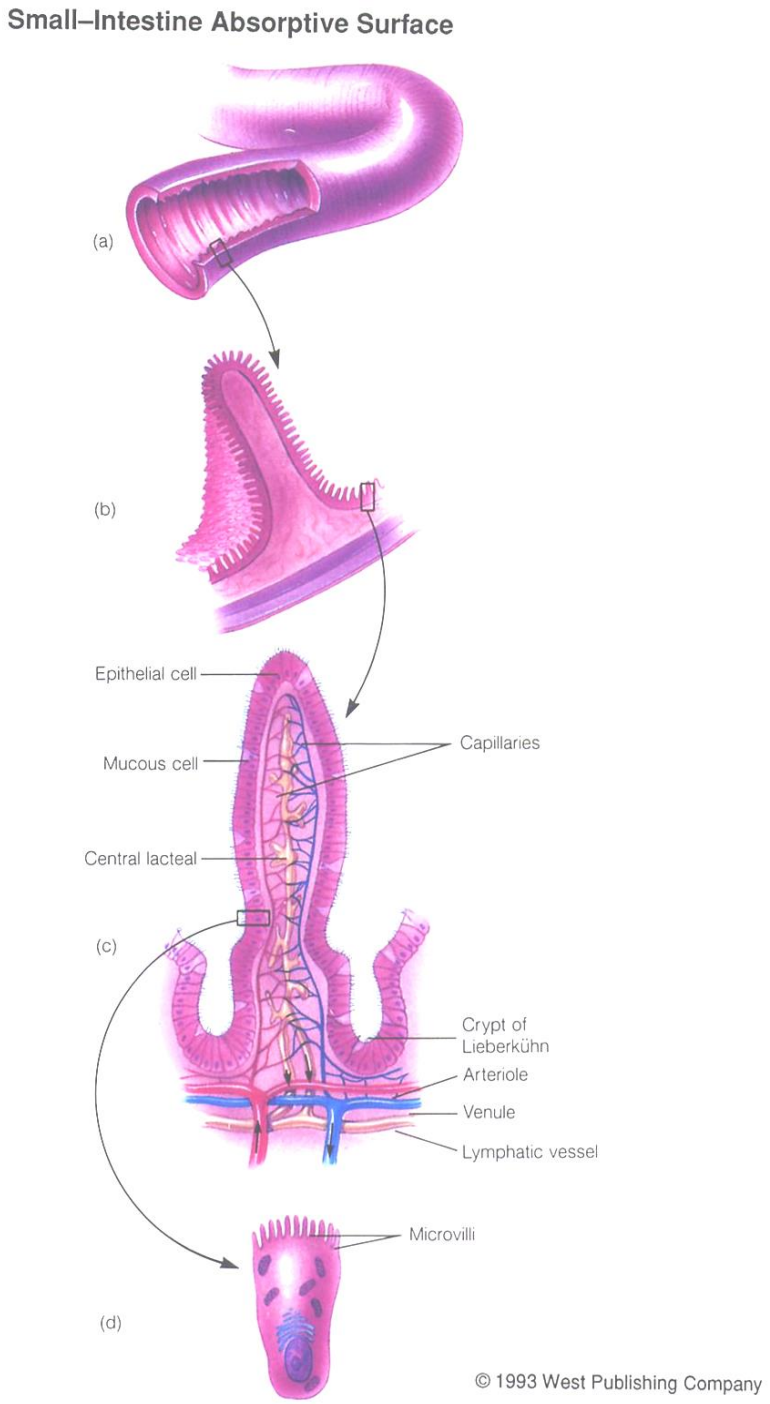
Digestion and Absorption

General Considerations

- **No absorption in esophagus**, little in the stomach and vast majority of absorption occurs in small intestine.
- The small intestine has **specialized structures to increase the absorptive** capacity by increasing the absorptive surface area of the mucosa.
- Most nutrients are absorbed **before reaching the ileum**.
- Colon is responsible for **final removal of electrolytes and water**.



Intestinal specialization

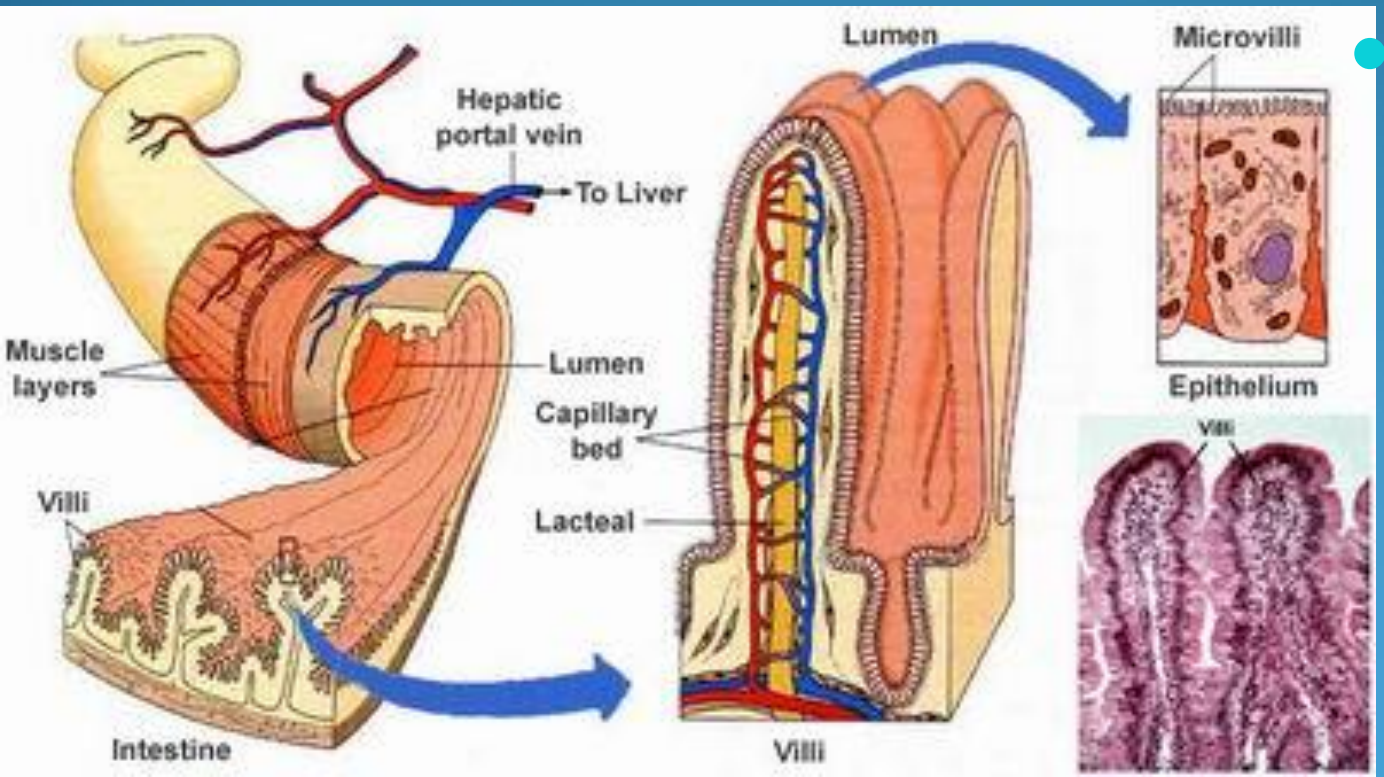
- Folds in mucosa and submucosa (Folds of Kerckring or Circular Folds)
- Villi which increases surface area 10 fold.
- Microvilli which increase surface area 20 fold.

The net increase in the surface area is 600 fold.

