NTR 306: Fundamentals of Nutrition

Chapter 3: Digestion, Absorption & Transport

In Real Life

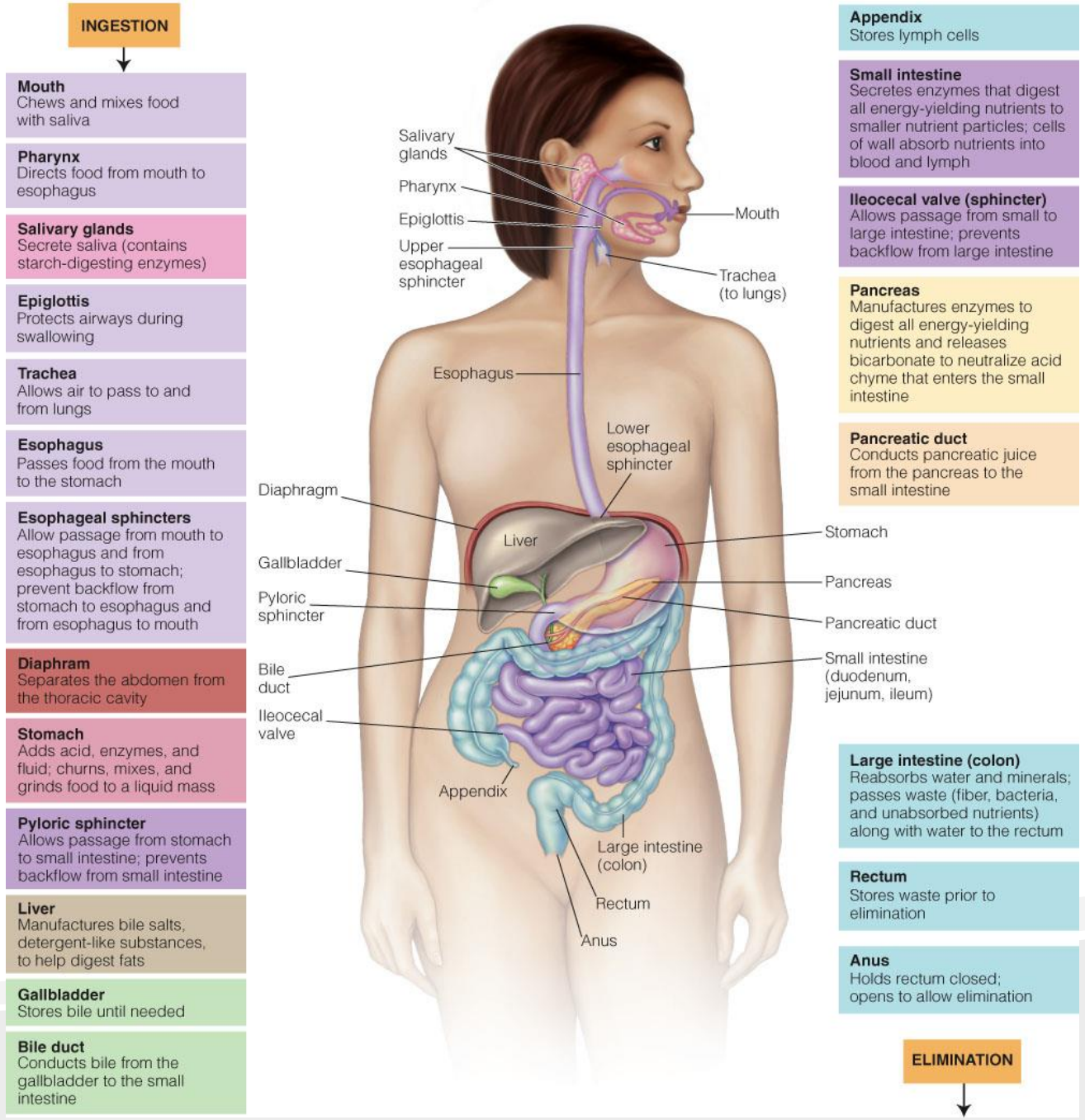
Digestion

- Breaking down foods into smaller molecules (nutrients)
- Challenges of digestion: *How can…*
  - the mouth and throat perform many different functions (eating, drinking, breathing)?
  - food pass from the mouth, through the diaphragm, and into the stomach?
  - the contents of the digestive tract keep moving forward at a steady pace?
  - food be lubricated with the right amount of fluid to facilitate smooth, efficient movement?
  - the digestive enzymes break down food without damaging our internal cells?
  - waste periodically (not continuously) be excreted?

GI Anatomy

- Gastrointestinal (GI) tract
  - Flexible and muscular tube with a continuous inner space (lumen)
  - Extends from mouth to anus!
  - Simplified path:

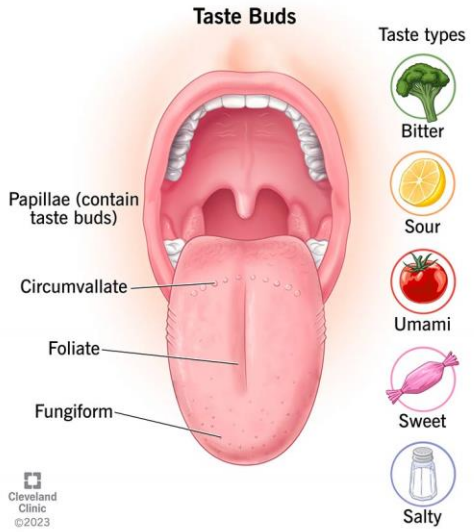
Mouth
Esophagus
Stomach
Small Intestine
Large Intestine
Rectum
Anus

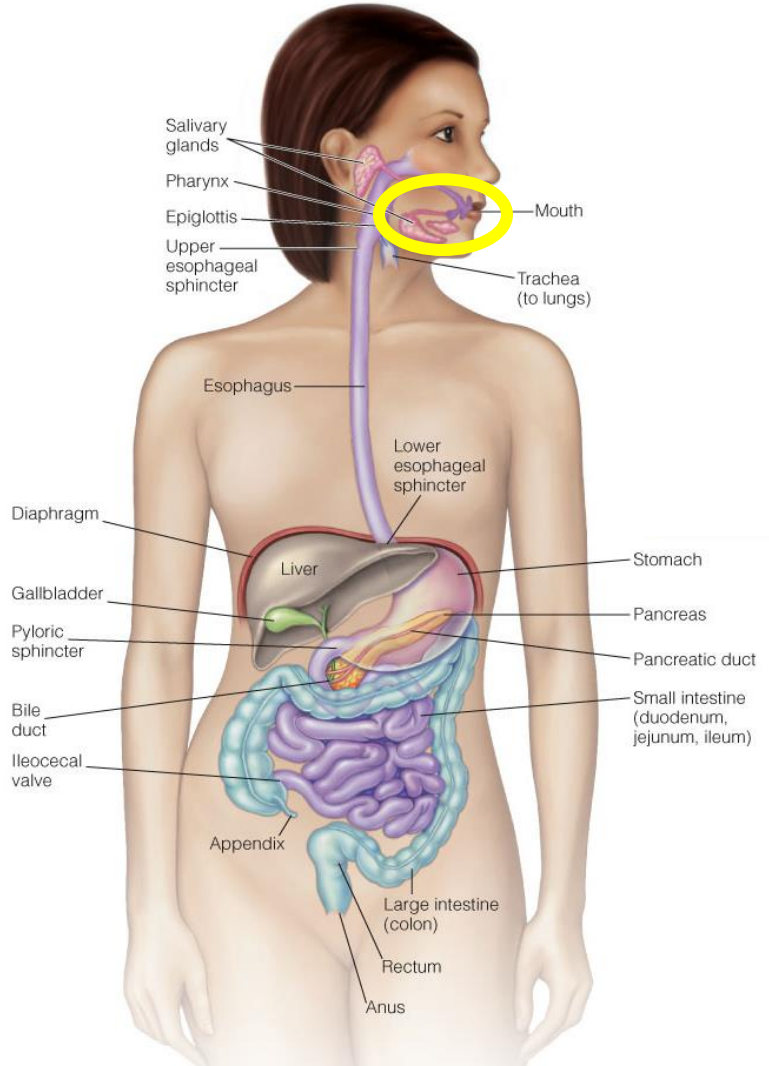


GI Anatomy

- Process of digestion begins
  - Mastication (chewing) to break apart food and mix it with saliva
  - Eases swallowing
- Taste perceptions:
  - Five basic taste sensations:

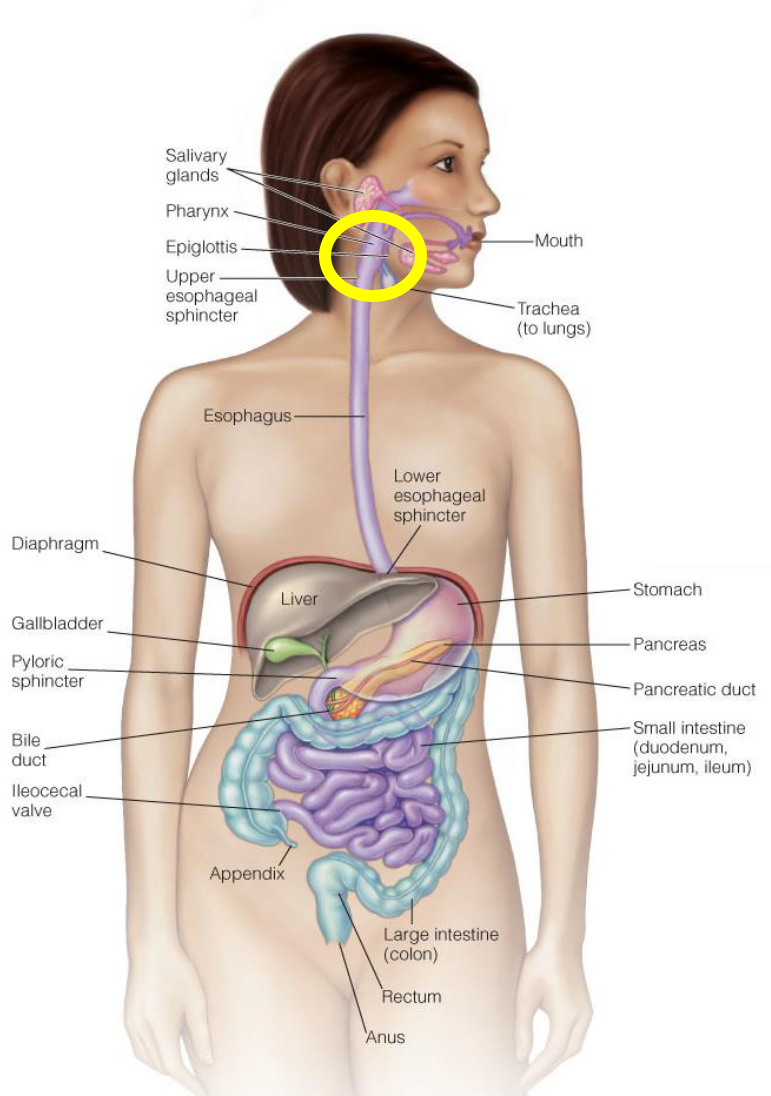
    sweet, sour, bitter, salty, umami
  - Aroma, appearance, texture, and temperature





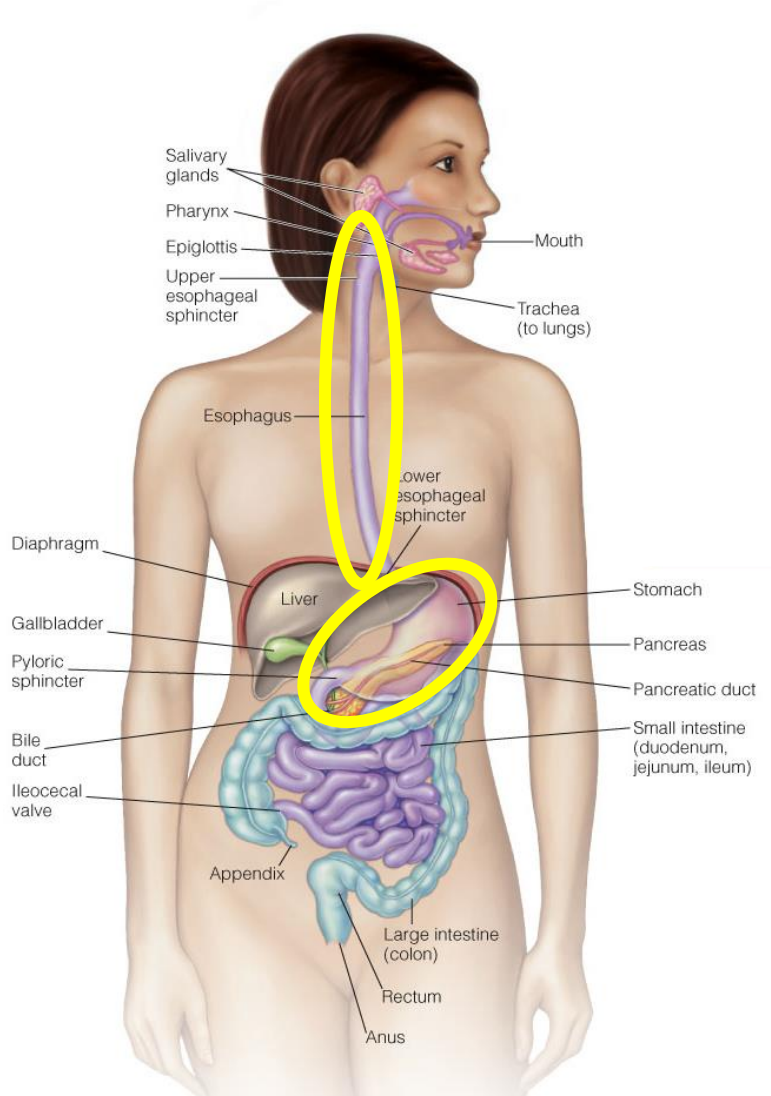
GI Anatomy

- Pharynx (both digestion and respiration)
- Epiglottis
  - Closes airway and prevents choking
- Bolus: food that has been chewed and swallowed



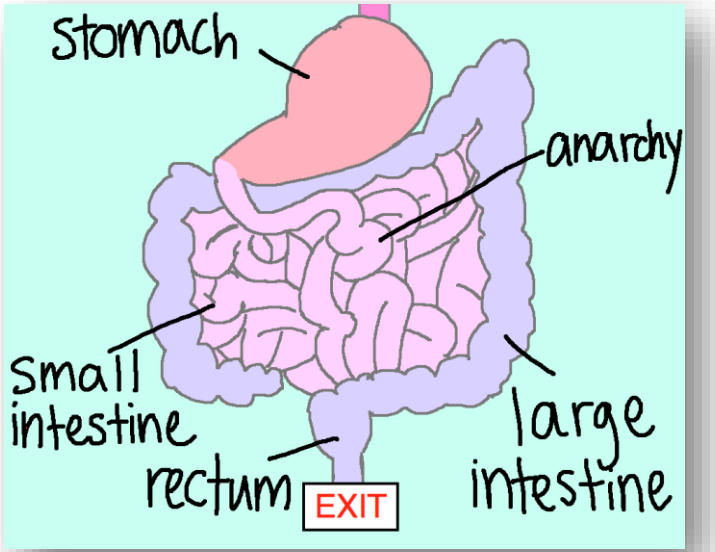
GI Anatomy - Upper

- Esophagus
  - Transport tube connecting mouth to stomach
  - ~1 ft long
- Stomach
  - Movement of bolus: upper to lower portion of stomach, mixes with digestive juices
    - ✓ Bolus → chyme (acidic, semiliquid mass)
  - Temporarily stores food (~1 liter, which is ~2 lbs)



