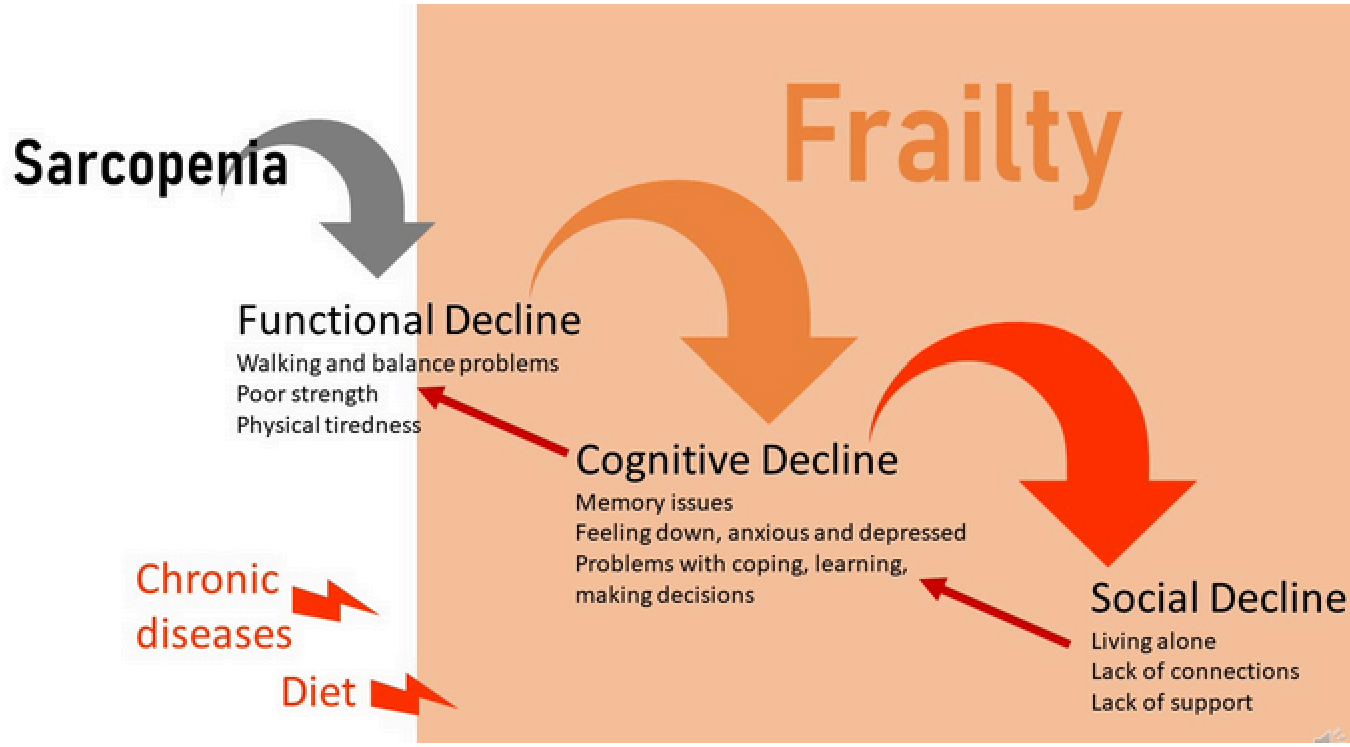


Prevention of sarcopenia by Zempleni, S. and Hanzel, E., CC BY-NC-ND 4.0

Does that mean that nothing can be done if sarcopenia develops with age? Here the research is promising. Short-term exercise interventions, including resistance training (about 5 months), have been effective in increasing quality of life and independence. Dietary interventions such as protein and vitamin D supplementation are researched as well, but with unclear results.

SARCOPENIA IS THE DRIVING FACTOR FOR FRAILTY

Failure to diagnose and effectively treat sarcopenia will inevitably lead to a state of frailty. When thinking of frailty, the word "fragile" comes to mind. If not handled with care, fragile objects can break/fall apart. While I hope you're not picking up elderly people and dropping them, someone experiencing frailty must be handled and treated with the utmost care, otherwise a cascading decline across multiple dimensions of health will begin.



Sarcopenia is driving factor for frailty by Zempleni, S. and Hanzel, E., CC BY-NC-ND 4.0

Sarcopenia leads first to a functional decline. Once people cross a certain sarcopenia threshold, poor strength and physical tiredness leads to walking and balancing problems. After developing these problems, people with sarcopenia go out less often and spend more time at home, eventually limiting physical activity entirely. Frailty sets in.

A life once full of activity and social interaction completely changes; as frail people begin spending more time alone, they tend to feel down, anxious, and depressed. Mitochondrial dysfunction also affects the brain which leads to problems with coping, learning, and making decisions.

Social isolation due to the inability to move and the avoidance of challenging situations will lead to social decline.

The three areas of frailty—functional, social and cognitive decline—are not isolated from each other. Social isolation leads to less stimulation which hastens the cognitive decline. Feeling bored and alone increase depression symptoms. Depression and social isolation leads to less movement because there is no reason to challenge oneself.

You can clearly see how sarcopenia, once it results in frailty, can start a vicious downward spiral.

THE DEVELOPMENT AND PROGRESSION OF FRAILTY IS A DYNAMIC PROCESS

[Frailty](#) by Zempleni, S. and Hanzel, E., [CC BY-NC-ND 4.0](#)

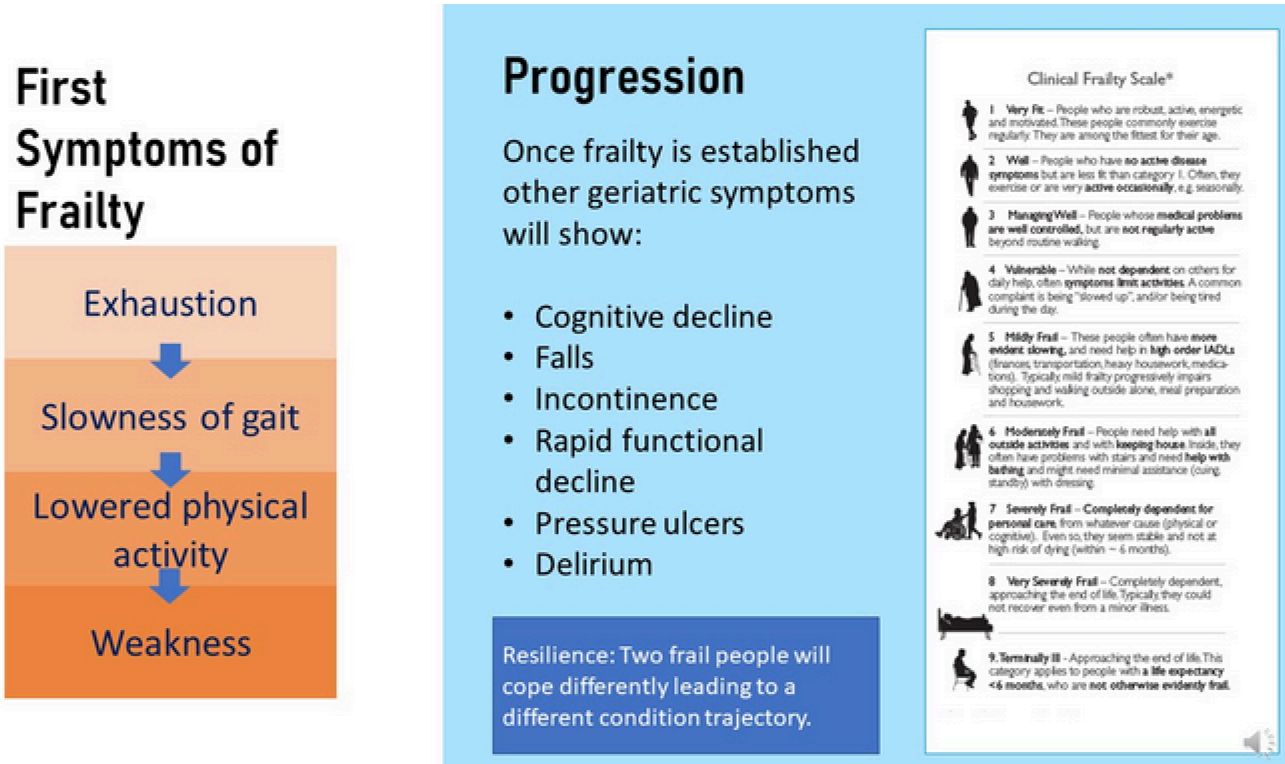
Frailty is an age-related clinical condition connected to a decline in functioning across several physiological systems, as well as an increased vulnerability to stressors. Frailty is not a straight line to death, rather the condition oscillates up and down until frailty spirals out of control and hastens death.

> *"The interconnected nature of frailty can lead to substantial declines across multiple forms of well-being. When I worked in a retirement home, multiple forms of frailty could be visibly seen in the residents. From a displeased scowl directed at the nights dinner to a resident socially isolating themselves in the corner of the dining room, it was easy to see these forms of frailty unfold.*
>
> *However, there were times when the socially isolated resident would meander over to a small table of three and engaged in small talk. I even walked into the four of them blissfully devouring dairy queen together, a interaction so humbling that branding the resident as isolated would have never have come to mind.*
>
> *This example actually represents the dynamic nature of frailty. It's not a simple linear decline towards dysfunctionality, but rather a wellbeing water slide with twists and turns that make some days great and others not so much.*
>
> *What separates the bad from the good days is usually the amount of stressors someone with frailty faces. Being in the declined state that they are, even the smallest forms of stress can have a huge impact. Waking up to find that the cereal, a routine order for one of my residents, was accidentally misplaced with a fruit bowl was too much for this resident to handle and it sent them into spiraling rage for the next few days.*
>
> *This dynamic, if not handled with care, will eventually lead to a dangerous state of frailty that contributes to health risks. Those most immediate risks include falls, delirium, and fluctuating disability. This inevitably leads to increases healthcare costs and can force some families to make the decision to admit an elderly relative to long-term care facilities or hospitals." ~ Eric*

Frailty is not equally distributed in our society. Women are more affected than men, and the more financial resources a person has, the less the aging process is connected with frailty. People with a low income cannot afford to live in an environment with ample social stimulation, a variety of exercise, or eating a healthy diet. Once frail seniors need to give up their home environment and live in a care facility, money determines their ability to live in an environment that offers cognitive and social stimulation, as well as exercise classes.