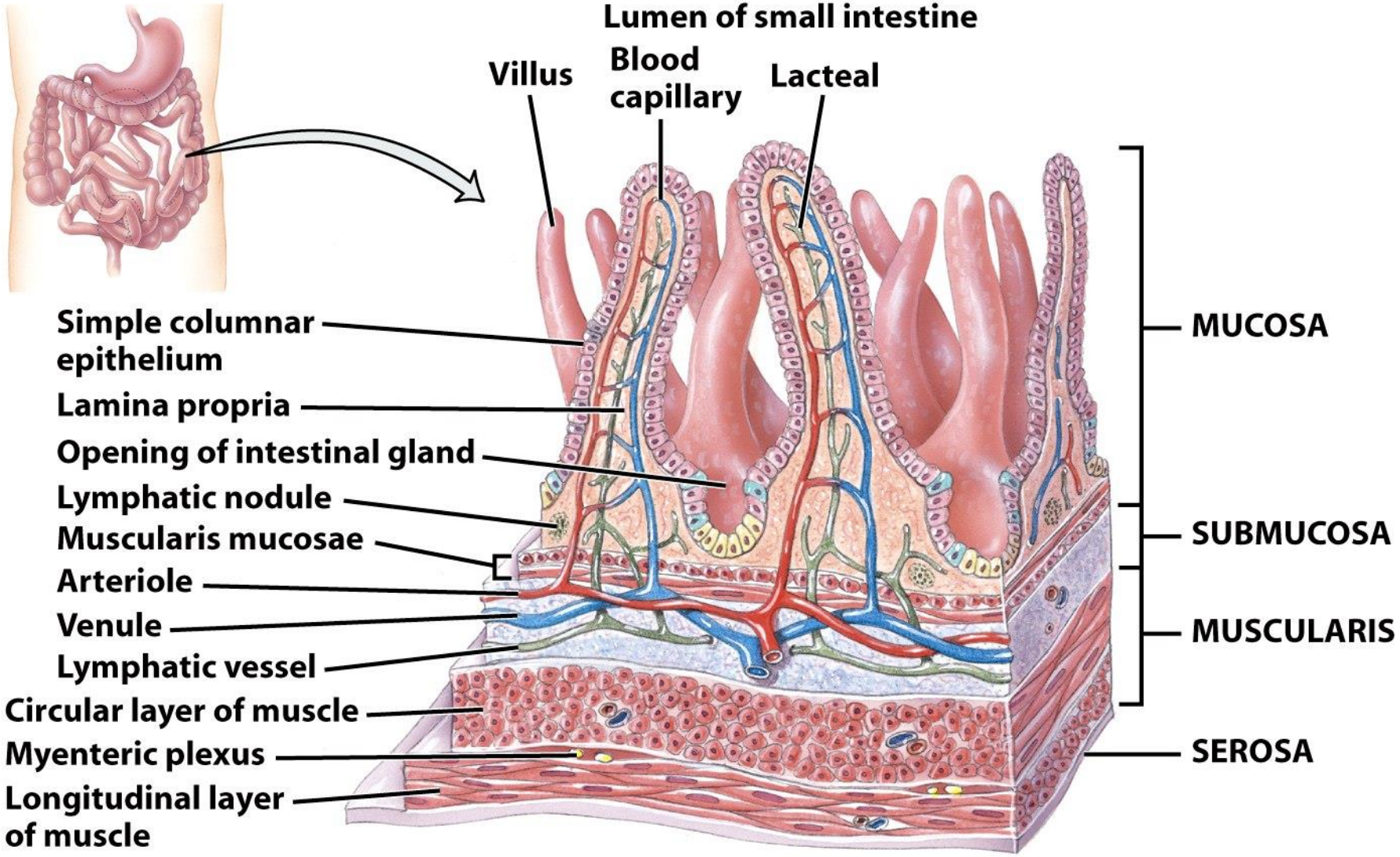
Intestinal specialization

Villus structure

- **Capillary network** which removes the absorbed nutrients very quickly.
- Lymphatic: **Central lacteals** removes lipids



- **Innervation** provides mechanism to regulate secretion by epithelial cells.



Three-dimensional view of layers of the small intestine showing villi

Figure 23-17a Anatomy and Physiology: From Science to Life

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Intestinal specialization

- Smooth muscle cells of the **muscularis mucosa** which allow folds to move and villi to wave in lumen.

- **Brush border enzymes**:

for final digestion of carbohydrate and proteins.

Digestion of carbohydrate

Forms of Ingested Carbohydrates

- - Mostly ingested as **starch** (a polymer of alpha 1-4 and alpha 1-6 linkages)
- - Lesser amounts as sugar **dimmers**:
  - **sucrose** (fructose and glucose) and
  - **lactose** (glucose and galactose).
- - **Cellulose** is a glucose polymer of 1,4 beta linkage.

Enzymes

Specialized enzymes that catalyze digestion (hydrolysis)

- **Ptyalin**: Begin process in oral cavity (alpha-amylase).

Optimal activity at neutral toward alkaline pH.

Starches → smaller polymers of glucose and α limit dextrins.

- **Pancreatic amylase**: digest 50-80% of starch.

Alpha amylase that attack at alpha 1,4 linkages → maltose, maltotriose and alpha limit dextrins

Enzymes

Brush border enzymes:

responsible for final hydrolysis of glucose polymers and disccharides → monosaccharides.

4 enzymes:

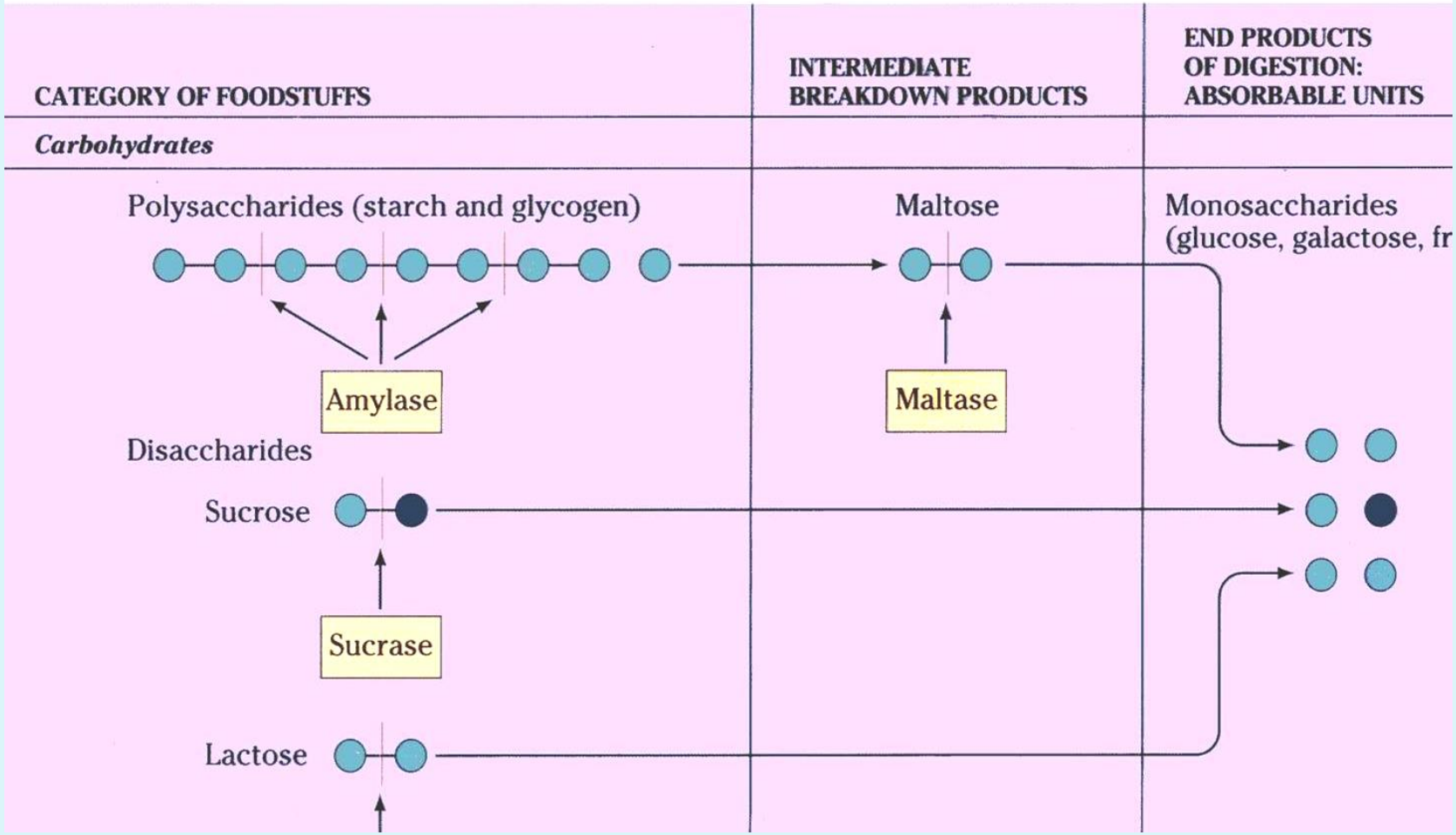
Lactase split lactose → glucose + galactose