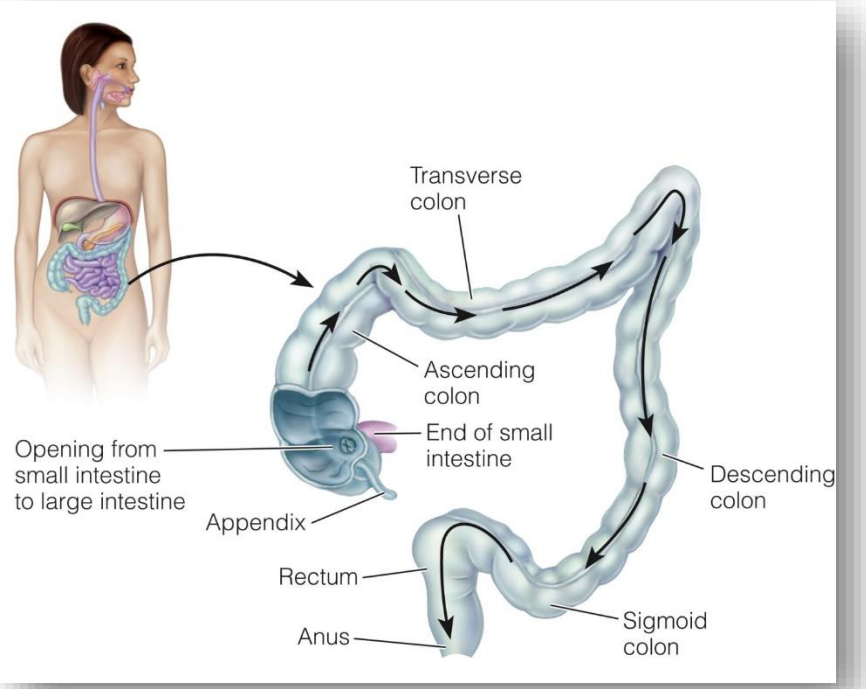
GI Anatomy – Small Intestine

- Nearly all absorption of macronutrients
- Travels down three segments:
  duodenum, jejunum, ileum
- ~10 feet long with surface area of 2700 square feet!
- Receives bile (from gall bladder)
- Receives digestive juices (from pancreas)



GI Anatomy – Large Intestine

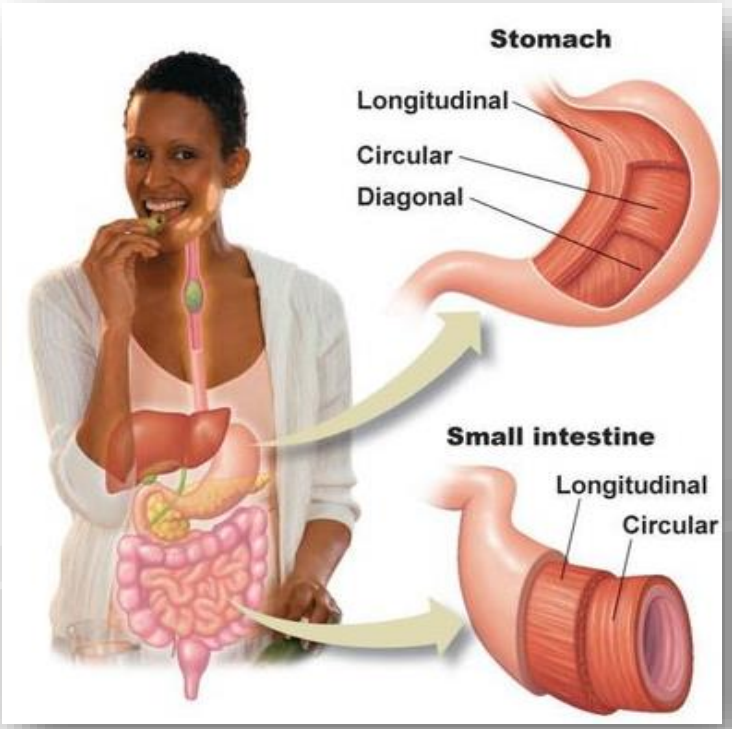
- Colon, Rectum, Anus (exit)
  - Colon segments: ascending → transverse → descending → sigmoid
  - Withdrawal of water from chyme
- ~100 trillion microbes inhabit GI tract
  - Bacteria, viruses, fungi, protozoa, archaebacteria, etc.
  - Role in health, metabolism, and disease
  - Differences in people with obesity vs. healthy weight
- Factors influencing GI bacteria
  - Early life exposures
  - Diet (meals and patterns)



Muscular Action of Digestion

- Physical breakdown of food using various muscles
  - Happens throughout GI tract (not just in mouth)

- GI motility: movement of digestive tract
  - Circular muscles (inside small intestine)
  - Longitudinal muscles (outside small intestine)



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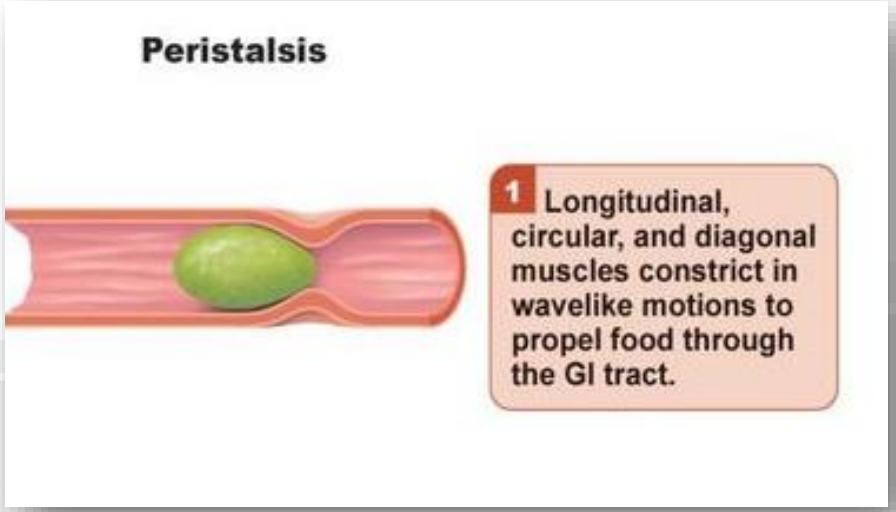
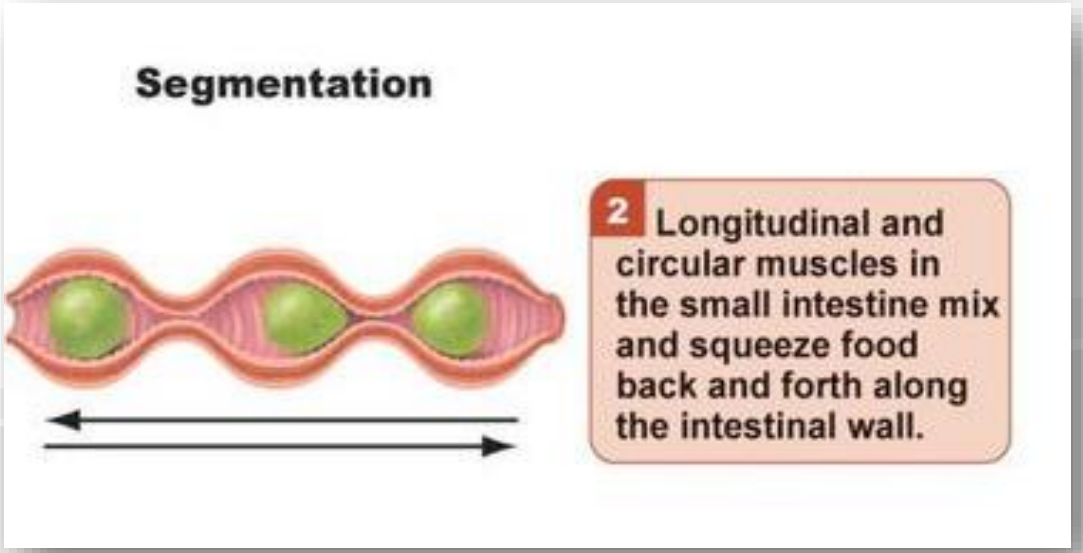
Muscular Action of Digestion

- Peristalsis
  - Circular and longitudinal muscles working together
    - **Moves** chyme forward
    - Rate and intensity of contractions vary, depends on section of GI tract and if food is present
    - Potential interference: stress, drugs, illness



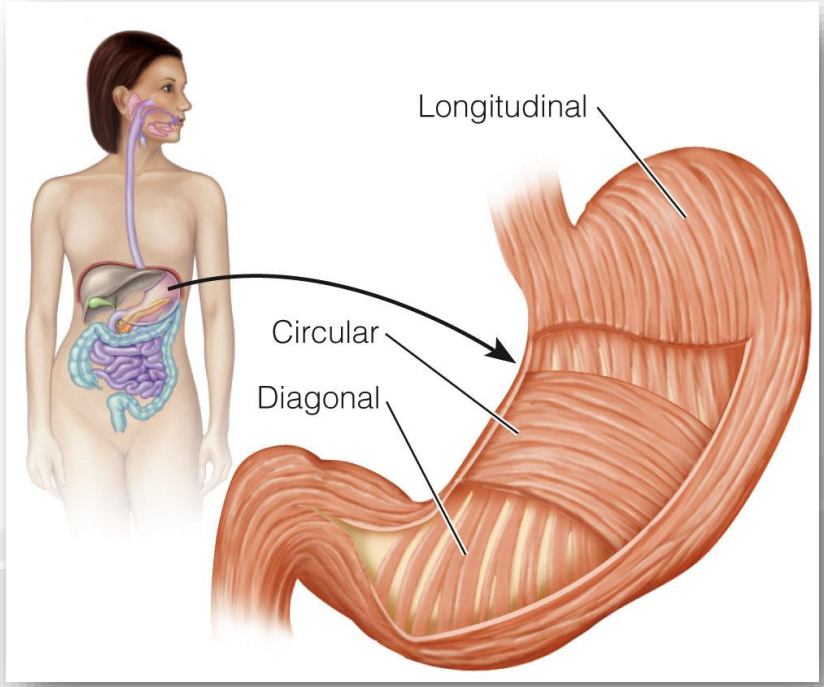
Muscular Action of Digestion

- Segmentation
  - Circular muscles in small intestine contract and relax
    - Churn chyme, **mixes** with digestive juices
    - Promote contact with absorbing cells of intestinal wall



Muscular Action of Digestion

- Stomach action
  - Strongest muscles of all GI organs
    - Circular, longitudinal, and diagonal muscles
    - Churn and force chyme downward
    - Mix chyme and gastric juice until chyme becomes liquified
  - Timing the release of (liquified) chyme
    - Pyloric sphincter opens 3x per minute
    - Small portions of chyme pass through



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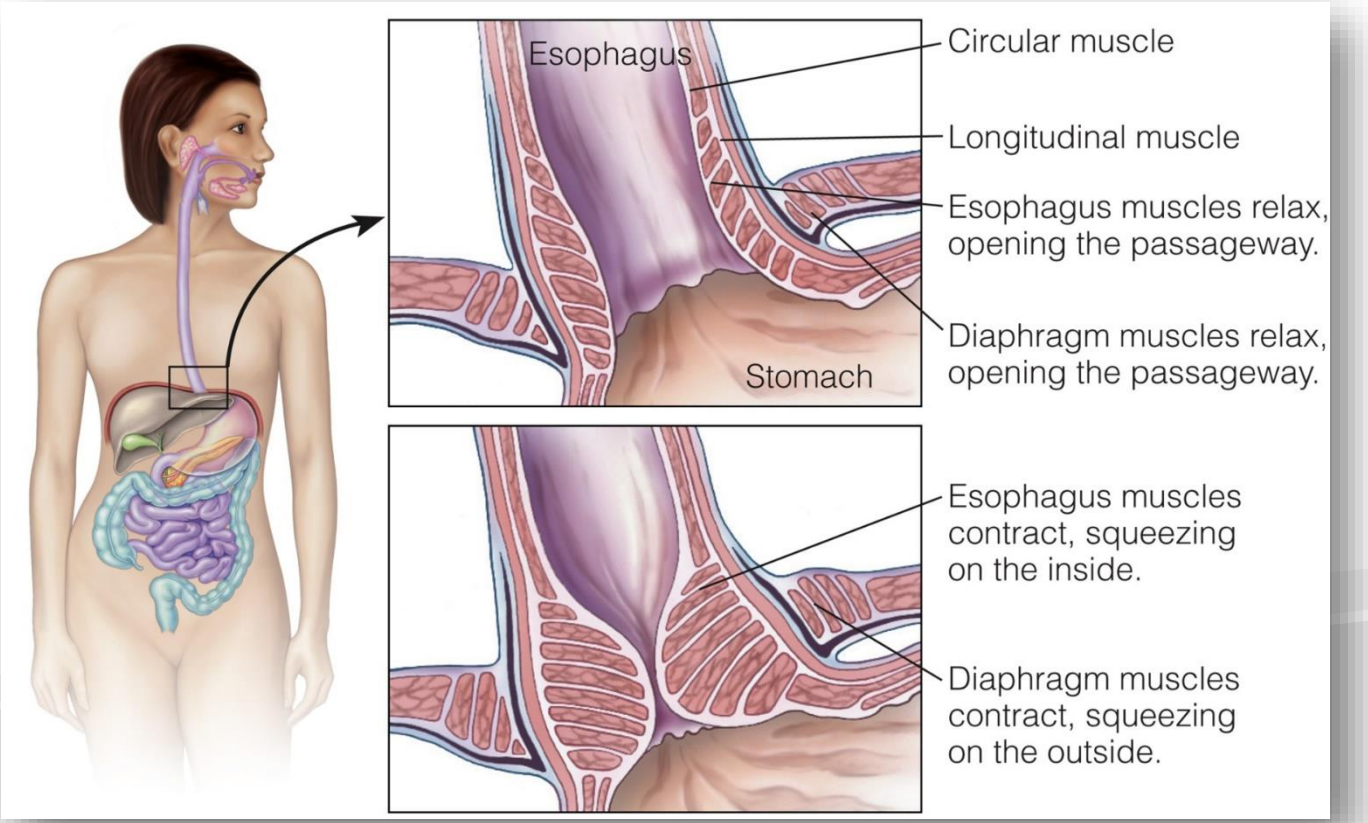
Muscular Action of Digestion

