Chapter 15

Gastrointestinal System

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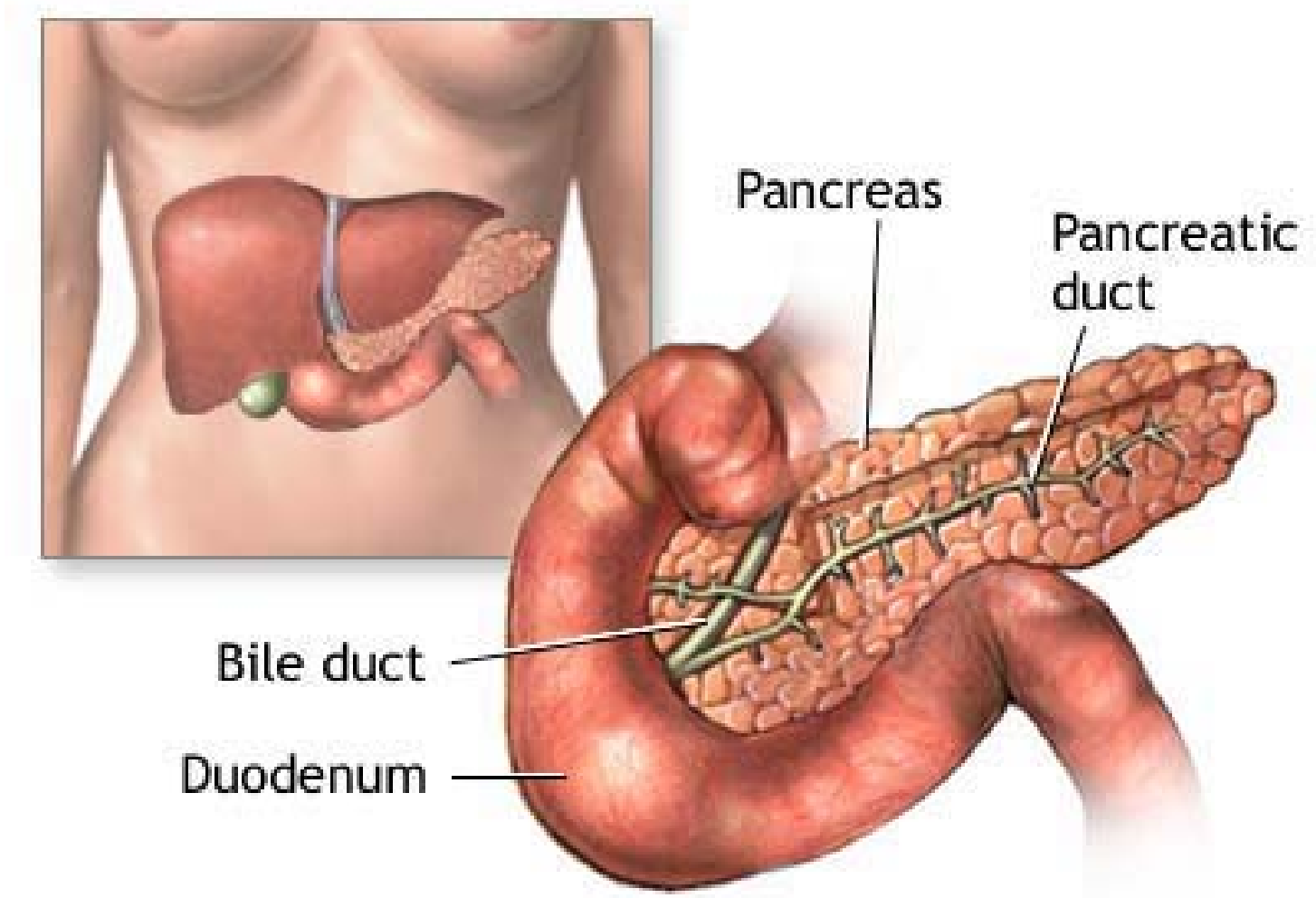
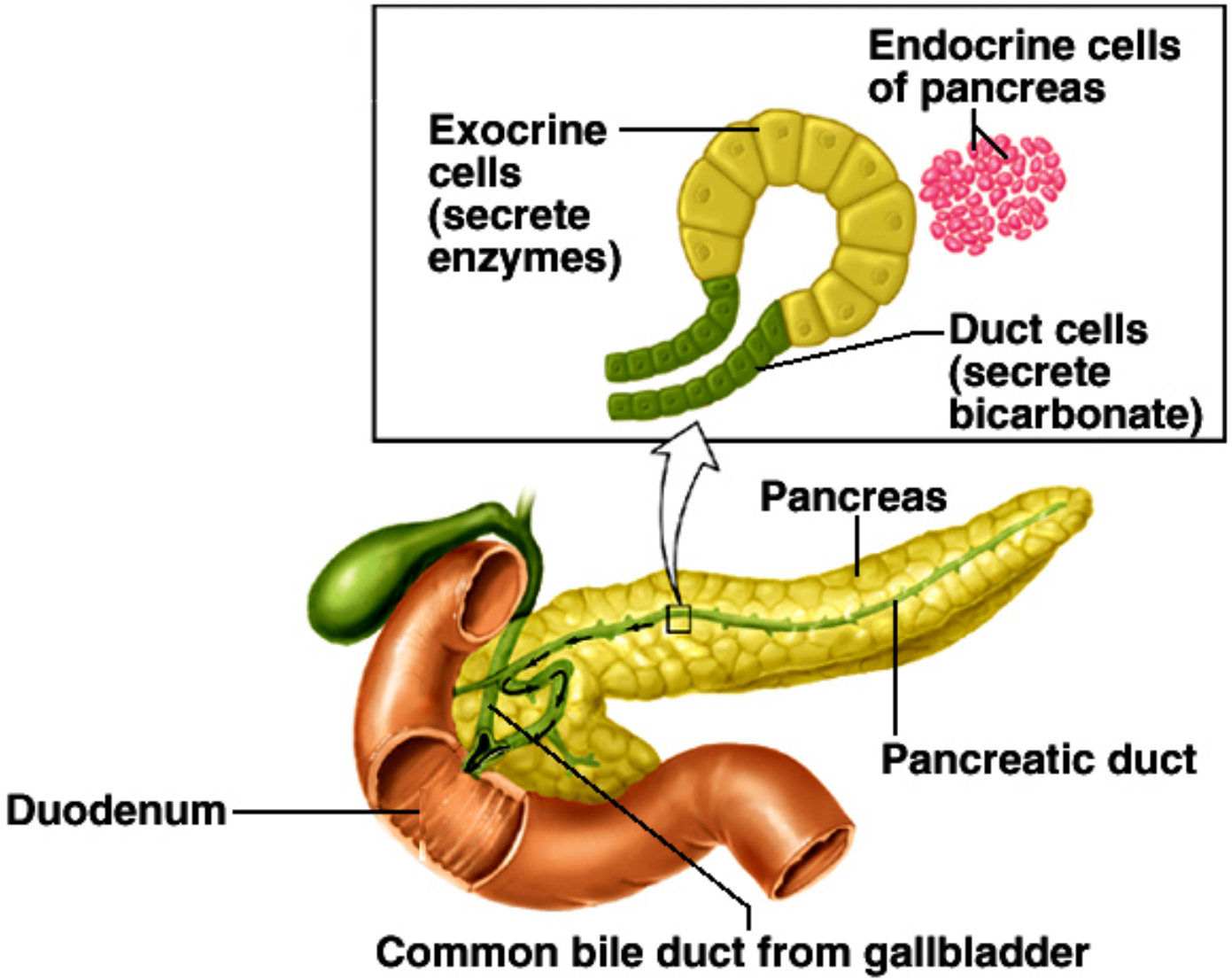
Pancreatic Secretion



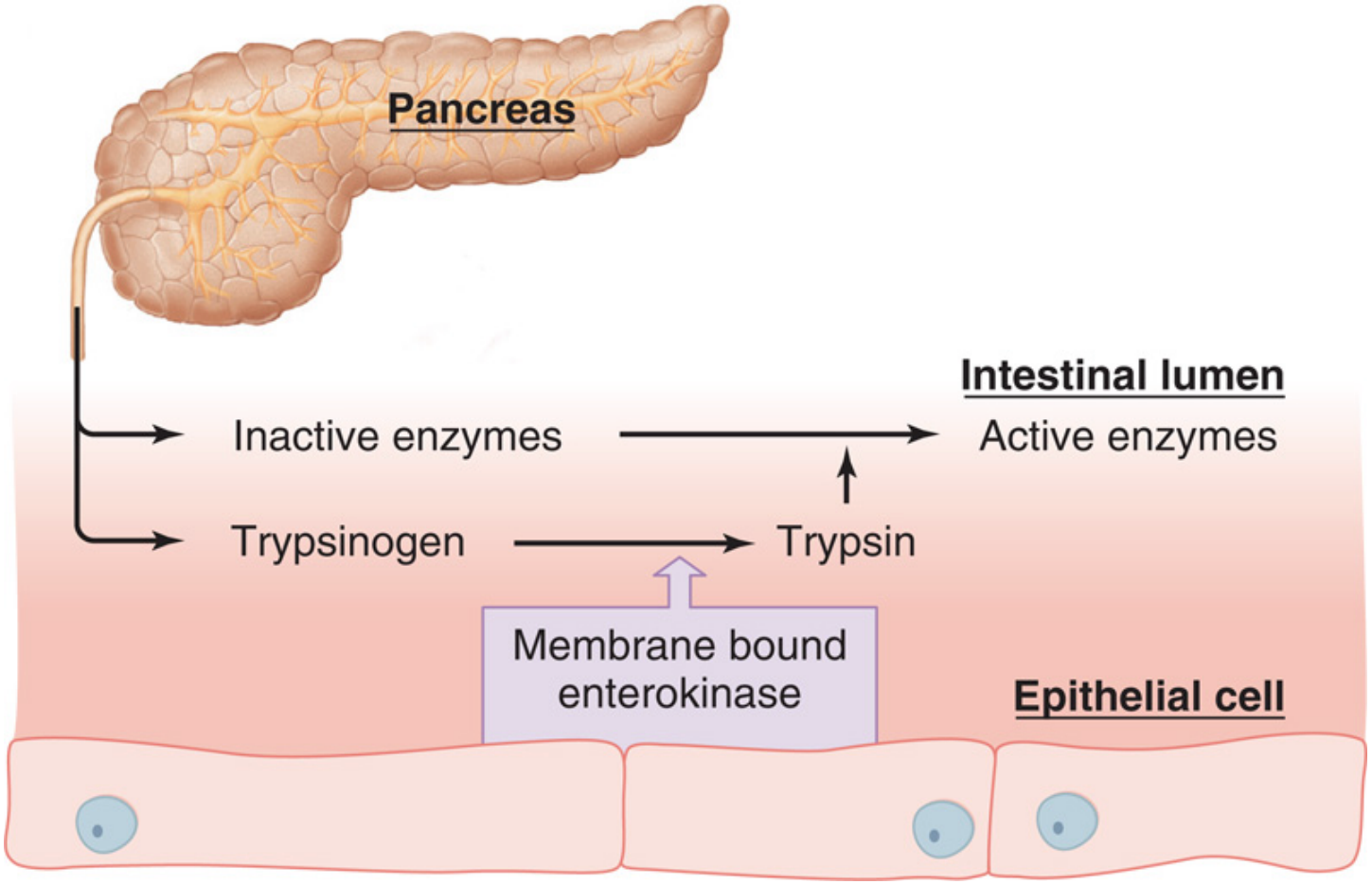


The exocrine cells in the pancreas play a central role in the production of digestive enzymes; the endocrine functions of the pancreas will be discussed at length in Chapter 16.

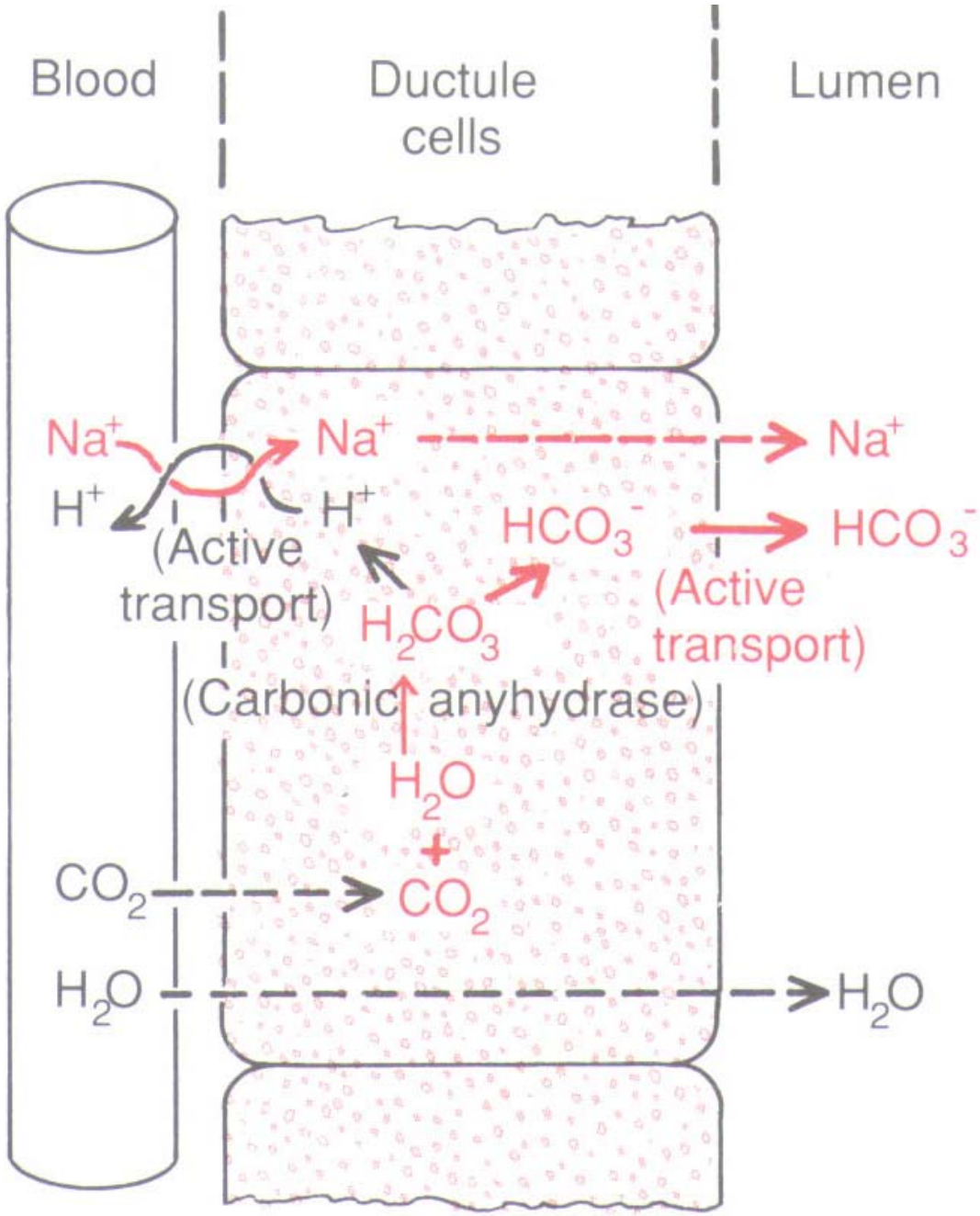
(I) Pancreatic juice

- pH 7.8~8.4
- ~1500 ml/day
- Isosmotic
- Components:
  - Pancreatic digestive enzymes: secreted by pancreatic acini
  - Sodium bicarbonate: secreted by small ductules and larger ducts

Were digestive enzymes synthesized in their active form, they would digest the very cells that make them. Hence, inactive precursors (e.g., trypsinogen) become activated (trypsin).



