

HOW YOU DIGEST FOOD

DIGESTION:

Breakdown of food



Small components

WHY?

- Carbohydrates → **Sugars**
- Protein → **Amino Acids**
- Fats → **Fatty Acids**

Absorption:

Taking Substances



Interior of Body
(blood)

ACCESSORY ORGANS

ALIMENTARY CANAL

Salivary glands

Mouth
Tongue

Pharynx

Esophagus

Liver

Gallbladder

Pancreas

Stomach

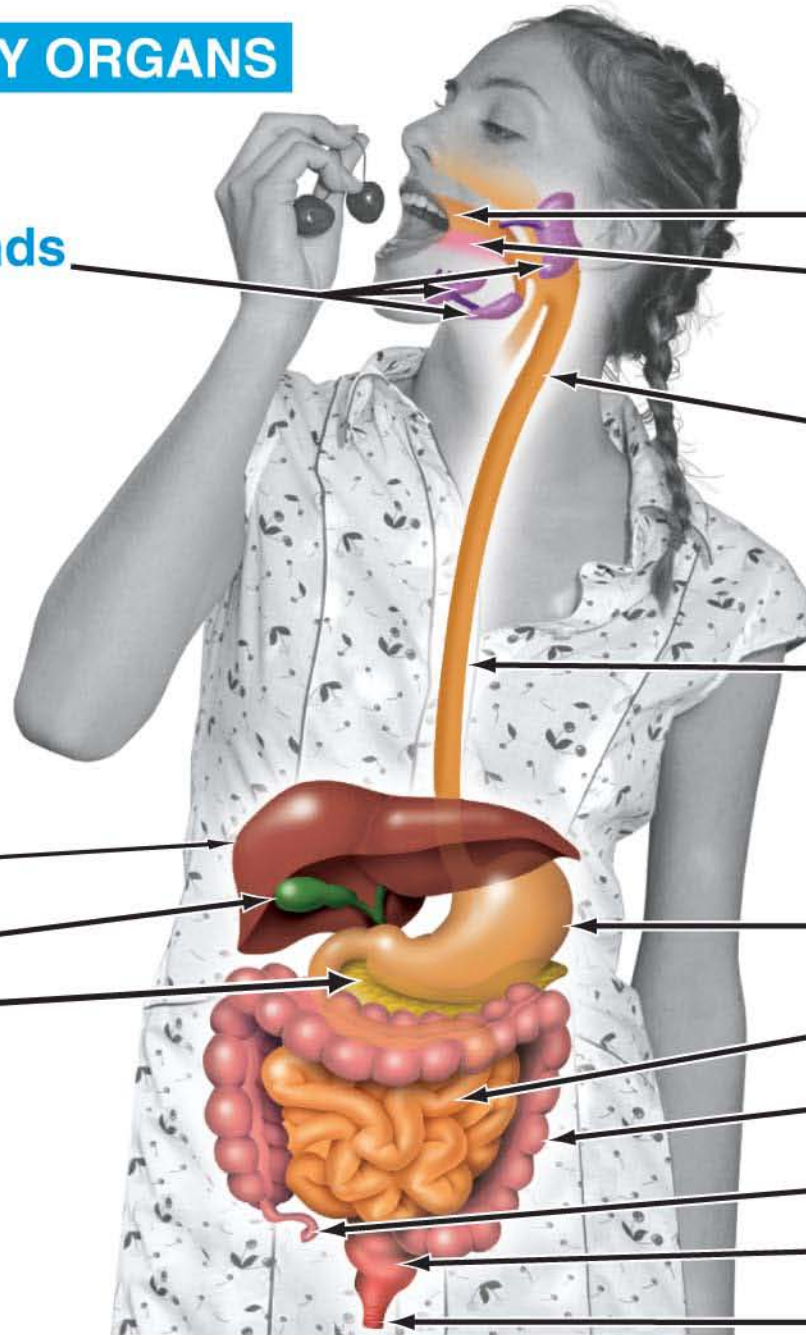
Small intestine

Colon of large intestine

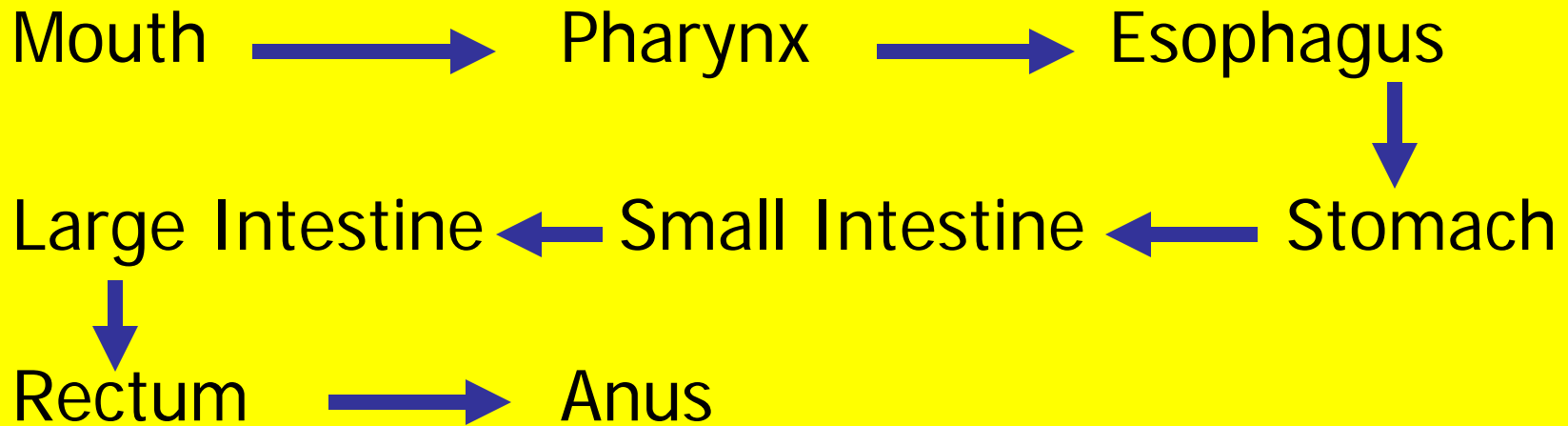
Appendix

Rectum

Anus



Gastrointestinal Tract: 30 feet long



Transit time- Food: Mouth → Anus
24-72 hours (small beads + meal)

Digestion Begins: "Mouth Waters"
Stomach → Gastric Juice

- **Sight**
- **Sounds**
- **Smell**

Mouth- Salivary Glands → Saliva

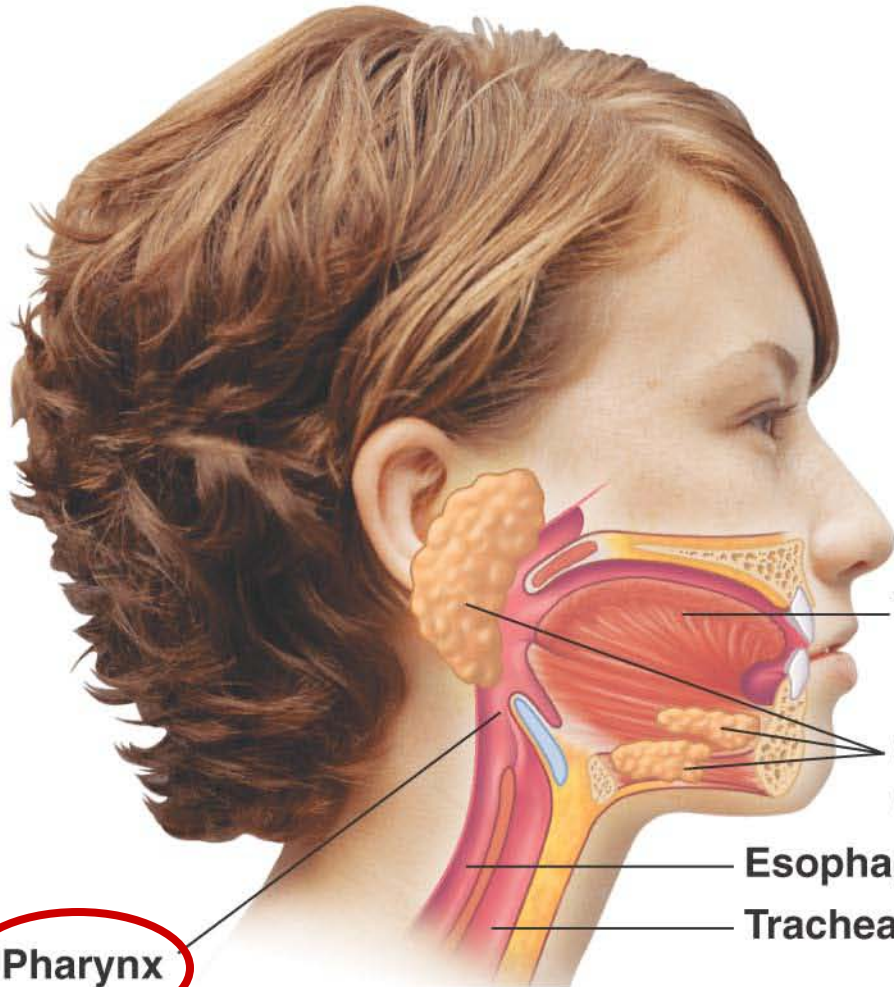
Saliva → Enzyme → Starch
(bread)

Enzymes (protein): speed up
chemical reaction, reused.

A → B
Substrate → Product(s)
enzyme

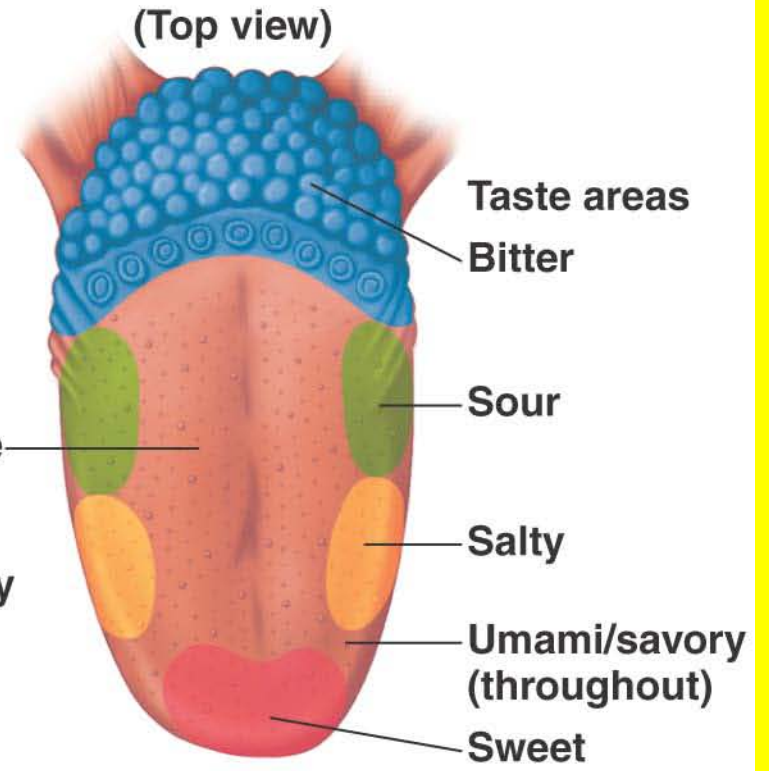
- **Chemical** Digestion
- Mechanical Digestion: **Chewing**

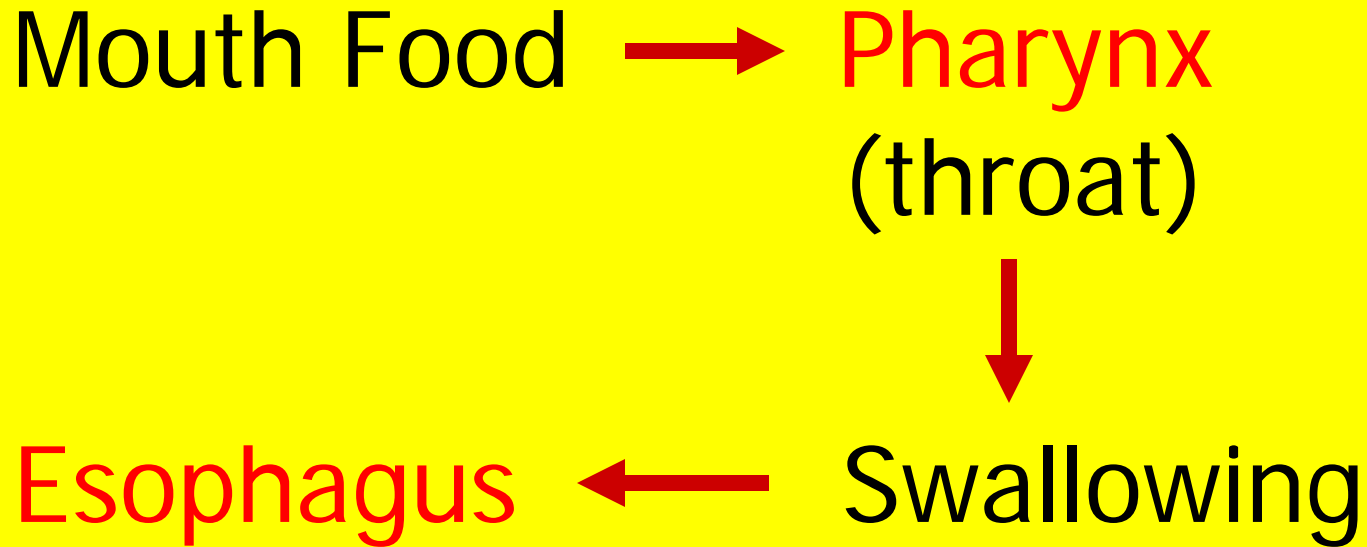
 **Surface Area-** Digestive
Juices



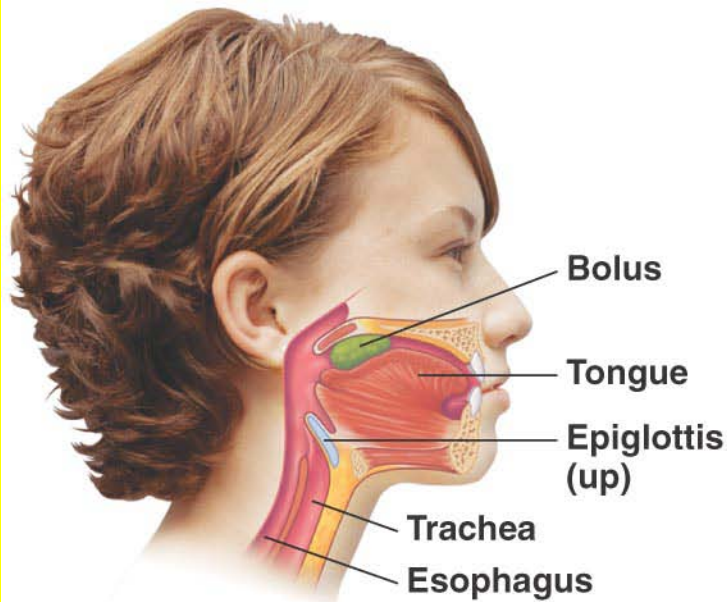
Pharynx

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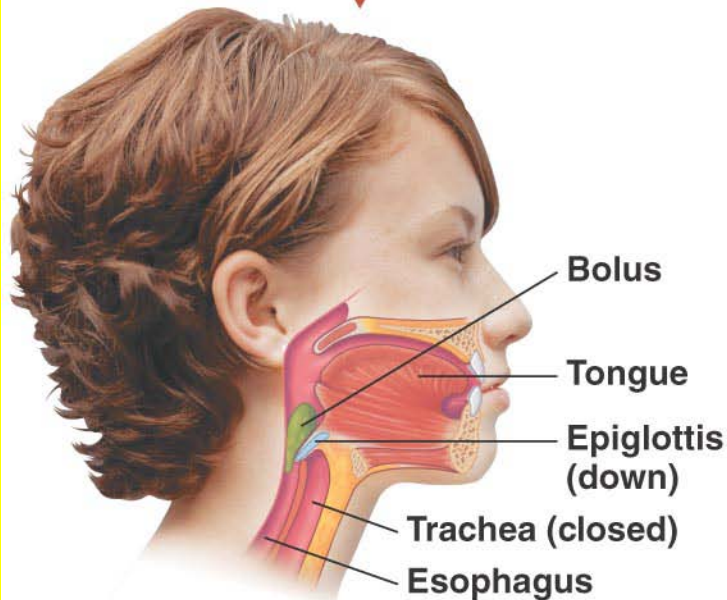




Epiglottis (trachea)



breathing

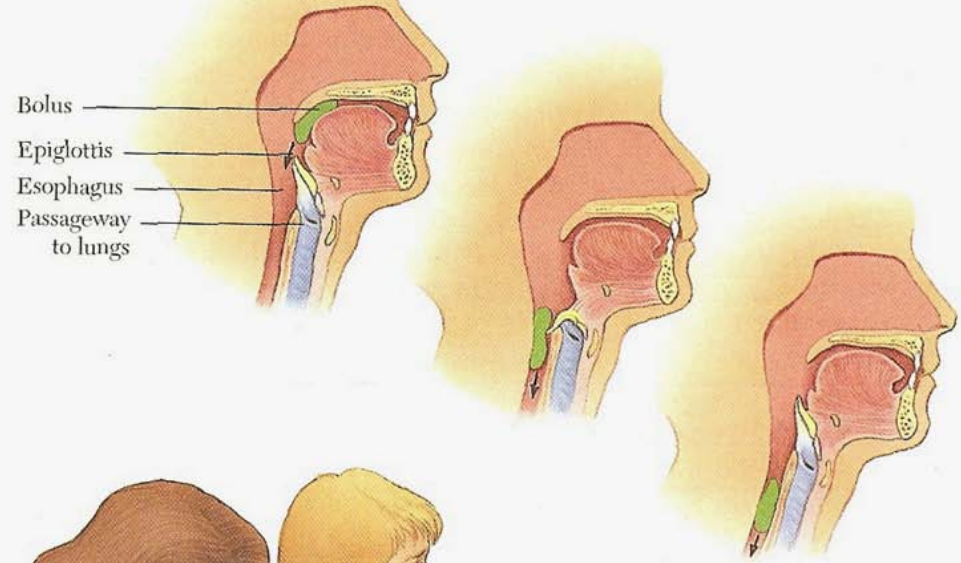


swallowing

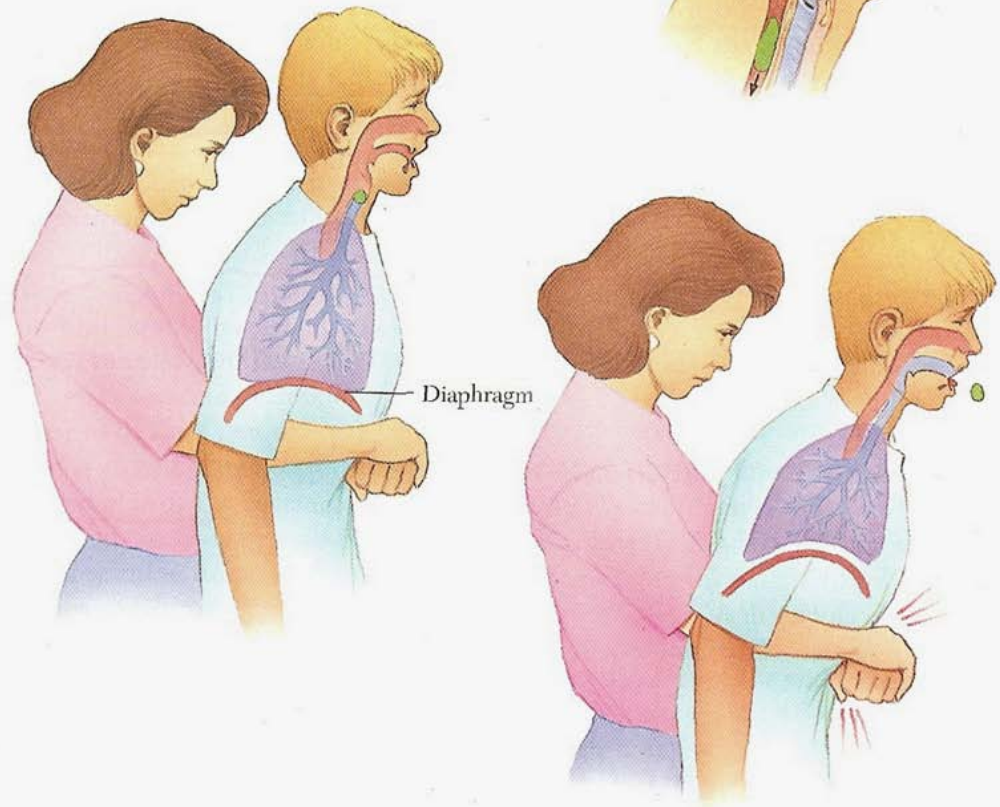
food

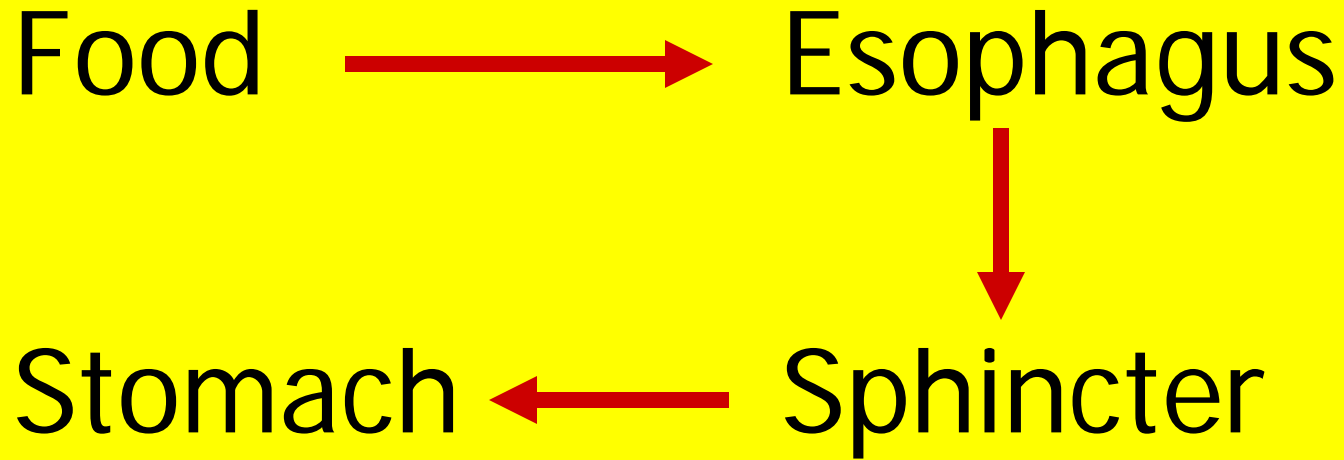


(a)

