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Matric No: 17/MHS05/004

Department: Human Physiology

Level: 300L{Carry over Student}

Course Code:

Course Title: Systemic Histology and Organology

Assignment Question(s):Describe the microanatomy of the small and large intestine respectively.

MICROANATOMY OF THE SMALL AND LARGE INTESTINE

1. Microanatomy of the Small Intestine

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

The small intestine is the part of the gastrointestinal tract that follows the stomach, which is in turn followed by the large intestine.

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).

The small intestine is divided into the duodenum, jejunum, and ileum.

Much of the small intestine is covered in projections called villi that increase the surface area of the tissue available to absorb nutrients from the gut contents.

Key Terms

duodenum: The first part of the small intestine that starts at the lower end of the stomach and extending to the jejunum.

ileum: The last, and usually the longest, division of the small intestine; the part between the jejunum and large intestine.

small intestine: The upper part of the intestine, between the stomach and the large intestine, that is divided into the duodenum, the jejunum, and the ileum.

jejunum: The central of the three divisions of the small intestine that lies between the duodenum and the ileum.

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.

This is an illustration of the small intestine with the duodenum, jejunum, and ileum labeled.

Small intestine: An illustration of the small intestine with the duodenum, jejunum, and ileum labeled.

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 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.

The muscularis is a region of muscle adjacent to the submucosa membrane. It is responsible for gut movement (also called 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; it also 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 differences. 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: Compound, tubular, submucosal glands found in that portion of the duodenum that is above the hepatopancreatic sphincter (sphincter of Oddi).

Peyer's patches: Patches of lymphoid tissue or lymphoid nodules on the walls of the ileum in the small intestine.

intestinal wall: The wall of the small intestine is composed of four layers, from the outside to the inside: serosa, muscularis, submucosa, and mucosa.

The Small Intestine's Layers

This is a drawing of a section of the duodenum. It shows the layers of the duodenum: the serosa, muscularis, submucosa, and mucosa.

Section of duodenum: This image shows the layers of the duodenum: the serosa, muscularis, submucosa, and mucosa.

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.

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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 differentiate 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

This is a low-magnification micrograph of small intestinal mucosa that shows villi.

Micrograph of the small intestine: A low-magnification micrograph of small intestinal mucosa that shows 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 diffusion, which is effective 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 effectiveness of diffusion increases.

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

The histological structure of the small intestine is similar to the other organs in the digestive tract. There are four main layers:

Mucosa (Innermost layer) – Contains the epithelium, lamina propria and muscularis mucosae.

Submucosa – Connective tissue layer, which contains blood vessels, lymphatics and the submucosal plexus.

Muscularis externa – Consists of two smooth muscle layers; the outer longitudinal layer and inner circular layer. The myenteric plexus lies between them.

Adventitia (Outermost layer) – Comprised of loosely arranged fibroblasts and collagen, with the vessels and nerves passing through it. The majority of the small intestine adventitia is covered by mesothelium and is commonly called the serosa.

The small intestine is the major absorptive site in the gastrointestinal tract, and therefore has a number of modifications to aid its function. The mucosa and submucosa form large numbers of folds (or plicae) arranged in a circular fashion in the lumen (therefore called plicae circulares). Additionally, the plicae contain microvilli to further increase the surface area, which increases absorption.

Cells of the Epithelium

The epithelium of the small intestine lines the luminal surface. There are a number of components to the epithelium:

Enterocytes – Tall columnar cells, which have an absorptive function. They contain brush border enzymes on the surface which have an important digestive function.

Goblet cells – Exocrine glands which secrete mucin.

Crypts of Lieberkuhn

The Crypts of Lieberkuhn are glands found in the epithelial lining. They contain numerous cells such as stem cells to produce new cells to replenish the cells lost due to abrasion, as well as enteroendocrine cells to synthesise and secrete hormones.

To protect from pathogens, there are Paneth cells which secrete protective agents (such as defensins and lyzozymes) and Peyer's patches which are only found in the ilium. Peyer's patches contain mucosal-associated lymphatic tissue (MALT) which house white blood cells and lymphocytes. These cells can produce antibodies to further protect the small intestine from infection.

Enteroendocrine Cells

The enteroendocrine cells are located within the Crypts of Lieberkuhn. They secrete hormones in response to various stimuli. There are four main classes of enteroendocrine cell, each with a different secretory product. These are I cells, S cells, K cells and enterochromaffin cells.