- Sphincter contractions
  - Periodically open and close
  - Control pace of GI tract contents
  - Needed anywhere there is a change in anatomy/function

1. Upper esophageal sphincter
2. Lower esophageal sphincter
3. Pyloric sphincter
4. Ileocecal valve
5. Anal sphincters (two)



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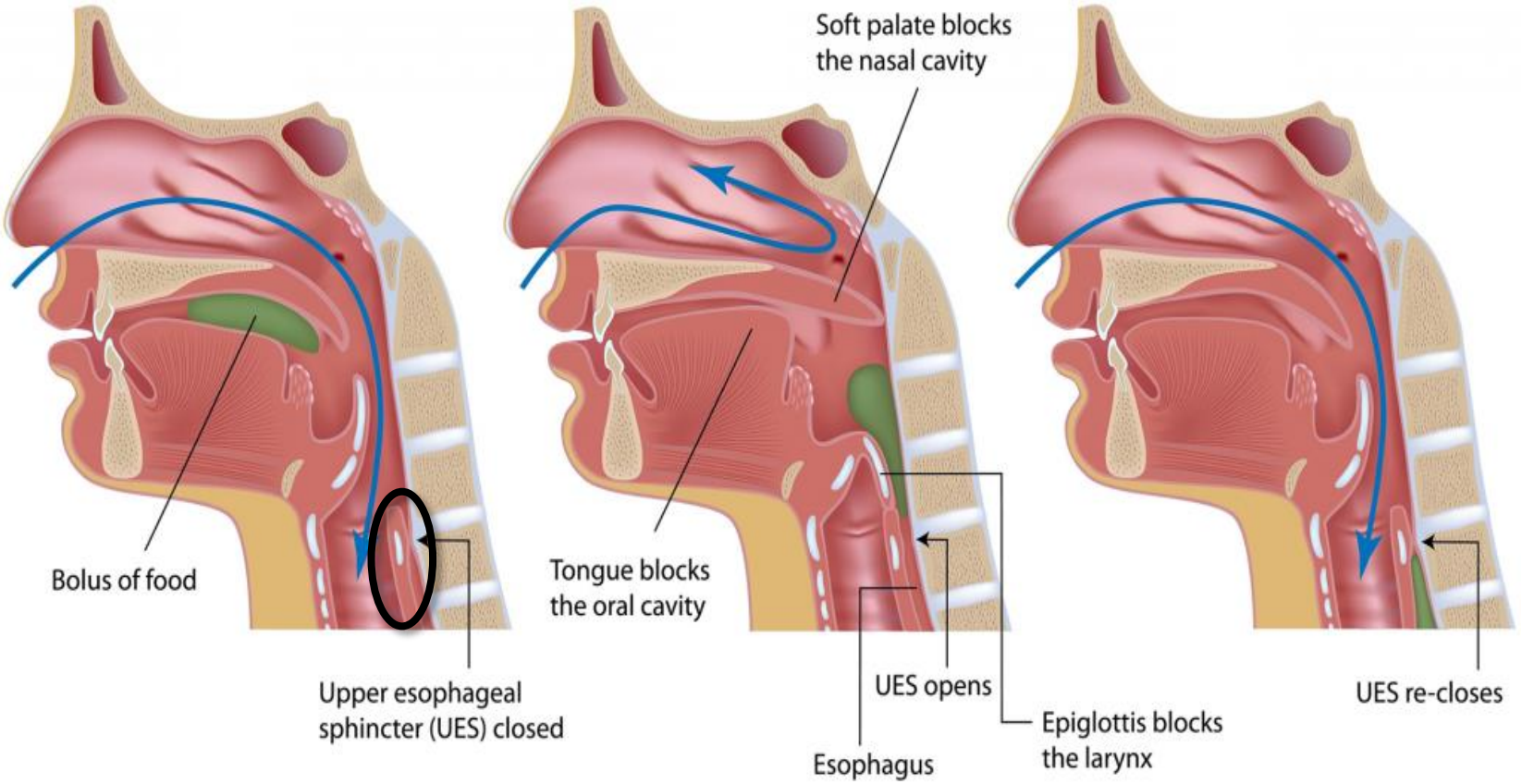
InstaPoll

- When you are coughing/choking and you say:
  "*Something must have gone down the wrong pipe*" … is that actually true?
  - YES!
  - Maybe?
  - No
  - I don't know

Mechanical Digestion and Propulsion

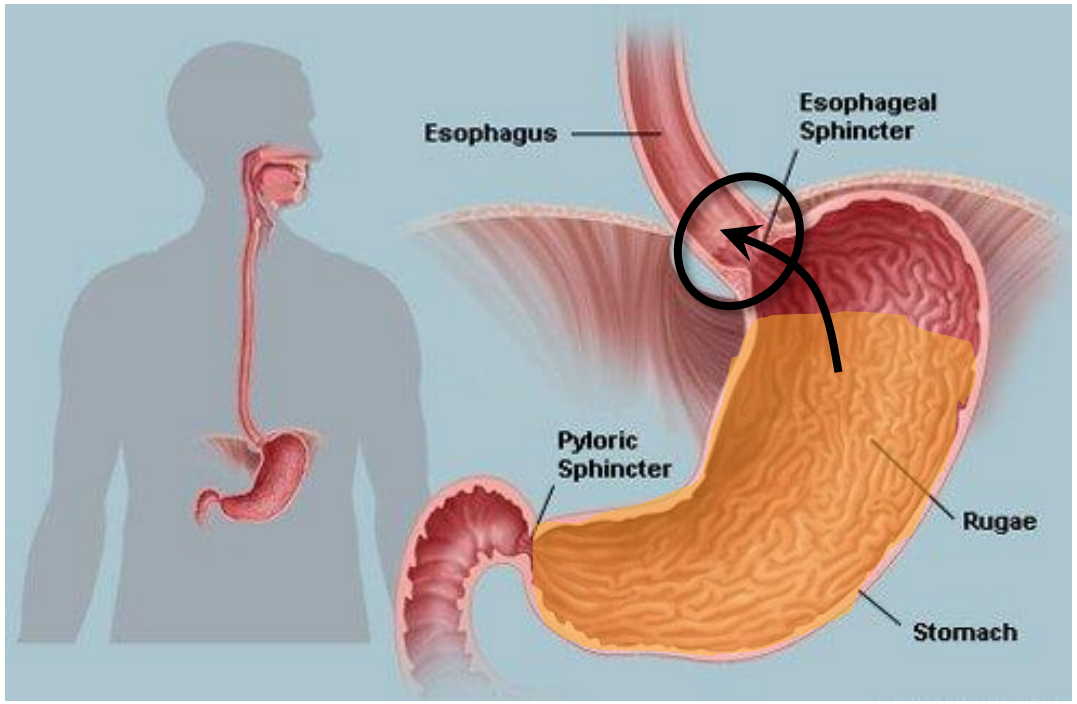
Upper Esophageal Sphincter (UES)



- Senses foods / beverages, allows them to pass down the esophagus
- Prevents foods / beverages from entering larynx/trachea

Mechanical Digestion and Propulsion

Lower Esophageal Sphincter (LES)



- Keeps gastric juices and chyme from going back into the esophagus

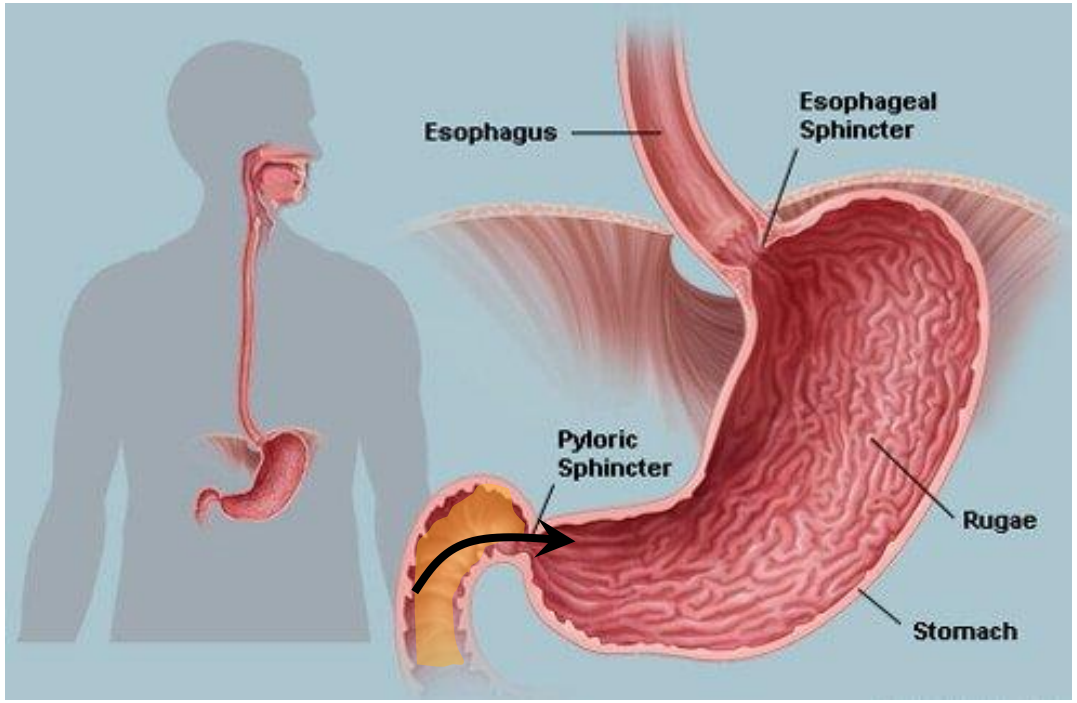
<u>Common Condition:</u>

<u>G</u>astric <u>E</u>sophageal <u>R</u>eflux <u>D</u>isease (GERD)

- Chronic acid reflex / "heartburn"
- Occurs in 20% of Americans
- Caused by:
  - ✓ types of food
  - ✓ abdomen pressure
  - ✓ medications

Mechanical Digestion and Propulsion

Pyloric Sphincter (PS)



- Controls when the chyme leaves the stomach and enters the small intestine
- Opens and closes depending on acidity levels

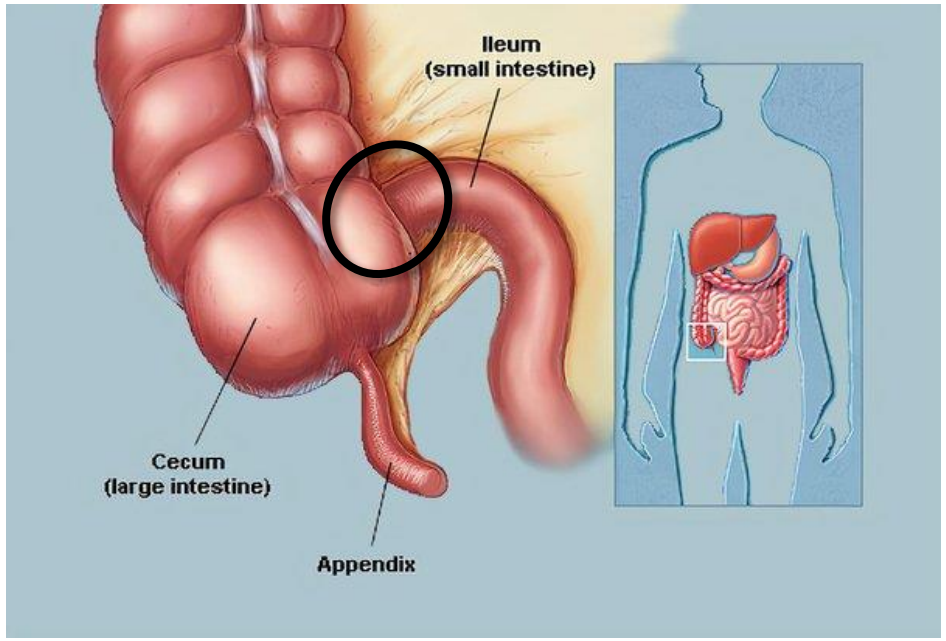
<u>Common Condition</u>:

Pyloric Stenosis

- Generally only occurs in infants
- PS fails to close completely
- Leads to:
  - ✓ Bile reflux
  - ✓ Bloating
  - ✓ Vomiting

Mechanical Digestion and Propulsion

Ileocecal Valve (ICV)



- Valve between the small and large intestine that controls flow into the large intestine, prevents chyme from moving back into small intestine

<u>Common Condition:</u>

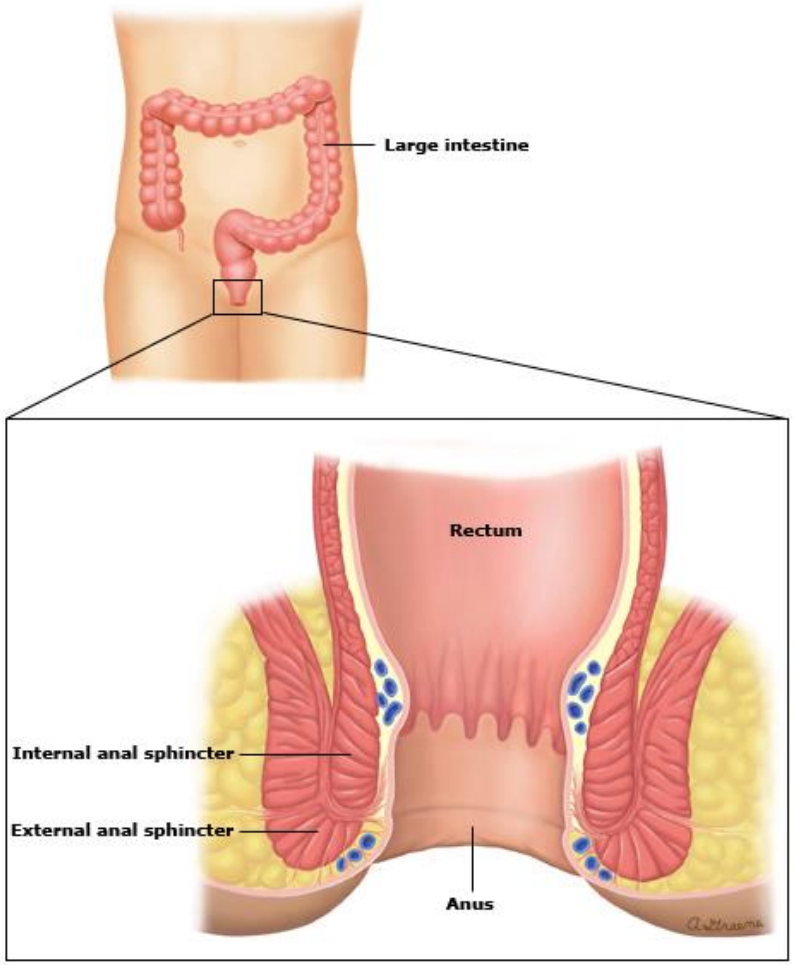
ICV syndrome

"I just don't feel well syndrome"

