

DIGESTIVE SYSTEM I

The Oral Cavity

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Learning Objectives

1. The general architecture of the digestive tract is that of a typical hollow tube.
2. Understand the histology of each of the layers: mucosa, submucosa, muscularis externa and the serosa.
3. The main components of the tongue are the mucosa and the muscular core.
4. The dorsal surface of the tongue has lingual papillae. Know which type of the papillae contains taste buds and which type does not.
5. The skeletal muscles of tongue are arranged in three axes.
6. Understand the differences between brachydont and hypsodont teeth.
7. Know the composition of enamel, dentin, cementum and the cells that produce them.
8. The dental pulp contains capillaries, nerves, lymphatics and loose connective tissue.
9. Salivary glands can be of the serous, mucous or the mixed seromucous type.
10. The secretory portion of the salivary gland contains both secretory cells and myoepithelial cells.
11. The ducts of the salivary glands contain epithelial and myoepithelial cells.
12. Understand the composition of the secretion from the salivary glands.

There is quite a bit of differences in the digestive systems of various species. The requirements differ considerably between the herbivores, carnivores and the omnivores. Species that are monogastric (with a single, true stomach) are quite different from the ruminants (with fermentative rumen).

Here we will present the general anatomy and function of the GI tract and will mention specific important differences where applicable.

Basic Functions of the Digestive Tract

The digestive tract has the following functions:

- Prehension (grasping) of food with the lips and mouth
- Mechanical breaking down of the food by chewing
- Digestion of foodstuff by enzymatic and chemical reactions
- Absorption of nutrients and water
- Elimination of wastes

Failure of an animal in carrying out any of these processes leads to malnutrition and other pathological process. Bear this in mind when studying the histology of the digestive system so as to integrate your knowledge of structure and function.

General Structure of the Digestive Tract

The digestive tract has the architecture of a typical hollow organ. It has a lumen and a wall consisting of several layers: mucosa, submucosa, muscularis externa and serosa/adventitia.

The mucosa is made up of an epithelial lining, a lamina propria of loose connective tissue and blood vessels and muscularis mucosae containing one or two thin layers of smooth muscles. In an organ that does not have muscularis mucosae, the lamina propria and the submucosa blend together to form the propria-submucosa.

The mucosa of the digestive tract is the surface across which most substances enter the body. It has many functions including: 1) Secretion of enzymes, acid, mucin, hormones and antibodies. 2) Absorption of the break down products of digestion, water, vitamins etc. 3) Barrier to prevent the entry of antigens, pathogenic organisms etc. 4) Immunologic protection via the lymphoid tissue in the submucosa.

The submucosa contains loose or dense connective tissue, blood and lymphatic vessels and the autonomic parasympathetic submucosal plexuses (Meissner's). Glands may be present in the submucosa of the oral cavity, esophagus, stomach and the intestines. Variable amounts of lymphoid tissue are seen here.

The muscularis externa contains two layers. The internal layer is generally circular and the external layer mostly longitudinal. Between these two layers are the autonomic parasympathetic myenteric plexuses (Auerbach's). In certain areas, skeletal muscles may be present.

The serosa is made up of loose connective tissue, blood and lymphatic vessels, some adipose tissue and an external covering of simple squamous epithelium (mesothelium).

The adventitia is similar to the serosa but does not have a mesothelial covering.

The epithelium serves as a selective barrier between the contents of the lumen in the digestive tract and the tissues of the body, an area for the digestion and absorption of food as well as the production of hormonal factors.

The abundant lymphoid tissue in the lamina propria and the submucosa serve a protective function against bacteria and viruses in the lumen. Secretory IgA produced in the GI tract is resistant to proteolytic enzymes and is functional in the lumen.

The muscle fibers propel and mix the food in the digestive tract. Parasympathetic and sympathetic fibers coordinate the contraction of the layers (peristalsis).

Digestive glands, developed as out-pockets of the tract, provide enzymes and secretion important in the breakdown and absorption of the ingesta.

LIPS

The lips help in the prehension of food in horses and small ruminants. The lips are highly sensitive and act as sense organs in horses, cattle and some other species.

The external surfaces of the lips are covered by typical skin (stratified squamous keratinized epithelium) with hairs and sebaceous glands up to the mucocutaneous junction.

The mucosa of the lips is covered by stratified squamous keratinized epithelium in horses and ruminants. In carnivores and pigs the mucosa is non-keratinized.

Seromucous labial glands are found in the propria-submucosa.

