**Overview**

The digestive system participates in the procurement and metabolism of energy-containing materials. Food is taken in through the mouth and digested in the digestive tract, and nutrients are transported to all parts of the body by the circulatory system. Molecules obtained as food are stored at a variety of sites in the body: glycogen is stored in the liver and muscle tissues; fats are stored in the liver and muscles in basal vertebrates and in adipose tissues in more advanced vertebrates. The components of proteins (amino acids), however, are not stored—they are used to build new proteins or are de-aminated in the liver to make simple sugars or fatty acids, which can be converted to storage molecules.

Digestion involves the chemical breakdown of complex food materials through the actions of enzymes. Chemically, it requires hydrolysis of the covalent bonds holding together large, polymeric molecules. Proteins are hydrolyzed into amino acids and starches into sugars. The smaller molecules resulting from digestion are easily absorbed. These small molecules are used by the animal either as sources of energy or as building blocks to make new molecules, such as proteins and nucleic acids that are characteristic for the species. Thus, when we digest bovine proteins in a hamburger, we reuse the amino acids to make human proteins or convert the amino acids to sugars that are used as an energy source.

Digestion can occur intracellularly or extracellularly. In simple organisms, such as protozoa and sponges, the individual cells of the organism ingest food materials by pinocytosis and phagocytosis and digestion occurs in food vacuoles inside of cells. Other organisms have extracellular digestion in special digestive organs that are either sac-like or tubular. Multicellular organisms, such as cnidarians and flatworms, have incomplete digestive tracts; these are blind sacs; that is, food enters the mouth, passes into a chamber where enzymatic digestion and absorption occur, and nondigestible material is expelled through the same opening. This seems to be a somewhat inefficient system because, when nondigestible material is expelled, recently ingested food may also be lost.

More complex animals have a complete digestive system, a continuous tube from the mouth to the anus in which food is sequentially broken down and absorbed. Different enzymes are secreted by glands at various points along the digestive tube, so that the digestion of different types of molecules occurs as food passes through the system.

Mere digestion, however, is not sufficient for processing food material. To be of value to the animal, absorption must also occur. In vertebrates, specialized regions of the digestive tube absorb nutrients, salts, and water from the digested material, or chyme. The undigested or nondigestible residues pass on to temporary storage areas before being defecated.

Arthropods and annelids have a digestive tube that passes more or less straight through the body from head to tail. The digestive tubes in such organisms include storage areas, grinding areas, digestive areas, and absorptive areas, but the tube is not longer than the organism. In vertebrates, on the other hand, the digestive tube is many times longer than the animal's length, with much of this length devoted to absorption. After absorption, the circulatory system carries food materials to cells throughout the body.
STUDENT Prelab PREPARATION
Prepare for this laboratory by reading your text and the lab manual.

You should use your textbook to review the definitions of the following terms:
smooth muscle  circular muscle  sphincter  esophagus  longitudinal muscle  villus
mucosa  Goblet cells

Learning Objectives:
• Describe the differences between incomplete and complete digestive tracts
• Outline the pathway of food through mammalian digestive tract
• Describe the anatomy of Hydra gastrovascular cavity
• Compare and contrast the anatomy of organs of the Vertebrate digestive system and explain how they’re anatomy reveals their function.

As a result of this review, you most likely have questions about terms, concepts, or how you will do the experiments included in this lab. Write these questions in your lab notebook.

Digestion Lab - Must have in your lab notebook

Diagrams
1. Gastrovascular cavity of a Hydra, Cnidarian OR Ctenophore
   a. Comparing anatomy of one-opening and two-opening digestive tubes

Dissections
2. Frog - Labeled
   a. Divisions of the body cavity
   b. Digestive organs in mesentaries and in body cavity
   c. Food remains – ID or color and consistency (if no remains, they should mention that; otherwise ½ point off)
3. Pig – labeled
   a. Digestive organs in the body cavity

Slides
1. Esophagus
   a. Smooth muscle
   b. Epithelial/Inner layer
2. Small Intestine X.S.
   a. Epithelial layer
   b. Villi
   c. Microvilli
3. Stomach X. S.
   a. Gastric pits
   b. Muscle layers
4. Pancreas or liver
   a. Glands/cuboidal cells for secretion
   b. Colon
Invertebrate Feeding Behavior in Hydra

Hydra is a small, freshwater Cnidarian related to the jellyfish and sea anemones. It lives attached to submerged rocks, leaves, and twigs. Hydra's body is organized simply, consisting of only two layers of cells surrounding a hollow cavity. However, the organism is highly specialized for food gathering; it uses tentacles to capture food and transfer it into the digestive (gastrovascular) cavity. The food is then digested by enzymes that are secreted by cells lining the cavity. Because of the organism's small size, the cells of Hydra obtain nutrients from the digestive cavity by simple diffusion. Each body cell exchanges O2 and CO2 directly with the surrounding water and releases cellular metabolic wastes directly into the water as well.