"Great Mimicker"

- Abdominal Pain/Cramping
- Constipation/Diarrhea/Bloating/Gas
- Chronic Fatigue/Lower Back Pain
- Occurs in 20% of Americans
- Caused by:
  - ✓ Stress
  - ✓ Diet (crunchy food, caffeine)
  - ✓ Food sensitivities

Mechanical Digestion and Propulsion



Anal Sphincters (2)

- Sphincters keep anus closed as stool collects in the rectum.
  - ✓ Internal – circular muscle, involuntary
  - ✓ External – striated muscle, voluntary

Chemical Digestion

- Chemical Digestion
  - Chemical breakdown of food via secretions
  - Occurs throughout the GI tract, not just in the mouth
  - Secretory organs: salivary glands, stomach, pancreas, liver, and small intestine

1.) Enzymes

- Protein facilitator of chemical reactions
  - Breaking down, making, or changing molecules
- Catalyst: enzymes remain unchanged
- Work (with water) via Hydrolysis: addition of water to break molecule into small pieces
- *Organ of origin* + *compound* + *-ase* = enzyme
  - *Example:* ***Gastric lipase*** = stomach enzyme that digests lipids

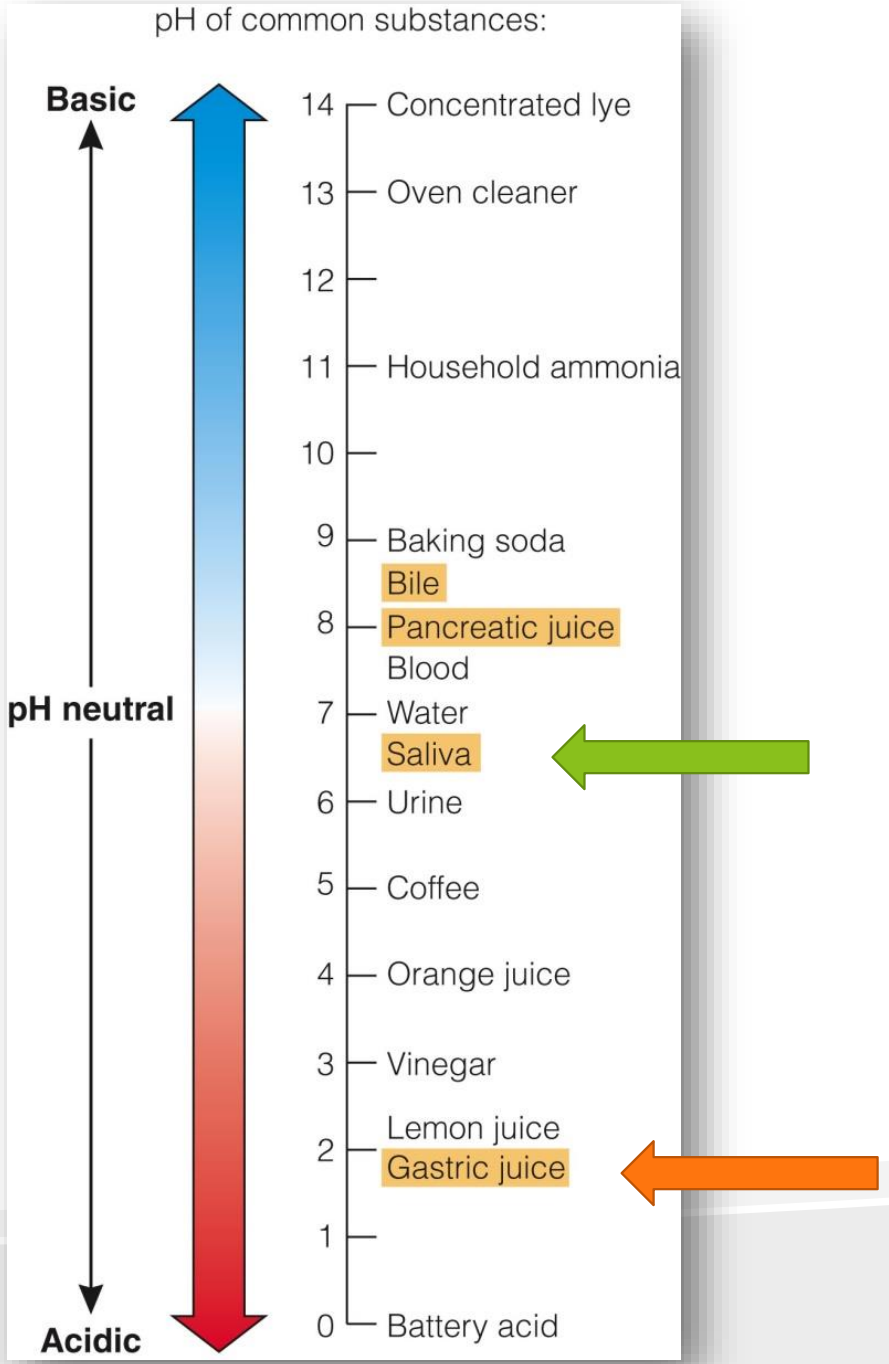
Secretions of Digestion

2.) *Saliva*

- Moistens food for easy passage
- Protective role: teeth, mouth, esophagus, stomach
- Enzymes initiate carbohydrate digestion

3.) *Gastric juice*

- Protein digestion (hydrochloric acid)
  - Heartburn
- Mucus protects stomach lining
- pH below 2 (more acidic than lemon juice)



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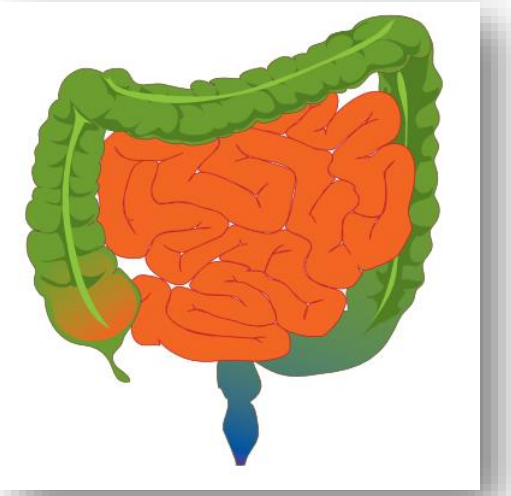
Secretions of Digestion

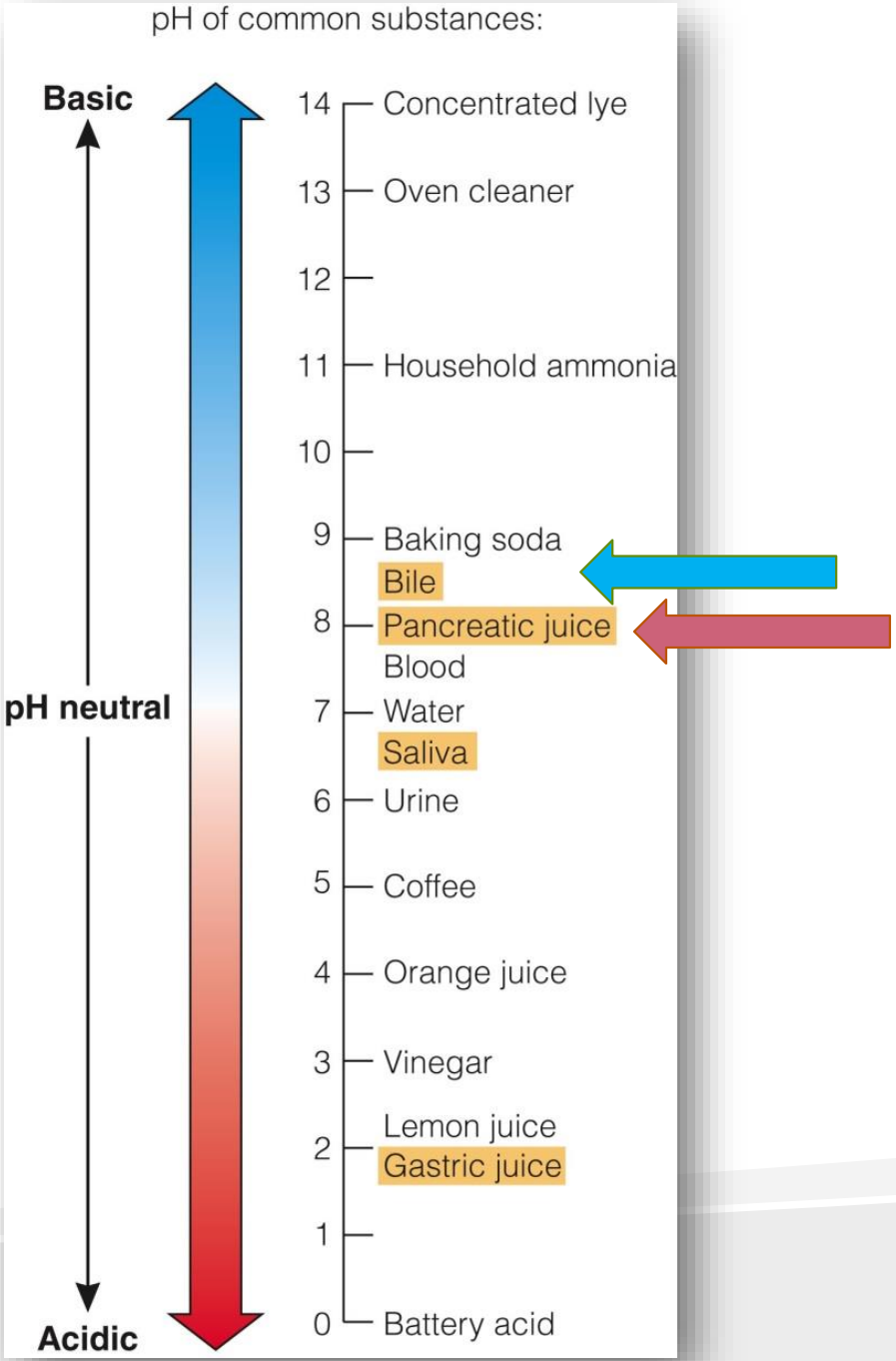
4.) *Pancreatic juice*

- Released via ducts into duodenum (small intestine)
- Enzymes act on all three energy nutrients:
  - Carbohydrates, fats, and proteins
- Sodium bicarbonate
  - Basic/alkaline
  - Neutralizes acid in chyme from stomach



5.) *Bile*

- Produced: liver
- Concentrated, stored, released: gallbladder
- Squirts into duodenum
- Emulsifier (NOT an enzyme)
  - Disperses fat in watery solutions
  - Gives digestive enzymes access to fat molecules



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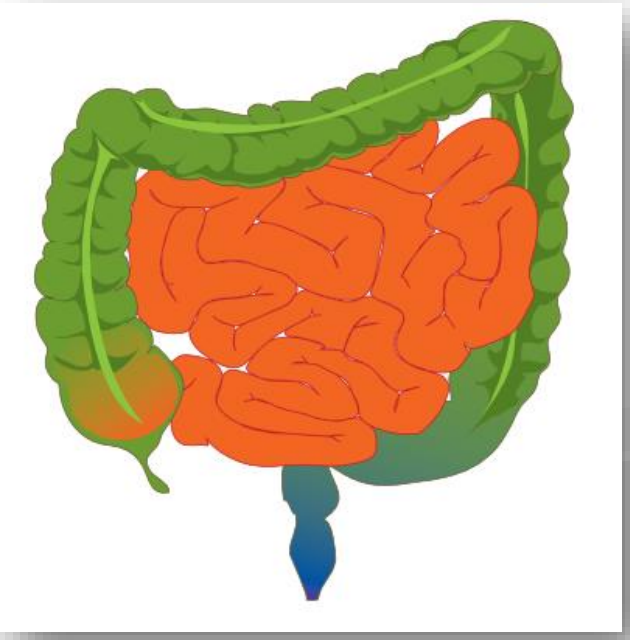
The Final Stage

- Carbohydrate, fat, and protein = digested & absorbed
- Vitamins and minerals = absorbed
- Undigested residues enter colon (large intestine):
  - Fluids, dissolved salts, fiber
- Colon
  - Intestinal bacteria ferment some fiber
    - Produces water, gas, and fat = energy for colon
  - Some fiber passes through unchanged
  - Water and dissolved salts
    - Recycled for use in other parts of body
- Rectum and anus
  - Eliminate stool

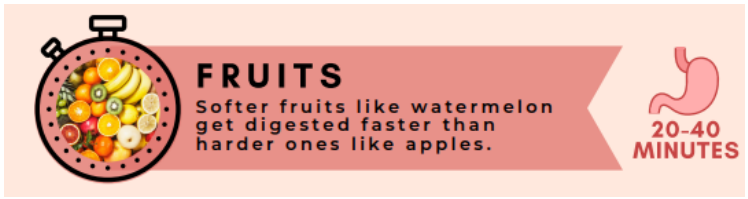


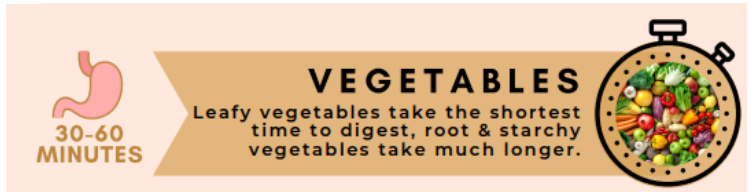
Instapoll

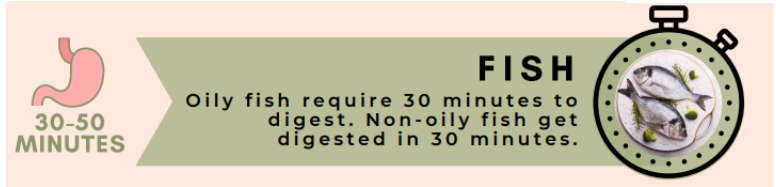
- How long does it take to digest meat?
  - 30 min
  - 1-2 hrs
  - 3-4 hrs
  - 1 day
  - 3-5 days
  - It never digests

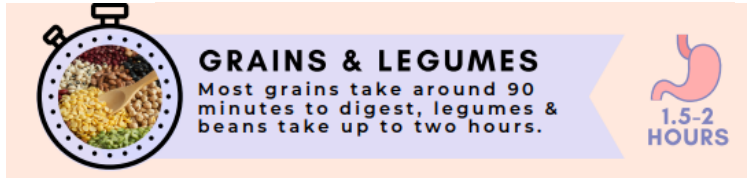
Digestion Times

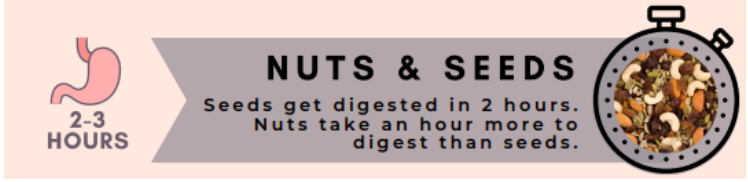
- Digestion times vary due to:
  Meal size + food combinations
- Carbs < Fats < Protein