PROGRESSING FRAILTY IS CONNECTED TO AN ARRAY OF GERIATRIC SYMPTOMS

When sarcopenia reaches a threshold, the first symptoms of frailty show. The first symptom is usually undue exhaustion as daily living starts to cause excessive fatigue. Consequently, the person slows down and eventually lowers physical activity entirely. The reduced physical activity leads to more muscle loss, and general weakness sets in.



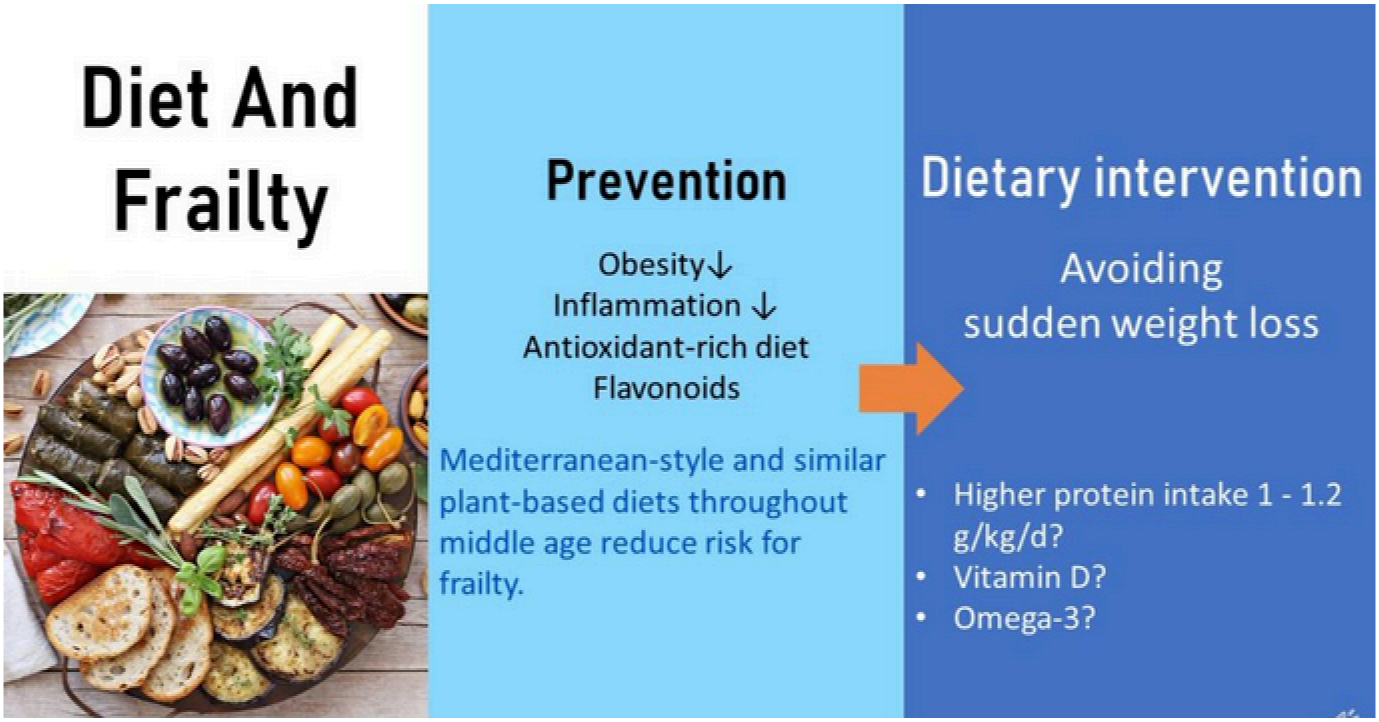
Geriatric symptoms by Zempleni, S. and Hanzel, E., *CC BY-NC-ND 4.0*

Once frailty takes hold and continues to progress, other feared geriatric symptoms can be detected, including cognitive decline, decreased strength, and balance problems. These symptoms often lead to increased instances of falls—resulting in broken bones and injuries—which further reduces physical activity and leads to an accelerated cognitive decline. Once the frail person spends most of the day in bed, pressure ulcers and delirium are feared.

In clinical settings, the clinical frailty scale (to the right in above graphic) is used to identify the degree of frailty and start appropriate interventions.

Keep in mind that people can cope very differently, and therefore the trajectory of frailty is very individual. A person that is still socially connected with plenty of family and friends will cope with a setback (for example, from a fall) easier and recuperate. Or not, if the frail person is more depressed or anxious by nature. The living environment plays a huge role here; meaningful social connections, cognitive stimulation, and continued exercising will keep the person on a much slower trajectory.

FRAILTY PREVENTION AND INTERVENTION STRATEGIES INCLUDE DIET AND EXERCISE



Diet and Frailty by Zempleni, S. and Hanzel, E., CC BY-NC-ND 4.0

Because frailty can be present in normal weight, overweight, or obese individuals, sudden weight loss is the best predictor for sarcopenia, developing frailty, and ultimately mortality. Spotting the sudden weight loss and starting lifestyle interventions can prolong life and increase quality of life.

The available knowledge for the effectiveness of nutrition intervention is limited, and no “perfect blueprint” has been found. Despite this, suggested dietary interventions generally prioritize reducing severe obesity for both easier physical activity and reduced inflammation. Generally, these goals are supported by eating a plant-heavy diet rich in antioxidants and flavonoids. At the moment, the recommended diet is a Mediterranean-style diet because studies have demonstrated a positive impact on inflammation, chronic diseases, and cognition. Because not all elderly people will accept a Mediterranean diet, similar culturally-appropriate diets such as the DASH diet are good choices as well.

The main goal of the dietary intervention is to prevent sudden weight loss, especially from muscle mass. Research has focused heavily on increased protein intake, vitamin D, omega-3 fatty acids, and antioxidant supplementation as intervention strategies. Although clinical trials have shown mixed results, the intake for these nutrients should be adequate to support maintenance of muscle mass and build reserves.

As always, prevention is better than intervention. A healthy, plant-based diet will be the first important preventative step to avoid sarcopenia and frailty. A focus on protein intake is more important once people reach old age, since most Americans have an over-adequate protein intake.

IMAGE CREDITS

1. Welch, G., Schwartz, L., Woloshin S. (2005). The exaggerated relations between diet, body weight and mortality: the case for a categorical data approach. *CMAJ 172* (7). DOI: https://doi.org/10.1503/cmaj.1041310

2. Kuk JL, Saunders TJ, Davidson LE, Ross R. Age-related changes in total and regional fat distribution. *Ageing Res Rev. 2009;8*(4):339–348. doi: 10.1016/j.arr.2009.06.001.
3. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, Cooper C, Landi F, Rolland Y, Sayer AA, Schneider SM, Sieber CC, Topinkova E, Vandewoude M, Visser M, Zamboni M; Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing. 2019 Jan 1;48*(1):16-31. doi: 10.1093/ageing/afy169.

CHAPTER ATTRIBUTION

The Risk For Malnutrition Increases With High Age

Learning Objectives

- Malnutrition is common in elderly adults due to a lack of access to meals, reduced quality of meals, and reduced mealtime experience
- Physiological changes make seniors vulnerable to malnutrition.
  - When eating difficulties develop, meals become stressful and appetite decreases.
  - Gastrointestinal changes increase satiety.
  - Risk for dehydration increases
- Nutritional status in elderly can be measured with the mini nutritional assessment.
- What can seniors do to prevent eating difficulties and reduce the risk for chronic diseases?
  - A diet for seniors should be nutrient dense and provide adequate amounts of protein.
  - Protein, vitamin B12, vitamin D, and omega-3 fatty intake need special attention.
  - Reducing cognitive decline can reduce the risk of malnutrition.

As we age, a variety of physiological and environmental changes can make it difficult to maintain a healthy lifestyle. Older individuals may begin to consume fewer calories and nutrients and/or limit physical activity as their strength decreases. This may result in malnutrition and other related health issues, which then increases risk of injury, disease, and hospitalizations. Any of these issues can ultimately speed up the aging process and lead to early death. Malnutrition may occur due to limited meal access, modified mealtime experiences, changes in meal quality, or a combination of these factors.

MALNUTRITION IS COMMON IN ELDERLY ADULTS

As we discussed in the beginning of the unit, growing older involves some decrease in body functioning as a whole, and on a cellular level, no matter how healthy of a lifestyle was lived. Declining mitochondrial function results in increased fatigue, reduced ability to fold proteins results in lower lean mass synthesis, and the accumulation of cellular garbage results in increased chronic systemic inflammation.

Depending on the genetic predisposition and the lifestyle up until the senior years, this decline may be more or less extreme, and can lead to decreased nutritional status.

Retirement is a common life event that can drastically change the daily life of an older individual. For some this may give them an opportunity to have more time with those that they love; however, for others it greatly reduces social contact, especially if the workplace was their main source of socialization and income. As the years go by, many older individuals will also lose loved ones, which further increases the risk of isolation.

Both depression and cognitive decline can lead an older individual to neglect their basic needs, such as regular consumption of nutrient-dense foods. Regular social contact and a engaging in a variety of activities can help reduce the risk of cognitive decline and depression.

In order to prevent malnutrition and other related negative consequences, older individuals are encouraged to remain member of a strong community where they can have ample social interactions. Maintaining multiple active roles, such as parent, spouse, or employee, can increase feelings of being valued and encourage a healthy outlook on life.

Something as simple as consuming meals with other people on a regular basis can increase the chances of regular food consumption, and also gives the chance for socialization.

It is clear that malnutrition is not just a problem of not eating enough or not eating quality foods.

Standard nutrition recommendation tend to focus on adequate nutrient intake, but adequate food intake depends on access to meals, the ability to purchase and prepare nutrient-dense, healthy meals, and the experience at mealtime. When giving dietary advice all meal related factors need to be considered.

Access to meals

Poverty increases with age. People over 80 years old have a higher poverty rate than any other age group in the US. The poverty rate in elderly increases from 8.4% in 65 to 69 year old adults to 11.1% in the 80+ year old group. The group of seniors most affected are Black and Hispanic Americans and never-married, single women over 65 years old (18%, 17%, 17% respectively). As you have learned in the food insecurity chapter, poverty is a major predictor for the inability to purchase sufficient quality and quantity of foods.

Especially in senior living alone increasing frailty, cognitive decline, loss of vision and hearing, and decreasing dexterity makes it difficult to go to a grocery store, purchase food and transport the food home. At home difficulty preparing meals and observing food safety rules can hinder eating regular meals.

