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ANA 204

Question: Describe the microanatomy of the small and large intestines.

**SMALL INTESTINES**

The small intestine is a crucial component of the digestive system that allows for the breakdown and absorption of important nutrients that permits the body to function at its peak performance. To do this, the small intestine is made up of a complex network of blood vessels, nerves, and muscles that work together to achieve this task. It is a massive organ that has an average length of 3 to 5 meters. The small intestine is the longest section of the digestive tube and consists of three segments forming a passage from the pylorus to the large intestine:

**Duodenum:** a short section that receives secretions from the pancreas and liver via the **pancreatic and common bile ducts**. The duodenum is the shortest section, on average measuring from 20 cm to 25 cm in length. Its proximal end is connected to the antrum of the stomach, separated by the pylorus. The distal end is at the ligament of Treitz, in which the jejunum begins. The duodenum surrounds the pancreases, in the shape of a "C." It receives chyme from the stomach, pancreatic enzymes, and bile from the liver.

**Jejunum:** considered to be roughly 40% of the small gut in man, but closer to 90% in animals. The jejunum is roughly 2.5 meters in length, contains plicae circulares (muscular flaps) and villi to absorb the products of digestion

**Ileum** empties into the large intestine; considered to be about 60% of the intestine in man, but veterinary anatomists usually refer to it as being only the short terminal section of the small intestine. Measuring around 3 m, and ends at the cecum. It absorbs any nutrients that got past the jejunum, with major absorptive products being vitamin B12 and bile acids

In most animals, the length of the small intestine is roughly 3.5 times body length - your small intestine, or that of a large dog, is about 6 meters in length. Although precise boundaries between these three segments of bowel are not observed grossly or microscopically, there are histologic differences among duodenum, jejunum and ileum.

A bulk of the small intestine is suspended from the body wall by an extension of the peritoneum called the mesentery. As seen in the image to the right, blood vessels to and from the intestine lie between the two sheets of the [mesentery](http://www.vivo.colostate.edu/hbooks/pathphys/digestion/basics/peritoneum.html). Lymphatic vessels are also present, but are not easy to discern grossly in normal specimens.

It is within the small intestine that the final stages of enzymatic digestion occur, liberating small molecules capable of being absorbed. The small intestine is also the sole site in the digestive tube for absorption of amino acids and monosaccharides. Most lipids are also absorbed in this organ. All of this absorption and much of the enzymatic digestion takes place on the surface of small intestinal epithelial cells, and to accomodate these processes, a huge mucosal surface area is required.

**Mucosal folds:** the inner surface of the small intestine is not flat, but thrown into circular folds, which not only increase surface area, but aid in mixing the ingesta by acting as baffles.

**Villi:** the mucosa forms multitudes of projections which protrude into the lumen and are covered with epithelial cells.

**Microvilli:** the lumenal plasma membrane of absorptive epithelial cells is studded with densely-packed microvilli.

**Layers of the Small Intestine**

* Serosa: The serosa is the outside layer of the small intestine and consists mesothelium and epithelium, which encircles the jejunum and ileum, and the anterior surface of the duodenum since the posterior side is retroperitoneal. The epithelial cells in the small intestine have a rapid renewal rate, with cells lasting for only 3 to 5 days.
* Muscularis: The muscularis consists of two smooth muscle layers, a thin outer longitudinal layer that shortens and elongates the gut, and a thicker inner circular layer of smooth muscle which causes constriction. Nerves lie between these two layers and allow these to muscle layers to work together to propagate food in a proximal to distal direction.
* Submucosa: The submucosa consists of a layer of connective tissue that contains the blood vessels, nerves, and lymphatics.
* Mucosa: The mucosa is the innermost layer and is designed for maximal absorption by being covered with villi protruding into the lumen that increases the surface area. The crypt layer of the small bowel that is the area of continual cell renewal and proliferation. Cells move from the crypts to the villi and change into either enterocytes; goblet cells; Paneth cells; or enteroendocrine cells.

Of importance is the mesentery, which is a double fold of the peritoneum that not only anchors the small intestines to the back of the abdominal wall, but also contains the blood vessels, nerves, and lymphatic vessels that supply the small intestine.