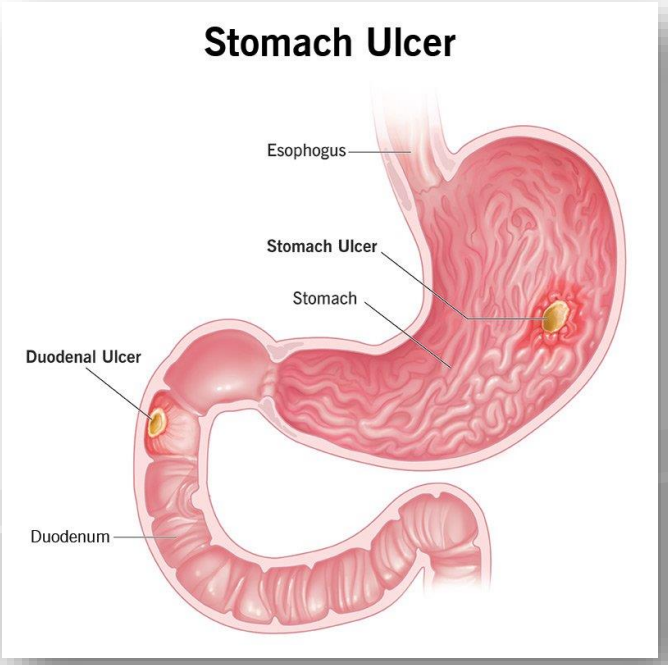


Digestive Problems

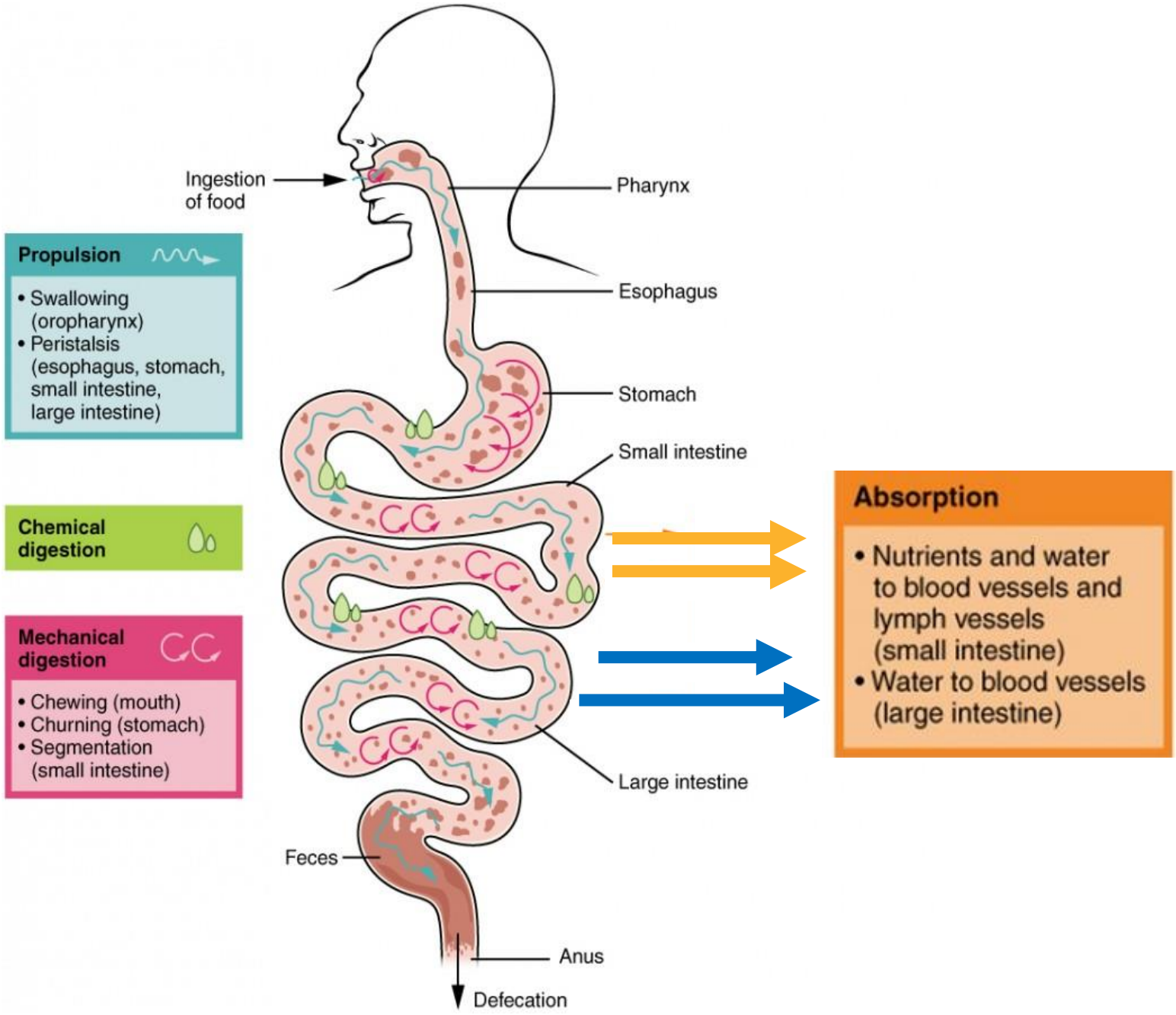
- Vomiting
  - Adaptive mechanism of the body to get rid of irritants
  - Medical treatment
    - ✓ Dehydration and loss of salt
    - ✓ Repeated vomiting = damage to esophagus, salivary glands, teeth, gums
- Diarrhea
  - Intestinal contents move too quickly
  - Dehydration and loss of salt
  - Symptom of medical conditions
    - ✓ Irritable bowel syndrome (IBS): identify and avoid irritating foods
    - ✓ Colitis: avoid greasy foods, milk products, and high-fiber foods
    - ✓ Celiac disease: gluten-free diet

Digestive Problems

- Peptic ulcers = lesion in lining of:
  - Stomach: Gastric ulcer
  - Duodenum: Duodenal ulcer
- Causes
  - Bacterial infection (*H. pylori*) - most common
  - Anti-inflammatory drugs (aspirin, ibuprofen, naproxen)
  - Excessive gastric acid secretion
- Ulcer treatment regimen
  - Treat for infection; eliminate foods that exacerbate discomfort; avoid coffee, caffeine, and alcohol

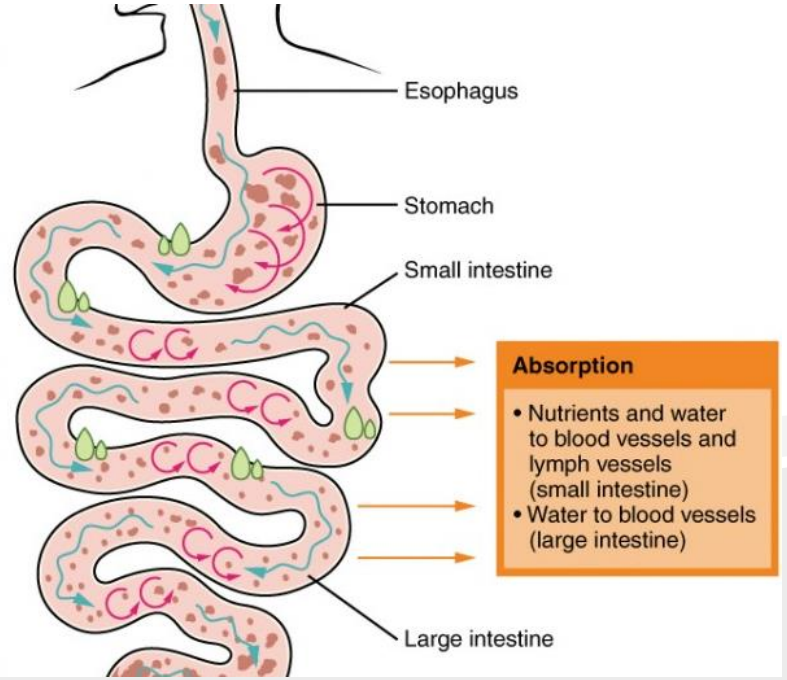


Absorption


Ingestion of food
Pharynx
Esophagus
Stomach
Small intestine
Large intestine
Feces
Anus
Defecation
Propulsion
• Swallowing (oropharynx)
• Peristalsis (esophagus, stomach, small intestine, large intestine)
Chemical digestion
Mechanical digestion
• Chewing (mouth)
• Churning (stomach)
• Segmentation (small intestine)
Absorption
• Nutrients and water to blood vessels and lymph vessels (small intestine)
• Water to blood vessels (large intestine)

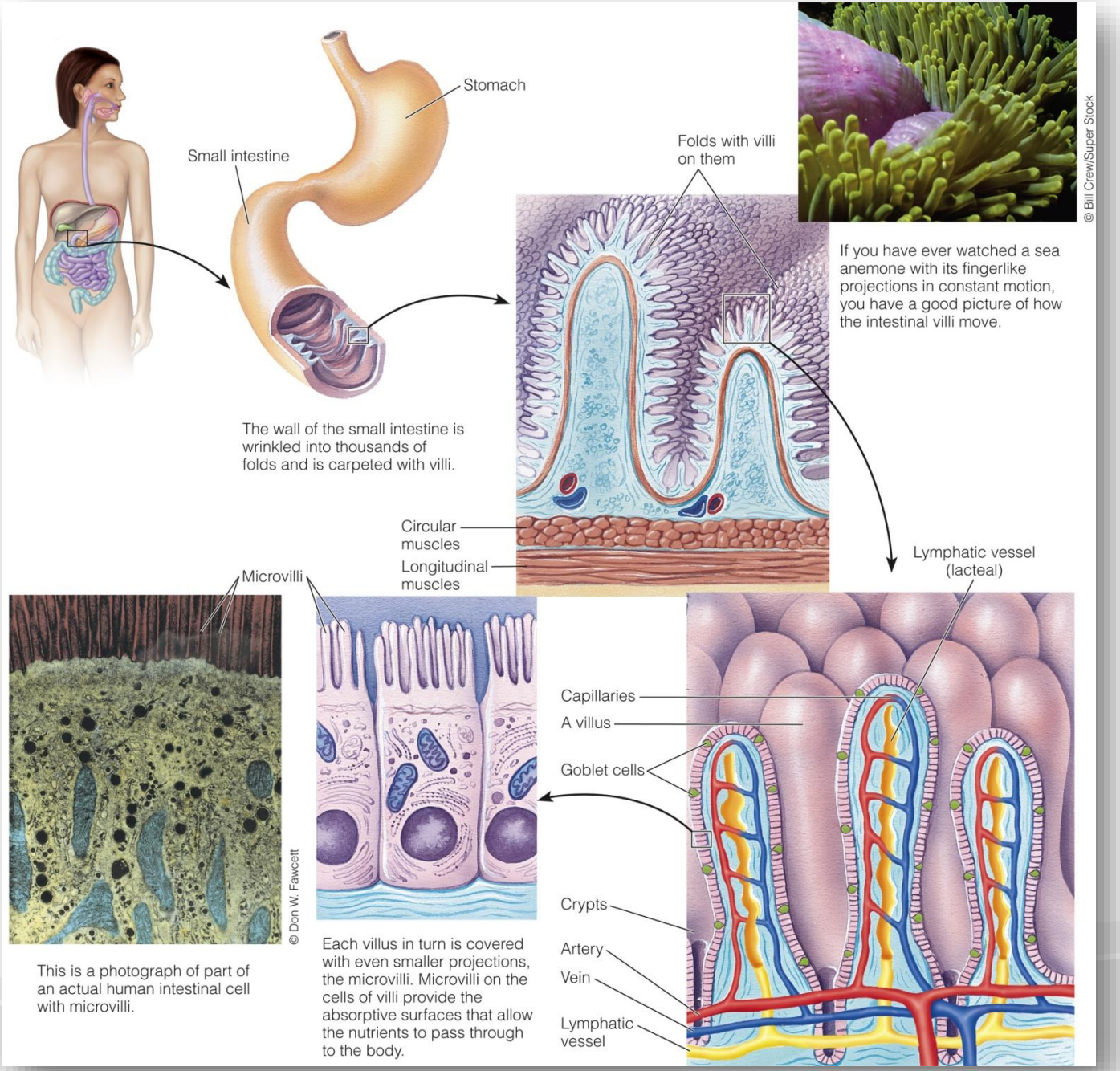
Absorption

- Movement of smaller molecules (from foods/beverages) out of the digestive tract and into the body via 2 different systems
- Esophagus and Stomach
  - No absorption
- Small Intestine
  - Majority of absorption of nutrients (except for water)
- Large Intestine
  - Majority of absorption of water



Absorptive System – Small Intestine

- Villi
  - Fingerlike projections on intestinal folds – thousands per fold!
  - Imagine: like a sea anemone
  - Select and regulate nutrients absorbed based on needs of body
- Microvilli
  - Enzymes and "pumps" act on different nutrients
- Crypts
  - Glands secrete intestinal juices = digestion
- Goblet cells
  - Secrete mucus = protection



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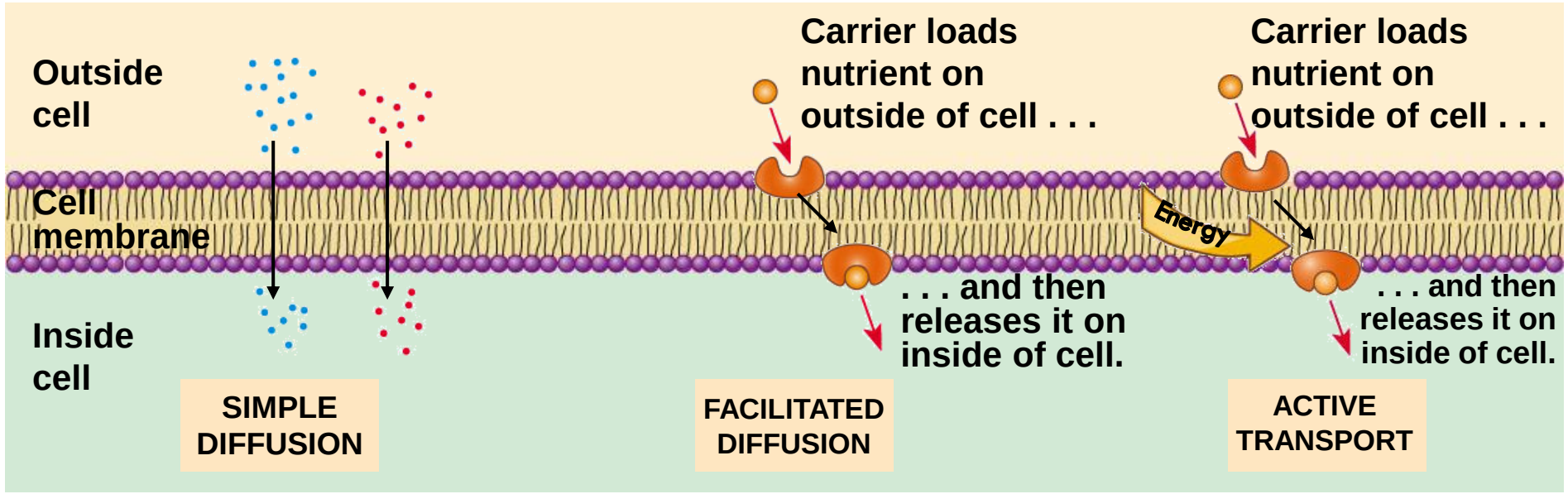
Absorption Techniques