- Secretion of bicarbonate ions
  - Secreted by the epithelial cells of the ductules and ducts that lead from acini
  - Up to 145mmol/L in pancreatic juice (5 times that in the plasma)
  - Neutralizing acid entering the duodenum from the stomach

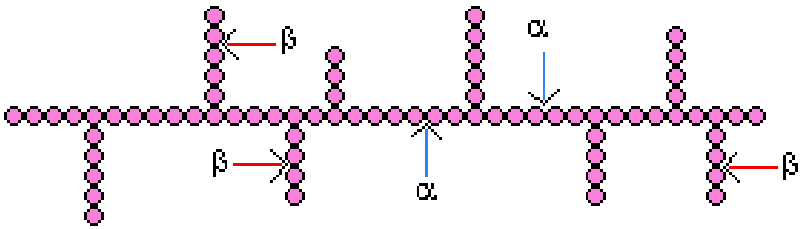

Blood
Ductule cells
Lumen
Na^+
H^+
(Active transport)
Na^+
H^+
HCO_3^-
H_2CO_3
(Carbonic anyhydrase)
H_2O
+
CO_2
CO_2
H_2O
Na^+
HCO_3^-
(Active transport)
H_2O

- Secretion of pancreatic digestive enzymes
  - Carbohydrates -- Pancreatic amylase
  - Fat
    - Pancreatic lipase
    - Cholesterol esterase
    - Phospholipase
  - Proteins
    - Trypsinogen
    - Chymotrypsinogen
    - Procarboxypolypeptidase
    - Proelastase

α = alfa-amylase

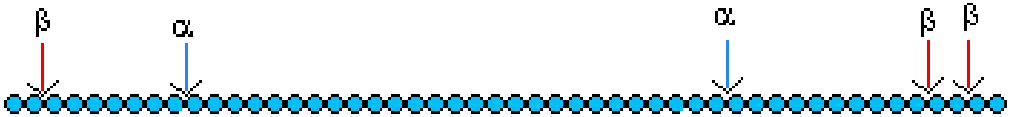
β= beta-amylase

(effect both amylases on starch)



amylopectine

Starches



amylose

Pancreatic amylase

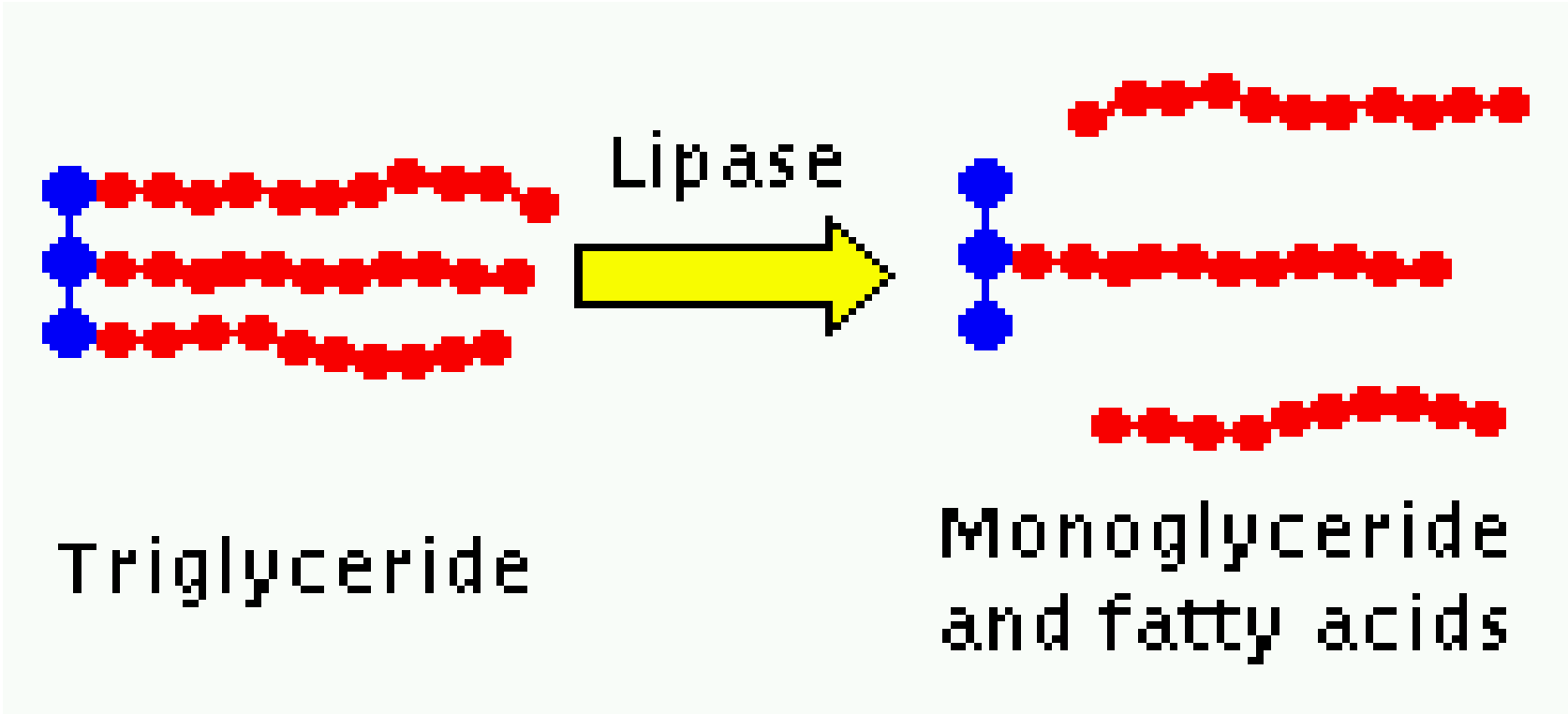
dextrine

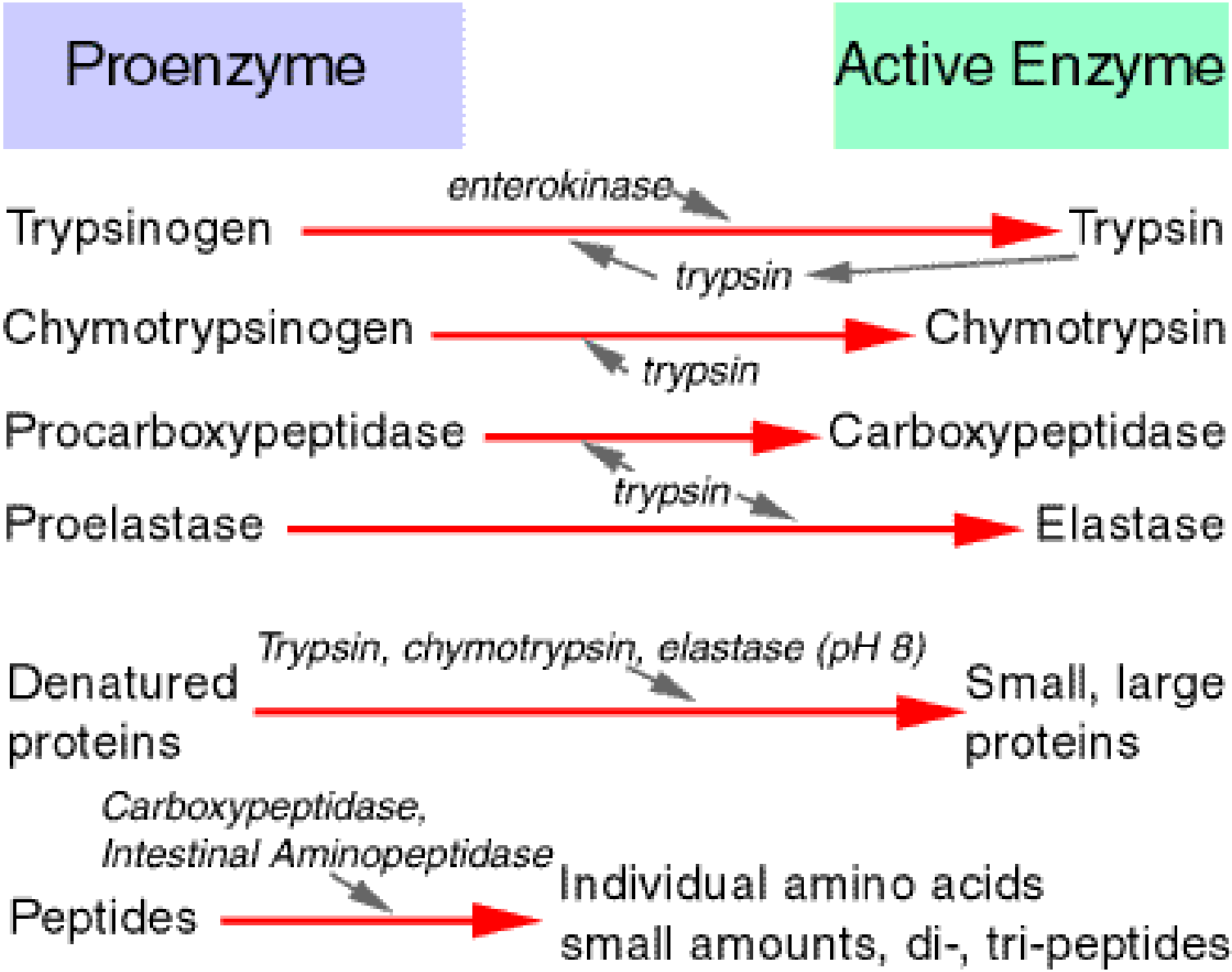
maltotriose

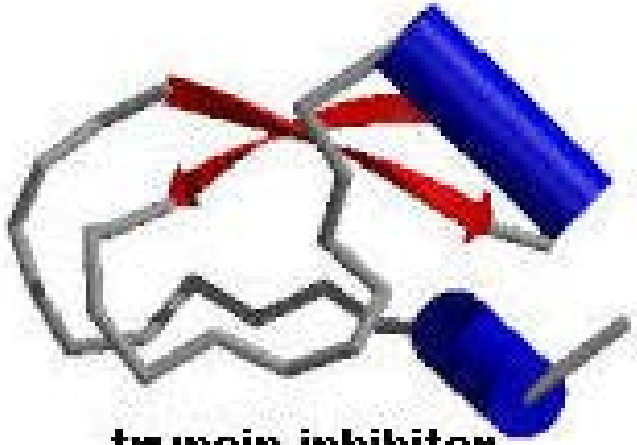
maltose

glucose

Maltose and
glucose polymers

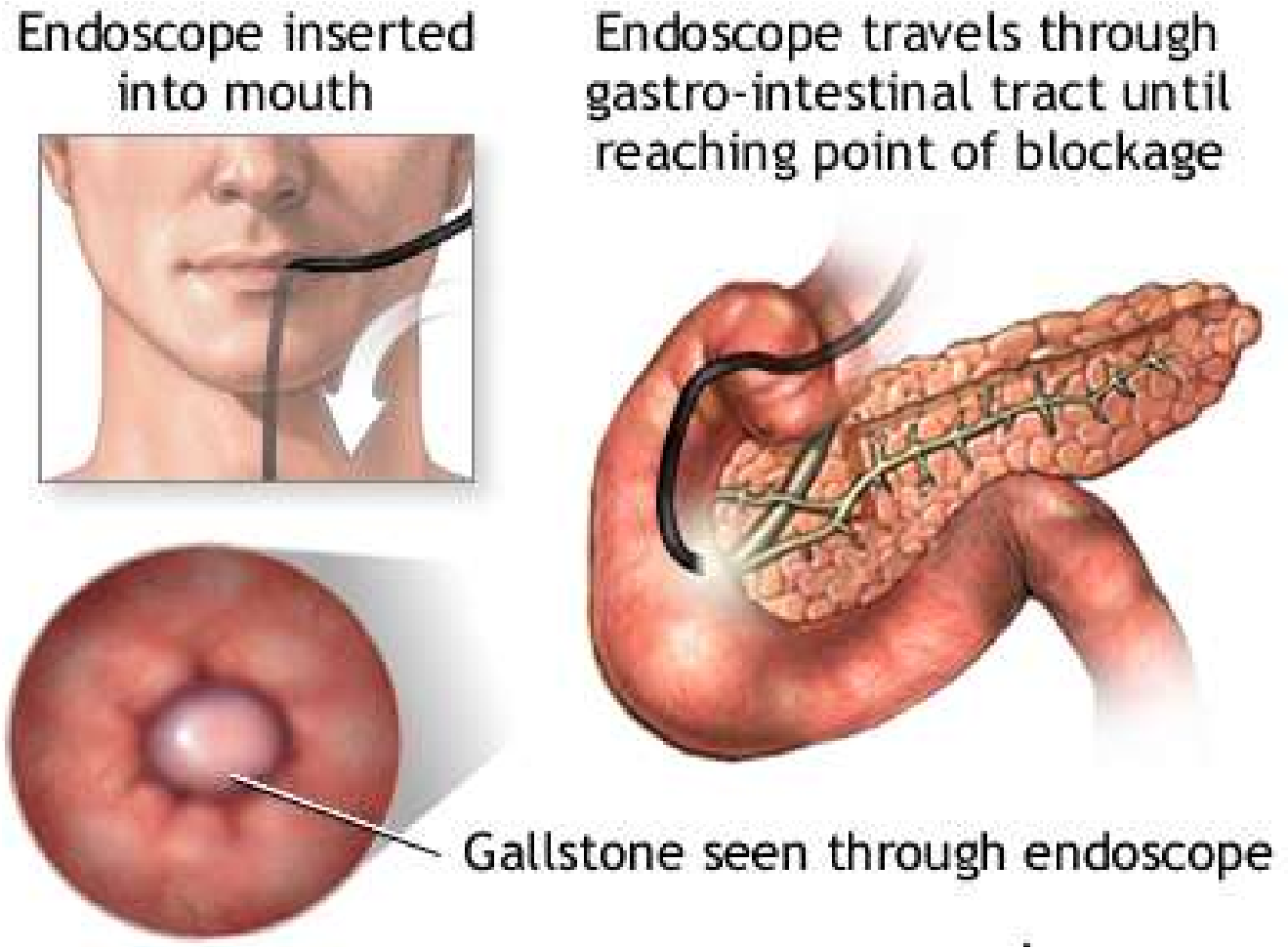

Lipase
Triglyceride
Monoglyceride
and fatty acids


Proenzyme
Active Enzyme
enterokinase
Trypsinogen
Trypsin
trypsin
Chymotrypsinogen
Chymotrypsin
trypsin
Procarboxypeptidase
Carboxypeptidase
trypsin
Proelastase
Elastase
Trypsin, chymotrypsin, elastase (pH 8)
Denatured proteins
Small, large proteins
Carboxypeptidase,
Intestinal Aminopeptidase
Peptides
Individual amino acids
small amounts, di-, tri-peptides