**Embryology**

The small intestine comes from the primitive gut, which is formed from the endodermal lining. The endodermal layer gives rise to the inner epithelial lining of the digestive tract, which is surrounded by the splanchnic mesoderm that makes up the muscular connective tissue and all the other layers of the small intestine. The jejunum and ileum come from the midgut. The duodenum, on the other hand, is derived from the foregut.

 Villi and crypts make up the lining of the small intestine. Originally, the small intestine is lined by cuboidal cells up until the ninth week of gestation, then villi begin to form. Crypt formation begin between the 10th to 12th weeks of gestation.

The epithelial cells which mature into absorptive epithelial cells that cover the villi. These are the cells that take up and deliver into blood virtually all nutrients from the diet. However, several other important cell types populate the small intestinal epithelium:

**Enteroendocrine cells** which, as part of the [enteric endocrine system](http://www.vivo.colostate.edu/hbooks/pathphys/digestion/basics/gi_endocrine.html) sense the lumenal environment and secrete hormones such as cholecystokinin and gastrin into blood.

**Goblet cells**, [which secrete a lubricating mucus](http://www.vivo.colostate.edu/hbooks/pathphys/topics/goblets.html) into the intestinal lumen.

**Paneth cells**, which provide an important [anti-bacterial defense for the small intestine](http://www.vivo.colostate.edu/hbooks/pathphys/digestion/smallgut/paneth.html).

**Stem cells**, which allow rapid and constant turnover of small intestinal epithelial cells

**LARCE INTESTINE**

In the large intestine – the final section of the gastrointestinal tract – absorption of water and electrolytes takes place and colonic bacteria complete the process of chemical digestion. The large intestine is also where faeces are formed from the remains of food and fluid combined with by-products of the body. Intestinal content is pushed back and forth by haustral contractions and antiperistaltic contractions, until faeces are finally pushed towards the anal canal by mass movements.

**Anatomy of the large intestine**

The large intestine is approximately 1.5m long and comprises the caecum, colon, rectum, anal canal and anus The structure of the large intestine is very similar to that of the small intestine except that its mucosa is completely devoid of villi.

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 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.

**Caecum and appendix**

Chyme that has not been absorbed by the time it leaves the small intestine passes through the ileocaecal valve and enters the large intestine at the caecum. On receipt of the contents of the ileum, the caecum continues the absorption of water and salts.

The caecum is about 6cm long and extends downwards into the appendix, a winding tubular sac containing lymphoid tissue. The appendix is thought to be the vestige of a redundant organ; its narrow and twisted shape makes it an attractive site for the accumulation and multiplication of intestinal bacteria.

Colon

At its other end, the caecum seamlessly joins up with the colon, this is the longest portion of the large intestine (Fig 1). Food residue starts by travelling upwards through the ascending colon, located on the right side of the abdomen. The ascending colon bends near the liver at the right colic flexure (or hepatic flexure) and becomes the transverse colon, passing across to the left side of the abdomen. Just above the spleen at the left colic flexure (or splenic flexure), the transverse colon becomes the descending colon, which runs down the left side of the abdomen. Before the next bend, the descending colon transforms into the sigmoid colon.

The colon has a segmented appearance; its segments, which are caused by sacculation, are called haustra. The ascending colon, descending colon and rectum are located in the retroperitoneum (outside the peritoneal cavity). The transverse and sigmoid colon are attached to the posterior abdominal wall by the mesocolon.

**Rectum, anal canal and anus**

Distally, the large intestine opens into the rectum, which is continued by the anal canal. The rectum forms the final 20cm of the GI tract. It is continuous with the sigmoid colon and connects with the anal canal and anus. The rectum ends in an expanded section called the rectal ampulla, where faeces are stored before being released; the rectum is usually empty since faeces are not normally stored there for long.

The anal canal located in the perineum (outside the abdominopelvic cavity), is 3.8-5cm long and opens to the exterior of the body at the anus. It has two sphincters:

Internal anal sphincter, which is controlled by involuntary muscles;

External anal sphincter, which is made of skeletal muscle and is under voluntary control.

Except during defecation, both anal sphincters normally remain closed.

