# Digestive System
# Stomach

# Esophagus-Stomach Junction

The morphologic characteristics of this junction vary considerably among species.

In the carnivores, the junction of the stratified squamous epithelium of the esophagus with the simple columnar epithelium of the cardiac gland region is abrupt.

In the cats, the junction is 3 to 5 mm cranial to the cardiac part (cardia) of the stomach, whereas in dogs, it is 1 to 2 cm cranial to the cardiac part.

## Esophagus-Stomach Junction

In horses and pigs, the stratified squamous epithelium extends throughout the nonglandular portion of the mucosa of the stomach, whereas in ruminants, it lines the entire forestomach.

## Esophagus-Stomach Junction

The glands of the esophagus may extend a short distance into the submucosa of the stomach in species in which they are present throughout the length of the esophagus.

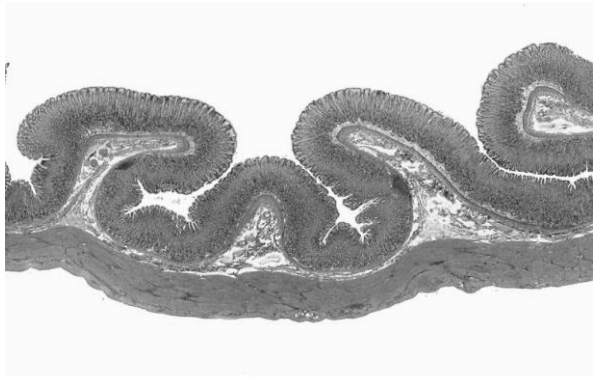
In species in which the skeletal muscle of the esophagus extends to the stomach (carnivores and ruminants), a gradual change from skeletal to smooth muscle occurs.

# STOMACH

The stomach is an enlarged part of the digestive tube specialized for initiating the enzymatic and hydrolytic breakdown of food into digestible nutrients.

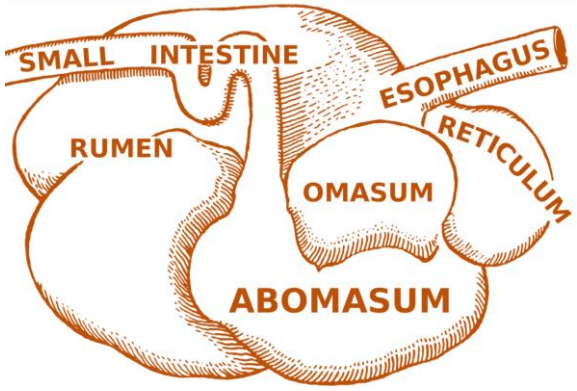
# STOMACH

The tunica muscularis aids in mixing the ingesta with gastric secretions.



# STOMACH

The stomach is lined exclusively by a glandular mucosa in carnivores, whereas herbivorous animals have, in addition to a glandular region, a nonglandular region of the mucosa lined with stratified squamous epithelium.



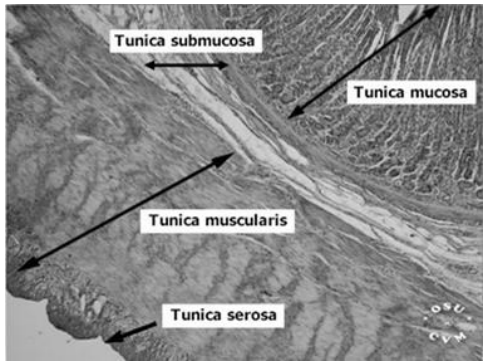
# STOMACH

The wall of the stomach has all the layers of a typical tubular organ.

The mucosa is composed of an epithelium, a lamina propria, and a lamina muscularis.

The submucosa contains collagen fibers, white adipose tissue, blood vessels, and the submucosal nerve plexus.

The tunica muscularis has three layers; inner oblique, middle circular, and outer longitudinal.



# STOMACH

The myenteric plexus is located between the middle and outer muscle layers. The serosa is composed of mesothelium overlying a layer of loose connective tissue.

## Nonglandular Region of the Tunica Mucosa

The nonglandular region of the mucosa is absent in carnivores and is small in pigs.

In horses, the nonglandular region extends a considerable distance from the esophagus and ends at the **margo plicatus**.

The nonglandular region reaches its greatest development in the ruminant stomach, where it lines the entire forestomach (rumen, reticulum, and omasum).

## Nonglandular Region of the Tunica Mucosa

The lining epithelium of the nonglandular region of the mucosa is stratified squamous and may be keratinized, depending on species and diet.