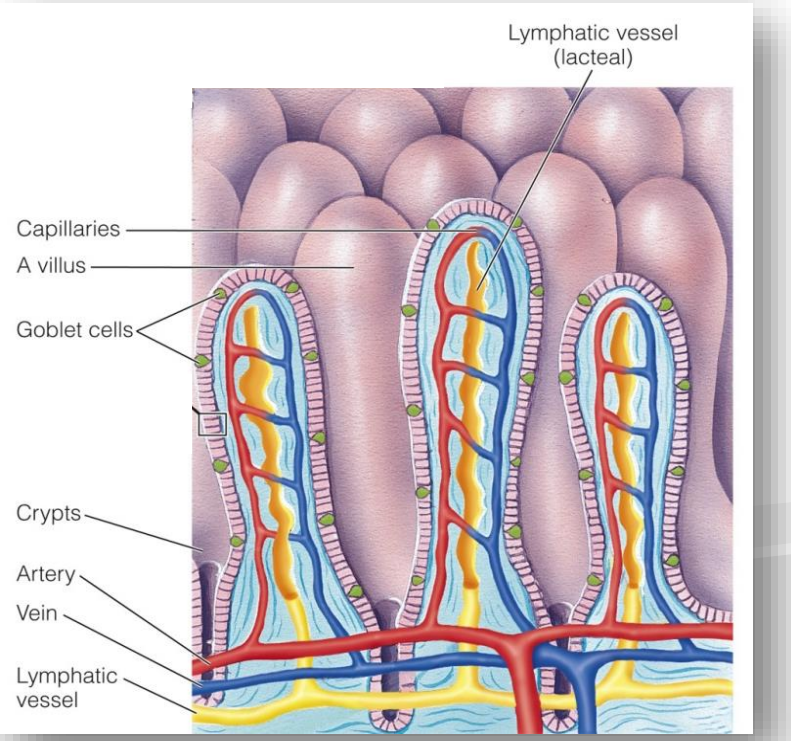
Some nutrients (such as water and small lipids) are absorbed by simple diffusion. They cross into intestinal cells freely.

Some nutrients (such as the water-soluble vitamins) are absorbed by facilitated diffusion. They need a specific carrier to transport them from one side of the cell membrane to the other. (Alternatively, facilitated diffusion may occur when the carrier changes the cell membrane in such a way that the nutrients can pass through.)

Some nutrients (such as glucose and amino acids) must be absorbed actively. These nutrients move against a concentration gradient (from areas of low concentration to areas of high concentration), which requires energy.

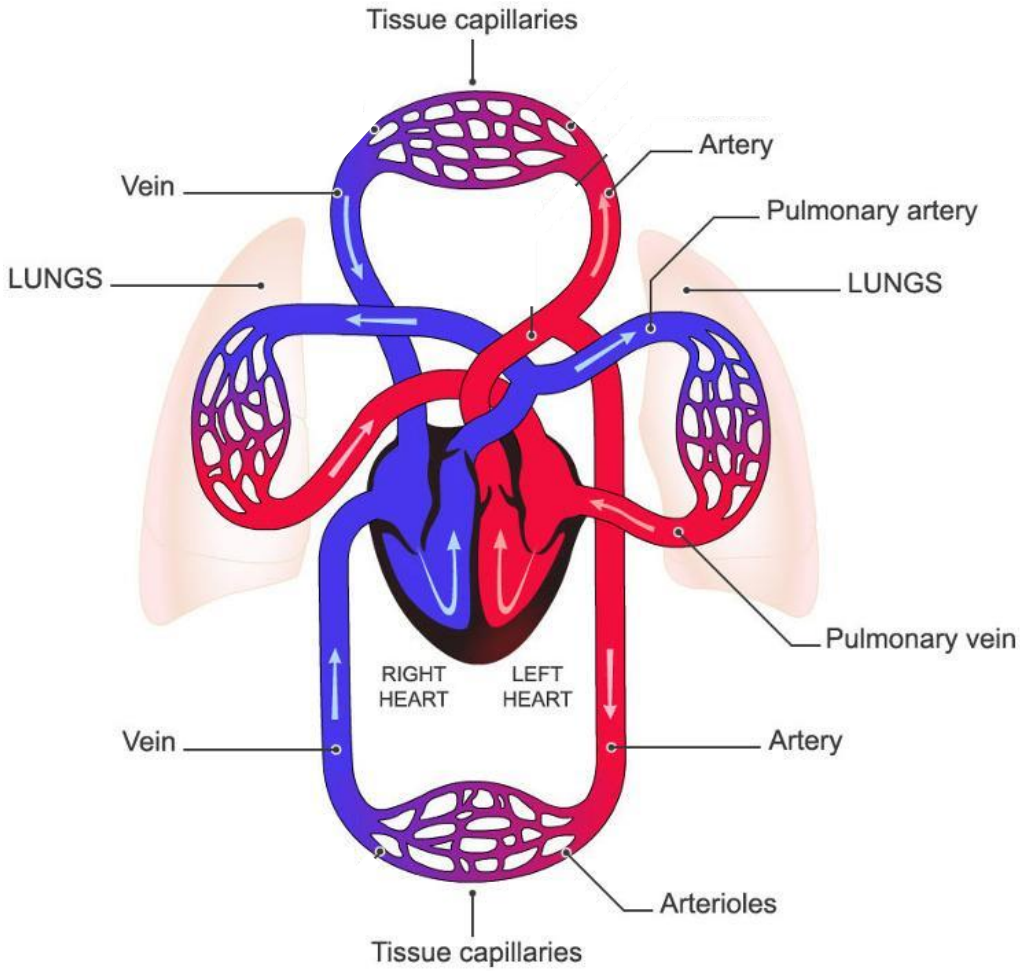
Transport Throughout the Body

- Nutrients enter into 1 (of 2) systems:
  - Directly to blood vessels (aka: 'circulation' or 'vascular system')
    - ✓ Water-soluble nutrients (can be dissolved in water)
    - ✓ Smaller products of fat digestion
  - Directly to lymphatic vessels, *then* to bloodstream
    - ✓ Larger fats, fat-soluble vitamins (*in*soluble in water)



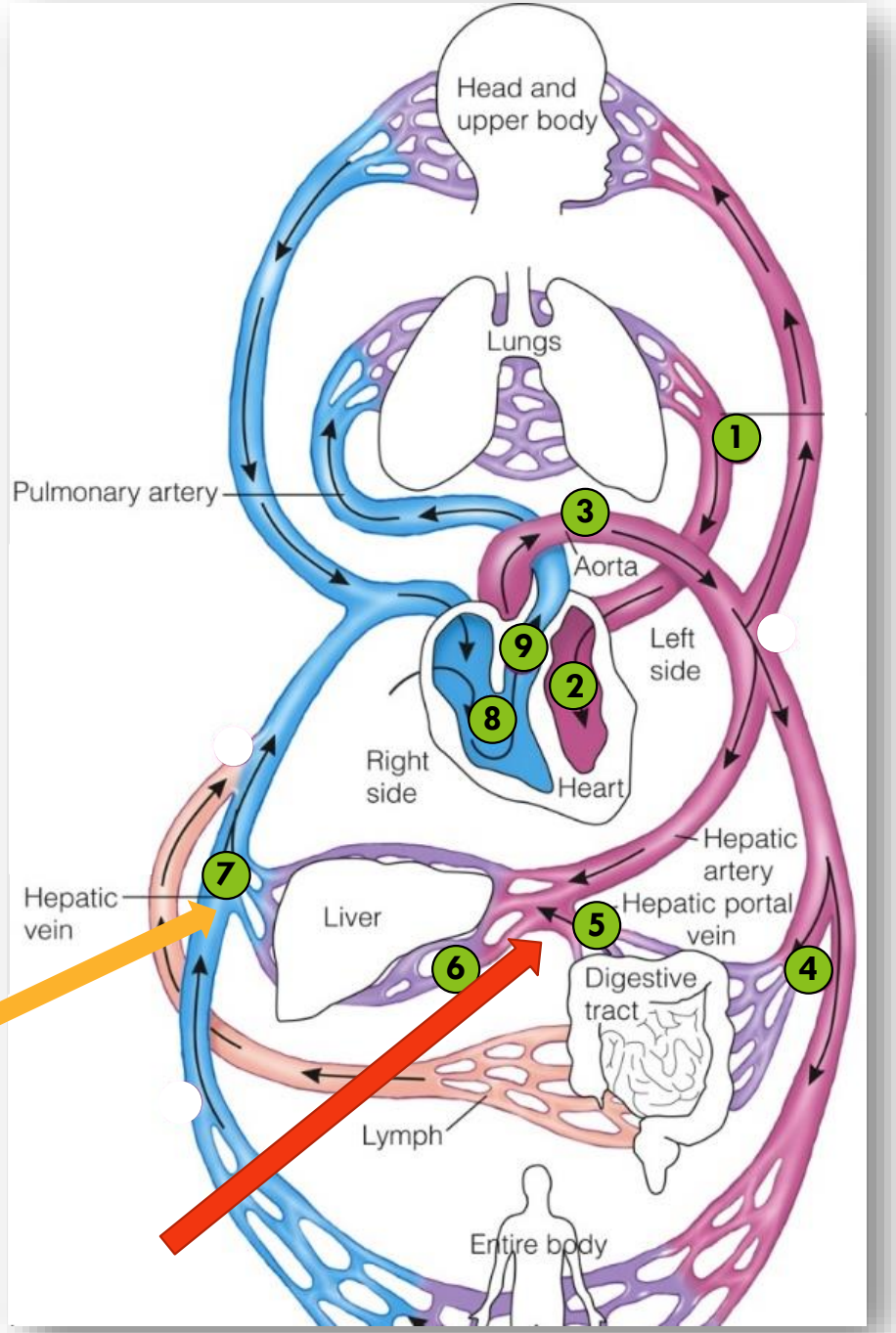
Vascular System

- Closed system: heart + blood vessels
- Delivers oxygen (O=red) and nutrients
- Removes carbon dioxide and waste via de-oxygenated blood (DO=blue)
- Normal blood flow:
  - Blood (from lungs to heart)
  - Heart
  - Arteries (A=away)
  - Capillaries → "Exchange zone"
  - Veins
  - Heart
  - Blood (to lungs)



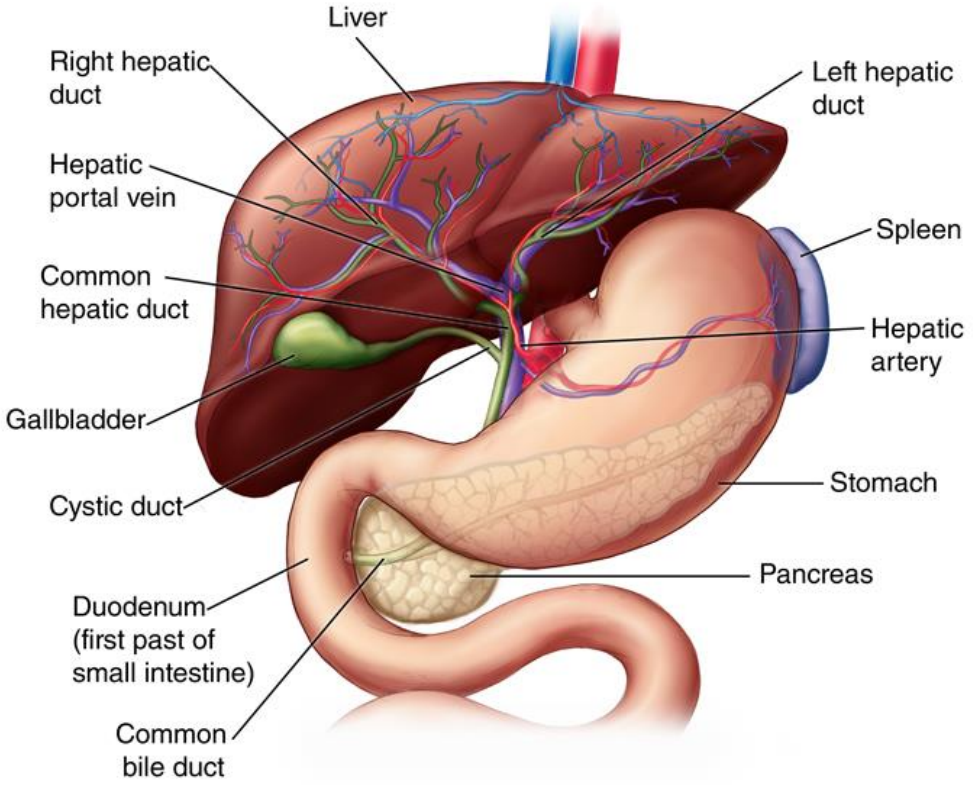
Vascular System

- Special route for digestive system blood:
  1) Blood (from lungs to heart)
  2) Heart
  3) Arteries (aorta)
  4) Capillaries (in small intestine)
  5) Hepatic Portal Veins
  6) Capillaries (in liver)
  7) Hepatic Vein
  8&9) Heart and Blood



