2.3: The Digestive System

Skills to Develop

- Learn about the digestive system

The process of digestion begins even before you put food into your mouth. When you feel hungry, your body sends a message to your brain that it is time to eat. Sights and smells influence your body’s preparedness for food. Smelling food sends a message to your brain. Your brain then tells the mouth to get ready, and you start to salivate in preparation for a meal.

Once you have eaten, your digestive system (Figure \(\PageIndex{1}\)) starts the process that breaks down the components of food into smaller components that can be absorbed and taken into the body. To do this, the digestive system functions on two levels, mechanically to move and mix ingested food and chemically to break down large molecules. The smaller nutrient molecules can then be absorbed and processed by cells throughout the body for energy or used as building blocks for new cells. The digestive system is one of the eleven organ systems of the human body, and it is composed of several hollow tube-shaped organs including the mouth, pharynx, esophagus, stomach, small intestine, large intestine (colon), rectum, and anus. It is lined with mucosal tissue that secretes digestive juices (which aid in the breakdown of food) and mucus (which facilitates the propulsion of food through the tract). Smooth muscle tissue surrounds the digestive tract and its contraction produces waves, known as peristalsis, that propel food down the tract. Nutrients, as well as some non-nutrients, are absorbed. Substances such as fiber get left behind and are appropriately excreted.
Figure 1: Digestion Breakdown of Macronutrients.

Digestion converts components of the food we eat into smaller molecules that can be absorbed into the body and utilized for energy needs or as building blocks for making larger molecules in cells.

everyday connection

Figure 2: Image by Gabriel Lee / CC BY-NC-SA.

There has been significant talk about pre- and probiotic foods in the mainstream media. The World Health Organization defines probiotics as live bacteria that confer beneficial health effects on their host. They are sometimes called “friendly bacteria.” The most common bacteria labeled as probiotic is lactic acid bacteria (lactobacilli). They are added as live cultures to certain fermented foods such as yogurt. Prebiotics are indigestible foods, primarily soluble fibers, that stimulate the growth of certain strains of bacteria in the large intestine and provide health benefits to the host. A review article in the June 2008 issue of the Journal of Nutrition concludes that there is scientific consensus that probiotics ward off viral-induced diarrhea and reduce the symptoms of lactose intolerance.[1]

Expert nutritionists agree that more health benefits of pre- and probiotics will likely reach scientific consensus. As the fields of pre- and probiotic manufacturing and their clinical study progress, more information on proper dosing and what exact strains of bacteria are potentially “friendly” will become available.
You may be interested in trying some of these foods in your diet. A simple food to try is kefir. Several websites provide good recipes, including http://www.kefir.net/recipes.htm. Kefir, a dairy product fermented with probiotic bacteria, can make a pleasant tasting milkshake.

**Figure (PageIndex{3}):** The Human Digestive System. Original figure by [LadyofHats](https://commons.wikimedia.org/wiki/File:Digestive_system_diagram_front_view.png) (Public Domain) with labels added by Allison Calabrese / [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

### From the Mouth to the Stomach

There are four steps in the digestion process (Figure (PageIndex{3})). The first step is ingestion, which is the intake of food into the digestive tract. It may seem a simple process, but ingestion involves smelling food, thinking about food, and the involuntary release of saliva in the mouth to prepare for food entry. In the mouth, where the second step of digestion starts, the mechanical and chemical breakdown of food begins. The chemical breakdown of food involves enzymes, such as salivary amylase that starts the breakdown of large starch molecules into smaller components.

