The Digestive System and Body Metabolism

Premedical Biology

The Digestive System and Body Metabolism

Digestion

- Breakdown of ingested food

Absorption

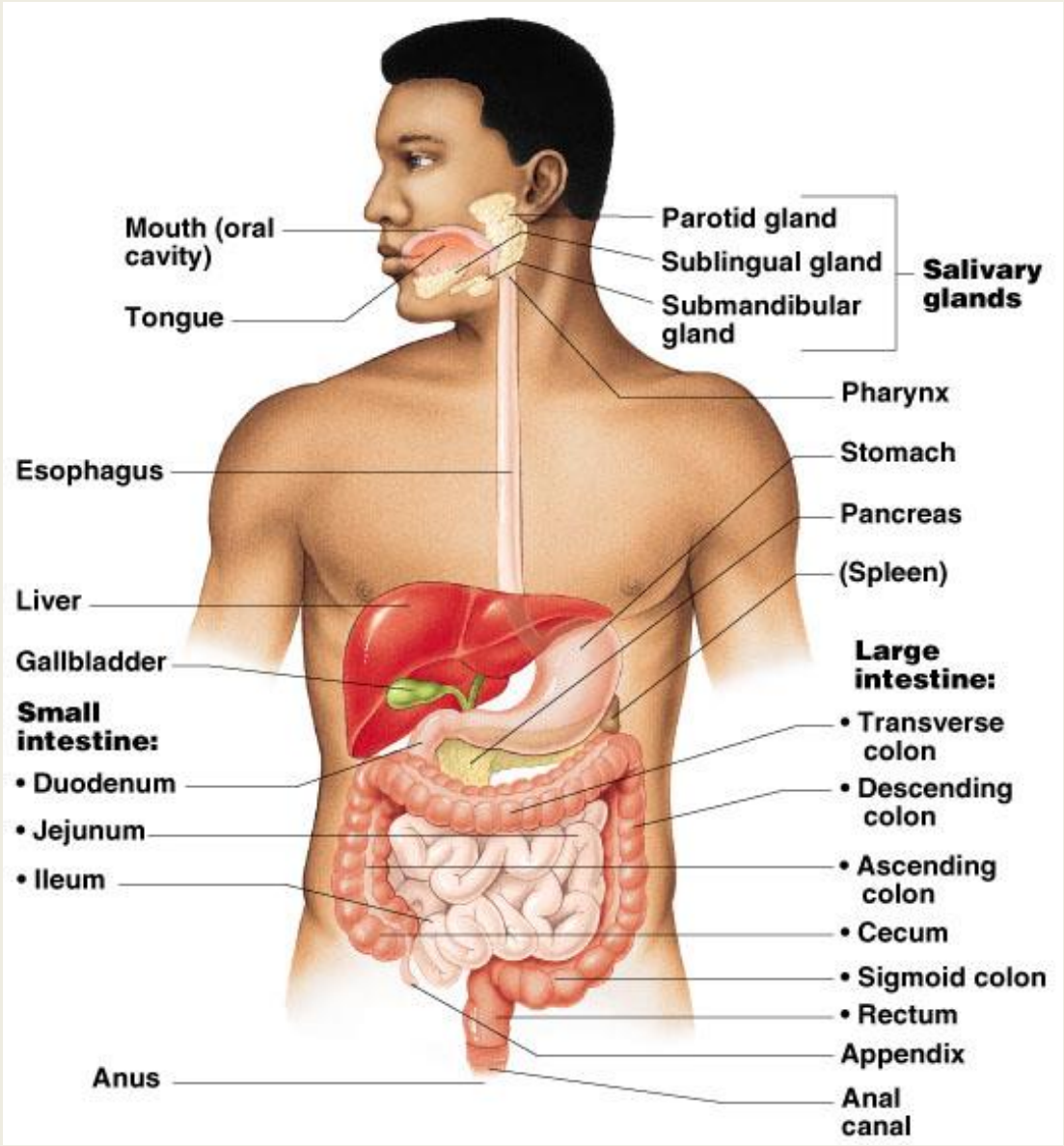
- Passage of nutrients into the blood

Metabolism

- Production of cellular energy (ATP)

Organs of the Digestive System

- Mouth
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Anus



Processes in mouth

- Mastication (chewing) of food
- Mixing food with saliva – salivary glands = exocrine glands, in three pairs, one in the cheek and two between the bones of the lower jaw.

  Saliva contain water, salts, MUCIN and (sometimes) salivary AMYLASE.

  Parotid glands

  Submandibular glands

  Sublingual glands
- Initiation of swallowing by the tongue
- Allowing for the sense of taste

Taste cells

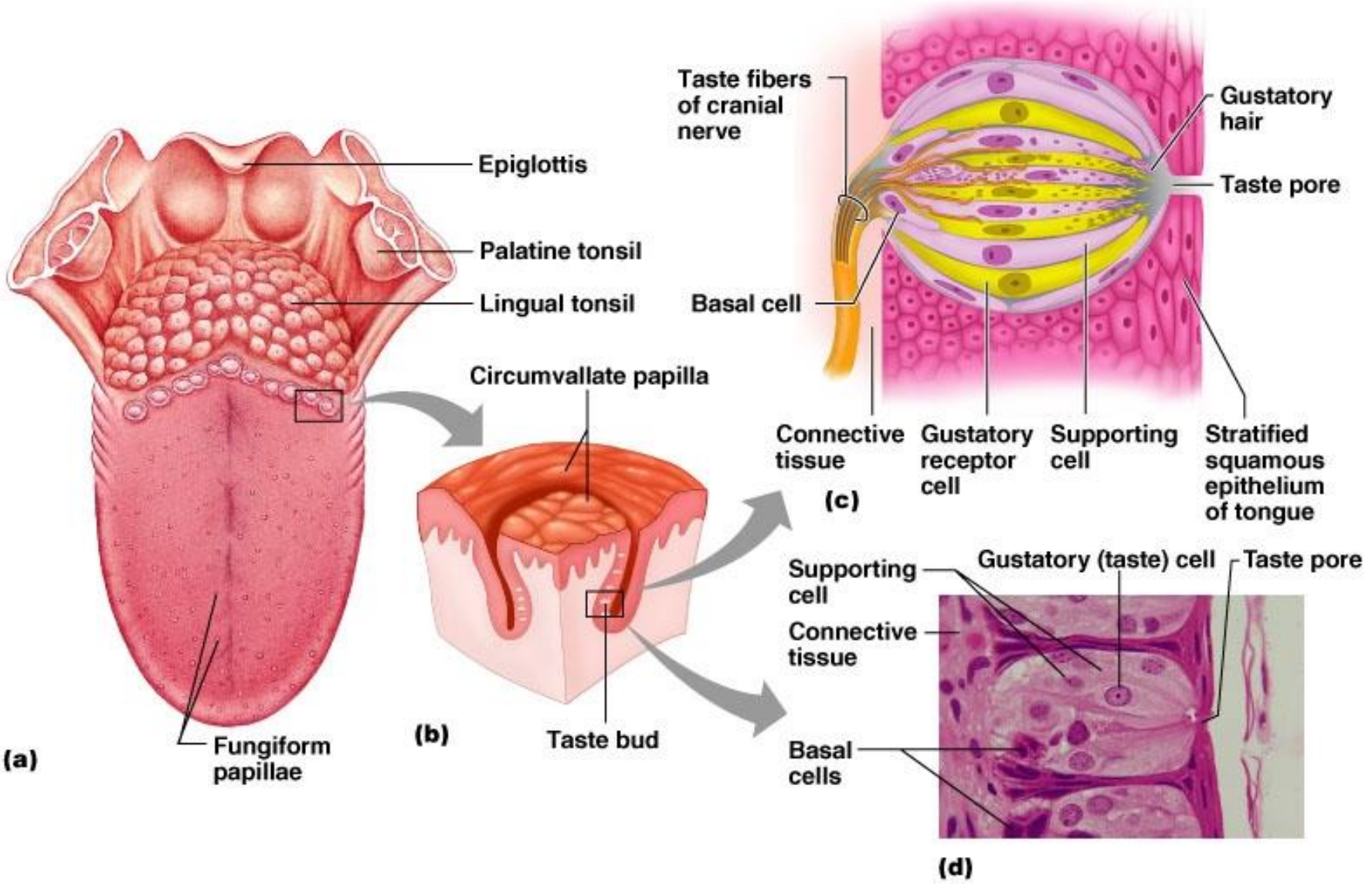
Tunica mucosa of mouth is folded into papillae

