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The small intestine is the part of the gastrointestinal tract where much of the digestion and absorption of food takes place.

The Small Intestine

The small intestine is the part of the gastrointestinal tract that follows the stomach, which is in turn followed by the large intestine. The small intestine is the site where almost all of the digestion and absorption of nutrients and minerals from food takes place.

The average length

of the small

intestine in an adult

human male is 6.9

m (22 feet, 6

inches), and in the

adult female 7.1 m

(23 feet, 4 inches). It

can vary greatly,

from as short as 4.6

m (15 feet) to as

long as 9.8 m (32 feet). The small intestine is approximately 2.5–3 cm in diameter, and is divided into three sections:

. The duodenum is the first section of the small intestine and is the shortest part of the small intestine. It is where most chemical digestion using enzymes takes place.

". The jejunum is the middle section of the small intestine. It has a lining which is designed to absorb carbohydrates and proteins. The inner surface of the jejunum, its mucous membrane, is covered in projections called villi, which increase the surface area of tissue available to absorb nutrients from the gut contents. The epithelial cells which line these villi possess even larger numbers of microvilli. The transport of nutrients across epithelial cells through the jejunum includes the passive transport of some carbohydrates and the active transport of amino acids, small peptides, vitamins, and most glucose. The villi in the jejunum are much longer than in the duodenum or ileum.

#. The ileum is the final section of the small intestine. The function of the ileum is mainly to absorb vitamin B12, bile salts, and any products of digestion that were not absorbed by the jejunum. The wall itself is made up of folds, each of which has many tiny finger-like projections known as villi on its surface. The ileum has an extremely large surface area both for the adsorption of enzyme molecules and for the absorption of products of digestion.

The Villi

The villi contain large numbers of capillaries that take the amino acids and glucose produced by digestion to the hepatic portal vein and the liver. Lacteals are the small lymph vessels that are present in villi. They absorb fatty acids and glycerol, the products of fat digestion, into direct circulation.

Layers of circular and longitudinal smooth muscle enable the digested food to be pushed along the ileum by waves of muscle contractions called peristalsis. The undigested food (waste and water) are sent to the colon.

Histology of the Small Intestine

The small intestine wall has four layers: the outermost serosa, muscularis, submucosa, and innermost mucosa.

The Small Intestine’s Layers

The small intestine has four tissue layers: The serosa is the outermost

layer of the

intestine. The

serosa is a

smooth

membrane

consisting of a

thin layer of

cells that

secrete

serous fluid,

and a thin layer of connective tissue. Serous fluid is a lubricating fluid that reduces friction from the movement of the muscularis.

". The muscularis is a region of muscle adjacent to the submucosa membrane. It is responsible for gut movement, or peristalsis. It usually has two distinct layers of smooth muscle: circular and longitudinal.

#. The submucosa is the layer of dense, irregular connective tissue or loose connective tissue that supports the mucosa, as well as joins the mucosa to the bulk of underlying smooth muscle.

%. The mucosa is the innermost tissue layer of the small intestines, and is a mucous membrane that secretes digestive enzymes and hormones. The intestinal villi are part of the mucosa.

The three sections of the small intestine look similar to each other at a microscopic level, but there are some important dierences. The jejunum and ileum do not have Brunner’s glands in the submucosa, while the ileum has Peyer’s patches in the mucosa, but the duodenum and jejunum do not.

Brunner’s Glands

Brunner’s glands (or duodenal glands) are compound tubular submucosal glands found in the duodenum. The main function of these glands is to produce a mucus-rich, alkaline secretion (containing bicarbonate) in order to neutralize the acidic content of chyme that is introduced into the duodenum from the stomach, and to provide an alkaline condition for optimal intestinal enzyme activity, thus enabling absorption to take place and lubricate the intestinal walls.

Peyer’s Patches

Peyer’s patches are organized lymph nodules. They are aggregations of lymphoid tissue that are found in the lowest portion of the small intestine, which dierentiate the ileum from the duodenum and jejunum.

Because the lumen of the gastrointestinal tract is exposed to the external environment, much of it is populated with potentially pathogenic microorganisms. Peyer’s patches function as the immune surveillance system of the intestinal lumen and facilitate the generation of the immune response within the mucosa.