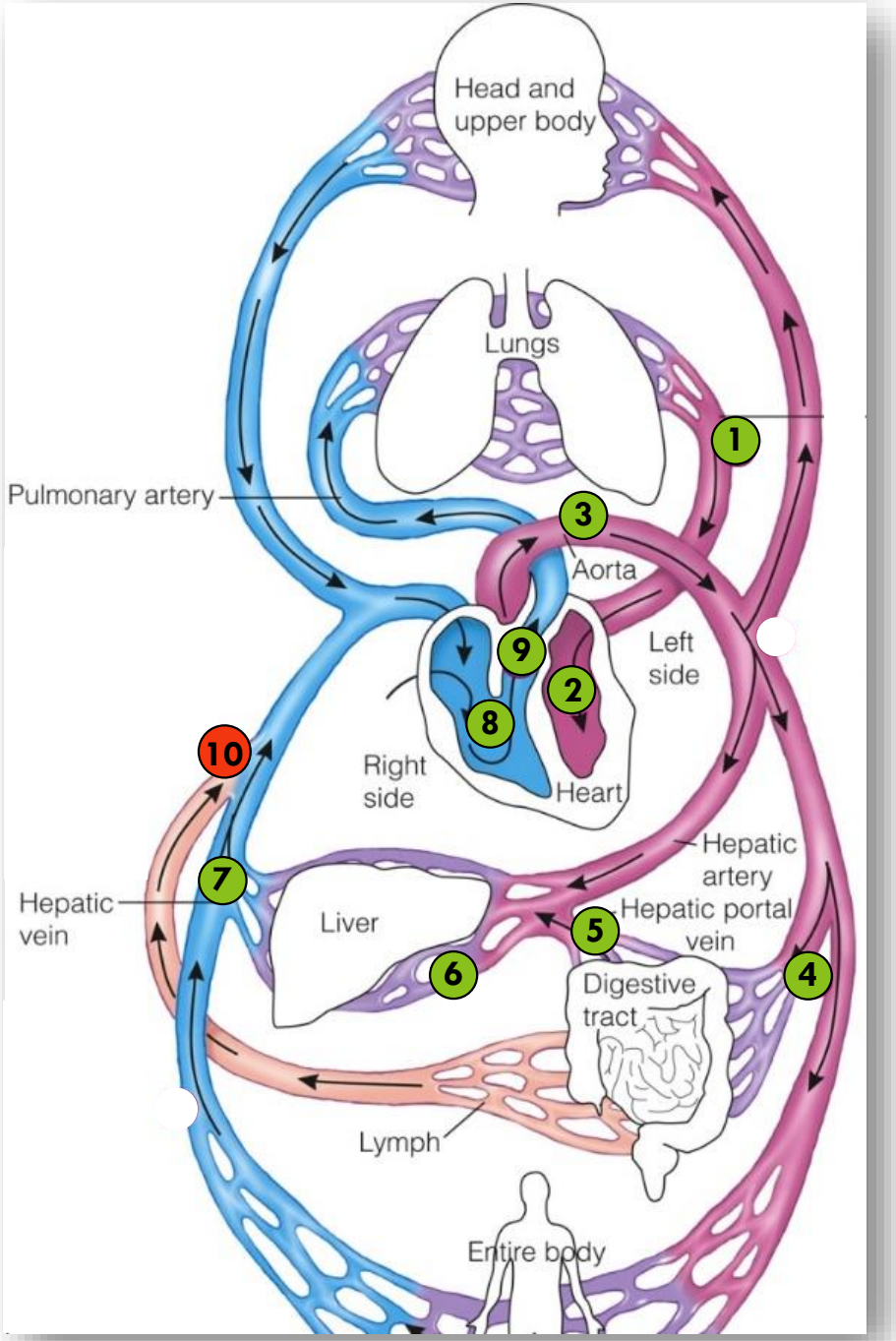
Liver = SUPERHERO

- 1st to receive nutrients from GI tract (before heart)
- Largest solid organ in the body (3 lbs)
- Prepares absorbed nutrients for use in body
- Filters blood to detoxify harmful substances (alcohol, drugs, bacteria, byproducts, etc.)
- Produces bile
- Storage site for glucose (glycogen) and micronutrients
- Regulates production of proteins
- 500+ vital jobs!



The Lymphatic System

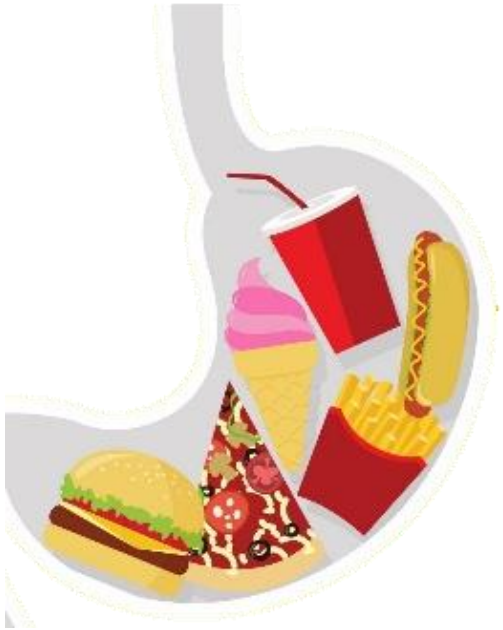
- One-way route, flows toward heart
- 3 main functions:
  - Return of excess body fluid back to blood
  - Removal of microorganisms
  - Absorption of fats and fat-soluble vitamins
- Lymph vessels connect into bloodstream (10) (near the heart, bypassing the liver)



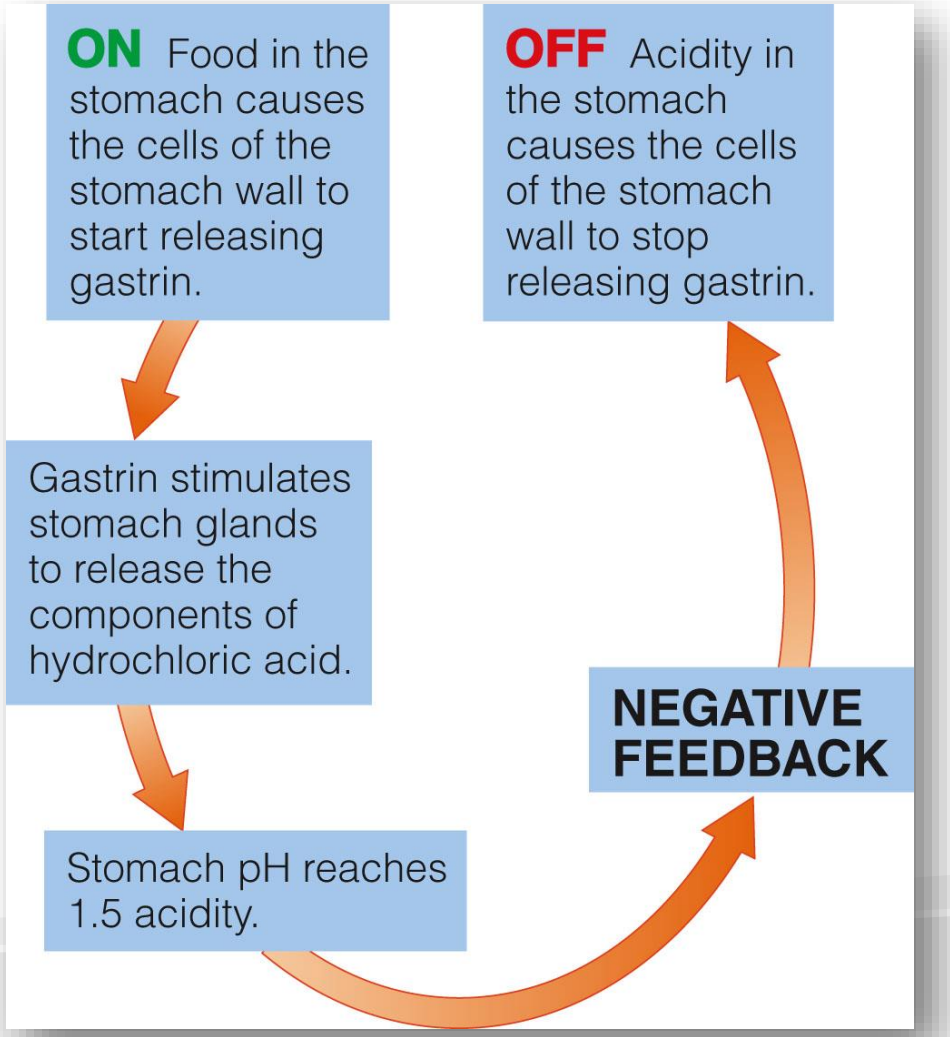
Regulation of GI Tract – Endocrine & Neural

- Homeostatic regulation: Any self-regulating process initiated by the body to maintain balance/stability while adjusting to changing conditions
  - Goal: "Business as usual"
  - Hormones (endocrine system) and nerve pathways (nervous system) coordinate all digestive and absorptive processes
    - Stimulation and inhibition of digestive secretions as food travels through GI tract
  - Feedback mechanisms
    - GI hormones regulate digestion and absorption with *negative* feedback loops
    - Example: home thermostat
      - **Gastrin:** secreted by cells in stomach wall
      - **Secretin:** secreted by cells in duodenum wall
      - **Cholecystokinin (CCK):** secreted by cells in intestinal wall

Regulation of GI Tract: Gastrin



<u>Hydrochloric Acid (HCl):</u> activates enzymes that break down protein



Whitney & Rolfes, Understanding Nutrition (15th ed.)

Regulation of GI Tract: Secretin

ON: Chyme in intestine causes the cells of the duodenal walls to start releasing secretin into the blood.

Secretin stimulates pancreas to release bicarbonate-rich juices.

Bicarbonate neutralizes acidic chyme.

OFF: Neutral pH of chyme no longer stimulates duodenal walls to release secretin.

NEGATIVE FEEDBACK

Bicarbonate (bicarb): decreases acid to optimize the environment for the digestive enzymes

Whitney & Rolfes, Understanding Nutrition (15th ed.)

Regulation of GI Tract: Cholecystokinin (CCK)

CCK stimulates pancreas to release bicarbonate and enzymes into small intestine.

ON: Fat in intestine stimulates the cells of the intestinal walls to start secreting CCK into the blood.

CCK stimulates gallbladder to contract and release bile into small intestine.

Fat in intestine is emulsified and begins to break down.

OFF: Partially digested fat no longer stimulates CCK release, gallbladder ceases contraction.

NEGATIVE FEEDBACK

Whitney & Rolfes, Understanding Nutrition (15th ed.)

Regulation of GI Tract

TABLE 3-1 The Primary Actions of Selected GI Hormones

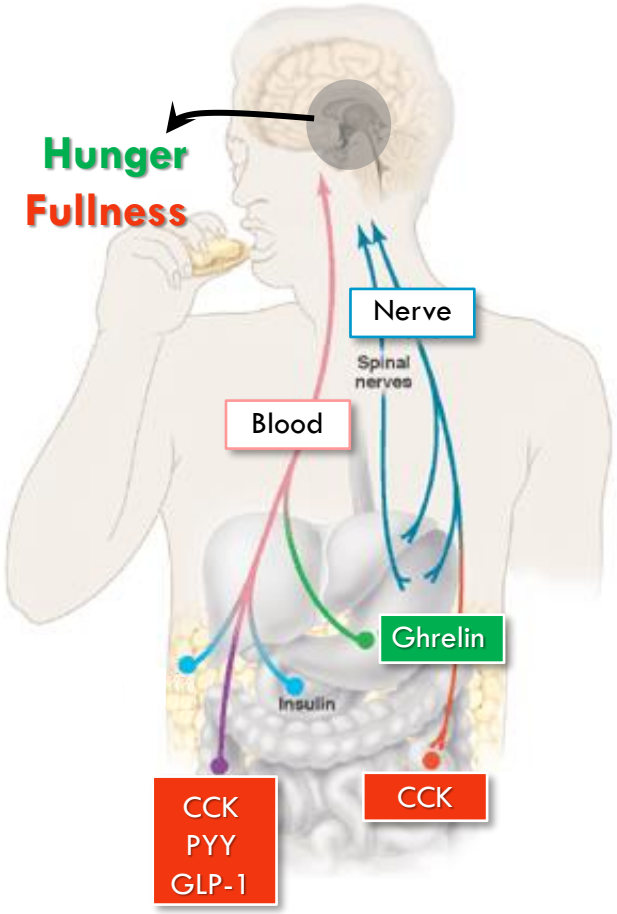
Hormone	Responds to	Secreted from	Stimulates	Response
Gastrin	Food in the stomach	Stomach wall	Stomach glands	Hydrochloric acid secreted into the stomach
Secretin	Acidic chyme in the small intestine	Duodenal wall	Pancreas	Bicarbonate-rich juices secreted into the small intestine
Cholecystokinin	Fat or protein in the small intestine	Intestinal wall	Gallbladder	Bile secreted into the duodenum
			Pancreas	Bicarbonate- and enzyme-rich juices secreted into the small intestine

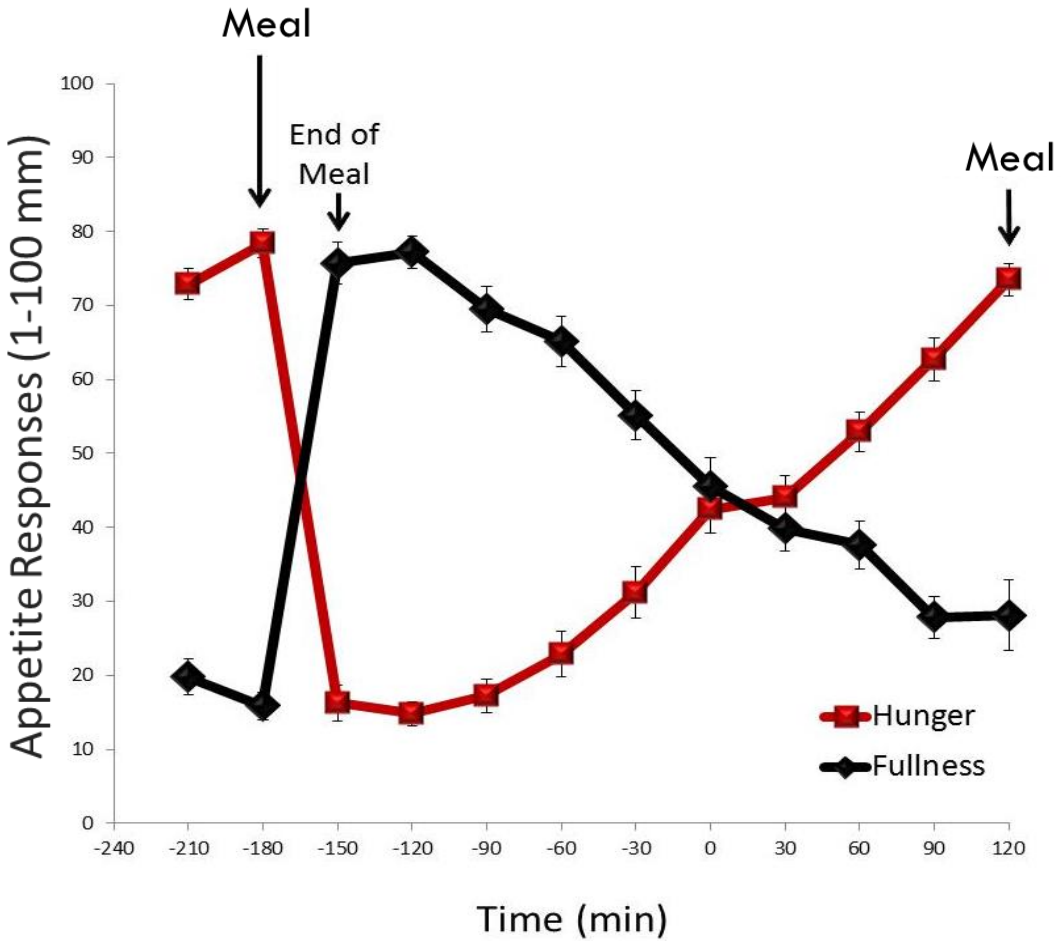
*Negative feedback loops: self-regulating system

