Digestive Physiology

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
- **→physical and chemical digestion**
- **→absorption**
- **→collect & eliminate nonuseable components**

lumen of GI tract is continuous with outside of body
- → food being digested must be isolated from body cells since it's the same composition as rest of body
- → digestion occurs OUTSIDE the internal environment of cells and tissues
- →protects internal cells

Movement of Materials

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

swallowing
- reflex controlled by medulla
- pharynx to esophagus

peristalsis
- sequential smooth muscle contractions in adjacent segments
  - →pushes food forward
- esophagus, stomach, small intestine, large intestine

segmentation
- 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

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

most (60%) of starch digestion by amylase from saliva occurs in stomach after swallowing bolus

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

2. Stomach

physical digestion involves muscular contractions to separate and mix food particles

in stomach bolus is mixed with gastric juices

gastric juices low pH ~2

hydrochloric acid

pepsin

→ ideal for breaking proteins into smaller fragments

body must be protected from harsh pH of gastric juices:

a. thick coating of bicarbonate rich mucous
b. tight junctions join epithelial cells to help prevent leakage
c. stomach lining is rapidly replaced
   → renewed every 3-6 days
d. pepsin and HCl are secreted in inactive forms

vomiting = medullary reflex:

triggered by irritants in stomach
closing nose and glottis
relaxes cardiac sphincter
spasm of diaphragm

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

3. Duodenum

all physical digestion has been completed

Completes chemical digestion of food
→most chemical digestion occurs here

receives digestive juices from **pancreas** and **gall bladder**

also produces its own set of enzymes

intestinal and pancreatic juices are alkaline
→ neutralize acidity of chyme:
enzymes in duodenum work best at alkaline pH

presence of chyme in duodenum triggers:
a. release of bile from liver & gall bladder
b. release of pancreatic secretions
c. release of duodenal secretions

a. Bile

contains no enzymes
contains
bile salts → made from cholesterol in liver
bile pigments →(bilirubin, biliverdin)
cholesterol → normally remains in solution
may precipitate out as **gall stones**
bile is a **surfactant**
→ emulsifies fats into smaller fat droplets to speed their digestion

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

include:

bicarbonates – to neutralize gastric acids
proteinases (esp trypsin and chymotrypsin)
- breaks proteins into peptides and amino acids
lipases – fats to fatty acids and glycerol
amylase – starches to mono & disaccharides
nucleases – nucleic acids into nucleotides

c. Duodenal Secretions

include:

peptidases – breaks polypeptides into amino acids
disaccharidases – disaccharides into monosaccharides
nucleosidases & phosphatases – break nucleotides into component parts

4. Large Intestine

some digestion occurs here due to bacteria
→esp in caecum

esp herbivores → large caecum
carnivores → small or no caecum

<u>Control of Digestive Secretions</u>

secretions from digestive glands is under nervous and hormonal control

digestion begins as mainly an autonomic nervous reflex

digestion is completed due mainly to hormonal controls

1. Saliva (~1500ml/day)

strictly a nervous reflex
reflex is triggered by:
mechanical and chemical presence of food in mouth
olfactory stimulation
visual stimulation
salivation can also be a learned response
→ learned by association: eg. Pavlov's dog

2. Gastric Secretions (~1500ml/day)

secretions occur in three separate phases:

cephalic phase
secretions first activated by sight, smell, taste and thoughts of food

gastric phase

continued secretion is triggered by presence of
polypeptides in pyloric region of stomach
stimulates parietal cells to secrete hormone = **gastrin**
gastrin circulates within capillaries of stomach and
enhance secretions from gastric glands in stomach wall
gastrin is secreted as long as there is food in stomach

intestinal phase

chyme is released into duodenum duodenum
presence of chyme causes release of **intestinal gastrin**
this further stimulates gastric secretions

Enterogastric Reflex

slows stomach emptying to once/~20 seconds
signaled by **stretch receptors** in duodenum

speed of reflex varies by

a. types of foods
eg. fats - slow; proteins – fast
b. fluidity
solids – slower; liquids – quicker
c. age
infant – fast; adult – slower

