DIGESTIVE SYSTEM

Food we like, our body does not!

Nutrients (carbohydrates, proteins, fats/lipids) need to be broken down to basic building blocks, absorbed and rebuilt into what our cells need.

It happens in 5 stages:

Ingestion — intake of food

Digestion — mechanical, chemical breakdown (teeth, stomach, intestines, HCl, enzymes, ...)

Absorption — uptake of nutrients into blood stream (food enters actually here)

Excretion — excretion or removal of waste (feces)

Defecation — absorption of waste (feces) (Feces, never technically, inside body)

Breakdown products of food items:

<table>
<thead>
<tr>
<th>Carbohydrates</th>
<th>Proteins</th>
<th>Fats/Lipids</th>
<th>Nucleic Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates (Polysaccharides)</td>
<td>Protein (Amino acid/s, Monoglycerides, Fatty acid/s)</td>
<td>Lipids</td>
<td>Nucleotides/s (e.g., Adenine, Thymine, Cytosine, Guanine)</td>
</tr>
</tbody>
</table>

- Monosaccharides: glucose, fructose, galactose

Note: We consume some nutritious substances as such example: vitamins, minerals, water, cholesterol.
ANATOMY OF DIGESTIVE SYSTEM

Two subdivisions:

Gastric (stomach)
Enteric (intestine)
Hepatic (liver)
Cystic (gall bladder)

Digestive Tract (alimentary canal)
- extends from mouth to anus
  - mouth > pharynx > esophagus > stomach
  > small intestine > large intestine > anus
- GI Tract - includes stomach, SI, LI
  (gastrointestinal)
- open to outside at both ends

Accessory Organs: Teeth, tongue, salivary glands, liver, gall bladder, pancreas

Fig. overview of the system
Layers of Digestive Tract (Wall)

- **Lumen** (space)
  - Mucosa
    - epithelium, thin muscular
    - submucosa (blood/lymphatic vessels) (smooth)
    - nervous, mucous glands
  - Mucosalis (inner circular)
  - serosa (outer longitudinal)
  - smooth muscle

**Mucosa**
- mucous membrane lines the space inside
- made of
  - epithelium > lamina propria > muscularis mucosa
    - simple columnar
    - stratified squamous (mouth to esophagus)
  - thin layer of smooth muscle
  - helps form rugae (folds)
  - lots of lymphocytes, lymphatic nodules (protection against pathogens)

**Submucosa**
- thick layer of loose connective tissue
- blood vessels, lymphatic vessels, nerve plexus
- mucous secreting mucous glands
  - for mucus secretion, lubrication

**Muscularis**
- 2 layers of smooth muscle
  - inner circular layer, forms valves (sphincters)
  - external
  - outer (longitudinal) layer, helps with motility
  - Myenteric plexus (nerves) that operate muscles (peristalsis)

**Serosa**
- thin layer of areolar tissue, simple squamous epithelium
- starts at lower end of esophagus, ends before rectum
- adventitia - fibrous connective tissue layer outside that attaches to adjacent organs
  - note: mesenteries attach organs to body wall
  - peritoneum - serous membrane lining body cavity
  - lesser omentum connects stomach to liver
  - greater omentum
  - peritoneum - covers small intestines
  - intra-peritoneal (within)
  - stomach
  - liver
  - retro-peritoneal (outside)
  - duodenum
  - pancreas

(Myo: muscle)
MOUTH (ORAL/BUCAL CAVITY)

- Helps with ingestion, chewing, swallowing, speech, respiration, and chemical digestion.
- Has tongue, teeth, palate, lips, (Salivary glands)
- Opens anteriorly between lips (oral fissure) and posteriorly to throat (fauces)
- Lined with stratified squamous epithelium (Keratinized for abrasion — gum, hard palate)
  (rest non-keratinized)
- Frenulum attaches lip to gum (between incisors)
- Vestibule is the space between lips/cheek and teeth
- Labium (lip) has external cutaneous area, red (vermilion) labial (adj.) are where lips meet, and internal mucosa.
- PALATE separates oral and nasal cavities, made up of anterior hard palate (bony — palatine bones, palatine process of maxilla) and posterior soft palate (no bone, sponge)
- UVULA — medial projection (hangs) from roof — holds food
- SALIVARY GLANDS
  - Intrinsic (internal) lingual/labial/buccal
  - Extrinsic (external) Parotid/sublingual, submandibular
- TOOTH (Deciduous 20
  - Permanent 32)
  - Incisors, Canines, Molars, Pre-molars
TONGUE

