**(Slide 1) Lecture 10**

**Digestive physiology**

**(Slide 2)** Lecture plan:

1. Definition of digestion.
2. Kinds of digestion.
3. Functions of Gastrointestinal Tract.
4. Physiology of digestion in the oral cavity.
5. Role of the tongue in digestion.
6. The Salivary Glands.
7. Regulation of Salivation.
8. Passage of Food through the Esophagus.

**(Slide 3)** For normal functioning the body requires plastic and energetic material. These substances are obtained from food, but only mineral salts, water and vitamins are assimilated in the form they enter the body. Proteins, fats and carbohydrates enter the body in the form of complex compounds and should undergo physical and chemical processing to be absorbed and assimilated. Here, food components should be deprived of their species specificity not to be recognized by the immune system as foreign matter. All the above functions are performed by the digestive system. Digestion is a complex of physical, chemical and physiological processes, which break down foodstuffs and convert them into chemical compounds capable of being absorbed by body cells. These processes occur in a strictly defined sequence in all parts of the gastrointestinal tract (the mouth, pharynx, esophagus, stomach, duodenum, small and large intestine) with participation of the liver, gallbladder and pancreas, and are controlled by regulatory mechanisms of different levels. This chain of processes which ends in a complete breakdown of food into monomers capable of being absorbed, is called a digestive conveyor.

**(Slide 4)** **Kinds of digestion.** Depending on the origin of the hydrolytic enzymes, three types of digestion are distinguished: digestion proper, symbiontic digestion and autolytic digestion.

Digestion proper is carried out by enzymes synthesized by digestive glands of humans and animals.

Symbiontic digestion is carried out by enzymes synthesized by symbionts (microorganisms) present in the digestive tract of a macroorganism. In this way cellulose is digested in the colon. This type of digestion is mostly used by herbivores.

Autolytic digestion is performed by enzymes present in the foodstuffs. For example, breast milk contains enzymes which cause its curdling.

**(Slide 5)** Depending on where hydrolysis of nutrients takes place, there are distinguished intracellular and extracellular digestion. Intracellular digestion consists in hydrolysis of substances inside cells by cellular (lysosomal) enzymes. Substances enter a cell by phagocytosis and pinocytosis. Intracellular digestion is characteristic of protozoa. In humans intracellular digestion takes place in leukocytes and in cells of lymphoreticular and histiocytic system. Higher animals and humans use extracellular digestion.

**(Slide 6)** Extracellular digestion is subdivided into distant (cavitary) and contact (parietal, or membrane) digestion. Distant, or cavitary, digestion occurs in the cavities of the gastrointestinal tract with the assistance of enzymes of digestive secretions at some distance from the place of production of these enzymes. Contact, or parietal, digestion (A. Ugolev) occurs in the glycocalix region of the small intestine, on the surface of microvilli, with participation of enzymes fixed on cell membranes, and ends in absorption (transport of nutrients across enterocytes into the blood or lymph).

**(Slide 7)** **Functions of Gastrointestinal Tract**

1. Secretory function is associated with production of digestive juices: saliva, gastric, pancreatic, intestinal juices and bile by glandular cells.

2. Motor function, or motility, is realized by musculature of the digestive apparatus at all stages of the digestive process, and includes chewing (mastication), swallowing, mixing, propelling food through the digestive tract and removing indigested residues from the organism. Motility also includes movements of villi and microvilli of the gastrointestinal epithelium.

3. Absorption function is carried out by mucous membrane of the gastrointestinal tract. Products of cleavage of proteins, fats and carbohydrates (amino acids, glycerol, fatty acids and monosaccharides), water, salts, medical drugs are absorbed into the blood and lymph from the lumen of a digestive organ.

4. Incretory, or intrasecretory function consists in release of hormones that regulate motility, secretion and absorption in the gastrointestinal tract. These hormones are: gastrin, secretin, cholecystokinin-pancreozymin, motilin, etc.

5. Excretory function consists in release into the gastrointestinal tract of metabolites by digestive glands (urea, ammonia, bile pigments), water, heavy metal salts, medical drugs to be further removed from the body.

Besides, digestive organs perform other functions, for example, participation in water-salt metabolism, local immune reactions, hematopoiesis, fibrinolysis, etc.