The muscularis external is made up of skeletal muscle fibers from the orbicularis oris muscle.

CHEEKS

The mucosa of the cheek (oral surface) is covered by a stratified squamous epithelium. Depending on the area in the cheek as well as the species, this epithelium may or may not be keratinized.

Ruminants have caudally oriented macroscopic conical buccal papillae on the surface. These structures help the manipulation and chewing of food. Salivary glands (buccal glands) are found in the propria-submucosa.

A middle layer is made up of loose connective tissue and skeletal muscle fibers (the buccinator).

The external covering of the cheek is regular skin.

PALATE

Hard Palate

The hard palate helps to retain food in the oral cavity where it can be chewed and act upon by digestive enzymes in the saliva.

Mucosa: Oral surface covered with mucous membrane containing stratified squamous keratinized epithelium. This masticatory mucosa is thrown into ridges (rugae).

Propria-Submucosa: (No muscularis mucosae). Contains palatine salivary glands caudally in all domestic animals except pigs and may be mucous or seromucous in

nature. There is a dense vascular network (mostly venous) in the connective tissue. The submucosa blends with the periosteum that covers the bony core of the hard palate.

Dental pad (pulvinus): found in ruminants. This is a rostral prominence in place of upper incisor teeth (as reflected in the dental formula I0). The epithelium and the submucosa are greatly thickened in this region forming the pad.

Soft Palate

Mucosa: Oral (ventral) surface covered by mucous membrane with stratified squamous epithelium. Nasal (dorsal) surface covered by respiratory epithelium (pseudostratified ciliated columnar). Stratified epithelium is found caudally.

Propria-Submucosa: (No muscularis mucosae). Mucous/seromucous glands (palatine glands), nodular and diffused lymphatic tissues, blood vessels and nerves. Pigs and horses have a tonsil on the oral surface.

Core: Flexible and contains skeletal muscle fibers and connective tissue.

OROPHARYNX

Mucosa: Mucous membrane with stratified squamous epithelium.

Propria-submucosa: Contains mucous glands and lymphoid tissues.

Muscularis externa: Formed by skeletal muscle fibers.

TONGUE

This organ is basically a core of muscle covered by stratified squamous epithelium.

Dorsal lingual surface: Surface epithelium stratified and keratinized. It is covered with numerous irregularities and elevations called lingual papillae.

Filiform papillae: These elongated cone-shaped structures are heavily keratinized and pointing caudally. They are quite numerous and are found over most of the surface of the tongue. Beneath the epithelium there is dense irregular connective tissue. These structures are involved in prehension of food in large ruminants, the uptake of liquids in carnivores, and grooming behavior in cats. They do *not* contain taste buds.

Conical papillae: These are like those in the cheek. They are found on the base of the tongue in dogs, cats and pigs, and on the torus linguae of ruminants. In pigs they are also called tonsillar papillae and contain a core of lymphoid tissue (forming the lingual tonsil). Used in moving food caudally. They do *not* contain taste buds.

Lenticular papillae: These are found mainly in ruminants. As the name implies, these are lens shaped. Used to move food caudally. They do *not* contain taste buds.

The above three kinds of papillae are basically involved in the movement of the ingesta.

Marginal papillae: long and flat papillae found in newborn carnivores and newborn swine. These are temporary structures located at the lateral edge of the tongue. They help to form a seal around the teat during suckling.

The following papillae contain taste buds in the surface epithelium. Each taste bud is a barrel-shaped structure containing supportive, secretory, precursor/basal and chemoreceptor cells. The cells in the taste buds are constantly turning over and are renewed about every 10 days.

Sensations of taste are carried by the facial, the glossopharyngeal, and vagus nerves.

Fungiform papillae: These are mushroom-shaped structures that contain taste buds on the dorsal surface in the slightly keratinized surface epithelium.

Circumvallate papillae: Large papilla surrounded by a moat (furrow), located on the dorsum and just rostral to the root of the tongue. Numerous taste buds are found on the sides of the papilla and appear as lighter staining areas in the epithelium. Serous glands (von Ebner's) open into the moat via ducts. Their secretion dissolves materials for taste perception and continuously flushes the moat, thus enabling the taste buds to respond rapidly to changing stimuli.

Foliate papillae: These are made up of a series of parallel mucosal folds with taste buds on the lateral walls. Serous glands with ducts open into the furrows separating the folds. Foliate papillae are rudimentary and without taste buds in the cats and are not present in ruminants. In rabbit, they are well developed and contain numerous taste buds.

