UNIT 1

DIGESTIVE SYSTEM & METABOLISM

wonders of the HUMAN BODY

INTRODUCTION

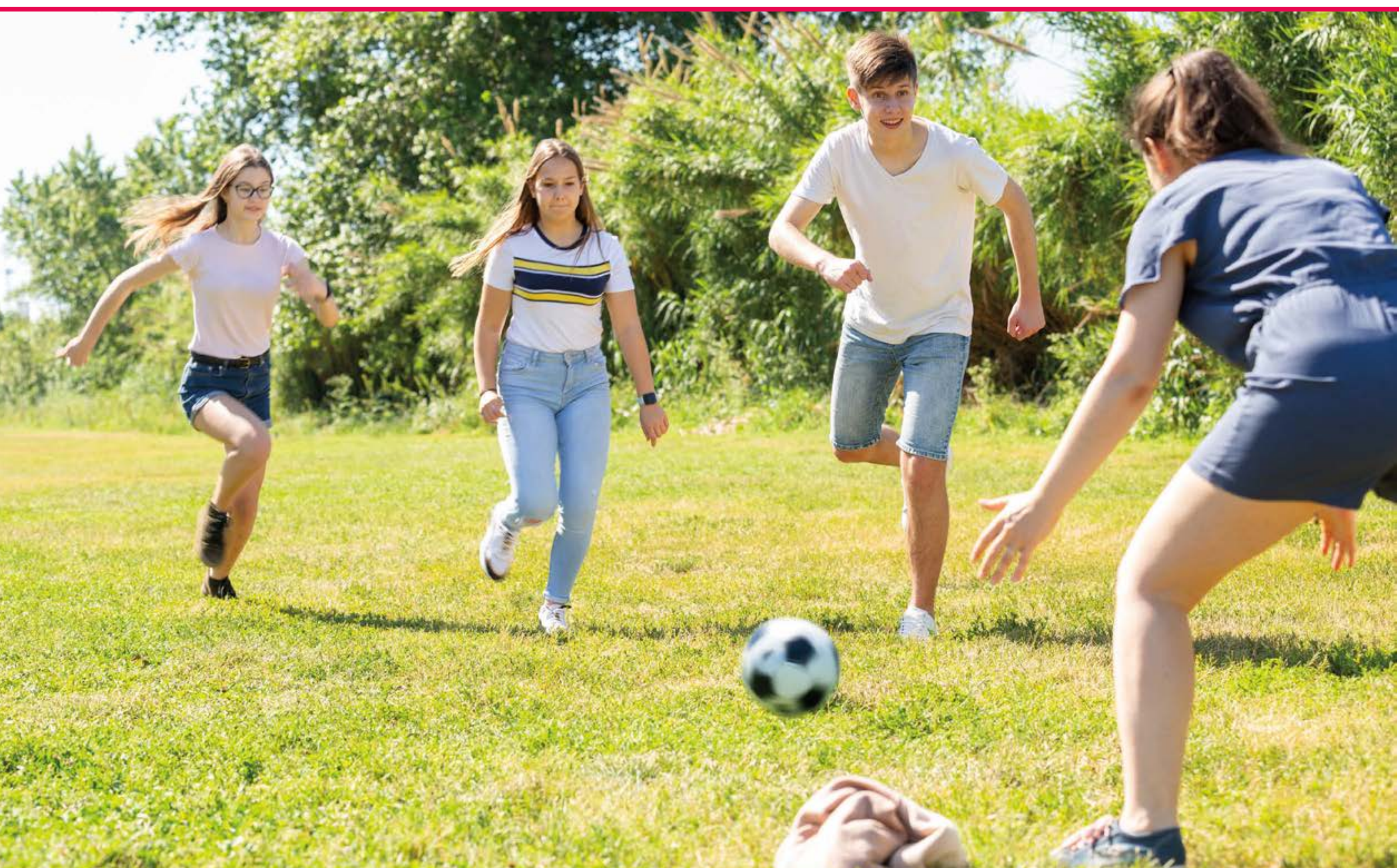
Here is a simple fact. Our bodies need energy.

Without a constant supply of energy, we could not think because our brains would not function. We could not walk because our muscles would not contract. We could not . . . well, you get the idea.

Where does all this energy come from? It comes from the food we take in!

Our bodies also need raw materials to repair a bone when it is broken and even to build up stronger muscles when we exercise. These raw materials come from the food we eat.



