Digestion and Absorption in the Gastrointestinal Tract

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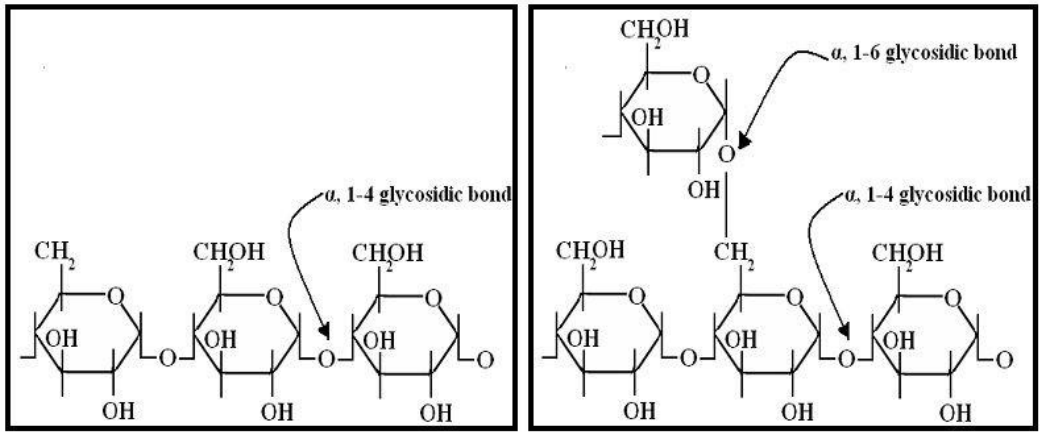
- The food we eat contains the following major macronutrients;
  - Carbohydrates
  - Proteins
  - Lipids

Digestion and Absorption of Carbohydrates

Digestion of Carbohydrates

- Food rich in carbohydrates **(e.g. bread, pizza, fruits, vegetables etc.)** contains carbohydrate molecules:
    - Cellulose – not absorbable b/c **humans lack enzyme cellulase.**
    - Amylose (linear structure)
    - Amylopectin (branched structure)
- The digestion of carbohydrates **begins in the mouth and stomach.**



(a) amylose (b) amylopectin

Salivary Amylase

- Saliva contains enzyme **salivary α- amylase (ptyalin).**

Starch (amylopectin, amylose) → Maltose + Galactose + Maltotriose + α – limit dextrins

Polysaccharides → disaccharides + oligosaccharides

- **Less than 5%** of the starch content of a meal is **hydrolyzed before swallowing**.

Pancreatic Amylase

- Pancreatic secretion, like saliva, contains a large quantity of **a-amylase.**
- The function of **pancreatic a-amylase** is almost **identical to that of the a-amylase in saliva.**
- It is **several times powerful** than salivary a-amylase.
- When the **chyme empties into the duodenum and mixes with pancreatic juice,** virtually **all the starches are digested.**

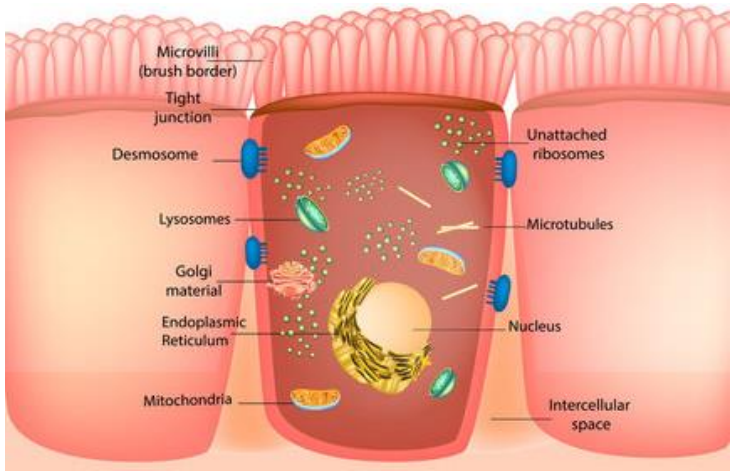
Brush Border Enzymes

- **Microvilli brush border enzymes** – present on the epithelial surface of microvilli. They are;

    1. Lactase **(lactose → glucose + galactose)**
    2. Maltase – also called ***glucoamylase*** **(maltose, maltotriose → glucose + glucose)**
    3. Sucrase **(sucrose → glucose + fructose**)
    4. Isomaltase – works on α – 1,6 glycosidic bonds
       (α-limit dextrin → glucose + glucose)

- **Glucose** represents **more than 80%**

of the final products of carbohydrate digestion.