Presence of **fatty chyme** in duodenum
(fats float → last to leave stomach)
stimulates release of **GIP** (gastric inhibitory peptide)
→ shuts down gastric secretions

4. **Bile** (~1000ml/day)
when chyme enters duodenum
→ secretes cholecystokinin
→ stimulates peristalsis of gall bladder

5. **Pancreatic Juices** (~1000ml/day)
when chyme enters duodenum it causes the release of:
cholecystokinin
→ stimulates pancreas to release enzymes
secretin
→ stimulates pancreas to release bicarbonates

6. **Duodenal Enzymes** (~2000ml/day)
may be another hormone that stimulates release of duodenal enzymes
don't know now

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

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

Most nutrient absorption occurs in the small intestine

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
   (=transepithelial transport)

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

   a. 1" diameter x 10' long
      → if smooth tube **= 0.33 m^2 (3 sq ft)**

   b. but: interior is folded
      → increases area ~3 x's

   c. also: fingerlike projections = **villi**
      each ~1mm tall
      contain capillary beds & lacteals
      → increases area another 10x's

   d. 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)

<u>Mechanisms of Absorption</u>

absorption can be an active or passive process

essentially some kind of membrane transport

In terms of transport processes involved:

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

2. some lipids are absorbed by **diffusion** to lacteals
   eg. fats
   fat soluble vitamins

3. water is absorbed by **osmosis**

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

In terms of the Absorption of Specific Nutrients:

1. **Carbohydrates**
   mono → facilitated diffusion → capillaries

2. **Proteins**
   amino acids → active transport → capillaries
   each requires a specific carrier
   eg. genetic diseases

   whole proteins → endocytosis → capillaries
   rarely absorbed,
   but more common in newborns
   →results in food allergies
   may also be how IgA are absorbed from mothers milk

3. **Lipids**

   bile salts are essential for absorption as well as digestion

   micelles = collections of fatty elements clustered together with bile salts
   polar on outside
   nonpolar core

   micelles are much smaller than emulsion droplets
   →easily diffuse between microvilli to come in contact with cell surface

   fats, cholesterol, fat soluble vitamins then leave the micelles and move through the cell membrane by diffusion into epithelial cells of villi

   once inside epithelial cells:
   triglycerides are coated with proteins
   →to produce **chylomicrons**

   golgi bodies process and secrete them

   most lipids enter **lacteals** in villi
   a few enter capillary beds

   micelles → diffusion → chylomicrons → lacteals

in absence of bile, (eg gall stones), most fat passes to large intestine

once in blood:

fats are hydrolyzed back into free fatty acids that can be used by cells for energy production or converted to fat in adipose tissue

4. Nucleic Acids

nucleotides → active transport → blood

5. Vitamins

a. water soluble vitamins
→ diffusion → blood

except B_{12}, very large, charged molecule
binds to intrinsic factor produced by stomach
taken in by endocytosis

b. fat soluble
→ micelles → etc

6. Electrolytes

most are actively absorbed throughout the length of intestine

Fe and Ca^{++} mainly in duodenum

for most nutrients the amount reaching the intestine is the amount absorbed

But absorption of Fe and Ca is closely tied to body's need:

Fe

is actively transported into mucosal cells
binds to protein **ferritin**
stored until needed or lost as cells sloughed off
women have 4x's more transport proteins than men
in blood Fe binds to protein = **transferrin**, for transport

Ca

regulated by Vitamin D
acts as a cofactor to facilitate Ca absorption
eg. <Bld Ca → >PTH:
→ >Ca release from bone
→ >reabsorption of Ca by kidney
→ renal activation of Vit D to increase

absorption in intestine

Na^+ is coupled with active absorption of glucose and Amino acids

K^+ moves in by simple diffusion

most anions passively diffuse along a gradient

but Cl^- is actively transported

7. Water

9 L of water enters small intestine daily
95% is absorbed by small intestine (osmosis)
coupled to solute uptake
rest is absorbed by large intestine
of ~ 500 ml of chyme entering large intestine
~150 ml of feces is produced