Sucrase split sucrose → fructose + glucose.

Maltase split maltose, glucose polymers → glucose.

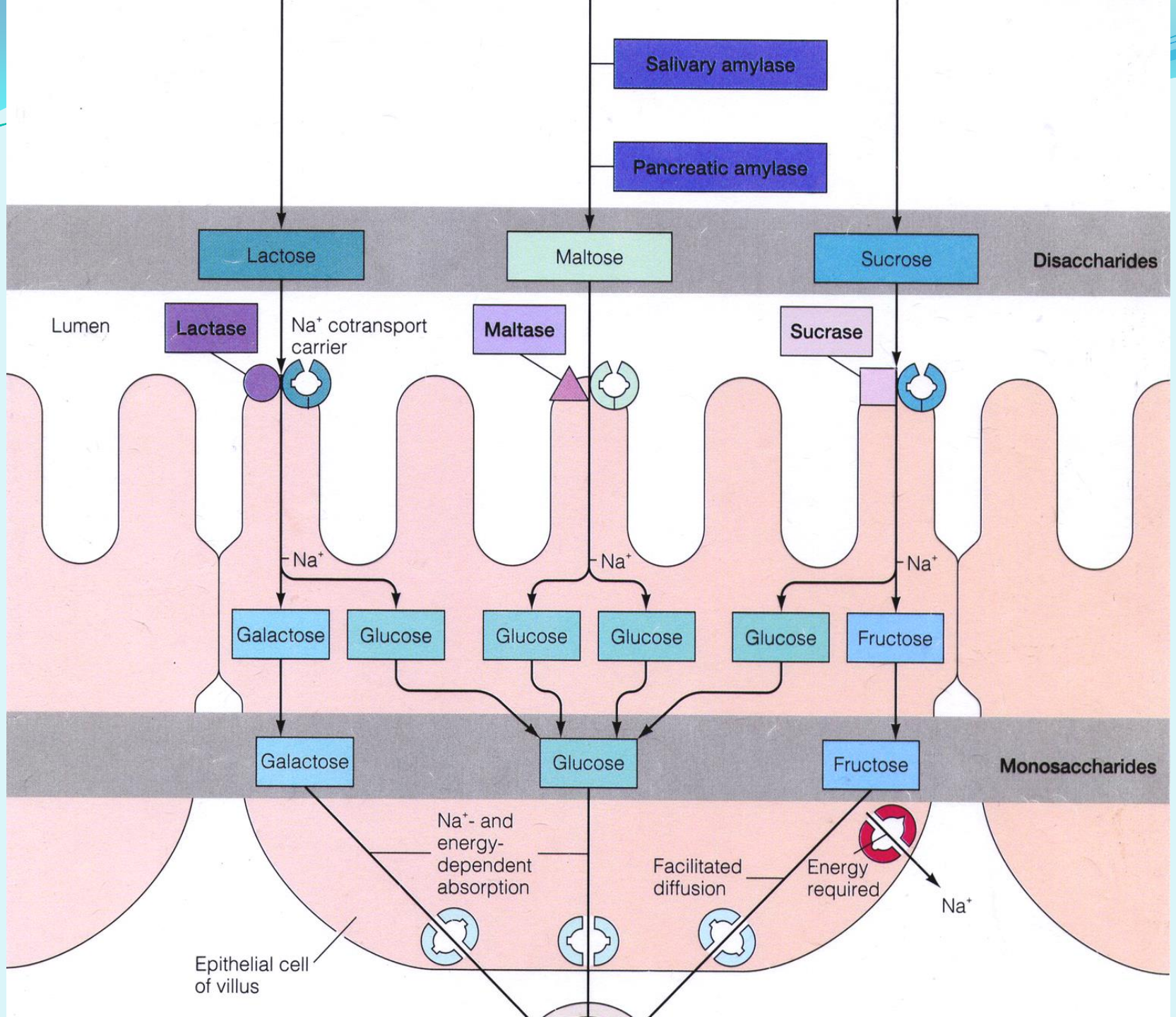
α- Dextrinase attack at alpha 1,6 linkage.

Process of Digestion



After final digestion of carbohydrate in intestinal lumen and Brush border → (Monomers)

glucose, fructose, galactose.


Salivary amylase
Pancreatic amylase
Lactose
Maltose
Sucrose
Disaccharides
Lumen
Lactase
Na+ cotransport carrier
Maltase
Sucrase
Na+
Na+
Na+
Galactose
Glucose
Glucose
Glucose
Glucose
Fructose
Galactose
Glucose
Fructose
Monosaccharides
Na+- and energy-dependent absorption
Facilitated diffusion
Energy required
Na+
Epithelial cell of villus

Absorption of Carbohydrates

Glucose

- Absorption is by a Na+ Dependent carrier (Secondary active co-transport).

- Absorption with solvent drag through the tight junction.