- Each papilla has 1-5 taste buds. **Taste buds contain taste receptor cells.** Each **taste cell** consists of small hairs that lie in the **taste pore**.

10,000 taste cells (chemoreceptors), nerve ends: **sweet, sour, bitter, salty, umami**.

- They cover the **tongue, palate, epiglottis**, and **pharynx.** There, dissolved food or drink **binds** to a **receptor**, like a key in a lock.

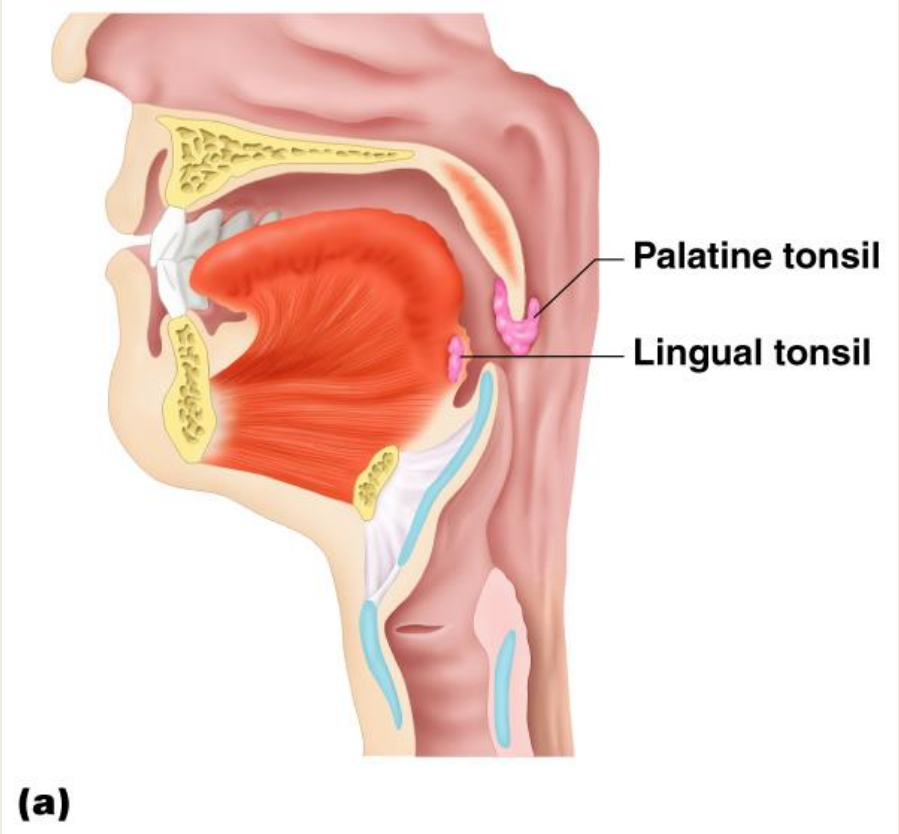
Taste cells



Mouth (Oral Cavity) Anatomy

- Tonsils
  - Lingual tonsil
  - Palatine tonsils - in the lateral wall of the oral pharynx,

They come into contact with various inhaled or ingested pathogens, which process and exposure them for the body

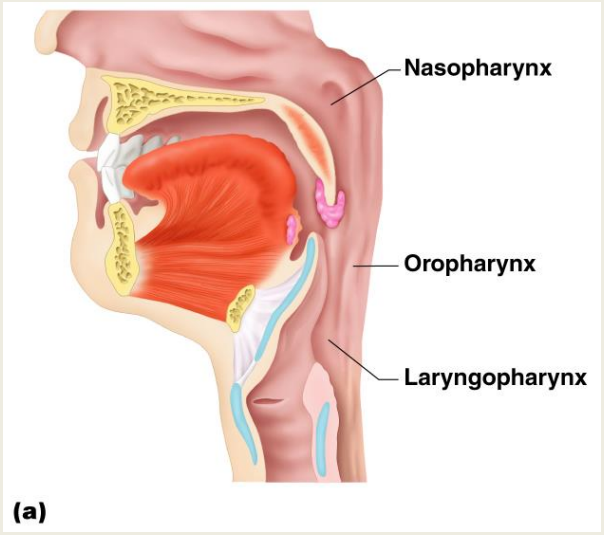


Anatomy of oral cavity and esophagus

- **Oral cavity** - nonkeratinized stratified squamous epithelium

  The mucosa of the nasal side of soft palate is lined by ciliated pseudostratified columnar epithelium with goblet cells.

- Nasopharynx - not part of the digestive system
- Oropharynx
- Laryngopharynx



- **Esophagus** – nonkeratinized stratified squamous epithelium, lymph follicles in lamina propria, mucosal smooth muscle, mucous glands in submucosis, **outer longitudinal** and **inner circular muscle layer in tunica muscularis**,

  Upper third of esophagus consists of **striated skeletal muscle**.

