

DIGESTIVE SYSTEM II

Esophagus and Stomach

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Learning Objectives

1. The esophagus is a typical hollow organ.
2. Know the histology of each of the layers of the esophagus.
3. The mucosa of the stomach may be glandular or nonglandular.
4. The cardiac region of the stomach contains short, coiled tubular glands that secrete mucous.
5. The fundic region of the stomach contains straight, branched tubular glands. Several types of cells are present in the glands. Know the appearance and the products of these cells.
6. The pyloric region of the stomach contains branched, coiled tubular glands that secrete mucous.
7. A number of gastrointestinal hormones, secreted by enteroendocrine cells, affect gastric secretion and motility.
8. The stomach of ruminants is made up of 4 structurally different parts: rumen, reticulum, omasum and abomasum.
9. The rumen is covered by small, tongue-shaped papillae. The stratified squamous epithelium has absorptive functions.
10. The reticulum has folds in the mucosa that look like honeycomb.
11. The omasum contains many longitudinal folds called laminae.
12. Know the histology of each of these parts and how to differentiate them.
13. The histology of the abomasum is similar to the glandular portion of the stomach.

ESOPHAGUS

The esophagus connects the oral cavity with the stomach and serves as a passage for food. The architecture is that of a typical hollow organ with four layers: mucosa, submucosa, muscularis externa, and serosa/adventitia.

In the carnivores, the pharyngoesophageal limen, an internal annular fold, is found at the junction of the laryngopharynx and esophagus.

Mucosa

The surface epithelium is of the stratified squamous type. The cells are keratinized to varying degrees depending on the type of food being ingested. This layer serves as a barrier that separates the lumen of the digestive tract from the rest of the animal. The stratified layers of epithelial cells provide protection from physical abrasion by ingested food. The lamina propria contains a relatively dense connective tissue, which includes an

abundant amount of elastic fibers. Immune response cells are scattered in the connective tissue. In pigs these cells may aggregate into solitary lymphatic nodules.

The muscularis mucosae consist of smooth muscle bundles that, although basically longitudinal, may appear to be spiraling. The bundles are absent cranially in pigs but highly developed (thick) in the caudal part. In dogs the muscle bundles are absent in the cranial part and interrupted in the middle part.

Submucosa

This is made up of loose connective tissue and contains arteries, veins, lymphatics, ganglia and nerves. Many seromucous glands are present in the submucosa. Ducts from the glands open to the luminal surface. The secretion of these glands helps the movements of the boluses of ingesta. The distribution of the glands vary in different species:

Dog: Mucous glands found through out the entire length of the esophagus extending into the stomach.

Pigs: Glands are more abundant in the cranial half but do not extend into the caudal half.

All other domestic animals: Glands are present in the cranial third (cervical region) of the esophagus.

Submucosal plexus (Meissner's) are present but may be quite small.

Muscularis Externa

This is made up of two muscle layers, an inner circular and an outer longitudinal layer. Depending on the location in the esophagus and the species involved, the musculature may be skeletal muscle, smooth muscle, or a mix of the two in transition. Myenteric plexus (Auerbach's) can be found between the muscular layers.

Contraction of the muscle cells (peristalsis) help to propel the boluses of ingesta toward the stomach.

Ruminants and dogs: Skeletal muscle fibers throughout the length of the esophagus.

Horse: Cranial two thirds skeletal; caudal one-third smooth.

Pig: Cranial one third skeletal, middle one-third mixed, caudal one third smooth.

Cats: Cranial four-fifth skeletal, caudal one-fifth smooth.

The inner circular muscle layers become thick and form a cardiac sphincter muscle at the cardiac ostium of the stomach in all domestic animals. In the horse this muscle is especially prominent. In ruminants the skeletal muscle, which runs throughout the esophagus, extend into the wall of the reticularis sulcus (groove).

Serosa/Adventitia

The outermost layer of the esophagus is the tunica serosa in the region where the esophagus is covered by the pleura or peritoneum (thoracic part in most species). This consists of loose connective tissue, blood vessels and a covering of mesothelial cells. In

the region of the esophagus, which is not covered by the pleura or peritoneum (usually the cervical part), the outermost layer of the esophagus is the tunica adventitia. This contains blood vessels and loose connective tissue that blends with the surrounding tissue.

Esophagus-Stomach Junction

There is quite a bit of difference between species here.

Carnivores: esophagus with stratified squamous ep. Changes abruptly into simple columnar glandular epithelium of stomach.

Horse and pig: Stratified squamous epithelium extends throughout the nonglandular portion of the mucosa of the stomach. (More on this later).

Ruminants: Stratified squamous epithelium lines the entire forestomach.

STOMACH (non-ruminant)

The stomach is a sack-like organ lined with a glandular, absorptive mucosa. The digestive enzymes in the acidic environment of the lumen, in concert with contractions of the muscular wall of the organ initiate the breakdown of the ingesta. When the stomach is contracted, the lining is thrown into numerous ridges called rugae. These ridges will stretch out and flatten when the stomach is distended.

