The Digestive System

We need food for cellular utilization:

→ nutrients as **building blocks** for synthesis
→ sugars, etc to break down for **energy**

most food that we eat cannot be directly used by the body

→ too large and complex to be absorbed
→ chemical composition must be modified to be usable by cells

digestive system functions to altered the chemical and physical composition of food so that it can be absorbed and used by the body; ie

**Functions of Digestive System:**

1. physical and chemical digestion
2. absorption
3. collect & eliminate nonuseable components of food

Anatomy of the Digestive System

organs of digestive system form essentially a long continuous tube open at both ends

→ **alimentary canal** (gastrointestinal tract)

mouth → pharynx → esophagus → stomach → small intestine → large intestine

attached to this tube are assorted **accessory organs** and structures that aid in the digestive processes

osalivary glands
teeth
gall bladder
pancreas
mesenteries

The GI tract (digestive system) is located mainly in **abdominopelvic cavity**

surrounded by **serous membrane**

= visceral peritoneum

this serous membrane is continuous with parietal peritoneum and extends between digestive organs as **mesenteries**

→ hold organs in place, prevent tangling

The wall of the alimentary canal consists of 4 layers:

outer

**serosa:**

visceral peritoneum,
mainly fibrous and areolar CT
with some pockets of adipose CT

**muscularis**

several layers of smooth muscle

**submucosa**

blood vessels, lymphatic vessels, nerves, connective tissue

inner

**mucosa:**

small band of muscle tissue, **muscularis mucosa**

mucus membrane lining contains goblet cells that secrete mucous for protection

these layers are modified within various organs

→ some have muscle layers well developed
→ some with mucous lining modified for secretion of digestive juices
→ some with mucous lining modified for absorption

1. **Mouth (Buccal Cavity, Oral Cavity)**

bordered above by hard and soft palate

forms partition between mouth and nasal passages

uvula

gingivitis = inflammation of gum surrounding teeth; can lead to

is suspended from rear of soft palate blocks nasal passages when swallowing

tongue

lines ventral border of mouth cavity
is skeletal muscle covered with mucous membrane
contains taste buds

frenulum is thin fold of mucous membrane on ventral surface of tongue that anchors the tongue to the floor of the mouth

short frenulum → “tongue tied”

**Teeth**

two sets

**deciduous** (=baby teeth) (20)
begin at 6 months; shed 6–13 yrs

**permanent** teeth (32)
each tooth has a

crown (above gum)
neck is where crown, gum and root meet
root (below gum)
imbedded in socket
periodontal disease
kinds of teeth modified for specific functions

**incisors** – 4+4; cut, knip
**canines** – 2+2; holding onto prey
**premolars** – 4+4; cutting, crushing
**molars** – 6+6; chewing, grinding, crushing

each tooth is composed of several layers:

**enamel**
- very hard
- outer surface
- on upper exposed crown only
- resists bacterial attack
- cannot regenerate if damaged

**dentin**
- below enamel
- less hard, similar to bone matrix
- decays quickly once enamel is penetrated

**pulp**
- living portion of tooth
- consists of blood vessels, nerves

**cementum**
- on root of tooth only
- outer surface
- holds root into socket in jaws

Salivary Glands
3 Pairs of **salivary glands**:

- **sublingual**
- **submandibular**
- **parotid**

- largest, below ears
- mumps = acute infection of parotid gland

secrete **saliva** (enzymes and mucous for digestion)

2. **Pharynx (throat)**

already discussed

3. **Esophagus**
collapsible tube ~ 10” long
extends from pharynx to stomach
→ gets food through thorax to abdominal cavity
posterior to trachea and heart
pierces diaphragm
uses peristalsis to move food to stomach
→ can swallow upside down

drains into stomach through the **lower esophageal sphincter**

4. **Stomach**
muscular sac just below diaphragm and liver
alimentary canal expands to form stomach
- 50 mL when empty; up to 1.5 L after meal

**Major functions of stomach:**

1. **physical digestion** – churning action
2. **chemical digestion** – esp proteins
3. **limited absorption** (some water, alcohol, certain drugs)

divided into 4 regions:

- **cardiac**
- **fundus**
- **body**
- **pyloris**

Muscle layers are very well developed in stomach
- **circular**
- **longitudinal**
- **oblique**

Help to break up food by churning action
results in milky white liquid = **chyme**