Intestinal Villi

Intestinal villi

(singular: villus) are

tiny, finger-like

projections that

protrude from the epithelial lining of

the mucosa. Each

villus is

approximately 0.5–

1.6 mm in length

and has many

microvilli (singular: microvillus), each of

which are much

smaller than a single villus.

Villi increase the internal surface area of the intestinal walls. This increased surface area allows for more intestinal wall area to be available for absorption. An increased absorptive area is useful because digested nutrients (including sugars and amino acids) pass into the villi, which is semi-permeable, through diusion, which is eective only at short distances.

In other words, the increased surface area (in contact with the fluid in the lumen) decreases the average distance traveled by the nutrient molecules, so the eectiveness of diusion increases.

The villi are connected to blood vessels that carry the nutrients away in the circulating blood.

Digestive Processes of the Small Intestine

The small intestine uses dierent enzymes and processes to digest proteins, lipids, and carbohydrates.

Chemical Digestion in the Small Intestine

The small intestine is where most chemical digestion takes place. Most of the digestive enzymes in the small intestine are secreted by the pancreas and enter the small intestine via the pancreatic duct.

These enzymes enter the small intestine in response to the hormone cholecystokinin, which is produced in response to the presence of nutrients. The hormone secretin also causes bicarbonate to be released into the small intestine from the pancreas to neutralize the potentially harmful acid coming from the stomach.

The three major classes of nutrients that undergo digestion are proteins, lipids (fats), and carbohydrates.

Proteins

Proteins are degraded into small peptides and amino acids before absorption. Their chemical breakdown begins in the stomach and continues through the large intestine.

Proteolytic enzymes, including trypsin and chymotrypsin, are secreted by the pancreas and cleave proteins into smaller peptides. Carboxypeptidase, a pancreatic brush border enzyme, splits one amino acid at a time. Aminopeptidase and dipeptidase free the end amino acid products.

Lipids

Lipids (fats) are degraded into fatty acids and glycerol. Pancreatic lipase breaks down triglycerides into free fatty acids and monoglycerides. Pancreatic lipase works with the help of the salts from bile secreted by the liver and the gallbladder.

Bile salts attach to triglycerides and help to emulsify them; this aids access by pancreatic lipase because the lipase is water-soluble, but the fatty triglycerides are hydrophobic and tend to orient toward each other and away from the watery intestinal surroundings.

The bile salts act to hold the triglycerides in their watery surroundings until the lipase can break them into the smaller components that are able to enter the villi for absorption.

Carbohydrates

Some carbohydrates are degraded into simple sugars, or monosaccharides (e.g., glucose, galactose) and are absorbed by the small intestine. Pancreatic amylase breaks down some carbohydrates (notably starch) into oligosaccharides. Other carbohydrates pass undigested into the large intestine, where they are digested by intestinal bacteria.

Brush border enzymes take over from there. The most important brush border enzymes are dextrinase and glucoamylase, which further break down oligosaccharides. Other brush border enzymes are maltase, sucrase, and lactase.

Lactase is absent in most adult humans and for them lactose, like most poly-saccharides, is not digested in the small intestine. Some carbohydrates, such as cellulose, are not digested at all, despite being made of multiple glucose units. This is because the cellulose is made out of beta-glucose that makes the inter-monosaccharidal bindings dierent from the ones present in starch, which consists of alpha-glucose. Humans lack the enzyme for splitting the beta- glucose-bonds—that is reserved for herbivores and bacteria in the large intestine.

Anatomy of the Large Intestine

The large intestine absorbs water from the remaining indigestible food matter and compacts feces prior to defecation.

Function and Form of the Large Intestine

The function of the large intestine (or large bowel) is to absorb water from the remaining indigestible food matter, and then to pass the useless waste material from the body. The large intestine consists of the cecum and colon.

This is a schematic drawing of the large intestine, with the colon marked as follows: cecum; 1) ascending colon; 2) transverse colon; 3) descending colon; 4) sigmoid colon; rectum and anus.

Large intestine: A schematic of the large intestine, with the colon marked as follows: cecum; 1) ascending colon; 2) transverse colon; 3) descending colon; 4) sigmoid colon, rectum, and anus.