Recall how Hydra feeds:

Include drawings showing how prey items are transferred from the tentacles to mouth.

Once food is in Hydra's gastrovascular cavity, digestion begins. Enzymes secreted by certain cells lining the cavities begin extracellular digestion. Partially digested bits of food material are later taken up by phagocytic cells in the cavity lining, and further digestion occurs inside the food vacuoles in these cells. This is intracellular digestion. Food absorbed by the cells lining the gastrovascular cavity supplies all cells of the body.

When animals increase in size and complexity, diffusion from the digestive cavity to the cells, as occurs in Hydra, is no longer adequate to supply the tissues’ demands. Increased complexity means special systems for the transport of material from cell to cell. The relationship of the vertebrate digestive and circulatory systems represents the height of this development from physiological and evolutionary perspectives.

Ceolom and Mesenteries

The coelom is a body cavity lined by mesoderm. In many invertebrates, a body cavity filled with fluid (hydrocoel) functions as a supporting skeleton for the body. However, in vertebrates the endoskeleton assumes this role, and the major role of the coelom in the course of evolution has been to allow the internal organs to lengthen, coil, and move independently of the outer body wall.

Over the course of Vertebrate evolution, the coelom (originally a single cavity) was subdivided into several body cavities containing different organs (Figure 1a). Early on, the heart came to occupy the pericardial cavity and was separated from the abdominal cavity by the transverse septum. As swim bladders or lungs developed in Vertebrates, they began to protrude into the abdominal cavity (pleuroperitoneal cavity) at the level of the heart and behind it (Figure 1b). As the development of the neck separated the head from the body, a lateral fold of the body wall joined the transverse septum, forming a pleuropericardial membrane separating the heart from the lungs (Figure 1c). In advanced vertebrates, the pleural cavities encasing the lungs became completely separated from the abdominal cavity by the pleuroperitoneal membranes (and transverse septum), which in mammals form the diaphragm, a muscular structure assisting the muscles of the body wall in ventilating the lungs (Figure 1d).

Coelomic body cavities are lined with a thin, permeable epithelium. On the inside surface of the body wall, this lining is called the parietal peritoneum. Visceral organs in the body cavity are suspended by extensions of the peritoneum called mesenteries (Table 1). Mesenteries contain small amounts of connective tissue, blood vessels, and nerves, and in advanced vertebrates may also contain adipose (fat) tissue. Body organs are covered by the visceral peritoneum, also part of the living of the coelom.

The heart tends to be free of suspensory mesenteries or ligaments which could constrain its activity. The pericardial cavity containing the heart is lined by a parietal pericardium and the heart is covered by the visceral pericardium.
Figure 1 Divisions of the coelom in vertebrates. In the vertebrate ancestors (a), there was a single body cavity. In fishes (b), the pericardial cavity is separated from the main body cavity. In amphibians and reptiles (c), lungs lie in the anterior portion of the pleuroperitoneal cavity above the heart, which moved caudally as the neck developed. In the mammals (d), lungs occupy a separate pleural cavity. The transverse septum and pleuroperitoneal membranes together form the diaphragm.

<table>
<thead>
<tr>
<th>Mesentaries</th>
<th>Organs supported</th>
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<tr>
<td>Dorsal mesentaries</td>
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<td>Mesogaster (greater omentum)</td>
<td>Stomach</td>
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<td>Mesentary proper (mesointestine)</td>
<td>Small intestine</td>
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<td>Mesocolon</td>
<td>Large intestine</td>
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<td>Ventral mesentaries</td>
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<tr>
<td>Gastrohepatic ligament (lesser omentum)</td>
<td>Liver (from stomach)</td>
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<tr>
<td>Falciform ligament</td>
<td>Liver (to ventral body wall)</td>
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<td>Median ligament</td>
<td>Bladder</td>
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Objectives

- Open the coelomic cavities of representative vertebrates and describe how the coelom of each is subdivided.
- Distinguish among the parietal peritoneum, the visceral peritoneum, and the parietal and visceral pericardia and be able to locate each.
- Describe the structure and the major functions of the mesenteries.

