DIGESTIVE SYSTEM
General consideration; Digestion in the Mouth; Sensation of Thirst

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• provide nutrient for the cells of the body
• a tube 5 meters in length of variable cross-sectional area which includes
  – Mouth
  – Pharynx
  – Esophagus
  – Stomach
  – the small and large intestines
  – rectum and anus
• other components:
  – salivary glands
  – Pancreas
  – biliary system ( liver, gallbladder, and bile ducts)
Microscopically, from Inside to Outside

- Mucus membrane thrown into folds and contains glands for mucus, enzyme and hormone secretions
- A thin layer of smooth muscle, longitudinal (submucous muscle)
- A layer of nerve cells and fibers (submucous plexus or Meissner’s plexus)
- Middle layer of smooth muscles arranged in a circular manner
- Another layer of nerve cells and fibers (Myenteric plexus or Auerbach’s plexus)
- Outer layer of smooth muscles arranged longitudinally
- Connective tissue layer (fibrous and elastic tissue fibers)
- Blood vessels, nerves and lymphatics
Innervation

- **Extrinsic innervation**
  - Parasympathetic cholinergic – excitatory
  - Sympathetic noradrenergic – inhibitory
- **Intrinsic to the GIT**
  - **Myenteric plexus**
    » located between the outer longitudinal and middle circular smooth muscle layers
    » excitatory mainly on the motor function of the GIT
    » major stimulus is stretch of intestinal wall
    » mucosal receptor are mainly mechanoreceptor
  - **Meissner’s plexus**
    » located between the middle circular smooth muscle layer and the mucosa
    » excitatory mainly on the secretory function of the gut
    » major stimulus is irritation of the intestinal mucosa
    » mucosal receptors are chemoreceptors that sense the composition of intestinal contents
GI Smooth Muscle

- arranged in bundles of as many as 1000 parallel fibers
- within each bundle the muscle fibers are electrically connected with one another through large numbers of gap junctions that allow low resistance movement of ions from one cell to the next
- each layer represents a branching latticework of smooth muscle bundles (syncytium)
Electrical Activity of GI Smooth Muscle

• Slow Waves
  – slow, undulating changes in the RMP
  – intensity varies between 5 and 15 mV, frequency ranges between 3 and 12 per minute (3 in the body of the stomach, 12 in the duodenum, and 8 or 9 in the terminal ileum)
  – cause unknown; mainly control the appearance of intermittent spike potentials

• Spike potentials
  – true action potentials
  – occur automatically when the RMP of the GI smooth muscle becomes positive than about -40mV
  – last as long as 10 to 20 msec
  – calcium-sodium channels
  – cause most of the muscle contraction
Changes in the voltage of the RMP

- RMP = -56mV
- Factors that depolarize the membrane
  - stretching of the muscle
  - stimulation by acetylcholine
  - stimulation by the parasympathetic nerves that secrete acetylcholine at their endings
  - stimulation by several specific GI hormones
Factors that Hyperpolarize the Membrane

- the effect of NE and epinephrine on the muscle membrane
- stimulation of the sympathetic nerves that secrete NE at their endings
Aspects of GIT Functions

- Motility
- Secretion
- Digestion
- Absorption
MOTOR Function of the GIT

- **Peristalsis**
  - for propulsion of food in the different segments of the GIT in analward or aboral direction

- **Segmenting contractions**
  - for mixing of food particles with the different secretions of the GI glands

- **Tonus of the GIT**
  - continuous degree of contraction of the smooth muscles for the prevention of too much distention of the gut esp in the region of the stomach, intestine and rectum
SECRETORY Function
Throughout the GIT, secretory glands subserve two primary functions:

- Digestive enzymes are secreted in most areas from the mouth to the distal end of the ileum.
- Mucous glands from the mouth to the anus provide mucus for lubrication and protection of all parts of the alimentary tract.
Anatomical Types of Glands

- **Mucous cells/Goblet cells**
  - single cell mucous glands found on the surface of the epithelium in most parts of the GIT

- **Crypts of Lieberkuhn**
  - pits in the SI that represents invaginations of the epithelium into the submucosa; they are deep and contain specialized secretory cells