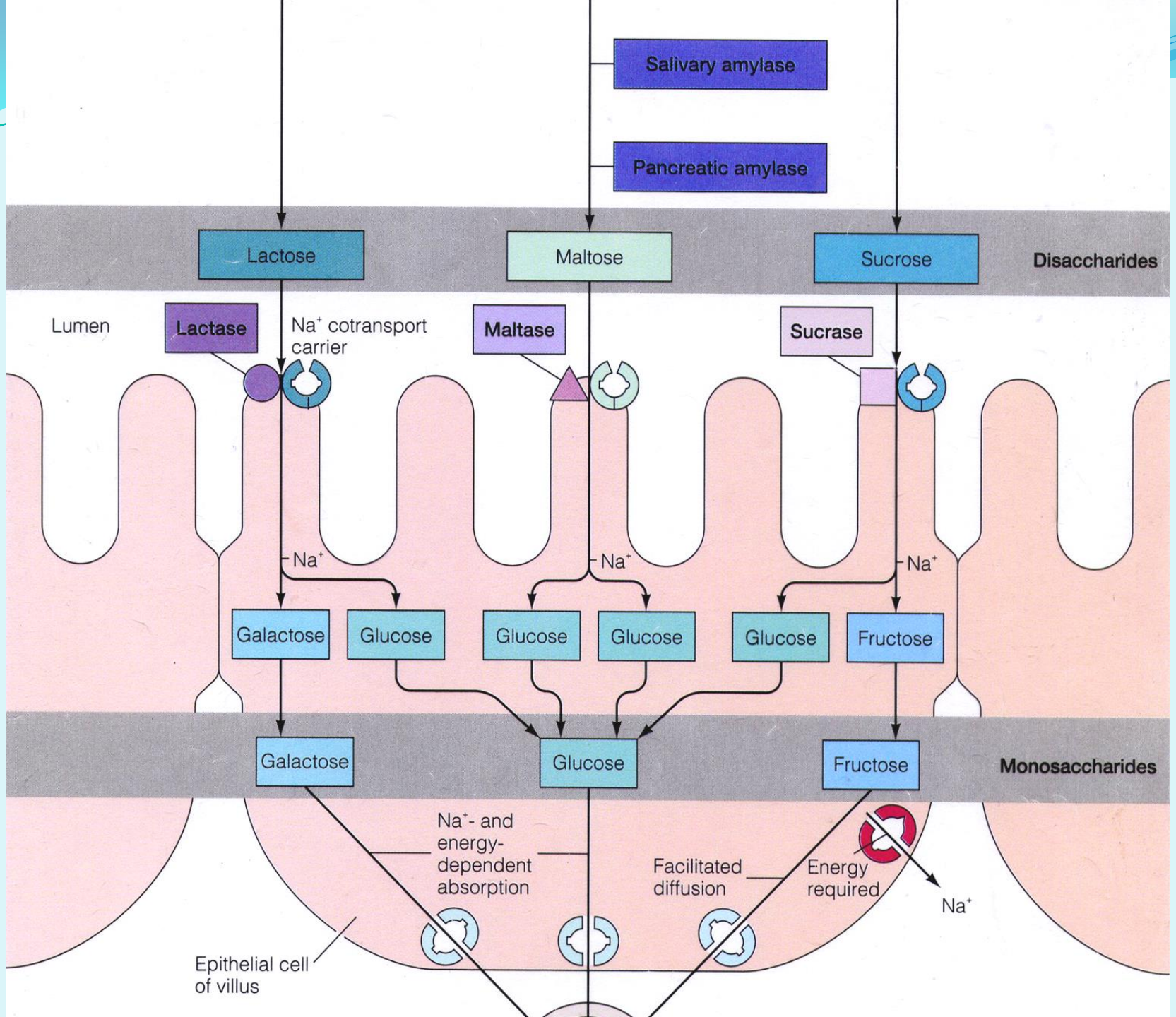
Increased glucose concentration in chyme → increased absorption → increased osmotic pressure in the paracellular space → increased fluid flow through the tight junction which carries anything dissolved.

Galactose

uses Na+ Dependent carriers as glucose (Secondary active transport).

Fructose

- Facilitated diffusion by using a Na+ independent carriers


Salivary amylase
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Sucrose
Disaccharides
Lumen
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Na+ cotransport carrier
Maltase
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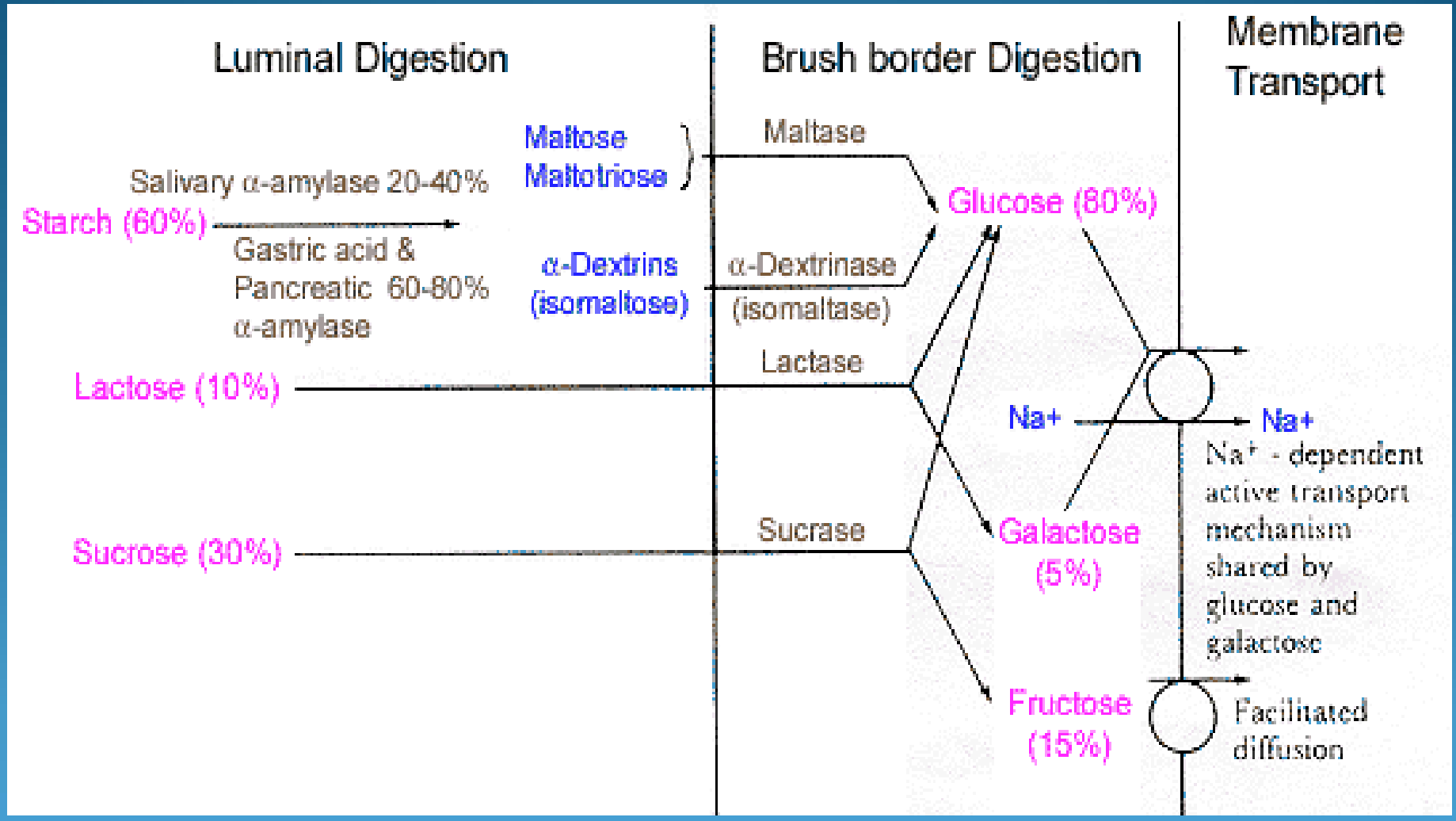
Na+
Na+
Na+
Galactose
Glucose
Glucose
Glucose
Glucose
Fructose
Galactose
Glucose
Fructose
Monosaccharides
Na+- and energy-dependent absorption
Facilitated diffusion
Energy required
Na+
Epithelial cell of villus

Summary
Digestion and absorption of carbohydrates



Digestion and Absorption of Proteins

Stomach

Protein digestion is very little (20%) by the activity of pepsin.

- Pepsin: This enzyme has an optimum activity at the pH 2-3.

Duodenal lumen

by proteolytic enzymes which include:

- Endopeptidases (trypsin and chymotrypsin).
- Exopeptidases: (carboxypeptidases)

protein hydrolysis →

small peptides and amino acids.