Procedure

It is customary to give dissection directions (right and left) in terms of the animal's right and left. When the animal's ventral surface is toward you, the animal's right is on your left and vice versa. We will follow this convention. Work in groups of two.

Frog

1. Turn your frog ventral side up. Using scissors make a shallow longitudinal cut through the thin skin of the ventral surface of the body (the skin will separate easily from the underlying muscles). Extend the cut from just in front of the cloacal aperture to the pectoral girdle. Make transverse cuts along the ventral surface of the forelimbs and hindlimbs as if making a large letter I. Free the skin from the underlying trunk and limbs and pull it back.

2. Now cut through the muscle layers of the ventral body wall slightly to the right of the midventral line (your left as you face the frog). Extend the cut from in front of the cloacal aperture to the hind margin of the forelimbs (you may need to veer left as you approach the pectoral girdle to avoid the sternum). Be careful not to damage the visceral organs and the heart. Lift up the left-hand flap of the body wall and locate the large ventral abdominal vein on its inner surface along the midline (this is why you cut to one side of the median plane). Carefully separate the vein from the inner surface of the body wall (use a probe or dissecting needle). Make transverse incisions through the body wall anterior to each hind leg and posterior to each front limb (avoid the vein). Extend these cuts about halfway up the side of the body. Rinse the preservative and dried blood from the coelomic cavity. Pour any preservative that has collected in your dissecting tray into the sink.

3. Pull the flaps of the body wall outward. If your dissecting pan has a wax lining, use dissecting pins to hold these flaps away from the opening into the coelomic cavities. The large pleuroperitoneal cavity houses the lungs and abdominal viscera. With the head pointed away from you, push the viscera to the frog's right to see the nature of the peritoneal wall and mesenteries.

   - Describe the appearance of the parietal peritoneum
   - Describe the appearance of the mesenteries.
   - What other organs or tissues are contained within them in the frog?

4. Find the transverse septum that forms the anterior wall of the pleuroperitoneal cavity. The liver, a large dark organ filling much of the anterior pleuroperitoneal cavity, is attached to it by the coronary ligament.

5. Find the heart, nestled between the lobes of the liver behind the pectoral girdle. It is located in the pericardial cavity.

   - What structure separates the pericardial cavity from the pleuroperitoneal cavity?
   - Does this separation appear to be complete in the frog?
The Digestive System

In primitive vertebrates, the digestive system consisted of little more than an anterior opening, the mouth; the pharynx; a foregut and a hindgut separated by a constriction (the pylorus); and a posterior opening, the anus. The first vertebrates were filter-feeders, feeding continuously on small particles of food suspended in the water. With the development of jaws, larger food items were taken at less regular intervals ("meals"), and a temporary storage area, the stomach, developed in the anterior part of the system. The remainder of the digestive system changed little during the course of evolution. See Figure 2.

Oral Cavity: The oral cavity was formed as jaws evolved to enclose a chamber between the anterior opening of the digestive tract (mouth) and the pharynx.

Pharynx: Behind the oral cavity is the pharynx. Its primary role is associated with gas exchange, so we will postpone our exploration of this area.

Foregut: The foregut extends from the pharynx to the pyloric constriction and often expands near the pylorus to form a storage organ, the stomach. The anterior portion of the foregut forms a connecting tube, the esophagus.

![Figure 2: The complete gut. A generalized schematic diagram of structures and organs associated with the digestive tract in various vertebrates. Note that no single vertebrate possesses all of these structures.](image)

When jaws developed, they enclosed a space in front of the pharynx, the oral cavity. Teeth lined the jaws and, with the change from gill to pulmonary respiration, the pharyngeal arches were modified to support a tongue used to gather and manipulate food. In terrestrial vertebrates, teeth became embedded in the bone of the jaw, anterior flaps of skin (lips) formed, and the angle of the jaw became closed (forming cheeks). In the evolutionary line leading to lobe-finned fishes and terrestrial vertebrates, internal nares arose and connected the roof of the oral cavity to the outside through nasal passages. In terrestrial vertebrates, salivary glands evolved to provide lubricating moisture for dry food and to protect the epithelial lining of the digestive tract.

The oral cavity evolved into the most complicated part of the digestive system, adapting to the wide range of diets in vertebrates.