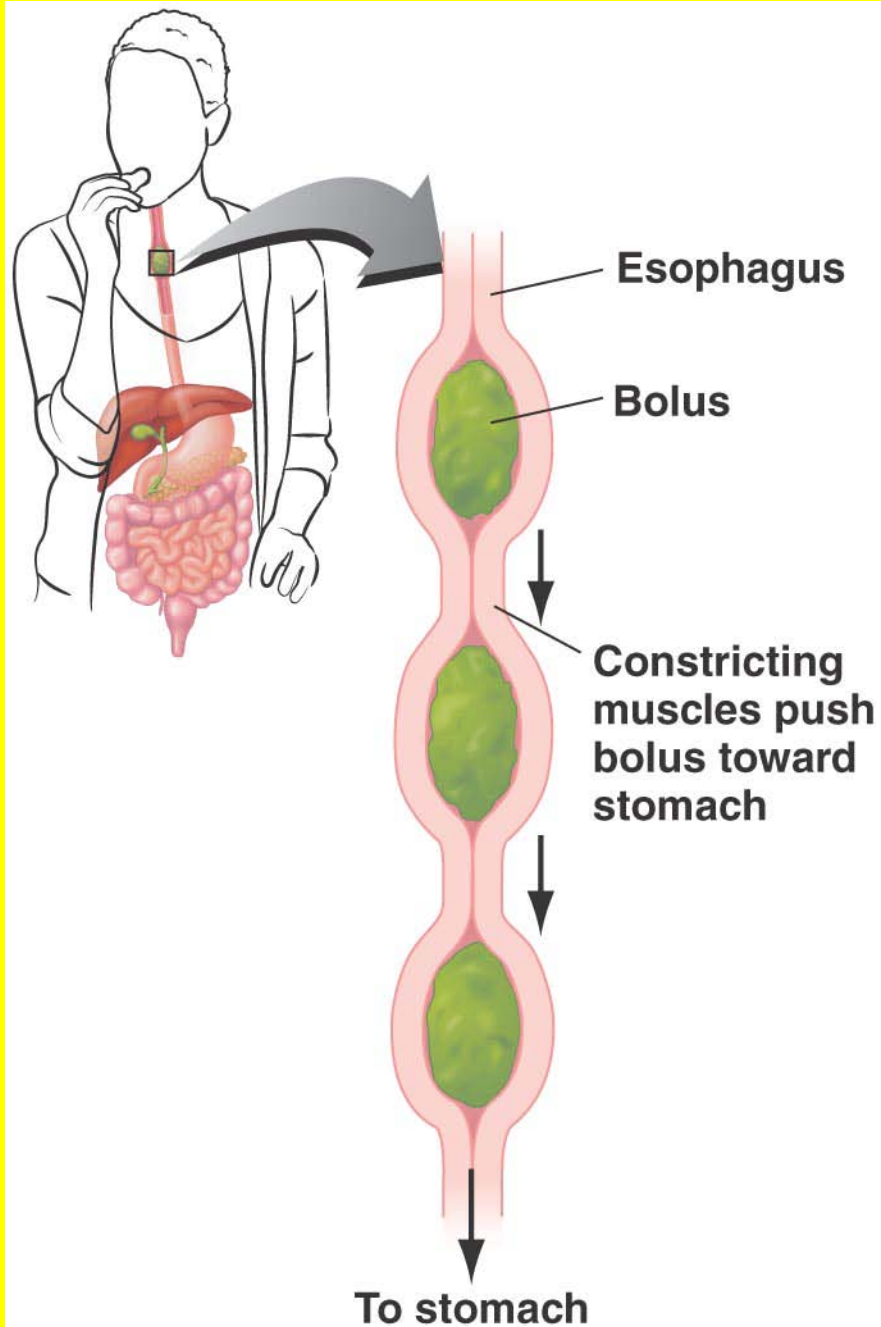


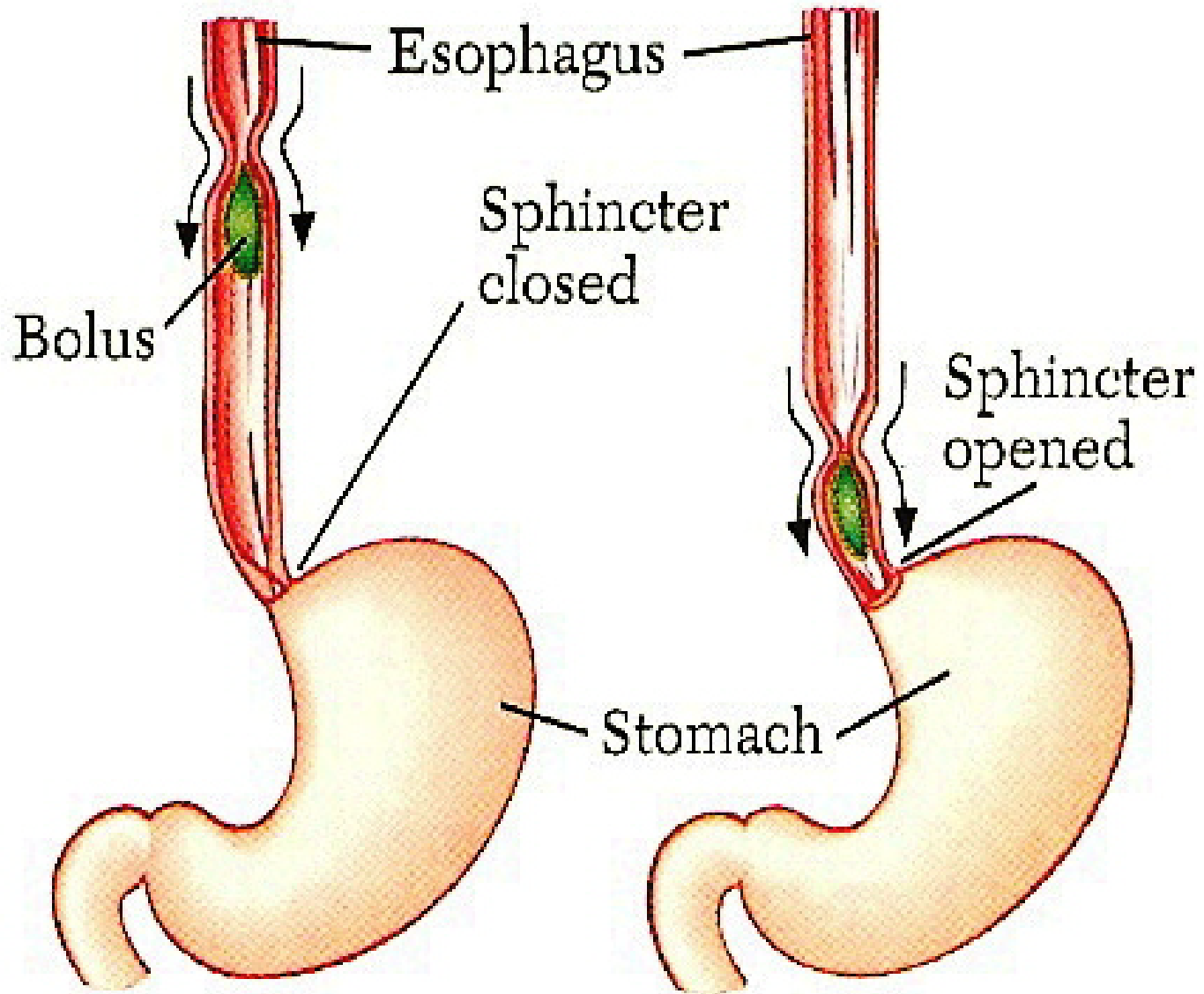
(b)





Peristalsis





- Vomiting
- Heartburn
- Gastroesophageal Reflux Disease
(GERD)
Backwash: stomach acid

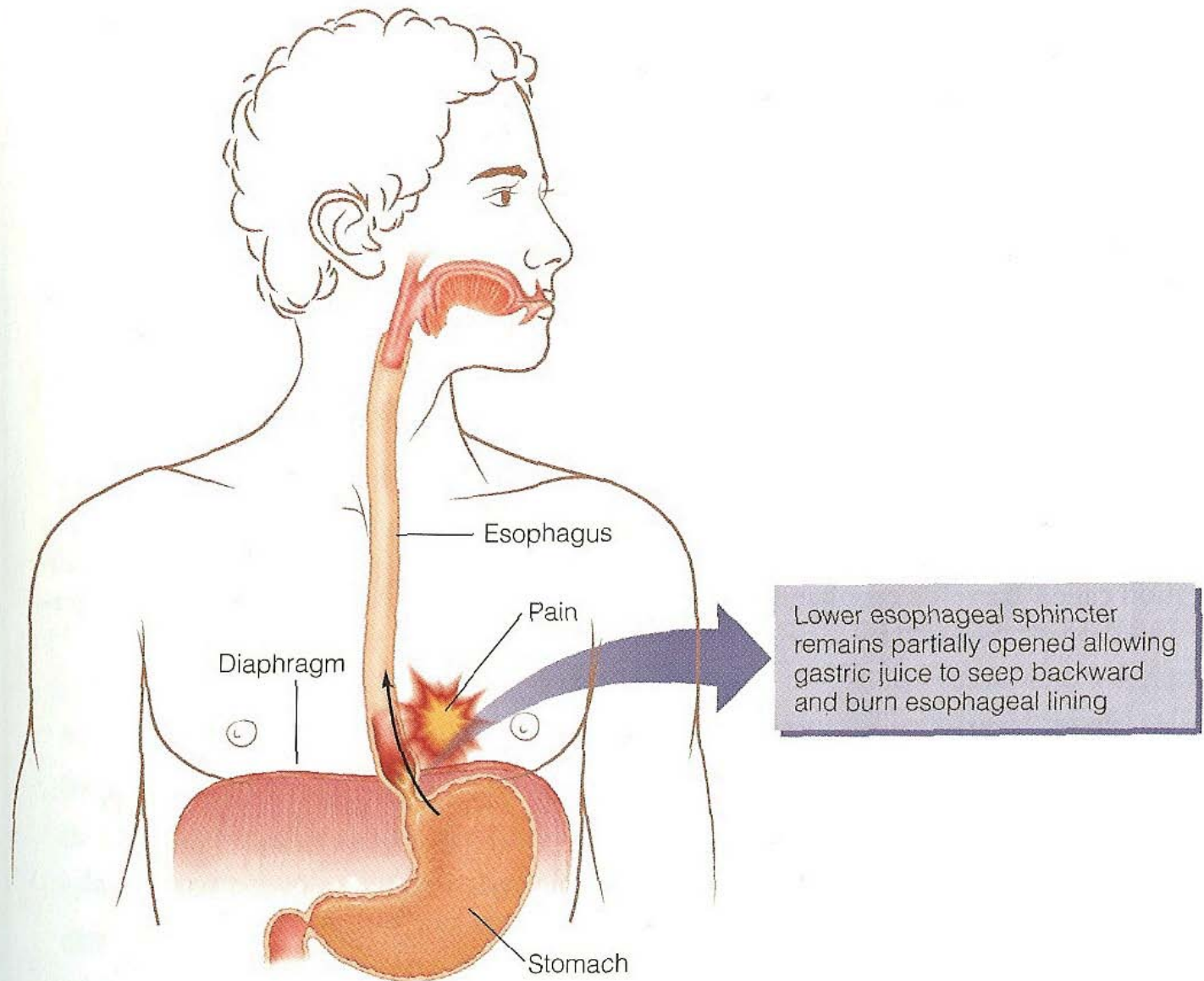


Figure 3.14 The mechanism of heartburn and gastroesophageal reflux disease is the same: acidic gastric juices seep backward through an open or relaxed sphincter into the lower portion of the esophagus, burning its lining. The pain is felt above the sternum, over the heart.

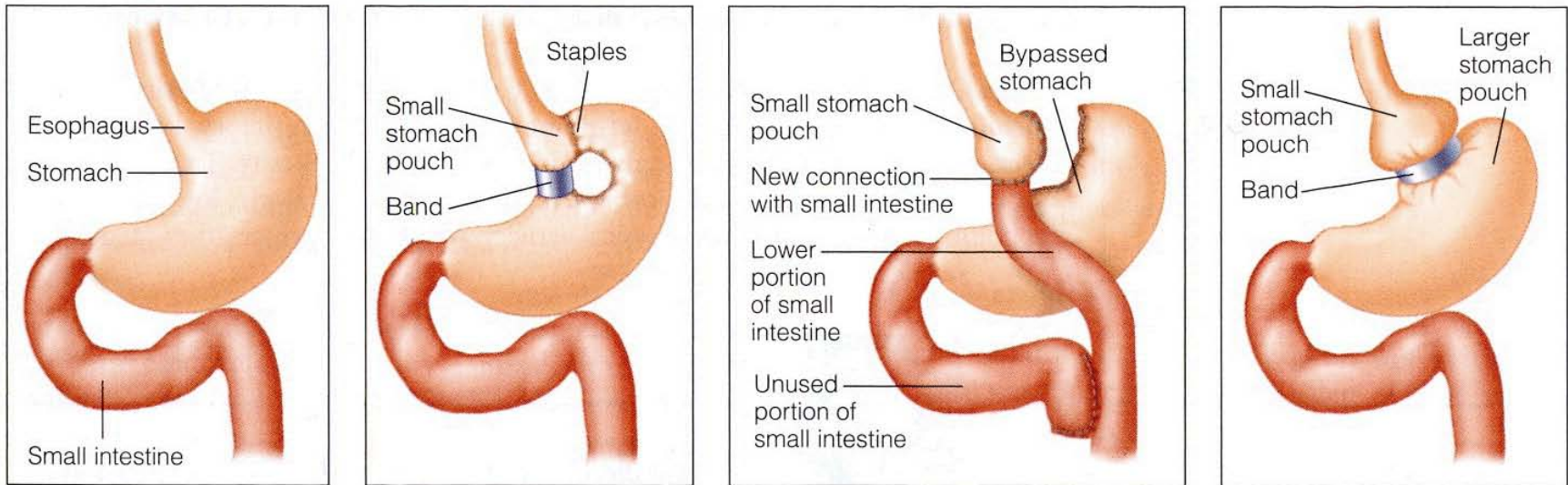
GERD: Possible causes

- Overweight
- Family history
- Hiatal hernia
- Smoking
- Excessive alcohol
- Large or high fat meals



Although the exact causes of gastroesophageal reflux disease (GERD) are unknown, smoking and being overweight may be contributing factors.

Obesity Surgery



(a) Normal anatomy

(b) Vertical banded gastroplasty

(c) Gastric bypass

(d) Gastric banding

Figure 11.11 Various forms of surgery alter the normal anatomy of the gastrointestinal tract (a) to result in weight loss. Vertical banded gastroplasty (b), gastric bypass (c), and gastric banding (d) are three surgical procedures used to reduce morbid obesity.