The lamina propria is composed of typical loose connective tissue. The lamina muscularis is distinct.

The junction between the epithelial linings of the nonglandular and glandular regions of the mucosa is abrupt, with stratified squamous epithelium joining simple columnar epithelium.

# Glandular Region of the Tunica Mucosa

The structure of the glandular region of the mucosa conforms to the general pattern described earlier.

The mucosa has extensive folds (gastric folds), which flatten as the stomach fills.

The surface is covered with small invaginations called **gastric pits**, which are continuous with the **gastric glands** and receive their secretory products.

## Glandular Region of the Tunica Mucosa

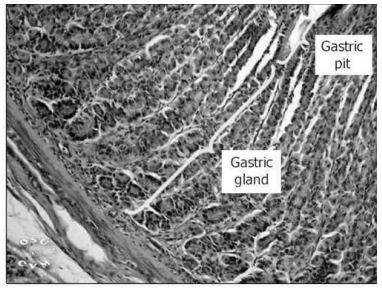
The mucosal surface, including the gastric pits, is lined with tall simple columnar epithelial cells, the mucous secretory product of which is released continuously and serves as a protective coat that prevents digestion of the mucosa.

The surface epithelial cells have a rapid turnover rate; within approximately 3 to 4 days, they are replaced by cells originating from mitosis in the gastric pit.

The gastric glands are densely packed within the lamina propria.

# Glandular Region of the Tunica Mucosa

The loose connective tissue in this area is often difficult to visualize because of the large amount of glandular epithelium.



## Glandular Region of the Tunica Mucosa

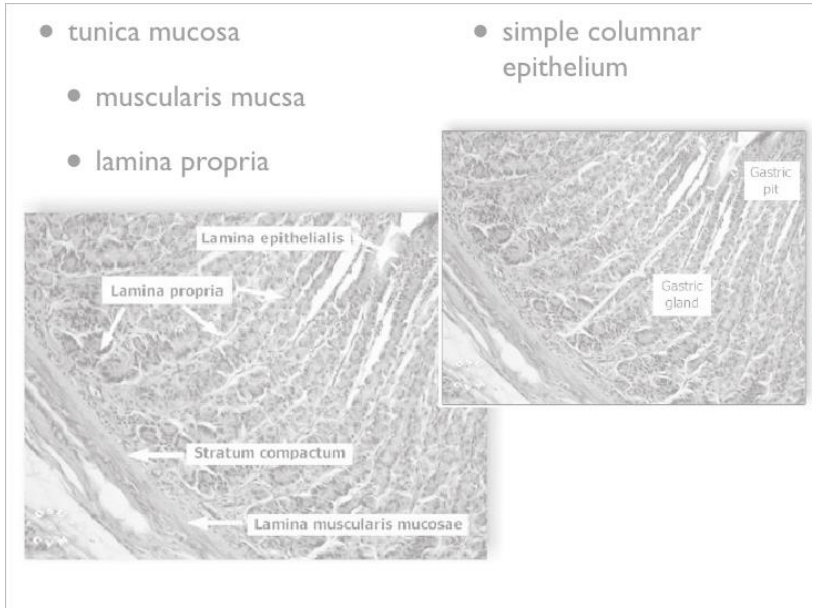
In carnivores, a layer of densely packed collagen fibers called the **stratum compactum** may be interposed between the bases of the gastric glands and the lamina muscularis.

The function of this layer may be to limit penetration of the stomach wall by sharp bones in the gastric contents.

# Glandular Region of the Tunica Mucosa

The lamina muscularis is relatively thick, usually comprising three layers.

Small bundles of smooth muscle cells extend into the lamina propria, coursing between the gastric glands.



## Glandular Region of the Tunica Mucosa

The glandular region of the mucosa of the stomach is divided into three distinct smaller regions named according to the various glandular types present: cardiac, proper gastric (fundic), and pyloric.

## Cardiac Gland Region

The cardiac gland region (B) of the mucosa occupies a narrow strip at the junction of the glandular and nonglandular mucosae in all domestic mammals except pigs, in which it covers nearly half the stomach, including most of the **diverticulum ventriculi**.