Layers of Alimentary Canal Organs

- **Mucosa** (tunica mucosa) lines the internal surface of the alimentary canal.

  principal functions: protection, secretion and absorption

  - Surface epithelium – **nonkeratinized stratified squamous epithelium** (oral cavity, esophagus, anal canal), **simple columnar epithelium**, **enteroendocrine cells** (secretory function)
  - Small amount of **loose connective tissue** (lamina propria mucosae), lymphatic follicles, glands, vessels
  - Small **smooth muscle layer** (lamina muscularis mucosae)

Layers of Alimentary Canal Organs

- **Submucosa (tunica submucosa)**

  Soft loose collagenous connective tissue with blood vessels, glands, nerve endings, and lymphatic tissue

  submucosal nerve plexus – ***plexus submucosus Meissneri***

- **Muscularis externa** – (tunica muscularis)
  - **Inner circular layer** – smooth muscle, which forms sphincters: pharyngoesophageal sphincter, pyloric sphincter, ileocecal valve and internal anal sphincter
  - **Outer longitudinal layer**
  - in upper one third of esophagus is also striated muscle

Layers of Alimentary Canal Organs

- **Serosa (tunica serosa) or adventitia (tunica adventitia)**
  - visceral peritoneum - **one layer of simple squamous epithelium** – the **mesothelium**, and an underlying connective tissue layer

These structures greatly increase the surface area available for resorption:

- Plicae circulares are submucosal folds in of the small intestine
- Villi are mucosal projections covering entire surface of the small intestine,
- Microvilli are microscopic projections of the apical surface of intestinal absorptive cells.