So how does the cereal you had for breakfast become energy? Or the popcorn you had at the ballgame? How does the chicken you had for supper provide the amino acids the body needs to build proteins? These are some of the things we will examine in depth in this first unit of *Wonders of the Human Body Volume 2*.

Welcome to our exploration of the digestive system!

What is Digestion?

At first glance, this may seem like a simple question. After all, we use the terms “digest” and “digestion” almost every day. But what do these words really mean?

Digestion is the process by which the food we take in is converted to substances needed by our bodies. Those substances may then serve as fuel from which energy is obtained or raw materials, which are building blocks for more complex molecules or structures. After all, the foods we eat are made up of very complex substances, aren’t they? An undigested carrot is of little use to the body. However, when the carrot is broken down into its much simpler components, it becomes very useful indeed. The same is true of the other things we eat. Yes, even Brussels sprouts can be broken down into things the body needs.

Think of it this way. The gasoline that we put into a car is used to power the car’s engine. The gasoline is already in a form that the car can directly burn to produce energy. This fuel is burned in the engine to make the car go. The gasoline does not need to be broken down (in a sense, digested) to be useful. It is used “as is.”

Food is different. It must be broken down into more useful forms before it can be used by our bodies, either as fuel or as raw material. It must be digested.

But things don’t end there. The substances that result from the breakdown of food must then be absorbed into the bloodstream to be utilized by the body. You will soon understand how all this takes place!

We are a Special Creation

As with all our explorations into the complexity of the human body, when you see the incredible design of the digestive system, you ultimately have to ask yourself, “Can this all possibly be an accident? Something that happened by chance?” The answer is obviously a resounding, “No!”

We are not the product of evolution. We are not animals. We are a special creation.

Then God said, “Let Us make man in Our image,
according to Our likeness;
let them have dominion over the fish of the sea,
over the birds of the air, and over the cattle,
over all the earth and over every creeping thing
that creeps on the earth.”
So God created man in His own image;
in the image of God He created him;
male and female He created them.

(Genesis 1:26–27)

May we continually acknowledge God our Creator as we proceed though our study.

OVERVIEW OF THE DIGESTIVE SYSTEM

The digestive system is composed of two groups of organs — the gastrointestinal (GI) tract and the accessory digestive organs.

The gastrointestinal tract, also known as the alimentary canal, is a long tube that extends from the mouth to the anus. Contraction of the muscles in this tube propels food along its journey from beginning to end. The GI tract is comprised of the mouth, pharynx, esophagus, stomach, small intestine, and large intestine. It is about 20–24 feet long in the average person.



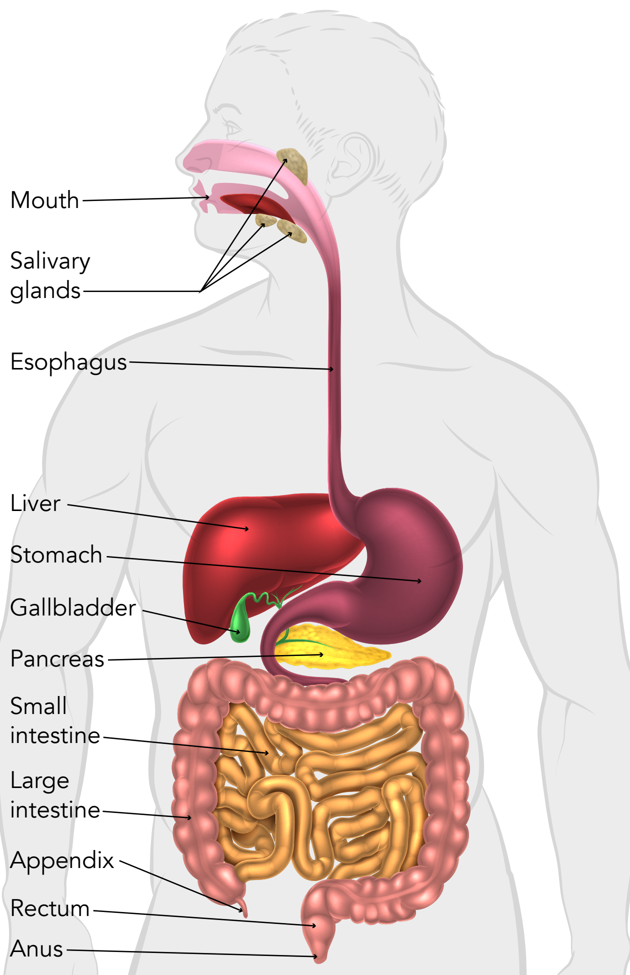

Microscopic section of the large intestine

The processes of digestion and absorption both take place in the GI tract. Interestingly, because the GI tract is open to the outside at both ends, food passing through it is technically not ever inside the body. Only the breakdown products from the digestion of food ever cross through the GI tract's walls to enter the body.