- Muscular organ, highly sensitive and active
- Lined with non-keratinized squamous epithelium
- Divided into body (anterior 2/3) occupies oral cavity, root (posterior 1/3) - "" oropharynx
- Has papillae (bumps/projections) with taste buds
- Lingual frenulum attaches tongue to floor of mouth
- Muscles — intrinsic (for fine movement — speaking)
  — extrinsic (found within tongue)
  — originate somewhere but insert into tongue
  - palatoglossus
  - hyoglossus
  - styloglossus
- Lingual glands — lingual lipase (enzyme)
- Lingual Tonsils

fig. of tongue/parts
Tooth

(teeth (pl.))

There are **20 teeth** in infants called **Deciduous Teeth**. (baby/milk)

- **Incisors** - help cut/chop
- **Canines** - help tear
- **Molars** - help grind
- **Pre-molars**

In adults, there are **32 teeth** called **Permanent Teeth**.

Note: **Pre-molars (Pm)** found only in adults (8)

**Molars** (3×4=12 (adults),
2×4=8 (infants))

Each tooth has **3 layers**.

- **Enamel** - outermost shiny layer
- **Dentine** - next inner layer
- **Pulp Cavity** - innermost layer

- blood vessels, nerve endings
- pain can be felt
- narrows down inferiorly as "root canal"

In general, a tooth has:

- **Crown** - extends above the gum (gingiva)

- **Neck** - region close to the gum

- **Root** - region inside the gum

The tooth is cemented (held in place) to the alveolar socket (spaces) within each upper (maxilla) and lower jaw (mandible) bones.
Inside Liver

HEPATO CYTES
Liver cells)

TRIAD
↑ Hepatic Artery (oxygen, nutrient)
↑ Hepatic Portal Vein (nutrient)
↓ Bile Ductule (Bile juice)

Note: Sinusoids (passage)
for Venous blood
Bile canalicus (Bile → Bile ductule)

PANCREAS

Acinar Cell/s
Pancreatic islets (α cells, β cells)

Pancreatic Duct
Accessory Duct/s

Note: Accessory ducts lead to Pancreatic duct
Acinar cells secrete Pancreatic Juice (mix of Pancreatic Islets regulate blood glucose enzymes)
α cells produce glucagon (raises glucose)
β cells produce insulin (lowers glucose)
Ducts of liver, gall bladder, pancreas

- Diaphragm
- Right hepatic ducts
- Cystic duct
- Hepatic duct
- Cystic duct
- Pancreatic duct
- Hepato pancreatic duct
- Ampulla
- Duodenum of small intestine
**Valves**

- Upper Esophageal
- Cardiac (Lower Esophageal)
- Pyloric
- Colo-cecal

**Movements**

- Mastication (chewing)
- Deglutition (swallowing)
- Peristalsis (squeezing)
- Churning
- Haustral contraction
  - Mass movement
  - Segmentation

**Enzymes**

- Zymogen (inactive enzyme)
- Salivary amylase
- Lingual lipase
- Lysozyme

**Food**

- Bolus

**Chyme**

- Gastric lipase (pH 0.5-3.0)
- Pepsinogen → Pepsin

- Pancreatic HCl → Entero (SI) Kinas
  - Trypsinogen → Trypsin
  - Chymotrypsinogen → Chymo
  - Pro carboxypeptidase → Carboxy
  - Pro aminopeptidase → Peptidase
  - Glucagon → Insulin/ endorphin
  - DNA poly ADP

**Feces**
LARGE INTESTINE:
- Digestion of cellulose, lignin, hemicellulose, pectin
- Water reabsorption
- Vitamin K (gas, flatulence)
- Done by >300 species of gut microflora

REFLEXES:
- Turn on/off

GLANDS & HORMONES:
- Acetylcholine (from Vagus nerves, enteric neurons) stimulates pancreatic juice
- Gastrin stimulates chief cells, responds to acidity of chyme, stimulates liver/pancreas to secrete alkaline bicarbonate
- Secretin (mucosa of duodenum and proximal jejunum) stimulates pancreas/duodenum secrections, responds to fat in stomach

IMMUNE CELLS:
- Palatine pharyngeal, Tonsils
- Parotid, sub-lingual, sub-mental, sub-mandibular

