

# 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 completed 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

## Control of Digestive Secretions

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<sup>2</sup> (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<sup>2</sup> (1800 sq ft)**

### **Mechanisms of Absorption**

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<sub>12</sub>, 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<sup>++</sup> 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

$\text{Na}^+$  is coupled with active absorption of glucose and Amino acids

$\text{K}^+$  moves in by simple diffusion

most anions passively diffuse along a gradient

but  $\text{Cl}^-$  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**

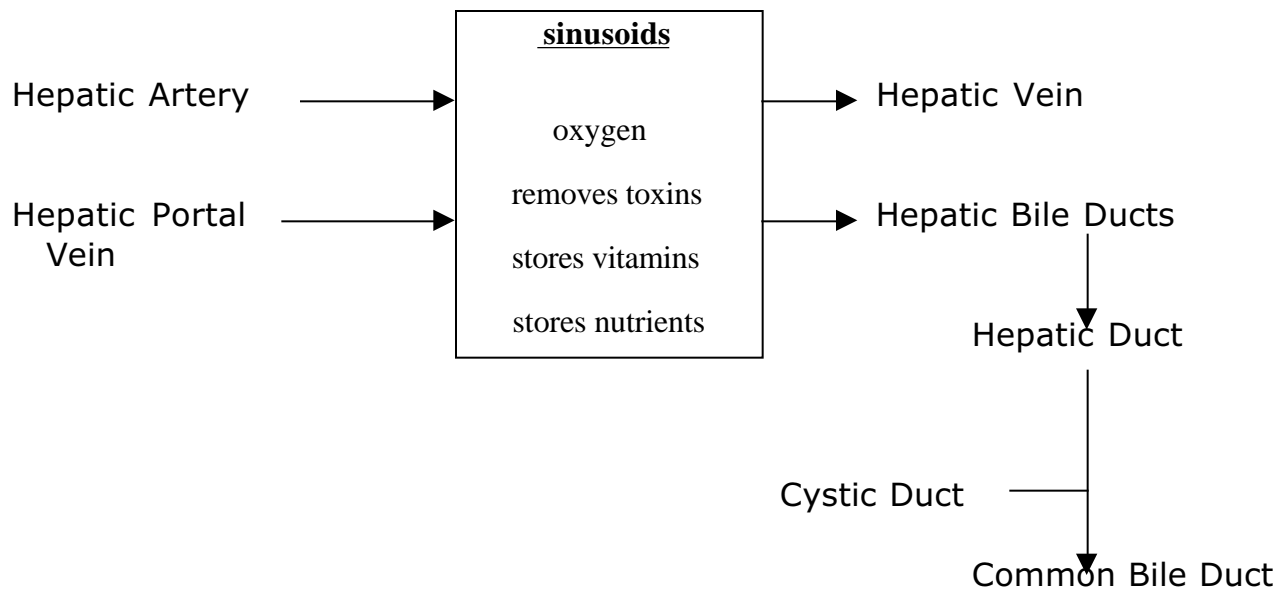
**hepatic bile ducts**

→ **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. Bulimia

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  
unnecessary  
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