**(Slide 8)** **The cheeks, tongue, and palate frame the mouth, which is also called the oral cavity (or buccal cavity).** At the entrance to the mouth are the lips, or labia (singular = labium). Their outer covering is skin, which transitions to a mucous membrane in the mouth proper. Lips are very vascular with only a thin layer of keratinized epithelium and therefore they look red due to the red blood cell color showing through the thin, transparent epithelium. They have a huge representation on the cerebral cortex, which probably explains the human fascination with kissing! The lips cover the orbicularis oris muscle, which regulates what comes in and goes out of the mouth. The labial frenulum is a midline fold of mucous membrane that attaches the inner surface of each lip to the gum. The cheeks make up the oral cavity’s sidewalls. While their outer covering is skin, their inner covering is mucous membrane. This membrane is made up of non-keratinized, stratified squamous epithelium. Between the skin and mucous membranes are connective tissue and buccinator muscles. The next time you eat some food, notice how the buccinator muscles in your cheeks and the orbicularis oris muscle in your lips contract, helping you keep the food from falling out of your mouth. Additionally, notice how these muscles work when you are speaking.

**(Slide 9)** The pocket-like part of the mouth that is framed on the inside by the gums and teeth, and on the outside by the cheeks and lips is called the oral vestibule. Moving farther into the mouth, the opening between the oral cavity and throat (oropharynx) is called the fauces (like the kitchen “faucet”). The main open area of the mouth, or oral cavity proper, runs from the gums and teeth to the fauces.

**(Slide 10)** When you are chewing, you do not find it difficult to breathe simultaneously. The next time you have food in your mouth, notice how the arched shape of the roof of your mouth allows you to handle both digestion and respiration at the same time. This arch is called the palate. The anterior region of the palate serves as a wall (or septum) between the oral and nasal cavities as well as a rigid shelf against which the tongue can push food. It is created by the maxillary and palatine bones of the skull and, given its bony structure, is known as **the hard palate**. If you run your tongue along the roof of your mouth, you’ll notice that the hard palate ends in the posterior oral cavity, and the tissue becomes fleshier. This part of the palate, known as the soft palate, is composed mainly of skeletal muscle. You can therefore manipulate, subconsciously, the soft palate − for instance, to yawn, swallow, or sing. A fleshy bead of tissue called the uvula drops down from the center of the posterior edge of **the** **soft palate**. Although some have suggested that the uvula is a vestigial organ, it serves an important purpose. When you swallow, the soft palate and uvula move upward, helping to keep foods and liquid from entering the nasal cavity. Unfortunately, it can also contribute to the sound produced by snoring. Two muscular folds extend downward from the soft palate, on either side of the uvula. Toward the front, the palatoglossal arch lies next to the base of the tongue; behind it, the palatopharyngeal arch forms the superior and lateral margins of the fauces. Between these two arches are the palatine tonsils, clusters of lymphoid tissue that protect the pharynx. The lingual tonsils are located at the base of the tongue.

**(Slide 11)** **The Tongue**

Perhaps you have heard it said that the tongue is the strongest muscle in the body. Those who stake this claim cite its strength proportionate to its size. Although it is difficult to quantify the relative strength of different muscles, it remains indisputable that the tongue is a workhorse, facilitating ingestion, mechanical digestion, chemical digestion (lingual lipase), sensation (of taste, texture, and temperature of food), swallowing, and vocalization.

The tongue is attached to the mandible, the styloid processes of the temporal bones, and the hyoid bone. The hyoid is unique in that it only distantly/indirectly articulates with other bones. The tongue is positioned over the floor of the oral cavity. A medial septum extends the entire length of the tongue, dividing it into symmetrical halves.

**(Slide 12)** Beneath its mucous membrane covering, each half of the tongue is composed of the same number and type of intrinsic and extrinsic skeletal muscles. The intrinsic muscles (those within the tongue) are the longitudinalis inferior, longitudinalis superior, transversus linguae, and verticalis linguae muscles. These allow you to change the size and shape of your tongue, as well as to stick it out, if you wish. Having such a flexible tongue facilitates both swallowing and speech.