Stomach Anatomy

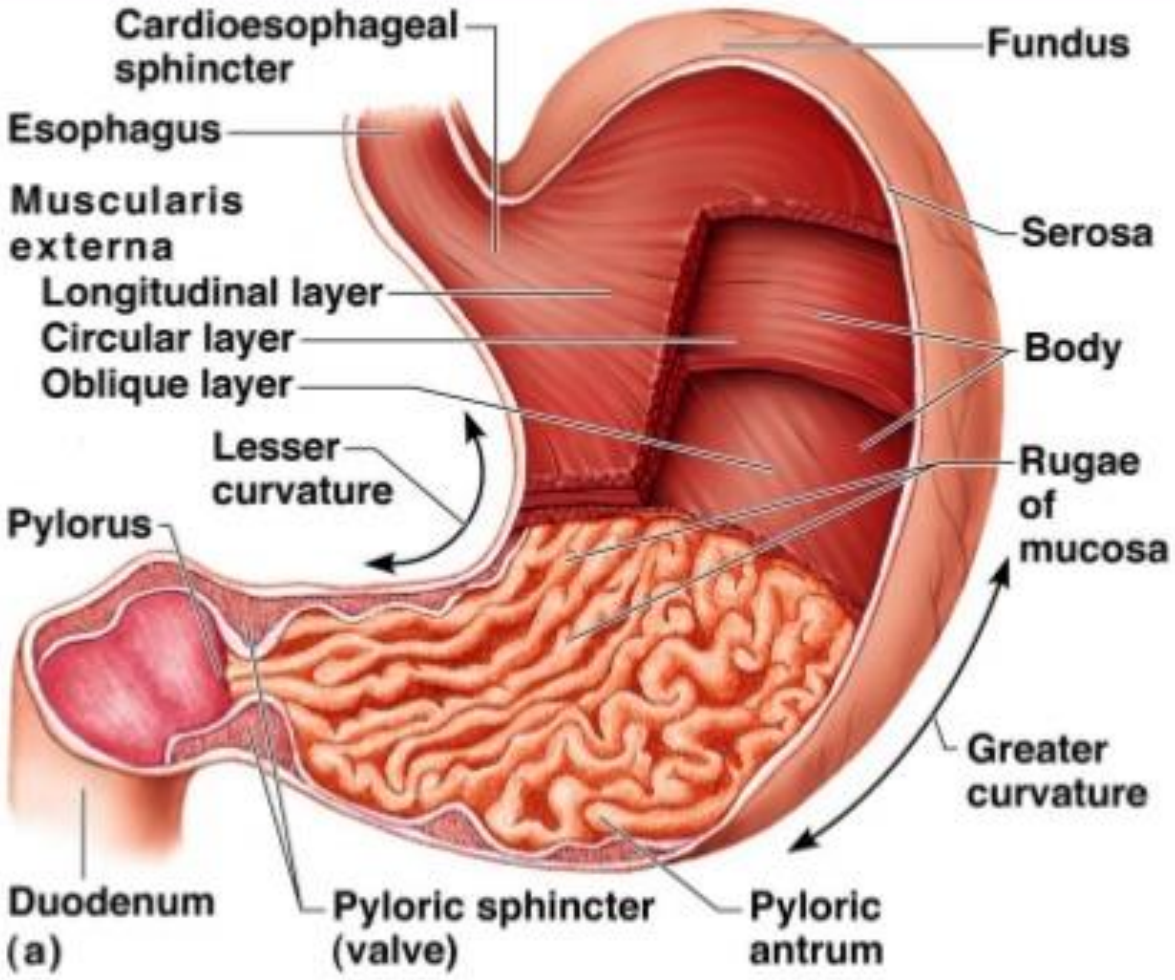


Figure 14.4a

Stomach functions and Mucosa

Mucosa forms **gastric pits with** simple **columnar epithelium.**

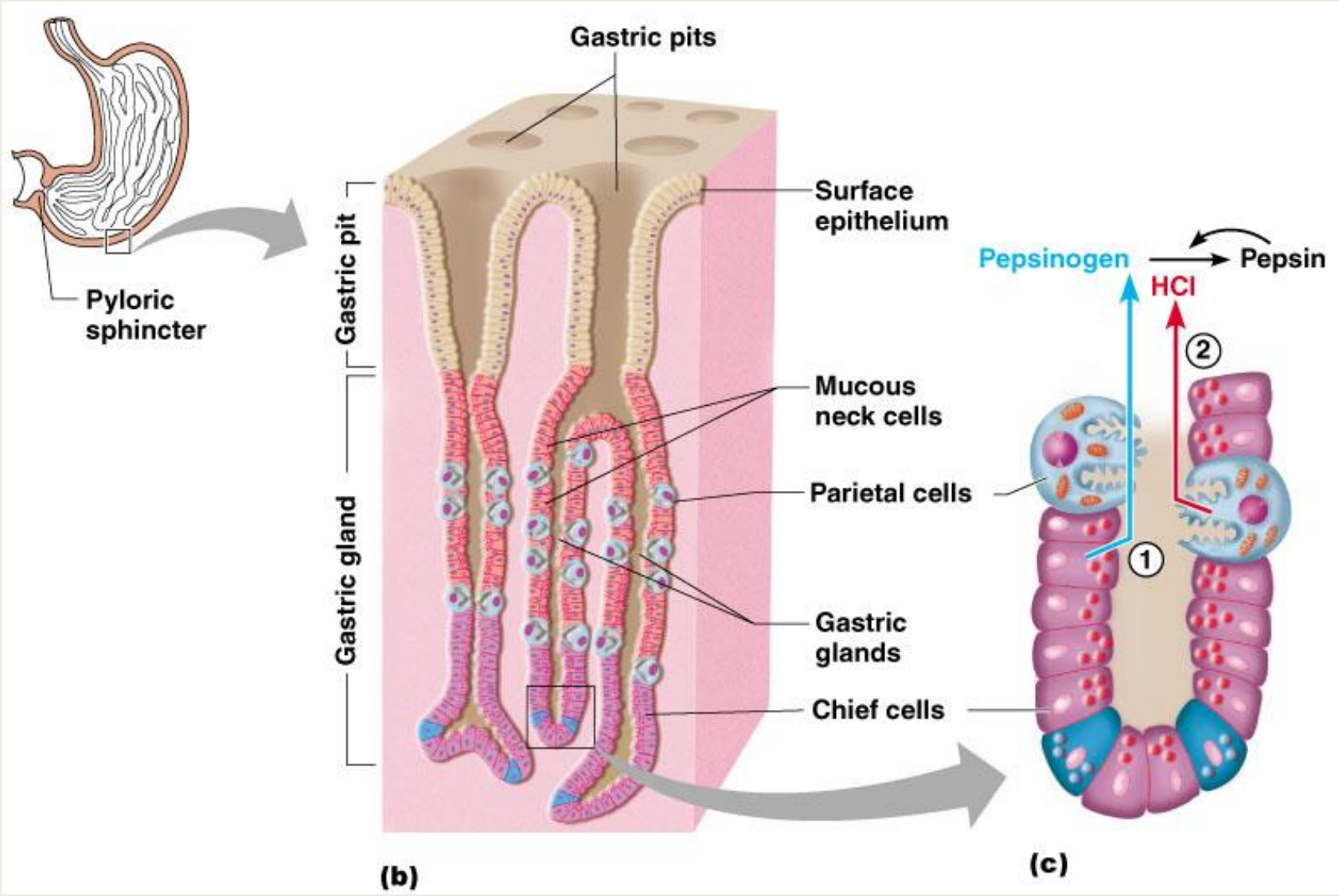
In the glandular lining are found **chief cells, parietal cells, mucous neck cells, undifferentiated stem cells and enteroendocrine cells.**

- **Mucous neck cells** – produce a sticky alkaline mucus
- **Chief cells** – produce protein-digesting enzymes (pepsinogens, lipase)
- **Parietal cells** – produce hydrochloric acid
- **Endocrine cells** – produce gastrin, somatostatin

Chyme (processed food)

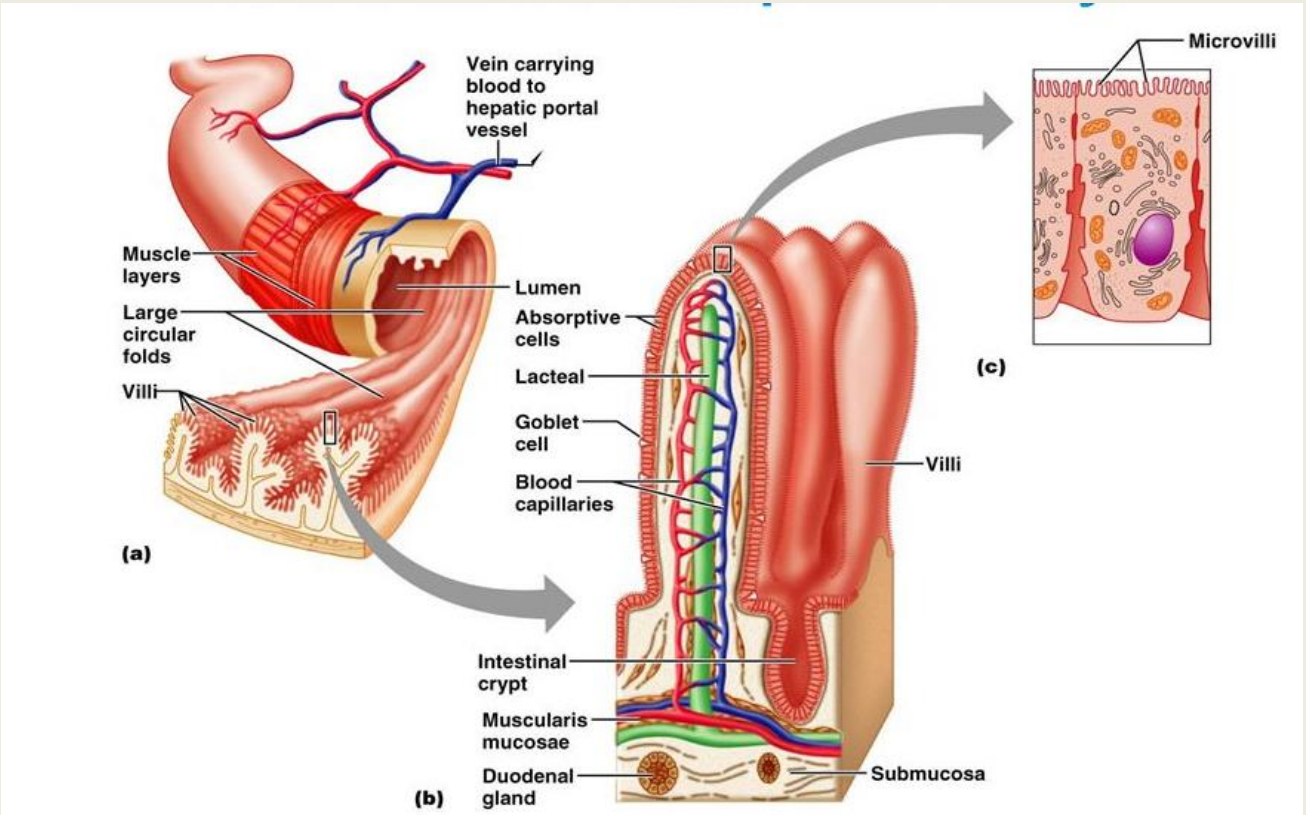
There are distinguished three muscular layers, oblique, circular and longitudinal.

