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 useable 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

salivary glands
teeth
liver
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 ↓ inner

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

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. <u>Mouth (Buccal Cavity, Oral Cavity)</u>

bordered above by **hard** and **soft palate**

forms partition between mouth and nasal passages

uvula

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

gingivitis = inflammation of gum surrounding teeth; can lead to

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 of 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 upsidedown

drains into stomach through the cardiac orifice surrounded by the **lower esophageal sphincter**

4. Stomach

muscular sac just below diaphragm and liver

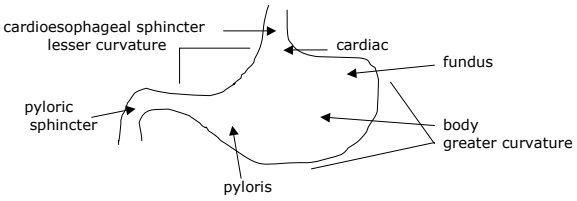
alimentary canal expands to form stomach

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:

cardioesphageal 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 caecum 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 lg 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

on the outer surface of the large intestine are 3 longitudinal bands of muscle tissue **= taenia coli**

→ muscle tone within these bands produces pouches = **haustrae** that allow distention

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 particulary group of intestinal bacteria

promising research has found that fecal transplants have cured symptoms of Parkinsons, 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. <u>Serous Membranes</u>

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

these 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

<u>Accessory Organs of Digestive Tract</u>

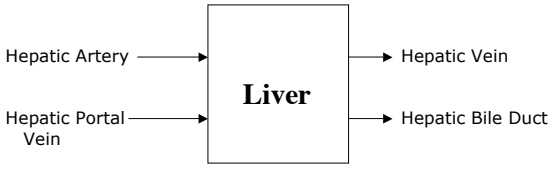
A. <u>Liver</u>

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**



blood leaving the liver enters the **Hepatic Vein** to the **Vena Cava**

bile leaves the liver through the **Hepatic Bile Duct**

B. <u>Gall Bladder</u>

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. <u>Pancreas</u>

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 foreward
→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

gall stones

hard masses of cholesterol, calcium carbonate & bilirubin

may block cystic duct

jaundice = bile ducts obstructed
→body cant get rid of bile
→bile is absorbed into blood
→causes yellowing of skin

droplets to speed their digestion

95% of bile secreted by gall bladder is reabsorbed after it is used in digestion

→ recycled back to liver

fiber inhibits reabsorption or bile

→ fiber rich diets help to lower cholesterol

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

c. Duodenal Secretions

secrete additional enzymes that help to complete the breakdown of organic molecules

peristaltic movements keep the food moving along the small intestine as it is digested and nutrients are absorbed

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 (eg. aspirin)

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

Jejunum
all food stuffs
most water
most electrolytes

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 cant move between cells
   materials must pass through cells to get to interstitial spaces
   (=transepithelial transport)

2. **surface area** is greatly increased for more efficient absorption of nutrients:

   1" diameter x 10' long
   → if smooth tube **= 0.33 m^2 (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 = 200m^2 (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, B_{12} & 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

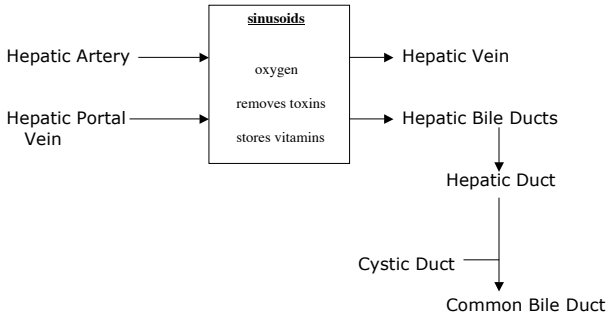
b. some vitamins and nutrients are removed and stored

c. synthesis of starches, lipids and proteins for storage

→ cholesterol, bile pigments and bile salts are secreted

into bile ducts for later use in digestion of fats

hepatic bile ducts join **cystic duct** → store bile in gall bladder



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

Colonic Irrigation
alternative medical practice
potentially harmful
unneccessary
can rupture the intestine

frequent use of laxatives and enemas:
can lead to dependency
upset body's fluid balance

mineral oil
can interfere with absorption of fat soluble vitamins

6. Belching
results from swallowed air
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 and 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 all patients with duodenal ulcers
→in 80% of patients with gastric 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 ingestio fo certain cereal grains, eg. wheat, barley, rye, & oats
disease 1st reported in second century by Aretaeus of Cappadochia
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