**(Slide 13)** As you learned in your study of the muscular system, the extrinsic muscles of the tongue are the mylohyoid, hyoglossus, styloglossus, and genioglossus muscles. These muscles originate outside the tongue and insert into connective tissues within the tongue. The mylohyoid is responsible for raising the tongue, the hyoglossus pulls it down and back, the styloglossus pulls it up and back, and the genioglossus pulls it forward. Working in concert, these muscles perform three important digestive functions in the mouth: (1) position food for optimal chewing, (2) gather food into a bolus (rounded mass), and (3) position food so it can be swallowed.

**(Slide 14)** The top and sides of the tongue are studded with papillae, extensions of lamina propria of the mucosa, which are covered in stratified squamous epithelium. Fungiform papillae, which are mushroom shaped, cover a large area of the tongue; they tend to be larger toward the rear of the tongue and smaller on the tip and sides. Circumvallate papillae are much fewer in number, only 8 to 12, and lie in a row along the posterior portion of the tongue anterior to the lingual tonsil. In contrast, filiform papillae are long and thin. Fungiform and circumvallate papillae contain taste buds, and filiform papillae have touch receptors that help the tongue move food around in the mouth. The filiform papillae create an abrasive surface that performs mechanically, much like a cat’s rough tongue that is used for grooming. Lingual glands in the lamina propria of the tongue secrete mucus and a watery serous fluid that contains the enzyme lingual lipase, which plays a minor role in breaking down triglycerides but does not begin working until it is activated in the stomach. A fold of mucous membrane on the underside of the tongue, the lingual frenulum, tethers the tongue to the floor of the mouth. People with the congenital anomaly ankyloglossia, also known by the non-medical term “tongue tie,” have a lingual frenulum that is too short or otherwise malformed. Severe ankyloglossia can impair speech and must be corrected with surgery.

**(Slide 15)** Many small salivary glands are housed within the mucous membranes of the mouth and tongue. These minor exocrine glands are constantly secreting saliva, either directly into the oral cavity or indirectly through ducts, even while you sleep. In fact, an average of 1 to 1.5 liters of saliva is secreted each day. Usually just enough saliva is present to moisten the mouth and teeth. Secretion increases when you eat, because saliva is essential to moisten food and initiate the chemical breakdown of carbohydrates. Small amounts of saliva are also secreted by the labial glands in the lips. In addition, the buccal glands in the cheeks, palatal glands in the palate, and lingual glands in the tongue help ensure that all areas of the mouth are supplied with adequate saliva.

**(Slide 16)** **The Major Salivary Glands**

Outside the oral mucosa are three pairs of major salivary glands, which secrete the majority of saliva into ducts that open into the mouth:

1. The submandibular glands, which are in the floor of the mouth, secrete saliva into the mouth through the submandibular ducts.

2. The sublingual glands, which lie below the tongue, use the lesser sublingual ducts to secrete saliva into the oral cavity.

3. The parotid glands lie between the skin and the masseter muscle, near the ears. They secrete saliva into the mouth through the parotid duct, which is located near the second upper molar tooth.

**(Slide 17)** Saliva is essentially (95.5 percent) water. The remaining 4.5 percent is a complex mixture of ions, glycoproteins, enzymes, growth factors, and waste products. Perhaps the most important ingredient in salvia from the perspective of digestion is the enzyme salivary amylase, which initiates the breakdown of carbohydrates. Food does not spend enough time in the mouth to allow all the carbohydrates to break down, but salivary amylase continues acting until it is inactivated by stomach acids. Bicarbonate and phosphate ions function as chemical buffers, maintaining saliva at a pH between 6.35 and 6.85. Salivary mucus helps lubricate food, facilitating movement in the mouth, bolus formation, and swallowing. Saliva contains immunoglobulin A, which prevents microbes from penetrating the epithelium, and lysozyme, which makes saliva antimicrobial. Saliva also contains epidermal growth factor, which might have given rise to the adage “a mother’s kiss can heal a wound.”

**(Slide 18)** Each of the major salivary glands secretes a unique formulation of saliva according to its cellular makeup. For example, the parotid glands secrete a watery solution that contains salivary amylase. The submandibular glands have cells similar to those of the parotid glands, as well as mucus-secreting cells. Therefore, saliva secreted by the submandibular glands also contains amylase but in a liquid thickened with mucus. The sublingual glands contain mostly mucous cells, and they secrete the thickest saliva with the least amount of salivary amylase.