The accessory digestive organs are the teeth, tongue, salivary glands, liver, gallbladder, and pancreas. The teeth and tongue are involved with chewing and swallowing. These are the only accessory digestive organs that come into contact with the food. The remaining four accessory organs function by producing and/or delivering secretions that assist in the digestion and absorption of food.

TAKING A CLOSER LOOK

The Digestive System



Major Functions of the Digestive System

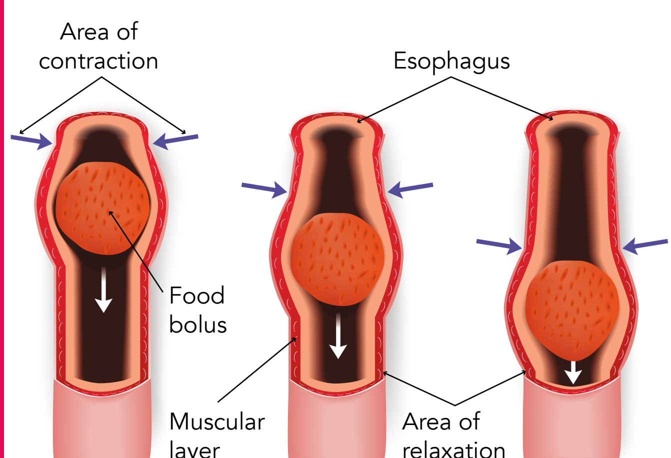
Even though the GI tract is, in one sense at least, simply a long tube, it performs remarkable functions. Our Creator designed the GI tract to carry out a complex set of activities. Let us examine the basic processes of the digestive system more closely.

The first function of the digestive system is called *ingestion*. No surprise here, right? This simply means taking food into the GI tract. Eating and drinking is ingestion.

The next function of the digestive system is *propulsion*. That is, the food is moved along the length of the GI tract. The muscular walls of the GI tract squeeze and relax in a process called *peristalsis*. As this muscle activity occurs, not only is food propelled along, but some mixing and grinding of the food also takes place.

TAKING A CLOSER LOOK

Peristalsis



Next, there is the process of *digestion*, and it has two components. First, there is *mechanical digestion,* which is the physical breaking down of food into smaller pieces. This includes the tearing and grinding of food by the teeth, and the churning of food in the stomach. Then, there is *chemical digestion*. Here, we find the various digestive enzymes breaking food down into its more basic components.

Next comes the process of *absorption*. Here, the breakdown products of chemical digestion move into the cells that line the lumen of the GI tract. From here, these substances then move into the bloodstream to be used throughout the body.

The final process is *elimination*. Here, indigestible material and other substances are removed as they reach the end of the GI tract. The material eliminated is called *feces* and leaves the body through the anus.