Mechanical breakdown starts with mastication (chewing) in the mouth. Teeth crush and grind large food particles, while saliva provides lubrication and enables food movement downward. The slippery mass of partially broken-down food is called a bolus, which moves down the digestive tract as you swallow. Swallowing may seem voluntary at first because it requires conscious effort to push the food with the tongue back toward the throat, but after this, swallowing proceeds involuntarily, meaning it cannot be stopped once it begins. As you swallow, the bolus is pushed from the mouth through the pharynx and into a muscular tube called the esophagus. As the bolus travels through the pharynx, a small flap called the epiglottis closes to prevent choking by keeping food from going into the trachea. Peristaltic contractions also known as peristalsis in the esophagus propel the food bolus down to the stomach (Figure (PageIndex{4})). At the junction between the esophagus and stomach there is a sphincter muscle that remains closed until the food bolus approaches. The pressure of the food bolus stimulates the lower esophageal sphincter to relax and open and food then moves from the esophagus into the stomach. The mechanical breakdown of food is accentuated by the muscular contractions of the stomach and small intestine that mash, mix, slosh, and propel food down the alimentary canal. Solid food takes between four and eight seconds to travel down the esophagus, and liquids take about one second.
From the Stomach to the Small Intestine

When food enters the stomach, a highly muscular organ, powerful peristaltic contractions help mash, pulverize, and churn food into chyme. Chyme is a semiliquid mass of partially digested food that also contains gastric juices secreted by cells in the stomach. These gastric juices contain hydrochloric acid and the enzyme pepsin, that chemically start breakdown of the protein components of food.

The length of time food spends in the stomach varies by the macronutrient composition of the meal. A high-fat or high-protein meal takes longer to break down than one rich in carbohydrates. It usually takes a few hours after a meal to empty the stomach contents completely into the small intestine.

The small intestine is divided into three structural parts: the duodenum, the jejunum, and the ileum. Once the chyme enters the duodenum (the first segment of the small intestine), the pancreas and gallbladder are stimulated and release juices that aid in digestion. The pancreas secretes up to 1.5 liters (.4 US gallons) of pancreatic juice through a duct into the duodenum per day. This fluid consists mostly of water, but it also contains bicarbonate ions that neutralize the acidity of the stomach-derived chyme and enzymes that further break down proteins, carbohydrates, and lipids. The gallbladder secretes a much smaller amount of a fluid called bile that helps to digest fats. Bile passes through a duct that joins the pancreatic ducts and is released into the duodenum. Bile is made in the liver and stored in the gall bladder. Bile’s components act like detergents by surrounding fats similar to the way dish soap removes grease from a frying pan. This allows for the movement of fats in the watery environment of the small intestine. Two different types of muscular contractions, called peristalsis and segmentation, control the movement and mixing of the food in various stages of digestion through the small intestine.

Similar to what occurs in the esophagus and stomach, peristalsis is circular waves of smooth muscle contraction that propel food forward. Segmentation from circular muscle contraction slows movement in the small intestine by forming temporary “sausage link” type of segments that allows chyme to slosh food back and forth in both directions to promote mixing of the chyme and enhance absorption of nutrients (Figure \(\PageIndex{5}\)). Almost all the components of food are completely broken down to their simplest units within the first 25 centimeters of the small intestine. Instead of
proteins, carbohydrates, and lipids, the chyme now consists of amino acids, monosaccharides, and emulsified components of triglycerides.

The third step of digestion (nutrient absorption) takes place mainly in the remaining length of the small intestine, or ileum (> 5 meters). The way the small intestine is structured gives it a huge surface area to maximize nutrient absorption. The surface area is increased by folds, villi, and microvilli. Digested nutrients are absorbed into either capillaries or lymphatic vessels contained within each microvillus.

The small intestine is perfectly structured for maximizing nutrient absorption. Its surface area is greater than 200 square meters, which is about the size of a tennis court. The large surface area is due to the multiple levels of folding. The internal tissue of the small intestine is covered in villi, which are tiny finger-like projections that are covered with even smaller projections, called microvilli (Figure \(\PageIndex{6}\)). The digested nutrients pass through the absorptive cells of the intestine via diffusion or special transport proteins. Amino acids, short fatty acids, and monosaccharides (sugars) are transported from the intestinal cells into capillaries, but the larger fatty acids, fat-soluble vitamins, and other lipids are transported first through lymphatic vessels, which soon meet up with blood vessels.
From the Small Intestine to the Large Intestine