Absorption of Carbohydrates

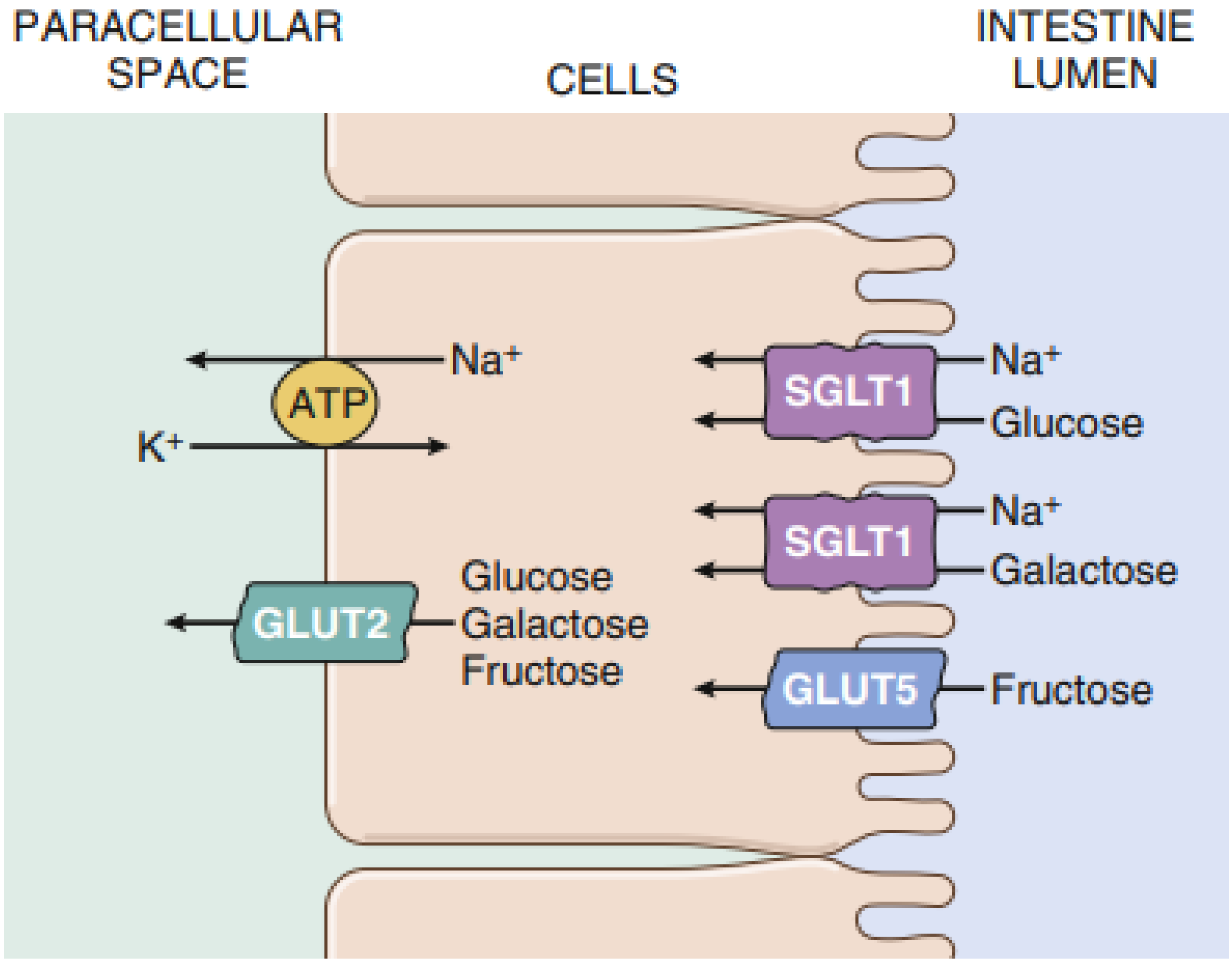
1. **GLUT-5 (glucose transporter)** facilitates the diffusion of fructose from intestinal lumen into the enterocyte.