The boundary between the oral cavity and pharynx lies behind the region where the anterior pituitary forms from the tissues of the roof of the oral cavity. In aquatic fishes, gills, derived from feeding structures, became adapted for gas exchange. Lungs (swim bladders) developed in ancestral bony fishes as out-pocketings of the pharyngeal floor and assumed the major role in respiration in terrestrial vertebrates. Gills are lost in terrestrial vertebrates, and the pharynx serves only as a passageway for food.

The foregut extends from the pharynx to the pyloric constriction. In filter feeders and jawless vertebrates, this portion of the digestive system was little more than a straight tube leading to the hindgut. However, with the development of jaws, which could provide large amounts of food at one time, the region near the pylorus expanded to form a storage organ, the stomach, with the anterior portion forming the esophagus. In advanced
vertebrates, enzymes and an acid environment combine to initiate the chemical digestion of proteins in the stomach, but few substances are assimilated (absorbed) in this region.

The digestive tract behind the pylorus is the hindgut, which is responsible for the chemical digestion of food and the uptake of the products formed by this process. The hindgut shows few phylogenetic changes except for an increase in the area of the absorptive surface, as seen in the cigar-shaped spiral intestine of the shark and some other fishes or the coils of intestine found in most vertebrates. The size of the small intestine is generally correlated with diet-it is shortest in those forms that feed on microscopic food particles and easily digested foods such as nectar; it is longer in animals with a high-protein diet of insects or other animals; and it is longest in herbivores that feed on masses of grass or foliage. In early bony fishes and most derived bony fishes, extra surface area is also added to the intestinal surface by pyloric caeca-blind sacs of the duodenum located near the pylorus.

The first section of the small intestine, the duodenum, receives ducts from the liver and pancreas, large exocrine glands (glands with ducts) in the abdominal cavity. The liver produces bile, a fluid containing bile pigments (the end product of metabolized blood pigments which color the bile brown to green) and bile salts (which emulsify fats into small droplets that can be digested or absorbed directly). Enzymes secreted by the pancreas and the wall of the duodenum digest food materials into simple chemical compounds that can be assimilated as food passes through the remainder of the small intestine. The posterior part of the intestine is called the large intestine or colon. In more advanced vertebrates, one or two sacs or caeca mark the junction of the small and large intestines. The large intestine is primarily a site where water is removed from the intestinal contents to make the semisolid feces.

Hindgut: The digestive tube behind the pylorus is the hindgut. It shows few phylogenetic changes in the vertebrate series except for an increase in internal surface area correlated with a more varied diet. The first section of the hindgut, or duodenum, receives ducts from large visceral organs, the liver and pancreas. The posterior part of the hindgut is the large intestine or colon. In many vertebrates (bony fishes and mammals are among the exceptions), the colon opens into the cloaca, a common chamber receiving fecal material from the digestive system, urine from the excretory system, and gametes from the reproductive system.

Anus: The anus is the terminal opening of the digestive system. The term may be used for the exterior opening through which feces are voided, regardless of whether or not they pass through a cloaca en route. The term "cloacal aperture" is also used for the opening of the cloaca

Objectives
Observe the digestive tracts of representative vertebrates and note differences in their structures.
Describe the role of the organs of the digestive system and their functional relationships to each other in the process of digestion.

Frog
1. Cut through the angle of the jaw, on both sides of the frog, until it reaches the anterior end of the esophagus. Open the mouth completely. Pull the lower jaw ventrally and to one side. Refer to Figure 3.
2. Find the muscular tongue attached near the anterior margin of the floor of the mouth (this structure can be extended quickly to catch passing insects, which adhere to its sticky surface). Find the opening of the trachea, the glottis, between the base of the tongue and the esophagus in the pharynx. This is the passageway for air to the lungs.
3. Did you find the small maxillary teeth earlier? Feel them along the margin of the upper jaw. Find the internal nares near the margin of the oral cavity. Between the nares are vomerine teeth, extensions of the bones in the palate of the skull. These structures help the frog to hold prey after it is captured. Locate the openings of the Eustachian tubes near the angle of the jaw. Between the Eustachian tubes and the internal nares, the roof of the oral cavity bulges downward because of the eyes, located above the cavity.
• Where is the boundary between the oral cavity and the pharynx in the frog?
• Which is larger in the frog: the oral cavity or the pharynx?