Meal quality

Since all functions decline in high age the gastrointestinal tract is not an exemption. The ability to properly digest foods and extract nutrients decreases due to gastrointestinal decline in old age. Therefore nutrient dense meals providing plenty of nutrients and phytonutrients become even more necessary. Balanced nutrient-rich meals can counter age-related inflammation, provide sufficient amounts of protein to counter loss of muscle mass and provide the energy to support daily physical activity. Meals also need to have an enjoyable flavor and texture so seniors can enjoy meals.

Mealtime Experience

Nutrition professionals tend to think about food quality and quantity but with increasing age it becomes more and more important to consider the mealtime experience as well. The best tasting healthiest meal is not enjoyable if all meals are eaten alone. As we all know companionship during a meal allows us to enjoy meals and therefore eat sufficient amounts of food. Elderly lonely eaters are more likely to eat less.

One hallmark of aging is the loss of resilience. Stress and loneliness can affect older individuals more severely. Stress and anxiety becomes aggravated with decreasing social interactions and mobility. These factors can discourage elderly individuals from regularly consuming balanced meals or partaking in physical activity.

Fatigue may also be related to the ability to have the strength for eating. This may mean that the individual has to rely on someone else to feed them which may not always be an option. This same principle applies to fluid consumption. Some elderly individuals may not be able to easily access fluids or intentionally decline fluids to reduce the amounts of times they use the bathroom because they need assistance to complete each of these tasks.

The mealtime experience can change immensely due to chronic diseases. Taste and appetite are changing profoundly in seniors dealing with age related diseases. In addition illnesses such as stroke or loss of teeth can reduce the ability to chew and swallow making meal times a stressful time of the day. Diseases resulting in restrictive diets may also make finding palatable foods more difficult.

Looking at the chart above you will see that malnutrition is common especially in hospital and rehabilitation settings. 86 to 91% of seniors being treated for a disease or recovering from a diseases experience malnutrition or are at a risk for it. Around 60% of seniors living at home are well-nourished. This prevalence declines to a third if seniors are living in a nursing home.

During the next section you will learn about physiological factors contributing to malnutrition in more detail.

PHYSIOLOGICAL CHANGES MAKE SENIORS VULNERABLE TO MALNUTRITION

When Eating Difficulties Develop Meals Become Stressful and Appetite Decreases

Appetite is the body's natural tendency to desire food. As we age, we may experience anorexia, or lack of appetite. Lack of appetite can be due to the above mentioned sociopsychological factors, but also due to physiological changes causing difficulty eating. The entire situation can lead to skipping meals or eating only very small amounts of food. Either way energy and nutrient intake will become inadequate.

It is not clear if in healthy aging taste and smell perception declines. It is more likely that this decline is connected to age-related diseases. This can lead to an increased desire for additional spices or flavorings for foods. While some may opt for increasing the salt or sugar content of the meal to make up for it, this may not always be the best option. Increasing salt intake can contribute to hypertension most seniors develop. High sugar intake is not ideal since insulin production is not optimal in high age.

A much better solution is to add umami flavors to meals. Foods that amp up the savory flavor of food are mushrooms, especially dried and powders, tomatoes, some herbs, and fish.

Difficulty chewing develops with lose teeth, loss of teeth, or ill-fitting dentures. Harder to chew foods such as steak, crunchy foods, or vegetables might not be an option anymore.

Difficulty swallowing is medically defined as dysphagia. The most common cause for dysphagia is dementia, Parkinson's, cancer, and stroke. Another cause for dysphagia is sarcopenia of the lingual musculature, decrease in size and strength of muscle fibers.

Often dysphagia is overlooked, and the senior slips rapidly into malnutrition. A speech pathologist can conduct a swallow study and determine appropriate treatment. This can include tongue strengthening exercises, such as tongue pressing and effortful swallow, but also a collaboration with a clinical dietitian who changes the consistency of foods to match swallowing ability.

Dysphagia diets have multiple levels including pureed, mechanically altered, and soft foods. Individuals with dysphagia may also need liquids thickened in order to prevent aspiration, or fluid going into the lungs. These levels are categorized as thin, nectar-thick, honey-thick, and spoon-thick.

Eating only pureed or semi-liquid food is not enhancing the enjoyment of eating. Recently, 3-D printer enable dietitians to print food that are adequate for the swallowing difficulties but look more visually appealing.

There may be other medical reasons for changing the diet such as declining organ function. Individuals with heart issues may be required to consume low amounts of sodium and fat. Some may be on carbohydrate restrictive diets due to diabetes or other related health conditions.

These diets can at times be limiting and make finding suitable foods more difficult. It is important to find a balance between strictly following the diet and providing some leeway so that the individual is actually consuming food and can maintain quality of life.

GASTROINTESTINAL CHANGES INCREASE SATIETY

When you talk to seniors about eating and digestion you will often hear a long list of foods that produce digestive problems. The reason for this is age-related changes of digestion. Food intolerances seem to be more common, but are less researched.

In general, gastrointestinal transition time slows down, and enzymes activity decreases. These changes can cause issues such as constipation and reduced ability for nutrient extraction.

Digestion begins in the mouth. Some seniors, often in connection with chronic diseases, experience a reduction in salivary production. This could be due to medications or neurological issues. Lack of saliva makes chewing and swallowing difficult. Dysphagia can develop and drastically limiting food selections.

Since gastrointestinal emptying is delayed food stays longer in the stomach. Some studies also show that less food extends the stomach faster. The stomach has pressure sensors and sends signals to produces less ghrelin. Satiety sets in faster and lasts longer.

Intestinal motility also declines, and food travels slower through the GI tract. Because of all of this, older individuals often eat less.

While changes in ghrelin and leptin secretion are less researched and unclear, we know quite a bit about two of the hormones secreted by the gastrointestinal tract during digestion: **Cholecystokinin** (CCK) and **Glucagon-Like Peptide-1** (GLP-1).

CCK is secreted by cells in the **duodenum** when stomach content is released. One of its functions is to regulate gastric emptying. In older people receptors are more sensitive, and gastric emptying is delayed. This increases satiety as CCK also seems to have a direct feedback to the satiety center in the hypothalamus. CCK also stimulates the gall bladder to contract and release bile into the duodenum which assists in fat digestion.

GLP-1 is involved in blood glucose regulation and insulin secretion. GLP-1 is secreted by the intestine in reaction to the presence of carbohydrates and stimulate the secretion of insulin before glucose is absorbed into the blood stream. GLP-1 also feeds back to the stomach and the hypothalamus regulating gastric emptying and signaling satiety. During advanced aging, high fat meals stimulate an increased secretion of GLP-1 which increases satiety.

Chronic inflammation of the stomach lining, common in elderly people, and reduced stomach acidity can make digestion of certain nutrients, such as vitamin B12, more difficult. Medications can also affect the pH of stomach acid. One of the purposes of the hydrochloric acid is to reduce pathogens in the food. Less stomach acid means a higher risk for foodborne illnesses.

RISK FOR DEHYDRATION INCREASES

Just as the gastrointestinal tract changes, renal function often declines as an individual ages. While some of this decline occurs naturally, the process can be sped up with regular use of medications and chronic conditions such as diabetes. Reduced renal function as well as a declining thirst mechanism can cause issues in hydration maintenance.

This can lead to increase risk of dehydration. Some issues with dehydration include kidney stones and hypovolemic shock.

NUTRITIONAL STATUS IN ELDERLY CAN BE MEASURED WITH THE MINI NUTRITIONAL ASSESSMENT

The first step in preventing and treating malnutrition is to assess the nutritional status. The Mini Nutritional Assessment or MNA® is a screening and assessment tool used for individuals over the age of 65 who are at risk or currently experiencing malnutrition. It was originally developed in the 1990s and has evolved over time.

The original full MNA was developed to provide a simple, reliable way to screen nutritional status of persons over age 65 and to add a nutrition component to the Comprehensive Geriatric Assessment. The full MNA® has 18 items and classifies one as normally nourished, at risk for malnutrition, or malnourished. The MNA is well validated in the hospital, community, and long term care settings.

To further streamline the MNA® and make it more clinically applicable, researchers revised and revalidated the MNA®-Short Form using pooled data on the MNA® from 28 previously published studies. the new MNA®-SF is a stand-alone screening tool, eliminates the need to complete the longer full MNA®, and reduces time to screen to less than 5 minutes.[1]

WHAT CAN SENIORS DO TO PREVENT EATING DIFFICULTIES AND REDUCE THE RISK FOR CHRONIC DISEASES?

A Diet For Seniors Should be Nutrient Dense and Provide Adequate Amounts of Protein. Eating should be enjoyable and culturally appropriate. Therefore, instead of recommending a specific diet, a culturally appropriate, familiar diet should be adapted to old age.

Nutrient-dense

A diet for seniors needs to provide adequate amounts of micronutrients while avoiding empty calories. Reduced appetite and increased satiety as well as a generally reduced need for energy makes it important that food is rich in micronutrients. This will allow for healthy weight maintenance.

Adequate protein

Chewing difficulties can lead to a decreased protein intake from meat. Adequate amounts are necessary to maintain LBM though. Fish, dairy (if tolerated), and plant protein sources are easier to chew and might be an option. Protein powders might be used to supplement.

Cognition maintenance

The Mediterranean diet rich in plant foods supplies antioxidants and fish supplies omega-3 fatty acids. These nutrients are discussed to decrease age-related chronic systemic inflammation and promote a healthy gut microbiome. Studies show moderate benefits on cognition. Fatty fish and plenty of plant food can be easily incorporated in any diet.

This type of diet can be expensive. Counseling by a dietitian can identify inexpensive foods and recipes to go with and identify resources to buy food.

1. Nestle Nutrition Institute. (n.d.). *Development and validation of the MNA*. https://www.mna-elderly.com/development_and_validation.html

PROTEIN, VITAMIN B12, VITAMIN D AND OMEGA-3 FATTY INTAKE NEED SPECIAL ATTENTION

The corner posts of eating in advanced age is a nutrient dense, plant-heavy diet and adequate protein intake. This will ensure the intake of micronutrients and phytochemicals even if the older person is not eating as much anymore. In addition there are four nutrients that might need special attention due to age-related physiological changes.

Protein intake in older adults will need special attention. While most Canadians tend to eat plenty of proteins the usual protein sources such as meat and poultry might be harder to eat due to eating problems. In addition, some older individuals experience food preference changes that decrease their appetite for meat.

Studies show that elderly adults are less responsive to low amounts of amino acid to build muscle. This lack of responsiveness in elderly adults can be overcome with higher levels of protein. Therefore, daily recommendations for protein increases from 0.8 g/kg/d to 1-1.1 g/kg/d in order to maintain adequate muscle mass. Keep in mind that this is a subtle increase equating at most 1 deck-of-card serving of chicken. Inadequate consumption of protein and calories can result in loss of lean muscle mass.