2. **Na^+/K^+ ATPase** – (pumps 3 Na^+ out, $2K^+$ into the enterocyte)
   - This causes ↑ conc. of Na+ in the lumen and ↓ conc. Of Na+ inside the enterocyte.
   - Na+ carries glucose and galactose along itself to the enterocyte through SGLT.

3. **SGLT-1 (sodium-glucose co-transporter)** transports glucose and galactose into the enterocyte.

4. **GLUT-2** transports **glucose, galactose, fructose** from the enterocyte to the paracellular space and then into the intestinal capillaries.

   Intestinal capillaries → Hepatic portal vein → Liver


PARACELLULAR SPACE
CELLS
INTESTINE LUMEN
Na+
ATP
K+
GLUT2
Glucose
Galactose
Fructose
SGLT1
Na+
Glucose
SGLT1
Na+
Galactose
GLUT5
Fructose

Digestion and Absorption of Proteins

Stomach

- **Digestion of proteins starts in the stomach.**
- Digestion of proteins takes place by **hydrolysis of polypeptides.**
- **Large polypeptides → Amino acids (by hydrolysis reaction)**
- In stomach;
- **Chief cells** – secrete **pepsinogen (inactive form)**
- **Parietal cells** – secrete **HCl**
  - Helps decrease the pH i.e. **1.8 – 3.5**
  - Stimulates conversion of **pepsinogen into pepsin (active form)**

- Large polypeptides → proteoses, peptones, multiple small polypeptides **(by pepsin)**

Pancreatic Proteolytic Enzymes

- Proteoses, peptones, large polypeptides → dipeptides, tripeptides **(pancreatic proteases)**
- **CCK** stimulates acinar cells of pancreases, and it triggers the release of digestive enzymes **(proteases)** from the pancreas and the digestive juice is released into the duodenum.
- **Pancreatic Proteases;**
  - **Trypsinogen (inactive)** – activated to **trypsin** by **enterokinase (by brush border enzymes)**
  - **Chymotrypsinogen (inactive)** – activated to **chymotrypsin** by trypsin.
  - **Procarboxypeptidases (inactive) -** activated to **carboxypeptidase** by trypsin.
  - **Proelastase (inactive) -** activated to **elastase** by trypsin.
- Polypeptides → smaller polypeptides i.e. dipeptides, tripeptides **(trypsin and chymotrypsin)**
- **Carboxypeptidase** act on the carboxyl (COO^-) end of the polypeptide.
- **Elastase** digests the elastin fibers that are present in meat.