I Cells secrete Cholecystokinin (CCK) in response to the presence of fat in the small intestine. CCK stimulates the contraction of the gallbladder (which pushes bile out into the cystic duct) and the release of pancreatic enzymes. Both bile and pancreatic enzymes have a key role in lipid digestion. S Cells secrete Secretin in response to the low pH of chyme in the small intestine. Secretin induces HCO_3^- secretion from the pancreas and inhibits gastric emptying.

K Cells secrete Gastric-Inhibitory Peptide (GIP), in response to chyme entering the small intestine. GIP has a misleading name as it actually stimulates insulin release, ready to put the newly digested carbohydrates into cells for storage.

Finally, Enterochromaffin Cells are mechanically stimulated by the presence of chyme in the small intestine. They release serotonin, which acts on the enteric nervous system to activate the cystic fibrosis transmembrane regulators (CFTR). This ion channel secretes Cl^- ions into the intestinal lumen, with Na^+ ions and H_2O following. Na^+ is required in the lumen for the absorption of a number of nutrients.

Secretions

The small intestine receives secretory products from other abdominal viscera. Here, we shall look at the exact mechanism of their secretion, and how they aid intestinal function.

There are three main substances that the small intestine receives: bile, pancreatic enzymes and

alkaline juice ($HCO3–$). Bile serves an important role in lipid digestion, and is secreted from the gallbladder into the common bile duct, in response to CCK. Pancreatic enzymes and alkaline juice are secreted from the pancreas into the pancreatic duct, in response to CCK and secretin.

Further information on the production of bile can be found here.

The common bile duct and pancreatic duct unite to form the hepatopancreatic ampulla (also known as the Ampulla of Vater). This opens out onto the internal surface of the duodenum, and is marked by the major duodenal papilla.

The major duodenal papilla serves as an important anatomical landmark, as it is where the embryonic foregut becomes midgut. The secretions into the small intestine are regulated by the sphincter of Oddi.

Pancreatic Enzymes

The pancreas plays an important role in digestion, as it produces many of the enzymes needed in digestion. These enzymes come in two forms. Some enzymes are already active, such as pancreatic lipase and pancreatic amylase, whilst some are secreted as inactive enzymes such as trypsinogen.

The inactive enzymes are released as zymogens (precursors of the active form) – this prevent the enzymes digesting the pancreas itself. Trypsinogen is converted to trypsin (active form) in the small intestine by coming into contact with the brush border enzyme enterokinase. Trypsin then converts the remaining inactive proteases to their active form.

Further information on the exocrine pancreas can be found here.

Clinical Relevance - Coeliac Disease

Coeliac disease is a condition which causes inflammation of the small intestine. It is autoimmune in aetiology, and affects roughly 1 in 100 people.

The immune-mediated damage of the small intestine occurs secondary to gluten exposure. When gluten is absorbed, it is broken down into a number of products. One product is gliadin, a protein. In coeliac disease, gliadin is presented to the T cells of the immune system as a foreign antigen. This stimulates the production of antibodies against gliadin and an inflammatory response to occur

In children, clinical features include abdominal distension, diarrhoea and a failure to thrive. Adults present with chronic diarrhoea and bloating. Small blisters can appear on the skin (dermatitis hepatiformis) due to deposits of IgA. Adults may also present with symptoms of malabsorption.

Serology and biopsy are the two main investigations for coeliac disease. Antibodies against gliadin and its other products can be found in the plasma. A biopsy of the small intestine shows flattening of the villi and hyperplasia of the crypts, with an increased number of intraepithelial lymphocytes present.

2. Microanatomy of the Large Intestine

The longitudinal layer of the muscularis of the large intestine is reduced to three, strap-like structures known as the taeniae coli—bands of longitudinal muscle fibers, each about 1/5 in wide.

The bands of longitudinal muscle fibers start at the base of the appendix and extend from the cecum to the rectum.

The wall of the large intestine is lined with simple columnar epithelium.

Both the small intestine and the large intestine have goblet cells, but they are abundant in the large intestine.

goblet cell:

columnar epithelium: Epithelial cells whose heights are at least four times their width.

mucin: A family of high molecular weight, heavily glycosylated proteins (glycoconjugates) produced by the epithelial tissues in most metazoans.

goblet cells: Glandular, simple, columnar epithelial cells whose sole function is to secrete mucin, which dissolves in water to form mucus.

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.