**(Slide 19)** Saliva contributes to the digestion of food and to the maintenance of oral hygiene. Without normal salivary function the frequency of dental caries, gum disease (gingivitis and periodontitis), and other oral problems increases significantly.

**(Slide 20)** **1. Lubricant.** Saliva coats the oral mucosa mechanically protecting it from trauma during eating, swallowing, and speaking. Mouth soreness is very common in people with reduced saliva (xerostomia) and food (especially dry food) sticks to the inside of the mouth.

**2. Digestion.** The digestive functions of saliva include moistening food and helping to create a food bolus. The lubricative function of saliva allows the food bolus to be passed easily from the mouth into the esophagus. Saliva contains the enzyme amylase, also called ptyalin, which is capable of breaking down starch into simpler sugars such as maltose and dextrin that can be further broken down in the small intestine. About 30% of starch digestion takes place in the mouth cavity. Salivary glands also secrete salivary lipase (a more potent form of lipase) to begin fat digestion. Salivary lipase plays a large role in fat digestion in newborn infants as their pancreatic lipase still needs some time to develop.

**3. Role in taste.** Saliva is very important in the sense of taste. It is the liquid medium in which chemicals are carried to taste receptor cells (mostly associated with lingual papillae). People with little saliva often complain of dysgeusia (i.e. disordered taste, e.g. reduced ability to taste, or having a bad, metallic taste at all times). A rare condition identified to affect taste is that of 'Saliva Hypernatrium', or excessive amounts of sodium in saliva that is not caused by any other condition (e.g., Sjögren syndrome), causing everything to taste 'salty'.

**(Slide 21)** **Other functions of saliva.**

1. Saliva maintains the pH of the mouth. Saliva is supersaturated with various ions. Certain salivary proteins prevent precipitation, which would form salts. These ions act as a buffer, keeping the acidity of the mouth within a certain range, typically pH 6.2–7.4. This prevents minerals in the dental hard tissues from dissolving.

2. Saliva secretes carbonic anhydrase (gustin), which is thought to play a role in the development of taste buds.

3. Saliva contains Epidermal Growth Factor. Epidermal Growth Factor results in cellular proliferation, differentiation, and survival. Epidermal Growth Factor is a low-molecular-weight polypeptide first purified from the mouse submandibular gland, but since then found in many human tissues including submandibular gland, parotid gland. Salivary Epidermal Growth Factor, which seems also regulated by dietary inorganic iodine, also plays an important physiological role in the maintenance of oro-esophageal and gastric tissue integrity. The biological effects of salivary Epidermal Growth Factor include healing of oral and gastroesophageal ulcers, inhibition of gastric acid secretion, stimulation of deoxyribonucleic acid synthesis as well as mucosal protection from intraluminal injurious factors such as gastric acid, bile acids, pepsin, and trypsin and to physical, chemical and bacterial agents.

**(Slide 22)** **Regulation of Salivation**

The autonomic nervous system regulates salivation (the secretion of saliva). In the absence of food, parasympathetic stimulation keeps saliva flowing at just the right level for comfort as you speak, swallow, sleep, and generally go about life. Over-salivation can occur, for example, if you are stimulated by the smell of food, but that food is not available for you to eat. Drooling is an extreme instance of the overproduction of saliva. During times of stress, such as before speaking in public, sympathetic stimulation takes over, reducing salivation and producing the symptom of dry mouth often associated with anxiety. When you are dehydrated, salivation is reduced, causing the mouth to feel dry and prompting you to take action to quench your thirst.

**(Slide 23)** Salivation can be stimulated by the sight, smell, and taste of food. It can even be stimulated by thinking about food. You might notice whether reading about food and salivation right now has had any effect on your production of saliva. How does the salivation process work while you are eating? Food contains chemicals that stimulate taste receptors on the tongue, which send impulses to the superior and inferior salivatory nuclei in the brain stem. These two nuclei then send back parasympathetic impulses through fibers in the glossopharyngeal and facial nerves, which stimulate salivation. Even after you swallow food, salivation is increased to cleanse the mouth and to water down and neutralize any irritating chemical remnants, such as that hot sauce in your burrito. Most saliva is swallowed along with food and is reabsorbed, so that fluid is not lost.