Absorption of Proteins

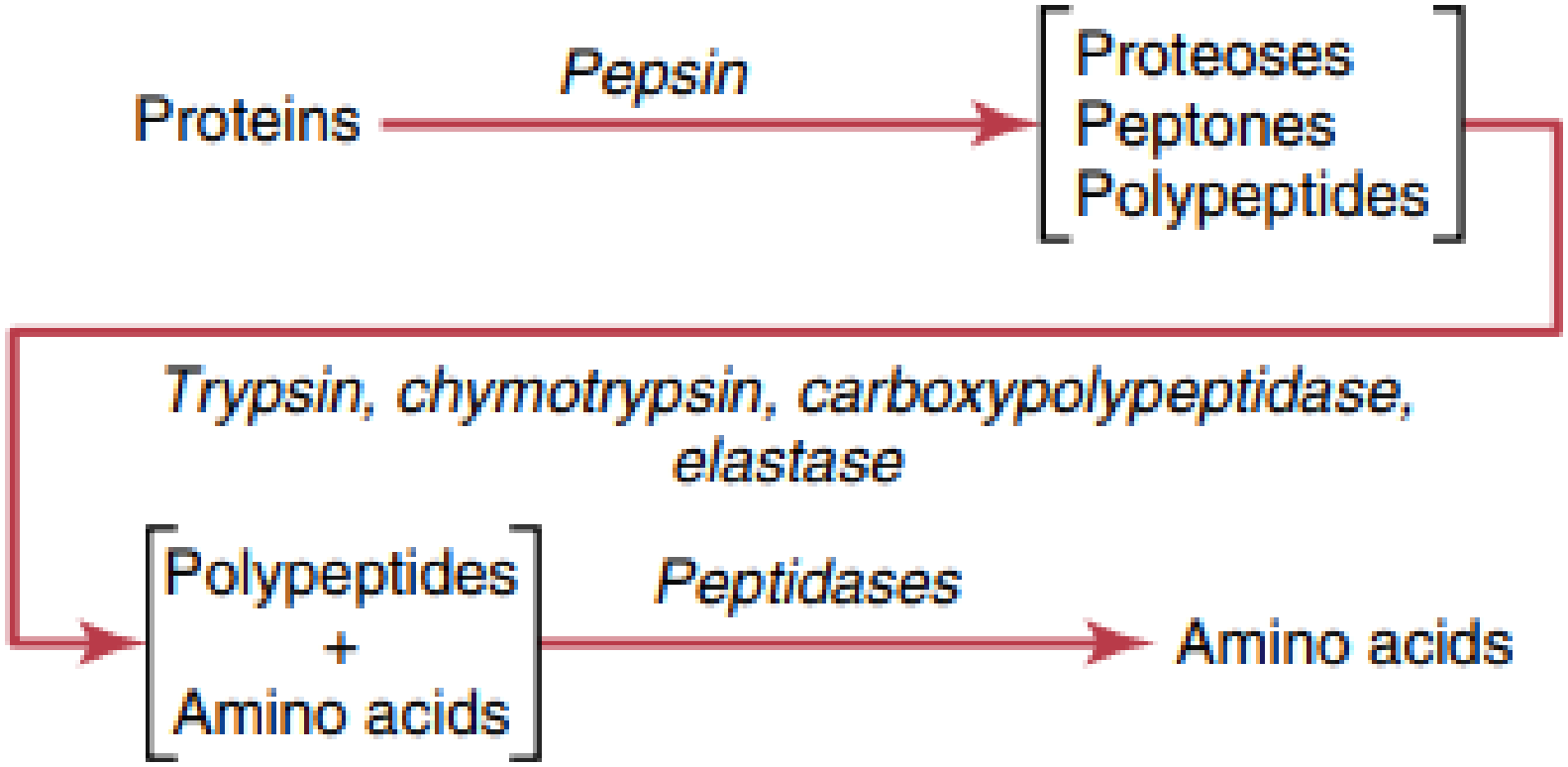
- Enterocyte – cytoplasmic extensions (microvilli on its surface contains – brush border enzymes)
- Brush border enzymes
  1. **Aminopolypeptidases** (cleave polypeptides at amino end - NH_2 and convert them into three A.A)
  2. **Di-peptidases** (splits dipeptides into individual peptidase)
- **Na^+-H^+ antiporter –** moves H+ out of the cell and Na+ inside the cell.
- Dipeptides enters the enterocyte by symport of **H+ and dipeptides.**
- Tripeptides enters the enterocyte by symport of **H+ and tripeptides.**
- Amino acids enters the enterocyte by **secondary active transport** – of Na+ and A.A.
  - **The electrochemical gradient is provided by Na+/K+ ATPase pump.**

- Once inside the enterocyte, dipeptides and tripeptides are splitted into individual amino acids by **peptidase.**

Dipeptides → free amino acids (peptidase)

Tripeptides → free amino acids (peptidase)