# Cardiac Gland Region

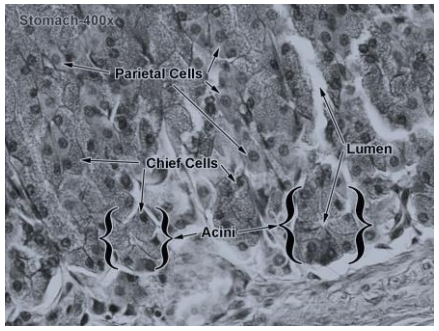
**The cardiac glands** are relatively short, simple, branched, coiled tubular glands that release a mucous secretory product.

The cells of the cardiac glands are cuboidal, and the nuclei are located in the basal portion of the cells.

The cardiac glands empty into relatively shallow gastric pits.

# Cardiac Gland Region

Parietal cells may occur at the junction of the cardiac and proper gastric (fundic) gland regions.



# Proper Gastric (Fundic) Gland Region

The proper gastric (fundic) gland region of the mucosa is well developed in all domestic mammals (C).

In carnivores, it occupies more than one half of the stomach mucosa; in horses, it occupies more than one third; and in pigs, it occupies approximately one fourth.

Two thirds of the mucosa of the abomasum in ruminants is occupied by proper gastric glands.

## Proper Gastric (Fundic) Gland Region

Proper gastric glands are simple, branched, straight tubular glands that extend to the lamina muscularis.

The gland consists of a short neck, a long body, and a slightly dilated blind and, the fundus.

Four structurally and functionally distinct cell types comprise the secretory epithelium of the proper gastric gland: mucous neck cells, chief cells, parietal cells, and endocrine cells.

# Proper Gastric (Fundic) Gland Region

The mucous neck cells occupy the neck of the proper gastric gland.

They are typical mucous cells, with a flat nucleus located toward the cell base.

They appear similar to the mucus-producing surface epithelial cells but have cytoplasm that is more basophilic.

In addition, when treated with PAS, the mucous neck cells are intenselly positive throughout, whereas the surface cells have PAS-positive material only in the upper two thirds of the cell.

# Proper Gastric (Fundic) Gland Region

The chief cells are the most numerous of the gastric gland cells.

They are cuboidal or pyramidal, with a spherical nucleus near the base of the cell.

The area between the nucleus and the free surface appears lacy owing to clear spaces that remain after fixation.

In the living state, zymogen granules occupy these vacuoles and are demonstrable with special fixation and staining.

## Proper Gastric (Fundic) Gland Region

Thus, chief cells are also referred to as zymogen cells.

The basal area of the chief cells has an extensive rough endoplasmic reticulum (rER), resulting in a basophilic staining reaction.

Chief cells secrete pepsinogen, which is transformed into pepsin by hydrochloric acid.

# Proper Gastric (Fundic) Gland Region

The parietal cells are larger and less numerous than the chief cells.

They have a tendency to occur singly  and are peripheral to the chief cells.

Usually, only a narrow apex of the cell borders the gland lumen.

Frequently, the base of the cell bulges outward from the external surface of the gland.

The parietal cells has a spherical nucleus. The cytoplasm stains deeply with eosin.

## Proper Gastric (Fundic) Gland Region

At the apex, the cell membrane invaginates to form a branching **intracellular canaliculus** that extends toward the center of the cell and cominicates with the lumen of the gastric gland.

Numerous microvilli of varying lengths project into the canaliculus, thereby providing an extensive surface area associated with the active transport system necessary for the production of free hydrochloric acid.

Parietal cells form carbonic acid through the action of the enzyme, carbonic anhydrase.

## Proper Gastric (Fundic) Gland Region

Carbonic acid dissociates into bicarbonate ions, which remain in the cell, and hydrogen ions, which are transported across the cell membrane into the intracellular canaliculus, where they combine with chloride ions.

Thus, free hydrochloric acid is formed within the canaliculus and lumen of the gastric gland.

## Proper Gastric (Fundic) Gland Region

Throughout the glandular regions of the gastric mucosa and continuing into the small and large intestines is a series of **endocrine cells** (enteroendocrine cells) responsible for the production of gastrointestinal hormones, such as gastrin, secretin, cholecystokinin, and gastric inhibitory polypeptide.

The hormon is released either into the blood or lymph vascular systems, where it circulates throughout the body or diffuses locally to its target cells (i.e. A paracrin mode of secretion).

## Proper Gastric (Fundic) Gland Region

These cells are difficult to identify in routin hematoxylin and eosin sections and generally appear clear or poorly stained.

Many of these cells demonstrate an affinity for silver stains and therefore have been referred to as argentaffin cells or argyrophilic cells.

Some of these cells can also be demonstrated with potassium dichromate solutions and are therefore reffered to as enterochromaffin cells.