Gastric bypass, stapling, banding

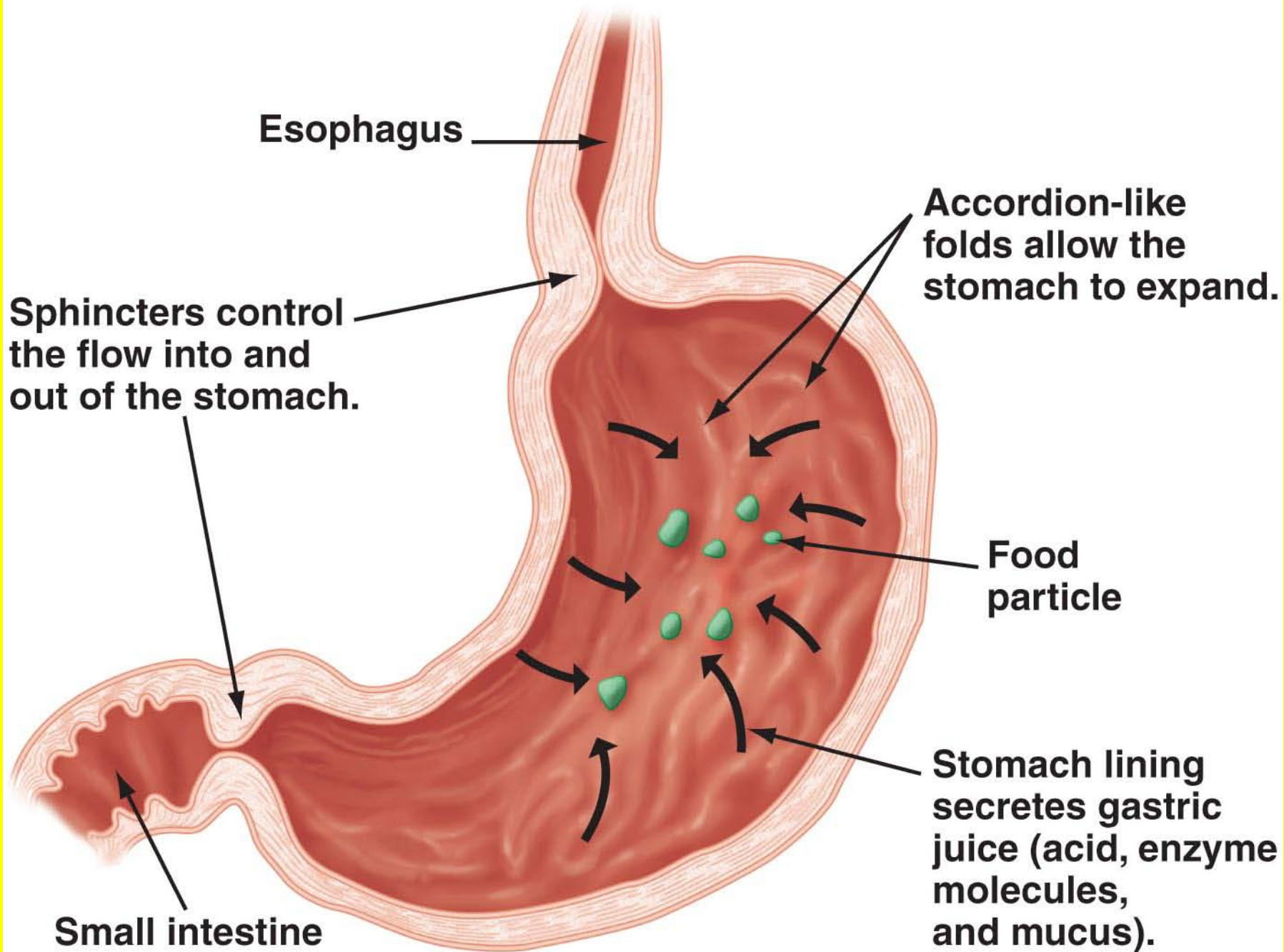
Digestion in Stomach

2-6 hours

- **Gastric Juice:** Acid (kills bacteria) + Enzymes
- Enzyme: **Pepsin** → Protein digestion
- **Contractions:** Churning, mixing food

Release of Gastric Juice

- **Nervous system:** thought, smell, taste- food → brain
↓
impulses
↓
gastric juice ← stomach
-
- ```
graph TD; A[thought, smell, taste- food] --> B[brain]; B --> C[impulses]; C --> D[stomach]; D --> E[gastric juice];
```



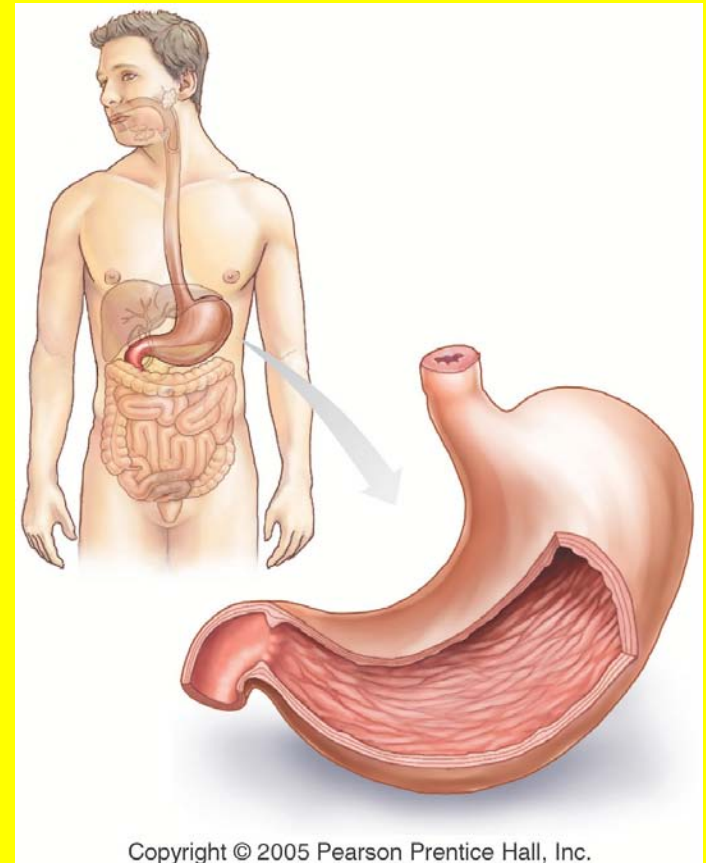
# Release of Gastric Juice

- **Hormone: Gastrin**

Response to food  
in stomach:

↑ Gastric Juice

↑ Contractions

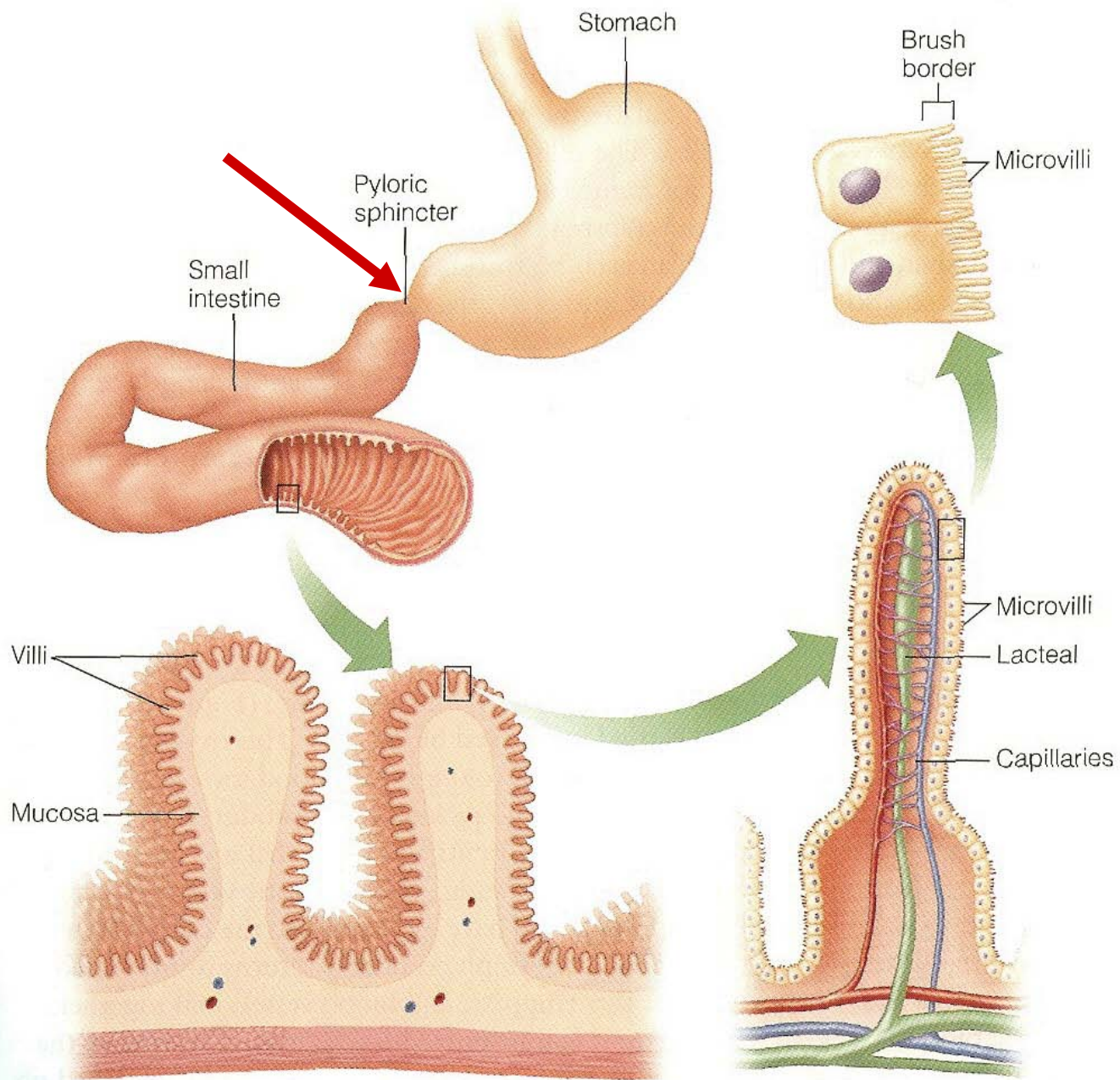


# Absorption (limited) in stomach

- Water
- Alcohol
- Aspirin, Acetaminophen  
(Tylenol)

**Chyme** (partially digested liquid food) → sphincter → small intestine (duodenum)

- **Large**, solid meal- slower
- **Small**, liquid meal-faster



**Figure 3.11** The brush border. Absorption of nutrients occurs via this specialized lining of the small intestine.

# Stomach Emptying

Carbohydrates ➤ Protein ➤ Fat

**Sadness/Fear** ↓ Emptying

**Aggression** ↑ Emptying + Contractions



# ULCERS

- Stomach lining- **gastric mucosa**
- **Erosions** (open sores) of lining-  
esophagus, stomach, duodenum:  
**peptic ulcer**
- 1 in 10 people

# ULCERS- Causes

- Bacteria (Helicobacter pylori)
- Aleve, Advil, Motrin (not Tylenol)
- Smoking
- Excess alcohol



This magnification shows the helical-shaped bacteria *Helicobacter pylori* attached to the gastric mucosa.

(Science Photo Library/Photo Researchers, Inc.)

# “An 11 year look inside the living stomach”

- 1822- Fur trapper's store Michigan.
- Gun accident: **St. Martin** shot  
**Dr. Beaumont** dressed wound
- Healing → **fistula** → gauze  
(opening)

# Dr. Beaumont and St. Martin



# Beaumont-St. Martin

- Bread → gastric juice release
- Remove fluid → test tube  
digest meat
- Anger: gastric mucosa **red**  
(blood)  
↑ contractions ↑ acid
- Fear: gastric mucosa **pale**  
↓ contractions

Most digestion: small intestine  
3-5 hours

Intestinal cells (lining)



**Intestinal Juice**



**Enzymes:** starch → sugars  
polypeptides → amino acids

# Pancreas

## Pancreatic Juice:



- Bicarbonates- neutralize acid
- Enzymes:

Starch  sugar

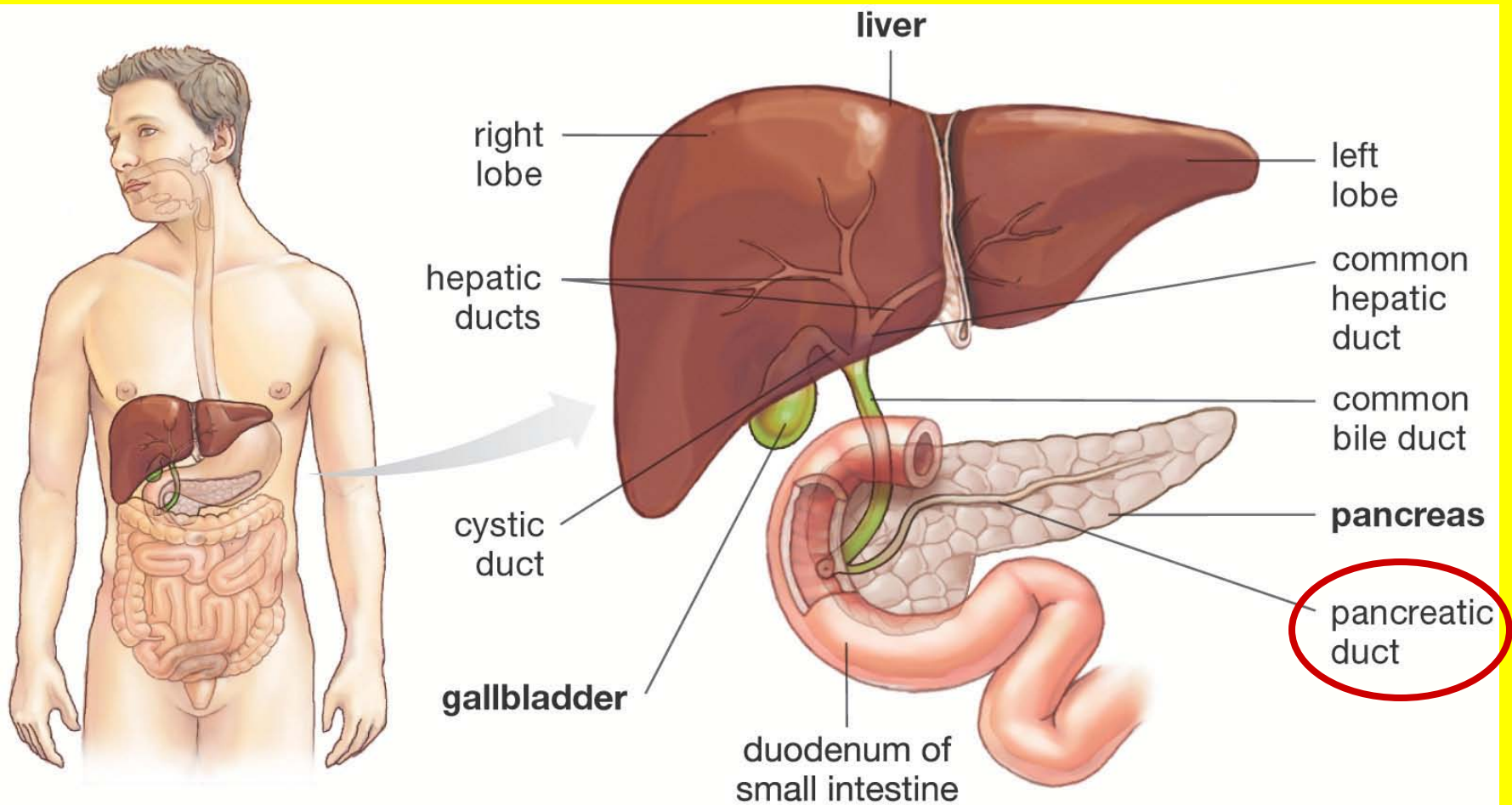
Protein  polypeptides  amino acids

Fats  fatty acids

# Pancreas

- **Exocrine** gland:  
secretions  ducts (tubes)  
(enzymes)
- **Endocrine** gland:  
secretions  blood  
(insulin)





# Gallbladder

Bile produced-**liver** → stored →  
gallbladder

**Bile** → duct → small intestine

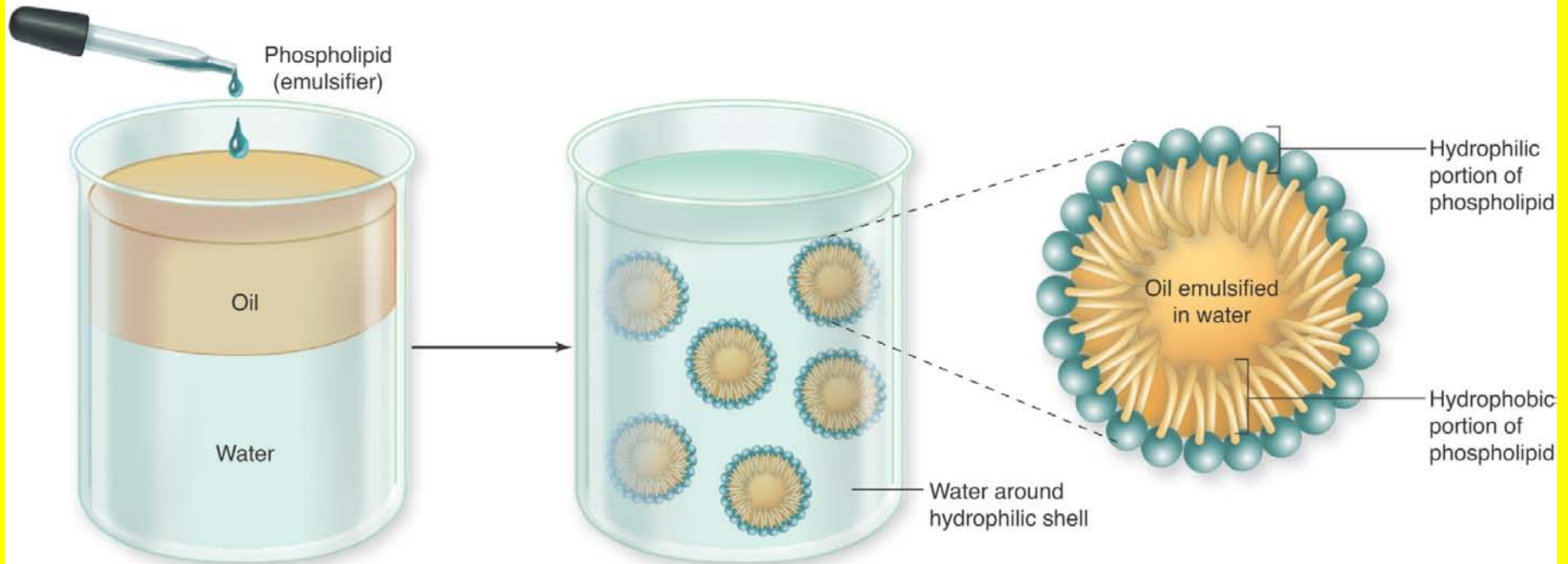


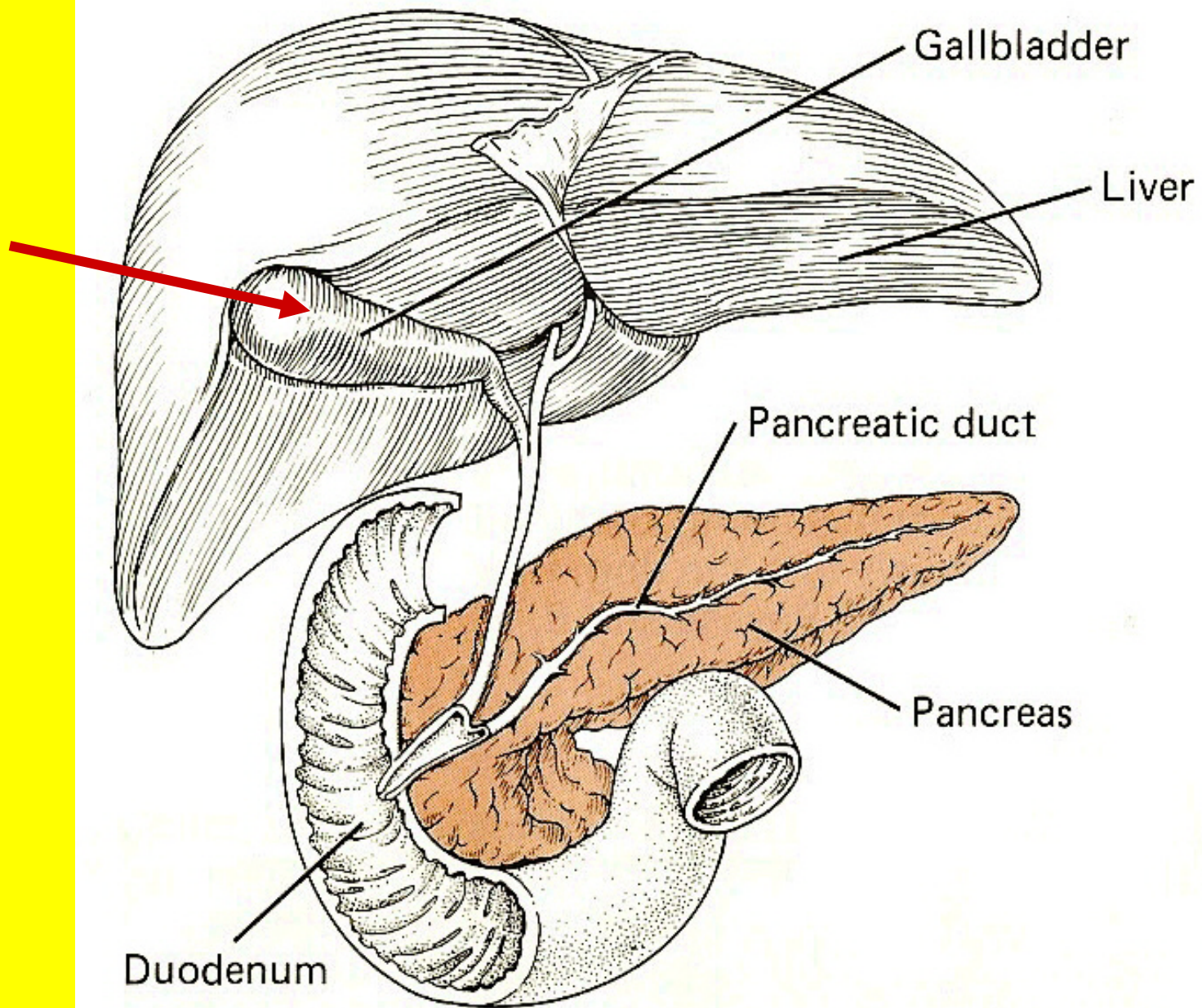
↑ **Surface area** (detergent)-helps fat  
digestive enzymes

ASSIGNMENT

**EMULSIFICATION  
EXPERIMENT**

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# Bile

- Bile acids (made from cholesterol)
- Cholesterol
- Lipids (lecithin)
- Bile pigments (hemoglobin breakdown → feces- color)