Nonglandular Region of the Gastric Mucosa

In some animals, in addition to the glandular portion, there exist a nonglandular region of the mucosa lined with stratified squamous epithelium with varying degrees of keratinization.

Horse: The nonglandular portion extends quite a distance from the esophagus and ends at the margo plicatus.

Ruminants: The nonglandular portion is extensive and lines the entire forestomach (rumen, reticulum, and omasum).

Carnivores and pigs do not have this nonglandular portion. The entire stomach is glandular.

Glandular Mucosa

The luminal surface of the glandular portion of the stomach has little indentations known as gastric pits (foveolae). These represent openings of gastric glands that are deeper in the mucosa. The gastric glands in the cardiac and pyloric portion of the stomach are different from those in the fundic and corpus of the stomach.

Epithelium

The surface epithelium of the stomach is made up of surface mucous cells. The continuous secretion of this material (mucous blanket) protects the lining of the stomach from the acid produced by the gastric glands. **amina propria**

This contains loose connective tissue, lymphoid cells and occasional lymphoid nodules. The gastric glands are also located in this layer.

Cardiac glands / Pyloric glands

These are branched tubular mucous glands. The mucous secreted, along with that of the surface epithelium, protect the lining of the stomach.

The mucous gland cells have flattened, basally located nuclei and pale cytoplasm. The overall picture of the cardiac and pyloric gland is that there is one cell type involved (as versus several and more colorful cell types in the fundic stomach). The cells of the glands are distinctively different from the surface mucous cells that have round or elongated nuclei and darker cytoplasm.

The gastric pits of the cardiac glands are less deep than those of the pyloric glands. However, this distinction may not be obvious in a routine section.

Fundic glands

These glands are found in the fundic and the corpus portions of the stomach. They produce the gastric juice of the stomach. They are branched tubular glands that contain several cell types:

Surface mucous cells: Columnar cells with basally located oval nuclei and abundant apical cytoplasm containing tiny mucous droplets. Cover the surface and line the gastric pits.

Mucous neck cells: Found at the neck of the gland. Smaller than surface mucous cells and contain less amount of mucin in the cytoplasm. Nucleus round. Secrete a soluble mucus. Best demonstrated with special stains such as PAS.

Undifferentiated reserve cells: Located at the neck region. Through cell division, give rise to both surface epithelial and glandular cells. Require special stain for visualization. The surface mucous cells are renewed at a fast rate (several days) while the deeper glandular cells have relatively longer lifespan.

Parietal cells (aka oxyntic cells): Found between the mucous neck cells and the chief cells. These are large, triangular cells with acidophilic cytoplasm and central nuclei. Electron microscopy shows that these cells have microvilli-lined intracellular canaliculi on the cell surface. There is an elaborate tubulovesicular membrane system (rich with H^+, K^+ -ATPase) associated with the canaliculi. These modifications increase the surface area of the cell greatly when the cell is stimulated to produce acid. Mitochondria can take up as much as 40% of the cell volume. They supply the ATP necessary to pump hydrogen and chloride ions out of the cells. They combine in the lumen to form hydrochloric acid.

Another product secreted by the parietal cells is gastric intrinsic factor, a glycoprotein that binds vitamin B₁₂, a step necessary for subsequent absorption of this vitamin in the small intestine.

Chief cells: These cells are located in the deeper part of the fundic glands. These are typical protein secreting cells with eosinophilic apical cytoplasm (zymogen granules) and basophilic basal cytoplasm (rER). They secrete pepsinogen that becomes the activated proteolytic enzyme, pepsin, when exposed to the acidic environment of the gastric lumen.

Chief cells in the ruminant abomasum secrete renin. In some species, the chief cells also secrete gastric intrinsic factor.

Stratum compactum is a layer of collagen and elastic fibers between the glands and the muscularis mucosae. It is often encountered in the carnivores.

Muscularis mucosae are usually made up of two layers of smooth muscles. Strands of smooth muscle cells can be seen extending upward in between the gastric glands. Contraction of these strands helps to empty the gastric glands.

Submucosa

In the connective tissue of the submucosa are lymphoid cells, blood vessels and lymphatics. Parasympathetic ganglia, known as submucosal / Meissner's plexus, are found here. They, along with sympathetic fibers, are involved in the contraction of the smooth muscle cells.

Muscularis externa

The outer wall of the stomach contains layers of smooth muscles. In addition to the circular and the longitudinal layers, there is a third oblique layer in the corpus (body) and fundus of the stomach.

Parasympathetic ganglia, known as the myenteric plexus (Auerbach's), are found between the layers of muscles. They are involved with, along with sympathetic fibers, control of the contraction of the muscles.

A well-defined muscular sphincter is present between the esophagus and the cardiac portion of the stomach. The inner circular muscle layer forms the cardiac sphincter. A distinctive muscular pyloric sphincter is also present between the pyloric stomach and the duodenum. This is called torus pyloricus in ruminant and pigs.