**sphincter muscles** close both stomach openings:

- **cardioesophageal sphincter**
  - =lower esophageal sphincter
  - heartburn → doesn’t close properly
- **pyloric sphincter**
  - cholic in babies → doesn’t open properly
  - given smooth muscle relaxers

mucosal lining of stomach is folded into **rugae** to allow for expansion with a meal

within the mucous lining of stomach are glandular tubes called **gastric pits**

→ within gastric pits are numerous microscopic **gastric glands**:
  - secrete **mucous** for protection
  - secretes various **digestive enzymes**
  - secretes **HCl**
5. **Small Intestine**

Longest part of alimentary canal:

- 1" diameter x 10' long (living) or 20' long (cadaver)

**Major functions of small intestine:**

1. **most chemical digestion** of food (duodenum)

2. secretes **hormones** which direct secretion of digestive juices by stomach, gall bladder, pancreas

3. **most absorption** of digested foodstuffs (jejunum & ileum)

Small intestine fills most of abdominal cavity

Held in place by **mesenteries** (=serous membranes)

Subdivided into 3 functional regions:

- **Duodenum**
  ~10" long
  Uppermost
  Drains pyloric stomach
  Receives ducts from gall bladder and pancreas

- **Jejunum**
  ~4'
  Central portion
  Mostly in umbilical region
  Especially rich blood supply
  Most digestion and absorption occurs here
  Absorbs most nutrients, water & salts

- **Ileum**
  ~5'
  Mainly in hypogastric region
  Joins to cecum of large intestine
  Absorbs and reclaims bile salts and some additional nutrients

Mucosal lining of the small intestine is folded into **plicae**

The intestinal mucosa also contains small finger-like projections = **villi**

- ~1mm tall
  Each villus contains absorptive epithelial cells and goblet cells
  Core of villus is filled with areolar tissue of lamina propria
  Within this is an arteriole, capillary bed, venule and lymphatic capillary = **lacteal**

6. **Large Intestine**

2.5" diameter x 6’ long

Valve-like sphincter separates small from large intestine = **ileocecal valve**

**Major functions of large intestine:**

1. **Absorb additional water** as needed by body

2. **Absorb** small amount of **additional nutrients**
Some Vit K and B's made by bacteria in large intestine

3. Collects, concentrates and **rids body of undigested wastes**

Subdivided into 3 regions:

- **Cecum**
  Blind ended sac that extends from point of attachment to small intestine
  Contains appendix ~3.5” (9cm) long
  Significant source of lymphocytes

- **Colon**
  Subdivided into:
  - Ascending colon
  - Transverse colon
  - Descending colon
  - Sigmoid colon

- **Rectum**
  Last 7-8”
  Ends at **anus**
  Held shut by two anal sphincters:
  - Internal anal sphincter of smooth muscle
  - External anal sphincter of skeletal muscle

**Intestinal Flora**

Our bacterial symbionts exist as a complex interacting community with specific characteristics

We’re finding that each person has a unique set of microorganisms on their skin and in their guts

The abundance of certain bacteria in your feces correlates with your age, gender, body mass index, and nationality

Our gut bacteria provide many benefits:
help break down hard to digest fibers and starches
make essential vitamins and additional nutrients
protect us from pathogens, toxins and some carcinogens
activate our immune systems to better resist infections

gut bacteria change and adapt as your foods change
those better able to metabolize dominant food tend to increase
gut bacteria affect our mood and behavior:
correlations have been found between gut flora and some psychiatric disorders such as depression, autism and schizophrenia
obesity, diabetes, Crohn’s disease, colitis, celiac disease, irritable bowel syndrome all may be the result of an imbalanced microbial ecosystem in our guts
some forms of severe malnutrition have been linked to a particular group of intestinal bacteria
promising research has found that fecal transplants have cured symptoms of Parkinson’s disease, diabetes and obesity
eg. 100% cure rate for C. difficile infections, a deadly disease common in patients on antibiotic therapy

use of antibiotics can cause dramatic and long term changes in our gut flora and increase risk of some chronic diseases
in the future:
- eg. might be able to test for changes in kinds and numbers of species as an early indication of certain diseases
- eg. doctors may prescribe bacterial supplements to improve physical health
- eg. fecal transplants: restores bowel flora to a healthy state