# Pathology: gallstones

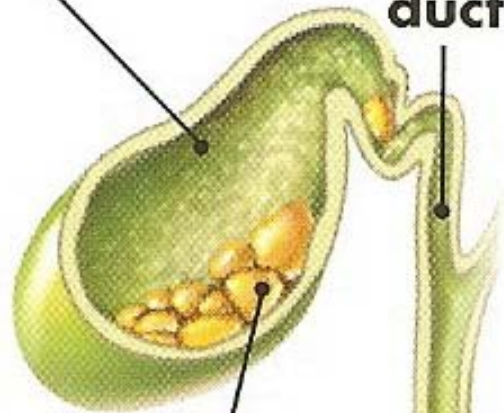
Bile: **supersaturated** with  
**cholesterol**

cholesterol → crystals → gallstones

Block ducts → ~~bile secretion~~

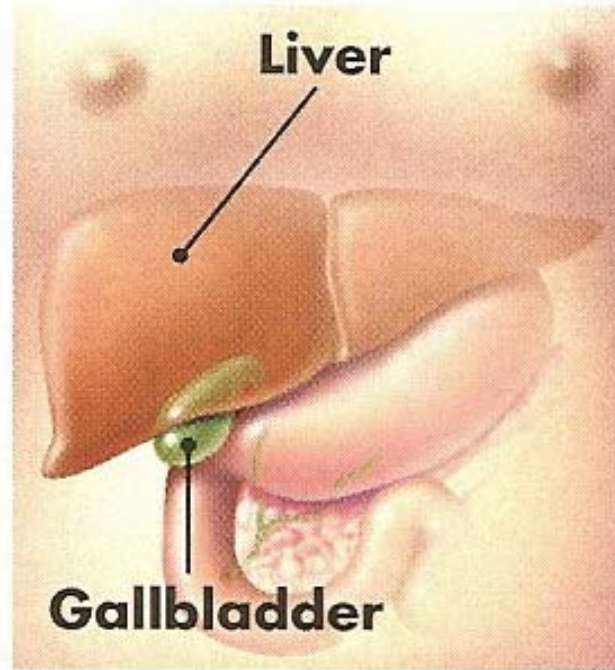
**Gallbladder**

**Cystic duct**



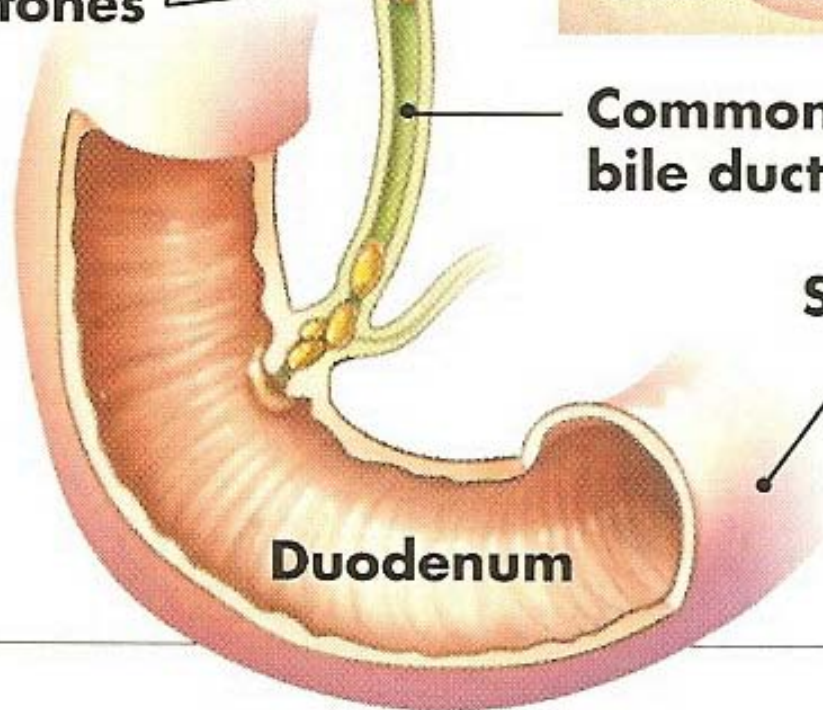
**Gallstones**

**Liver**



**Gallbladder**

**Common bile duct**



**Small intestine**

**Duodenum**

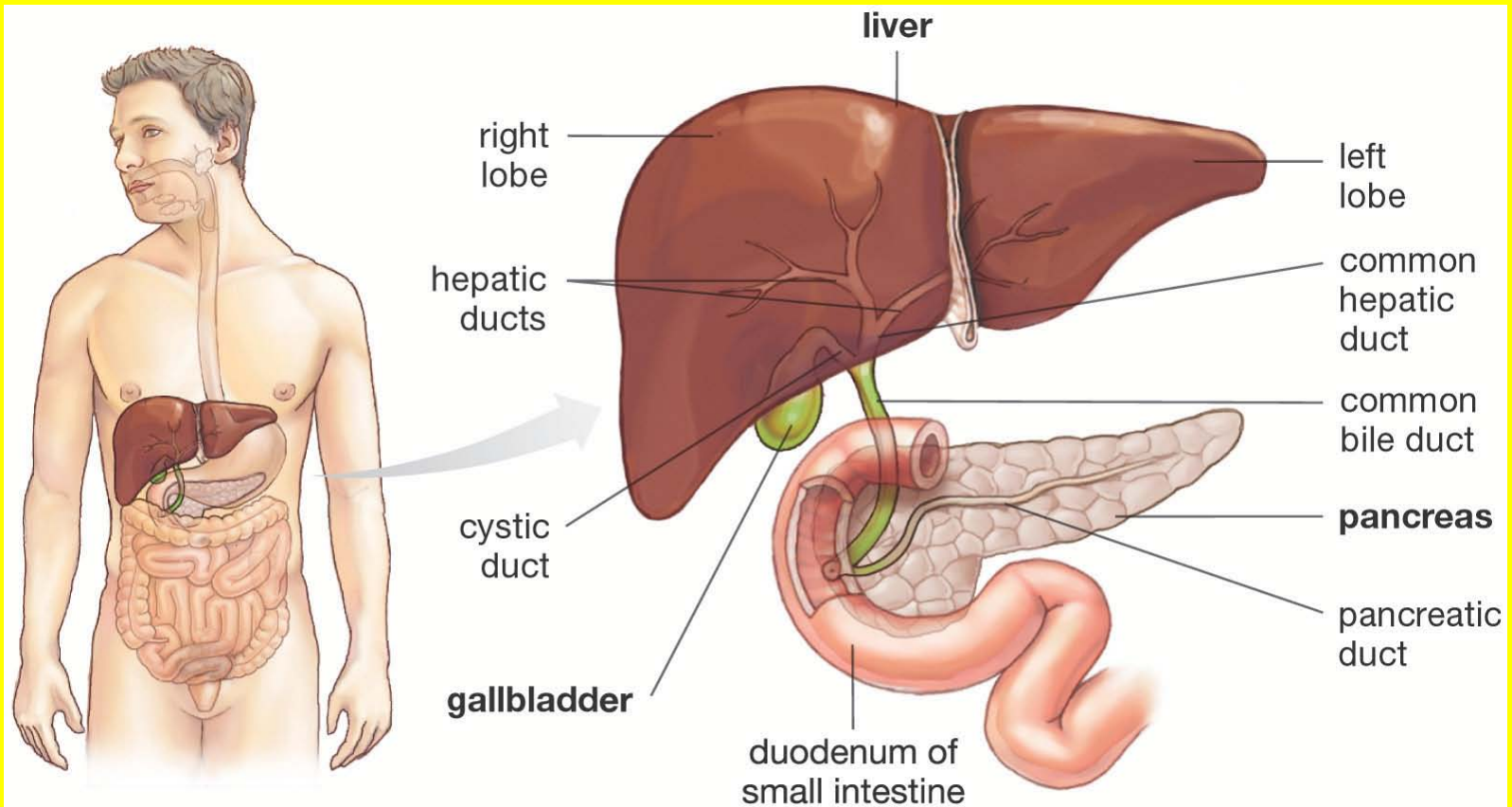


# Obstructive jaundice

- Backup- bile pigments
- Yellow skin, eyes
- Fat malabsorption
- Surgery:  
remove stones



# Your Liver: what it does for you



**Liver unique:** can  
**regenerate** completely

- After injury
- After partial surgical removal
- Adjusts to body shape
- **Liver transplant** (living donor- usually close relative)
- Donor & recipient: liver grows to **full size: 2 months**



# Liver Functions

1. Makes **Bile** (digestion)

2. **Glucostat**- regulates blood glucose (homeostasis)

**Fasting:** glycogen  glucose 

blood

**After meal:**    
Blood glucose      liver      glycogen

# Liver Functions

## 3. Urea formation:

amino acids breakdown



urea



urine ← kidneys

# Liver functions

## 4. **Synthesis & breakdown:**

lipoproteins, other proteins  
(albumin, clotting proteins)

## 5. **Detoxification:** Drugs, toxins, alcohol

# Liver functions

6. Stores **vitamins & iron**
7. Destroys old **red blood cells**

# ABSORPTION

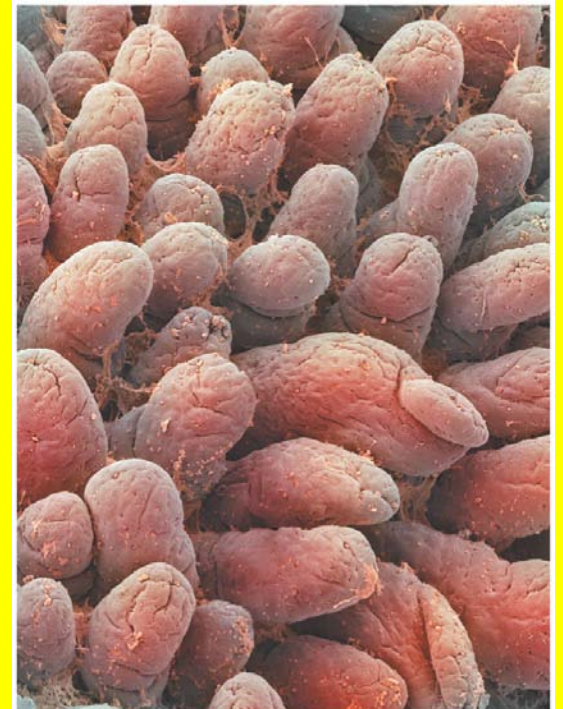
Small end products- digestion:

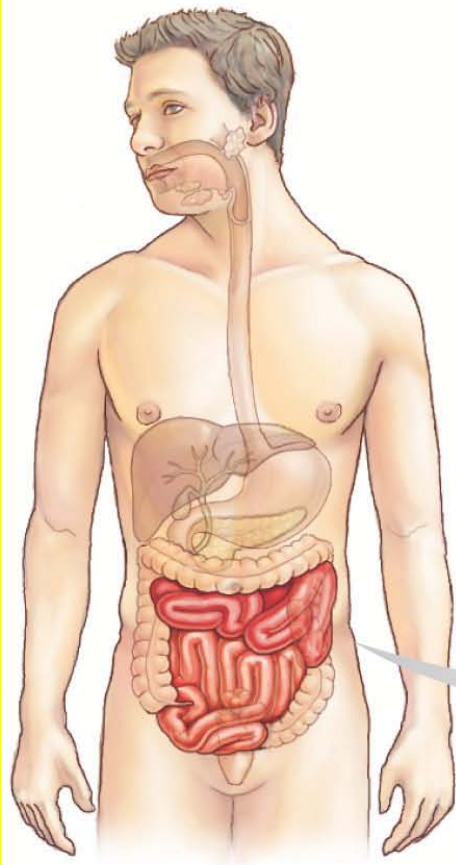
- glucose
- amino acids
- fatty acids
- H<sub>2</sub>O
- minerals
- vitamins



# Small Intestine

- **20** feet long
- Major site: absorption “nutrients”
- Huge **surface area**:  
tennis court



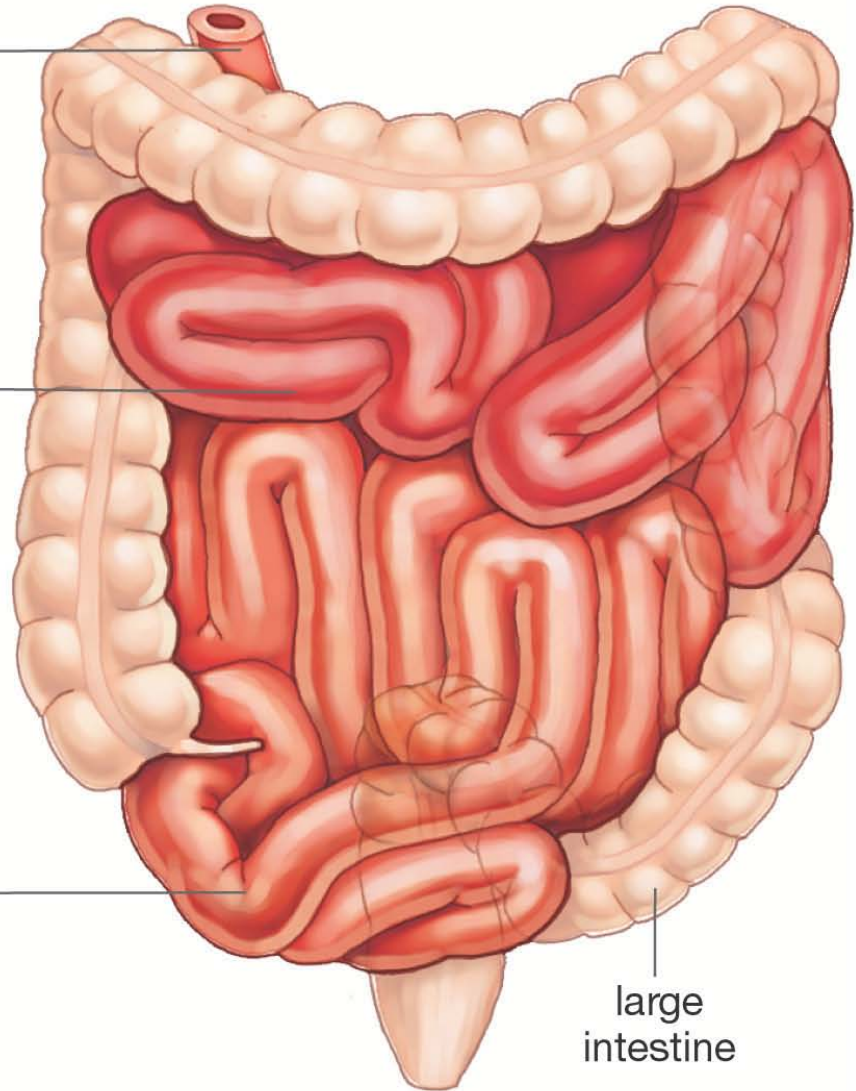


## small intestine

**duodenum:**  
receives chyme  
from stomach  
and secretions  
from pancreas  
and liver

**jejunum:**  
region of  
most digestion  
and nutrient  
absorption

**ileum:**  
absorption  
continues

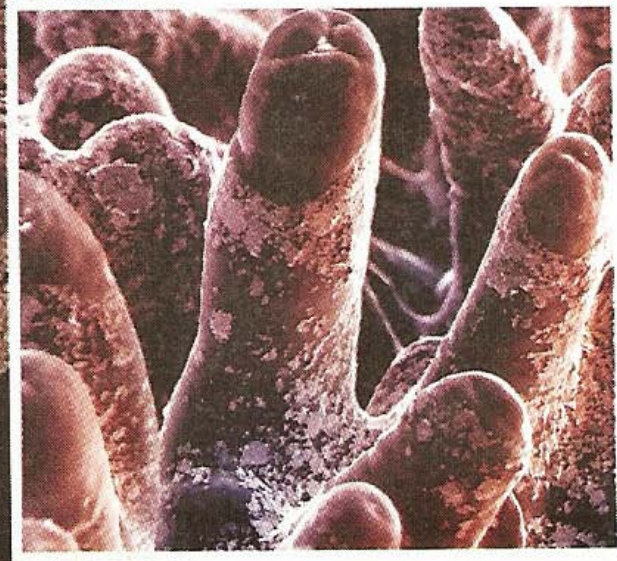


large  
intestine





(a)



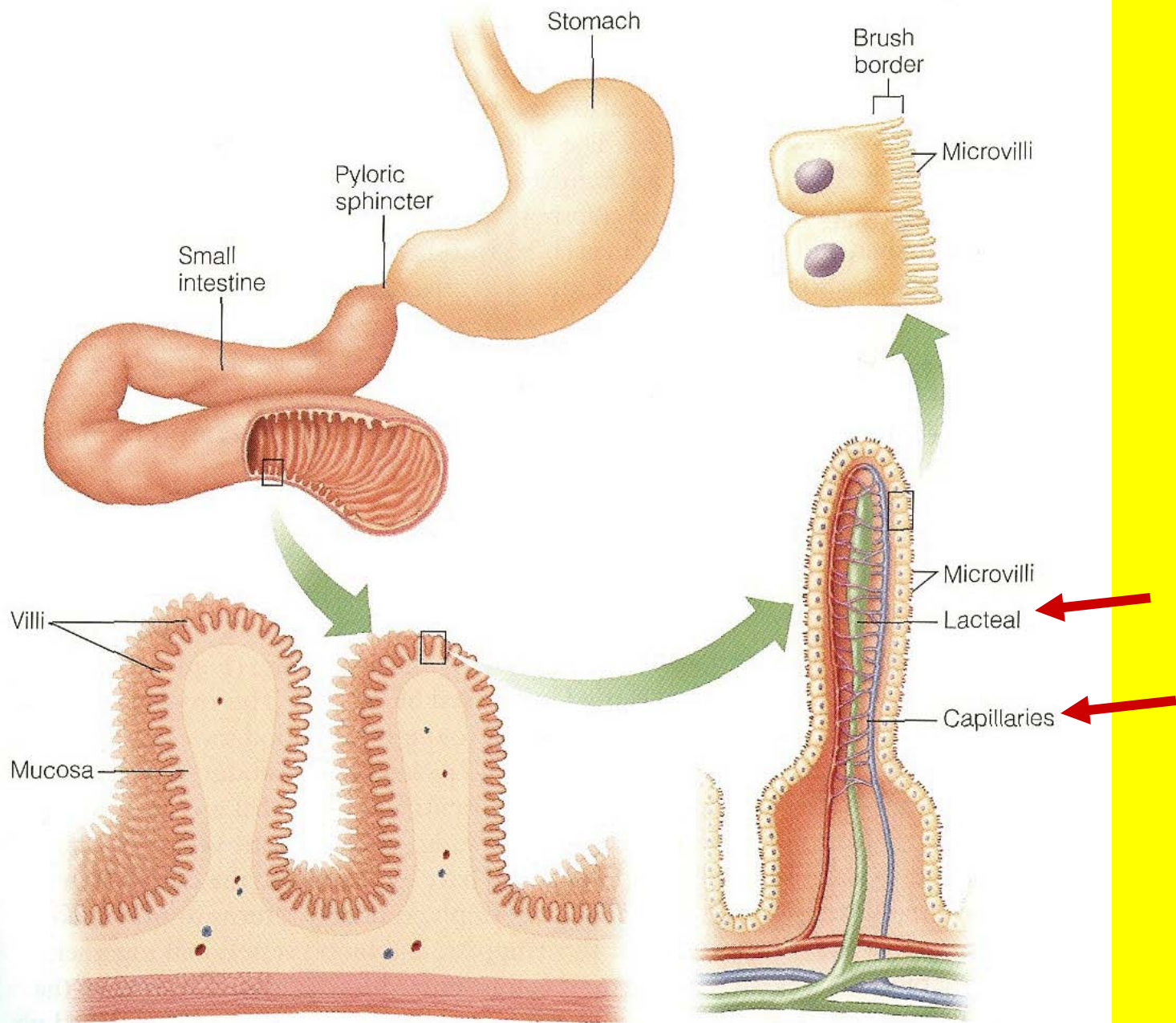
(b)

The small intestine. **(a)** The interior of the small intestine, also called the mucosal membrane. **(b)** The lining of the small intestine has thousands of folds and finger-like projections called villi that increase its surface area over 500 times, significantly increasing the small intestine's absorptive capacity.