Leidy, et al. 2010; Obesity; 18(9): 1725-1732

Regulation of Eating Behavior

Appetite Sensations



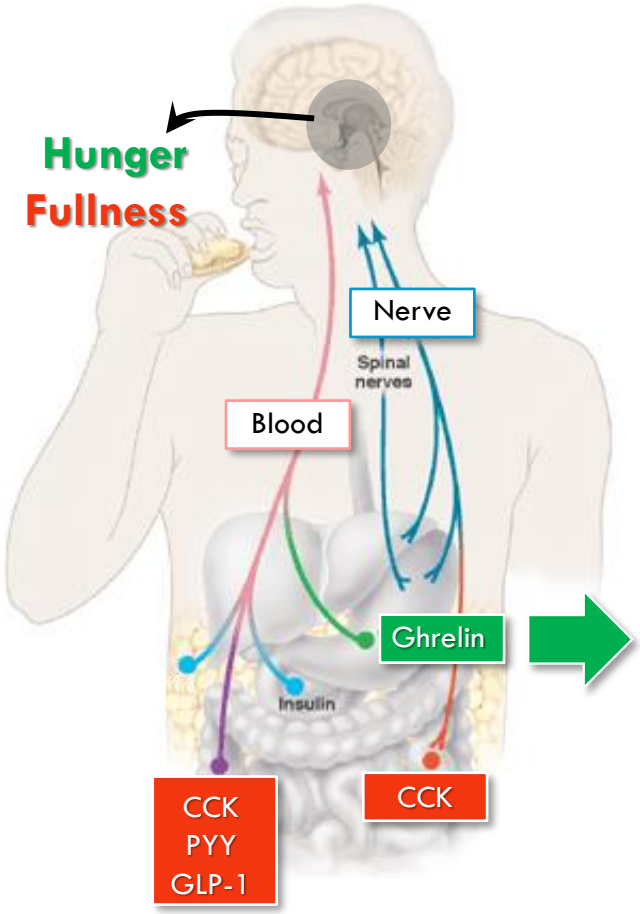


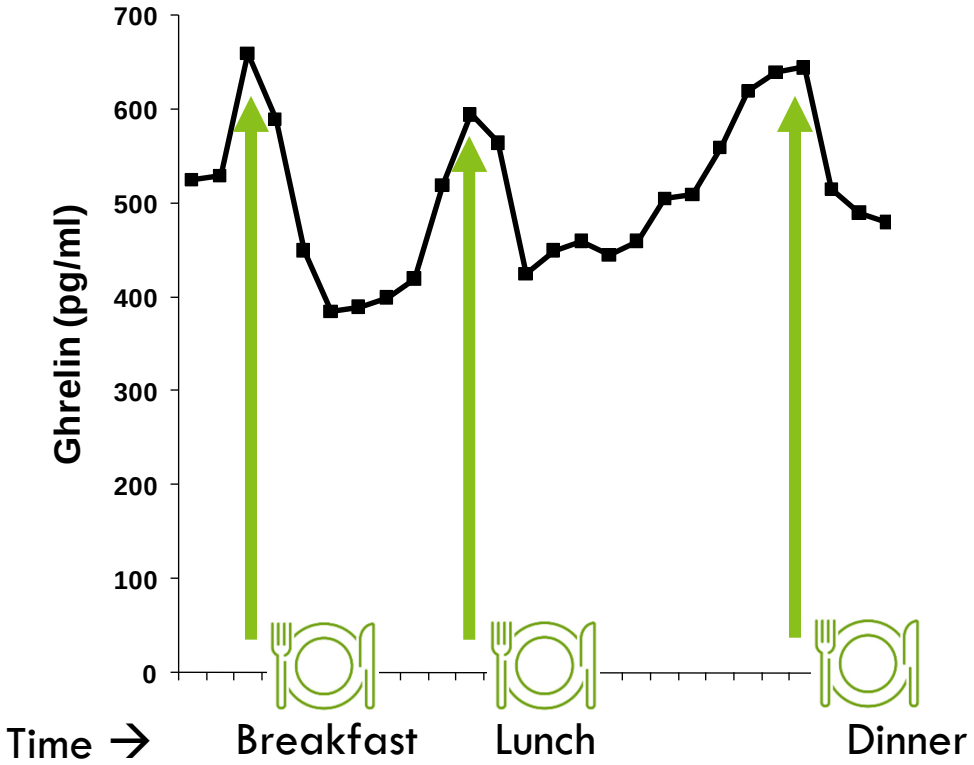
Homeostatic Signals

Leidy, et al. 2010; Obesity; 18(9): 1725-1732

Regulation of Eating Behavior

Appetite Sensations



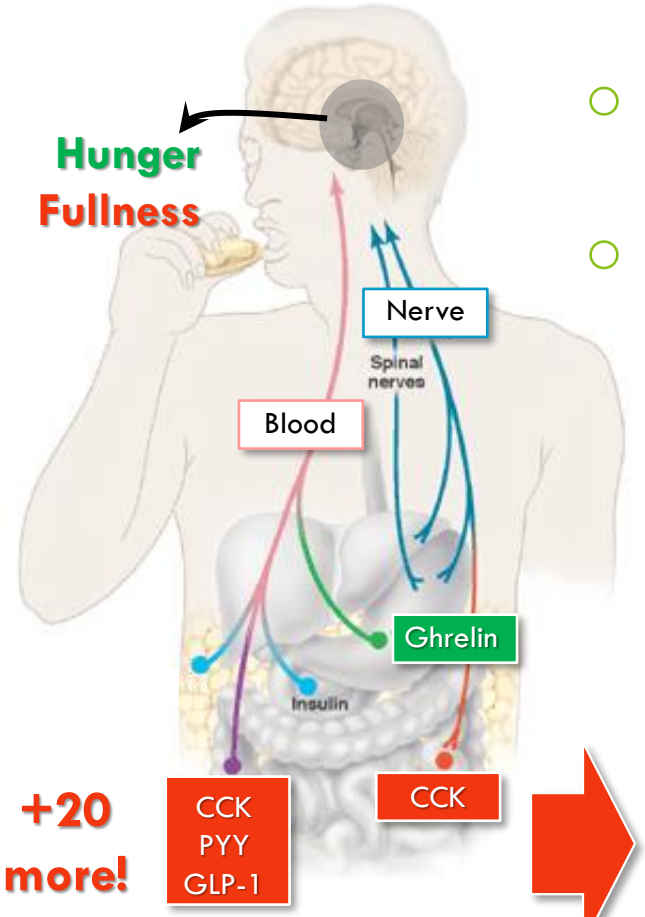


Homeostatic Signals

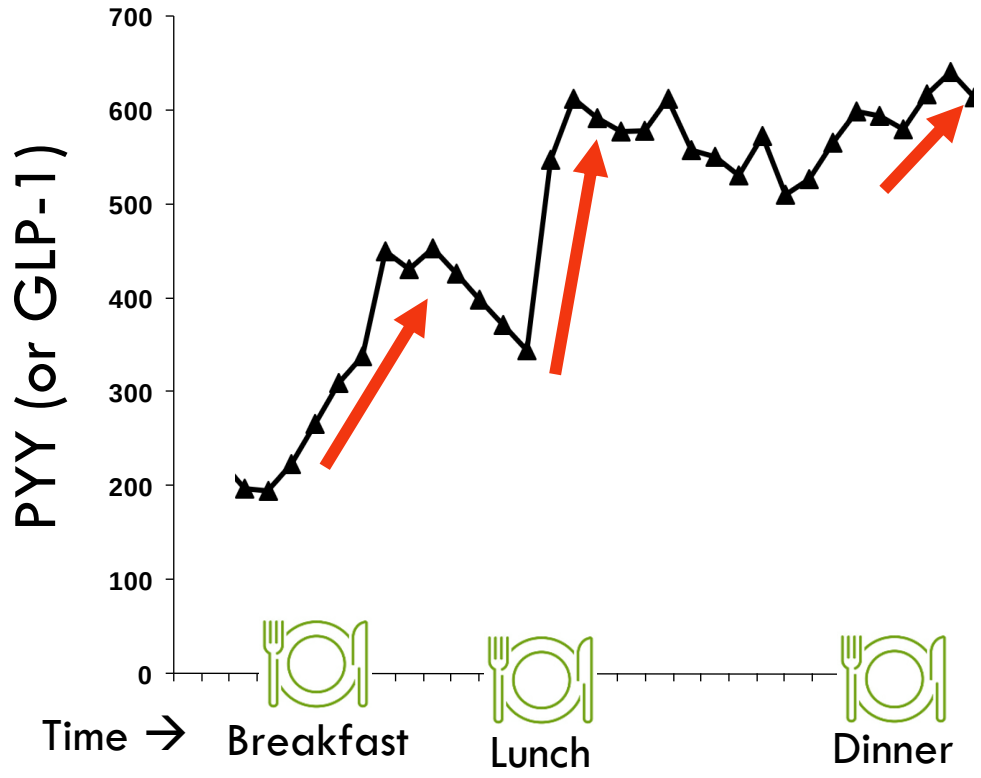
Leidy, et al. 2010; Obesity; 18(9): 1725-1732

Regulation of Eating Behavior

Appetite Sensations

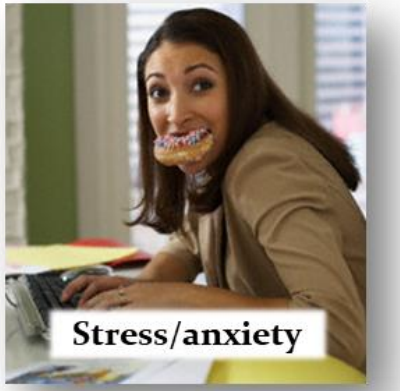


- Within Meal (Satiation): CCK
- Between Meals (Satiety): GLP-1& PYY



Homeostatic Signals

…so why do we overeat?



- External cues can override our satiety signals and stimulate “reward eating”

And can we actually get "addicted" to food?

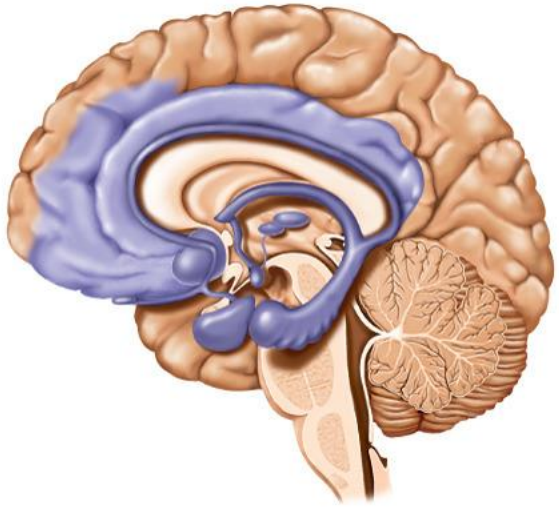
- Specific brain regions are highly sensitive and responsive

Is food a drug?

<u>Cortico-Limbic regions</u>:

Reward areas (purple)

Release dopamine = pleasure



Activated by food and drugs

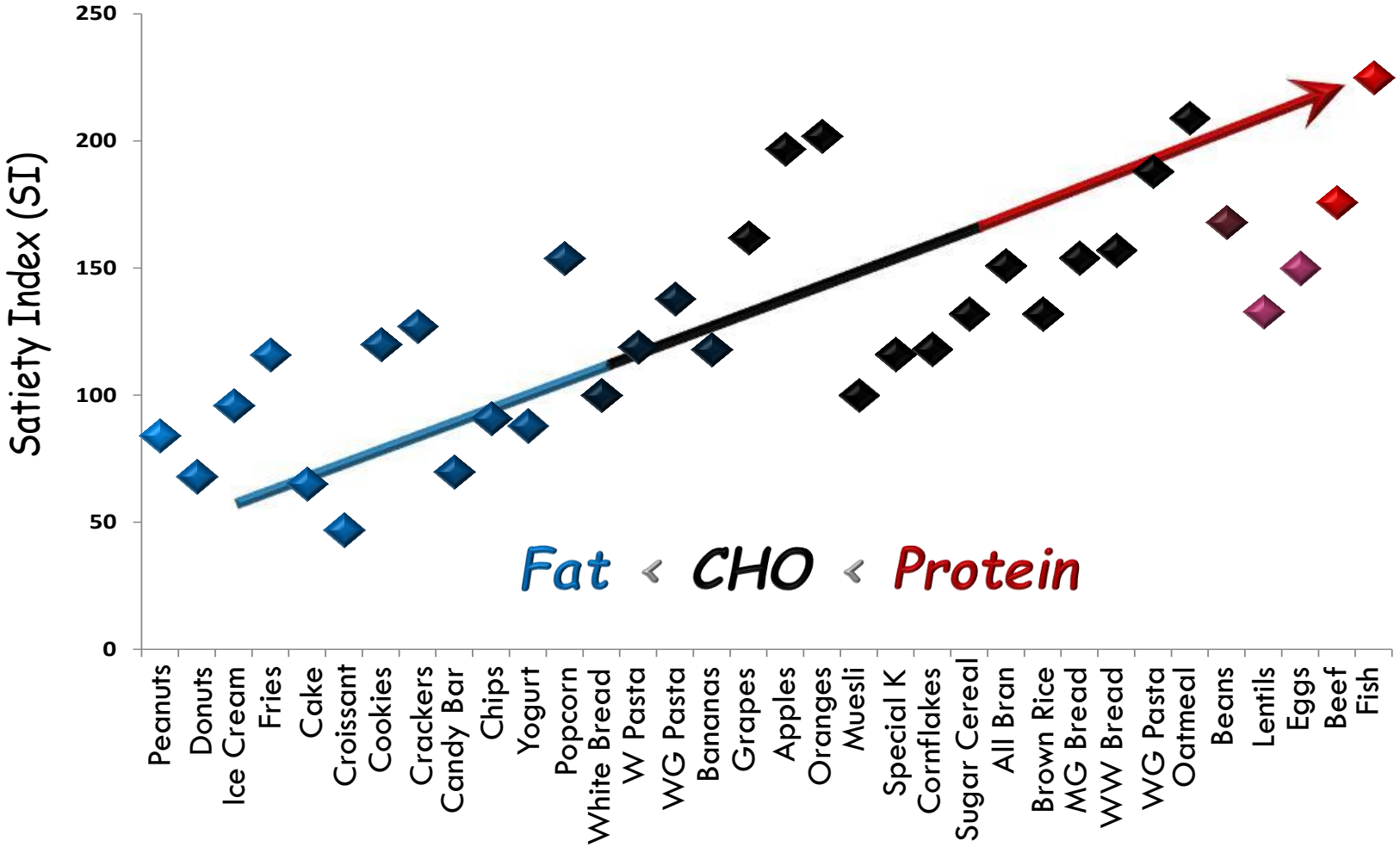
Impact of Addiction
(fMRI Brain Imaging)

Red areas = increased dopamine (reward)

Holt et al., 1995 A Satiety Index of Common Foods; European Journal of Clinical Nutrition; 675-690

Stay full!

- Satiety-stimulating ("filling") foods can reduce food cravings + prevent overeating



Satiating Foods/Beverages

- Protein
- Fiber
- Foods (vs. beverages)