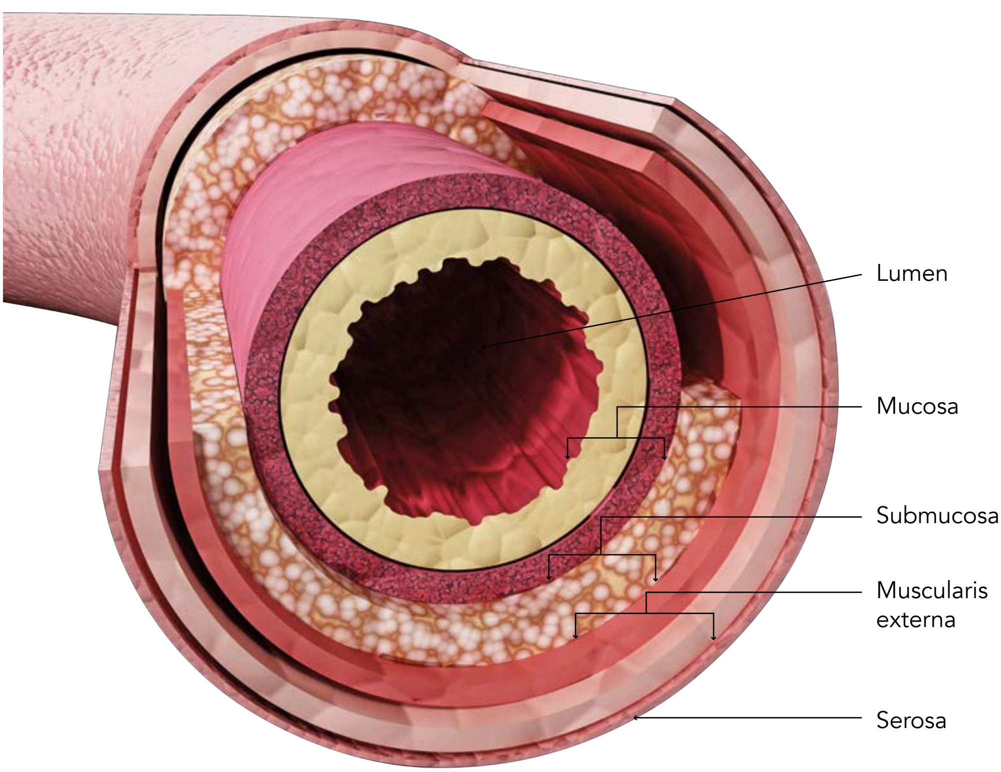
Layers of the GI Tract

The GI tract is essentially a long tube. The wall of the tube is made of several layers. In order for you to digest your food and absorb nutrients from it, the tissues in the GI tract wall must perform a variety of functions, such as squeezing the tube's contents, secreting chemicals that help digest food, and allowing the nutrients to travel through the wall. The wall of each section of the GI tract has its own anatomical features that enable it to do its jobs. While the oral cavity and pharynx have their own unique anatomy, the remaining sections of the GI tract, from esophagus to anus, have walls made of the same four basic layers. Let's see how they are arranged.

If you look at a cross section of the GI tract, you will see an opening in the middle, called the *lumen*. The food you chew up and swallow enters the lumen, where it is processed and moved along from section to section. The lumen is surrounded by four layers of tissue. Starting at the lumen and moving outward, these layers are the *mucosa*, the *submucosa*, the *muscularis externa*, and the *serosa*.

TAKING A CLOSER LOOK

Tissue Layers of the GI Tract



The Mucosa

The innermost tissue layer in the GI tract wall is called the mucosa. This layer lines the lumen of the GI tract and thus comes into contact with material passing though the digestive system. The mucosa is itself made up of three layers (wouldn't you just know it . . .).

The first is the *epithelium*. This is the layer in direct contact with the lumen. It is made up of different types of cells that perform needed functions. Some cells in the epithelium secrete mucus. This mucus not only helps food slide through the GI tract, but also helps protect digestive organs from being damaged by the chemicals secreted to digest food.