Amino acids have other metabolic functions. This includes immune system, wound healing, blood pressure and bone health. Inadequate protein intake will impair the immune system and wound healing which could mean increased hospitalization time which is in itself a factor contributing to an increased risk of malnutrition.

Vitamin B12 is another nutrient of concern. Around 20% of seniors have mild vitamin B12 deficiency that results in neurological symptoms similar to early dementia symptoms such as memory loss, lack of physical coordination, vision problems, and difficulty speaking. The diagnosis is rather dementia and not vitamin B12 deficiency because only severe vitamin B12 deficiency will produce pernicious anemia which is easier to diagnose.

The risk for mild vitamin B12 deficiency is related to a chronic inflammation of the stomach lining, atrophic gastritis. Stomach ulcers and certain medications can also cause issues in absorption.

Why is vitamin B12 more susceptible to digestion and absorption issues in high age? The digestion mechanism is very complex and involves several steps as you see on the slide above. The key step impacting vitamin B12 absorption in old age is a reduced production of intrinsic factor by the parietal cells in the stomach. If the stomach lining is chronically inflamed the secretory function of stomach cells declines. Over time the chronic inflammation will lead to replacement of healthy stomach tissue with fibrous tissue.

Most of the **vitamin D** we need is produced in the top layers of the skin through sun exposure. Food sources for vitamin D are slim and only fish and eggs contain naturally good amounts of vitamin D. The remaining food sources are vitamin D fortified milk, plant milks, and cereals.

With age the ability to produce vitamin D in the skin becomes less effective. In addition, frail seniors might not spend a lot of time outdoors in the sun. More food vitamin D is needed, but milk, the main source of vitamin D might not be consumed due to lactose intolerance.

Vitamin D deficiency causes a variety of issues. As it is important for calcium absorption, deficiency in vitamin D limits the amount of calcium that can be absorbed. This causes the body to pull calcium from the bones, ultimately increasing risk of frailty. Vitamin D deficiency is also linked to decreased cognition, however more research is needed in this area.

Lately **omega-3 fatty acids** made it on the list of special attention nutrients for seniors. This is related to newer research results showing that adequate consumption of omega-3 fatty acids might help maintain brain health and cognitive function and improve age-related chronic systemic inflammation. Fatty fish consumption, the main source for omega-3 fatty acids is not common in landlocked parts of Canada and plant sources seem not to be as effective when it comes to cognition.

Supplementation of all these nutrients, especially if food intake is low, may be necessary to maintain adequate supply in the body.

REDUCING COGNITIVE DECLINE CAN REDUCE THE RISK FOR MALNUTRITION

There are various other lifestyle modifications besides diet that can improve health status in elderly individuals. Cognitive decline can be a normal process of aging, but a healthy lifestyle can help maintain as much cognitive ability as possible.

Not all cognitive function is affected equally by the aging process. Memory function is most affected followed by problem-solving skills and speed processing. There is currently no pharmacological treatment for cognitive decline, but a stimulating environment, a healthy diet, and plenty of exercise can prevent rapid loss.

One of the simplest ways to prevent cognitive decline is through **environmental enrichment.** This involves activities that provide the learning of new skills such as painting, playing musical instruments or reading. Stimulating hobbies can be started at any age and provide large benefits. Those with higher levels of education or people speaking more than one language show resistance to memory decline.

Another way to reduce risk of cognitive decline is through regular **exercise**. Aerobic exercise improves hippocampal memory function at any age. It is not clear if the improvement of cardiorespiratory function improves memory function or if there is a similar direct affect we see during environmental enrichment.

While less researched, high **social engagement** is correlated with hippocampal health. Group interaction seems to be more beneficial than individual relationships. As previously mentioned, regular interaction with others decreases the risk of depression, which can impair cognitive abilities.

Ensuring that the individual continues to take care of the body and mind through diet, exercise, and environmental enrichment decreases the risk of malnutrition, frailty, and overall decline of function.

FOOD INSECURITY

Perspective: Food Insecurity

FROM CHARITY TO SOLIDARITY: FOOD INSECURITY AND IMAGINING OTHER WORLDS

Learning Outcomes

After reading and discussing this text, students should be able to:

- Describe the systemic dynamics that contribute to food (in)security
- Understand the be able to express the limits of food charity
- Interpret new paradigms that can reframe food insecurity and support its solutions

INTRODUCTION

The global COVID pandemic has had far-reaching food systems implications, including for those experiencing food insecurity and for **food justice** organizations, advocates, and activists. Community-engaged scholars witnessed first-hand how food justice and allied organizations shifted the focus of their work as COVID descended. In a moment of acute and cascading crisis, many organizations returned (if perhaps temporarily) to a charitable **food bank** model. This case, looking at an example from Ontario, Canada, provides reflections on a number of themes that emerged in the intervening months related to **food insecurity**, food systems change, and broader issues of social change.

SETTING THE TABLE

How we understand the problems associated with our food systems is a function, in part, of how we conceive of our food systems in the first place. For interdisciplinary food scholars and activists, understanding food systems means being attentive to a wide range of issues, including “historically specific webs of social relations, processes, structures, and institutional arrangements that cover human interaction with nature and with other humans involving the production, distribution, preparation, consumption, and disposal of food.”[1] What this means in practice isn’t always so clear, however. Nonetheless, thinking through food insecurity, and responses to it, can help provide some clarity and demonstrate why the way we think about food systems matters.

By any measure, food insecurity is a crisis in Canada, and around the world, and it has worsened during the pandemic. The United Nations World Food Programme estimates that there are nearly 700 million food insecure people worldwide, 270 million of whom experience crisis levels of hunger, meaning that they face severe calorie

1. Koç, M., J. Sumner, and A. Winson. (2012). *Critical Perspectives in Food Studies.* Don Mills, Oxford University Press.

deficiencies and are at high risk of mortality.[2] In more stark terms, the organization estimates that between 6,000 and 12,000 people may be dying of hunger every day. In Canada, about 4.4 million people were living with food insecurity before the global pandemic.[3] By May of 2020, just a few months into the pandemic, food insecurity had risen by 39%.

It is important to keep in mind that these alarming food insecurity rates are unequally distributed across the population, so some demographic groups are much more likely to experience food insecurity than others. For example, a study conducted in Toronto found that Black households are about three-and-a-half times more likely to be food insecure than White households. Indigenous populations throughout the territory known as Canada experience rates of food insecurity from as high as 33% off reserve[4] to 100% on reserve.[5] Among all income brackets, rates of food insecurity are highest for households in the lowest income bracket, and the prevalence of food insecurity declines as household income increases.[6] These numbers (and others) demonstrate that food insecurity isn't just a food issue, narrowly conceived. Food access is structured within unequal socio-economic, cultural, and ecological systems. In other words, food insecurity is an issue of equity and justice.

One of the main ways we have attempted to address food insecurity in Canada is through food banks. While they may seem like timeless institutions, Canada's first food bank opened in Edmonton in 1981 to provide *temporary* measures to support people struggling within the compounding context of high rates of inflation, recession, and scaled-back federal unemployment and provincial social supports.[7] These interventions were always intended to be short-term, stop-gap measures, and yet, by the mid-1980s, there were over 75 food banks across Canada.[8] This was just the beginning of the normalization and institutionalization of the charitable food banking model in Canada—Food Banks Canada reports that there are now more than 3000 food banks and frontline food-serving agencies in their network.[9] The problem is, there are far more food insecure people in Canada now than ever before. So, if the point of food banks is to provide food to those in need of it, they aren't succeeding even on their own terms. In fact, research shows that only about one in five food insecure people even use food banks.[10]

In contrast to food banks, many organizations can be considered food justice organizations. These organizations don't understand food insecurity as simply the absence of food, but rather they conceive of food insecurity as a result of broader, inequitable structures resulting from colonialism, White supremacy, misogyny, and unfettered capitalism. Consequently, they also frame food insecurity as more than simply a food issue. As a result of looking at the entire food system through interdisciplinary and equity lenses, many food justice organizations understand the root causes of food insecurity as comprising intersecting social, political, and ecological inequities, and therefore propose solutions beyond food banks.

2. World Food Programme. (2020). *World Food Programme to Assist Largest Number of Hungry People Ever, as Coronavirus Devastates Poor Nations.* https://www.wfp.org/news/world-food-programme-assist-largest-number-hungry-people-ever-coronavirus-devastates-poor
3. Tarasuk, V. and A. Mitchell. (2020). Household Food Insecurity in Canada, 2017-2018. *PROOF Food Insecurity Policy Research.* https://proof.utoronto.ca/wp-content/uploads/2020/03/Household-Food-Insecurity-in-Canada-2017-2018-Full-Reportpdf.pdf*f*
4. Health Canada. (2004). Canadian Community Health Survey, Cycle 2.2, Nutrition. Income-Related Household Food Security in Canada.
5. Thompson, S., A. Gulrukh, M. Ballard, B. Beardy, D. Islam, V. Lozeznik, and K. Wong. (2011). Is Community Economic Development Putting Health Food on the Table? Food Sovereignty in Northern Manitoba's Aboriginal Communities., p,24. *The Journal of Aboriginal Economic Development 7* (2): 14–29.
6. Tarasuk, V. and Mitchell, A. (2020). Household Food Insecurity in Canada, 2017-2018. *PROOF Food Insecurity Policy Research.*
7. Wakefield, S., Fleming,J., Klassen, C., and Skinner, A. (2012). Sweet Charity, Revisited: Organizational Response to Food Insecurity in Hamilton and Toronto, Canada. *Critical Social Policy 33* (3): 427–450.
8. Riches, G. (1986). *Food Banks and the Welfare Crisis.* Canadian Council on Social Development.
9. Food Banks Canada. (2020). *Relieving and Preventing Hunger in Canada.*
10. Tarasuk, V., Fafard St-Germain, A., and Loopstra, R. (2020). The relationship between food banks and food insecurity: Insights from Canada. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations 31*, 841–852. https://doi.org/10.1007/s11266-019-00092-w

FoodShare Toronto, a leading food justice organization in Toronto, Ontario, was founded in 1985. It was originally established as a temporary initiative to coordinate among the City of Toronto's 45 front line emergency food service agencies. Very quickly, the organization understood that broader systems change was required to address the systemic and root causes of hunger. Today, FoodShare is dedicated to pursuing food justice in ways that centre the experience of those most impacted by poverty and food insecurity—Black, Indigenous, People of Colour and People with Disabilities through a variety of programs and initiatives that go far beyond the food bank model.