In opening the body cavity of the frog, you exposed and located the heart anteriorly (Figure 3). The large dark organ behind and beside it is the liver—it consists of three lobes in the frog. The liver produces bile which is stored in the gall bladder, a small greenish sac embedded in the middle (left posterior) lobe of the liver.
• What is the function of bile in digestion?
• In excretion?

4. Lift the left lobes of the liver. Find the esophagus and the stomach, an enlarged part of the foregut that arcs to the left. Make an incision through the outer curvature of the stomach; remove any food and examine the wall of the organ. It contains folds or rugae, much like those of the shark, which allow the stomach to expand to hold food.
• Identify any food remains in the stomach.

5. Follow the stomach to the right. Locate the pylorus where the stomach joins the small intestine. The first section of the small intestine is the duodenum; ducts from the liver and pancreas enter here and many of the enzymes of the intestine are produced in this section of the gut. The remainder of the small intestine is coiled within the body cavity. Trace it to its junction with the large intestine (colon) in the dorsal area of the coelom. The colon empties into the cloaca. Find the urinary bladder ventral to the large intestine.

In reptiles, birds, and mammals, the bladder develops from one of the extraembryonic membranes (the allantois) formed during development of the embryo. However, frogs lack this membrane, so it is likely that the urinary bladder of the frog developed independently from the cloacal wall.

6. The spleen is a rounded, dark-colored organ located in the coils of the intestine. The pancreas is a whitish organ between the stomach and duodenum. Find and name as many of the mesenteries supporting the abdominal visceral organs as you can (Table 1).
• Which belong to the dorsal mesentery system?
• The ventral mesentery system?
Figure 3 (a) Oral and pharyngeal cavities of the frog.
(b) Visceral organs of the frog.
Mammalian Digestive System
If you have not already done so, get a fetal pig and dissection tray.

PROCEDURE: Anatomy of the Mouth

Located in the upper neck region beneath the skin are three pairs of salivary glands: parotid, submaxillary, and the sublingual, which is difficult to find. They produce saliva containing the enzyme salivary amylase that hydrolyzes starch during chewing.

1. To view the salivary glands, remove the skin and muscle layer from one side of the face and neck, as in figure 4 to reveal the rather dark, triangular-shaped parotid gland. Note the difference in appearance between muscle tissue and glandular tissue. If you dissected carefully, you should find the duct that drains the gland into the mouth near the upper premolar teeth. Try to trace the duct. The other salivary glands lie beneath and below the parotid gland.

2. With heavy scissors, a razor blade, or scalpel, cut through the comers of the mouth and extend the cut to a point below and caudal to the eye.

3. Open the mouth, as in figure 5 and observe the hard palate, composed of bone covered with mucous membrane, and the soft palate, which is a caudal continuation of the soft tissue covering the hard palate. The oral cavity ends and the pharynx begin at the base of the tongue.

4. The pharynx is a common passageway for the digestive and respiratory tracts, as seen in figure 6. The opening to the esophagus may be found by passing a blunt probe (not a needle) down along the back of the pharynx on the midline. This collapsible tube connects the pharynx with the stomach. The glottis is the opening into the trachea or windpipe and lies ventral to the esophagus. It is covered by a small white tab of cartilage, the epiglottis. The epiglottis may be hidden from view in the throat; if so, you will have to pull it forward with forceps or a probe to see it.
**Figure 4** Dissected fetal pig's head showing salivary glands

**Figure 5** Anatomy of the fetal pig mouth

**Figure 6**
Passage of food and air through the pharynx
Anatomy of the Alimentary Canal

5. To view the rest of the alimentary tract and associated glands, use the scalpel or a pair of scissors to make the incision into the abdominal cavity. Cut carefully through only through the skin and muscles to avoid damaging the internal organs.

6. The flap containing the umbilical cord will be held in place by blood vessels. Tie both ends of a piece of thread to the blood vessels about 1cm apart. Cut the vessels between the two knots and lay this tissue flap back. Leave the thread in place so you can later trace the circulatory system.

7. Find the thin, transparent membranes, the mesenteries, which suspend and support the internal organs in the body cavity. The dark brown, multilobed liver should be visible caudal to the diaphragm (fig. 7). If you trace the umbilical vein from the thread to the liver, you will see a green colored sac, the gallbladder, located just below the entrance of the vein into the liver. It stores bile produced in the liver. Bile travels from the gallbladder to the small intestine via the bile duct but the duct is quite small. Bile is an emulsifying agent that aids in digestion of fats.