Structure of the Stomach Mucosa



Villi of the Small Intestine

- The mucosal (epit., lam prop.) projections **are intestinal villi** (picture: b) **+** tubular intestinal glands (glands of Leiberkühn) between villi



Small Intestine

The structures greatly increase the surface area available for resorption. The place of nutrient absorption into the blood

The body's major digestive organ

Anatomy:

- **Duodenum**
- **Jejunum**
- **Ileum**

Mucosa of small intestine forms circular **folds – plicae circulares** Kercringi (picture: a))

Microvilli of the Small Intestine

- **Simple columnar epithelium** with enterorocytes (picture c)), which have **microvilli**
- **Goblet cells** are unicellular mucous glands dispersed between enterocytes in intestinal mucosa.
- **Glands of Lieberkühn** - crypts, which contain columnar enterocytes, mucous cells, Paneth cells, stem cells and enteroendocrine cells.

Paneth cells synthesize antibacterial enzyme lysozyme and other defensive proteins.

Enteroendocrine cells produce biologically active proteins e.g. gastrin, cholecystokinin and secretin.

Aggregation of lymphatic tissue - MALT

Resorption in the Small Intestine

- Water is absorbed along the length of the small intestine
- End products of digestion
  - Most substances are absorbed by active transport through cell membranes
  - Lipids are absorbed by diffusion
- Substances are transported to the liver by the **hepatic portal vein** or lymph

Functions of the Large Intestine

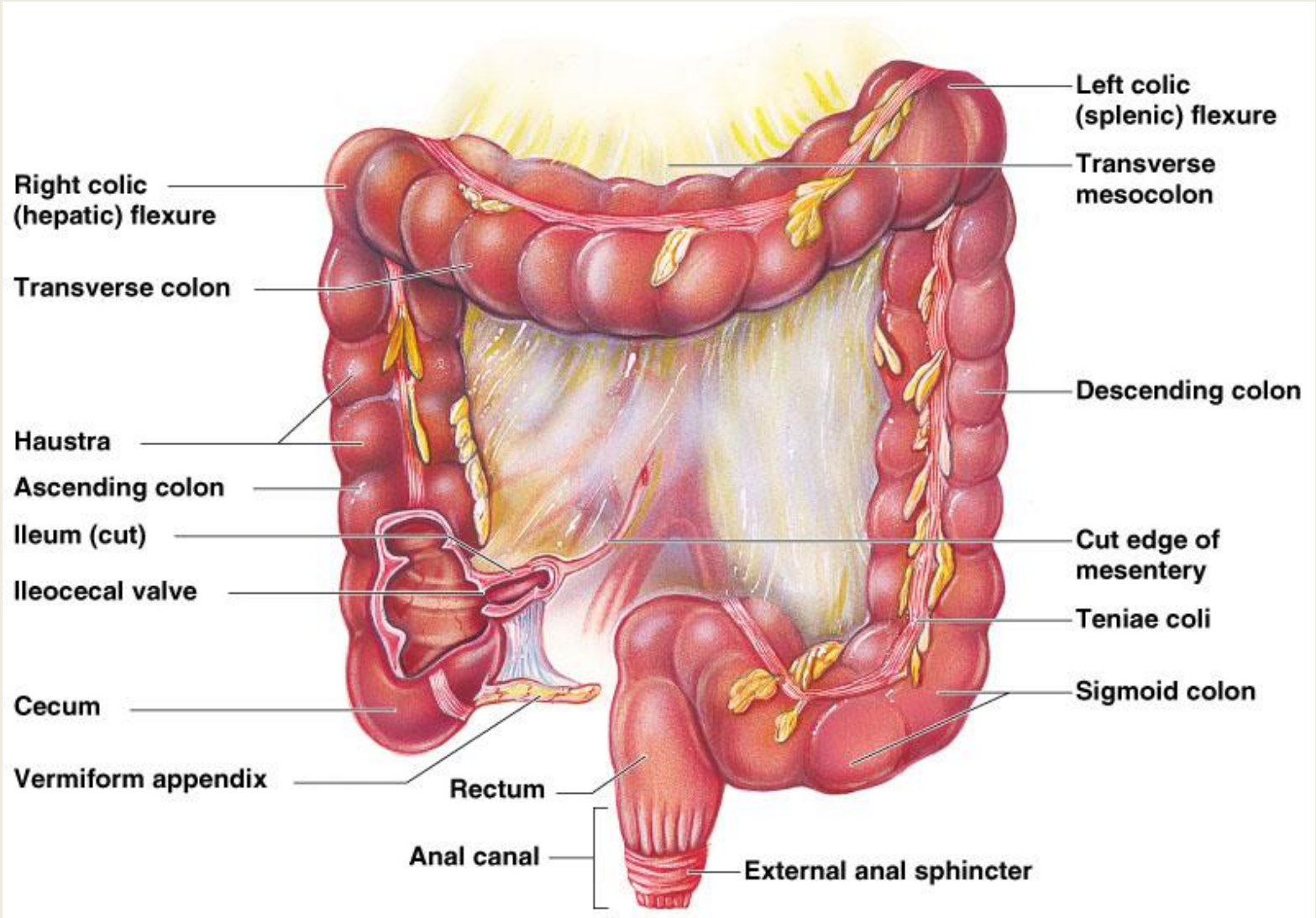
- Absorption of water
- Eliminates indigestible food from the body as feces
- Does not participate in digestion of food
- Goblet cells produce mucus to act as a lubricant
- Resident bacteria digest remaining nutrients

Structures of the Large Intestine

Mucosa lacks circular folds and villi (villi intestinales). Crypts of Lieberkühn are frequent. They are lined with simple columnar epithelium containing numerous goblet cells, colonocytes and small number of entero-endocrine cells. Lamina propria is rich in lymphatic tissue

- Colon
  - Ascending
  - Transverse
  - Descending
  - S-shaped sigmoidal
- Rectum and Anus – external body opening
- Tunica muscularis is composed of outer longitudinal and inner circular layer is thicker in area of rectum and in area of anal canal creates the **inner anal sphincter**.