So, for example, rather than simply providing low-quality, highly processed food to those in need, some food justice organizations offer weekly fresh-produce box programs. Some support the establishment of farmers' markets in low-income, marginalized, and racialized communities (communities that typically don't have access to farmers' markets). In some cases, these organizations buy directly from local growers, in an attempt to address food insecurity while also supporting local, small-scale growers—attending to the struggles of both marginalized eaters and growers.

Beyond providing food for those who need it, some food justice activists, organizations and networks also agitate for policy change. As an example, there have recently been various efforts by a diverse network of food justice and other organizations to compel the federal government to institute a basic income (BI) in Canada. This means that all Canadians would be provided with a sufficient and guaranteed income to meet their basic needs, including food. Research shows that when people have a reliable and sufficient income, rates of food insecurity are significantly reduced.[11]

Other research points to the political economy of our food system, noting that food is in fact a human right, and that Canada is legally bound by international agreements to fulfill the right to food.[12] In Canada just four companies—Loblaws, Metro, Sobeys, and Walmart—control upwards of 80% of the retail market.[13] And these companies prefer establishing larger stores typically in higher-income areas, resulting in an unequal distribution of food access across Canada. Food, many advocates argue, is too important to be treated as a commodity governed by a retail **oligopoly.**

When the impact of the COVID pandemic began to be felt across Canada, and rates of food insecurity began to spike, we saw many food justice organizations—at least temporarily—adopt a food charity/food bank model. In part, this reflects the efforts of food justice organizations to respond to the increasing intensity of the food insecurity crisis during the pandemic in whatever ways they could. However, this response was also the result of the federal government nudging organizations in the food bank direction. By December 2021, the federal government made $330 million available through the Emergency Food Security Fund. These funds were disbursed through a handful of national and regional emergency food and food justice agencies to smaller, front-line serving organizations. The money was earmarked for the purchase of emergency food provisions, personal protective equipment, and to hire additional workers.[14] In other words, the Canadian federal government conscripted food banks as well as food justice and community development organizations into its efforts to address dramatically increasing rates of food insecurity across the country through charity emergency food provisioning.

11. Tarasuk, V. (2017). Implications of a Basic Income Guarantee for Household Food Insecurity. *Research Paper 24*. Northern Policy Institute.
12. Food Secure Canada. (2012). *The Right to Food in Canada.*
13. MacRae, R. (2021). *Equitable Access to the Food Distribution System.*
14. Agriculture and Agri-food Canada. (2021). Emergency Food Security Fund. https://agriculture.canada.ca/en/agricultural-programs-and-services/emergency-food-security-fund

This graphic was produced by illustrator Jason Wilkins at a webinar titled "Thinking outside the donation box," featuring Dr. Elaine Power and Dr. Rod MacRae. It captures some of the ways we can think about addressing food insecurity beyond food banks.

SOLIDARITY, NOT CHARITY

The first six months of the pandemic were profoundly challenging for many food justice organizations as they adjusted to increased demand for basic food-provisioning services, a reduced volunteer base, emotionally exhausted staff, intense uncertainty, and increasingly marginalized community members. While these challenges persist, many organizations have recalibrated within this difficult context and, in ongoing recognition of the need for food justice, are redoubling their efforts to realize broader structural social change. FoodShare, a leading food justice organization in Toronto, for example, has recently underscored their commitment to food justice, democratic control, and political mobilization as we transition out of the global pandemic.[15]

The COVID pandemic—and the spectre of new, different pandemics resulting from our corporatized and globalized food system—makes the words of feminist philosopher Val Plumwood truer now than ever before, "If our species does not survive…it will probably be due to our failure…to work out new ways to live with the earth, to repower ourselves… We will go onwards in a different mode of humanity, or not at all."[16] One way to reframe this

15. Future of Food. (2021). *FoodShare: Locally-Rooted Food Justice Approach to COVID-19 Response.* https://futureoffood.org/insights/foodshare-covid-19-response/
16. Plumwood, V. (2007). A review of Deborah Bird Rose's Reports from a Wild Country: Ethics of Decolonization. *Australian Humanities Review 42* 1–4.

sentiment within the context of food insecurity is to move beyond thinking about how to end food insecurity, to thinking about how we can create a world within which food insecurity is unthinkable.

As dissatisfying as it may be, there are no clear blueprints to direct us on how to do this. However, there are paradigms and ways of thinking that can inform the development of a comprehensive and integrated plan to transition toward more just and equitable food systems. The feminist economists J.K Gibson-Graham[17] illuminate how ways of *knowing* and *being* in the world are already informing how we can move beyond the need for charity. They see hope in reciprocal relationships, mutual support, care work, and myriad other everyday occurrences that exist outside of the formal capitalist economy. In this, they see the beginnings of a new economic ethic for the **Anthropocene** —a way of reclaiming the economy as a site of equitable decision making, not simply the accumulation of profit.

The global peasant movement, La Via Campesina, similarly understands food systems as entanglements of human-nature relationships through which to advance equity and justice, a perspective that contrasts markedly with the dominant capitalist food system within which food is treated as a simple commodity. La Via Campesina advances **food sovereignty** and **agroecology**, food systems paradigms that promote equity, democratic control, and empowerment of traditionally marginalized groups of people. In various places around the world, these approaches espoused by La Via Campesina have demonstrably resulted in better overall nutrition and enhanced food security.[18][19]

Another paradigm that can help broaden our political imagination is the notion of mutual aid. This perspective contrasts explicitly with the charitable model by weaving ways of supporting each other into the very fabric of everyday life. It should also be noted that in contrast to some of the approaches summarized above, mutual aid assumes that it is unlikely that the state will ever substantively support food justice. However, the significant resources and policy levers of the state are still necessary for effecting change on a profound and universal basis. As the Big Door Brigade puts it, “Mutual aid is when people get together to meet each other’s basic survival needs with a shared understanding that the systems we live under are not going to meet our needs.”[20] The movement is gaining traction, and recently the United States Congresswoman Alexandria Ocasio-Cortez collaborated on the development of a Mutual Aid strategy resource. The trans-rights activist and lawyer, Dean Spade, argues that moving from charity to solidarity through mutual aid strategies “will be the most effective way to support vulnerable populations to survive, mobilize significant resistance, and build the infrastructure we need for the coming disasters.”[21]

(RE)SETTING THE TABLE

That the negative consequences of the global pandemic have been so disproportionately shouldered by those who are already struggling underscores the fundamental inequities in our world. In Canada, our initial response to deepening food insecurity was to double down on a 40-year-old food charity model that we already knew was ineffective. However, this acute crisis has also inspired many food justice organizations, activists, and scholars to intensify their commitment to food justice, and to imagine new ways of organizing our relationships with each other and nature in ways that make inequity unthinkable.

Discussion Questions

17. Gibson-Graham, J.K. (2006). *A Postcapitalist Politics*. University of Minnesota Press.
18. Ogle, B., Dao,H., Generose,M. and Hamnbraeus, B. (2012). Micronutrient Composition and Nutritional Importance of Gathered Vegetables in Vietnam. *International Journal of Food Sciences and Nutrition 52* (6): 485–99.
19. Roos, N., Islam,M. and Thilsted, S. (2003). Small Indigenous Fish Species in Bangladesh Contribution to Vitamin A, Calcium and Iron Intakes. *Journal of Nutrition 133* (11) (Suppl. 2): 4031S–26S.
20. Big Door Brigade. n.d. What is Mutual Aid? https://bigdoorbrigade.com/what-is-mutual-aid/
21. Spade, D. (2020). Solidarity Not Charity: Mutual Aid for Mobilization and Survival. *Social Text 142* (1): 131-151.

- Why might one's **social location** have an impact on their level of food (in)security?
- What other food issues might be reframed by looking at them through interdisciplinary and equity lenses?
- How can we reframe our relationship with food in our everyday lives? What are the limits of individual actions on those relationships?

Exercise

Find and compare websites of a food bank and a food justice organization in your area.

- How does each frame food?
- What activities does each organization do?
- What differences do you notice?

Additional Resources

- Big Door Brigade
- Community Economies
- Food Secure Canada
- FoodShare Toronto
- La Via Campesina
- Nourish Project

CHAPTER ATTRIBUTION

Glossary

nutrition facts tables [NFT]

Information on nutrition labels about serving size, calories, nutrients, and the percent daily value of nutrients.

Nutrition labelling

Information included on labels of packaged foods about nutrient content.

Acceptable Macronutrient Distribution Range (AMDR)

The recommended proprotion of a person's daily calories that should come from protein (10-35%), fat (20-35%), and carbohydrates (45-65%).

active transport

Form of nutrient absorption that requires both a carrier and energy in the form of ATP. This means that nutrients can be absorbed even if there are already many in the blood (against a concentration gradient)

Added sugars

Sugars and/or syrups added to food during preparation, processing, or at the table.

adipose

body fat

adulteration

substituting a poorer quality, inferior ingredient or substance into a produce reducing the quality of the original product

aerobic respiration

Process by which organisms use oxygen to turn fuels such as glucose and fatty acids, into chemical energy (ATP)

agroecology

the organisms and environment of a cultivated agricultural area.

alcohol dehydrogenase

Enzyme used to breakdown alcohol (ethanol) in the liver.

Alcohol Use Disorder

Characteristics describing the cycle of alcohol addiction: binge/intoxication stage, withdrawal/negative stage, and the preoccupation/anticipation stage.

alcoholism

The inability to control drinking due to both a physical and emotional dependence on alcohol.

amino acid pool
Amino acids from ingested proteins plus dismantled proteins that can be used by the body cells for protein synthesis.