# Small Intestine

- Inner surface: fingerlike **villi**
- Each villus- covered- **microvilli**
- ↑ absorptive surface
- **Inside villus:**
  1. **Capillaries - blood**
  2. **Lacteal - lymphatic system**

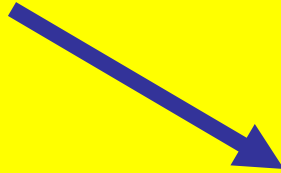




**Figure 3.11** The brush border. Absorption of nutrients occurs via this specialized lining of the small intestine.

# Absorption- small intestine

Nutrients



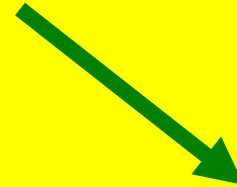
Intestinal absorptive

cells



**Blood**

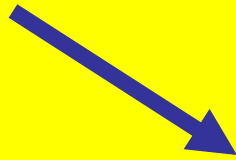
or



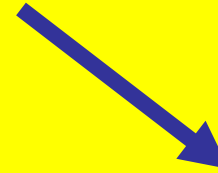
**Lymph**

# Glucose absorption

Glucose



small intestine cells



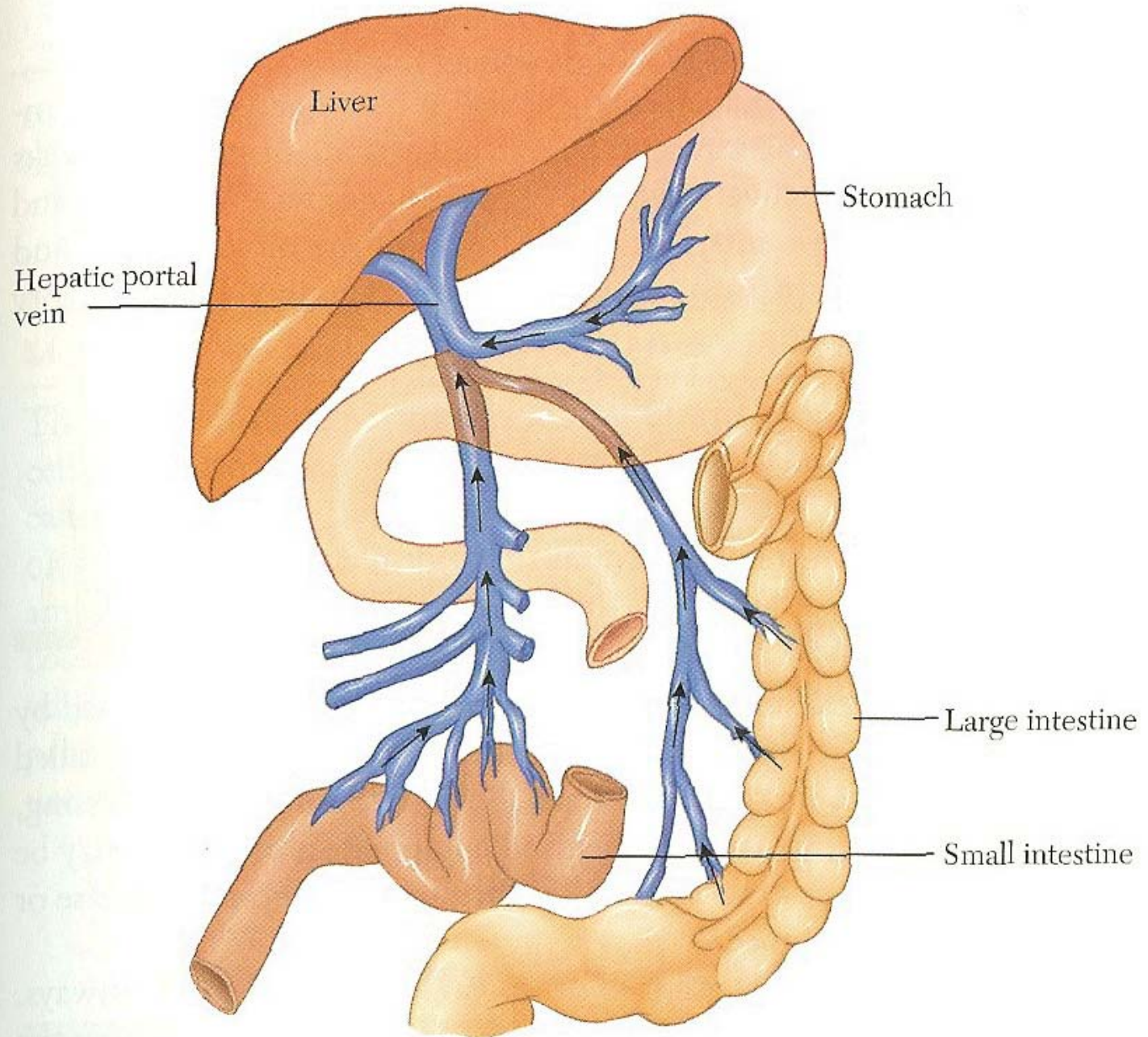
villus capillaries

liver



vein



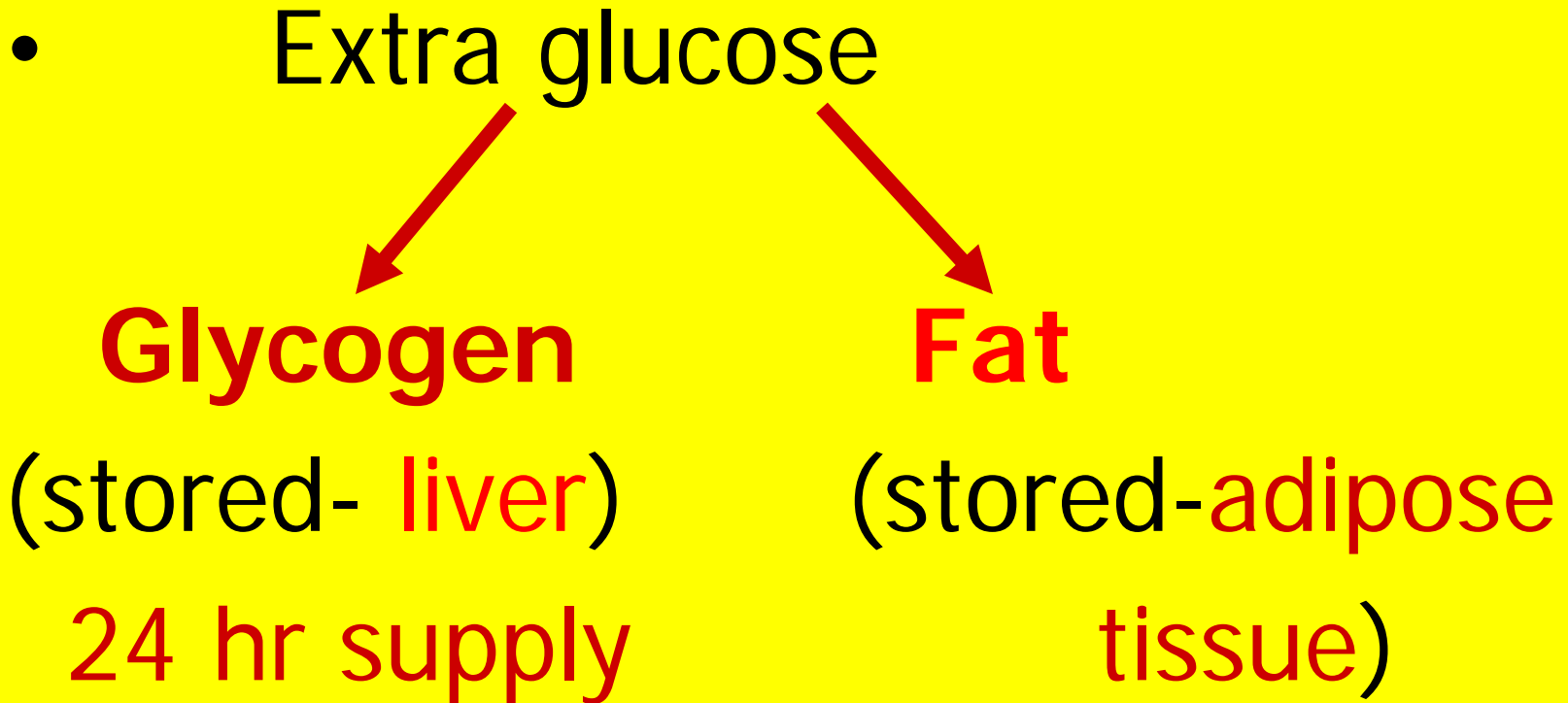




# Glucose: How it's used

- Glucose- liver cells: **energy**
- Glucose- liver → vein → **heart**
- **General circulation:** glucose  
energy ← cells/tissues ←

# Glucose: How it's used




# FASTING

After 24 hours- no new glucose  
(food)

Brain senses ↓ glucose

Liver: amino acids → glucose  
(homeostasis) blood ↙

# Carbohydrate loading marathoners

- **Muscle glycogen**- used 1<sup>st</sup>: intense exercise
- **Loading**: restrict carbohydrate- few weeks
- Day before event- **carbohydrate loading**: replenish stores   
(muscle/liver)

# Amino acid absorption and use

- Amino acid absorption- same as glucose

Intestine capillaries → vein → liver

- Amino acid use:

enzymes, hormones, new protein structure

Excess **amino acids**

In liver: excess amino acids

**urea**

**glucose**

**glycogen (stored)**

**fat**

(stored)

Fasting  $\longrightarrow$  Starvation

Example:

anorexia nervosa

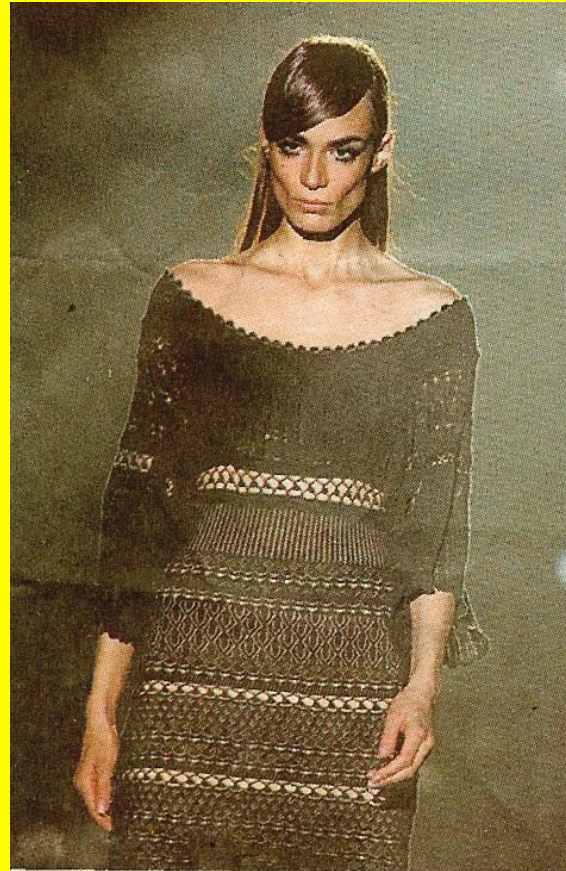
BMI:  $\frac{\text{Weight (lbs)}}{\text{Height (inches)}^2} \times 703$



# NY Times 9/17/06 "As models strut in London, new call to ban the skeletal"

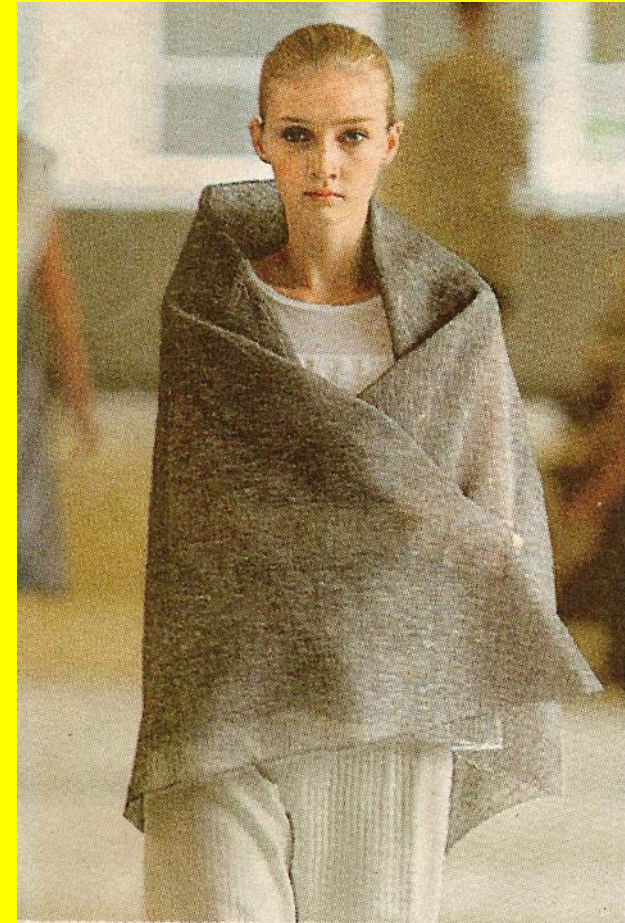


Elizabeth Lippman for The New York Times



Marilynn K. Yee/The New York Times

**NOW YOU SEE HER** An unsurprising runway trend: the ever-thinner waif-model.



JP Yim/WireImage




NY Times 9/17/06 & 12/20/06

- 2006/2007: Madrid's Fashion Week banned models with BMI below 18. Milan bans models BMI  $\leq 18.5$
- To achieve BMI of 18: 5' 9" model would weigh 125 pounds.
- Average 5'9" runway model: 115 pounds

# NY Times 11/17/06 "Brazil model dies of anorexia"

- Ana Carolina Reston died 11/14/06- complications-  
**anorexia**
- **5' 8" 88 pounds (BMI: 13)**
- **Mother: "emotional appeal take better care of children-  
aspiring young models."**



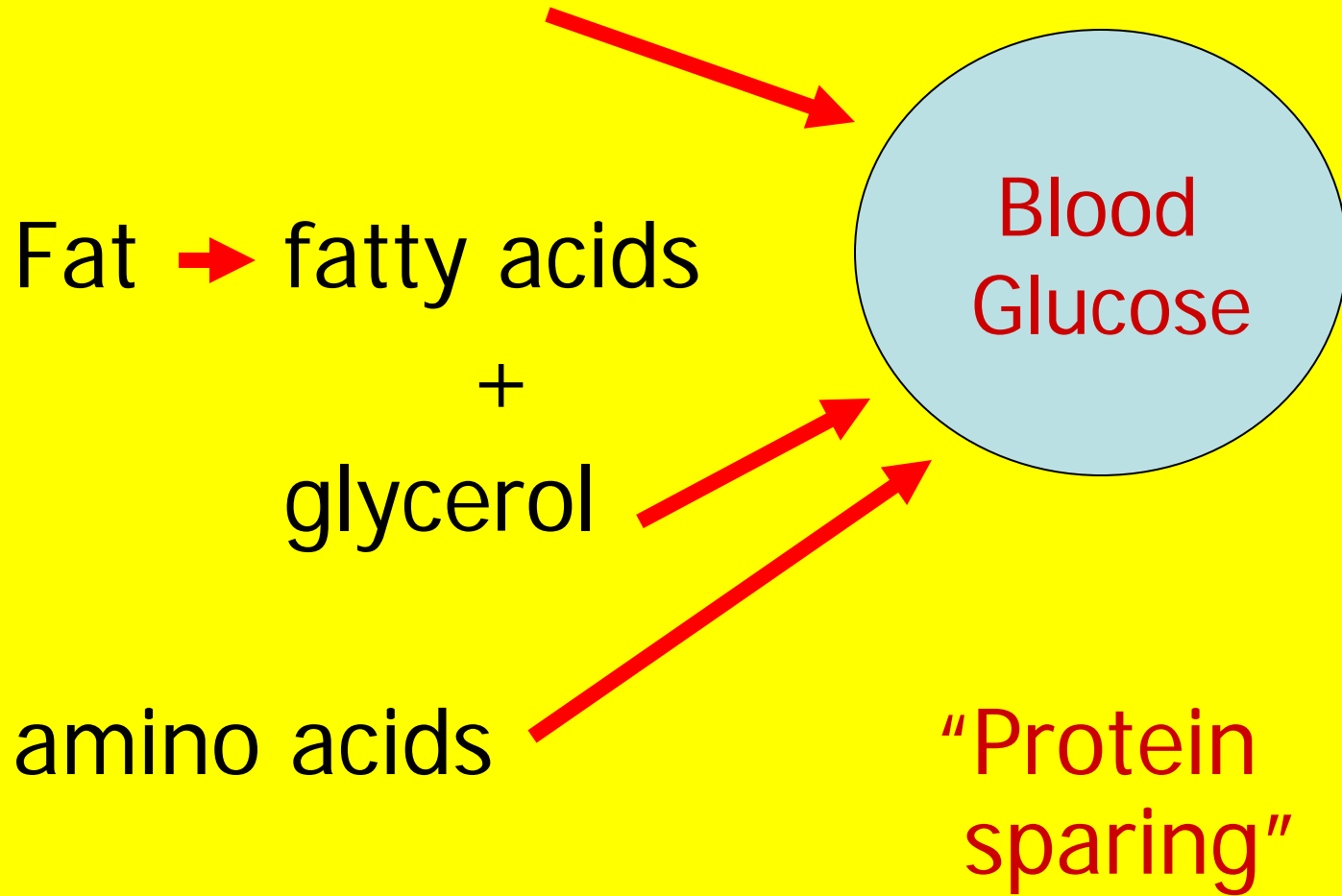
Fasting  Starvation

Body tries to keep blood glucose



brain  normal level 

# EARLY ON

Liver glycogen (becomes depleted)




# Later

- Carbohydrate- depleted
- Fats rapidly broken down (**ketosis**)  
  
**ketones**
- Acetone odor- breath; upsets pH
- Brain adapts  50% energy-  
ketones

# Finally

- Protein (structure)- liver, spleen, muscles broken down
- Break down heart muscle
- Death

# Atkins Diet

- Low carbohydrate
- Theory:  Fat breakdown  
Ketosis  
Appetite

Comparison:

Atkins (2-16% carbs- stage of diet) vs.  
Control diet (60% carbs)



# Comparison: Atkins vs. Control

- Atkins- greater **initial** weight loss
- Early weight loss- **H<sub>2</sub>O**
- At **18** months- **no difference**
- Long-term safety?