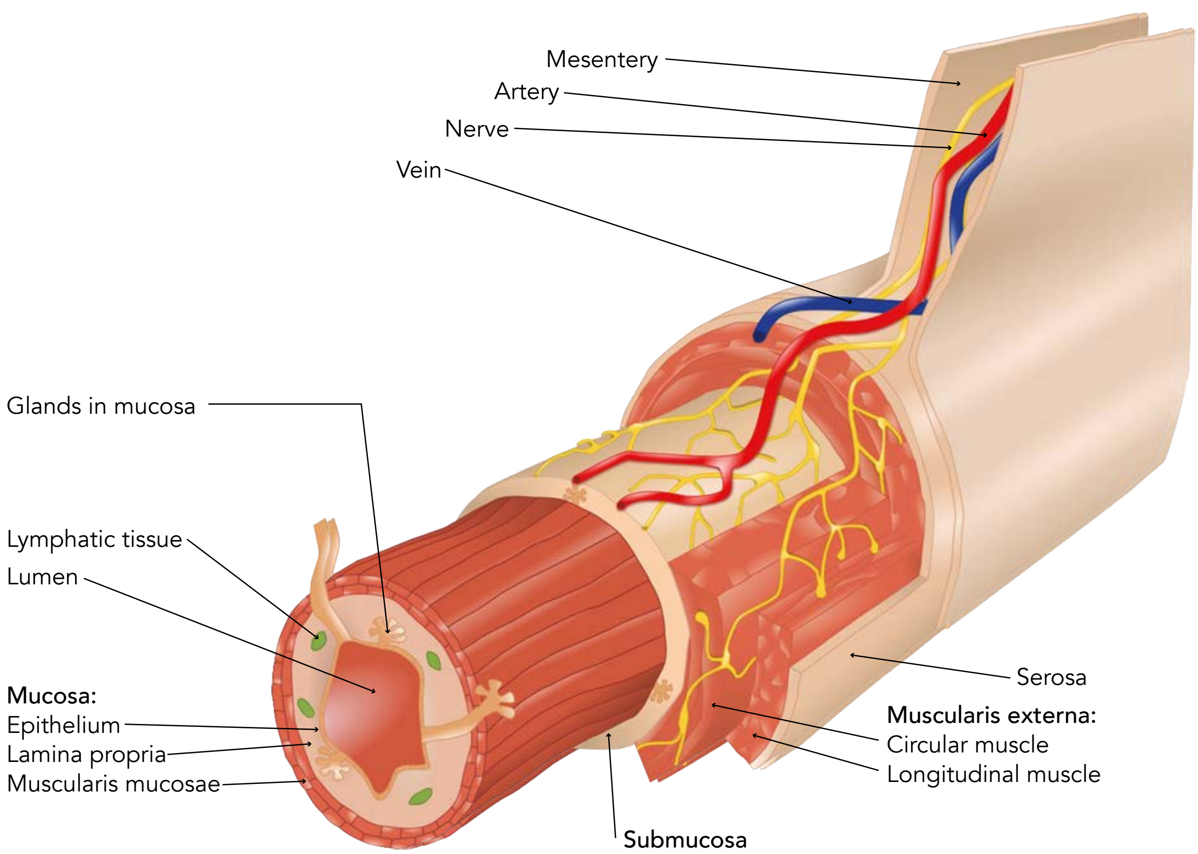
Scattered throughout the GI tract epithelium are several specialized cell types. Some secrete chemicals and enzymes that help digest food. Others aid in absorption of the breakdown products as food is digested. We will explore many of these in depth as our study progresses.

Cells in the epithelium are replaced rapidly. They usually last about 7 days. The old cells slough off into the lumen and are carried away and eliminated in the feces.

Moving outward from the lumen, we find the *lamina propria*. This layer of connective tissue contains lots of capillaries. Blood in the capillaries brings oxygen and nutrients to the epithelial cells. These blood vessels also carry away materials absorbed from the

TAKING A CLOSER LOOK

Layers of the GI Tract



lumen as food is digested. Also found in the lamina propria are special immune system cells. These cells prevent infectious agents (bacteria, etc.) from invading the body through the walls of the GI tract.

The third layer of the mucosa is the *muscularis mucosae*. This is a tiny layer of smooth muscle fibers. These fibers allow the epithelial lining of the mucosa to expand and contract as conditions warrant. This helps regulate the surface area available for secretion and absorption. This thin muscular layer is not the only muscle found in the GI tract wall. A more robust layer of muscle is found farther out in the wall.

The Submucosa

Below the mucosa is the *submucosa*, a word that literally means "below the mucosa," just like *submarine* means "below the sea." Indeed, the submucosa provides a foundation for the mucosa. The dense connective tissue of the submucosa supports the overlying mucosa as it expands to accommodate food to be digested and shrinks back when digestion is completed.