## Proper Gastric (Fundic) Gland Region

Most frequently, these cells are wedged between the basement membrane and the chief cells and do not reach the surface of the epithelium.

Some of these cells, however, do extend to the lumen and are believed to monitör the luminal contents and respond with the release hormones.

At least 12 different endocrine cell types have been identified by electron microscopy in the gastrointestinal tract.

## Proper Gastric (Fundic) Gland Region

They all have numerous small membrane-bounded granules, mostly within the basal cytoplasm, and also contain relatively little rER and small Golgi complexes.

The endocrine cells of the gastrointestinal tract are part of a larger group of cells designated as the **diffuse neuroendocrine system** (DNES).

## Pyloric Gland Region

The pyloric gland region (D) occupies approximately one half of the gastric mucosa in carnivores, but only one third of the gastric mucosa in horses and one third of the abomasal mucosa in ruminants.

In pigs, the pyloric gland region (D) is small, representing approximately one fourth of the mucosa.

# Pyloric Gland Region

Pyloric glands are simple, branched, coiled tubular glands that are relatively short compared to the other gastric glands.

The gastric pits are considerably deeper than those in the cardiac and proper gastric gland regions.

The cells of the pyloric glands have the appearance of typical mucus-secreting cells with flat nuclei located at the base of the cell and a lightly stained apical cytoplasm.

# Pyloric Gland Region

At the pylorus-duodenum junction, submucosal intestinal glands extend into the submucosa of the pyloric gland region from the duodenum.

The middle circular layer of the tunica muscularis thickens at the pylorus to form the pyloric sphincter muscle, which causes the submucosa and mucosa to bulge into the lümen.

In ruminants and pigs, this protuberance, called the torus pyloricus, is especially prominent.

# Species Differences

In carnivores, the cardiac gland region (B) is a relatively narrow area, with the proper gastric (fundic) (C) and pyloric gland regions (D) occupying the remainder of the stomach.

In dogs, the proper gastric gland region ($C_1$.$C_2$) is devided into two zones.

The light zone ($C_1$) has a thinner mucosa with deep gastric pits (foveola gastrica) and short tortuous glands that appear in groups and do not reach the lamina muscularis.

The dark zone ($C_2$) is adjacent to the pyloric gland region and has a thicker mucosa, shallow gastric pits, and proper gastric glands that more closely resemble those of the other species.

# Species Differences

The stomach of  the pig has a very large cardiac gland region (B) that contains numerous lymphatic nodules in the lamina propria.

The parietal cells in the proper gastric gland region (C) tend to occur in clusters.

The stomach of the horse has an extensive nonglandular region of the mucosa that terminates abruptly, forming the **margo plicatus**.

The cardiac gland region (B) is almost nonexistent, whereas the proper gastric and pyloric gland region follow the normal pattern.

# Ruminant Stomach

The stomach of ruminants is composed of four structurally distinct parts.

The first three parts (the **rumen**, **reticulum**, and **omasum**) are collectively called the forestomach or proventriculus.

# Ruminant Stomach

The forestomach is lined entirely by a nonglandular mucosa having a keratinized stratified squamous epithelium.

The fourth part of the ruminant stomach (the abomasum) (C-D) is lined by a glandular mucosa that is similar to the stomach of other species.

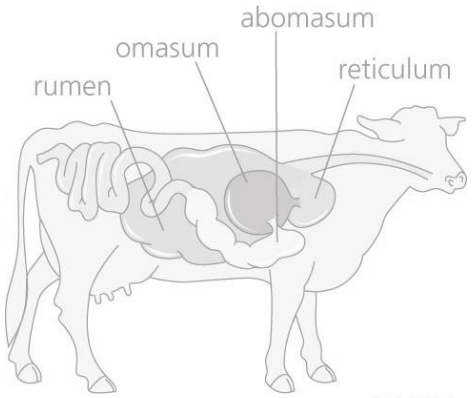
# Ruminant Stomach

The forestomach is effective in breaking down the coarse, fibrous ingesta into absorbable nutrients by both mechanical and chemical action.

The rumen acts as a fermentation vat where a large population of bacteria and protozoa act on the ingesta, thereby producing short-chain, volatile fatty acids, which are then absorbed through the mucosa into the blood.

The reticulum and omasum exert a mechanical action on the ingesta that reduces the mass to fine particles.

The wall of the omasum is especially well adapted for this function.