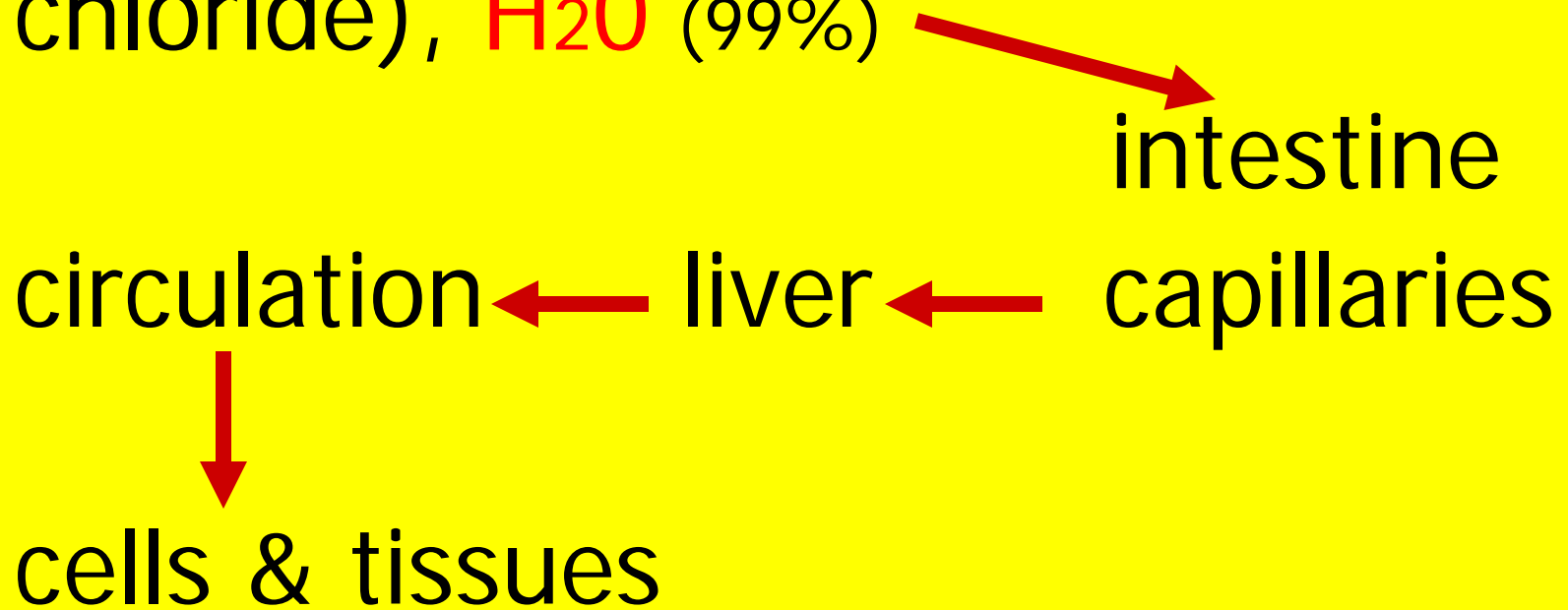
High % protein (animal) & **fat**  
**(saturated, cholesterol)**

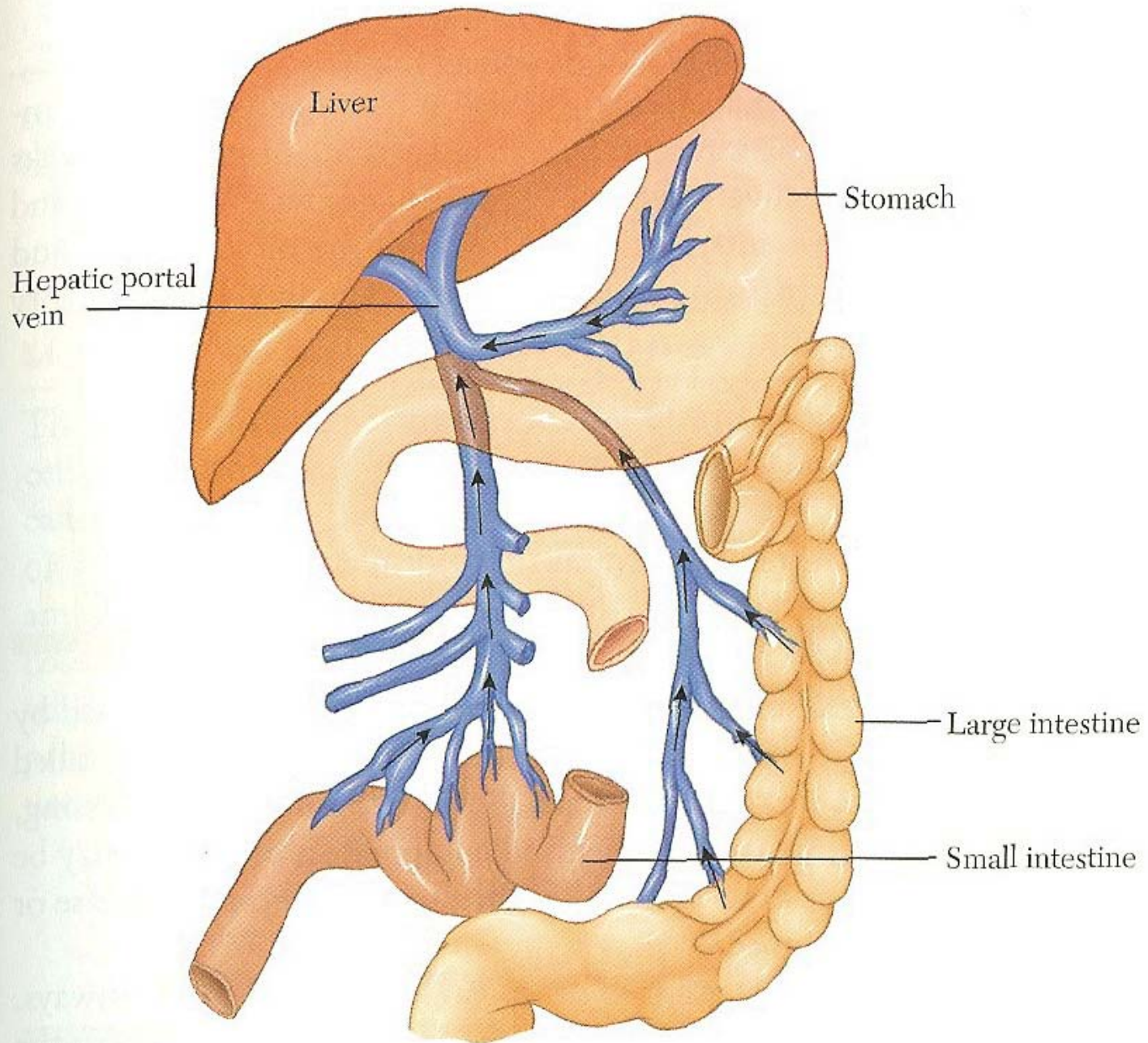
↑ urinary calcium loss- kidney  
stones?

↑ uric acid blood?

# Vitamins, minerals, H<sub>2</sub>O absorption

- **Vitamins** (water-soluble B, C), **minerals** (sodium, potassium, chloride), **H<sub>2</sub>O** (99%)




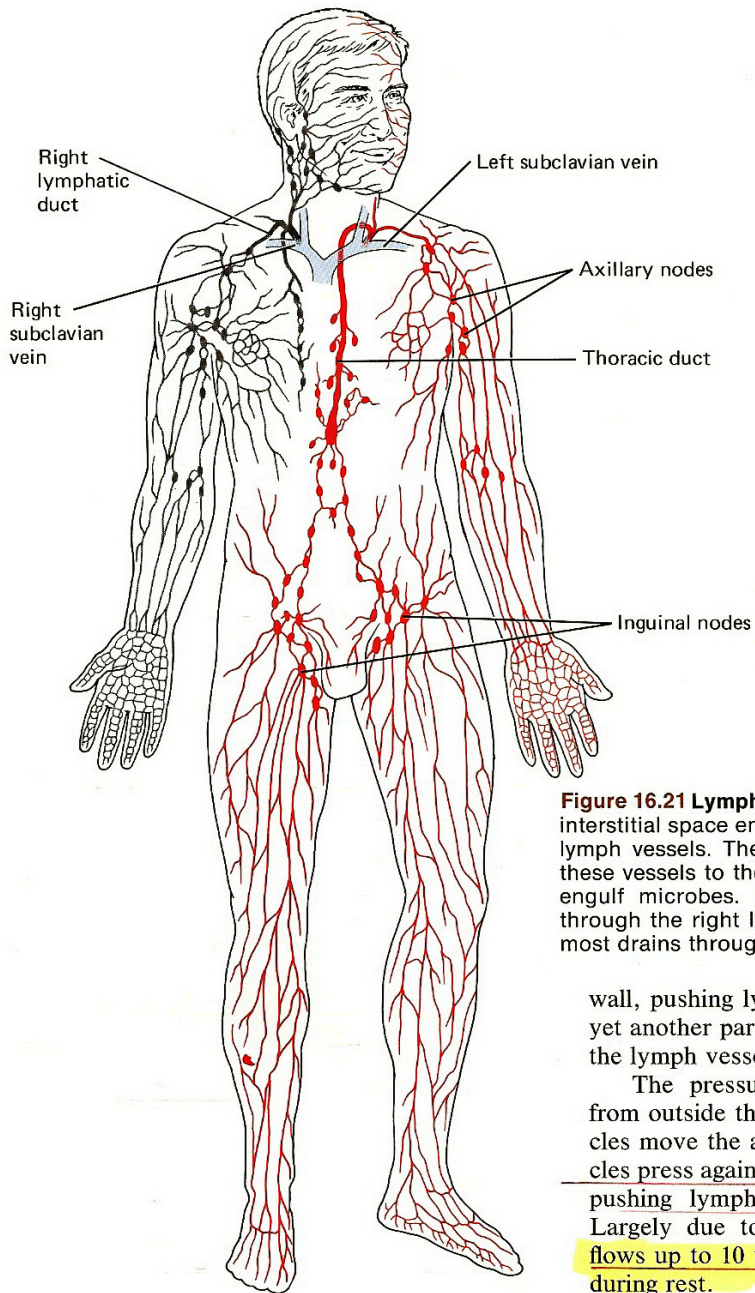


# Fat Absorption & lymphatic system

- Capillaries “leaky” → fluid, protein tissues → tissue fluid
- **Lymphatic system**: system of vessels- **collect** leaked fluid

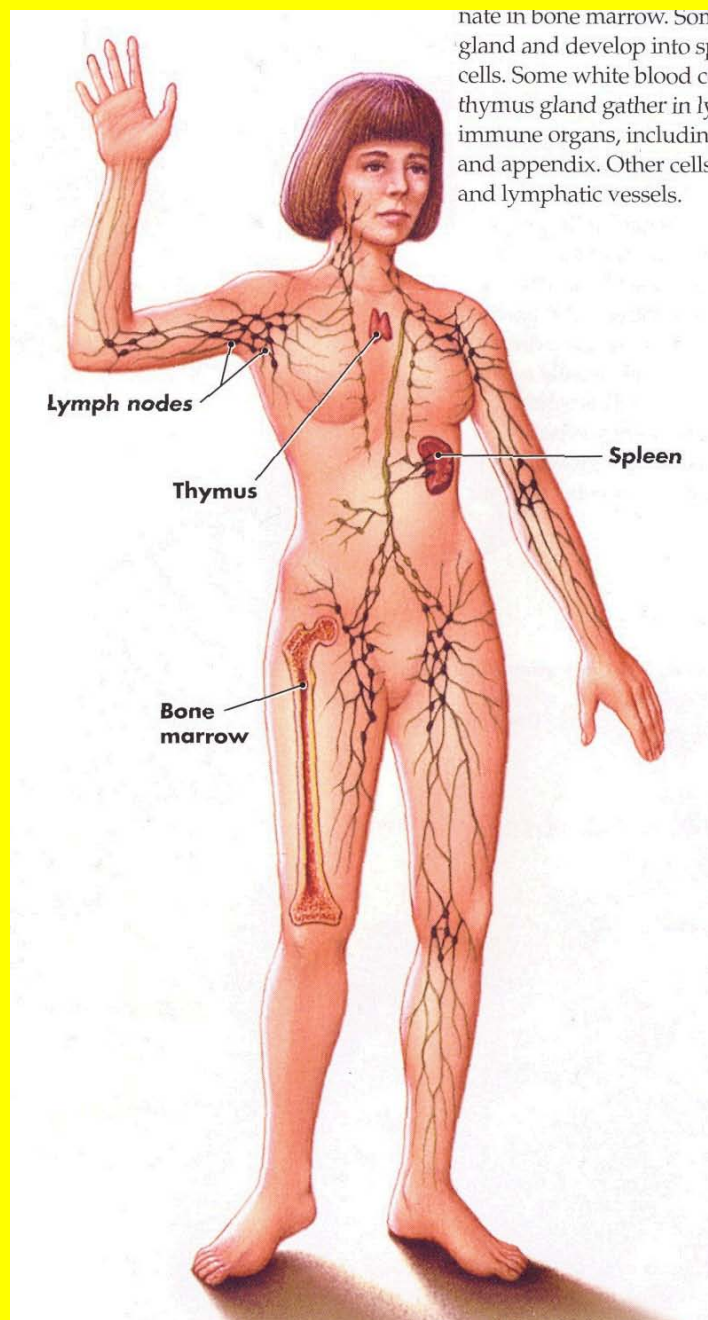
# Lymphatic System

- Tissue fluid inside lymph vessels=  
**lymph**
- Lymph  veins in shoulders  
as **muscles** contract
- Exercise: **10X** faster return-lymph



**Figure 16.21 Lymph**  
 interstitial space en  
 lymph vessels. The  
 these vessels to the  
 engulf microbes. :  
 through the right l  
 most drains through

wall, pushing ly  
 yet another par  
 the lymph vesse  
 The pressu  
 from outside th  
 cles move the a  
 cles press again  
 pushing lymph  
 Largely due to  
 flows up to 10 t  
 during rest.

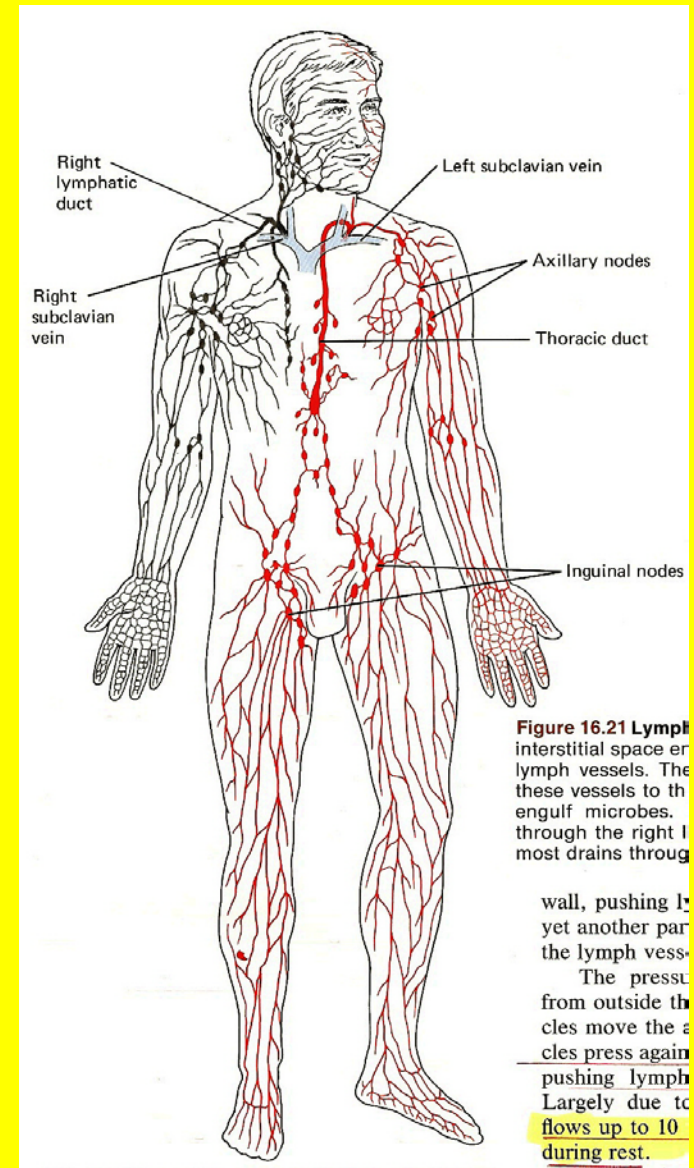


nate in bone marrow. Som  
 gland and develop into sp  
 cells. Some white blood c  
 thymus gland gather in ly  
 immune organs, includin  
 and appendix. Other cells  
 and lymphatic vessels.

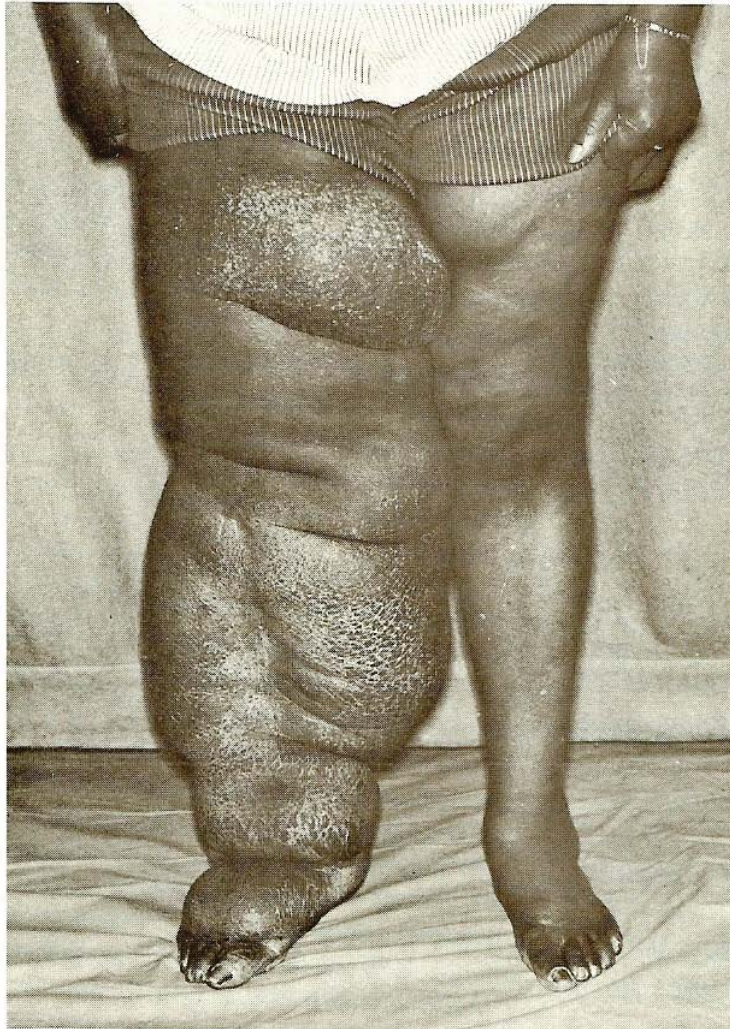


# Lymphatic System

- **Lymph nodes:** filters, white blood cells: bacteria, cancers
- Throat infection- lymph nodes near jaw: sore, swollen







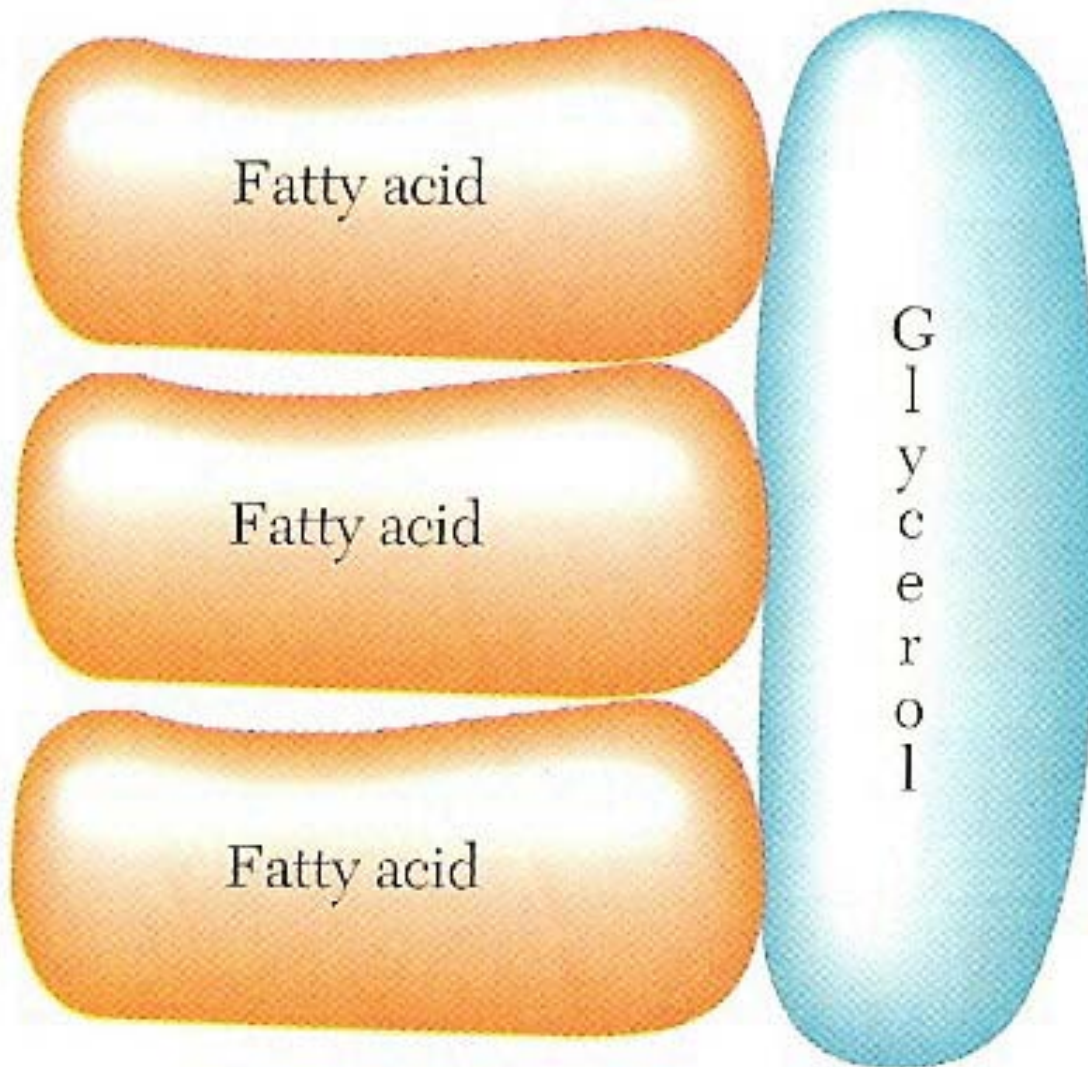
**Figure 16.25 Elephantiasis.** Roundworms and connective tissue block the flow through lymph nodes in this person, preventing the return of lymph to the blood. Lymph and interstitial fluid accumulate behind the block, causing a tremendous swelling. (From the Armed Forces Institute of Pathology, Negative No. 76-18002.)