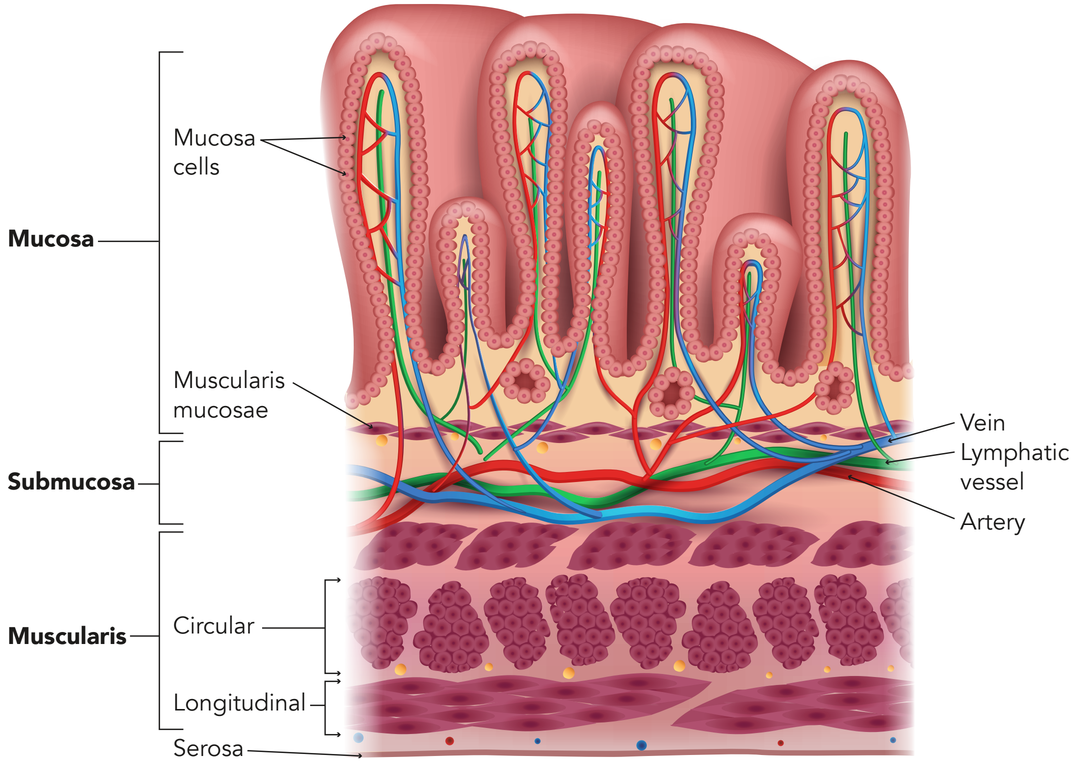
The blood and nerve supply of the GI tract run through this foundation. Nerve fibers regulate the GI tract's activities. The blood vessels carry away the breakdown products of food as it is absorbed. The blood vessels in the submucosa also bring oxygen and nutrients to the GI tract tissues, because the walls of the GI tract, though responsible for getting nutrients from the food we eat, are not directly supplied by those nutrients.

The Muscularis Externa

Moving farther away from the lumen, the next layer is the *muscularis externa*. This sturdy layer of muscle propels food through the GI tract.

TAKING A CLOSER LOOK

The Mucosa, Submucosa, and Muscularis



Two different types of muscle compose the muscularis externa. Which type dominates varies from section to section. In the mouth, pharynx, and upper esophagus, as well as in the final portion of the colon, the muscles in the muscularis externa are skeletal muscle. As you (hopefully!) recall, skeletal muscle is under voluntary conscious control.

This means you can control the act of swallowing and the mechanics of elimination. It does not take much imagination to appreciate the importance of having voluntary control of these activities.

Throughout the remainder of the GI tract, the muscularis externa consists of smooth muscle, which is not under voluntary control. This is just as it should be. After all, it would be very inconvenient if you had to consciously control each step of the digestive process, thinking, "That hamburger has spent enough time being processed in this part of my small intestine and is ready to slowly move along to the next." Fortunately, you don't. Your smooth muscle responds to the instructions provided by the mechanisms that automatically monitor and regulate all the activities of the marvelous factory-like assembly line that is your GI tract.

Once again, our Master Designer has put exactly the right kinds of muscles in all the right places! Skeletal muscle where you need conscious control, smooth muscle where you don't. Sounds like the right design to me.

The Serosa

Once you swallow your food, it enters the part of the GI tract that is located in the abdominopelvic cavity, starting with the stomach. From the stomach onward, the GI tract tube is covered by a layer of connective tissue called the *serosa*. The serosa is the outermost of the layers of the GI tract, and it helps provide support for the organs of the GI tract. The serosa forms not only the outer covering for the GI tract, but at the same time acts as the slick lining that covers the contents of the abdominopelvic cavity.

The words *serosa* and *serous membrane* are related to the Latin word *serum,* which is a thin, watery fluid. The serosa is made of connective tissue covered by a thin layer of epithelium called *mesothelium*. The epithelial tissue covering most internal organs and lining most body cavities is called mesothelium. Mesothelial cells secrete a lubricating fluid that helps organs covered by mesothelium slide past each other.