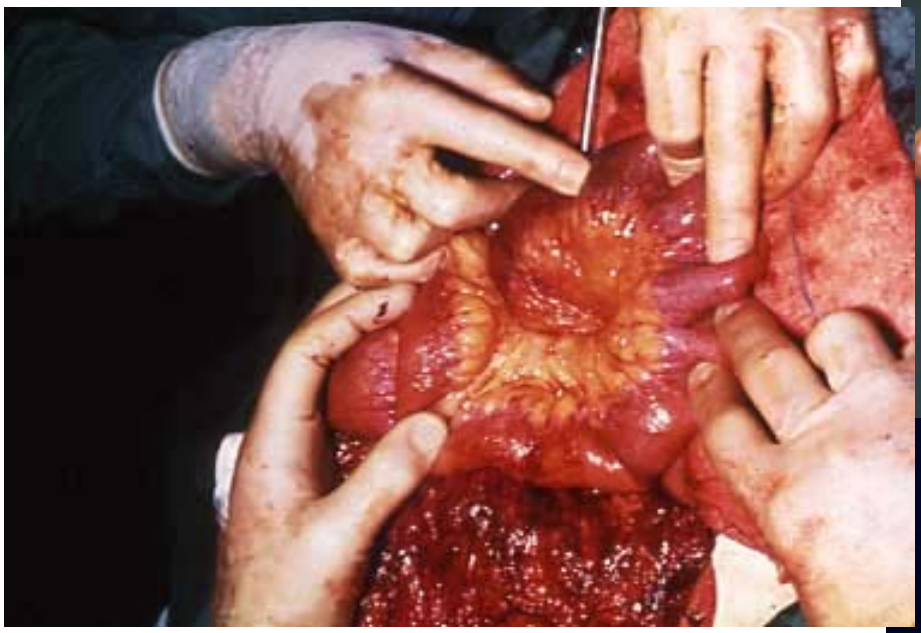


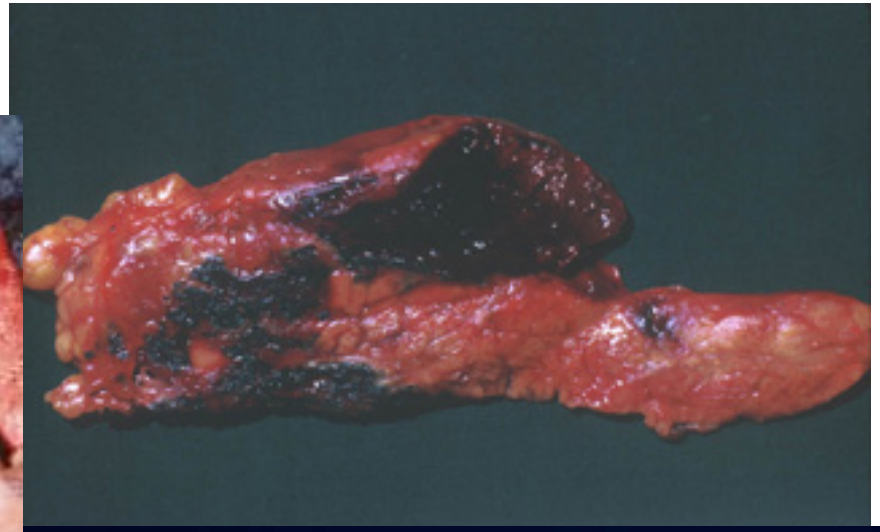
- Trypsin Inhibitor
  - Inhibits the activity of trypsin and thus guards against the possible activation of trypsin and the subsequent autodigestion of the pancreas

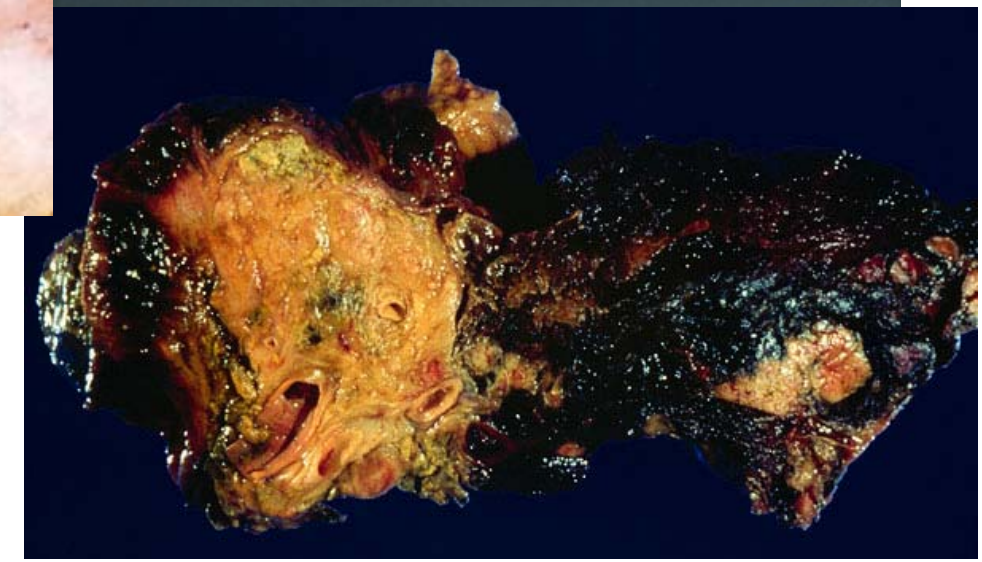
Acute pancreatitis



Acute pancreatitis



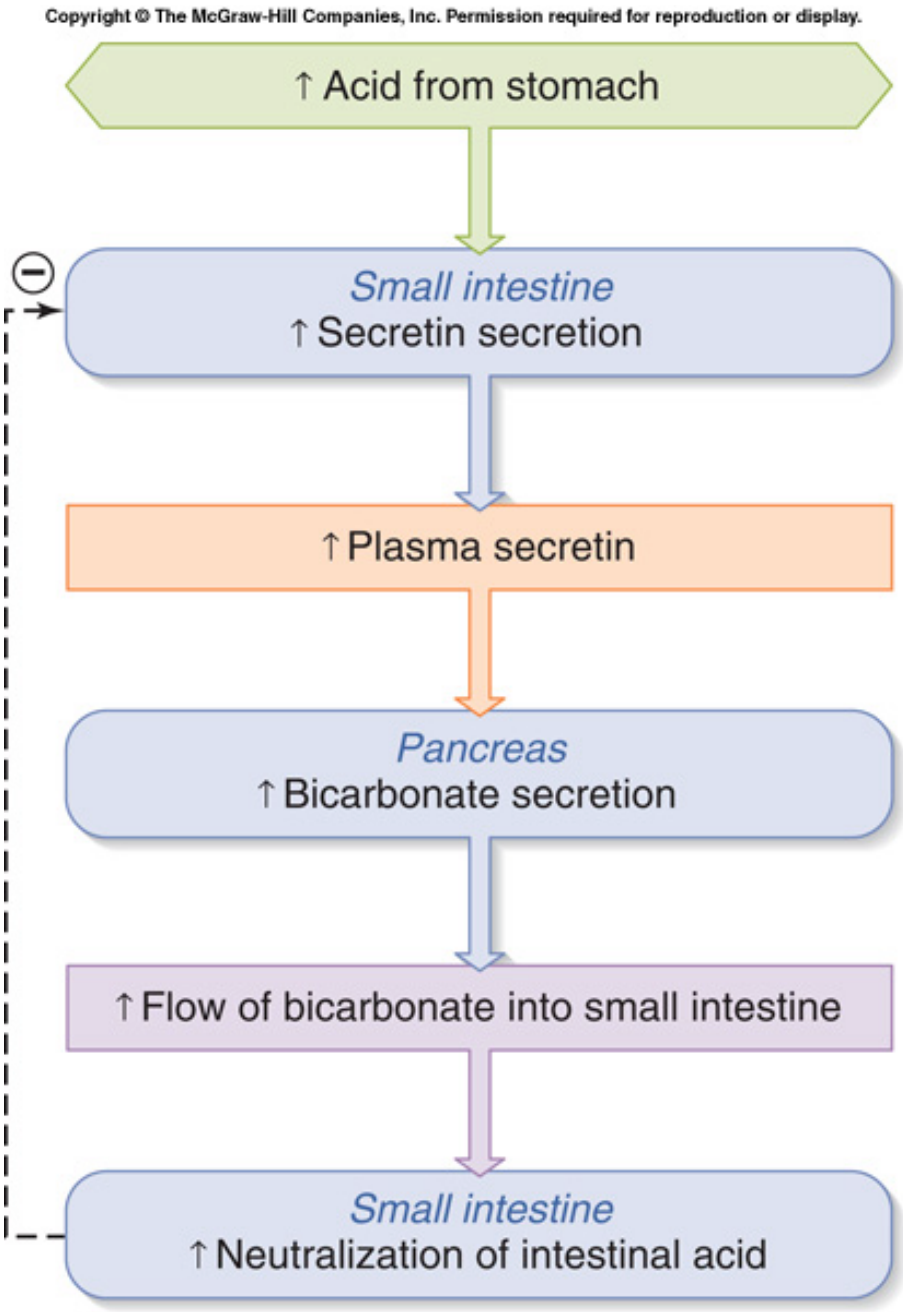




(II) Regulation of pancreatic secretion

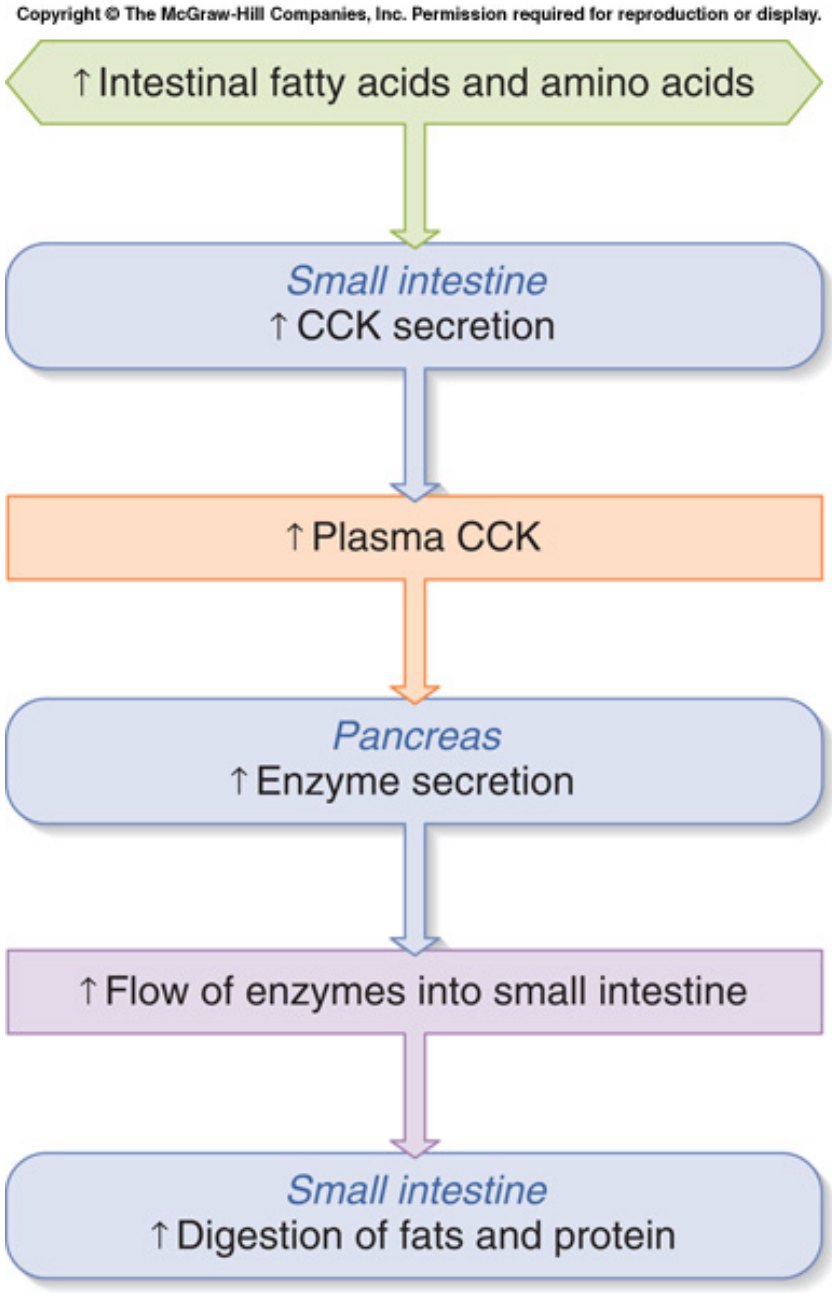
- Basic stimuli that cause pancreatic secretion
  - Ach
  - Cholecystokinin:
    - Secreted by I cells
    - Stimulates the acinar cells to secrete large amounts of enzymes
  - Secretin:
    - Released by S cells
    - Acts primarily on the duct cells to stimulate the secretion of a large volume of solution with a high HCO_3^- concentration

Secretin's receptors are found in the pancreas, which responds with additional bicarbonate delivery: gastric motility and secretion are inhibited.