- **Tubular glands**
  - found in the stomach and upper duodenum

- **Salivary glands, Pancreas, and Liver**
  - complex glands which provide secretions for digestion or emulsification of food
Autonomic Stimulation of Secretion
Parasympathetic Stimulation

- increases the rates of glandular secretion:
  - Glands in the upper portion of the tract (vagus and other cranial parasympathetic nerves)
  - salivary glands, esophageal glands, gastric glands, pancreas, and Brunner’s glands in the duodenum
  - Glands of the distal portion of the LI (pelvic parasympathetic nerves)
Sympathetic stimulation

• dual effect:
  – usually slightly increases secretion
  – superimposed sympathetic stimulation usually reduces the secretion mainly because of reduced blood supply
Regulation of Glandular Secretion by GI hormones

- They are liberated from the GI mucosa in response to the presence of foods in the lumen of the gut.
- They are absorbed into the blood and carried to the glands, where they stimulate secretion.
- Hormonal stimulation of the GB wall causes it to empty its stored bile into the duodenum.
SECRETION OF SALIVA

- Daily secretion of saliva
  - 800 to 1500 ml
- pH
  - 6 to 7
Saliva contains two major types of protein secretion

- a serous secretion that contains ptyalin (an alpha-amylase), an enzyme for digesting starches
- mucous secretion that contains mucin for lubricating and for surface protective purposes
The principal glands of salivation are

• parotid glands
  – serous secretion
• submandibular glands
  – serous and mucus
• sublingual glands
  – serous and mucus
• buccal glands
  – mucus secretion
Salivary secretion is a two-stage operation

- acini
- salivary ducts

The acini secrete a primary secretion that contains ptyalin/mucin in a solution of ions.

As the primary secretion flows through the ducts, two major active transport processes take place:

- Sodium reabsorption and potassium secretion
- This creates negativity of about -70 mv in the salivary ducts. This causes chloride ions to be reabsorbed passively.
- Bicarbonate ions are secreted by the ductal epithelium into the lumen of the duct. This is partly caused by exchange of bicarbonate for chloride ions and partly by an active secretory process.
Concentrations of ions in the saliva under resting conditions

- **Sodium and Chloride**
  - 15 mEq/L each (1/7 to 1/10 their concentration in plasma)

- **Potassium**
  - 30 mEq/L (7x as great as its concentration in plasma)

- **Bicarbonate**
  - 50 – 70 mEq/L (2-3x that of plasma)
• During maximal salivation, the NaCl concentration rises to about $\frac{1}{2}$ to $\frac{2}{3}$ that of plasma, whereas K concentration falls to only 4x that of plasma

• Excess aldosterone secretion $\rightarrow$ sodium and chloride reabsorption and the potassium secretion become greatly increased
Function of Saliva for Oral Hygiene

- Saliva helps prevent the deteriorative processes in several ways
  - The flow of saliva helps wash away the pathogenic bacteria as well as the food particles that provide their metabolic support.
  - The saliva contains several factors that destroy bacteria:
    » thiocyanate ions
    » proteolytic enzymes (lysozyme)
      • attack the bacteria
      • aid the thiocyanate ions in entering the bacteria, where they in turn become bactericidal
      • digest food particles, helping further to remove the bacterial metabolic support
    » Saliva often contains significant amounts of protein antibodies that can destroy oral bacteria, including those that cause dental carries.
Nervous Regulation of Salivary Secretion

- Parasympathetic nervous signals from the superior and inferior salivatory nuclei in the brain stem
  - control the salivary glands
  - located at the juncture of the medulla and pons
  - excited by both taste and tactile stimuli from the tongue and other areas of the mouth and pharynx
  - can be stimulated or inhibited by nervous signals coming from the higher centers of the CNS (salivation is increased when smells or eats favorite foods)
- Salivation occurs in response to reflexes originating in the stomach and upper intestines
- Sympathetic stimulation increase salivation to moderate amount
- Blood supply to the glands
Esophageal Secretion