Ventral lingual surface: the epithelium is of the stratified squamous type without papillae.

The submucosa of the tongue contains scattered lingual salivary glands.

The intrinsic and extrinsic skeletal muscle fibers of the tongue are grouped into bundles separated by connective tissue. The fibers cross each other in three planes, with each arranged at right angles to the other two. This accounts for the tongue's tremendous flexibility.

Special features

Horse: There is a cord-like dorsal lingual hyaline cartilage in the tongue.

Ruminants: Torus linguae is a dorsal prominence that is rich in adipose tissue.

Dog: A lyssa in the central midline, made up of a cord of skeletal muscle and adipose tissue, surrounded by dense connective tissue, is present.

Cats and pigs: A lyssa in the central midline, made up of adipose tissue, is present.

TEETH

In domestic animals, teeth are either of the brachydont or of the hypsodont type.

Brachydont teeth: All the carnivore teeth, teeth of pigs (except boar's tusks) and the incisors of ruminant are of this type. The tooth *stops* growing after eruption. (Brachyodont, same thing. Brachy- G. brachys, short; + G. odous, tooth)

Each brachydont tooth is a short structure with a crown (above gingiva), a neck (constricted area just below the gingival line) and one or more roots embedded in the alveolar bone of the jaw. The teeth are more pointed on the occlusal surface and are well suited for the holding of preys and tearing or shredding of food.

The crown is covered by a cap of enamel that extends down to the neck. The root is covered by a layer of cementum. (Cementum is not found above the gingival line.) Under the enamel and cementum is a thick layer of dentin.

Hypsodont teeth: All teeth of the horse, the cheek teeth of ruminants and the tusks of boars are of this type. They *continue* to grow during the adult life of the animal and are longer than brachydont teeth. The constant wearing of these teeth keep their lengths in check.

Each tooth has a rough occlusal surface for crushing and grinding food. The body of the tooth is elongated. The tooth does not have a crown or neck. Cementum covers the body (above and below the gingival line). Deeper in is a layer of enamel throughout the length of the body. Deep to the enamel is a thick layer of dentin. Cementum and enamel both invaginate into the dentin.

The occlusal surfaces of the hypsodont teeth are mostly flat and more suitable for the grinding of plant and grain material.

Structure

Enamel is a hard, mineralized substance composed mainly of hydroxyapatite and a little bit of organic material. This covers the crown of brachydont teeth. In hypsodont teeth, enamel covers almost the entire body. Invaginations on the occlusal surface (infundibula) and folds on the sides (plicae) are also covered by enamel.

Enamel is secreted by ameloblasts during tooth development. The ameloblast is a polarized cell with mitochondria and the nucleus in the base. The supranuclear area contains elaborate rER and Golgi. The apex of the cell takes the shape of a broad process, Tomes' process that is in contact with the calcified matrix. Granules secreted by the ameloblasts contain proteins and interrod enamel. In the extracellular matrix enamel takes the form of enamel rods with interrod regions between the rods. Each enamel rod contains highly packed hydroxyapatite crystals.

After eruption, the ameloblasts degenerate in the brachydont teeth, which then stop growing. In hypsodont teeth, the ameloblast may continue to actively synthesize enamel at the root.

Dentin is found beneath the enamel of the crown and the cementum of the root in brachydont teeth, and the enamel of the body of the hypsodont teeth.

Odontoblasts, cells that secrete dentin throughout the life of the tooth, are located at the pulp-dentin border. Odontoblasts secrete nonmineralized predentin adjacent to the cell body. This matrix becomes dentin that is 70% mineral (hydroxyapatite, fluoroapatite) and 30% organic material (type I collagen, glycoproteins). At the apical process of the odontoblast is a long dentinal tube the tip of which abuts the enamel. The proximal portion of the process is surrounded by predentin while the distal portion is surrounded by dentin.

Cementum is similar to woven bone but may be acellular in some areas. It is made up of lamellae oriented parallel to the surface of the tooth with cementocytes occupying lacunae (spaces). Bundles of collagen fibers (Sharpey's or cemento-alveolar fibers) extend from the alveolar bone into the cementum. These fibers form the periodontal ligament and anchor the tooth in the alveolar bone. Cementum surrounds the dentin in the root of the brachydont tooth. In hypsodont tooth, cementum covers the entire body.

Periodontal ligament firmly anchors the tooth in the bone socket. It is made up of collagen fibers that extend from the alveolar bone into the cementum.