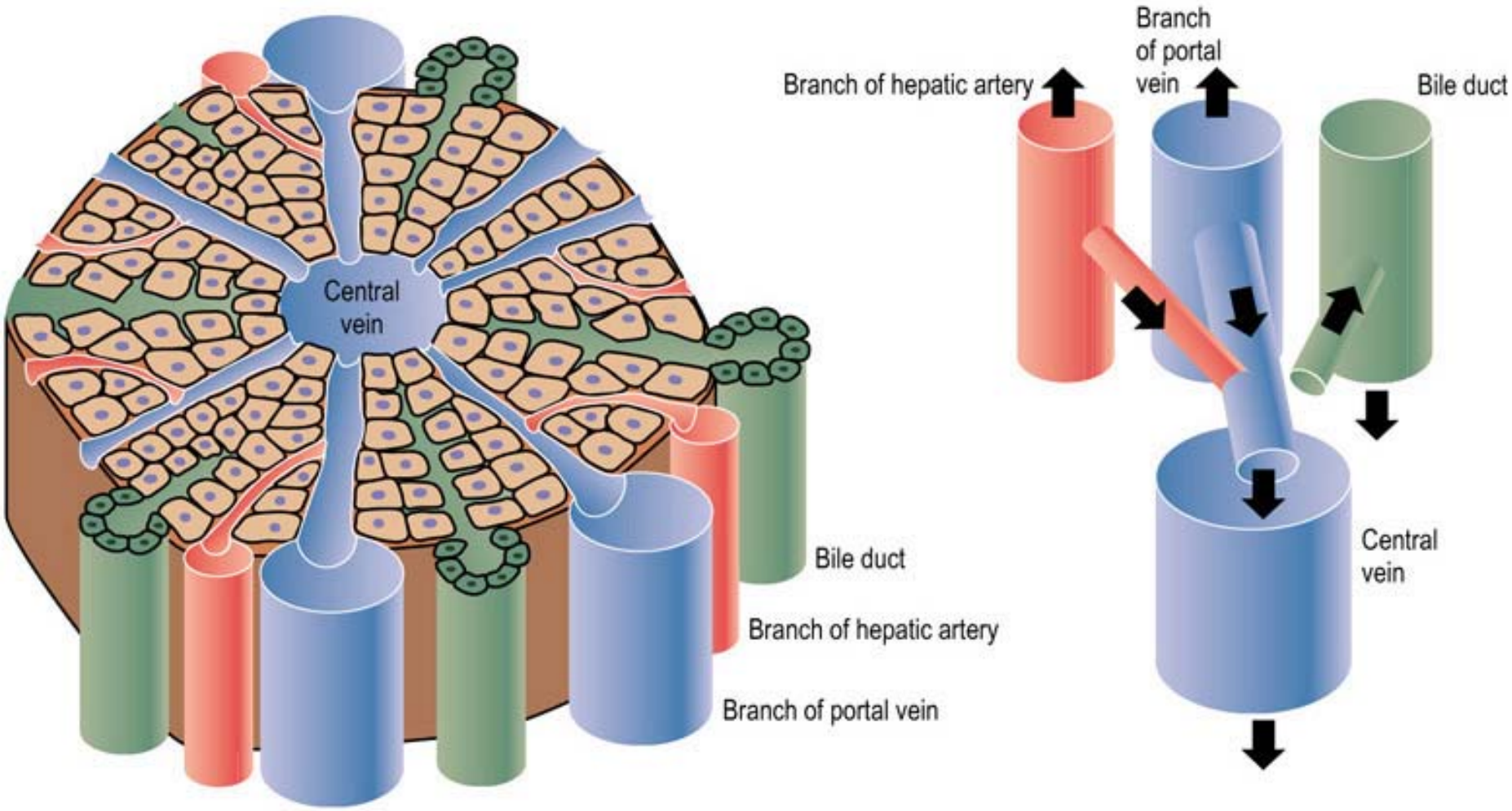
Cholecystokinin's receptors are located:

- **in the pancreas, which responds with additional enzyme delivery**
- **in the gallbladder, which contracts to deliver more bile**
- **in the sphincter of Oddi, which relaxes to facilitate delivery of the enzymes and bile salts**



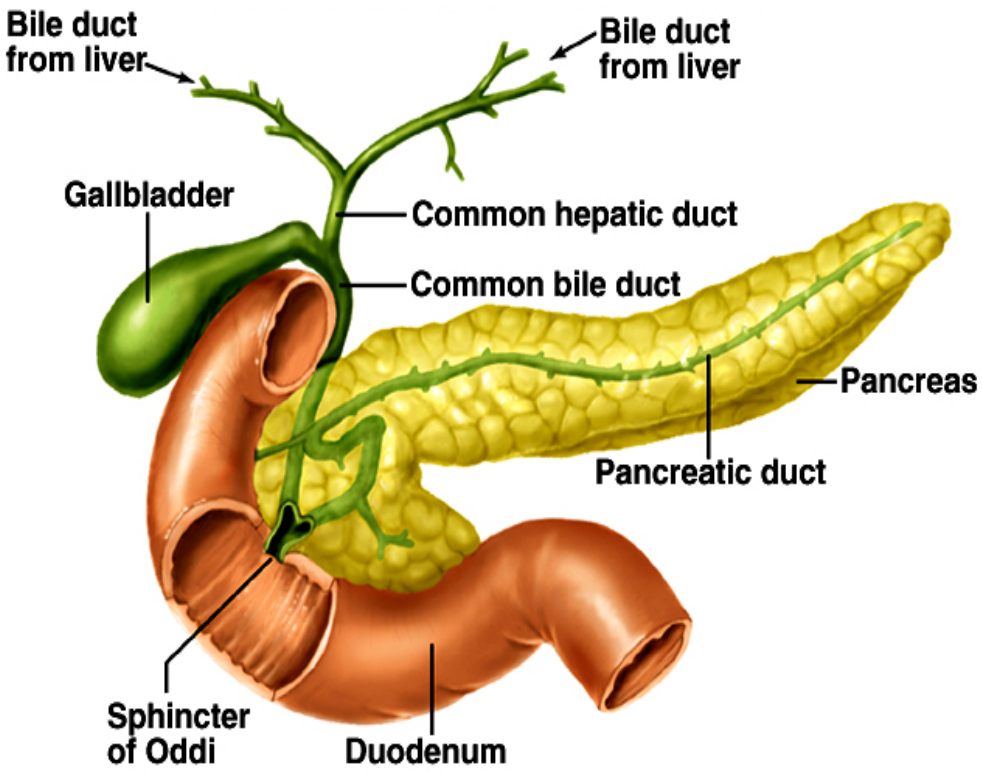
- Phases of pancreatic secretion
  - Cephalic Phase: taste of food- ‘long’ parasympathetic pathways
  - Gastric Phase: distension of stomach- ‘long’ parasympathetic reflex pathways
  - Intestinal Phase ★
    - The most important regulators are CCK and secretin
    - Acid, fats, amino acids, peptides and protein are the main stimulus for pancreatic production and secretion

Bile Secretion and Liver Function



Composition of bile

- HCO_3^-
- Bile salts
- Lecithin
- Cholesterol
- Bile pigments
- Trace metals …

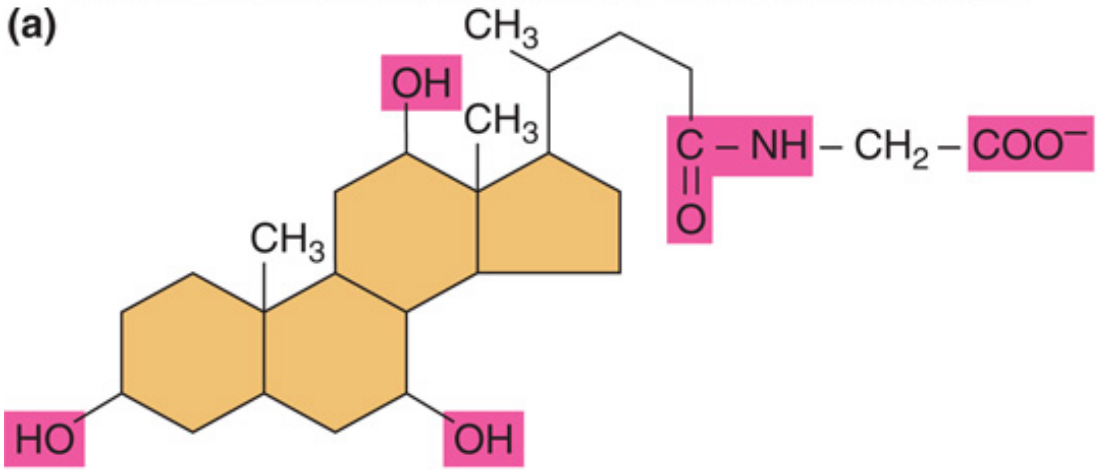


Function of bile

(1) Bile are critical for digestion and absorption of fats and fat-soluble vitamins

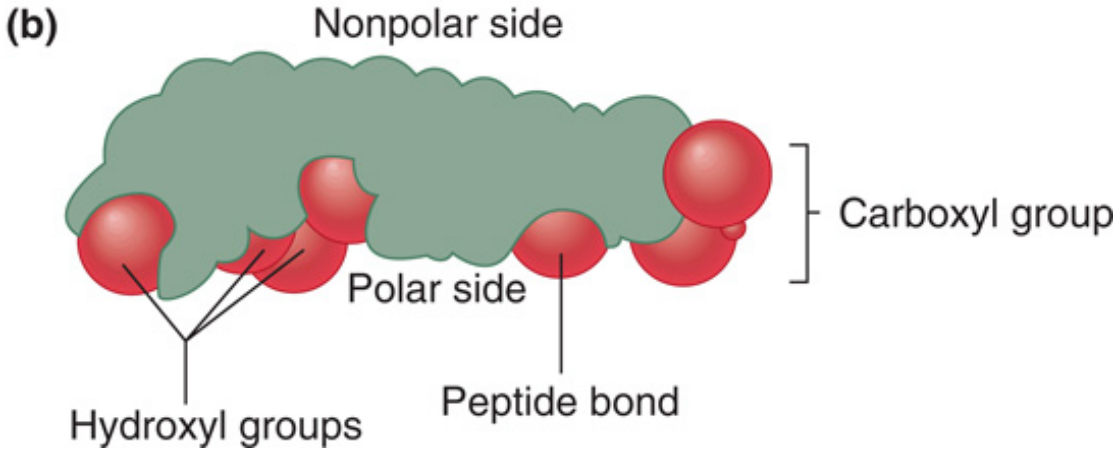
- Bile salts are facial amphipathic

A molecular model of a bile salt, with the cholesterol-derived "core" in yellow.



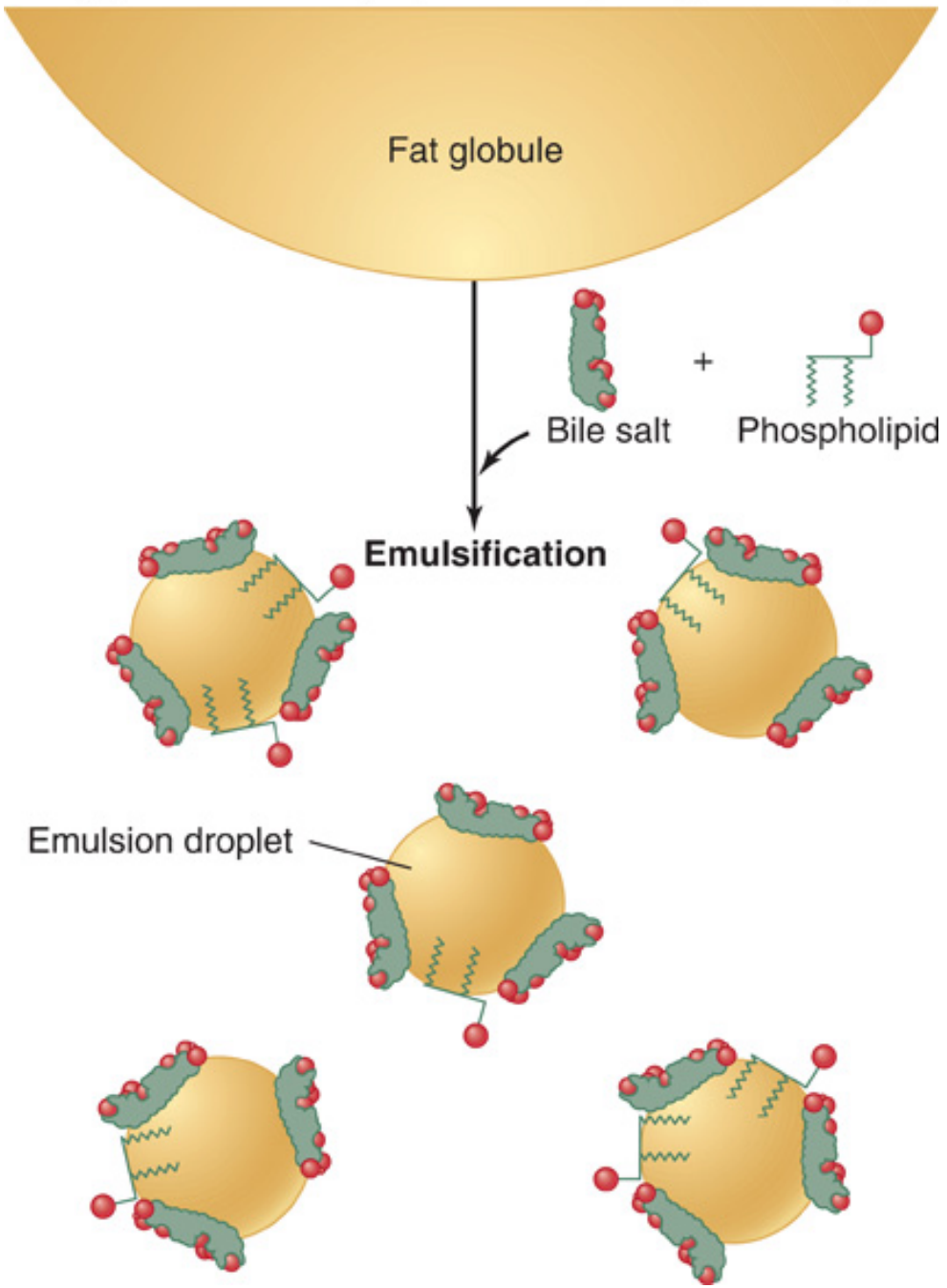
Bile salt (glycocholic acid)

A space-filling model of a bile salt. The non-polar surface helps emulsify fats, and the polar surface promotes water solubility.