Small intestine

Brush border enzymes :

Aminopeptidase

→ **small peptides** and **amino acids.**

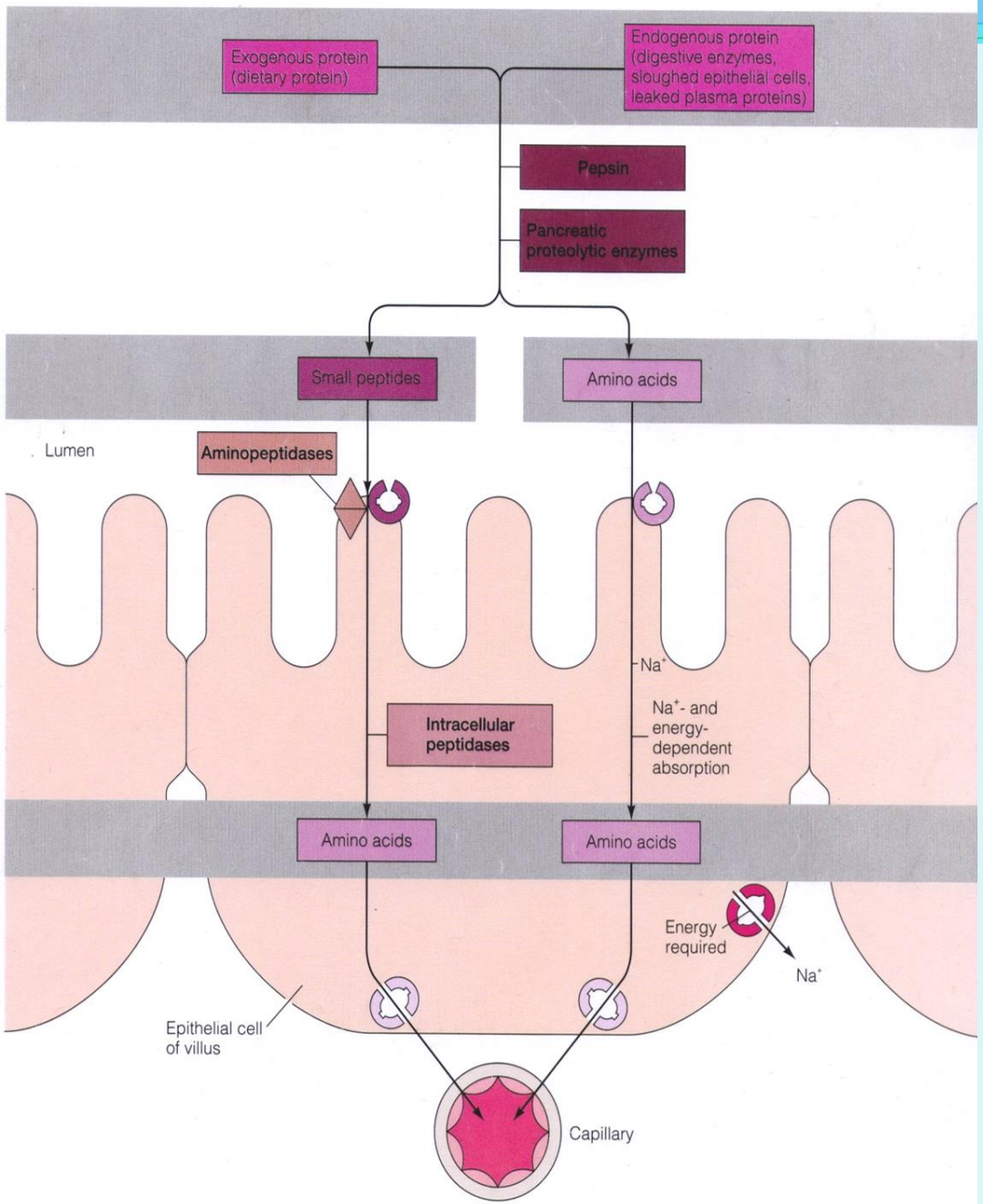
After absorption

Inside absorptive cells

Intracellular peptidase

small peptides → amino acids

Protein Digestion and Absorption



Protein Absorption

Small peptides

Di- and Tri-peptides are transported into the enterocyte by a Na+ dependent carrier mediated transport system (secondary active co-transport).

Amino acids

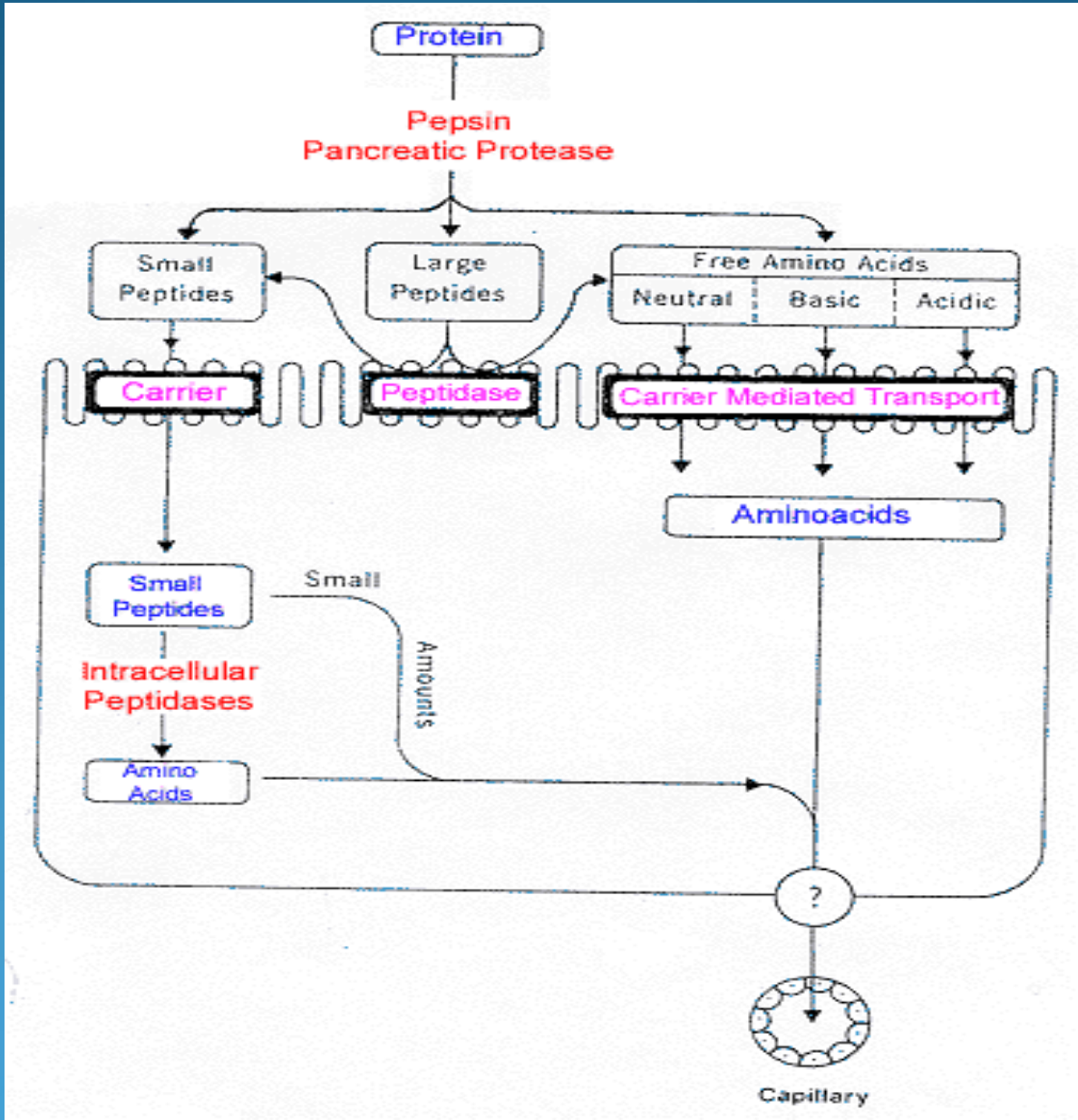
Transported by a membrane bound carriers:

* Na+ dependent carriers: 3 different carriers:

- For neutral amino acids.
- Proline and hydroxyproline.
- Phenylalanine and methionine.