7. **Serous Membranes**

body wall and organs of abdomen are lined with **peritoneum**
- parietal peritoneum
- visceral peritoneum

most, but not all, of the visceral organs are completely lined with visceral peritoneum

tese layers are continuous with thin flaps of serous tissues = mesenteries

mesenteries allow free movement while holding organs in place and prevent them from tangling

greater omentum
fold of mesentery extending from stomach and

duodenum
loosely covers the small intestine like an apron
contains fat deposits

lesser omentum
smaller fold of mesentery between liver and stomach

**Accessory Organs of Digestive Tract**

A. **Liver**

is the largest gland in body
lies immediately under the diaphragm
consist of 2 lobes separated by falciform ligament
receives blood from the **Hepatic Artery** and the **Hepatic Portal Vein**

bile leaves the liver through the **Hepatic Vein** to the **Vena Cava**

B. **Gall Bladder**

lies on undersurface of liver
3-4” long and 1.5” wide
liver produces 0.6 – 1.2L of bile/day
bile travels up **Cystic Duct** to gall bladder for storage
can hold 30-50 ml of bile
gall bladder stores and concentrates bile
When needed bile travels down **Cystic Duct** to **Common bile Duct** to the duodenum

C. **Pancreas**

most digestion is carried out by pancreatic enzymes
in curve of duodenum and dorsal to greater curvature of the stomach (retroperitoneal)
6-9 “ long
composed of 2 kinds of glandular tissue:

- **endocrine** → secretes hormones
  - islets = 2% of total mass of pancreas
  - their secretions pass into circulatory system
  - secrete insulin and glucagon
- **exocrine** → digestive function

pancreatic digestive secretions average ~2L/day

→ mainly on demand, in short timespans

pancreatic secretions are collected in **pancreatic duct** and usually a smaller accessory pancreatic duct that both drain into the duodenum

**Digestive Physiology**

**Muscular Movements (=motility) in GI Tract**

as materials are being processed they are moved through alimentary canal by by several muscular processes:

- **chewing**
  - voluntary movements of skeletal muscles
- **swallowing**
  - coordinated activity of skeletal and smooth muscles
  - reflex controlled by medulla
  - pharynx to esophagus
- **peristalsis**
  - propulsive movements
  - sequential smooth muscle contractions in adjacent segments
  - pushes food forward
  - esophagus, stomach, small intestine, large intestine
- **segmentation**
  - mixing movements
  - alternating contractions and relaxations of adjoining portions of intestine
  - food is moved backward and forward
  - helps to physically break up and mix contents for better digestion & absorption
- **mass movements**
  - occur 1-3 times/day when all circular muscle constricts in a long stretch of intestine to push food toward anus
  - main propulsive force in large intestine

**sphincters**

tonic contractions of smooth and skeletal muscles that control the emptying and filling of various portions of the GI tract

**Digestion**

digestion = all food changes that occur in the alimentary canal

need to convert food into a form that can be absorbed and used by body cells

two types of digestion:

- **physical digestion**
  - breaking large pieces down into smaller pieces
- **chemical digestion**
  - breaking large molecules (proteins, fats, starches, etc)
  - into small molecules (amino acids, fatty acids, sugars, etc)

**1. Mouth**

food entering mouth is physically broken down teeth

mixed with saliva lubricant enzyme = amylase

→ begins carbohydrate digestion

at end of digestion in mouth, food = **bolus**

**2. Pharynx**

bolus is swallowed

uvula closes off nares

epiglottis closes off glottis of larynx

**3. Esophagus**

wave of reflex contractions = peristalsis

**4. Stomach**

muscular contractions separate and mix food particles and move them toward the pylorus

in stomach bolus is mixed with gastric juices **gastric juices** low pH ~2

→ ideal for breaking proteins into smaller fragments

**gastric ulcers**: *Helicobacter pylori*

part of normal flora of stomach

can neutralize stomach acids

excessive growth can irritate stomach lining to produce ulcers

**physical digestion is completed in stomach**

once digestion in stomach is competed have a white milky liquid = **chyme**

stomach takes about 2-6 hours to empty after a meal
gastric emptying is controlled by enterogastric reflex:
periodic opening/ closing of pyloric valve
prevents overburdening smaller duodenum

5. Duodenum
all physical digestion has been completed
→ most chemical digestion occurs here
receives digestive juices from pancreas and gall bladder
also produces its own set of enzymes

a. Bile
bile contains no enzymes
does contain bile salts, cholesterol and other lipids
most lipids are very insoluble in water
→ must be made somewhat soluble before they can be digested and absorbed
bile is a surfactant
→ emulsifies fats into smaller fat

b. Pancreatic Juices
pancreas is an endocrine gland (insulin, glucagon)
but 98% of its tissues make and secrete digestive juices through ducts to the duodenum