Amino acids
building blocks of protein

anabolism
building

anaerobic
Without oxygen

anions
negatively charged electrolytes

Anthropocene
a proposed geologic epoch characterized by significant human impact on the natural world.

appetite
the psychological desire for food

ariboflavinosis
Condition of deficiency of riboflavin (vitamin B2)

Arteries
blood vessels that carry blood away from the heart and to the lungs for gas exchange and to the body cells to deliver oxygen and nutrients and to pick up wastes

atrophy
A reduction or shrinking of the size of a cell or tissue.

basal metabolic rate (BMR)
The amount of energy required by the body to conduct basic functions. For most people it is 50-70% of the total calories they require each day.

beriberi
Condition caused by deficiency of thiamin (vitamin B1)

bicarbonate

Binge drinking
consuming 5 or more alcoholic drinks per day for men, 4 or more for women

binge/intoxication stage
Stage 1 of Alcohol Use Disorder, alcohol consumption initiates the reward/pleasure system of the brain.

bioavailability
The amount of a substance that is absorbed, transported, and subsequently used in the body

blood alcohol concentration (BAC)
legal measurement used to assess intoxication and the impairment and ability to perform certain activities such as driving a car

body composition
the amount of fat tissue versus the amount of lean tissue in a body, idetified as % fat

calorie
unit of measurement of food energy; the amount of energy required to raise 1 kilogram of water 1 degree Celsius.

capillary
tiniest blood vessels

catabolism
breakdown

cations
positively charged electrolytes

cholecystokinin (CCK
hormone released from the duodenum that initiates bile release from the gallbladder

cholecystokinin (CCK)

Cholesterol
Most well known sterol in the body important for cell membrane structure and the formation of substances like hormones and bile. Found only in animal foods in the diet.

chylomicron
lipoprotein that transports lipid from the small intestine into the lymph vessel for transport to the liver

clinical signs
things that can be easily seen such as bleeding, vomiting or fainting

cofactor
A non-protein chemical compound (often a mineral) that is required for some enzymes to function.

Colostrum
breast milk produced immediately after birth and for first few days after birth; contains protein, fat soluble vitamins, minerals, and antibodies beneficial for the infant's new immune system

Complementary proteins
two or more incomplete protein foods that, when consumed together, provide all nine of the essential amino acids

complete protein sources
Foods that contain all nine essential amino acids in relatively high amounts

conditionally essential
a normally non-essential nutrient that becomes essential due to a disease, condition, or medication

confounding variables
factors other than the ones being tested in a research study that could be influencing the results. It is important to control for as many variables as possible to assure research results are valid

control group
group in a research study that does not receive any type of treatment

critical periods
Times during pregnancy where the infrastructure for body parts is developed. The developing baby is particularly vulnerable to damage caused by poor nutrition, medications, alcohol, or other harmful exposures.

Daily Value (DV)
Located on nutrition fact labels, this value represents the percentage of the recommended amount of a given nutrient per one serving of a particular food.

dehydration synthesis
Process of combining molecules by removing a water molecule. This occurs in many instances in the body including the building of macromolecules such as glycogen, storage fat, and protein.

dental caries
cavities

Dietary fibers
polysaccharides found in plants that are not digestible in humans due to lack of fiber-digesting enzymes

dioxins
Chemical compounds created during manufacturing that can pollute water sources. Fish become contaminated, and the compounds can cause cancer.

Disease
any abnormal condition affecting the health of organisms, characterized by specific signs and symptoms

disordered eating
A disturbed and unhealthy eating pattern that may or may not meet the diagnostic criteria for an eating disorder.

double blind study
a type of research study design in which neither the participant nor the researcher know in which group (treatment or control) the participant is assigned; It is a way to minimize bias

duodenum
First and smallest section of the small intestine, where the bulk of chemical digestion of foods occurs.

duration
length of an exercise session

dysphagia
impaired ability to swallow

embryo
second stage of pregnancy; multi-celled organism that implants in uterus

empty calorie
Food or beverages such as sugary sodas or candy containing calories but no beneficial nutrients

Energy balance
energy intake equals energy required

energy dense or calorie dense
Foods containing many kcal per amount consumed

energy nutrients
macronutrients that can provide energy in the form of kilocalories (kcal)

Enrichment
Replacement of nutrients that are lost with food processing.

Enzymes
proteins that catalyze specific chemical reactions by lowering the amount of energy and time it takes for the reaction to occur

Epidemiological studies
types of scientific studies that observe what happens in a population in relation to health over time in order to find risk factors for a health event; these types of studies do not determine cause

epiglottis
Small flap that covers the entrance of the trachea when you swallow to stop the bolus of food from entering the trachea instead of the esophagus

epinephrine
Hormone released from adrenal glands. Considered the "fight-or-flight" hormone, it promotes breakdown of glycogen to provide quick energy to primarily the brain in addition to increasing heart rate and blood pressure, expanding air passages in the lungs, and enlarging pupils in the eyes.

epinephrine (adrenalin)
fight-or-flight hormone released from the adrenal gland

Ergogenic aids
substances, devices, practices, or treatments that improve athletic of physical performance

essential
required by the body, and it must be consumed in the diet

essential fat
The amount of body fat a person requires to function. In males it is generally considered to be 2-5%, in females 10-12%

essential fatty acid
fatty acids that cannot be synthesized in adequate amounts by the body and must be consumed in the diet

Exercise
form of physical activity that is structured, planned, repetitive, and performed with the goal of improving health or fitness

extracellular
outside of cells

extrusion reflex
Automatic reflex where a baby will push food placed on their tongue back out of the mouth

facilitated diffusion
Transport mechanism requiring a protein carrier which shuttles molecules such as some nutrients across cell membranes. The process does not require energy so is considered passive.

female athlete triad
A condition caused by disordered eating patterns (usually insufficient calories) which leads to issues in female athletes such as irregular menstruation or amenorrhea, which can lead to low bone density (osteopenia).

fetal
third and final stage of pregnancy

fetus
final stage of pregnancy; fetal development includes maturation of organ systems until they are able to work outside the womb

food allergy
an immune response to a protein in a food product, the response can involve any area of the body: mouth, tongue, skin, GI tract, lungs, cardiovascular system, and can even cause death

food bank
a place where food—generally basic, non-perishable provisions such as rice, pasta and canned goods—can be accessed by those experiencing food insecurity.

food infections
Infection caused when ingested food contains a pathogen (bacteria, virus, etc)

food intolerance
a negative response to a food product involving primarily the gastrointestinal system (gas, bloating, cramps, diarrhea)

food intoxications
Occurs when ingested food contains a toxin such as mold or toxic pollutants

Food irradiation
The application of ionizing radiation to food that improves the safety and extends the shelf life of foods by reducing or eliminating microorganisms and insects.

food jag
A period of time where children want to eat only the same few things for several days and at every meal.

food justice
the process of eliminating oppression and inequity in food systems; note that there are multiple definitions of food justice, depending on context.

Food loss

Edible amount of food post harvest that is available for human consumption but is not consumed for any reason

Food preservation

The handling or treatment of food to prevent or slow spoilage. Preservation techniques include refrigeration, curing, smoking, canning, picking, drying, vacuum packing, and pasteurization.

Food processing

The transformation of raw ingredients into packaged foods

food secure

having adequate access to food and enough nutrients to achieve a healthy lifestyle

food sovereignty

a political framework developed by the international peasant organization, La Via Campesina, emphasizing the rights of peoples to determine their own food systems, including the production and consumption of food through methods that are environmentally, culturally, and socially sustainable.

food swamps

Neighborhoods where the food environment consists primarily of fast food and junk food, with limited healthier alternatives

Food waste

Decrease in quality or quantity of food because of the actions of food retailers, food service providers, and consumers.

Foremilk

type of mature milk secreted early in a feeding; contains water, vitamins, and protein

fortified

Nutrients added to a food product that would not naturally occur in that product.

Frequency

how often one participates in exercise; usually expressed in days per week

gastric distension

stomach stretching

genome

sequence of DNA that makes up your genes

ghrelin

hunger hormone secreted from the stomach when it is empty

gluconeogenesis

Formation of glucose from non-carbohydrate sources such as lipids and fats

glucose

main form of carbohydrate in the body

glycemic index
: numeric value given to carbohydrate-containing foods based on their ability to raise blood glucose levels

glycemic load
: An indicator of both the glycemic index and the actual effect on blood glucose a food will provide.

glycogen
: stored form of glucose in animals including humans; stored in liver and skeletal muscle

glycogenesis
: The formation of glycogen from excess glucose molecules, occurring in the liver and muscle cells

glycogenolysis
: The breakdown of glycogen to glucose for use as energy

glycolysis
: The breakdown of glucose specifically to create energy (ATP)

goiter
: Enlargement of the thyroid gland caused by a severe and chronic deficiency of iodine.

heme iron
: Form of iron that is most easily absorbed, found only in animal foods.

High-density lipoprotein
: Lipoprotein made and secreted from the liver that travels through the blood, picks up LDL, and returns it to the liver. Often called "good" cholesterol

Hind-milk
: form of mature milk released during a feeding after fore milk; contains higher levels of fat necessary for weight gain

Hunger
: physical feeling of emptiness accompanied by other symptoms caused by lack calorie intake

Hydrogenation
: Adding hydrogen atoms to an unsaturated fatty acid which allows the double bonds to break and become single bonds. Used in food processing to extend shelf life and harden fats.

hyperkalemia
: High levels of potassium in the blood which can be life threatening.

hyperplasia
: increase in cell number

hypertrophy
: increase in the size of a cell or tissue such as fat cells or muscle

hypokalemia
: Low levels of potassium in the blood.

hyponatremia
very low levels of sodium in the blood; can be life-threatening, usually caused by excessive water intake (water intoxication)

hypothyroidism
Decreased production of thyroid hormones, primarily T3 and T4.

ibid.

ileum
Third and final section of the small intestine where much nutrient absorption occurs.

incomplete protein sources
Food that contain fewer than nine of the essential amino acids

incubation period
time between exposure to a pathogen or toxin and the onset of physical symptoms

ingredients list
Required on food labeling; ingredients are listed in descending order by weight

Intensity
an estimate of how hard one is working during an exercise bout

Intermediate-density lipoprotein
remains of VLDL after transport in the blood; contains cholesterol; will become LDL

interstitial
space between cells

Interventional clinical trial studies
studies that change one variable between groups to determine causal relationships

Intoxication
When blood alcohol level exceeds the rate at which the liver can metabolize it; leading to physical and mental impairment

intracellular
within cells

intrinsic factor
substance made in the stomach that is required for vitamin B12 absorption; secretion of this substance slowly naturally declines after age 50

ions
a charged atom

Iron deficiency anemia (IDA)
Most common nutrient deficiency disease in the world, caused by inadequate iron levels in the body. Common symptoms are fatigue, weakness, pale skin, dizziness, and shortness of breath.

jejunum
Second and longest section of the small intestine where chemical digestion and absorption of nutrients occurs

kilocalorie
one thousand calories, denoted as kcal or Calorie (capital C) on nutrition food labels

kwashiorkor
Form of malnutrition that occurs when calorie intake is adequate but protein intake is lacking. It primarily affects children.

lactate (lactic acid)
Produced when oxygen is limited during physical activity; build up of lactate causes muscle fatigue

Lactation
also called lactogenesis, it is the synthesis and secretion of breast mlk

lactose intolerance
Condition where a person does not generate enough lactase so they cannot completely digest lactose. This causes gas, bloating, diarrhea, and cramping.

leptin
hormone released by fat cells; signals to the hypothalamus that eating is not required, often called the satiety hormone; helps regulate long term food intake

lipogenesis
The process that forms triglycerides from glycerol and fatty acids.