*Na+ independent carriers: for basic and neutral aminoacids.

Summary of protein digestion and absorption

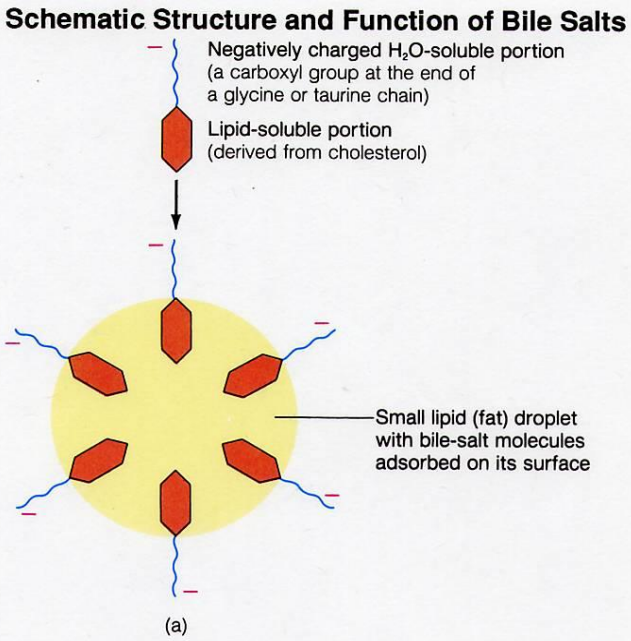


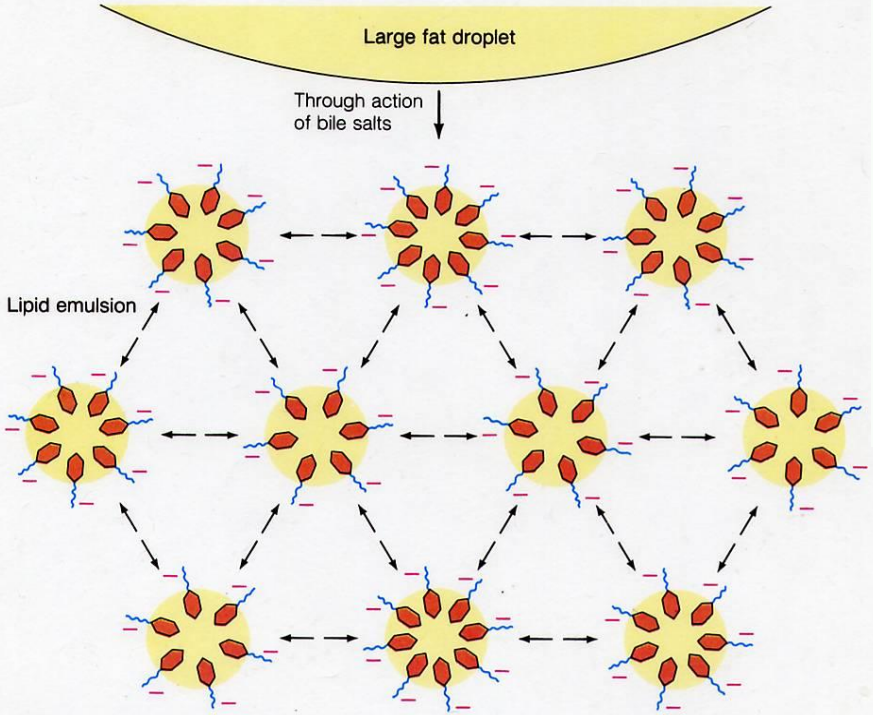
Lipid Digestion and Absorption

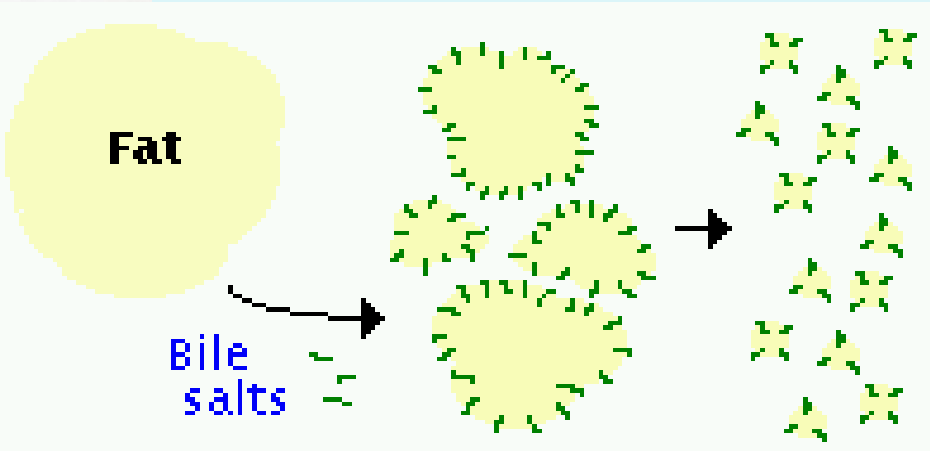
*Stomach: Little or no digestion or absorption of fat in the stomach.

*Intestine:

- In duodenum lipid is emulsified → small droplets (0.5-1micron) which are stabilized by bile salts.







Acetate 151 (Figure 16-20)

(b)

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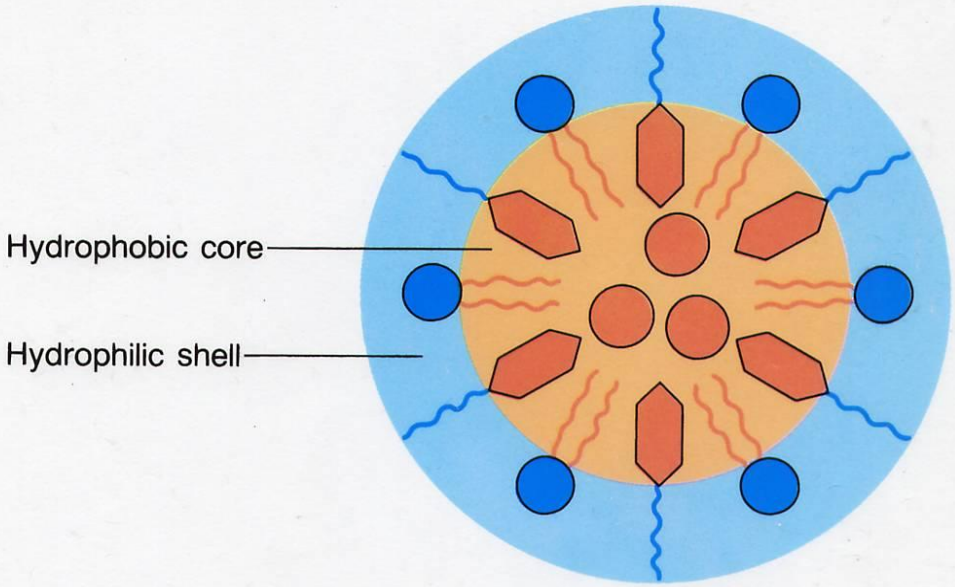
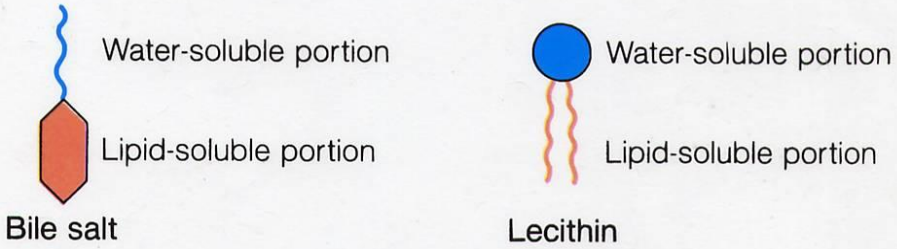
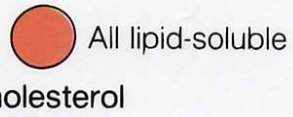
Schematic Representation of a Micelle