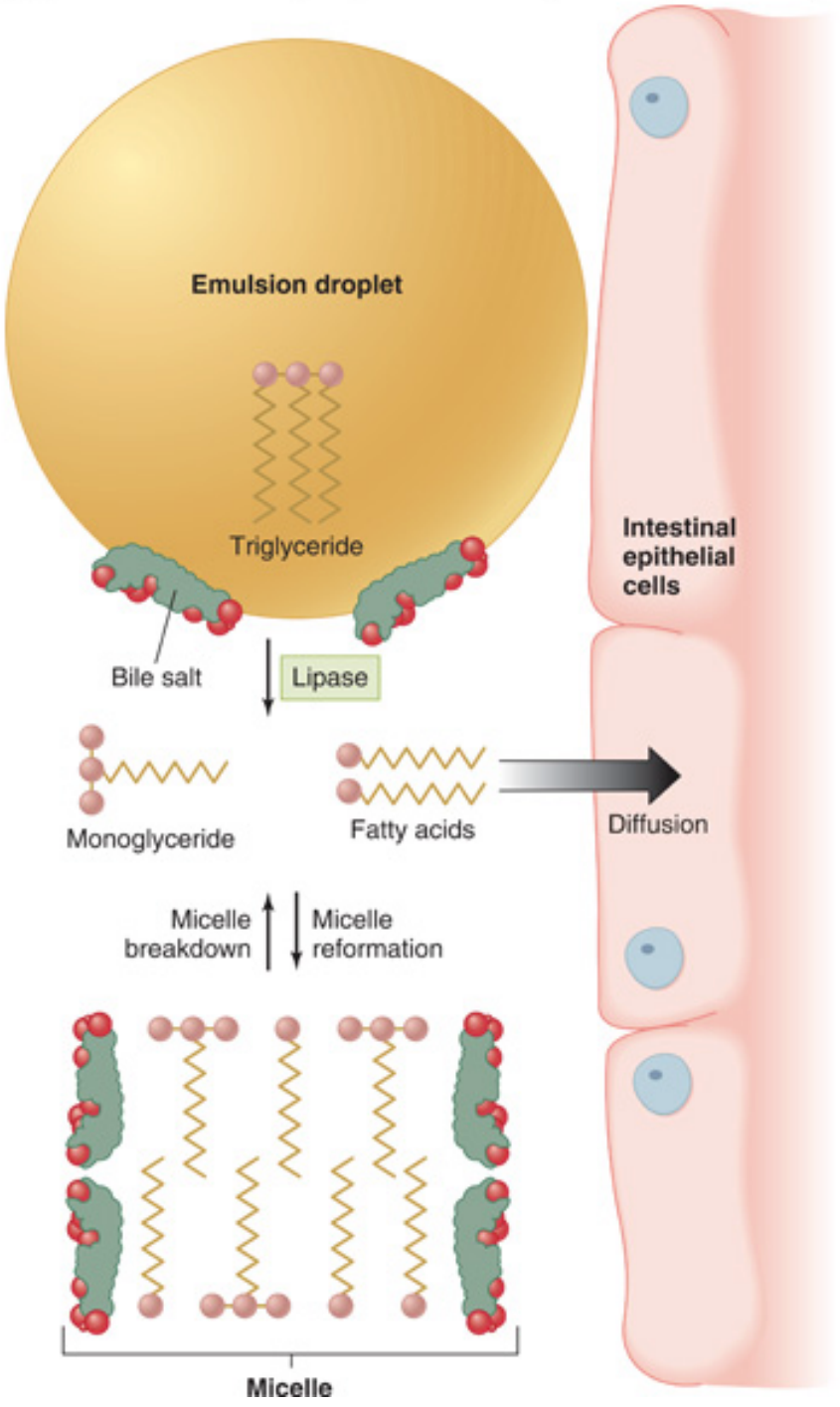


Bile salts and phospholipids convert large fat globules into smaller pieces with polar surfaces that inhibit reaggregation. ---

- Emulsification



Emulsified fat globules small enough that lipas enzymes gain access to degrade triglycerides to monoglycerides and fatty acids



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Big Droplets of Fat

↓

Small Droplets of Fat

↓

Micelles

↓

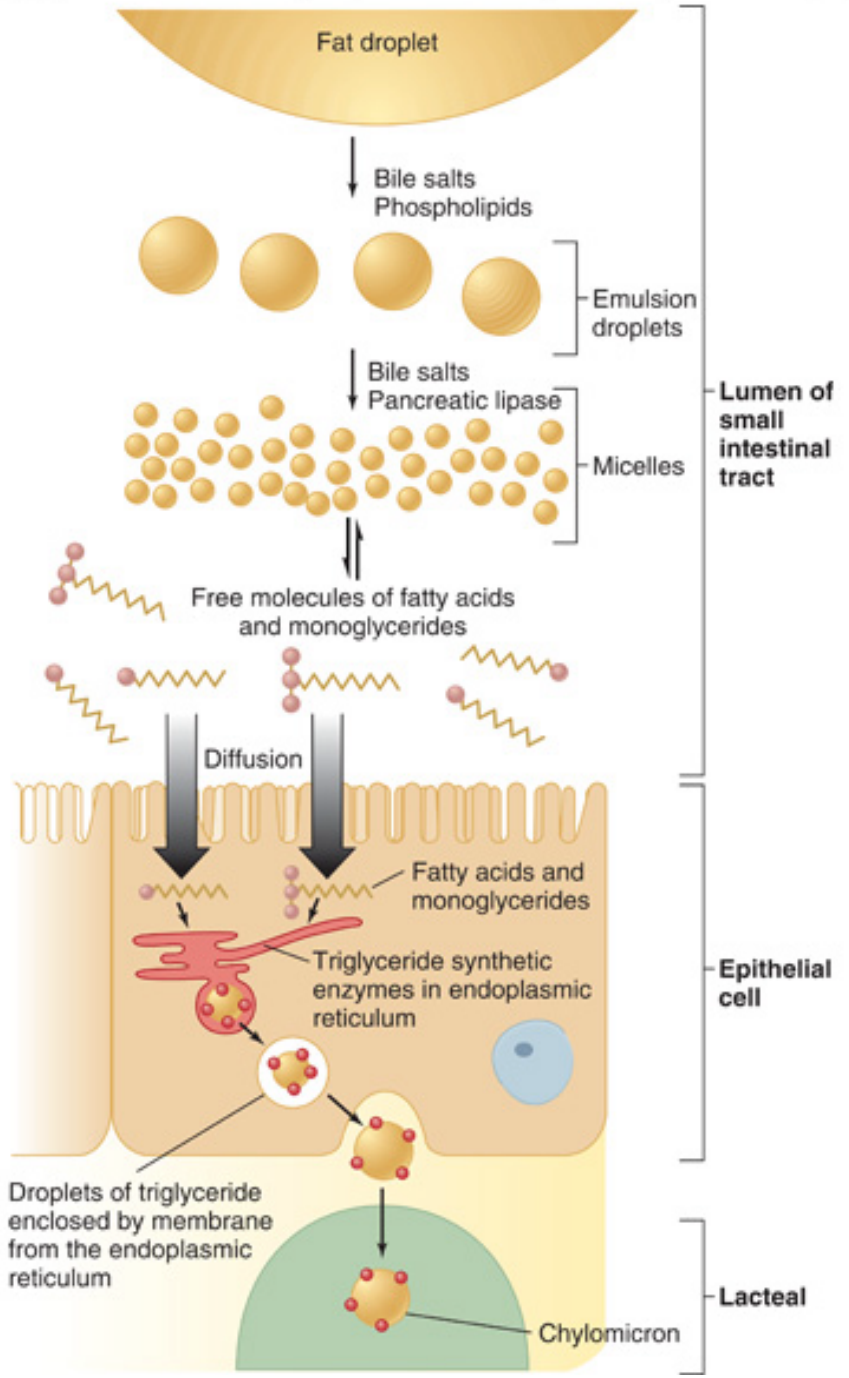
Fatty Acids and Monoglycerides

↓

Chylomicron Assembly

↓

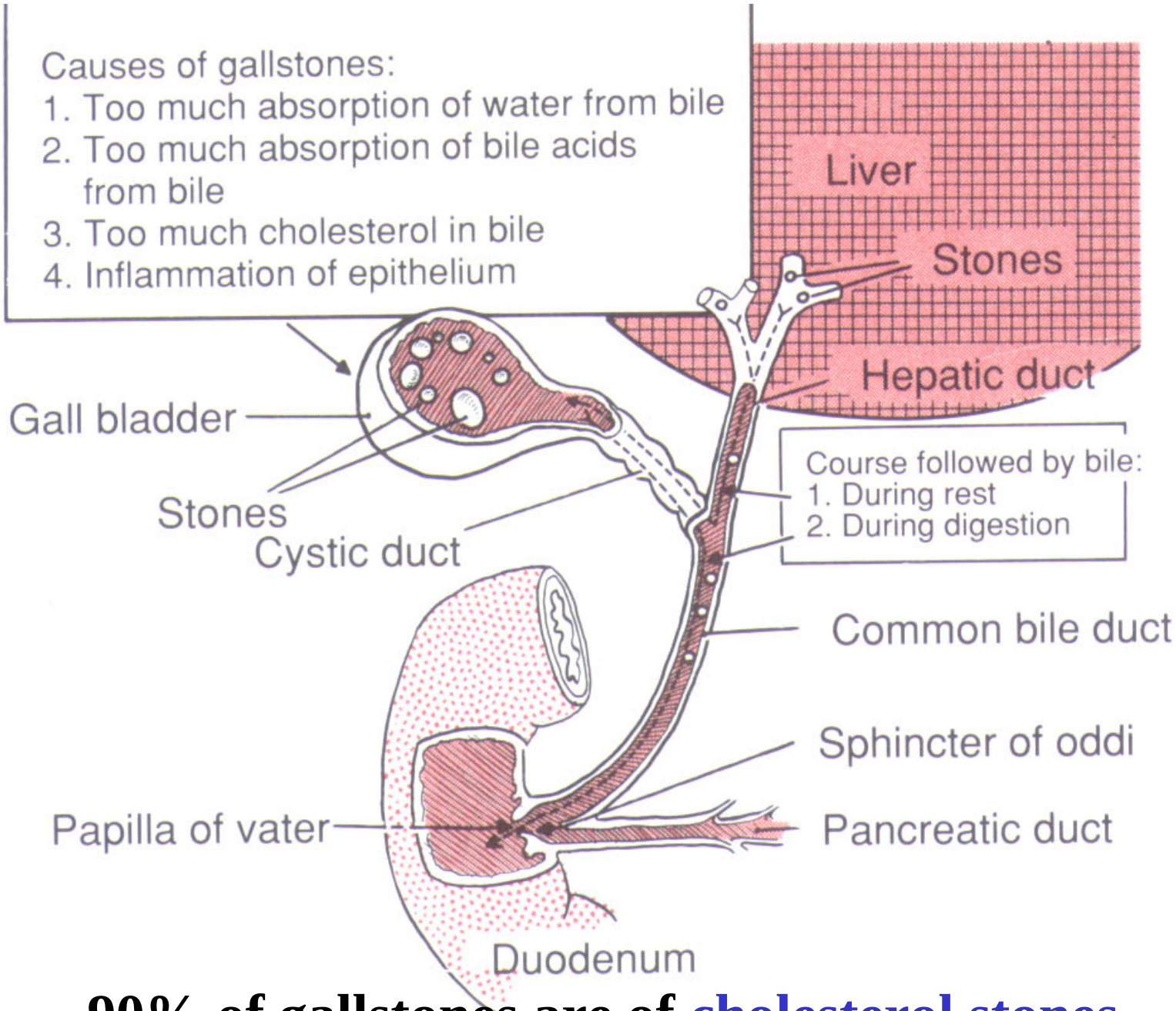
Distribution and Processing



(2) Eliminate many waste products

– Excrete bile pigments or drug metabolites

Bilirubin (useless and toxic breakdown product of hemoglobin)