**Functions of the large intestine**

Meals pass from the small to the large intestine within 8-9 hours of ingestion. The small intestine will have absorbed about 90% of the ingested water. The large intestine absorbs most of the remaining water, a process that converts liquid chyme residue into semi-solid stools or faeces. The large intestine has three major functions:

Absorption of water and electrolytes;

Formation and transport of faeces;

Chemical digestion by gut microbes.

**Absorption of water and electrolytes**

The presence of food residues in the colon stimulates haustral contractions, which occur approximately every 30 minutes and last about one minute each. With each contraction, each haustrum distends and contracts, pushing the food residues into the next haustrum. The contractions also mix the food residues, thereby facilitating the absorption of water.

The large intestine also absorbs electrolytes. Sodium ions are actively absorbed by the action of the odium/potassium pump; this moves sodium and potassium ions in opposite directions across cell membranes, fostering sodium absorption and potassium loss by releasing the hormone aldosterone.

Antiperistaltic contractions move food residues back towards the ileocaecal valve, slowing transit down and giving more time to the large intestine to absorb water and electrolytes.

**Formation and transport of faeces**

Of every 500ml of food residue that enters the caecum each day, about 150ml become faeces. These contain mostly bacteria, old epithelial cells from the intestinal mucosa, inorganic waste, undigested food matter and fibre, as well as water to help it pass smoothly through the GI tract. They also contain small quantities of fats and proteins. Their characteristic brown colour is due to the presence of stercobilin and urobilin, breakdown products of haemoglobin from old red blood cells.

Since chyme residue lingers in the large intestine for 12-24 hours, most of the 1.5L of fluid entering the large intestine every day is absorbed, leaving less than 100ml to pass out in the faeces. This small quantity of fluid gives faeces their semi-solid consistency. Faeces are also softened by dietary fibre. Mucus, secreted by goblet cells lining the entire colon, helps to bind dehydrated chyme and also lubricates the passage of faeces.

Transit in the colon is slow: it takes three days to clear 70% of a meal and complete expulsion of all remnants can take up to a week; transit is faster in men than women (Degen and Phillips, 1996). Normal bowel emptying patterns vary greatly between individuals, from three times per day to three times per week (Walter et al, 2010).

**Colonic mass movements**

Peristalsis in the ileum forces chyme into the caecum. Distention of the caecum triggers the gastric colic reflex and colonic mass movements begin. Stimulated by stomach distension and colonic irritation, mass movements usually occur three or four times a day, often during or immediately after meals. These strong waves, which can last up to 30 minutes, start midway through the transverse colon. Helped by haustral contractions, they push the now largely dehydrated contents along the colon toward the rectum. Fibre in the diet increases the power of colonic contractions propelling faeces towards the anus.

Colonic mass movements fill the rectum, creating an urge to defecate. It is important to act on this urge, as once the movements have passed, the urge also ceases. If the urge to defecate is ignored for an extended period of time, the rectum overfills, the large intestine absorbs more water and faeces become harder and drier. This can cause constipation.

**Physiology of defecation**

As faeces begin to fill the rectum, the rectal wall stretches, which sends an impulse to nervous centres in the spinal cord to initiate the spinal defecation reflex. This results in the relaxation of the internal anal sphincter, which allows a small quantity of faeces to pass into the anus. The anus detects whether the material is gaseous or solid and acts accordingly. If the material is solid, the external anal sphincter opens up and defecation takes place. However, the external anal sphincter is controlled by voluntary muscles, so it can be consciously restrained to delay defecation until a more convenient time. Children have usually learned this behaviour by the age of two or three years. People with severe dementia may no longer know how to do this.

Faeces are normally passed by contracting the rectal muscles, helped by a voluntary procedure called Valsalva’s manoeuvre. This involves contracting the diaphragm and abdominal wall muscles, which increases intra-abdominal pressure and pushes faeces out of the rectum.

If the nerves between the external anal sphincter and the defecation centre in the medulla are damaged – as may be the case after a stroke, in multiple sclerosis, or after spinal injury – the ability to suppress defecation may be lost, resulting in faecal incontinence. Also, with ageing, the ability of the anus to detect whether it contains gas or faeces may become impaired and faecal matter may be treated as gas, causing faecal incontinence.