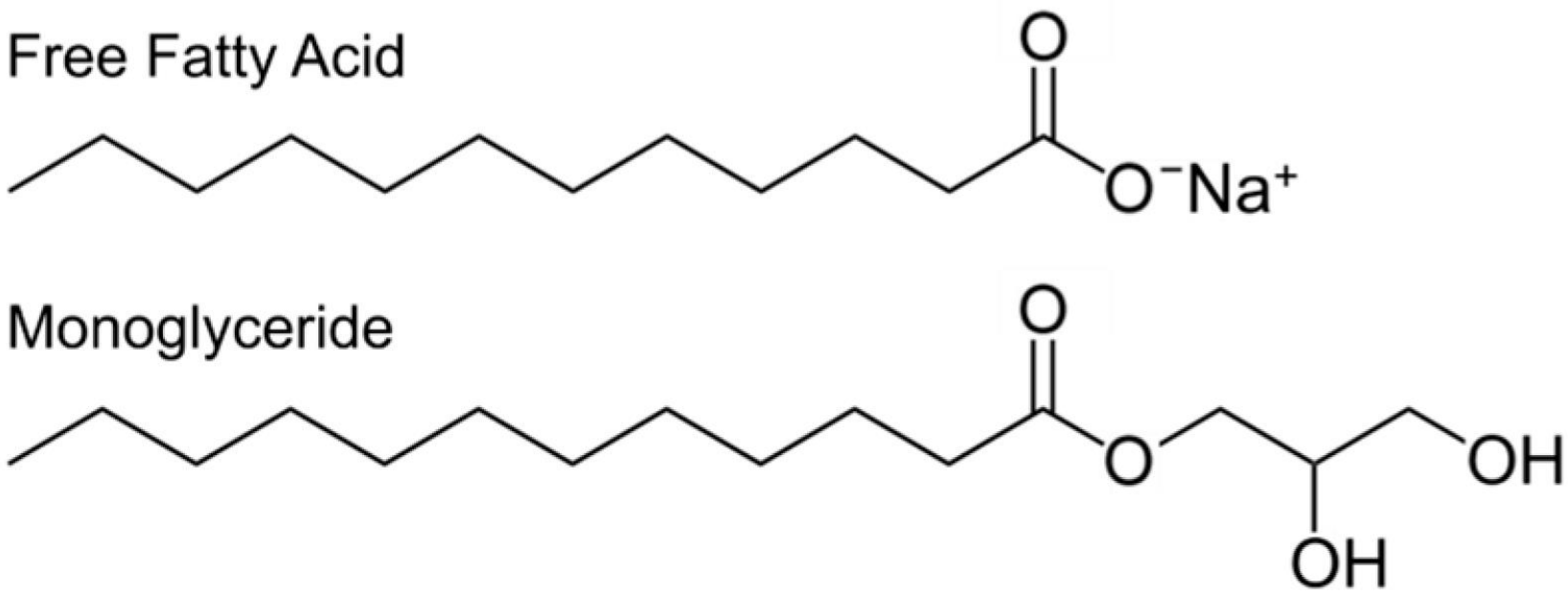
- These free amino acids are then transported into the blood.



Digestion and Absorption of Lipids

Digestion of Lipids

- Lipid polymers broken down into monomers.
  - Triglycerides → **Fatty acids + monoacetylglycerol**
  - Cholesterol ester → **cholesterol**
  - Phospholipids → **glycerol + fatty acids**



Oral Cavity

- Sublingual and parotid salivary glands – secrete **lingual lipase.**
- Partial digestion of lipids.
- Triglycerides (glycerol) → **mono acetyl glycerol (MAG) + free fatty acids (breakdown ester bonds)**