# Ruminant Stomach

In addition to fermentation and mechanical activities, considerable absorption occurs across the keratinized squamous epithelium of all three portions of the forestomach.

The enzymatic digestive processes in the abomasum further degrade the ingesta, along with accompanying microorganisms, to such substances as glucose and amino acids in a manner similar to that of the stomach of nonruminants.

# RUMEN

The mucosa of the rumen is characterized by small tongue shaped papilla, The size and shape of which vary considerably from one region of the rumen to another.

The papillae develop prenatally and remain small as long as the animal is on a milk diet.

When roughage is included in the diet and fermentation begins in the rumen, the papillae increase rapidly in size.

# RUMEN

The ruminal epithelium is keratinized stratified squamous and performs at least three important functions; protection, metabolism, and absorbtion .

The stratum corneum (A) forms a protective shield against the rough, fibrous ingesta, whereas the deeper strata metabolize short-chain, volatile fatty acids, particularly butyric, acetic, and propionic acids, the chief products of fermentation.

Sodium, potassium, ammonia, urea, and many other products are also absorbed from the ruminal contents.

# RUMEN

The stratum corneum varies in thickness from one  to two cells to as many as 10 to 20 cells.

Stainable nuclei may or may not be present.

The stratum granulosum (B) is usually one to three cells thick.

The cells are distinctly flattened, and keratohyalin granules are present in the cytoplasm.

# RUMEN

Cells of the stratum granulosum (B) near the stratum corneum (A) are frequently swollen and are characterized by a pyknotic nucleus surrounded by clear, electron-lucent cytoplasm.

The peripheral cytoplasm of these cells contains keratohyalin granules, tonofilaments, and numerous membrane-bounded, electron-dense granules.

The stratum spinosum (E) consists of polyhedral cells that are slightly larger than the basal cells.

# RUMEN

The thickness of this layer varies from one to 10 cells (E).

Cytologic features of these cells (E) include numerous mitochondria and ribosomes distributed throughout the cytoplasm.

Adjacent cells are connected through numerous desmosomes.

The cells of the stratum basale (F) are columnar and extend numerous processes to the basement membrane, which greatly increases the basal cell membrane surface area.

Cytologic features of the basal cells are similar to those of the stratum spinosum.

# RUMEN

The intercellular spaces throughout the entire epithelium are distended to varying degrees.

The spaces may be wide and contain flocculent material that is passing through the epithelium, or in other areas, they may be collapsed with no flocculent material present, thus reflecting a period of little or no movement of material across the epithelium.