Acetate 152 (Figure 16-21)

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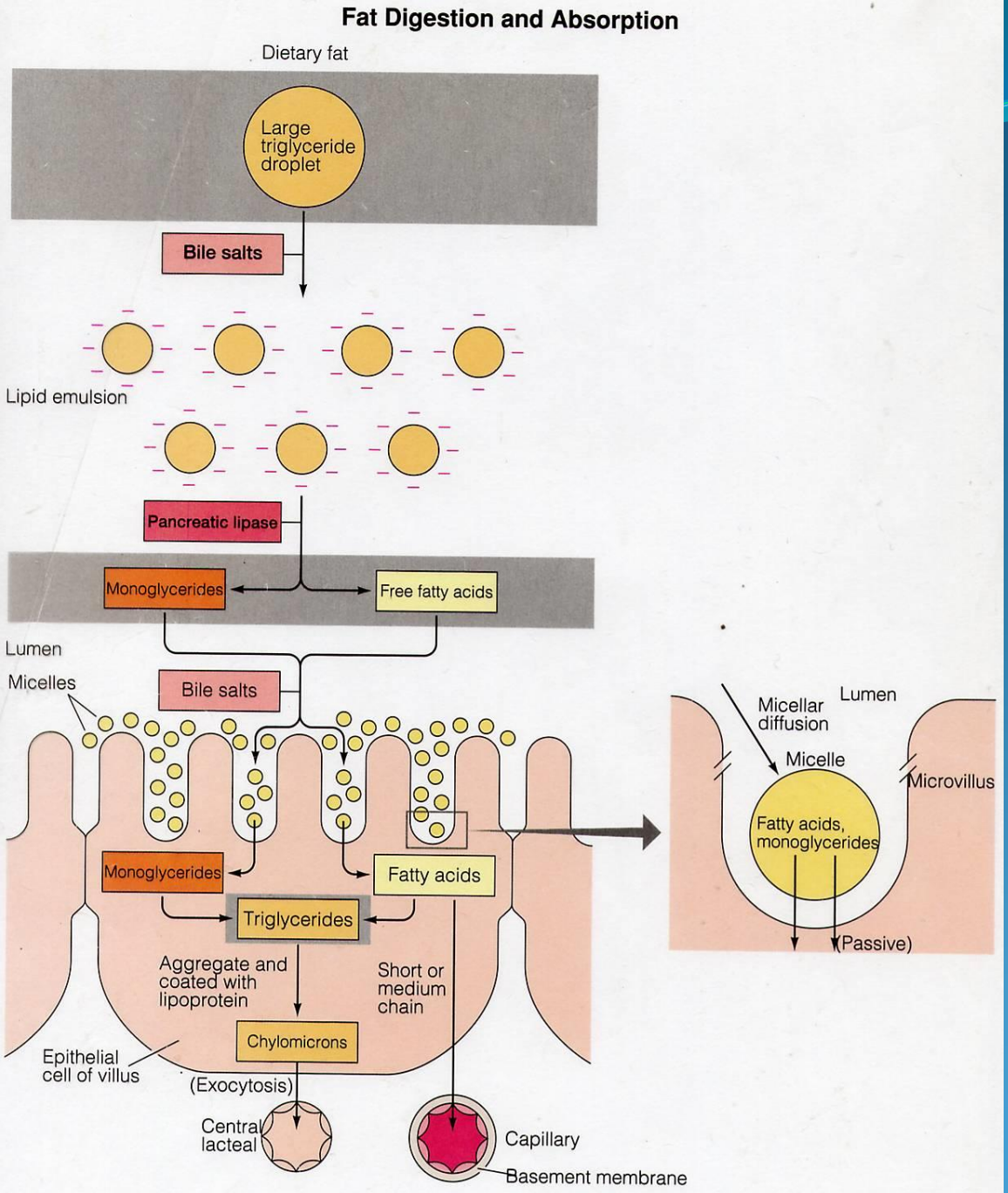
Lipid absorption

-Absorption across the lumenal membrane ***simple diffusion***.

-Once inside the epithelium,

FFA + monoglycerides → *Triglycerides*.

Triglycerides (80-90%) + cholesterol (3%) + phospholipids (10%) + B- lipoprotein (5%) **are combined → *chylomicrons*** (60-750nm diameter).→ expelled by **exocytosis**


Fat Digestion and Absorption
Dietary fat
Large triglyceride droplet
Bile salts
Lipid emulsion
Pancreatic lipase
Monoglycerides
Free fatty acids
Lumen
Micelles
Bile salts
Monoglycerides
Fatty acids
Triglycerides
Aggregate and coated with lipoprotein
Short or medium chain
Chylomicrons
Epithelial cell of villus
(Exocytosis)
Central lacteal
Capillary
Basement membrane
Micellar diffusion
Lumen
Micelle
Microvillus
Fatty acids, monoglycerides
(Passive)
Acetate 157 (Figure 16-28)
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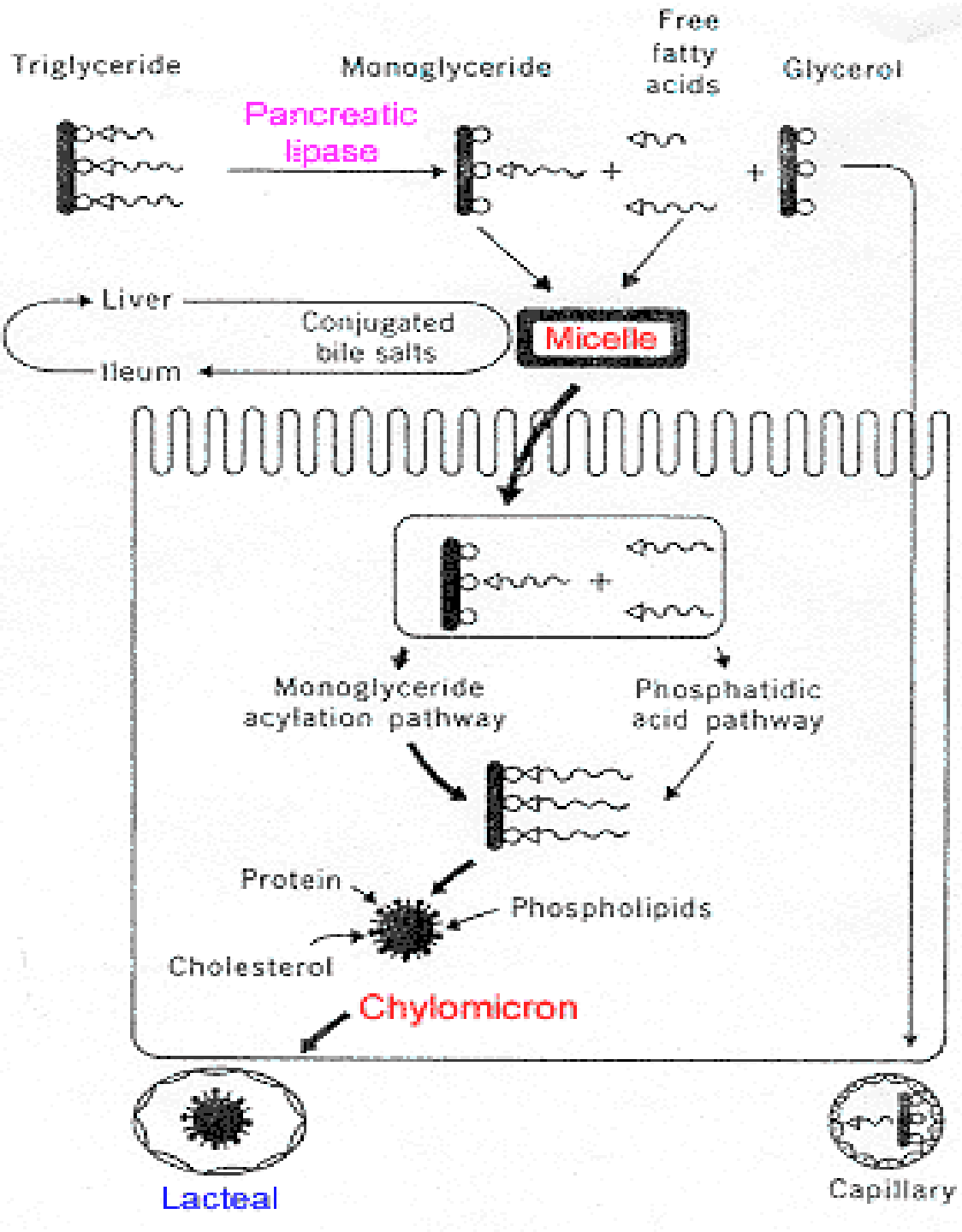