**(Slide 24)** **Passage of Food through the Esophagus**

The upper esophageal sphincter, which is continuous with the inferior pharyngeal constrictor, controls the movement of food from the pharynx into the esophagus. The upper two-thirds of the esophagus consists of both smooth and skeletal muscle fibers, with the latter fading out in the bottom third of the esophagus. Rhythmic waves of peristalsis, which begin in the upper esophagus, propel the bolus of food toward the stomach. Meanwhile, secretions from the esophageal mucosa lubricate the esophagus and food. Food passes from the esophagus into the stomach at the lower esophageal sphincter (also called the gastroesophageal or cardiac sphincter). Recall that sphincters are muscles that surround tubes and serve as valves, closing the tube when the sphincters contract and opening it when they relax. The lower esophageal sphincter relaxes to let food pass into the stomach, and then contracts to prevent stomach acids from backing up into the esophagus. Surrounding this sphincter is the muscular diaphragm, which helps close off the sphincter when no food is being swallowed. When the lower esophageal sphincter does not completely close, the stomach’s contents can reflux (that is, back up into the esophagus), causing heartburn or gastroesophageal reflux disease (GERD).

**(Slide 25)** **Deglutition** is another word for swallowing—the movement of food from the mouth to the stomach. The entire process takes about 4 to 8 seconds for solid or semisolid food, and about 1 second for very soft food and liquids. Although this sounds quick and effortless, deglutition is, in fact, a complex process that involves both the skeletal muscle of the tongue and the muscles of the pharynx and esophagus. It is aided by the presence of mucus and saliva. There are three stages in deglutition: the voluntary phase, the pharyngeal phase, and the esophageal phase (Figure 23.3.8). The autonomic nervous system controls the latter two phases.

**(Slide 26)** **The Voluntary Phase**

The voluntary phase of deglutition (also known as the oral or buccal phase) is so called because you can control when you swallow food. In this phase, chewing has been completed and swallowing is set in motion. The tongue moves upward and backward against the palate, pushing the bolus to the back of the oral cavity and into the oropharynx. Other muscles keep the mouth closed and prevent food from falling out. At this point, the two involuntary phases of swallowing begin.

**The Pharyngeal Phase**

In the pharyngeal phase, stimulation of receptors in the oropharynx sends impulses to the deglutition center (a collection of neurons that controls swallowing) in the medulla oblongata. Impulses are then sent back to the uvula and soft palate, causing them to move upward and close off the nasopharynx. The laryngeal muscles also constrict to prevent aspiration of food into the trachea. At this point, deglutition apnea takes place, which means that breathing ceases for a very brief time. Contractions of the pharyngeal constrictor muscles move the bolus through the oropharynx and laryngopharynx. Relaxation of the upper esophageal sphincter then allows food to enter the esophagus.

**(Slide 27) The Esophageal Phase**

The entry of food into the esophagus marks the beginning of the esophageal phase of deglutition and the initiation of peristalsis. As in the previous phase, the complex neuromuscular actions are controlled by the medulla oblongata. Peristalsis propels the bolus through the esophagus and toward the stomach. The circular muscle layer of the muscularis contracts, pinching the esophageal wall and forcing the bolus forward. At the same time, the longitudinal muscle layer of the muscularis also contracts, shortening this area and pushing out its walls to receive the bolus. In this way, a series of contractions keeps moving food toward the stomach. When the bolus nears the stomach, distention of the esophagus initiates a short reflex relaxation of the lower esophageal sphincter that allows the bolus to pass into the stomach. During the esophageal phase, esophageal glands secrete mucus that lubricates the bolus and minimizes friction.

**(Slide 24)** Lesson assignment:

Lauralee Sherwood. Fundamentals of Human Physiology: On the website of the department

Pages: 437 – 447.

Questions that we will analyze for a lesson on this topic:

1. General characteristics of the digestive system: the importance of digestion for the body, the essence of digestion.
2. Digestive system functions.
3. Features of digestion in the oral cavity.
4. Composition and amount of saliva.
5. Saliva functions.
6. The adaptive nature of the work of the salivary glands.
7. Regulation of salivation.
8. Passage of Food through the Esophagus.

Finish for today

The full lecture is at the indicated website.

**Thank you for attention**