# Fat Absorption- how you do it

- Digested **fatty acids**

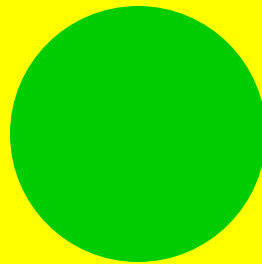
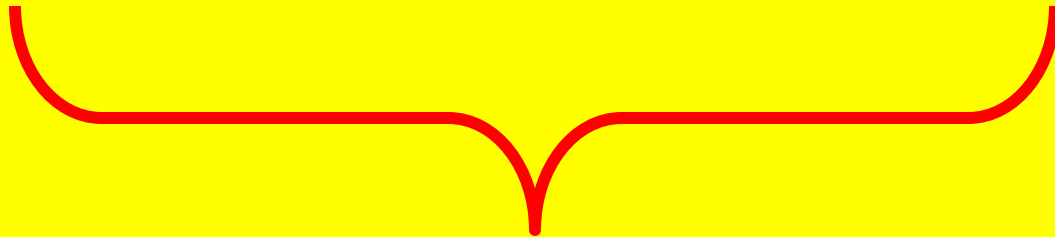
intestine cells

Reform **triglyceride**



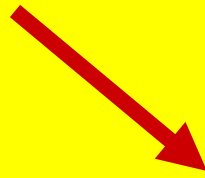
Triglyceride

Triglyceride + Fat soluble  
**vitamins** (A,D,E,K) + protein

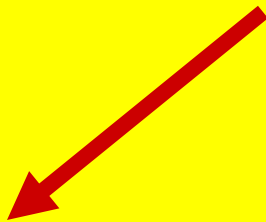


**Chylomicron** (lipoprotein)

Chylomicrons



Enter lacteals



Lymph vessels



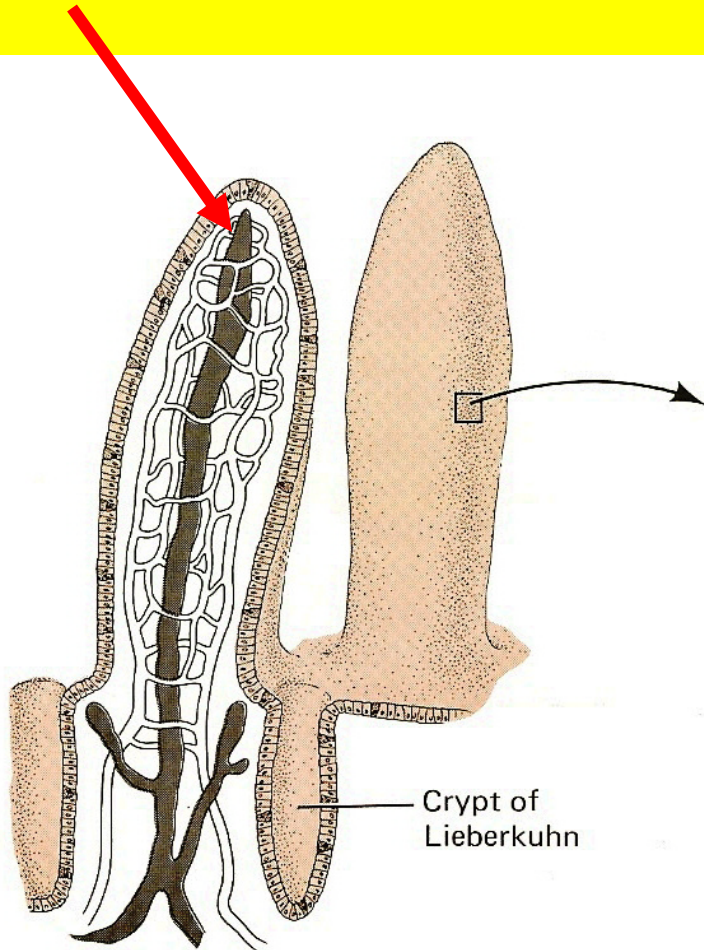
Vein left shoulder



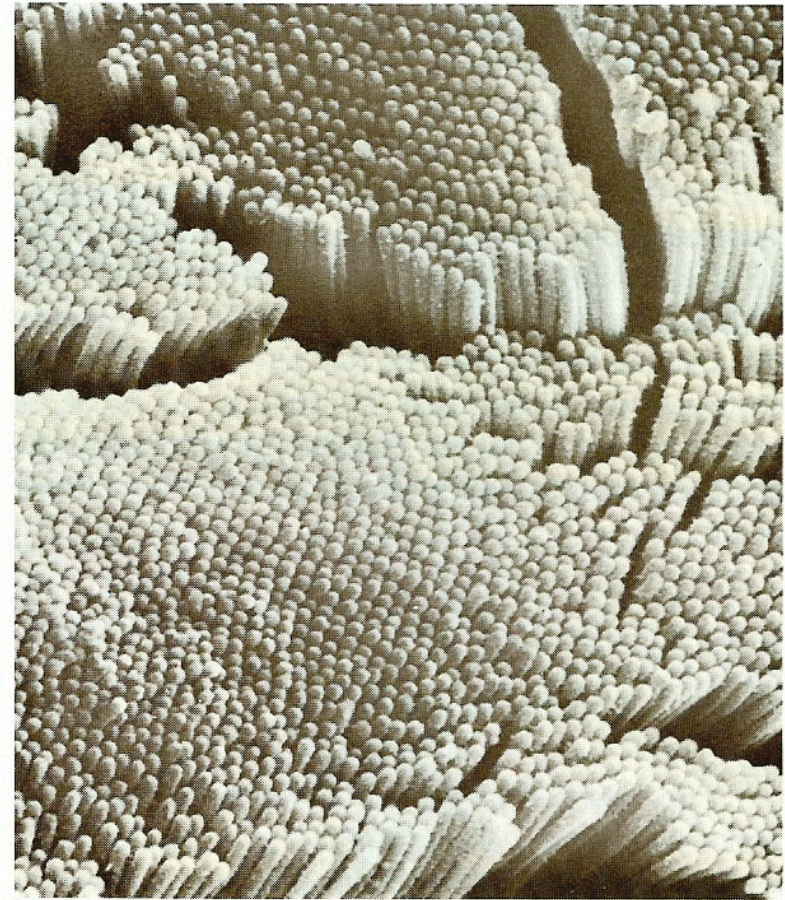
General circulation



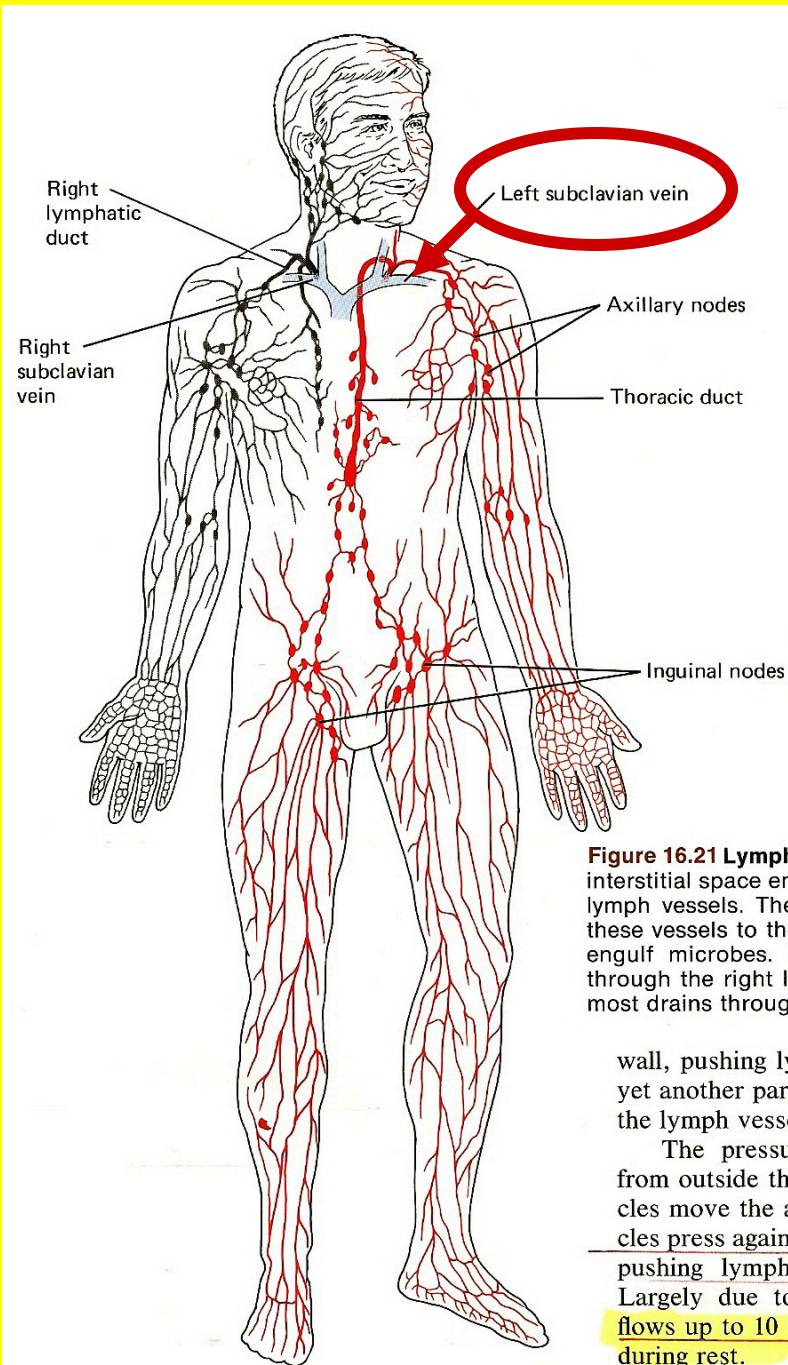
# Lacteal



(c) Villi and crypt



(d) Intestinal microvilli

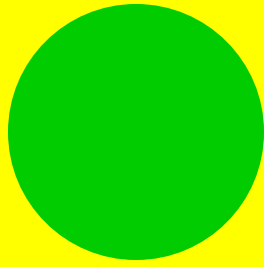


**Figure 16.21 Lymph**  
interstitial space en  
lymph vessels. The  
these vessels to the  
engulf microbes. S  
through the right l  
most drains throug

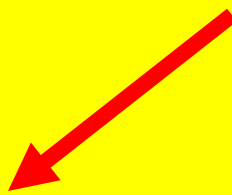
wall, pushing ly  
yet another par  
the lymph vesse

The pressu  
from outside th  
cles move the a  
cles press again  
pushing lymph  
Largely due to  
flows up to 10 t  
during rest.





Chylomicron triglyceride

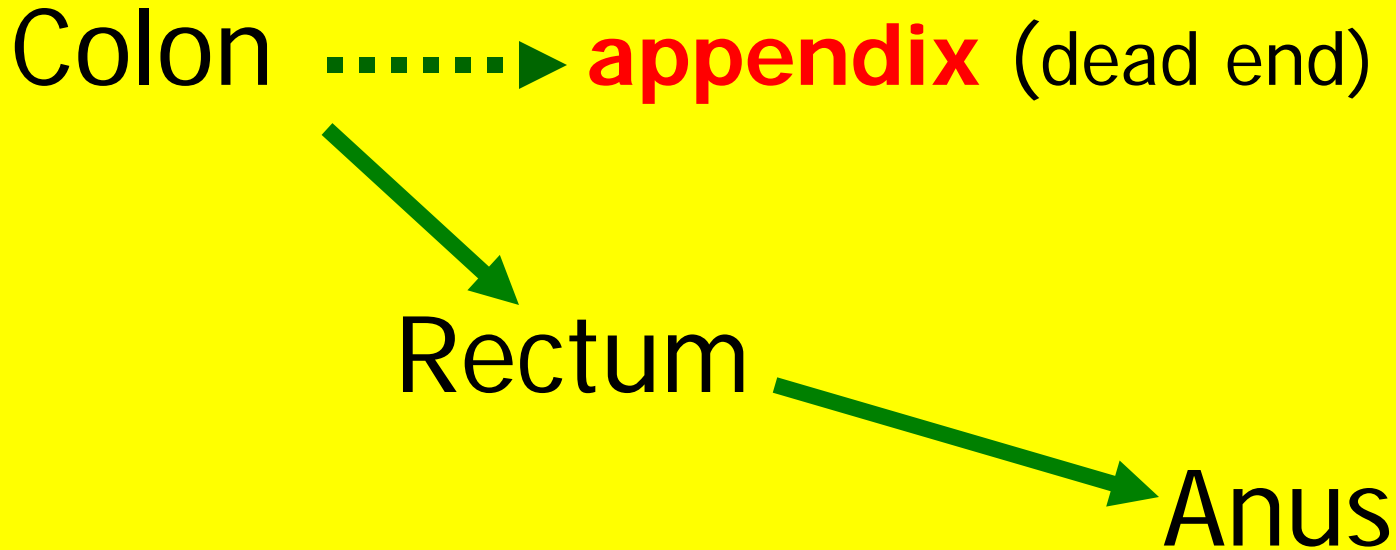


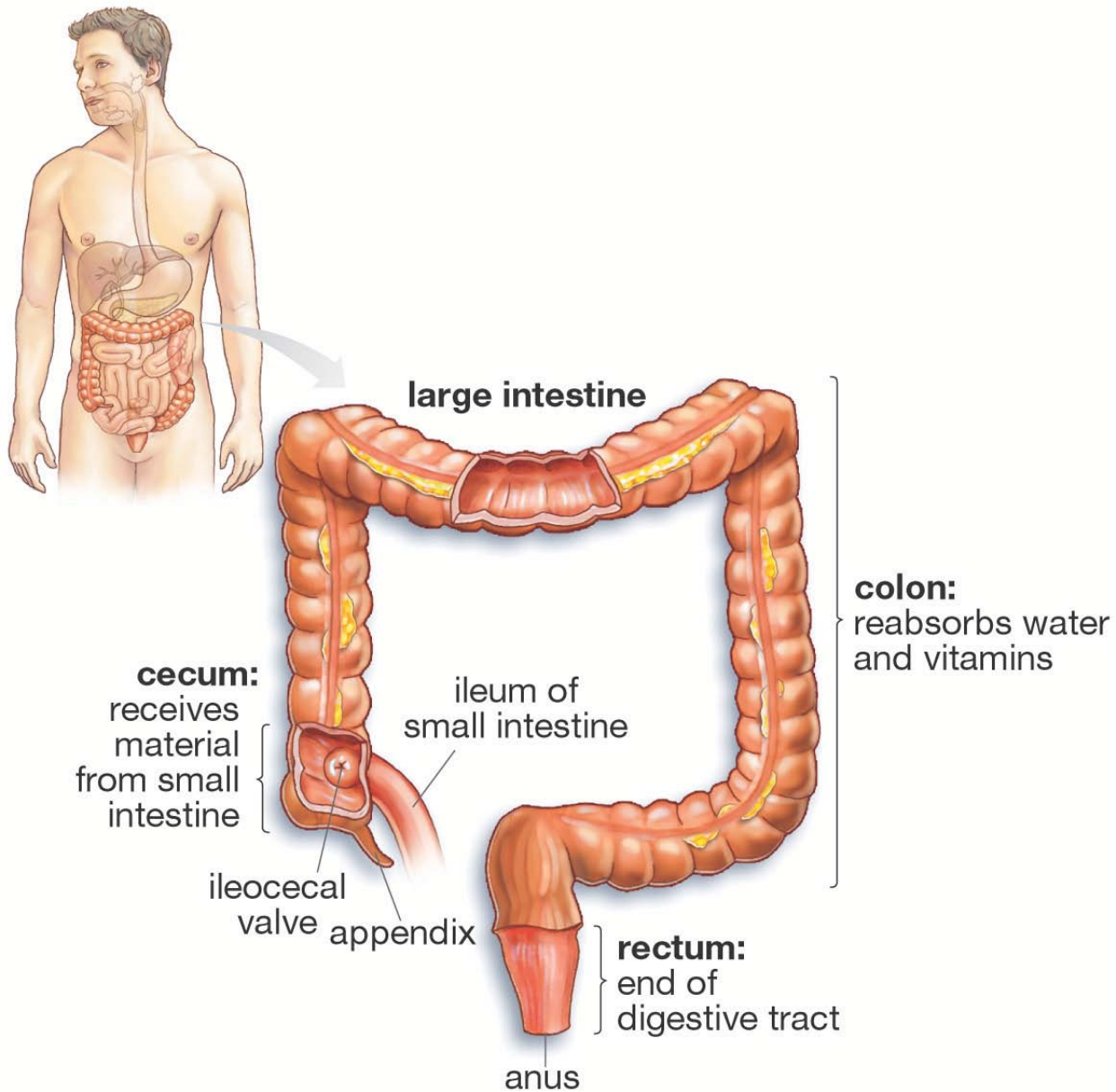
muscle

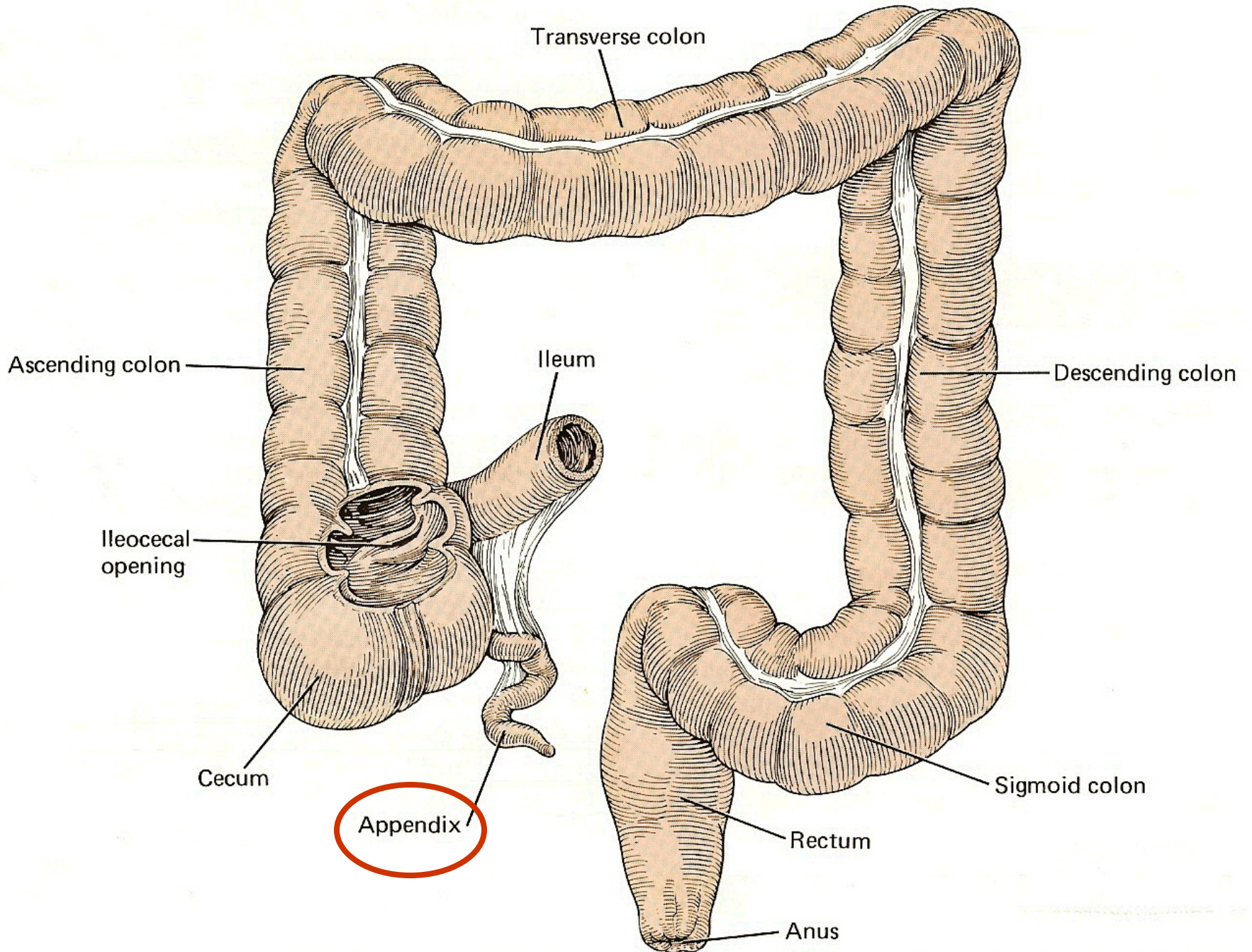
adipose tissue

**Fat Stored**

Colon: 5 feet long



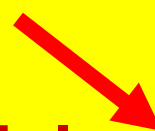
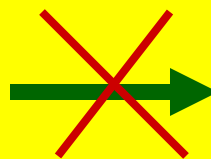