8. Under the liver is the stomach. Locate the point where the esophagus enters the cardiac region of the stomach. Gastric glands in the wall of the stomach secrete pepsinogen, hydrochloric acid, and rennin. Pepsinogen is activated by hydrochloric acid to become pepsin, which digests proteins. Rennin is an enzyme that hydrolyzes milk protein. Food leaves the stomach as a fluid suspension, chyme. It enters the duodenum, the first part of the small intestine.

9. Find the pancreas, a glandular mass lying in the angle between the curve of the stomach and duodenum. It secretes several enzymes into the duodenum that digest proteins, lipids, carbohydrates, and nucleic acids. Certain cells in the pancreas act as endocrine cells and secrete the hormones insulin and glucagon. In fact, insulin used in human diabetes therapy can be extracted from the pancreases of pigs collected at slaughterhouses.

10. Although it is not part of the digestive system, identify the spleen attached by mesenteries to the outer curvature of the stomach. It is made of lymphatic tissue and is important in development of immunity and the scavenging of iron from red blood cells when they break down.

11. Slit the stomach lengthwise, cutting through the cardiac and pyloric sphincters, muscles that regulate passage of material into and out of the stomach. The internal surface of the stomach is covered by gastric mucosal cells, which secrete mucus that prevents the stomach from digesting itself. When this protection fails, a peptic ulcer develops.

12. The small intestine is made up of three sequentially arranged regions: duodenum, jejunum, and ileum. These areas are difficult to differentiate from each other. Cut out a 2-cm section of the small intestine about 5 cm posterior from the stomach, slit it open, and place it under water in a dish. Use your dissecting microscope to observe the velvety internal lining made up of numerous fingerlike projections called villi. The villi are highly vascularized, containing capillaries and lymphatics that transport the products of digestion to other parts of the body, especially the liver.

13. The ileum opens into the large intestine, or colon. They join at an angle, forming a blind pouch, the cecum, which in primates and some other mammals often ends in a slender appendage, the appendix. In many herbivores, the caecum is very large and contains microorganisms that aid digestion by breaking down cellulose.

14. The rectum is the caudal part of the large intestine, where compacted, undigested food material is temporarily stored before being released through the anus. The colon of vertebrates contains large numbers of symbiotic bacteria, especially Escherichia coli. These bacteria produce vitamin K, which is absorbed and plays a vital role in blood clotting.
Figure 7 Major organs in the fetal pig
Histology of Small Intestine

Obtain a prepared slide of a cross section of a mammalian small intestine. Examine it under scanning power with the compound microscope. Compare what you see to figure 8.

The central opening is called the lumen and is the space through which food passes as chyme during digestion. Switch to low power and observe the small fingerlike projections of the intestine's inner surface. These are villi and are covered by a layer of cells called the mucosa. You should be able to distinguish two cell types in the intestinal mucosa: goblet cells and columnar epithelial cells. Examine them with the high-power objective. The goblet cells secrete mucus into the small intestine, serving as a lubricant for the passage of chyme. Epithelial cells are involved in absorption.

Return to the low-power objective and observe the submucosa, a layer of connective tissue that underlies the mucosa. Look for the blood vessels and lymphatic vessels that ramify through this layer. Sugars, amino acids, glycerides, and other components of digested food must move through the mucosal cells into the submucosa before they can enter the circulatory system and be distributed throughout the body.

To the outside of the submucosa are two smooth muscle layers: an inner circular layer and outer longitudinal layer. The inner circular muscles change the diameter of the intestine, and the outer muscles alter its length. These muscles contract in a wavelike motion called peristalsis, which pushes chyme through the digestive tract. The small intestine is covered by a layer of peritoneal cells that together with underlying connective tissue is called the serosa.

Figure 8 shows scanning electron micrographs of the three-dimensional arrangement of the small intestine. Note how the villi and microvilli increase the surface area.

- What important process following digestion is facilitated by this increased surface area?
Figure 8 Microstructure of intestine. (a) photo taken through a light microscope of cross section of small intestine. (h) Scanning electron micrograph of cross section of small intestine showing villi (Vi), lumen (Lu), submucosa layer (Su), and muscle layers (Mu). The epithelial cells on the surface of the villi have highly folded membranes, microvilli (Mv), which greatly increase the absorptive surface area of the cell layer, as seen in (c) a transmission electron micrograph showing highly folded cell membrane. (h) From R. G. Kessel and R. H. Kardon. Tissues and Organs: A Text-Atlas of Scanning Electron Microscopy. 1979. W. H. Freeman and Company.