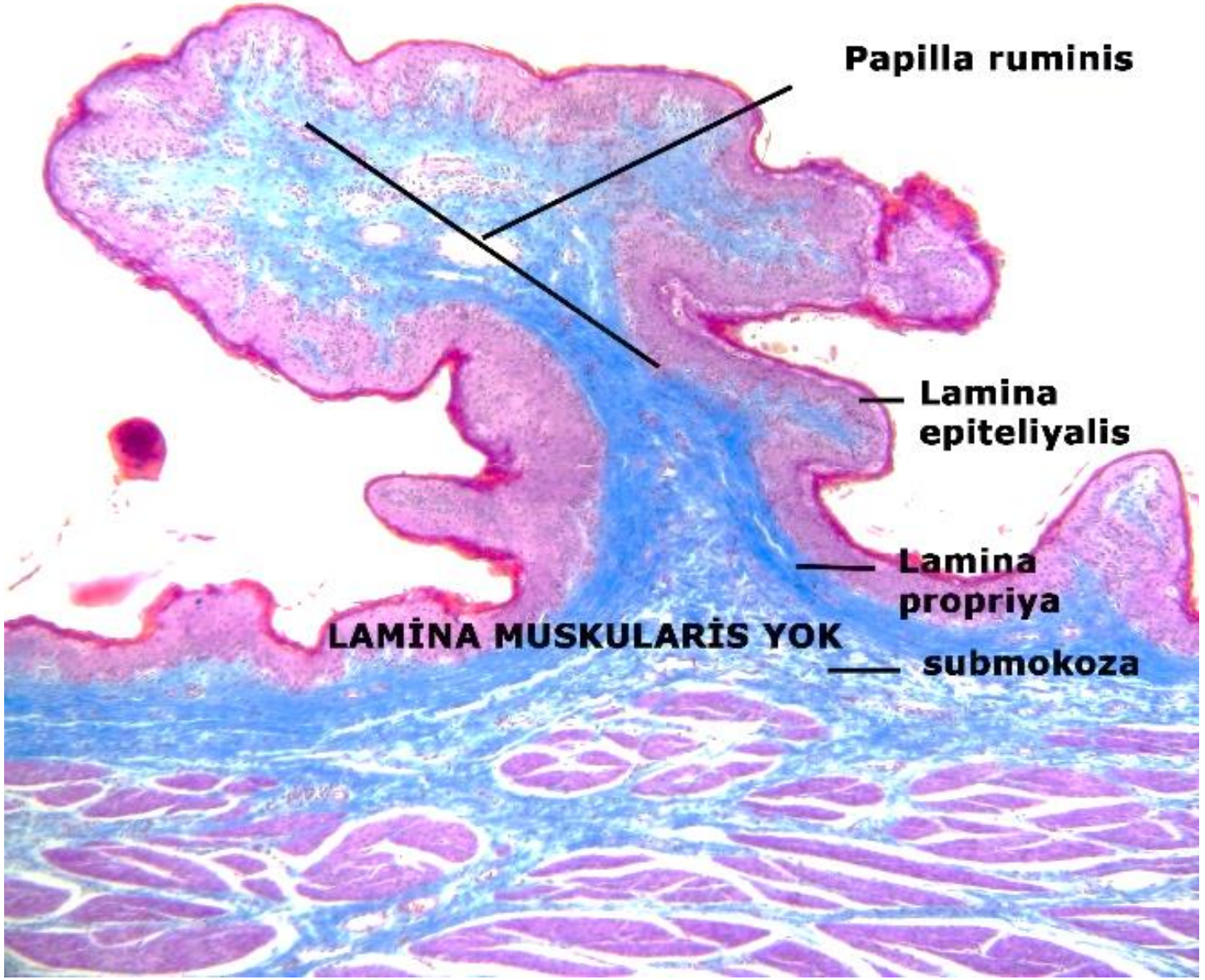
# RUMEN

A lamina muscularis is absent; thus the lamina propria blends with the submucosa, forming a propria-submucosa.

Each papilla has a core (an extension of the propria-submucosa) containing a dens network of fenestrated capillaries lies just beneath the basement membrane of the epithelium.

Near the tunica muscularis, the connective tissue of the propria-submucosa is more loosely arranged.

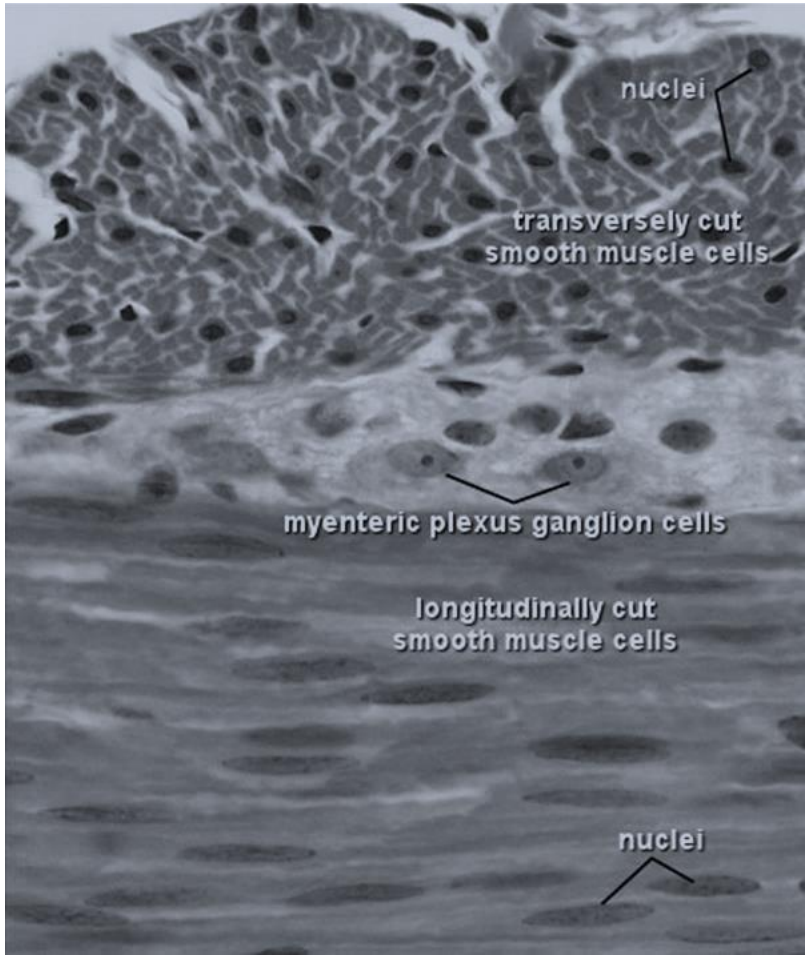
A network of blood vessels and the submucosal nerve plexus is located within this layer.