Large Intestine



Digestion

Source of enzymes (intestinal cells, pancreas) that are mixed with chyme

Enzymes: break double sugars into simple sugars - **pancreatic amylase**

Complete some protein digestion **exopeptidase and endopeptidase: trypsin, chymotrypsin**

Pancreatic enzymes play the major digestive function **(lipase)**

Bile enters from the **gall bladder -** the bile is necessary for lipid digestion: bile salts, bile pigment (mostly bilirubin from the breakdown of hemoglobin), cholesterol, phospholipids electrolytes

DIGESTIVE ENZYMES

in the small intestine & pancreas

MENDLS & LAPIE

PANCREAS

Maltose - digests maltose

Exopepsidase - removes amino acids until dipeptides are left

Nuclease - digests DNA & RNA

Dipepsidase - digests dipeptides into single amino acids

Lactase - digests lactase

Sucrase - digests sucrose

SMALL INTESTINE

Lipase - digests triglycerides in fatty acid + glycerol

Amylase - digests starch into maltose

Phospholipase - digests phospholipids into fatty acids + glycerol & phosphate group

Insulin - regulates glucose in blood

Endopepsidase - digests proteins into short polypeptides

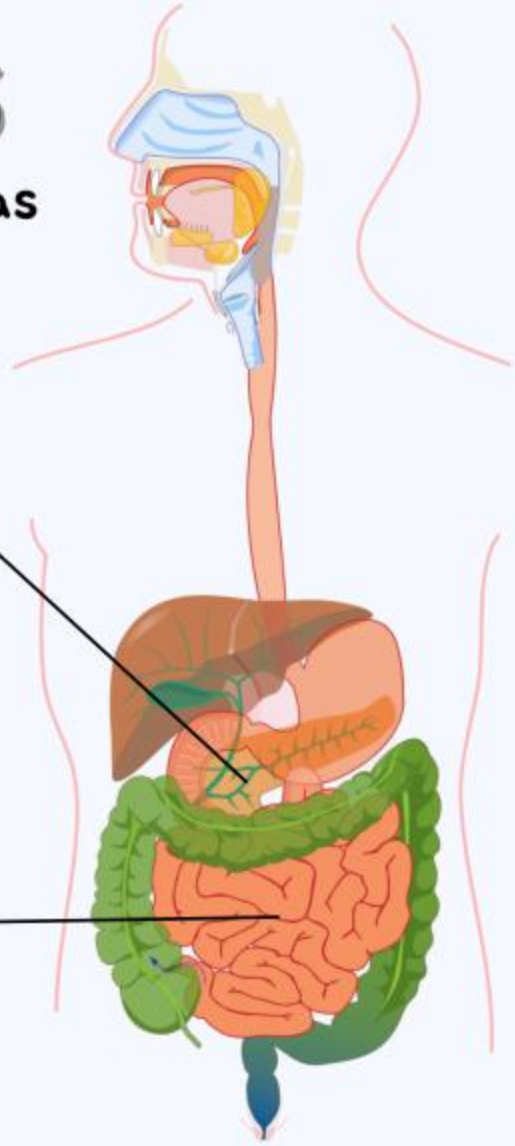


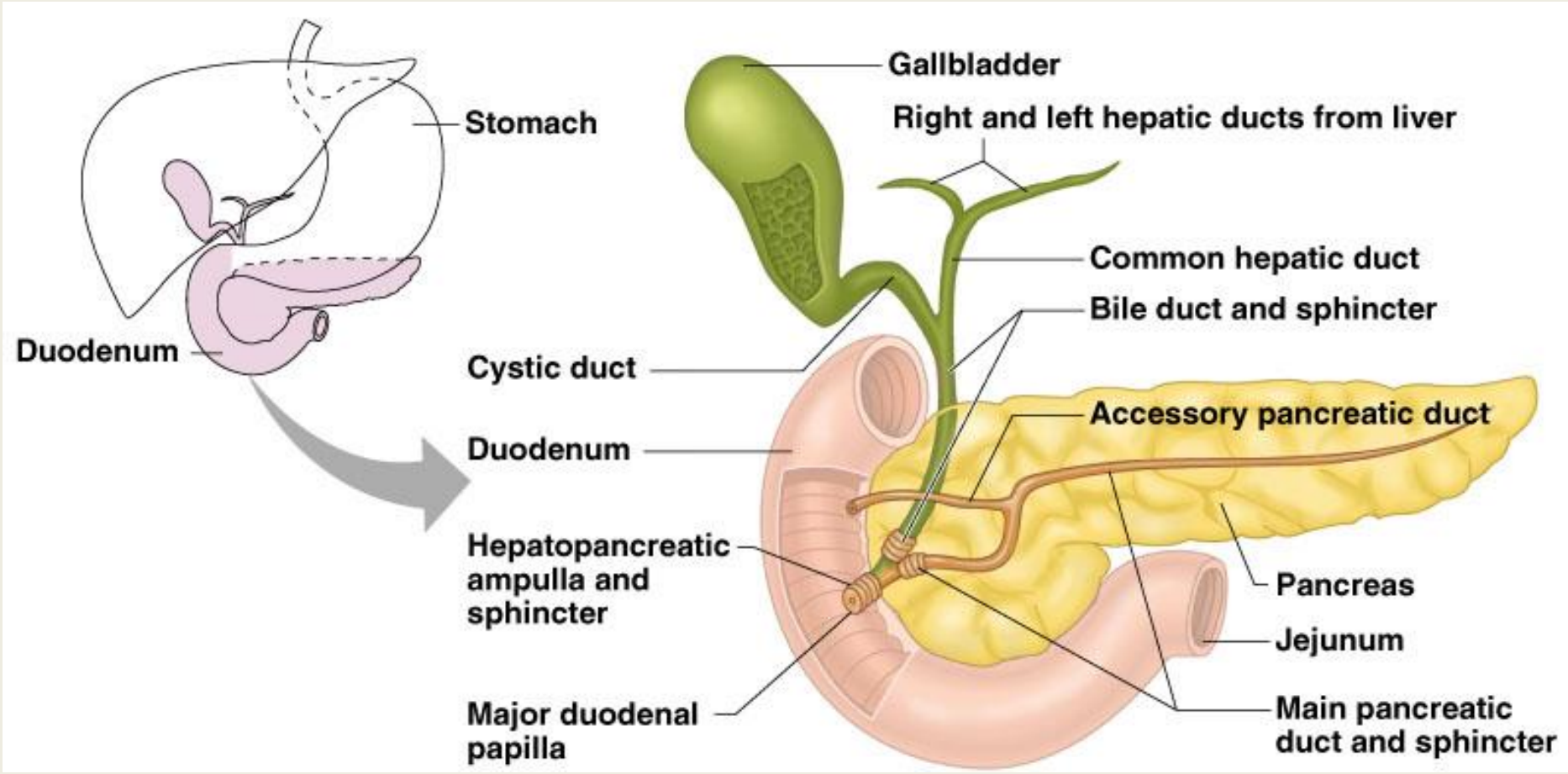
image from Mariana Ruiz (Wikimedia Commons)

https://en.wikipedia.org/wiki/Digestive_enzyme#/media/File:Digestive_Enzymes.svg

Pancreas – chemical digestion

Exocrine and endocrine part – different compartments

Exocrine serous glands with **zymogen granules** involves the whole organ, but endocrine is represented by **a islet of Langerhans.** Granules contain digestive enzymes in inactive form.