Dental pulp is the material found in the pulp cavity, the central portion of the tooth. This core contains capillaries, nerves, lymphatics and loose connective tissue. The most peripheral part of the pulp contains the layer of odontoblasts that manufacture dentin. The pulp cavity decreases with age.

SALIVARY GLANDS

Functions of the Salivary Glands

Secretions from the salivary glands contain enzymes (amylase, starts digestion of carbohydrates), water (moistens), glycoproteins (lubricate) that, working together, help swallowing (deglutition). Secretory IgA, lactoferrin and lysozyme in the saliva perform protective functions.

Amylase is found in the saliva of omnivores such as rats and pigs, but is absent in carnivores like dogs and cats. This enzyme breaks down amylose in starch.

Lipases may be found in some young animals that are nursing or on a high-milk diet (e.g. calves).

Saliva can serve a neutralizing function if it contains a high concentration of sodium bicarbonate and phosphate (e.g. cattle).

Saliva is used in evaporating cooling by dogs.

Structure of the Salivary Glands

Surrounding each major salivary gland is a connective tissue capsule. Septa of connective tissue from the capsule extend into the gland and divide the organ into lobes and then lobules. A rich vascular and nerves plexus surrounds the secretory units and the ducts.

Each salivary gland contains these components:

Secretory units made up of serous, mucous or a combination of these cells types. The cells are arranged as acini or tubulo-acini. A secretory acinus can be of serous, mucous or mixed type.

A pyramidal serous cell has the typical features of a protein-secreting cell. The basal cytoplasm contains the rER while the secretory products (zymogen granules) are found in the apical cytoplasm. The cells are eosinophilic with centrally located nuclei.

The cuboidal mucous cell has a basally located, flat or oval nucleus. The mucous material (mucinogen granules) in the cytoplasm stains palely in an H&E preparation but will stain brilliantly magenta in a PAS preparation.

Sometimes at the distal end of a mucous tubuloalveolar gland you will find a few serous cells arranged in a crescent. This is called a serous demilune.

In the connective tissue surrounding the acini are lymphocytes and plasma cells. Immunoglobulin A (IgA) is synthesized by the plasma cells. The acini cells synthesize a secretory protein. The secretory IgA complex, resistant to proteolysis, is then released into the saliva.

Myoepithelial cells wrap around the secretory units and the ducts. Contraction of these cells, which have numerous microfilaments in their cytoplasm, helps to discharge saliva out of the secretory units and ducts. These cells are best demonstrated with the help of immunohistochemistry.

Ducts can be classified (from small to large) into intercalated, striated intralobular, interlobular and finally, the main excretory duct.

The small ducts leading away from the secretory units are the intercalated ducts. The cells are low cuboidal and pale staining. They are most prominent in serous glands. Situated inside the lobule.

The striated ducts are larger intralobular ducts. The low columnar cells have radial basal striations extending from the base of the cells to the level of the nuclei. These striations are actually numerous infolding of the basal plasma membrane with many mitochondria associated with them. These cells are involved with active transport (reabsorption of sodium from the primary secretion and the secretion of potassium and bicarbonate into the secretion).

The next type of ducts, interlobular, is found in the connective tissue between the lobules. Simple cuboidal to low columnar cells form the epithelium.

The interlobar duct is found in the significant amount of connective tissue between the lobes. The epithelium may be stratified cuboidal to stratified columnar.

The main duct of each salivary gland has stratified cuboidal or stratified columnar epithelium. Goblet cells may be present in the epithelium. This changes to non-keratinized stratified squamous epithelium as it opens into the oral cavity.

Parotid gland: Purely serous acini are found in the parotid glands of most domestic animals. In dogs, however, mucous acini are found singly or in groups between the serous cells.

Mandibular gland: This mixed seromucous gland contains a combination of tubules and terminal acini with mucous cells, as well as peripheral serous demilunes. In dogs and cat, the mucous acini predominate.

Sublingual gland: In cows, sheep and pigs, this gland contains mainly mucous cells. In dogs and cat, this is a mixed seromucous gland.

A number of **minor salivary glands** are also present. These seromucous glands include labial, buccal, molar, lingual, palatine and (only in carnivores) zygomatic glands. Minor salivary glands do not have connective tissue capsules.

Lymphoid Tissues

The lymphoid tissues of the oral cavity include the ring of tonsils and the diffuse lymphoid tissues in the connective tissues. These are part of the body's first line of immune response (the lumen of the GI tract, starting from the oral cavity, is physically continuous with the outside world).