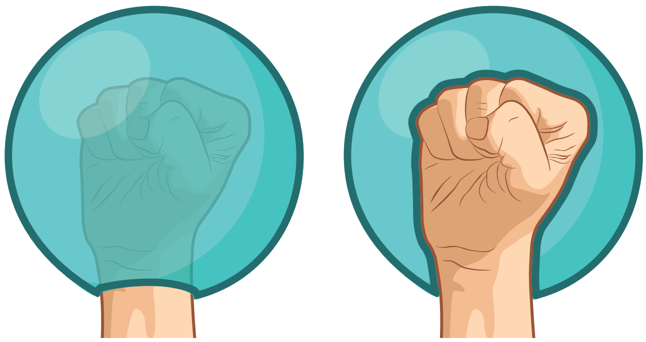
The outermost layer of the GI tract is slightly different for the esophagus. This organ resides in the thoracic cavity and lacks a full serosal covering. The esophagus, as we shall see later, is anchored in the chest cavity and doesn't need to slide past anything. The esophagus, therefore, instead of a serosa, has only a thin connective tissue layer helping hold it in place. This layer is called the *adventitia*.

The Peritoneum

The double-layered serous membrane that lines the abdominopelvic cavity is called the peritoneum. The peritoneum covers, at least partially, most of the organs in the abdomen. It also forms the innermost layer of the abdominal wall.

The peritoneal membrane, like other body cavity linings, consists of connective tissue covered by a thin layer of mesothelium. Does this sound familiar? Does this sound like the serosa we learned about earlier? You recall that the serosa — made of connective tissue covered by mesothelium — covers the outside of the GI tract. Well, the part of the peritoneum that covers the surface of the organs is called the *visceral peritoneum*. This is just another name for the serosa! They are one and the same. The other portion of the peritoneum that lines the abdominopelvic cavity just beneath the abdominal wall is called the *parietal peritoneum*.

The double-layered construction of the peritoneum is most easily understood by a simple analogy. If you take a partially inflated balloon and push your fist slowly into it, you get the idea of how the peritoneum works. Think of your fist as an organ. Your fist is covered tightly by a layer analogous to the *visceral peritoneum.* The other side of the balloon is analogous to the *parietal peritoneum,* the portion of the peritoneum that contacts the



abdominal wall. Your peritoneum-covered fist is now inside a peritoneum-lined abdominal cavity. That's pretty much how the peritoneum works. In fact, that's pretty much how the peritoneum forms in a developing baby, long before birth when its organs are taking shape.

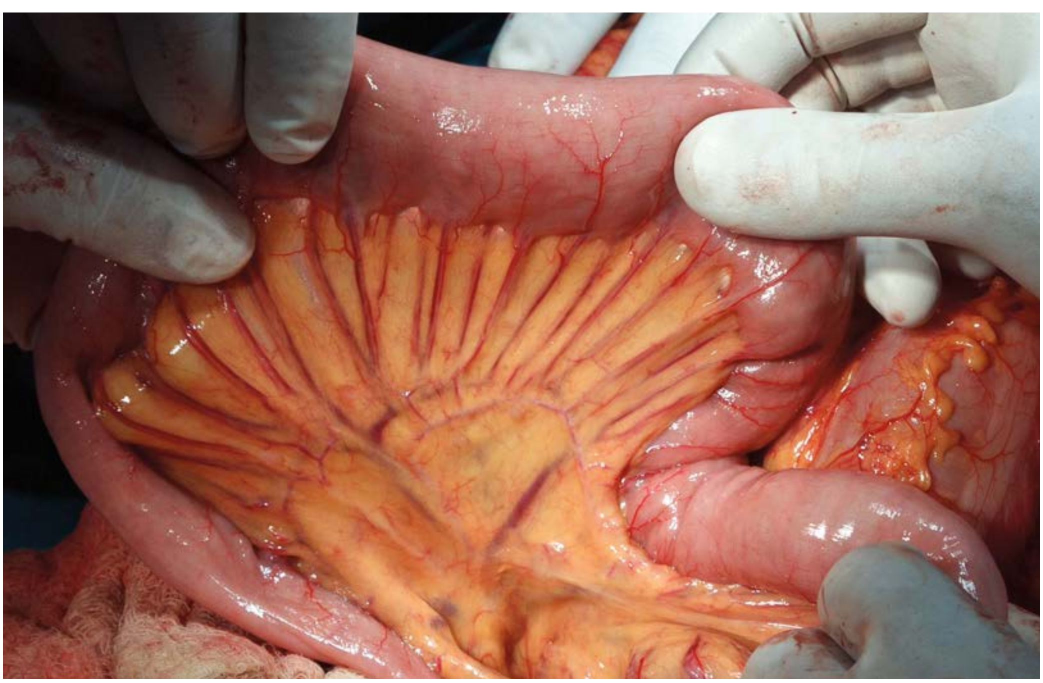
Remember, the reason that the peritoneum is called a serous membrane is that the cells of the mesothelium secrete a small amount of serum-like fluid to lubricate the peritoneal cavity. This lubrication allows the surfaces of organs to glide across one another easily, protecting the organs by preventing friction and snags.