Liver

- The largest gland in the body, the second largest organ
- Located on the right side of the body under the diaphragm
- Consists of **four lobes**, which are divided **into lobules.** Branches of the portal vein and hepatic artery enters the lobes and transport oxygenated blood and nutrients into sinusoidal capillaries surrounded by **hepatocytes.**
- The hepatocyte cytoplasm contains **numerous mitochondria**, rough and smooth **endoplasmic reticulum**, deposits of glycogen, lipid droplets, large number of lysosomes and peroxisomes and multiple Golgi complexes.

- Connected to the gall bladder via the common hepatic duct.

Liver lobules

Microscopic Anatomy of the Liver

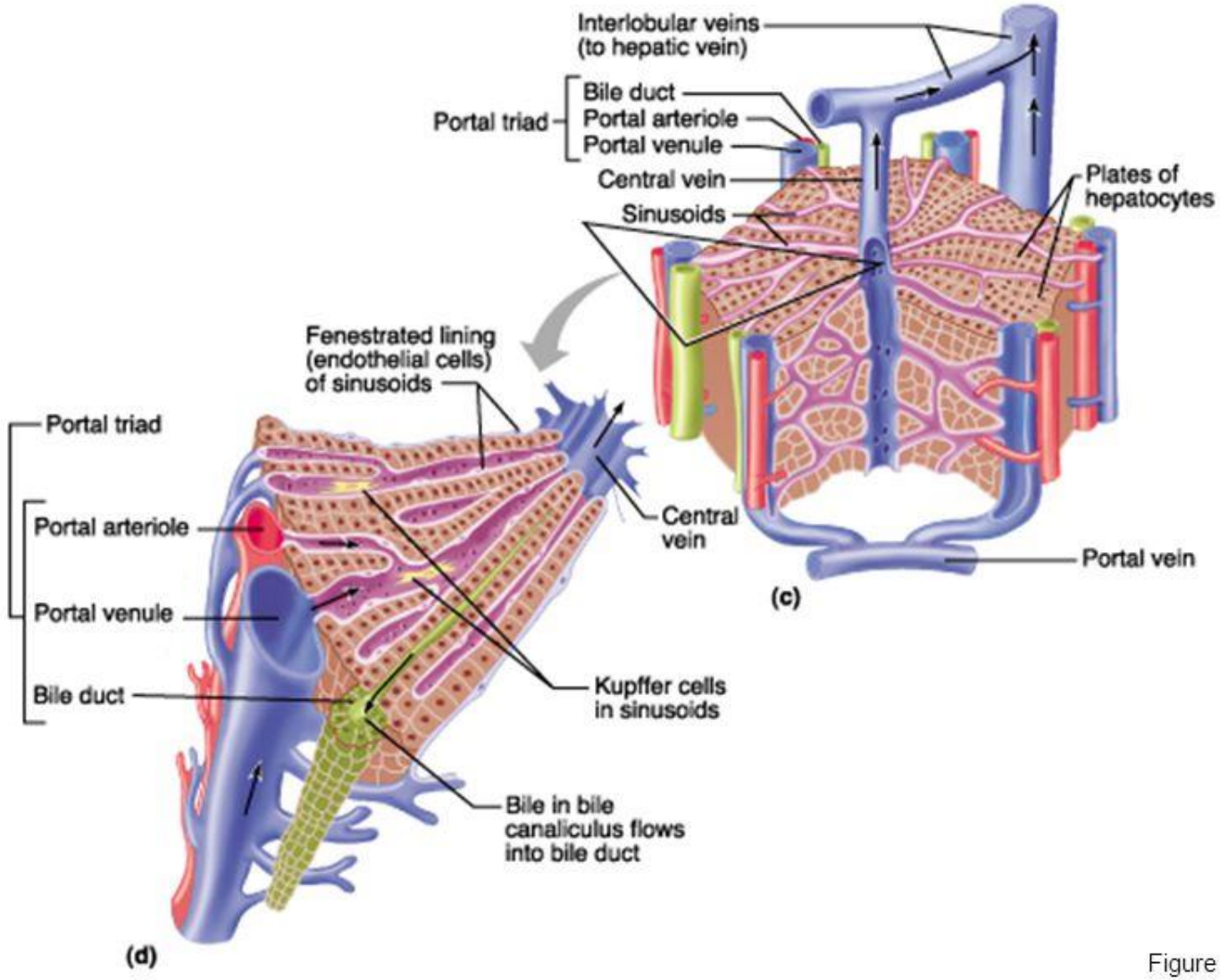


Figure 24.24c, d

Role of the Liver in Metabolism

- (1) maintenance of internal environment (i.e. homeostasis)
- (2) reciprocal conversions of nutrients, ammonium detoxification, saccharide metabolism, lipid metabolism - production of cholesterol, plasma transport proteins, albumin and clotting proteins, non-essential amino acids
- (3) regulation of storing and releasing energy,
- (4) modifications of hormones and vitamins,
- (5) detoxification (xenobiotic biotransformation) from drugs and alcohol
- The liver has also secretory function – it produces bile.
- The liver has endocrine function (it produces (1) erythropoietin (only 10 %), (2) calcidiol, (3) insulin-like growth factors – somatomedins).

Metabolism of saccharides, lipids

- There is a high glucose concentration after a meal in the portal blood. This leads to glycogen synthesis in the liver.

  In high glucose excess (and full liver glycogen stores) is glucose converted to fatty acids and then to TAG.

  In fasting glycaemia decreases this in turn leads to glycogen decomposition (glycogenolysis) and then is glucose released to the blood. In prolonged fasting glycogen stores become depleted and the liver starts to produce glucose from non-saccharide substrates (lac, glucogenic amino acids, glycerol) – gluconeogenesis.