It starts in the right iliac region of the pelvis, just at or below the right waist, where it is joined to the bottom end of the small intestine (cecum). From here it continues up the abdomen (ascending colon), then across the width of the abdominal cavity (transverse colon), and then it turns down (descending colon), continuing to its endpoint at the anus (sigmoid colon to rectum to anus). The large intestine is about 4.9 feet (1.5 m) long—about one-fifth of the whole length of the intestinal canal.

Differences Between Large and Small Intestine

The large intestine differs in physical form from the small intestine in several ways. The large intestine is much wider, and the longitudinal layers of the muscularis are reduced to three, strap-like structures known as the taeniae coli.

The wall of the large intestine is lined with simple columnar epithelium. Instead of having the evaginations of the small intestine (villi), the large intestine has invaginations (the intestinal glands).

While both the small intestine and the large intestine have goblet cells, they are more abundant in the large intestine.

Additional Structures

The appendix is attached to its inferior surface of the cecum. It contains the least lymphoid tissue, and it is a part of mucosa-associated lymphoid tissue, which gives it an important role in immunity.

Appendicitis is the result of a blockage that traps infectious material in the lumen. The appendix can be removed with no apparent damage or consequence to the patient.

On the surface of the large intestine, bands of longitudinal muscle fibers called taeniae coli, each about 0.2 inches wide, can be identified. There are three bands, starting at the base of the appendix and extending from the cecum to the rectum.

Along the sides of the taeniae, tags of peritoneum filled with fat, called epiploic appendages (or appendices epiploicae) are found. The sacculations, called haustra, are characteristic features of the large intestine, and distinguish it from the small intestine.

Histology of the Large Intestine

The large intestine has taeniae coli and invaginations (the intestinal glands), unlike the small intestines.

Histology of the Large Intestine

This is a micrograph of a colon biopsy.

Colon biopsy: Micrograph of a colon biopsy.

The large intestine, or large bowel, is the last part of the digestive system in vertebrate animals. Its function is to absorb water from the remaining indigestible food matter, and then to pass the useless waste material from the body. The large intestine consists of the cecum, colon, rectum, and anal canal.

It starts in the right iliac region of the pelvis, just at or below the right waist, where it is joined to the bottom end of the small intestine. From here it continues up the abdomen, across the width of the abdominal cavity, and then it turns downward, continuing to its endpoint at the anus.

The large intestine differs in physical form from the small intestine in being much wider. The longitudinal layer of the muscularis is reduced to three strap-like structures known as the taeniae coli—bands of longitudinal muscle fibers, each about 1/5 in wide. These three bands start at the base of the appendix and extend from the cecum to the rectum.

Along the sides of the taeniae are tags of peritoneum filled with fat; these are called epiploic appendages, or appendices epiploicae. The wall of the large intestine is lined with simple columnar epithelium.

Instead of having the evaginations of the small intestine ( villi ), the large intestine has invaginations (the intestinal glands). While both the small intestine and the large intestine have goblet cells that secrete mucin to form mucus in water, they are abundant in the large intestine.

This photograph of the large bowel (sigmoid colon) shows multiple diverticula on either side of the longitudinal muscle bundle (Taenia coli).

Sigmoid colon: A photograph of the large bowel (sigmoid colon) that shows multiple diverticula on either side of the longitudinal muscle bundle (Taenia coli).

In histology, an intestinal crypt—called the crypt of Lieberkühn—is a gland found in the epithelial lining of the small intestine and colon. The crypts and intestinal villi are covered by epithelium that contains two types of cells: goblet cells that secrete mucus and enterocytes that secrete water and electrolytes.

The enterocytes in the mucosa contain digestive enzymes that digest specific food while they are being absorbed through the epithelium. These enzymes include peptidases, sucrase, maltase, lactase and intestinal lipase. This is in contrast to the stomach, where the chief cells secrete pepsinogen. In the intestine, the digestive enzymes are not secreted by the cells of the intestine.

Also, new epithelium is formed here, which is important because the cells at this site are continuously worn away by the passing food. The basal portion of the crypt, further from the intestinal lumen, contains multipotent stem cells.