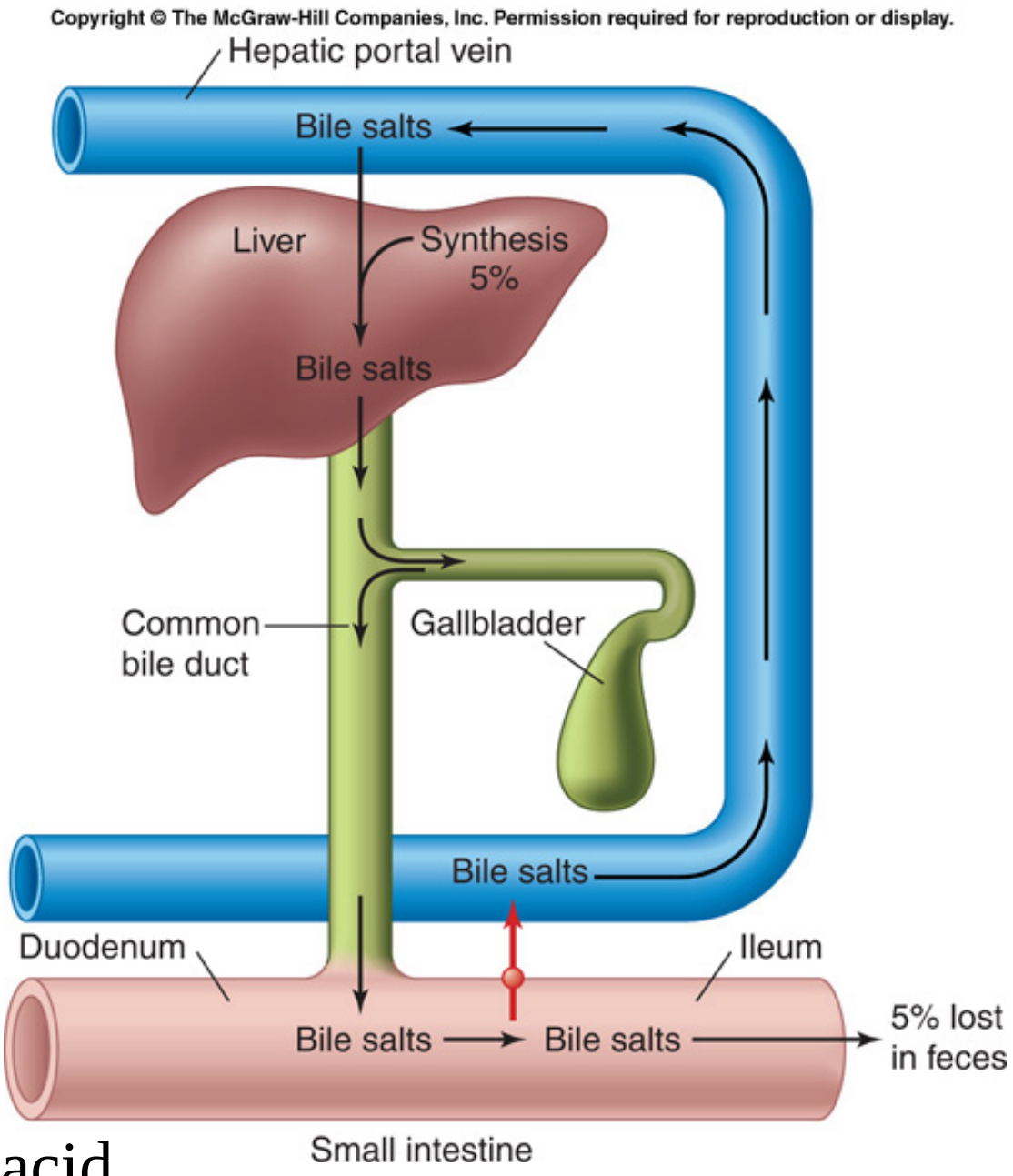


90% of gallstones are of cholesterol stones

(4) Increasing bile synthesis & secretion

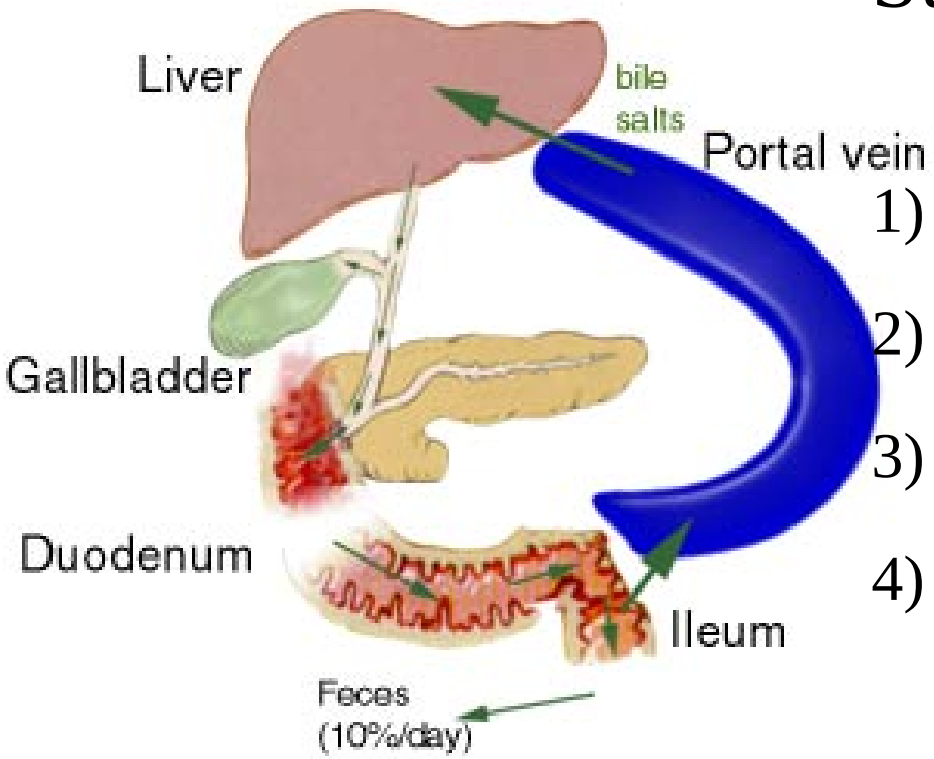
Up to 95% of the cholesterol-based bile salts are "recycled" by reabsorption along the intestine.

Enterohepatic circulation



(5) neutralize the stomach acid

Regulation of bile secretion



Substances increasing bile production

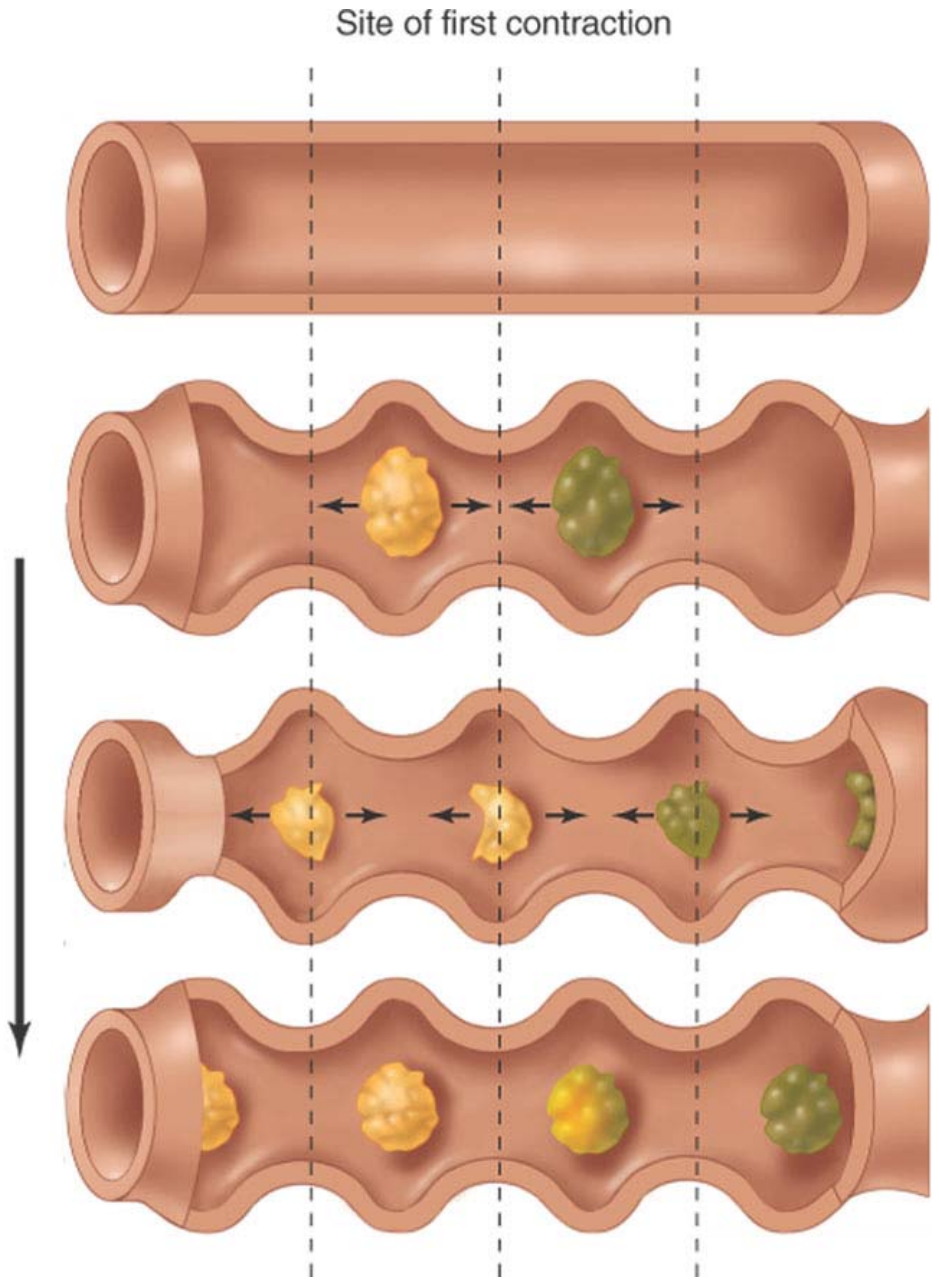
1) Bile salts
2) Secretin
3) Cholecystokinin
4) parasympathetic input

Small Intestine

- Secreted by Brunner's glands of duodenum
- pH 7.5-8.0
- 1~3 L/day
- Isosmotic

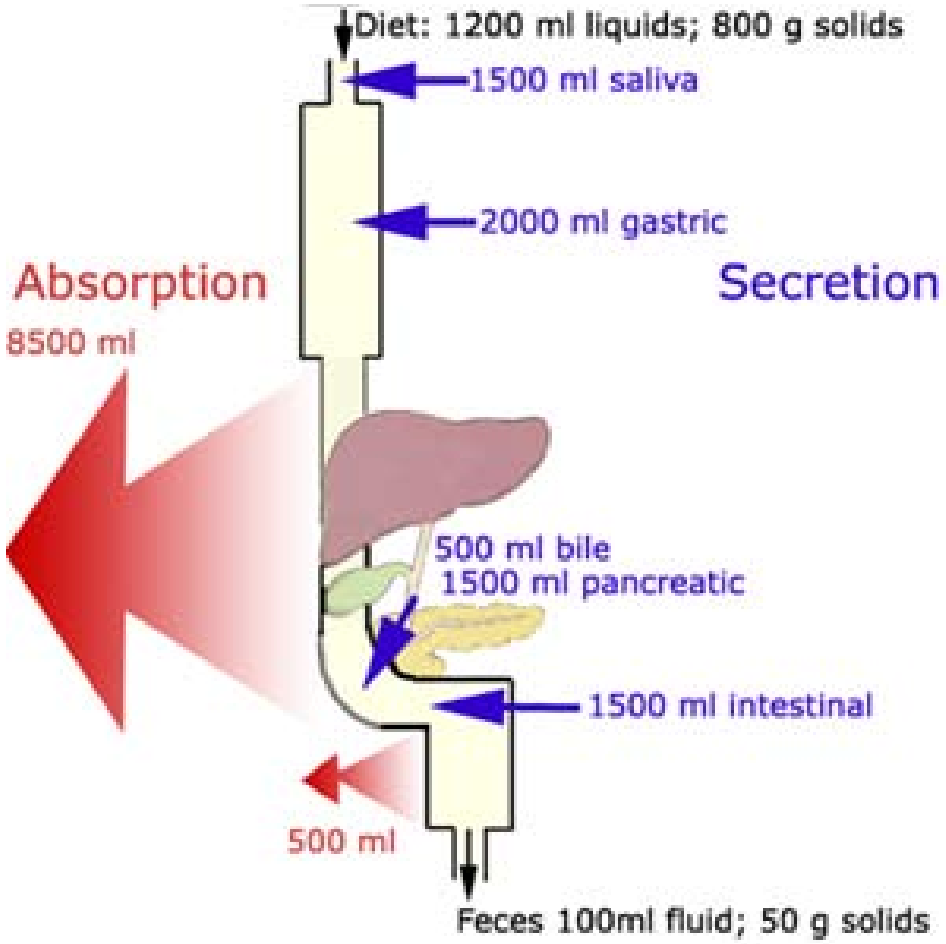
- Components
  - H_2O
  - Electrolytes (Na^+, K^+, Ca^{2+}, Cl^-)
  - Mucus
  - IgA
  - Enterokinase

Most of the contractions of the small intestine are of the mixing and churning actions portrayed here as segmentation contractions; peristalsis and the downstream movement of materials is infrequent.