Stomach

- **Chief cells** – secrete **gastric lipase (similar to lingual lipase)**

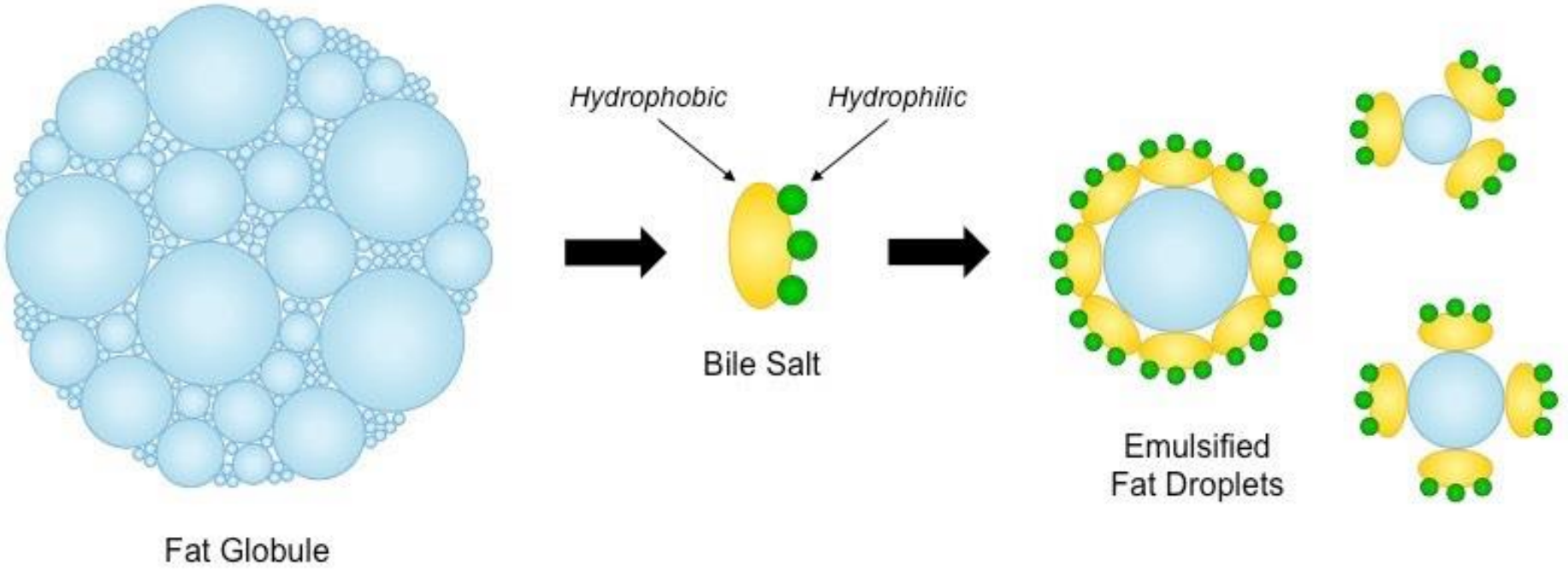
- Triglycerides (glycerol) → **mono acetyl glycerol (MAG) + free fatty acids (breakdown ester bonds)**

Small Intestine (Duodenum)

- **Bile – emulsification agent**
- **Emulsification** – breakdown of large fat globule into small fat droplets
- **Bile**
  - Phospholipids – lecithin
  - Bile salts – cholic acid, chenodeoxycholic acid (derivatives of cholesterol)

Pancreatic lipase

- Pancreatic lipase with colipase – breakdown triglycerides in fat droplets into → **mono acetyl glycerol (MAG) + free fatty acids**