Not all organs are completely surrounded by the peritoneum. Some organs are located in the very back of the abdominopelvic cavity. Only their front surfaces are covered by the peritoneum. These organs are said to be *retroperitoneal*. This word means "behind the peritoneum."

There are places where the peritoneal membrane's layers, after enveloping an organ, are actually fused together. This is another very important design. This fused membrane is called a *mesentery*. Mesenteries help secure organs to the body wall and hold them in the proper position so that they won't twist while also suspending them to allow them room to expand and to slide along other organs. These mesenteries are also a pathway by which nerves and blood vessels reach the organs suspended by them.

Regulation of the Digestive System

Your digestive system is sometimes very, very busy, and other times it is almost resting. How does it know when to get busy, or what it should do when presented with a chewed-up hamburger? You have probably been told that you should not swim right after you eat a big meal. That is because your digestive system will be very busy and, if you suddenly divert most of the blood and oxygen it needs to do its work to your arms and legs for a vigorous swim, you might get a painful cramp as your GI tract protests the interruption. So before moving into a detailed exploration of the digestive



Small intestine with mesentery

system, we need to understand the basics of how this system is controlled, or regulated.

Some of the activity of the digestive system is under local control. That is to say that some mechanisms that control digestion can be found in the digestive system itself. The lining of the GI tract contains lots of special receptors. Some are triggered by stretching of the surrounding structures, like when a rounded ball of chewed food — called a *bolus* — enters the lumen. Other receptors are triggered by the presence of certain hormones or certain types of food. Greasy food, for instance, requires certain chemicals to process it, chemicals not needed to process saltine crackers. Food leaving the stomach has been mixed with a strong acid, and changes in the acid levels in the contents of the lumen can also be detected by receptors in the GI tract walls.

When triggered, some receptors stimulate smooth muscle to contract. Others cause glands to increase or decrease release of digestive enzymes or other chemicals. Some receptors, when stimulated, trigger release of certain hormones into the blood. You see, lots of things happen in the walls of the organs in the digestive system.

Further, the GI tract has its own nervous system, called the *enteric nervous system*. These neurons found in the walls of the GI tract are essential to adequate regulation of the digestive system. It has been estimated that the enteric nervous system contains 100 million neurons (No, I don't know who counted them . . .)! Some have gone as far as to call this collection of neurons the "gut brain." These neurons help control not only the motility of the GI tract, but also the secretory activity of cells in the epithelium.

Lastly, there are control mechanisms involving the central nervous system. These bring a level of control from outside the digestive tract. It is control of this sort that may divert blood and oxygen from the digestive tract to your muscles when you swim, causing the digestive tract to cramp at the interruption until it has time to respond to the message.

These regulatory mechanisms will be described in more detail as we continue our study.

Peritonitis

Peritonitis is a condition resulting from an acute inflammation of the peritoneum. This is a serious medical condition and is most often (although not always) the result of bacterial contamination of the abdominal cavity. The contamination can be the result of leakage from a burst ulcer or from a ruptured diverticulum in the colon. One of the most common causes of peritonitis is bacterial leakage from a ruptured appendix.

Symptoms of peritonitis include abdominal pain and fever. Patients with peritonitis often exhibit significant pain during examination of the abdomen. Any movement of the abdominal wall is very painful to someone with an inflamed peritoneum.

Peritonitis can also result from penetrating injuries to the abdominal wall. Violent trauma to the abdomen, such as stabbing or gunshots, are always dangerous, but the risk of dying from them was even worse in the past. Even if trauma victims did not bleed to death right away, contamination of the peritoneal cavity by bacteria would soon cause peritonitis. Modern surgical procedures and the discovery of antibiotics have dramatically decreased the mortality rate from peritonitis, whether due to disease or trauma.

Treatment of peritonitis includes intravenous fluids and intensive antibiotic therapy, often with multiple antibiotics. Sometimes surgical intervention is required, even in those cases unrelated to trauma. Surgery may be needed to correct the cause of the problem (i.e., fix the leak) or to drain pus from a localized abscess. Peritonitis today is usually treatable. However, in severe cases, it can still be fatal.