6. Large Intestine
contains a mixture of remnants of several meals eaten over a day or two
food is mixed and compacted by segmentation
peristaltic contractions propel food toward anus
mass movements occur 1-3 times/day when all circular muscle constricts in a long stretch of intestine to push food toward anus
→ main propulsive force in large intestine
some digestion occurs here due to bacteria
esp in caecum
as feces enters rectum, stretch receptors trigger the awareness of need for defecation
defecation proceeds by coordinated activity of smooth and skeletal muscles in the defecation reflex

Absorption
~9-10 liters (2.5 gallons) of food, liquids and GI secretions enter tract/day
~1000 ml reaches the large intestine
150 ml is expelled as feces
~half of that is bacteria from intestines
→ 75 ml wastes/d
absorption occurs throughout digestive tract
~90% occurs in small intestine
~10% in large intestine and stomach

Stomach
some water
alcohol
a few drugs (e.g. aspirin)

Small Intestine
absorb ~90% of materials
absorbs virtually all foodstuffs
absorbs 80% of electrolytes
absorbs most water

Jejunum
all food stuffs
most water
Ileum
reclaims some additional bile salts
Small intestine is greatly modified for absorption

1. epithelial cells are joined by **tight junctions**
   better control of what is absorbed
   substances can’t move between cells
   materials must pass through cells to get to interstitial spaces
   (=trans epithelial transport)

2. **surface area** is greatly increased for more efficient absorption of nutrients:
   1" diameter x 10’ long → if smooth tube = 0.33 m² (3 sq ft)
   but: interior is folded → increases area ~3 x’s
   also: fingerlike projections = villi
   ~1mm tall
   contain capillary beds contain lacteals
   → increases area another 10x’s
   also: each epithelial cell of villus has microvilli
   up to 1700/cell = brush border
   → increases area another 20x’s
   **Total Area = 200m² (1800 sq ft)**

Large Intestine
additional water if body needs it
some Vit K and B’s made by bacteria there

**Mechanisms of Absorption**
absorption can be an active or passive process:

1. most nutrients are absorbed by **active transport**
   eg. glucose amino acids
   some minerals

2. water is absorbed by **osmosis**

3. large molecules are absorbed by **pinocytosis**
   eg. a few large fats and proteins; fats passed to lacteals with other fats

4. some lipids are absorbed by **diffusion** to lacteals

**Feces** = “residue of digestion”
cellulose connective tissues, fibers, toxins from meats
undigested fats and mucous
bacteria (~50%) feces may also contain recognizable remnants of poorly
digested foods: corn, peanuts, peas, carrots, cereals, beans

Liver Processing
the liver is main organ for metabolic regulation in the body
→ over 200 specific functions

1. **stores** iron, vitamin A, B₁₂ & D

2. helps stabilize blood glucose levels by storing excess glucose or synthesizing glucose if needed

3. carries out most of body’s fat synthesis including cholesterol and phospholipids

4. **synthesizes** plasma proteins & degrades excess amino acids

5. phagocytes remove old/damaged blood cells and pathogens

6. **detoxify** blood from digestive system removes drugs, alcohol, antibiotics, etc

7. is largest **blood reservoir** in body receives 25% of cardiac output

8. collects and removes metabolic wastes such as cholesterol, products of RBC destruction, etc

9. secrete bile to aid in digestion (~1pt /day)

Liver Lobule
**lobule** is functional unit of liver
→ each liver lobe is divided into 1000’s of lobules

tiny hexagonal cylinders (~2mm x 1mm)
~ 1 million lobules in human liver
small branches of hepatic vein extend through middle of each lobule as central vein
sinusoid spaces lined with hepatic cells extend outward from central vein
around periphery of each lobule are branches of hepatic portal vein
hepatic artery hepatic bile ducts

→ arterial blood brings oxygen to liver cells

→ venous blood from hepatic portal vein delivers blood through lobule for “inspection”:
  a. phagocytic cells remove toxic compounds and convert them to nontoxic compounds
  b. some vitamins and nutrients are removed and stored
  c. synthesis of starches, lipids and proteins for storage

→ cholesterol, bile pigments and bile salts are secreted
The Aging Digestive System

shows significant senescence in old age:
- less saliva
  - food less flavorful, harder swallowing

~half of those over 65 yrs wear dentures

gastric mucosa secretes less acid
  - reduces absorption of Calcium, iron, zinc and folic acid

gastric mucosa secretes less intrinsic factor
  - reduces absorption of vitamin B12
  - leads to pernicious anemia