Absorption in the gastrointestinal tract

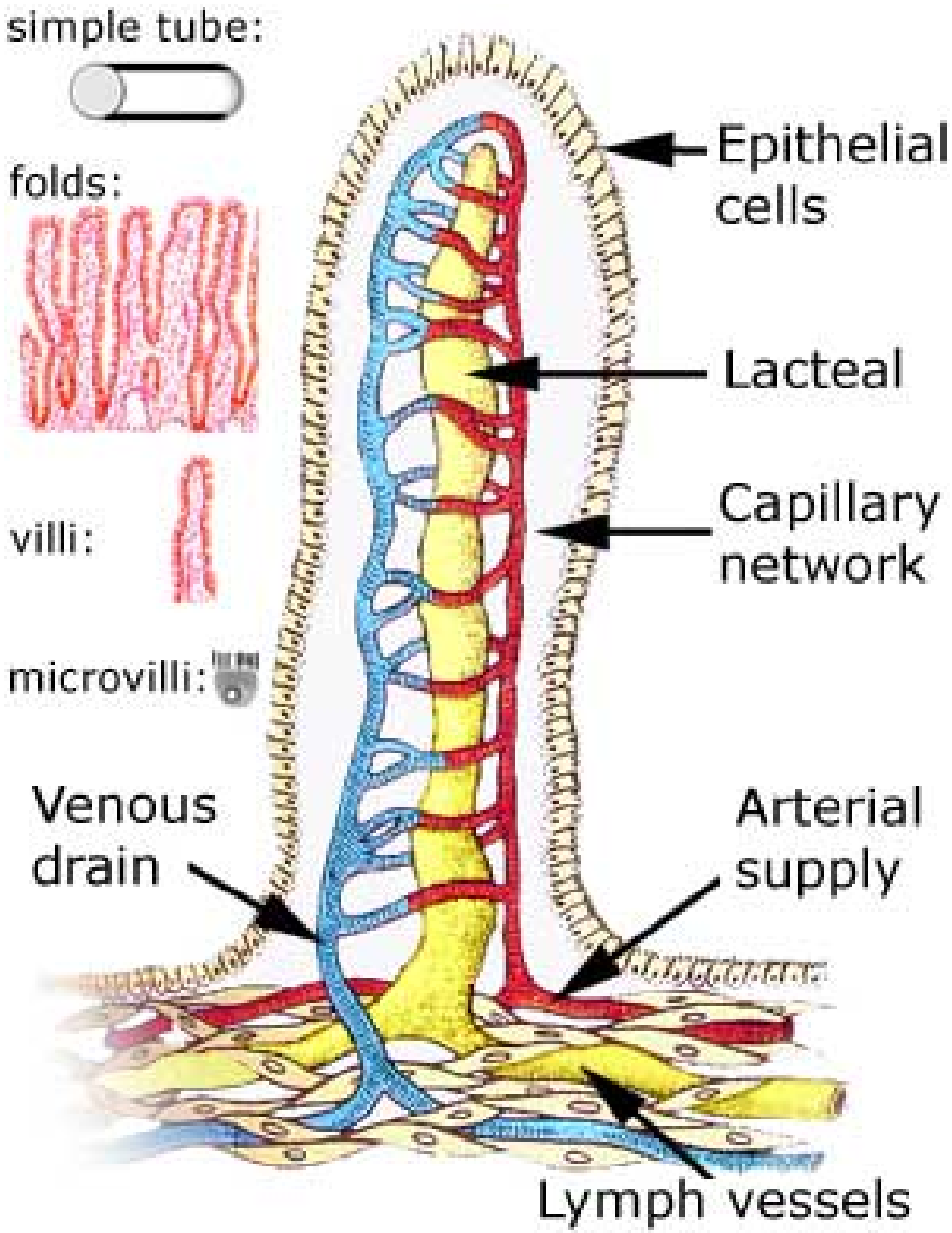
(I) Basic principle of absorption



Almost all absorption of nutrients occurs in the small intestine

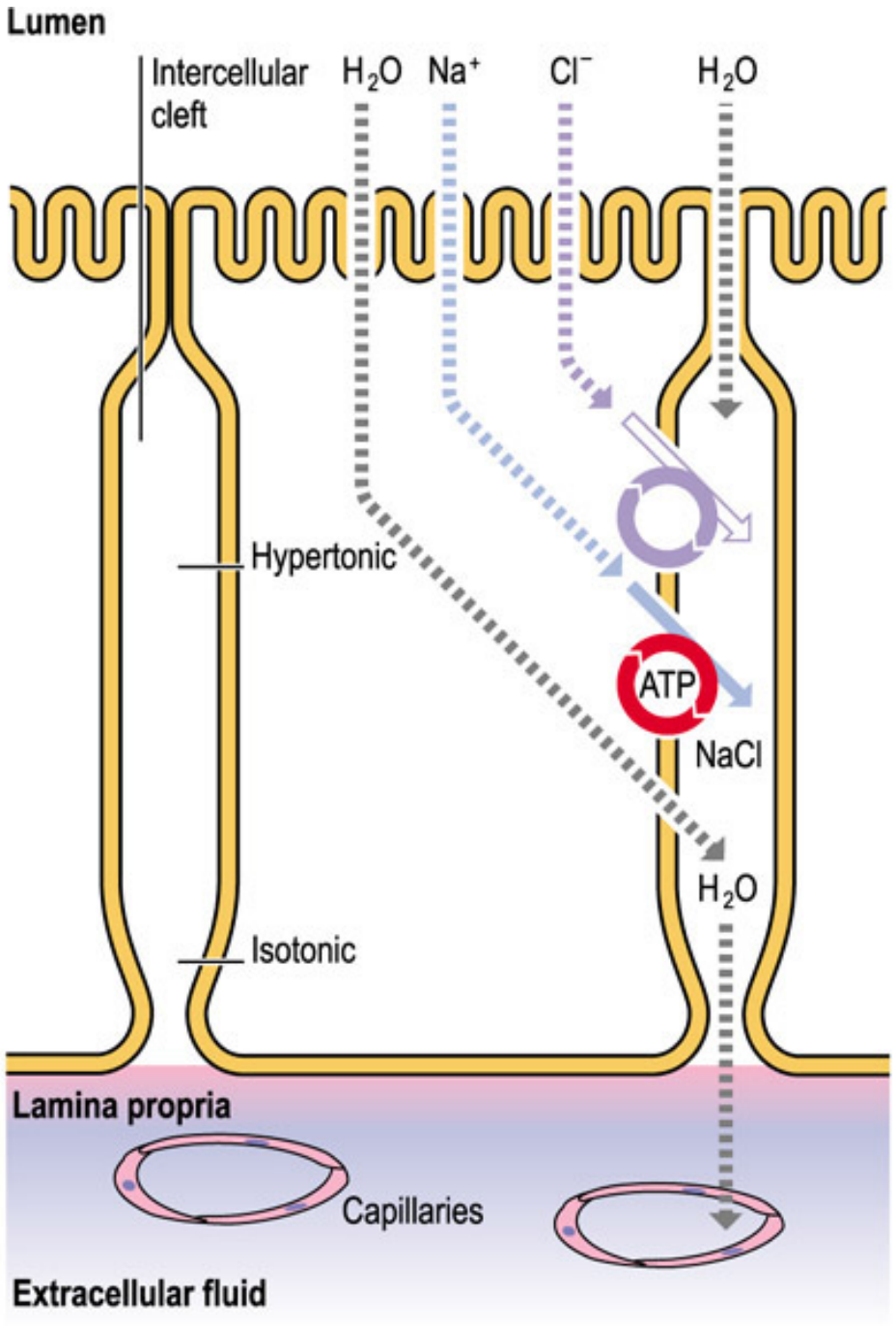
1. Absorptive surface of small intestinal mucosa

- Total area of 250 m^2:
  - Folds: 3-fold
  - Villi: 10-fold
  - Microvilli: 20-fold



2. Absorption pathways

- transcellular route
- paracellular route



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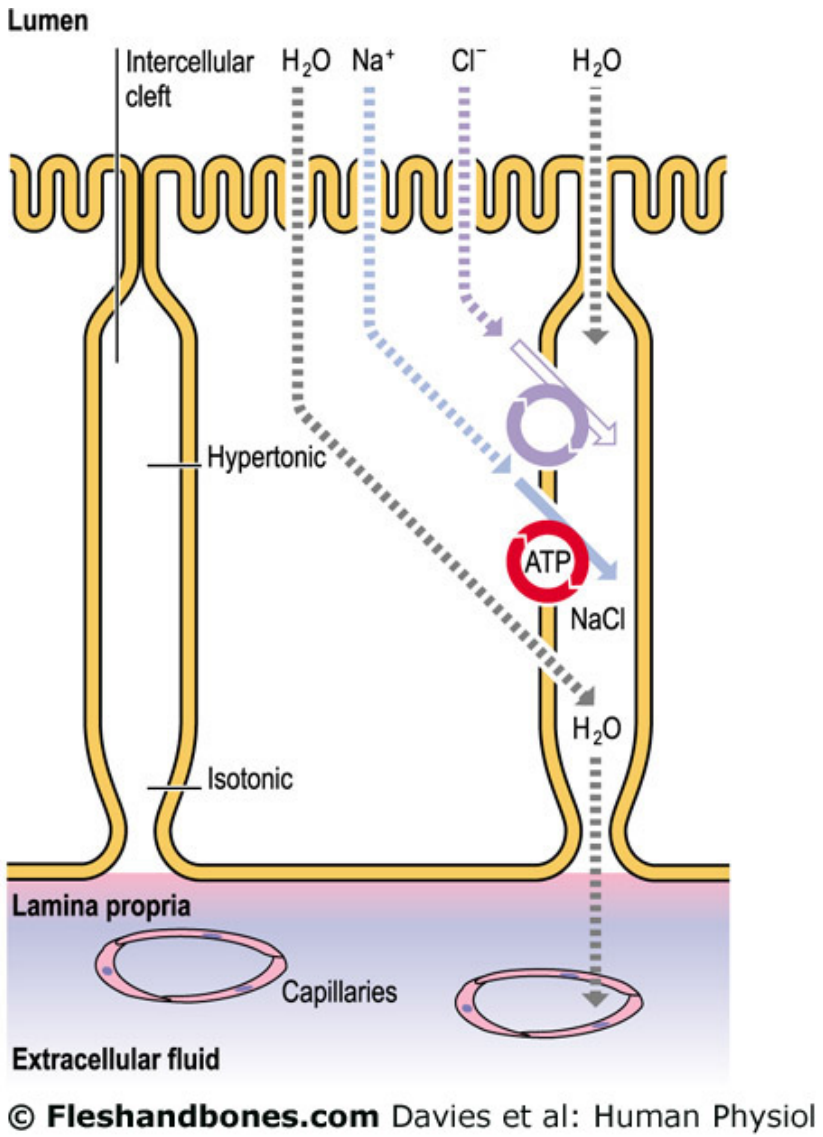
3. Absorption mechanisms

- Active transport
- Diffusion
- Solvent drag

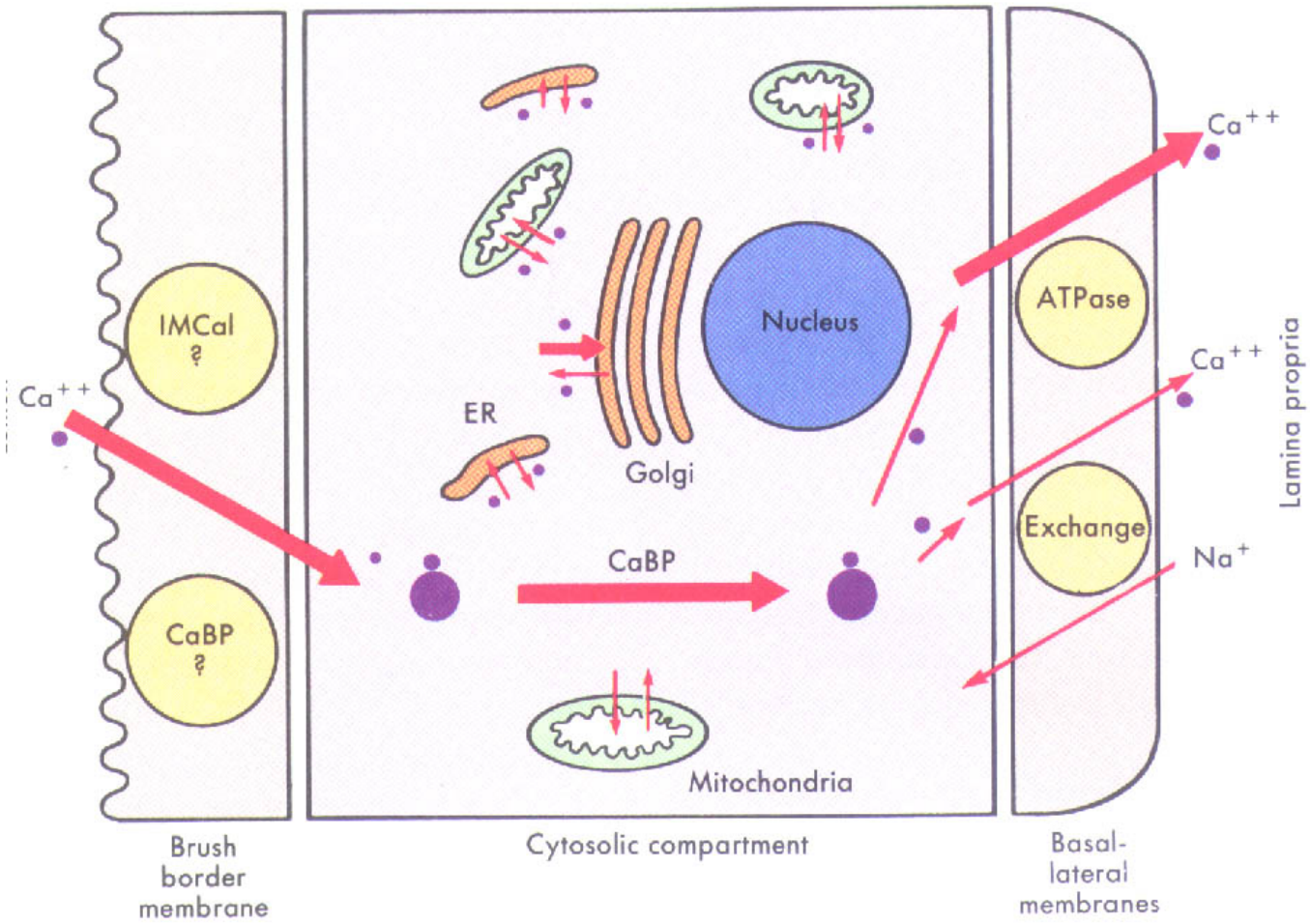
(II) Absorption of major nutrients

1. Water and Electrolytes

- H_2O: osmosis, diffusion
- Na^+:
  - Cotransporter
  - Carrier-mediated facilitated diffusion

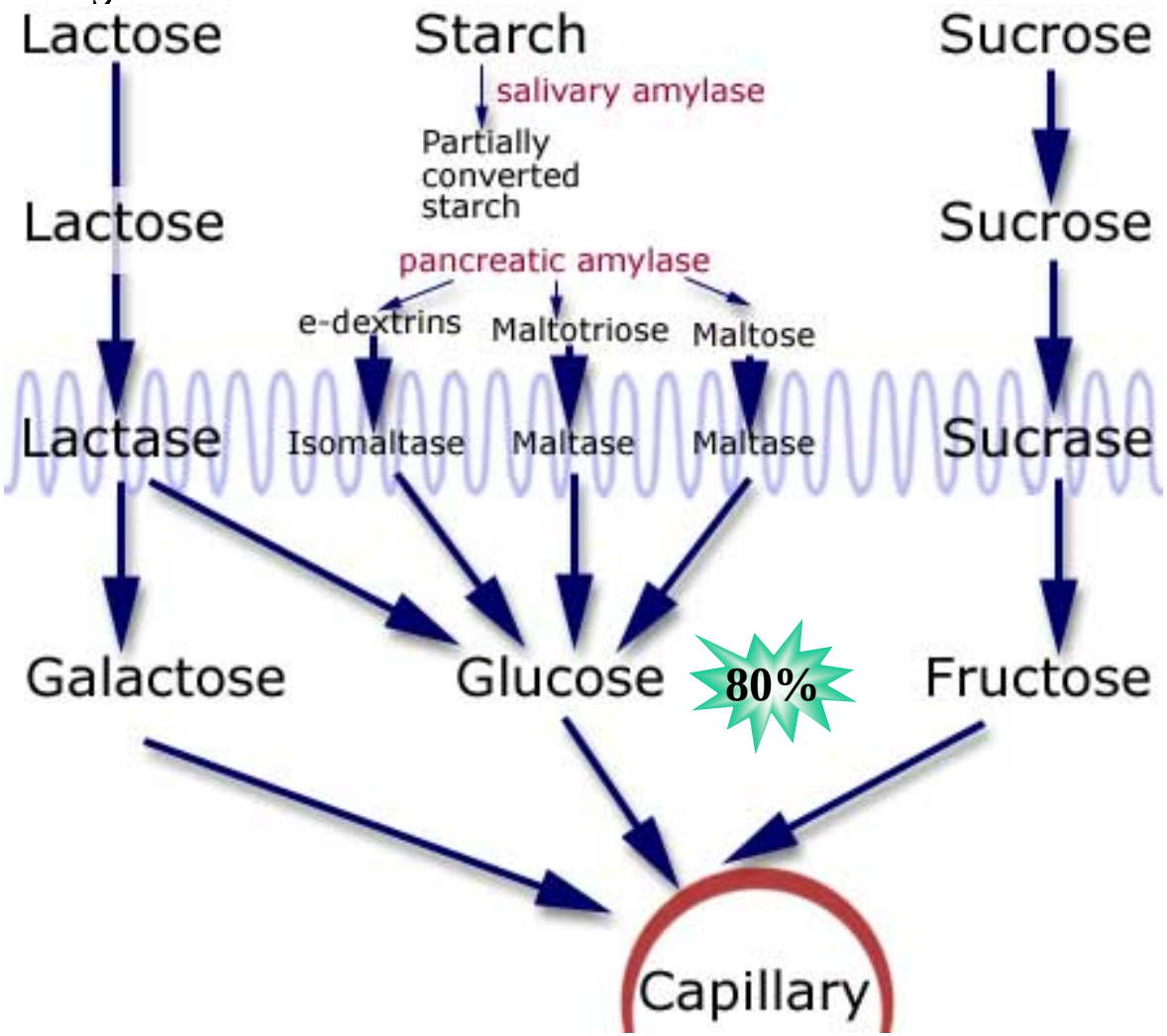


– Ca^{2+} : Ca^{2+} pump


IMCal
?
CaBP
?
Ca++
ER
Golgi
Nucleus
CaBP
Mitochondria
ATPase
Exchange
Ca++
Ca++
Na+
Lamina propria
Brush
border
membrane
Cytosolic compartment
Basal-
lateral
membranes