During each mitosis, one of the two daughter cells remains in the crypt as a stem cell, while the other differentiates and migrates up the side of the crypt and eventually into the villus. Goblet cells are among the cells produced in this fashion. Many genes have been shown to be important for the differentiation of intestinal stem cells.

The loss of proliferation control in the crypts is thought to lead to colorectal cancer.

Bacterial Flora

The largest bacteria ecosystem in the human body is in the large intestine, where it plays a variety of important roles.

Bacterial Flora

The large intestine houses over 700 species of bacteria that perform a wide variety of functions; it is the largest bacterial ecosystem in the human body. The large intestine absorbs some of the products formed by the bacteria that inhabit this region.

For example, undigested polysaccharides (fiber) are metabolized to short-chain fatty acids by the bacteria in the large intestine, and then are absorbed by passive diffusion. The bicarbonate that the large intestine secretes helps to neutralize the increased acidity that results from the formation of these fatty acids.

Bacteria and Vitamins

This is a photograph of a microscope slide of Escherichia coli, one of the many species of bacteria present in the human gut.

Bacterial flora: Escherichia coli is one of the many species of bacteria present in the human gut.

These bacteria also produce large amounts of vitamins, especially vitamin K and biotin (a B vitamin), for absorption into the blood. Although this source of vitamins, in general, provides only a small part of the daily requirement, it makes a significant contribution when dietary vitamin intake is low.

An individual who depends just on the absorption of vitamins formed by bacteria in the large intestine may become vitamin deficient if treated with antibiotics that inhibit other species of bacteria, as well as the disease-causing bacteria.

Other bacterial products include gas (flatus), which is a mixture of nitrogen and carbon dioxide, with small amounts of hydrogen, methane, and hydrogen sulphide. These are produced as a result of the bacterial fermentation of undigested polysaccharides. The normal flora is also essential for the development of certain tissues, including the cecum and lymphatics.

Bacteria and Antibodies

Bacterial flora is also involved in the production of cross-reactive antibodies. These are antibodies produced by the immune system against the normal flora, that are also effective against related pathogens, and prevent infection or invasion.

The most prevalent bacteria are the bacteroides, which have been implicated in the initiation of colitis and colon cancer. Bifidobacteria are also abundant, and are often described as friendly bacteria.

A mucus layer protects the large intestine from attacks from colonic commensal bacteria. Some factors that disrupt the microorganism population of the large intestine include antibiotics, stress, and parasites.

Digestive Processes of the Large Intestine

In the large intestine, a host of microorganisms known as gut flora help digest the remaining food matter and create vitamins.

The large intestine takes about 16 hours to finish up the remaining processes of the digestive system. Food is no longer broken down at this stage of digestion. The colon absorbs vitamins created by the colonic bacteria—such as vitamin K (especially important as the daily ingestion of vitamin K is not normally enough to maintain adequate blood coagulation), vitamin B12, thiamine, and riboflavin. It also compacts feces, and stores fecal matter in the rectum until it can be defecated.

Gut Flora

Gut flora consists of microorganisms that live in the digestive tracts of animals—the gut is the largest reservoir of human flora. The human body, which consists of about 10 trillion cells, carries about ten times as many microorganisms in the intestines.

The metabolic activities performed by these bacteria resemble those of an organ, leading some to liken gut bacteria to a forgotten organ. It is estimated that these gut flora have around a hundred times as many genes in aggregate as there are in the human genome.

Bacteria make up most of the flora in the colon and up to 60 percent of the dry mass of feces. Somewhere between 300 and 1000 different species live in the gut, with most estimates at about 500. Ninety-nine percent of the bacteria probably come from about 30 or 40 species.

Research suggests that the relationship between gut flora and humans is not merely commensal (a non-harmful coexistence), but rather a mutualistic relationship. Though people can survive without gut flora, the microorganisms perform a host of useful functions, such as:

Fermenting unused energy substrates.

Training the immune system.

Preventing growth of harmful, pathogenic bacteria.

Regulating the development of the gut.

Producing vitamins for the host (such as biotin and vitamin K).

Producing hormones to direct the host to store fats.