# RUMEN

The tunica muscularis is composed of inner circular and outer longitudinal layers of smooth muscle.

The myenteric plexus is located between the layer.



# RUMEN

The serosa of the rumen is a loose connective tissue covered by a mesothelium.

Varying amounts of white adipose tissue, as well as blood vessels, lymph vessels, and nerves, are located in the loose connective tissue of the serosa.

# Reticulum and Reticular Sulcus

The reticulum has mucosa with permanent interconnecting folds, the reticular crest, giving it the appearance of a honeycomb.

These crests are of two different heights.

The taller crests separate the mucosal surface into shallow compartments, the reticular cells, which are further divided into smaller areas by the shorter crests.

The sides of the crests have vertical ridges, and the mucosa between the crests is covered by conical reticular papillae (crista reticularis) that Project into the lumen.

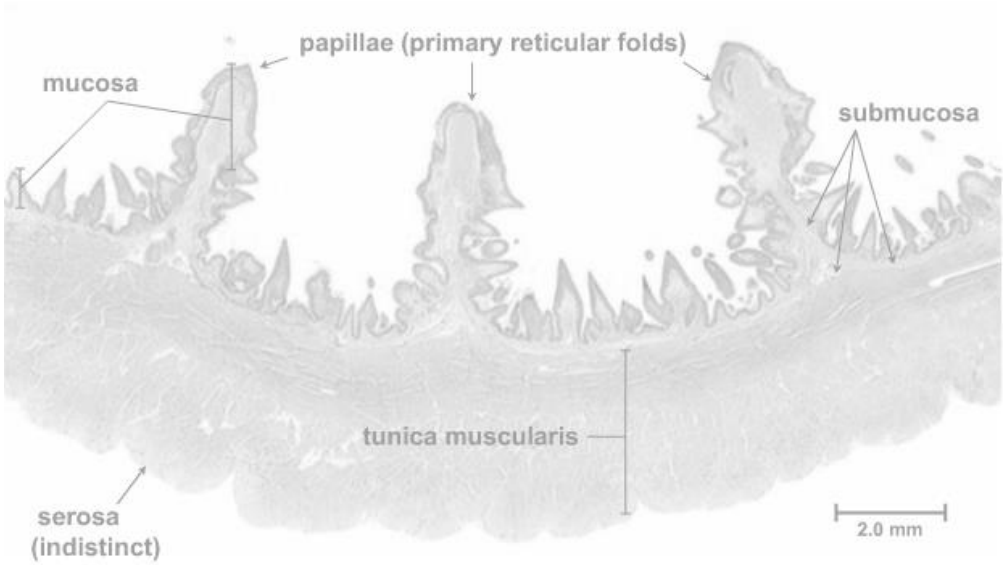
# Reticulum and Reticular Sulcus

The keratinized stratified squamous epithelium resembles that of the rumen.

The propria- submucosa consists predominantly of a feltwork of collagen and elastic fibers.

A lamina muscularis is located only in the upper part of the larger reticular crests; therefore, the lamina propria and the submucosa blend imperceptibly.

The lamina muscularis is continuous with that of the esophagus.



# Reticulum and Reticular Sulcus

The smooth muscle bundles pass from one crest into another where the the crests intersect, thus forming a continuous network of smooth muscle throughout the reticular mucosa.

The tunica muscularis consists of two layers of smooth muscle cells that follow an oblique course and cross at right angles.

The serosa is like that of the rumen.

# Reticulum and Reticular Sulcus

The reticular sulcus (groove) begins at the cardiac ostium and passes ventrally on the medial wall of the reticulum to end at the reticulo-omasal ostium.

The sulcus is bordered by two thick folds, the labia (lips).

The entire sulcus is lined by keratinized stratified squamous epithelium

The propria-submucosa consists of predominantly of collagen and elastic fibers.

The lamina muscularis, an extension of the esophageal lamina muscularis, is incomplete and is most conspicuous in the labia of the sulcus.

It forms a complete layer near the omasum.

# Reticulum and Reticular Sulcus

The tunica muscularis of the reticular sulcus is composed largely of smooth muscle fibers.