# Colon functions (last chance)

- Absorb H<sub>2</sub>O (dehydrator) → blood
- Convert chyme (liquid) → feces
- Absorb vitamins/minerals → blood
- Home: **bacteria**: cecum (pouch) + appendix

# **Bacteria** (300-500 species)

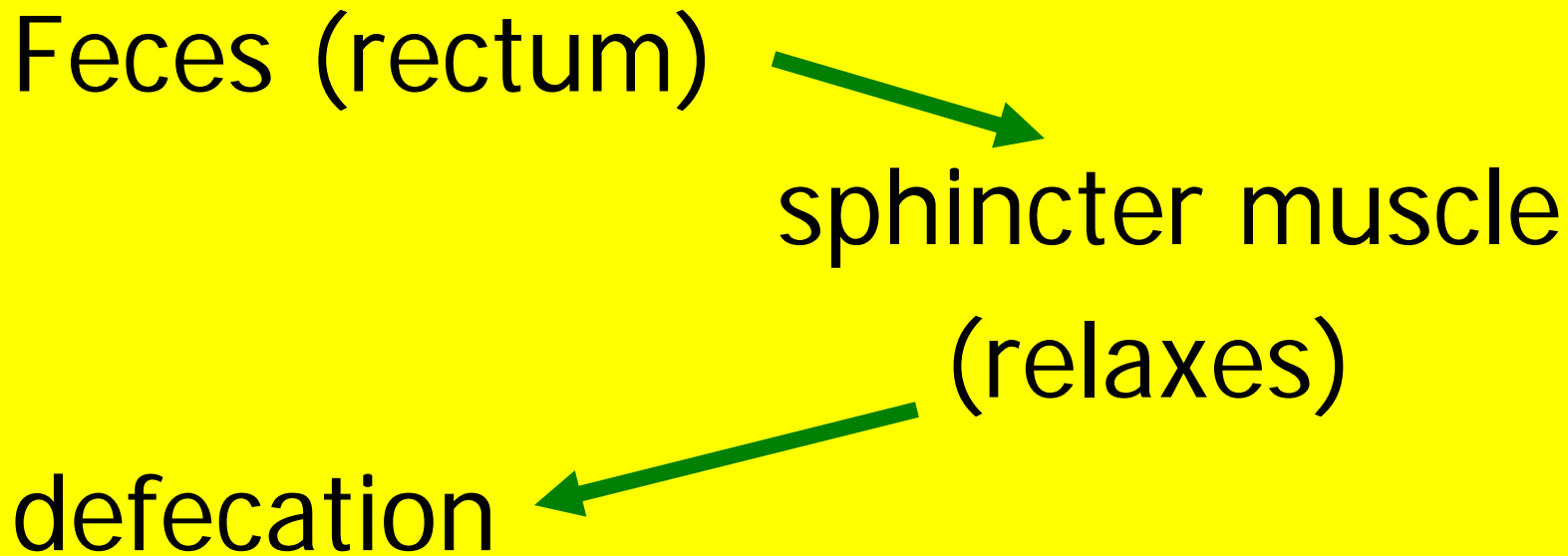
- Make B vitamins & vitamin K  blood
- You: enzymes  digest fiber
- **Bacteria**- guests partially digest fiber (cellulose- plant cell walls)
- Gas production (fermentation)

# Feces

- Undigested fiber, dead cells, water, bacteria
- Water in feces:
  - ↑ Fiber – attracts H<sub>2</sub>O feces: softer-easier bowel movements
  - ↓ Fiber- hard/dry → constipation



**Peristalsis**- slower than small intestine



# Digestive System: Problems/Diseases

- Colonoscopy –cancer screening-  
gold standard: everyone  $\geq 50$

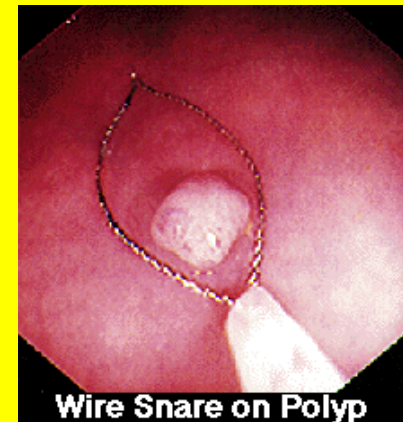
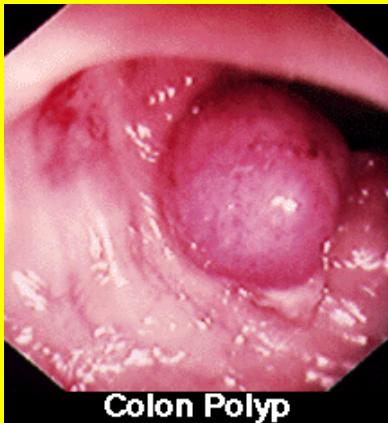
- Flexible tube  $\longrightarrow$  rectum

camera  $\longleftarrow$  large intestine

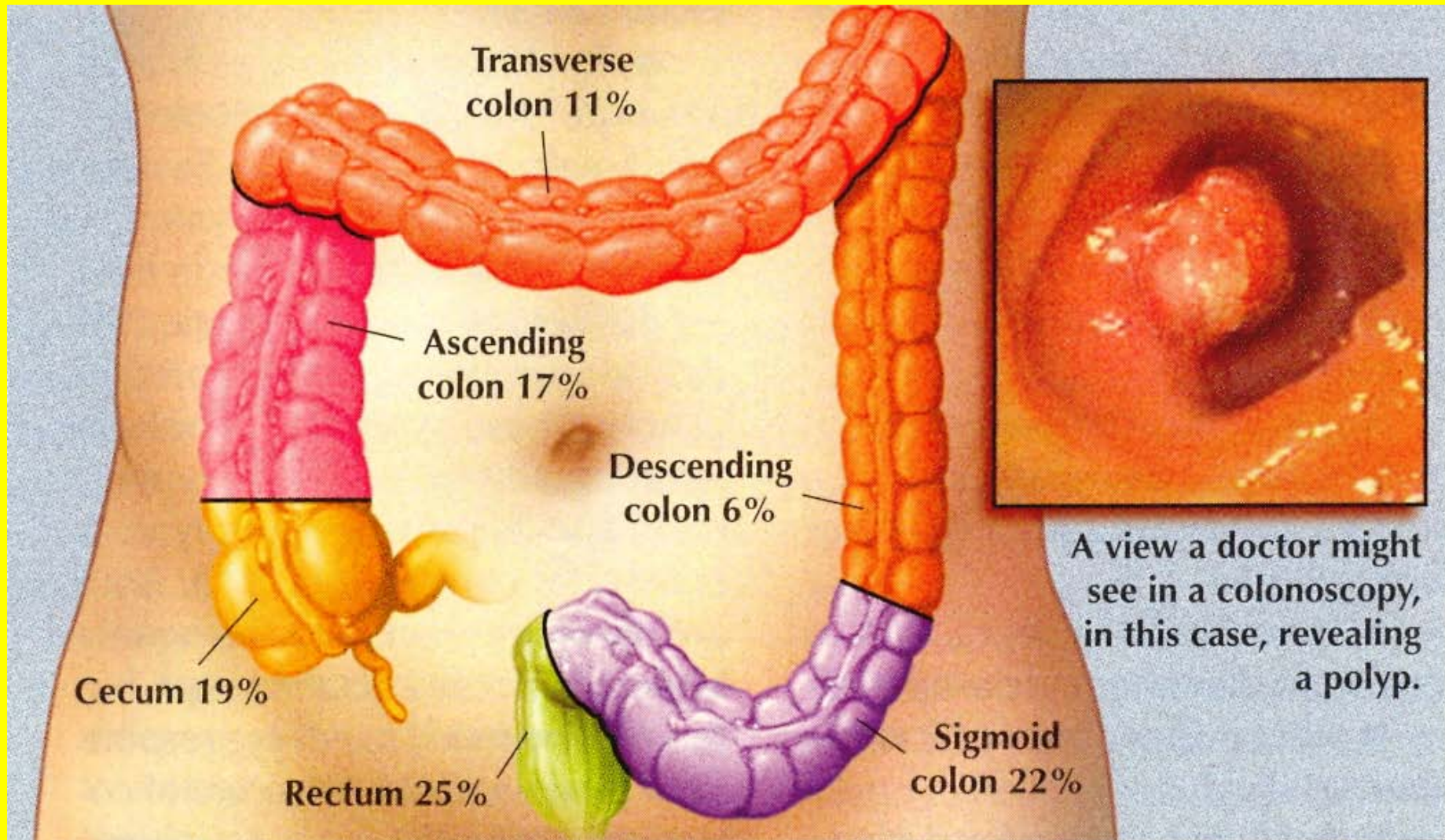
view entire colon

# Colon Pathology

- Colonoscopy: polyps (pre-cancerous) removed
- Afterward doctor recommends: exercise + aspirin



# Where Colon Cancer Occurs

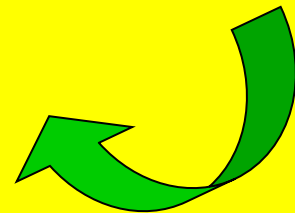


# Probiotics

- Population- **good** bacteria:  
essential health/normal functions
- Prevent growth- bad bacteria
- Bad bacteria-take over: diarrhea,  
infection

**Should you eat bacteria?**

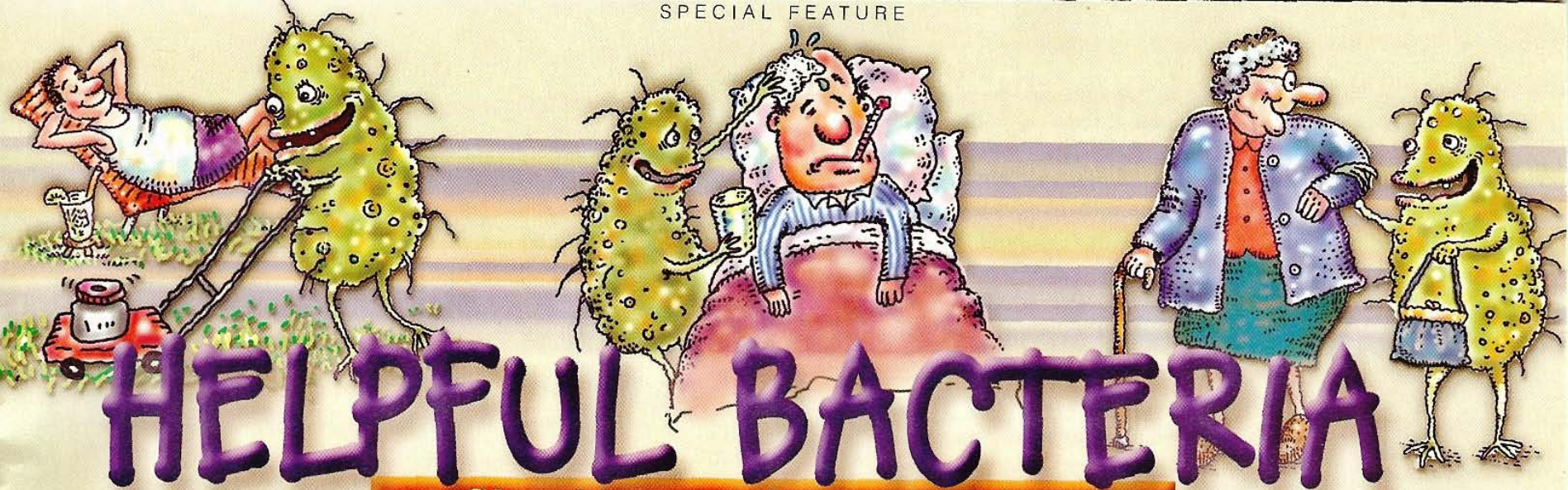
**Probiotics:** eat living organisms  
health benefit



# Probiotics: Benefits

- Help- immune function- intestine
- Reduce toxins-colon
- Inhibit enzymes → carcinogens
- **Relieve constipation,  
bloating,  
diarrhea, gas**





# HELPFUL BACTERIA

Should you take probiotics?

BY DAVID SCHARDT

## Activia Yogurt

### What's in it:

*Bifidum regularis*, Dannon's name for *Bifidobacterium animalis* DN-173 010.

**Cost:** \$20-\$60 a month for one to three 4-oz. yogurts a day.



## Stonyfield Farm Yogurt

**What's in it:** *L. acidophilus*, *Bifidus*, *L. casei*, and *L. reuteri* 55730. Stonyfield Farm says that it sells the only U.S. yogurt with *L. reuteri*.

**Cost:** About \$30 a month for one 6-oz. tub a day.

**Claims:** *L. reuteri* can fight "viruses and bacteria associated with diarrhea and gastrointestinal disease" and "harmful bacteria such as *Salmonella*, *E. coli*,

*Staphylococcus*, *Candida* yeast, and other harmful microorganisms."





# Federal Trade Commission

2010 Ruling: Ads **deceptive**



- Nestlé stops ads: **Kids Essentials**

(probiotics in straw): ↑ immune system

↓ colds, diarrhea, missing school

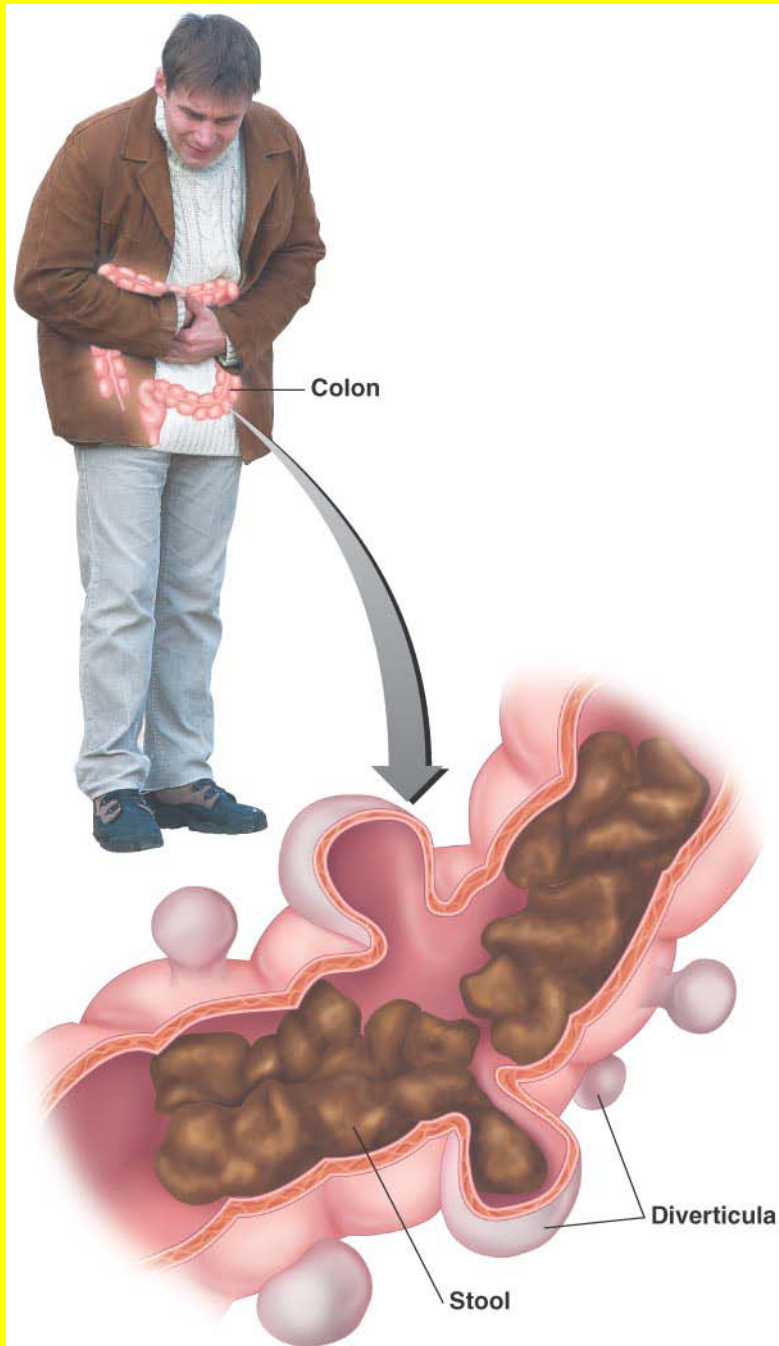
- Kellogg stops ads:

Rice Krispies ↓ illness children

Frosted Mini-wheats ↑ 20%  
attentiveness

# Diverticulitis

- Small pouches in colon (diverticula) → inflamed/painful (**diverticulitis**)
- Treatment
  - ↑ Soluble fiber (reduces pressure)
  - ↑ H<sub>2</sub>O



# Nuts & Diverticulitis



Older view: People with  
diverticulitis: **avoid** nuts, small  
seeds

Intestinal problems ?


New study 2008: 47,000 men

Ate nuts/ popcorn 2X/week

↓ Risk Diverticulitis

No Complications

# Colostomy

- Example: colon cancer
- Diseased colon removed
- Separate opening- abdomen
- Remaining colon  opening  
(**stoma**)
- Permanent **fistula**
- Bag-collect feces; anus: non-  
functional

# Other Digestive Disorders (Harkin/Deen 2005)

| Disorder     | What is it?                                | What helps                        |
|--------------|--------------------------------------------|-----------------------------------|
| Constipation | Infrequent/<br>difficult passage<br>stools | ↑ fiber<br>↑ fluids<br>↑ exercise |



Disorder

What is it?

What helps

Diarrhea

Frequent,  
loose, watery  
stools

↓ Fiber  
(short-term)

↑ Soluble  
Fiber  
(long-term)

↓ Sorbitol

↑ Fluids


Disorder

What is it?

What helps

Irritable  
Bowel  
Syndrome

Abdominal  
pain,  
bloating,  
excessive  
gas

Low fat, high  
fiber diet  
 caffeine

Disorder

What is it?

What helps

Lactose  
Intolerance

Inability-  
digest milk  
sugar (lactose)



Milk/milk  
products  
choose:  
low-lactose,  
lactose-free  
drinks; take  
calcium &  
vitamin D  
supplements

Disorder

What is it?

What helps

Celiac  
Disease

Small intestine  
damage due  
to **gluten**  
(proteins in  
cereals, grains  
**(wheat)**); result:  
malabsorption

Exclude  
gluten  
from diet;  
Read labels

| Disorder        | What is it?                                     | What helps                         |
|-----------------|-------------------------------------------------|------------------------------------|
| Crohn's Disease | Inflammatory disorder of ileum & colon;         | Diet low in fat, fiber, lactose;   |
|                 | mutant gene-immune response to healthy bacteria | Take: vitamin & mineral supplement |

Disorder

What is it?

What helps

Ulcerative  
Colitis

Inflammation  
& ulcers- colon,  
rectum;

Mutant gene-  
response to  
healthy bacteria

↑ insoluble  
fiber;

Take  
vitamin  
&  
mineral  
supplements