Low-density lipoprotein
Made in the liver from IDLs, transport cholesterol to the body from the liver

lower esophageal sphincter
sphincter between the esophagus and the stomach

macronutrients
Classes of nutrients needed in relatively large amounts. These include carbohydrate, protein, lipid, and water.

malnutrition
nutrient intake which does not meet calorie and/or nutrient requirements for health

marasmus
Form of malnutrition that occurs when both calories and protein intake are inadequate. It affects both children and adults.

Mature milk
final form of breast milk secreted beginning two weeks after birth; contains fore-milk and hind-milk

Metabolic homeostasis
State where nutrients absorbed match energy required to carry out biological processes

muscle motor unit
Basic functional unit of the skeletal muscle comprised of the motoneuron and the muscle fiber innervated

mycotoxins
Natural, poisonous substances contained in molds that develop in crops such as grains, nuts, and produce.

n
letter used in research studies to indicate the number of participants in the study; ex. n=150 means there are 150 participants in the study. Generally the higher the n the more credible the results of the study

negative energy balance
energy intake is less than energy required

negative feedback
a reaction that causes the output of a system to be lessened, leading to homeostasis

Negative health
level of health associated with illness, and, at the extreme, premature death

negative nitrogen balance
Amount of nitrogen excreted is greater than the amount ingested through protein intake. To compensate the body must break down proteins to meet cellular requirements. Occurs primarily when a person is diseased or is consuming a low protein diet.

niacin flush
Side effect in some people of excessive consumption of niacin (vitamin B3). Causes redness of the face, arms, chest due to vasodilation of small blood vessels. You may also experience tingling, burning and itching.

nitrogen balance
The balance between nitrogen consumed through protein intake and nitrogen losses in urine, feces, hair, nails and skin.

nixtamilization
The soaking of corn in wood ash or pickling lime to make the niacin more bioavailable. Native American cultures so it when making masa harina, the corn meal used to make corn tortillas and tamales.

Non-essential
nutrients that can be manufactured by the body in adequate amounts so consumption is not required

Non-exercise activity thermogenesis (NEAT)
Energy expended for everything a person does throughout the day that is not sleeping, eating, or sports-like activities. It consists of activities of daily living and varies greatly from person to person and day to day.

non-heme
Form of iron not well absorbed that is found in both plant and animal foods

nutrient dense
the amount of nutrients a food contains relative to the energy it provides

nutrigenetics
Identification of genetic markers in genes that modify the need for or use of various nutrients.

nutrigenomics
study of the relationships among genes, diet, and health outcomes

Nutrition assessment
: systematic process of collecting and interpreting information in order to make decisions about the nature and cause of nutrition-related health issues that affect an individual

Obese
: Condition of having excess body fat.

oligopoly
: a condition of very limited market competition dominated by a small number of firms.

organic molecule
: term used in chemistry to denote that a molecule contains the carbon atom

osmolality
: the concentration of dissolved particles (solutes) in a fluid

Osmoregulation
: control of fluid balance in the body using solutes; keeps fluids from becoming too diluted or too concentrated

osteoblasts
: bone-building cells

osteoclasts
: bone crushing cells

osteomalacia
: low bone density in adults

overload
: increasing frequency, intensity, or duration of an exercise bout to improve fitness

Overweight
: Having more weight than is typical for a particular height.

Oxytocin
: hormone involved in milk release or ejection from the breast (milk letdown)

pancreatic lipase
: Lipid digesting enzyme released from the pancreas

pathogen
: a microorganism that can cause disease

pathogens
: Bacterial or viral agents that cause illness.

pellagra
: condition caused by severe niacin (vitamin B3) deficiency

pepsin
: First active protein-digesting enzyme, found in the stomach. Pepsin begins the chemical breakdown of proteins into smaller units.

peptidases

Enzymes released from the intestinal villi that chemically digest tri- and di-peptides, splitting them into individual amino acids

peptide bonds

bonds linking amino acids together

percent daily value (% DV) of nutrients

The amount of a certain nutrient in one serving.

pH

Measure of how acidic or basic a substance is. A low pH indicates more acidic, a pH of 7.0 is considered neutral, and a high pH is more basic.

pharynx

Anatomical description of the throat area containing the epiglottis and opening of the trachea

Phospholipids

Form of lipid made up of two fatty acids attached to a hydrophilic head. Often used in cell membranes and emulsifiers

Physical activity

any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level

Physical fitness

ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and respond to emergencies

Physical training

specific use of exercise to promote fitness and strength or improved performance in a specific task

Phytochemicals

non-nutritive chemical compounds found in the edible parts of plants that provide characteristics to the plant like color, taste, smell. They may also provide health benefits beyond the traditional nutrients

pica

craving for and consumption of non-food items

polypeptides

Protein consisting of many four or more amino acids

positive energy balance

energy intake is greater than energy required

Positive health

health levels that allow a person to enjoy life and to withstand challenges

Positive nitrogen balance

Occurs when nitrogen intake via protein consumption is greater than nitrogen excretion. This occurs during times of child growth, pregnancy, and wound healing.

preoccupation/anticipation stage
Stage 3 of Alcohol Use Disorder. The drinker seeks out alcohol to combat the negative and stressful withdrawal, leading to additional and continued consumption of alcohol.

Preventive nutrition
dietary practices for reducing disease and promoting health

primary deficiency
nutrient deficiency caused by inadequate intake

primary nutrient deficiency
deficiency of a nutrient caused by inadequate intake

proenzyme
an inactive precursor to an active or functional enzyme

progression
small, continual changes in overload with subsequent adaptation to the imposed stressor resulting in fitness improvements

Prolactin
hormone that initiates growth of the milk duct system in breast tissue and maintains milk production in the alveoli of the breast

proteases
Enzymes that chemically digest proteins

protein energy malnutrition (PEM)
A dangerous combination of low protein intake and low calorie intake leading to malnutrition.

protein synthesis
The creation of proteins in body cells by combining amino acids is specific sequences.

protein turnover
Body processes of protein breakdown and protein synthesis

psychoactive drug
any substance that crosses the blood-brain barrier that affects brain function

pyloric sphincter
sphincter between the stomach and the small intestine

pyruvate
Product created at the end of anaerobic glycolysis

randomized
type of study where participants are assigned by chance to a particular group that compares different treatments

ribosome
Organelle of a cell where protein synthesis occurs

rickets
Condition of soft, weak, deformed bones in children caused by a deficiency of vitamin D

risk factor
characteristic that increases the risk of developing a disease

salivary amylase
Carbohydrate specific enzyme in saliva that begins to chemically break down amylose and amylopectin into smaller chains of glucose

sarcopenia
reduction of muscle mass in the body; often accompanies aging

satiety
the sensation of being full

scientific method
a system by which a hypothesis is developed based on observation, then the hypothesis is tested and modified based on the outcome of tests and experiments

secondary deficiency
Adequate intake of a nutrient occurs, but for some reason the body cannot use it so deficiency signs and symptoms occur.

secondary nutrient deficiency
nutrient deficiency that occurs when a person consumes an adequate amount of a nutrient, but for some reason the body cannot use what is consumed

secretin
hormone released from the duodenum that initiates release of pancreatic juices containing macronutrient-digesting enzymes and bicarbonate for neutralizing hydrochloric acid from the stomach

Sedentary behavior
Lack of physical activity or activities where energy expenditure is no more than 1.5 times the amount of energy expended while at rest. This includes sitting, reclining, or lying down while awake.

smoke point
term used to describe the termperature at which an oil stops shimmering and starts smoking. Based on the chemical composition of the oil, smoke points can range from 325-520 degrees Fahrenheit

social location
the groups to which people belong, due to their position in history and society.

specificity
sports training that is relevant and appropriate to the sport for which the individual is training. Only those muscles most used during training will adapt to the imposed demands.

sphincters
muscular rings separating digestive organs that open and close to allow food to move through the digestive tract in a more orderly fashion

starches
stored form of carbohydrate in plants

Sterols
Form of lipid made up of several ringed structures.

storage fat
The amount of body fat beyond that which is required for essential body functioning. This fat provides energy for movement and other body processes.

subcutaneous
fat found directly beneath the skin

subcutaneous fat
body fat found under the skin

symptoms
things that cannot be easily seen and are usually reported by a patient such as headache, dizziness, pain, or nausea

thermic effect of food (TEF)
The energy it takes to digest, absorb, transport, and store nutrients from a meal.

thermoregulation
balancing heat gain with heat loss to maintain homeostasis

total daily energy expenditure (TDEE)
Total number of kcals a person expends daily. It is made up of BMR, energy spent on physical activity, TEF, and NEAT.

toxicity
being "toxic" or poisonous - able to cause damage to the body

toxin
poisonous substance produced within living cells or organisms

trachea
Tube that carries air from the mouth and nose into the lungs

transamination
transformation process that changes one amino acid into another by modifying the R group

transcription
First step of protein synthesis where the gene recipe for a protein is copied onto messenger RNA (mRNA)

Transitional milk
form of breast milk released from 2-4 days after birth until about 2 weeks after birth; includes high levels of fat, lactose, and water soluble vitamins

translation
Second step of protein synthesis where the gene-coded recipe for a protein on the messenger RNA is followed

and amino acids are combined in a specific order to make a unique protein. Translation occurs in the ribosome of a cell.

Triglycerides
Type of lipid made up of a glycerol backbone attached to three fatty acids; the most common form of lipid in the body and in food

Very low-density lipoproteins
lipoproteins made in the liver that transport fat from liver to the body cells

visceral
fat located in and around body organs

visceral fat
body fat centrally located around abdominal organs

withdrawal/negative affect stage
Stage 2 of Alcohol Use Disorder. In this stage the body experiences withdrawal symptoms when alcohol is not consumed.

zygote
a fertilized egg; first stage of pregnancy

Appendix A: Comparison of Dietary Reference Intake Values

Adult men and women daily values for micronutrients with the tolerable upper intake levels (UL), safe upper levels (SUL), and guidance levels.