The process of digestion is fairly efficient. Any food that is still incompletely broken down (usually less than ten percent of food consumed) and the food’s indigestible fiber content move from the small intestine to the large intestine (colon) through a connecting valve. A main task of the large intestine is to absorb much of the remaining water. Remember, water is present not only in solid foods and beverages, but also the stomach releases a few hundred milliliters of gastric juice, and the pancreas adds approximately 500 milliliters during the digestion of the meal. For the body to conserve water, it is important that excessive water is not lost in fecal matter. In the large intestine, no further chemical or mechanical breakdown of food takes place unless it is accomplished by the bacteria that inhabit this portion of the intestinal tract. The number of bacteria residing in the large intestine is estimated to be greater than 10^{14}, which is more than the total number of cells in the human body (10^{13}). This may seem rather unpleasant, but the great majority of bacteria in the large intestine are harmless and many are even beneficial.

From the Large Intestine to the Anus

After a few hours in the stomach, plus three to six hours in the small intestine, and about sixteen hours in the large intestine, the digestion process enters step four, which is the elimination of indigestible food matter as feces. Feces contain indigestible food components and gut bacteria (almost 50 percent of content). It is stored in the rectum until it is expelled through the anus via defecation.

Nutrients Are Essential for Cell and Organ Function

When the digestive system has broken down food to its nutrient components, the body eagerly awaits delivery. Water soluble nutrients absorbed into the blood travel directly to the liver via a major blood vessel called the portal vein. One of the liver’s primary functions is to regulate metabolic homeostasis. Metabolic homeostasis is achieved when the nutrients consumed and absorbed match the energy required to carry out life’s biological processes. Simply put, nutrient energy
intake equals energy output. Whereas glucose and amino acids are directly transported from the small intestine to the liver, lipids are transported to the liver by a more circuitous route involving the lymphatic system. The lymphatic system is a one-way system of vessels that transports lymph, a fluid rich in white blood cells, and lipid soluble substances after a meal containing lipids. The lymphatic system slowly moves its contents through the lymphatic vessels and empties into blood vessels in the upper chest area. Now, the absorbed lipid soluble components are in the blood where they can be distributed throughout the body and utilized by cells (see Figure \(\PageIndex{7}\)).

![Image of the Absorption of Nutrients](https://med.libretexts.org/Courses/Folsom_Lake_College/FLC%3A_Nutri_300_(Giordano)/FLC_Nutrition_Courses_-_Giordano/02%3A_The_Human_Body/2.03%3A_The_Digestive_System)

*Figure \(\PageIndex{7}\): The Absorption of Nutrients.*

Maintaining the body’s energy status quo is crucial because when metabolic homeostasis is disturbed by an eating disorder or disease, bodily function suffers. This will be discussed in more depth in the last section of this chapter. The liver is the only organ in the human body that is capable of exporting nutrients for energy production to other tissues. Therefore, when a person is in between meals (fasted state) the liver exports nutrients, and when a person has just eaten (fed state) the liver stores nutrients within itself. Nutrient levels and the hormones that respond to their levels in the blood provide the input so that the liver can distinguish between the fasted and fed states and distribute nutrients appropriately. Although not considered to be an organ, adipose tissue stores fat in the fed state and mobilizes fat components to supply energy to other parts of the body when energy is needed.

All eleven organ systems in the human body require nutrient input to perform their specific biological functions. Overall health and the ability to carry out all of life’s basic processes is fueled by energy-supplying nutrients (carbohydrate, fat, and protein). Without them, organ systems would fail, humans would not reproduce, and the race would disappear. In this section, we will discuss some of the critical nutrients that support specific organ system functions.
Footnotes


Contributors

- University of Hawai‘i at Mānoa Food Science and Human Nutrition Program: Allison Calabrese, Cheryl Gibby, Billy Meinke, Marie Kainoa Fialkowski Revilla, and Alan Titchenal