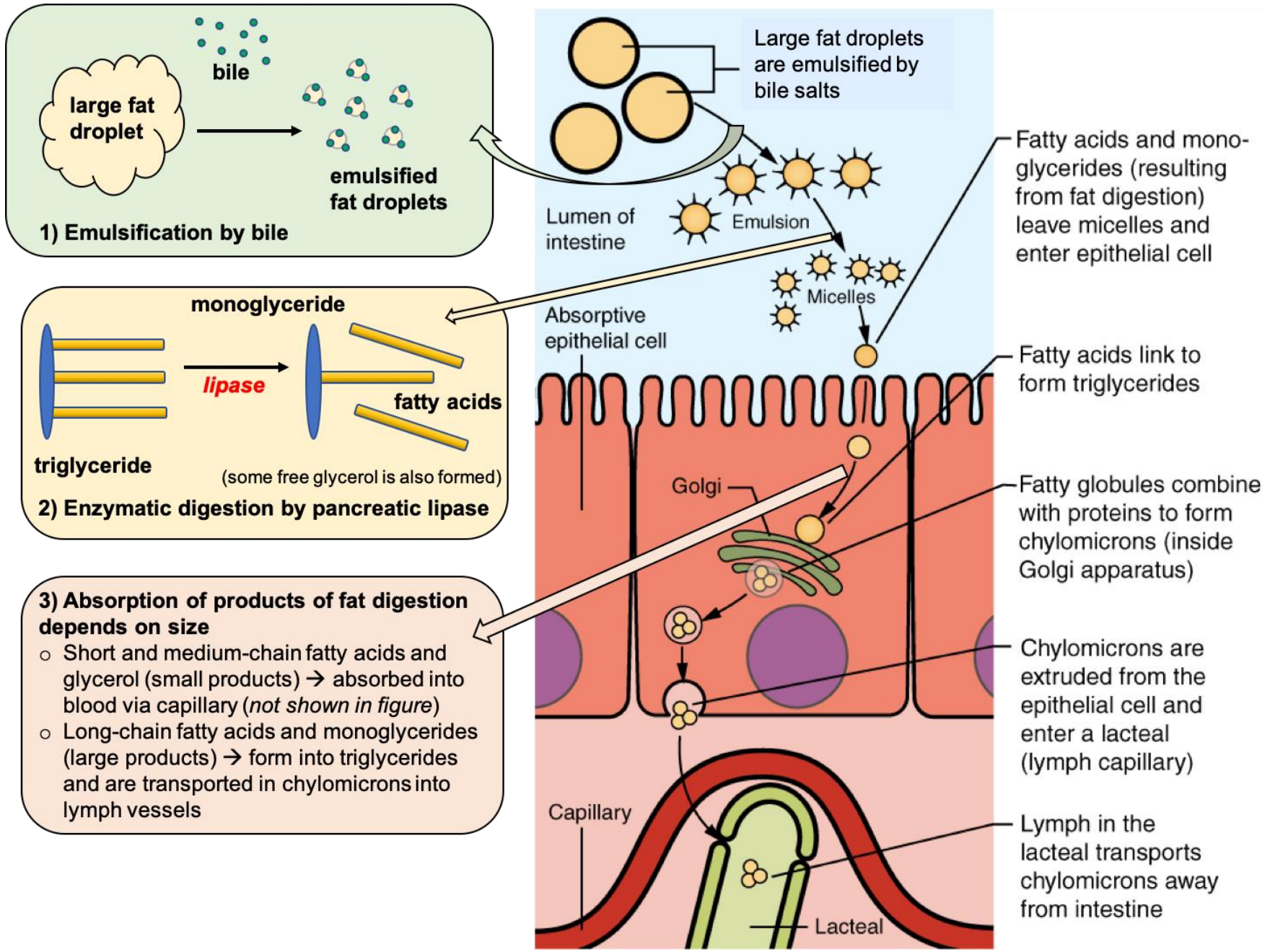


Fat $\xrightarrow{\textit{(Bile + agitation)}}$ Emulsified fat

Emulsified fat $\xrightarrow{\textit{Pancreatic lipase}}$ Fatty acids and 2-monoglycerides

Absorption of Lipids

- **Micelles**
  - Central fat globule (MAG + free FA)
  - Bile salts – projecting outward covering the surface of micelles
- Bile salt micelles - carry **monoglycerides + free FA** to the **brush borders of the intestinal epithelial cells.**
- Free fatty acids and monoglycerides – **leave micelle and enter enterocytes.**
- In enterocytes, free fatty acids – **converted into triglycerides** and **combine with proteins** to form **chylomicrons (in Golgi complex)**
- **Chylomicrons – through exocytosis leave the cell and enter lacteals.**
- **Lacteals** carry chylomicrons through lymph fluid to the target organs **(e.g. mucles, adipose tissue)**


bile
large fat droplet
emulsified fat droplets
1) Emulsification by bile
monoglyceride
lipase
fatty acids
triglyceride
(some free glycerol is also formed)
2) Enzymatic digestion by pancreatic lipase
3) Absorption of products of fat digestion depends on size
Short and medium-chain fatty acids and glycerol (small products) → absorbed into blood via capillary (not shown in figure)
Long-chain fatty acids and monoglycerides (large products) → form into triglycerides and are transported in chylomicrons into lymph vessels
Large fat droplets are emulsified by bile salts
Lumen of intestine
Emulsion
Micelles
Absorptive epithelial cell
Golgi
Capillary
Lacteal
Fatty acids and mono-glycerides (resulting from fat digestion) leave micelles and enter epithelial cell
Fatty acids link to form triglycerides
Fatty globules combine with proteins to form chylomicrons (inside Golgi apparatus)
Chylomicrons are extruded from the epithelial cell and enter a lacteal (lymph capillary)
Lymph in the lacteal transports chylomicrons away from intestine

Thank You