- entirely mucoid in character and principally provide lubrication for swallowing
- simple mucus glands
  - lines the main body of the esophagus
- compound mucus glands
  - many at the initial portion of the esophagus
  - in the upper esophagus it prevents mucosal excoriation by the newly entering food
  - near the esophagogastric junction it protects the esophageal wall from digestion by gastric juices that often reflux from the stomach back into the lower esophagus
DIGESTION in the MOUTH
Movements in the Mouth

- Mastication
- Swallowing (Deglutition)
Mastication

- a process wherein a reasonable number of opposing teeth interdigitate to adequately breakdown food particles and mix them with saliva to facilitate swallowing
  - teeth (incisors, molars)
  - muscles of chewing – innervated by the motor branch of CN V
    » masseter and temporalis muscle – power muscles that produce the crushing force between the teeth when they occlude or contact a rough bolus of food
    » medial pterygoid muscle – mandibular elevator
    » lateral pterygoid and suprathyroid muscles open the mouth by pulling forward on the mandibular condyles and down backward on the symphysis
    » periodontal ligaments of the teeth contain proprioceptors that function to inhibit the powerful elevator muscles
Mastication

- Chewing process
  - controlled by nuclei in the brain stem
  - Stimulation of the reticular formation near the brain stem centers for taste can cause continual rhythmical chewing movements.
  - Stimulation of areas in the hypothalamus, amygdala, and cerebral cortex near the sensory areas for taste and smell can often cause chewing.

Chewing reflex:
- bolus of food in the mouth → initiates reflex inhibition of the muscles of mastication allowing the lower jaw to drop → initiates a stretch reflex of the jaw muscles → rebound contraction → automatically raises the jaw to cause closure of the teeth → compresses the bolus again against the linings of the mouth, inhibits the jaw muscles
Swallowing (Deglutition)

- movement responsible for transporting material from the mouth to the stomach.
- It is divided into:
  - Voluntary stage
    - initiates the swallowing process; food is voluntarily squeezed or rolled posteriorly into the pharynx by pressure of the tongue upward and backward against the palate
  - Pharyngeal stage
    - involuntary; constitutes the passage of food through the pharynx into the esophagus
    - reflex act; almost always initiated by voluntary movement of food into the back of the mouth, which in turn excites the sensory receptors that elicit the swallowing reflex
Swallowing (Deglutition)

- bolus of food enters the posterior mouth and pharynx → stimulates swallowing receptor areas (opening of the pharynx, tonsillar pillars) → impulses pass to the brain stem initiate a series of automatic pharyngeal muscle contractions:
  - The soft palate is pulled upward to close the posterior nares
  - The palatopharyngeal folds on either side of the pharynx are pulled medially to approximate each other.
  - The vocal cords of the larynx are strongly approximated, and the larynx is pulled upward and anteriorly by the neck muscles
  - The upward movement of the larynx also pulls up and enlarges the opening of the esophagus. At the same time, UES relaxes allowing food to move easily and freely from the posterior pharynx into the upper esophagus.
  - The entire muscular wall of the pharynx contracts (rapid peristaltic wave which propels the food)
(a) Position of structures before swallowing

(b) During the pharyngeal stage of swallowing
Deglutition or Swallowing Center

- areas in the medulla and lower pons that control swallowing
- CN V, IX, X, XII
  - transmit the motor impulses from the swallowing center to the pharynx and esophagus that cause swallowing
Effect of the Pharyngeal Stage of Swallowing on Respiration

- The entire pharyngeal stage of swallowing occurs in less than 2 seconds, thereby interrupting respiration for only a fraction of a usual respiratory cycle.
Swallowing