Skeletal muscle fibers from the tunica muscularis of the esophagus are present near the cardiac ostium but fade out rapidly in the sulcus.

Both longitudinally and transversely oriented smooth muscle fibers are found in the floor of the sulcus, whereas the labia contain mainly longitudinally oriented smooth muscle fibers.

The longitudinal muscle fibers in the labia form a loop around the cardiac ostium corresponing to the cardiac loop of animals with simple stomachs.

# Reticulum and Reticular Sulcus

At the ventral end of the reticular sulcus, the muscle fibers pass into the sphincter of the reticulo-omasal ostium.

In the young animal, the smooth muscle layers of the labia contract reflexly during suckling.

As a result, the edges of the labia come together to create a channel that allows milk to bypass the reticulum and rumen.

The milk passes through a very short omasal groove directly into the abomasum.

The serosa of the reticulum is similar to that of the other parts of the forestomach.

# OMASUM

The omasum is nearly filled with approximately 100 longitudinal folds, the laminae, that arise from the internal surface of the greater curvature and sides of the organ.

The largest laminae, approximately 12 in number, have a thick, concave, free edge that reaches to within a short distance of the lesser curvature.

# OMASUM

Second, thirth, fourth, and fifth orders of shorter laminae progressively decrease in length.

The omasal contents are pressed into thin layers in the narrow spaces between the laminae (interlaminar recesses) and are reduced to a fine pulp by the numerous rounded, horny omasal papillae that stud the surface  of the mucosa.

The papillae are directed so that the movement of the laminae works the solid contents from the reticulo-omasal ostium into the interlaminar recesses and out at the omaso-abomasal ostium.

## OMASUM

The lining is keratinized stratified squamous epithelium, and the aglandular lamina propria contains a dense subepithelial capillary network.

# OMASUM

The laminae muscularis mucosae extends into the omasal laminae usually in two layers.

In between these two layers of the laminae muscularis mucosae there is a layer of smooth muscle belonging to the tunica muscularis.

# OMASUM

These three layers of smooth muscle intertwine as they extend toward the tip of the laminae and eventually fuse to form one large mass of muscle at the tip.

# OMASUM

The tunica muscularis is composed of thin, outer longitudinal layer and a thicker, inner circular layer of smooth muscle.

# OMASUM

The innermost fibers of the circular layer are continued into the large omasal laminae (first through third orders) as the intermediate muscle sheet.

# ABOMASUM

The omaso-abomasal ostium is marked by two mucosal folds, the vela abomasica, where the epithelium changes abruptly from keratinized stratified squamous to simple columnar.

In cattle, this change is on the apex of the folds, whereas in small ruminants, the change occurs on the omasal side.

# ABOMASUM

The lamina propria becomes less dense on the abomasal side of the folds and frequently exhibits a lymphatic nodule beneath the epithelial junction.

The mucosa of the abomasum has all the characteristic glandular regions of the stomach described previously.

# CHICKEN STOMACH

The **stomach** of the chicken consists of a glandular **proventriculus** and a **muscular ventriculus (gizzard ).**

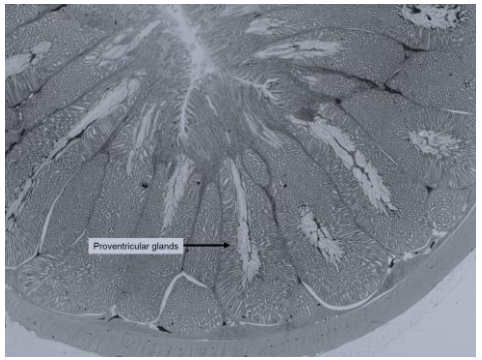
## CHICKEN STOMACH

The mucosa of the proventriculus is thrown into folds (plicae).

The wall of the proventriculus consists of large, compound, tubular glands.

The secretory cells, which are cuboidal to low columnar, produce both pepsinogen and hydrochloric acid, thus combining the function of mammalian chief and parietal cells.

Each gland opens to the lumen of the stomach through a conical papilla.



The ventriculus is a highly muscular grinding organ.

It is lined by an epithelium that invaginates into the lamina propria, forming elongated pits, each of which bears terminal tubular gastric glands.

Cells of the latter secrete a thick, horny material.

Although keratin-like, this substance, usually called keratinoid, is not chemically equivalent to keratin. It forms the tough inner lining, about 1 mm thick, of the ventriculus**.**