- Fatty acids oxidation and ketone bodies synthesis; fatty acid and TAG production; lipoprotein metabolism: VLDL synthesis, partially HDL synthesis, conversion of IDL to LDL, chylomicron remnants, HDL and LDL degradation

Metabolism of aminoacids and other nitrogen compounds

- Aminoacids deamination and transamination; non-essential amino acids synthesis; ammonium detoxification by urea synthesis (the ornithine cycle) or glutamine synthesis.
- Purine degradation
- Choline and creatinine synthesis
- Heme metabolism – biliverdin – bilirubin –bile pigments
- Bile compositions: 97 % water, bile acids, inorganic ions (Na^+, $Cl^–$, $HCO_3^–$), cholesterol, phospholipids, bile pigments - phospholipids and bile acids – together they form micelles. Bile acids cause lipid emulsification in lipid digestion and absorption in the intestine.
- Conversion of provitamins to vitamins (e.g. carotene → vitamin A), vitamins are stored (lipophilic vitamins, vitamin B12, conversion to active forms of vitamin (25-hydroxylation of vitamin D → calcidiol, production of enzyme cofactors – mainly B-vitamins)

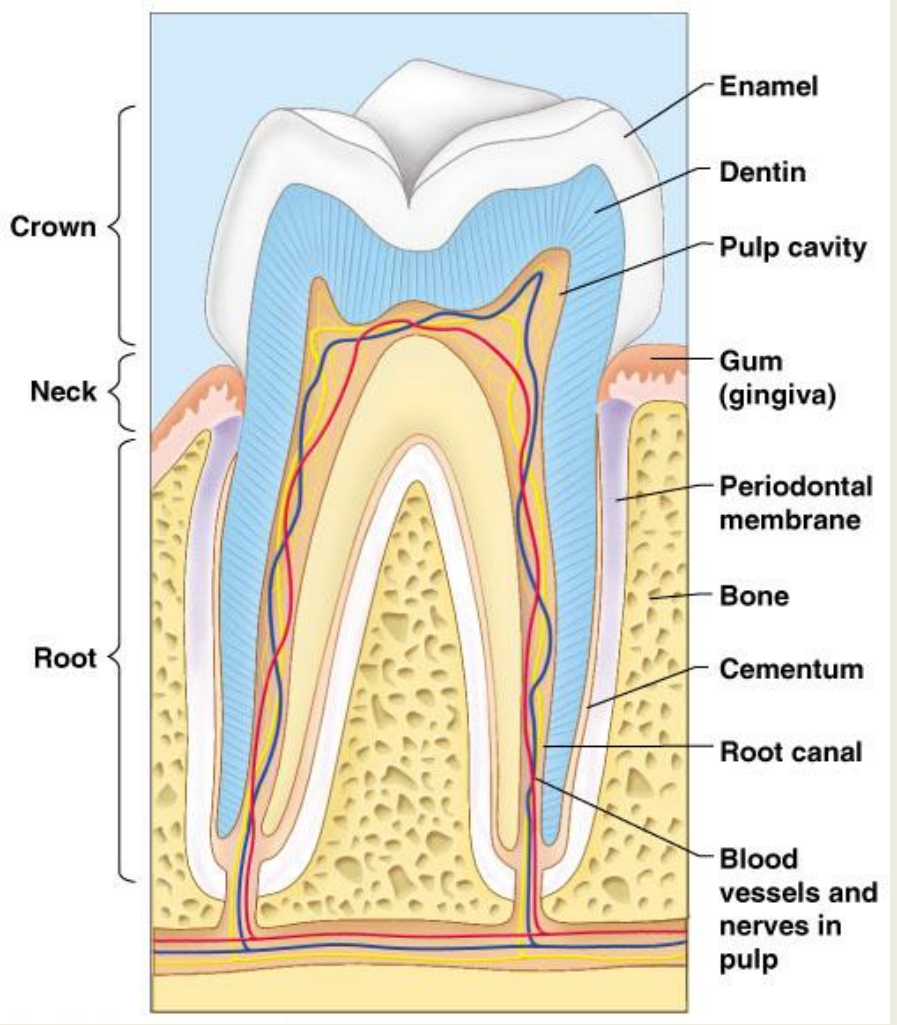
Teeth

- Humans have two sets of teeth
  - Deciduous (baby or milk) teeth, 20
  - Permanent teeth
    - Replace deciduous teeth between ages of 6 to 12
    - A full set is 32 teeth, but some people do not have wisdom teeth

- Incisors (8)
- Canines (4)
- Premolars (8)
- Molars (12)

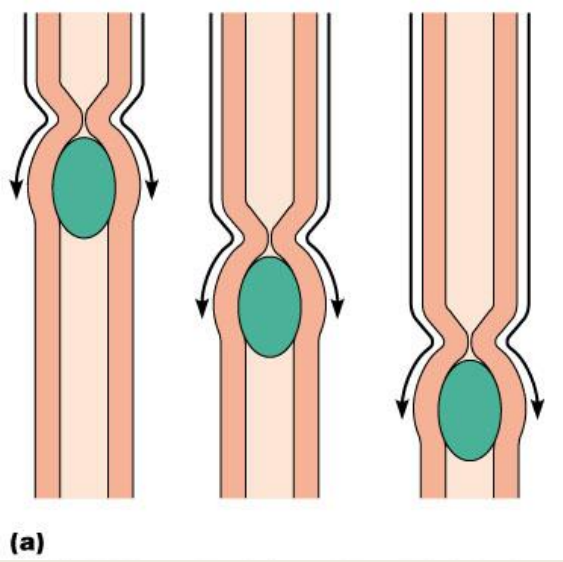
Regions of a tooth

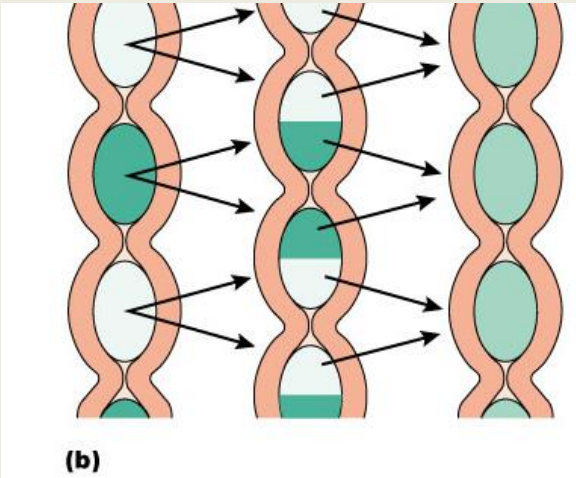
- Crown – exposed part
  - Outer enamel - **hardest substance in the human body**
  - Dentin
  - Pulp cavity
- Neck
  - Region in contact with the gum
  - Connects crown to root



Processes of the Digestive System

- Peristalsis
- Segmentation – moving materials back and forth to mix





Thank you for your attention

Campbell, Neil A., Reece, Jane B., Cain Michael L., Jackson, Robert B., Minorsky, Peter V.**,** **Biology**, Benjamin-Cummings Publishing Company, 1996 – 2010.