Heartburn becomes more common

most common digestive complaint of older people is constipation
  - due to:
    - less muscle tone
    - weaker colon peristalsis
    - reduced sensitivity to neurotransmitters
    - less fiber & water in diet
    - less exercise

activity of liver, gall bladder and pancreas are reduced only slightly in old age

Digestive Problems

1. Choking
   - food in air passages
   - usually meats, hot dogs, grapes, carrots, hard candy, popcorn, peanut butter
   - may not be able to make a sound
   - DON'T hit on back

2. Vomiting
   - symptom of many diseases
   - waves of reverse peristalsis
   - if severe may empty duodenum as well
   - rest and drink small amounts of fluids
   - guard against massive fluid loss

3. Bulemia
   - self induced vomiting
   - may cause damage and infection of esophagus, pharynx, or salivary glands
   - erosion of teeth, more dental caries
   - esophagus may rupture or tear

4. Diarrhea
   - frequent loose watery stool
   - intestinal contents moving too fast for fluid absorption to occur
   - main danger is fluid loss
   - also upsets acid/base balance

5. Constipation
   - caused by:
     - lifestyle ➔ inadequate water input
     - lack of physical activity
     - side effect of medication
   - controlled by increase in fiber, prunes, laxatives
     ➔ attracts water ➔ softens stool

6. Belching
   - results from swallowed air
   - can rupture the intestine
   - carbonated drinks and chewing gums can contribute
   - occasionally can be a sign of a more serious disorder: gall bladder pain, colonic distress
   - eat slowly, chew thoroughly
   - relax while eating

7. Hiccups
   - repeated spasms of diaphragm
   - may be triggered by eating or drinking too fast

8. Gas
   - large intestine generates 7-10 L of gas/day
   - normally we expel ~500ml of gas/day
   - the rest is reabsorbed
   - most is odorless
   - 1% are "volatile" gasses
   - high carb foods known to produce excess gas

9. Heartburn (& gastroesophageal reflux disease)
   - cardiac sphincter doesn't close properly
   - affects 50% of US, esp white males
eat or drink too much
clothing too tight
cure:
  eat small meals
drink liquids 1 hr before or 1 hr after meal
don’t lie down or bend over
lose weight if overweight
don’t smoke
use antacids but sparingly

10. Peptic Ulcers
a lesion of stomach or duodenum caused by acids or pepsin
  duodenal ulcers are the most common
  perforated ulcer extend through entire wall of GI tract
caused by:
  bacterial infection, Helicobacter pylori, is important cause of most ulcers
  in 80% of patients with duodenal ulcers
  probably disrupt mucosal barrier
  use of some antiinflammatory drugs
  disorders that cause excessive gastric secretions
  reduced mucosal defense
  diet therapy used to be main cure, now antibiotics
  also advised to stop smoking and avoid alcohol and caffeine

11. Celiac Disease
chronic disorder in which the mucosa of small intestine is damaged by ingestion of certain cereal grains, eg. wheat, barley, rye, & oats
  disease 1st reported in second century by Aretaeus of Cappadocia
  these grains have large amounts of a protein, =gluten,
  causes loss of villi & brush border, and increased numbers of WBC’s
  leads to inadequate intestinal absorption
  symptoms: diarrhea, weight loss, abdominal distension and bloating and weakness
  due to genetic and environmental factors
  patients with such sensitivity must adhere to gluten-free diet
  substitute: corn, millet, buckwheat, sorghum & rice

12. Pica
the compulsion to swallow nonfood items
  pica behavior is normal for infants
  they explore their world through their mouth's
  in adults it could become dangerous or even life threatening
  eg. pregnant women - rich smell of soil drove them to eat it
  eg. another pregnant woman was eating almost half a kg of baking soda each day
  eg. compulsive consumption of ice is often associated with iron deficiency
  eg. 9 year old girl routinely ate cloth an string was helped by taking vitamin supplements
  eg. soil eating is common in many traditional societies
  may be instinctive way to get trace minerals like Fe or Zn
  pica is also common among people with cognitive or psychiatric disorders such as autism and schizophrenia
  eg. a compulsion to eat cigarette lighters or $650 worth of coins

Gall Stones
“calculi” can form in kidney, urinary bladder and gall bladder
seed becomes surrounded by layers of crystalline deposits
if large enough can block cystic duct or common bile duct and cause jaundice