APPENDIX
- Peyer's patches
Oral Cavity

Bolus

Upper esophageal sphincter

Esophagus

Cardiac sphincter

Stomach

Gastric pits

Chief cells

Pepsinogen, lipase

G cells—gastrin

Gastric glands

Chyme

Pancreatic amylase

Trypsinogen — Trypsin

Pancreatic lipase

Chymotrypsinogen — Chymotrypsin

Pro carboxypeptidase — Carboxypeptidase

Pro aminopeptidase — Aminopeptidase

Endopeptidase

Sucrose — Sucrase

Fructose — Fructase

Maltose — Maltase

Cellulose

Hemicellulose

Tannin

Pectin

Feces <Haustral contraction> <Mass movement>
Digestive Physiology

- Food (sight, smell, texture, etc...) stimulates digestive enzyme secretion assisted by endocrine hormones.
- Food is mainly composed of carbohydrates, proteins, and lipids (fats) made up of glucose/other sugars, amino acids, and fatty acids, respectively.
- Mechanical digestion is accomplished by teeth and tongue (chewing = mastication), before swallowing (= deglutition).
- Chemical digestion begins when saliva helps to moisten the food, make it into a bolus-like bolus. Saliva helps to moisten/stick food particles besides helping with its other components.
  - Mucus (makes food sticky)
  - Lysozyme (breaks down/kills bacteria like lysol does)
  - Antibodies (Ig A) defend against foreign antigens
  - Electrolytes such as Na⁺, Cl⁻
  - Enzymes for breakdown of starch (Salivary amylase), lipids/fats (Tingual lipase)
- The bolus moves through the upper esophageal sphincter value to the esophagus and moved along by a wave of contractions (squeezing) = "peristalsis".
- Bolus enters the stomach through the lower esophageal sphincter value (= cardiac sphincter).
- Arrival of bolus in the stomach extends the stomach, sends signals (nerve), to release 'Gastrin'.
- Inside the stomach, gastric pits are found harboring various cells
  - Stem cells or regenerative cells,
  - Mucus cells to secrete mucus,
  - Parietal cells to secrete HCl, Intrinsic factor, Ghrelin (Intrinsic factor, GH, Erythropoietin, Chewing)
  - Chief cells to secrete pepsinogen and gastric lipase
- Gastrin stimulates parietal and chief cells
- 'Bolus' is processed by the action of HCl, (hormone) into a paste 'chyme'.
- HCl activates pepsinogen → Pepsin (acts on long polypeptides)
- Gastric lipase breaks down lipids, works in acidic pH
The acidic 'chyme' enters the duodenum of small intestine. The mucosa of duodenum and proximal jejunum are induced to release 'Secretin', a hormone. Secretin in turn leads to release of bicarbonates which act as buffer and encounter/neutralize the acidity of 'chyme' and also protect the mucous membrane. Now, the basic/alkaline chyme will be acted upon by a mix/cocktail of enzymes in the Pancreatic Juice and those enzymes from the brush-border of villi. (Details follow use chart with figure).

- The mucosa of small intestine is modified into circular folds with microscopic finger-like projections called 'Villi' (Villus singular) and 'microvilli' within each villus. Villi and microvilli increase surface area available for nutrient absorption.
  - Mucous cells, absorptive cells (enterocytes) line the surface of each villus giving a 'brush-border' like appearance.
  - Inside each villus, a special duct 'Lacteal' helps move 'fat/lipid' away to lymphatic system. will be seen besides fine arterioles and venules.
- Nutrients are absorbed into the blood
  - Hepatic portal vein brings excess nutrients such as glucose for processing and storage as 'glycogen' in the liver (for later use, as needed).

- The processed 'chyme' from which most nutrients have been removed enters the 'Cecum' of large intestine via ileocecal valve.

- Appendix, structure seen outside the cecum serves as a source of immune cells.
- Immune cells form a patch 'Peyer's patches' that protect against any harmful microbes.
In the large intestine, most of the remaining water is reabsorbed in the colon.

- There are hundreds of species of micro "gut flora" (collection of microbes) which help with:
  - Digestion of cellulose, hemicellulose, lignin, pectin
  - Synthesis of Vitamin K

In the process, a mixture of gases 'flatus' forms. It contains NH3, SO2, CH4 which add to the 'foul odor'.

- Once 'feces' enters, fills the rectum, neural signals from the internal sphincter (intrinsic defecation reflex)
- Cerebral cortex sends signals via (extrinsic defecation reflex) to the external sphincter.

Both reflexes coordinate their responses and facilitate 'defecation' to occur as appropriate.
Oral Cavity:

Dentition
DUCTS

SALIVARY GLANDS & TONSILS (T)