- **Esophageal stage**
  - **Primary peristalsis**
    » continuation of the peristaltic wave that begins in the pharynx and spreads into the esophagus during the pharyngeal stage
    » passes all the way from the pharynx to the stomach in about 8 to 10 seconds
  - **Secondary peristalsis**
    » result from distention of the esophagus from the retained food
    » initiated partly by intrinsic neural circuits in the esophageal myenteric nervous system and partly by reflexes that are transmitted through vagal afferent fibers from the esophagus to the medulla and then back again to the esophagus through vagal efferent fibers.
    » The musculature of the pharynx and the upper third of the esophagus is striated muscle. The peristaltic waves in these regions are controlled only by skeletal nerve impulses in the glossopharyngeal and vagus nerves.
    » In the lower 2/3 of the esophagus, the musculature is smooth, but it is also strongly controlled by the vagus nerves acting through their connections with the myenteric nervous system.
Anterior view of frontal sections peristalsis in esophagus
Hydrolysis

• the basic process of digestion
The total quantity of fluid that must be absorbed each day is equal to the ingested fluid (about 1.5 liters) plus that secreted in the various gastrointestinal secretions (about 7 liters).

All but about 1.5 liters of this is absorbed in the SI, leaving only this 1.5 liters to pass through the ileocecal valve into the colon each day.
INGESTED AND SECRETED

- Saliva (1 liter)
- Ingestion of liquids (2.3 liters)
- Gastric juice (2 liters)
- Bile (1 liter)
- Pancreatic juice (2 liters)
- Intestinal juice (1 liter)

Total ingested and secreted = 9.3 liters

Absorbed

- Small intestine (8.3 liters)
- Large intestine (0.9 liters)

Total absorbed = 9.2 liters

Fluid balance in GI tract

Excreted in feces (0.1 liter)
Basic Mechanisms of Absorption

- **Active transport**
  - imparts energy to the substance as it is being transported for the purpose of concentrating it on the other side of the membrane or moving it against an electrical potential

- **Diffusion**
  - transport of substances through the membrane as a result of molecular movement along an electrochemical gradient

- **Solvent drag**
  - anytime a solvent is absorbed because of physical absorptive forces, the movement of the solvent will drag dissolved substances along at the same time
Thirst

- Hypothalamic control

Figure 14-8. Diagrammatic representation of the way changes in plasma osmolality and changes in ECF volume affect thirst by separate pathways.
Osmolality

- acts via osmoreceptors
  - receptors that sense the osmolality of the body fluids
  - located in the anterior hypothalamus
Decrease in ECF volume

• stimulate thirst by a pathway independent of that mediating thirst in response to increase plasma osmolality

• Hemorrhage causes increased drinking even though there is no change in the osmolality of the plasma.

• Neural input from cardiopulmonary and systemic arterial baroreceptors in the circulation
Angiotensin II

- Acts on the subfornical organ and on the organum vasculosum of the lamina terminalis
  - Areas that are outside the blood-brain barrier
- + by hypovolemia and low blood pressure
- Kidney (decrease excretion)

![Circumventricular organs. The neurohypophysis (NH), organum vasculosum of the lamina terminalis (OVLT, supraoptic crest), subfornical organ (SFO), and area postrema (AP) are shown projected on a sagittal section of the human brain. SCO, subcommissural organ. X/pineal.](image)
**Control of Thirst**

<table>
<thead>
<tr>
<th>INCREASE THIRST</th>
<th>DECREASE THIRST</th>
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<tr>
<td>Inc. Osmolality</td>
<td>Dec. Osmolality</td>
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<tr>
<td>Inc. Angiotensin II</td>
<td>Dec. Angiotensin II</td>
</tr>
<tr>
<td>Dryness of Mouth</td>
<td>Gastric Distention</td>
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The 4 major stimuli to thirst are:

- **Hypertonicity**: Cellular dehydration acts via an osmoreceptor mechanism in the hypothalamus.
- **Hypovolemia**: Low volume is sensed via the low pressure baroreceptors in the great veins and right atrium.
- **Hypotension**: The high pressure baroreceptors in carotid sinus & aorta provide the sensors for this input.
- **Angiotensin II**: This is produced consequent to the release of renin by the kidney (eg in response to renal hypotension).
Threshold for Osmolar Stimulus of Drinking

- Kidney must continually excrete some fluid to rid excess solutes that are ingested
- THRESHOLD for DRINKING
  - When the sodium concentration increases about 2 mEq/liter above normal Thirst Mechanism is activated
Thank You!

For not Listening