This table compares the typical levels of recommended daily nutrient intake (RDA and AI), Tolerable Upper Intake Levels (ULs) and the United Kingdom's Safe Upper Levels (SULs). The Recommended Dietary Allowance (RDA) and Adequate Intake (AI) values are considered to be levels of nutrient intake that meet or exceed the needs of practically all healthy people. The Daily Value amounts, that are currently used as reference values on food and supplement labels, are similar to the RDA/AI values, but differ in some cases. UL values are the amounts that are considered to be the maximum safe level of intake from food and supplements combined. SUL values are the maximum level of intake of a nutrient from dietary supplements that can be considered to be reasonably safe.

HOW MUCH IS TOO MUCH?

Comparison of Dietary Reference Intake Values (for adult men and women) and Daily Values for Micronutrients with the Tolerable Upper Intake Levels (UL),[a],[c] Safe Upper Levels (SUL),[d] and Guidance Levels[d]

Nutrient	RDA/AI[b] (men / women) ages 31-50	Daily Value (Food Labels)	UL[c]	SUL or Guidance Level[d]	Selected Potential Effects of Excess Intake
Vitamin A (mcg)	900 / 700	1500 (5000 IU)	3000	1500** (5000 IU)	Liver damage, bone & joint pain, dry skin, loss of hair, headache, vomiting
beta-Carotene (mg)	–	–	–	7 (11,655 IU)	Increased risk of lung cancer in smokers and those heavily exposed to asbestos
Vitamin D (mcg)	15 (600 IU)	10 (400 IU)	100	25 (1000 IU)	Calcification of brain, arteries, increased blood calcium, loss of appetite, nausea
Vitamin E (mg)	15	20 (30 IU)	1000	540 (800 IU)	Deficient blood clotting
Vitamin K (mcg)	120 / 90*	80	–	1000**	Red blood cell damage/anemia; liver damage
Thiamin (B1) (mg)	1.2 / 1.1	1.5	–	100**	Headache, nausea, irritability, insomnia, rapid pulse, weakness (7000+ mg dose)
Riboflavin (B2) (mg)	1.3 / 1.1	1.7	–	40**	Generally considered harmless; yellow discoloration of urine
Niacin (mg)	16 / 14	20	35	500**	Liver damage, flushing, nausea, gastrointestinal problems
Vitamin B6 (mg)	1.3	2	100	10	Neurological problems, numbness and pain in limbs
Vitamin B12 (mcg)	2.4	6	–	2000**	
Folic acid (mcg)	400	400	1000	1000**	Masks B12 deficiency (which can cause neurological problems)
Pantothenic acid (mg)	5*	10	–	200**	Diarrhea & gastrointestinal disturbance (10,000+ mg/day)
Biotin (mcg)	30*	300	–	900**	No reports of toxicity from oral ingestion
Choline (mcg)	550/425*	–	3500	–	Fishy body odor (trimethylaminuria), hepatotoxicity
Vitamin C (mg)	90 / 75	60	2000	1000**	Nausea, diarrhea, kidney stones
Boron (mg)	–	–	20	9.6	Adverse effects on male and female reproductive system
Calcium (mg)	1000	1000	2500	1500**	Nausea, constipation, kidney stones
Chloride (mg)	2300*	3400	3600	–	Increased blood pressure in salt-sensitive individuals (when consumed as sodium chloride)
Chromium (mcg)	35/25*	120	–	10,000**	Potential adverse effects on liver and kidneys; picolinate form possibly mutagenic
Cobalt (mg)	–	–	–	1.4**	Cardiotoxic effects; not appropriate in a dietary supplement except as vitamin B-12
Copper (mcg)	900	2000	10000	10000	Gastrointestinal distress, liver damage
Fluoride (mg)	4 / 3*	–	10	–	Bone, kidney, muscle, and nerve damage; supplement with professional guidance
Germanium	–	–	–	zero**	Kidney toxin; should not be in a dietary supplement
Iodine (mcg)	150	150	1100	500**	Elevated thyroid hormone concentration
Iron (mg)	8 / 18	18	45	17**	Gastrointestinal distress, increased risk of heart disease, oxidative stress
Magnesium (mg)	420 / 320	400	350[e]	400**	Diarrhea
Manganese (mg)	2.3 / 1.8*	2	11	4**	Neurotoxicity
Molybdenum (mcg)	45	75	2000	zero**	Gout-like symptom; joint pains; increased uric acid
Nickel (mcg)	–	–	1000	260**	Increased sensitivity of skin reaction to nickel in jewelry
Phosphorus (mg)	700	1000	4000	250**	Alteration of parathyroid hormone levels; reduced bone mineral density
Potassium (mg)	4700*	3500	–	3700**	Gastrointestinal damage
Selenium (mcg)	55	70	400	450	Nausea, diarrhea, fatigue, hair and nail loss
Silicon (mg)	–	–	–	700	Low toxicity; possibility of kidney stones
Sodium (mg)	1500*	2400	2300	–	Increased blood pressure in salt-sensitive individuals (when consumed as sodium chloride)

Vanadium (mg)	–	–	1.8	zero	Gastrointestinal irritation; fatigue
Zinc (mg)	11 / 8	15	40	25	Impaired immune function, low HDL-cholesterol

[a]Food and Nutrition Board, Institute of Medicine (U.S.). Dietary Reference Intakes Tables.

[b](RDA) = Recommended Dietary Allowance, AI = Adequate Intake, indicated with *

[c]UL = Tolerable Upper Intake Level (from food & supplements combined)

[d]SUL = Safe Upper Levels; SULs and Guidance Levels (indicated by **) set by the Expert Group on Vitamins and Minerals of the Food Standards Agency, United Kingdom. These are intended to be levels of daily intake of nutrients in dietary supplements that potentially susceptible individuals could take daily on a life-long basis without medical supervision in reasonable safety. When the evidence base was considered inadequate to set a SUL, Guidance Levels were set based on limited data. SULs and Guidance Levels tend to be conservative and it is possible that, for some vitamins and minerals, greater amounts could be consumed for short periods without risk to health. The values presented are for a 60 kg (132 lb) adult.

Consult the full publication for values expressed per kg body weight. FSA publication, Safe Upper Levels for Vitamins and Minerals

[e]The UL for magnesium represents intake specifically from pharmacological agents and/or dietary supplements in addition to dietary intake.

CHAPTER ATTRIBUTION

Version History

Clinical Nutrition is a remixed adapted open textbook created with content from the following open textbooks:

- Consumer Nutrition by Megan Grimsley and Susan Kazen published in 2021 under a CC BY-NC-SA license.
- Nutrition: Science and Everyday Application by Alice Callahan, Heather Leonard, and Tamberly Powell; Lane Community College, published in 2021 under a CC BY-NC license.
- Human Nutrition in a Canadian Context by Karine Hamm published by BCcampus in 2021 under a CC BY License.
- Nutrition Through the Lifecycle by Sabine Zempleni
- Food Studies: Matter, Meaning, Movement by David Szanto, Amanda Di Battista, and Irena Knezevic published by ecampus Ontario in 2022 under a CC BY-NC-SA license.

NSCC EDITION CHANGES

- All in-text citations changed to footnotes to increase readability.
- Chapter formatting changed to provide consistency, and meet accessibility standards.
- Image attribution statements revised for clarity and to ensure CC license conditions are met. Problematic images removed.

NSCC Edition Remix Mapping	
Introduction	
Introduction to Nutrition	Chapter 1 from Consumer Nutrition
Designing A Healthy Diet	
Introduction to Designing a Healthy Diet	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.0
Nutrition and Health	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.1
An Introduction to Molecules	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.2
Classification of Nutrients	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.3
Defining Nutrient Requirements: Dietary Reference Intakes	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.4
Understanding Food Labels	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.5
Tools for Achieving a Healthy Diet	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.6
Introduction to Nutrition Science and Information Literacy	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.7
The Scientific Method	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.8
Types of Research Studies and How To Interpret Them	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.9
Healthy Skepticism in Nutrition Science	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.10
Finding Accurate Sources of Nutrition Information	Designing a Healthy Diet (Unit 1) from Nutrition: Science and Everyday Application 1.11
Nutrition and the Human Body	Chapter 4 from Consumer Nutrition
Water and Electrolytes	
Introduction	Chapter 4 Human Nutrition in a Canadian Context 4.0
Overview of Fluid and Electrolyte Balance	Chapter 4 Human Nutrition in a Canadian Context 4.1
Water's Importance to Vitality	Chapter 4 Human Nutrition in a Canadian Context 4.2
Regulation of Water Balance	Chapter 4 Human Nutrition in a Canadian Context 4.3
Electrolytes Important for Fluid Balance	Chapter 4 Human Nutrition in a Canadian Context 4.4
Sodium	Chapter 4 Human Nutrition in a Canadian Context 4.5
Chloride	Chapter 4 Human Nutrition in a Canadian Context 4.6
Potassium	Chapter 4 Human Nutrition in a Canadian Context 4.7
Consequences of Deficiency or Excess	Chapter 4 Human Nutrition in a Canadian Context 4.8
Water Concerns	Chapter 4 Human Nutrition in a Canadian Context 4.9
Popular Beverage Choices	Chapter 4 Human Nutrition in a Canadian Context 4.10
Carbohydrates	
Introduction	Chapter 5 Human Nutrition in a Canadian Context 5.0
Digestion and Absorption of Carbohydrates	Chapter 5 Human Nutrition in a Canadian Context 5.1
The Functions of Carbohydrates in the Body	Chapter 5 Human Nutrition in a Canadian Context 5.2
Health Consequences and Benefits of High-Carbohydrate Diets	Chapter 5 Human Nutrition in a Canadian Context 5.3
Carbohydrates and Personal Diet Choices	Chapter 5 Human Nutrition in a Canadian Context 5.4
Lipids	
Introduction	Chapter 6 Human Nutrition in a Canadian Context 6.0

Molybdenum	Chapter 12 Human Nutrition in a Canadian Context 12.8
Fluoride	Chapter 12 Human Nutrition in a Canadian Context 12.9
Summary of Trace Minerals	Chapter 12 Human Nutrition in a Canadian Context 12.10
Life Cycle	
Nutrition Through the Lifecycle	Chapter 16 in Consumer Nutrition
Longevity	
Obesity, Sarcopenia, and Frailty Prevent Longevity	Chapter 31 in Nutrition Through the Lifecycle
The Risk For Malnutrition Increases With High Age	Chapter 32 in Nutrition Through the Lifecycle
Food Insecurity	
Perspective: Food Insecurity	Perspective: Food Insecurity in Food Studies: Matter, Meaning, Movement
Glossary	
Appendix A: Comparison of Dietary Reference Intake Values	Appendix in Human Nutrition in a Canadian Context