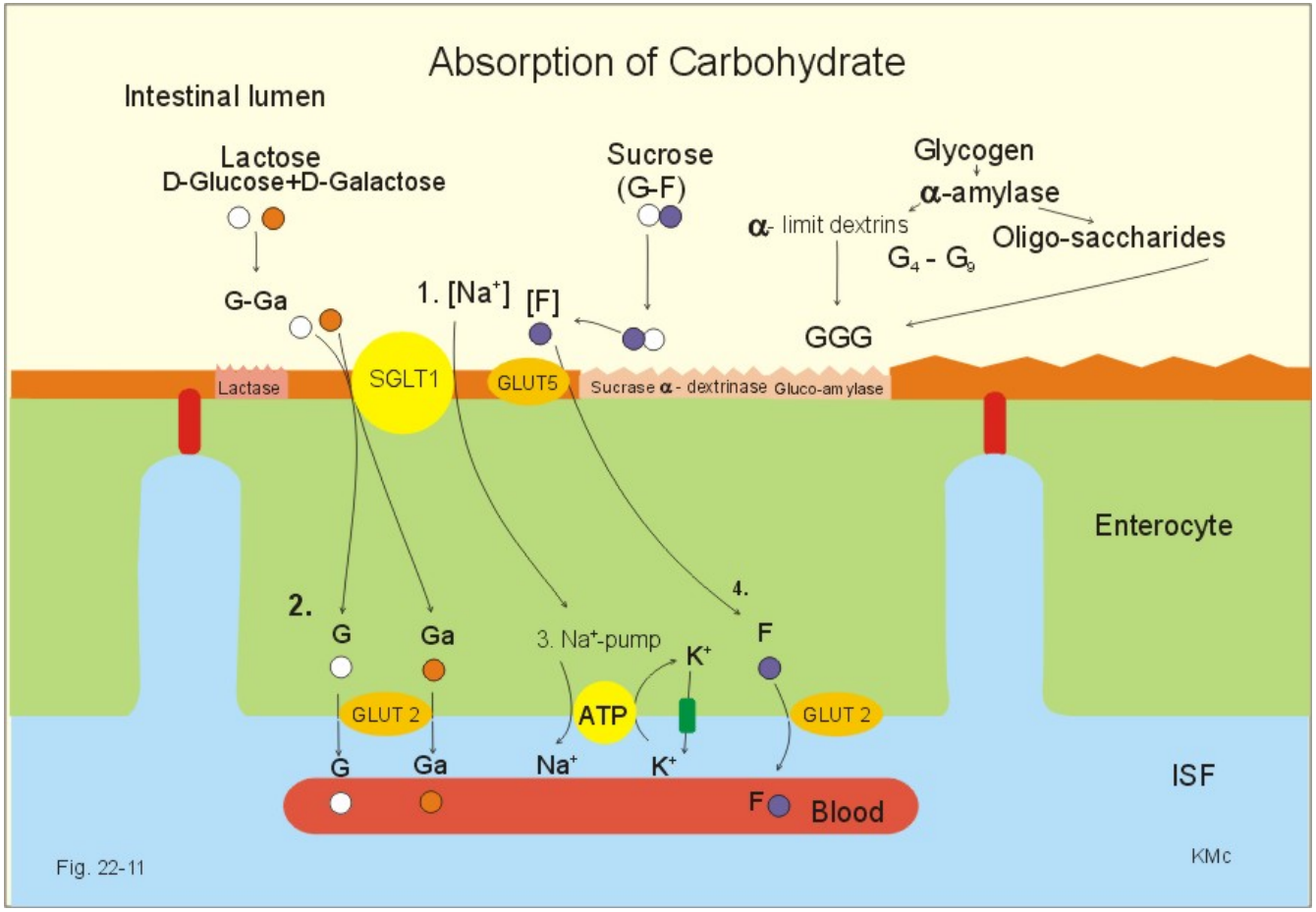
2. Carbohydrates

- Mainly in the form of monosaccharides



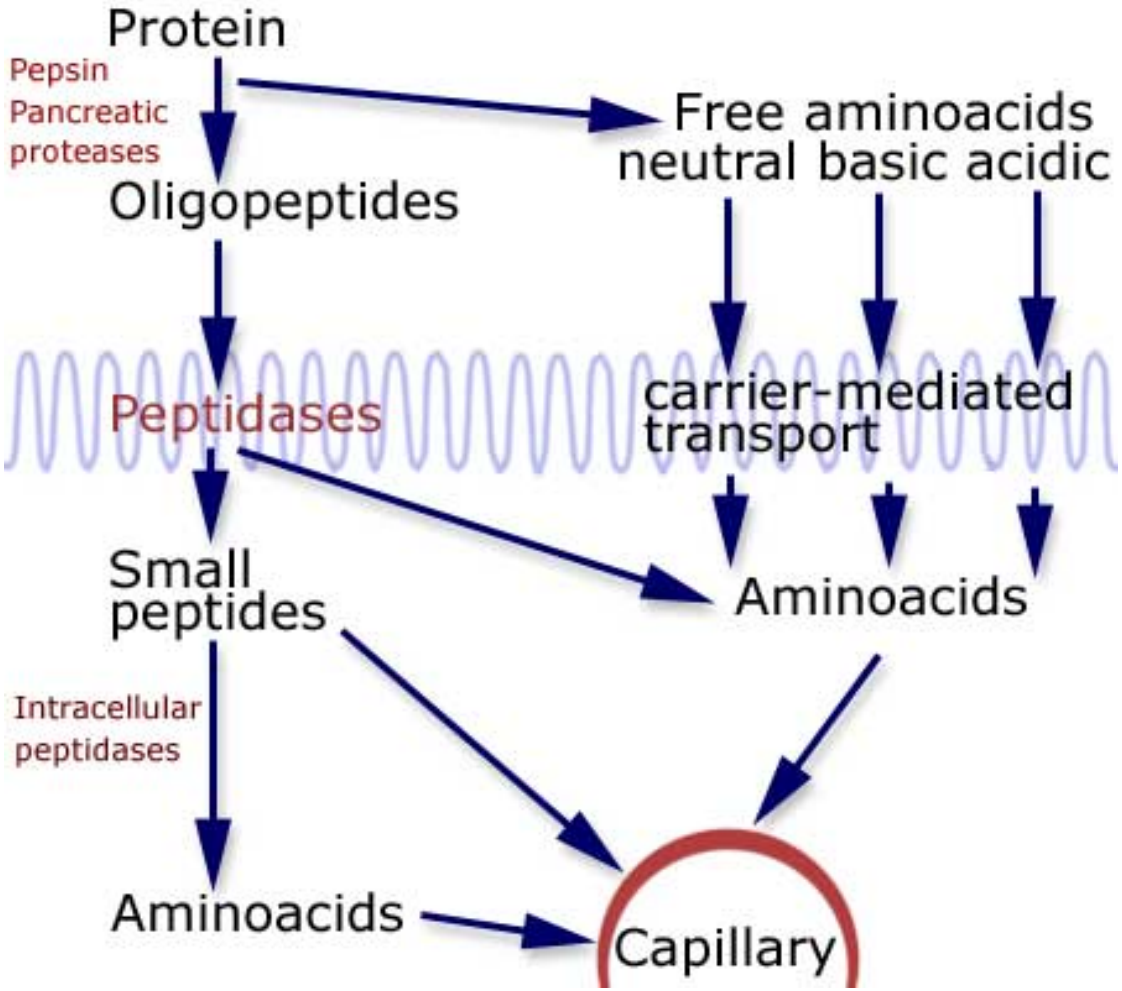
(1) Glucose and galactose: Secondary active transport (cotransport with sodium)

(2) fructose: facillitated diffusion



3. Proteins

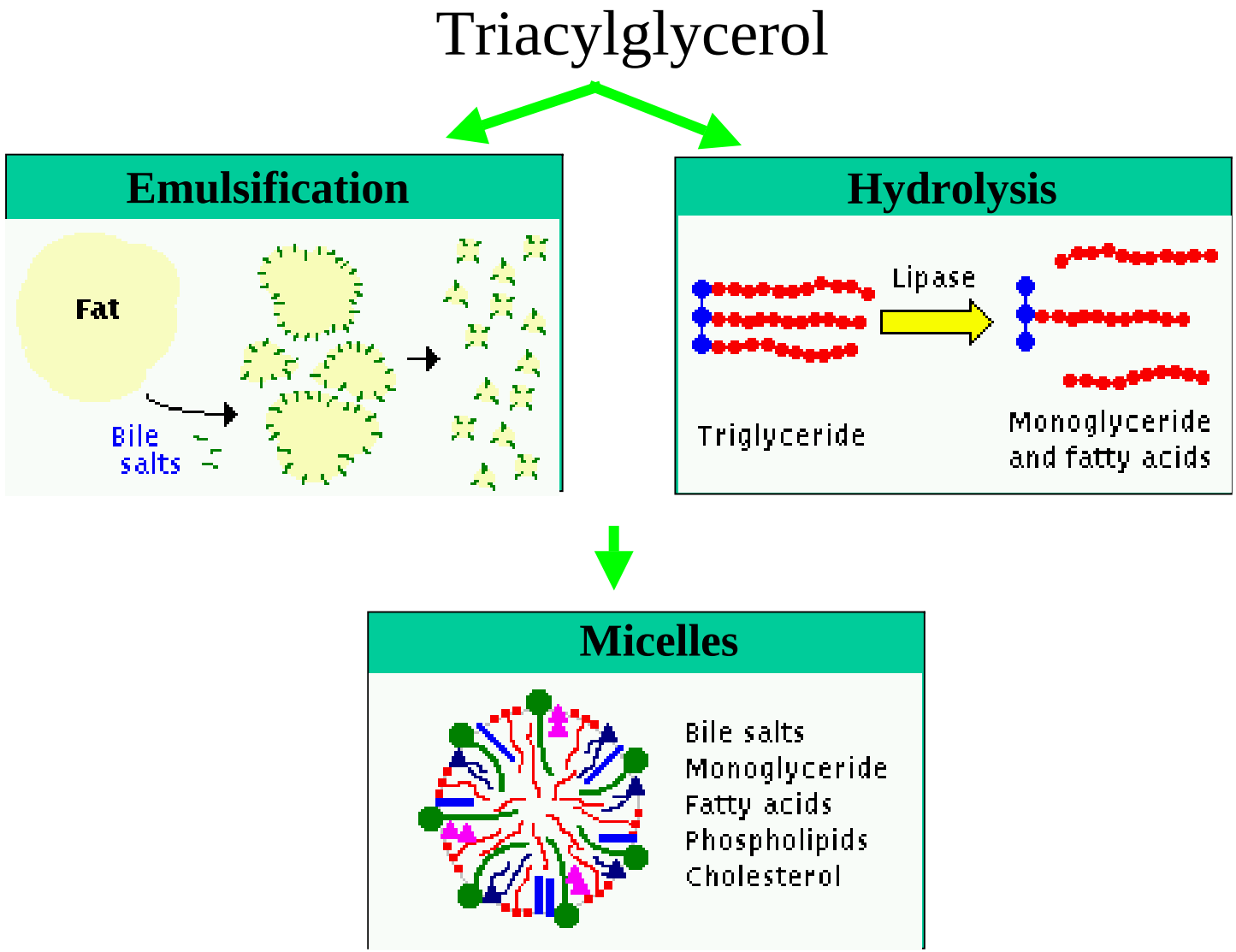
- In the form of dipeptides, tripeptides and a few free amino acides

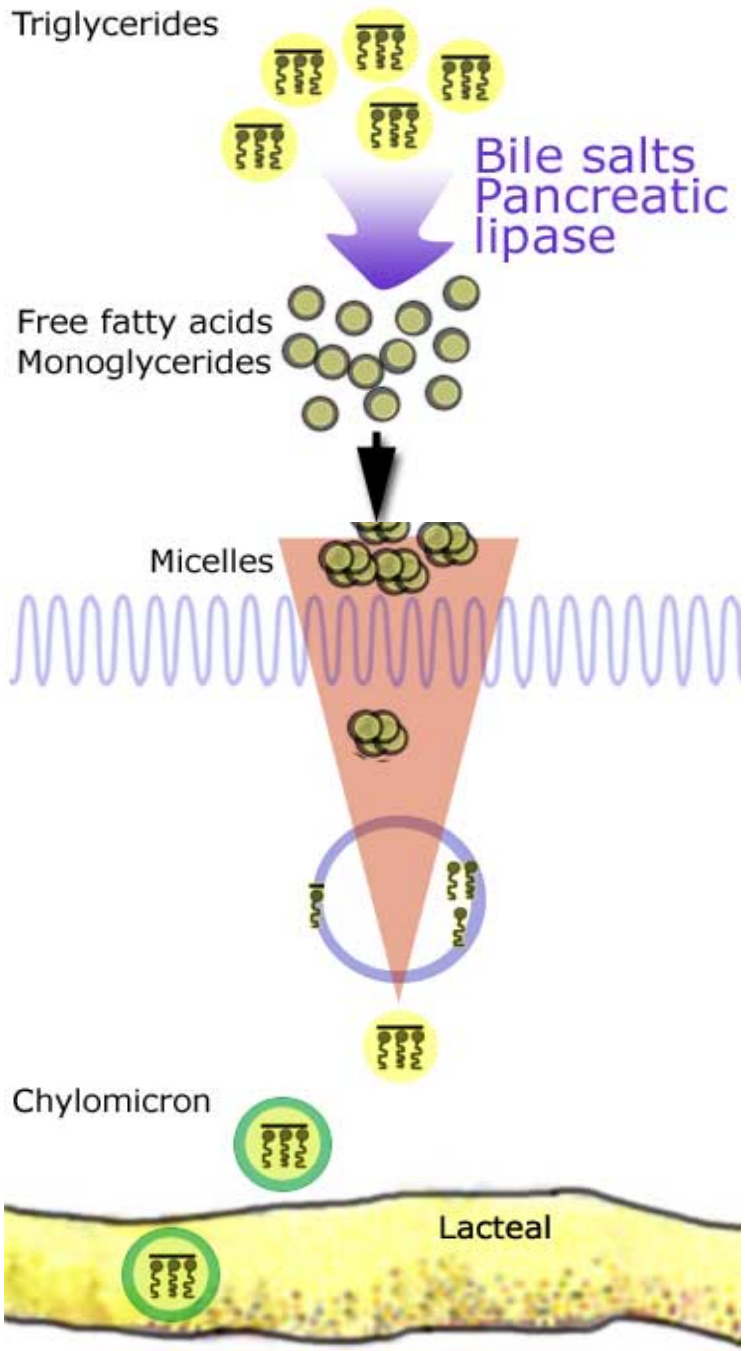


(1) Amino Acids and Peptides : Secondary active transport

(2) A few amino acids: facilited diffusion

4. Fats


Triacylglycerol
Emulsification
Fat
Bile salts
Hydrolysis
Lipase
Triglyceride
Monoglyceride and fatty acids
Micelles
Bile salts
Monoglyceride
Fatty acids
Phospholipids
Cholesterol



(1) Absorption through lymph duct to the circulatory blood

- fatty acids and monoglycerides → micelles bump into epithelial cell→ form new triglycerides →transport in lymph chylomicron →lacteal

(2) Direct absorption into the portal blood

- Short- and medium chain fatty acids (more water-soluble)

Summary

- Pancreatic secretion (including the composition and physiological function of the pancreatic juice, the regulation of pancreatic secretion)
- Biliary secretion (including the composition and physiological function of the bile)
- Absorption in the small intestine
- Describe the digestion of carbohydrates, proteins and fat

Intensive reading

- Textbook of Human Physiology
  - P601-610


Thank you!