Serosa

The outermost layer of the stomach is the tunica serosa (visceral peritoneum). It contains loose connective tissue, blood vessels and a covering of mesothelial cells.

Control of gastric secretion and motility

Neuronal and hormonal factors are involved in the control of gastric secretion and motility.

The impulses from the vagus nerve stimulate gastric secretion.

A variety of enteroendocrine cells, close to two dozen types, are found throughout the stomach and intestine, secrete gastrointestinal hormones. Some of the cells have long slender processes that reach to the glandular lumen. Other cell types are not in contact with the glandular lumen. Secretory granules of these cells are always in the basal cytoplasm. These cells can be demonstrated with silver or chromium containing stains (thus the older names enterochromaffin, argentaffin and argyrophil cells). Immunohistochemical staining, using antibodies against specific hormones, is now the preferred method to demonstrate these cells. Some of the hormones are:

Gastrin: Found in G cells located in the pyloric stomach and the duodenum. Stimulates secretion of pepsinogen and hydrochloric acid. Also promotes contraction of the gastric musculature.

Cholecystokinin (CKK): Produced in the duodenum in response to the arrival of chyme (semifluid mass of partly digested food coming from the stomach). Inhibits gastric secretion and motility. Stimulates contraction of the gall bladder.

Secretin: Produced in the duodenum in response to the arrival of acidic contents from the stomach. Stimulates release of pepsinogen from chief cells. Induces pancreatic bicarbonate and fluid secretion.

Somatostatin: Inhibits the release of gastrin by the gastric mucosa and secretin by the intestinal mucosa.

Gastric inhibitory peptide: Aka urogastrone, produced in the small intestine, release induced by fat and glucose. This hormone inhibits gastric secretion.

RUMINANT STOMACH

The ruminant stomach has four parts: 1. Rumen (“paunch”). 2. Reticulum (“honeycomb tripe”). 3. Omasum (“book”). and 4. Abomasum. The first three parts form the forestomach and are histologically quite different from the abomasum that is similar to the glandular stomach discussed in the previous section. At birth, the forestomach is underdeveloped and, not until the ingestion of solid food or roughage, does the forestomach become stimulated to develop.

Stratified squamous epithelium lines the forestomach. This epithelium has absorptive capabilities and is structurally different from the stratified squamous epithelium in other organs. The cells have abundant mitochondria, especially in the spinosum layer, which

allows active transport of nutrients. Beneath the epithelium is an elaborate network of capillaries. Digestive glands are *not* present in the forestomach.

The forestomach serves as a large fermentation vat. With the aid of microorganisms, otherwise unavailable food material is broken down and absorbed through this modified epithelium. Other functions of the forestomach include mixing, regurgitation and eructation (belching).

The mucosa is usually thrown into tongue-like projections, which increase the surface area of the organ. The epithelium is of the stratified squamous type with absorptive capabilities. The lamina propria contains connective tissue and capillary network. Muscularis mucosae may or may not be present. The muscularis externa contains two layers of muscles typical of a hollow organ.

Rumen

The mucosa forms finger-like papillae containing highly vascularized connective tissue core and covered by stratified squamous epithelium. The epithelium is involved in the absorption of short-chain fatty acids (i.e. sodium salts, the microbial breakdown products of cellulose). This transepithelial transport is highest in areas where the cells appear to be swollen.

Muscularis mucosae are *absent* in this part of the forestomach.

The muscularis externa contains two layers of smooth muscle fibers. Myenteric plexus can be found between these layers.

Reticulum

The mucosa contains rows of folds (laminae) that form square honeycomb-like compartments called cells. On the surface of the laminae are short, conical projections called papillae. The stratified squamous epithelium also absorbs short-chain fatty acids. Near the margins of the folds are strands of smooth muscle fibers forming the muscularis mucosae. Contractions of the honeycomb cells, with the purse-string action of the smooth muscle strands, help the mechanical digestion of the ingesta.

This is the most cranial part of the forestomach. Food and sometimes non-food “objects” drop in here first (hardware disease, traumatic reticuloperitonitis).

Omasum

The mucosa and portions of muscularis mucosae form parallel folds that resemble pages of an open book. The folds are called laminae and they have little projections (papillae) on their surfaces.

The mucosal surface is covered by stratified squamous epithelium. This absorbs water and other nutrients.

The core of the laminae are quite characteristic with *three* layers of smooth muscle. Extending upward from the muscularis mucosae are fibers that form the two outer layers. The orientation of the muscle cells is parallel to the free edge of the laminae. Sandwiched between these two layers is a single inner layer of smooth muscle. This is derived from the muscularis externa and the fibers are perpendicular to those of the outer layers.

Movements of the laminae folds help to crush the ingesta. After becoming more compact due to the absorption of water, the ingesta is passed on into the abomasum.

Abomasum

The abomasum is the glandular portion of the ruminant stomach. The histology of this is similar to the glandular stomachs discussed earlier.

Gastric grooves are seen in calves. This allows milk to empty directly into the abomasum and bypassing the forestomach.