Processing of Absorbed Nutrients

Liver

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

1. **stores** carbohydrates, iron, vitamin A, B12 & D
2. **synthesizes** plasma proteins
3. releases nutrients (eg glucose) to maintain blood levels
4. phagocytes remove old/damaged blood cells and pathogens
5. **detoxify** blood from digestive system
6. is largest **blood reservoir** in body
   receives 25% of cardiac output
7. collects and removes metabolic wastes such as cholesterol, products of RBC destruction, etc
8. secrete bile to aid in digestion (~1pt /day)

lobule is functional unit of liver
→each liver lobe is divided into millions of lobules

tiny hexagonal cylinders (~2mm x 1mm)

sinusoid spaces with small branch of **hepatic vein** extends through middle

hepatic cells extend outward from hepatic vein branches

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 passes through lobule for "inspection"

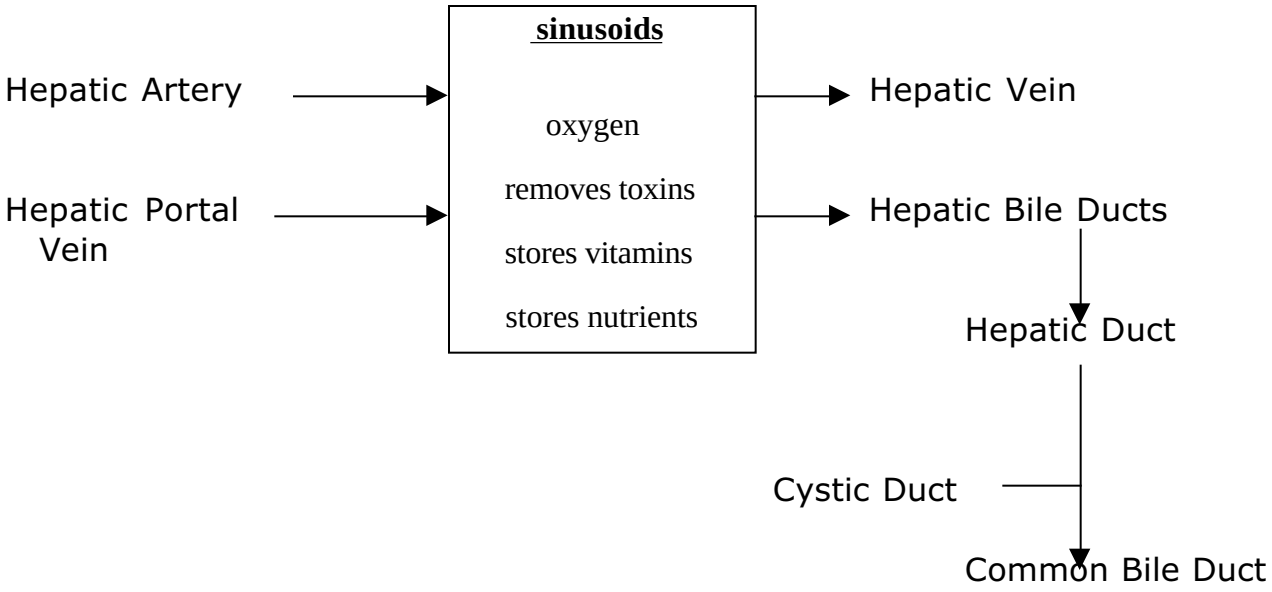
within each lobule:

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

d. cholesterol, bile pigments and bile salts are secreted into bile ducts for later use in digestion of fats



Gall Bladder

stores and concentrates bile

can hold 30-50 ml of bile

gall stones

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

Pancreas

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

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

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

normally we expell several 100 ml of gas/day
most is odorless
1% are "volatile" gasses
high carb foods known to produce excess gas

9. Heartburn

cardiac sphincter doesn't close properly
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. Ulcers

caused by:
bacterial infection
use of some antiinflammatory drugs
disorders that cause excessive gastric secretions
diet therapy used to be main cure, now antibiotics