Triglyceride
Monoglyceride
Free fatty acids
Glycerol
Pancreatic lipase
Liver
Conjugated bile salts
Ileum
Micelle
Monoglyceride acylation pathway
Phosphatidic acid pathway
Protein
Phospholipids
Cholesterol
Chylomicron
Lacteal
Capillary

Absorption of water and electrolytes

- **Water** absorption is driven by Na+ absorption,

- **Na+:** Absorbed **actively** in the small intestine by the co-transport systems and colon.

- **Cl-:**

-Absorbed mainly in the upper part of the small intestine (duodenum and jejunum).

Absorption is passive and driven by the electrical gradient established by the absorption of Na+.

- **K+:**

-Absorbed passively in small intestine.

-In colon usually secreted in exchange for Na+.

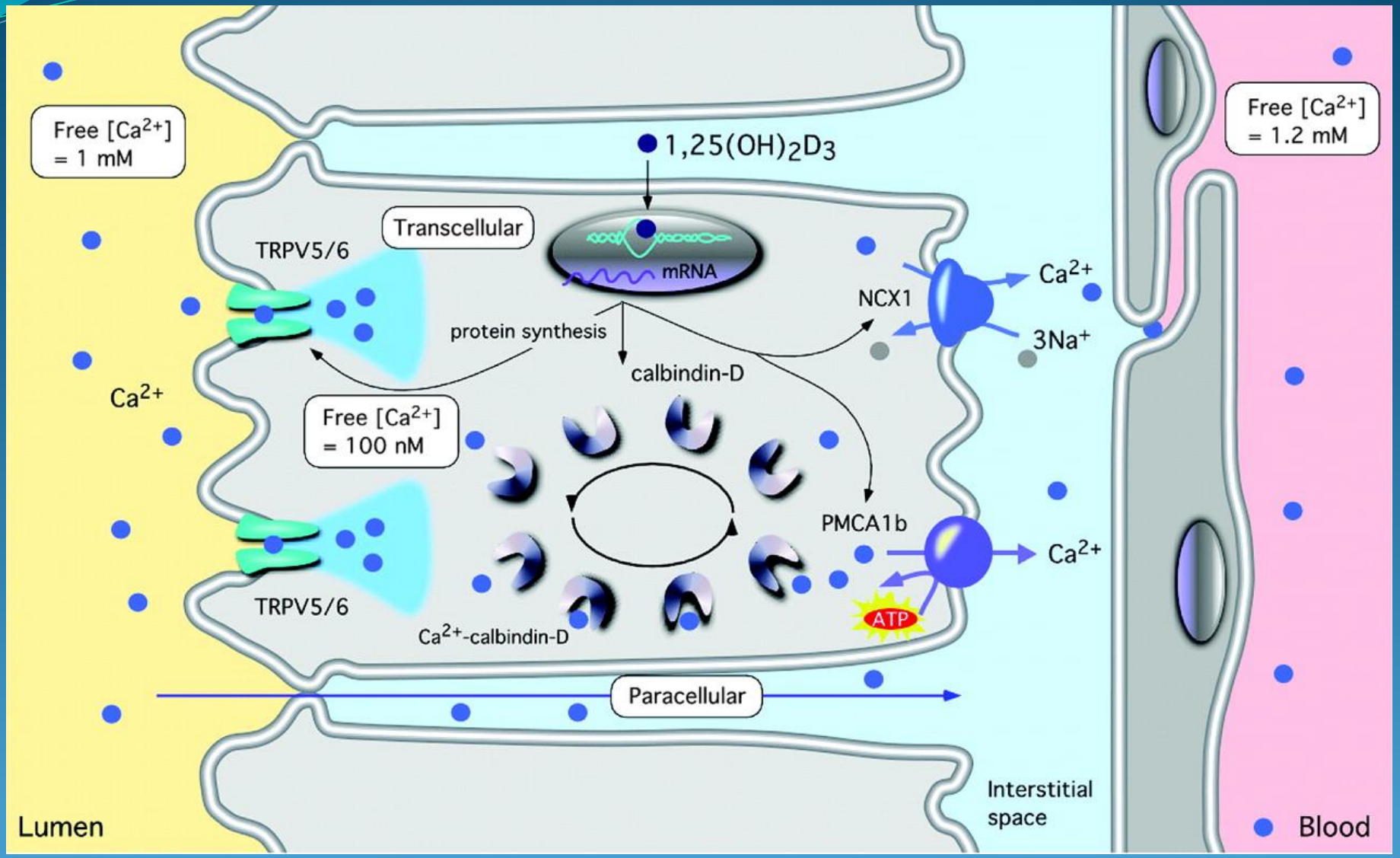
- **Ca++:** (active absorption)

It binds to a protein at the brush border membrane (may be a carrier).

- Once Ca++ is inside it bind to a cytosolic Ca++ binding protein called ***calbindin*** Which transports Ca++ across the cell.

-Ca++ is pumped out at the basolateral membrane by an active process.

-Ca++ absorption is increased by vitamin D and parathyroid hormone.


Free [Ca2+] = 1 mM
1,25(OH)2D3
Transcellular
TRPV5/6
mRNA
protein synthesis
calbindin-D
NCX1
Ca2+
3Na+
Free [Ca2+] = 100 nM
Ca2+
PMCA1b
Ca2+
ATP
TRPV5/6
Ca2+-calbindin-D
Paracellular
Free [Ca2+] = 1.2 mM
Lumen
Interstitial space
Blood

Fe++ (iron):

-Absorption is mainly in the upper part of the small intestine (duodenum and the adjacent jejunum).

-Iron absorption is **enhanced** by acidic pH of gastric juice and vitamin C.

-Fe++(ferrous iron) is more soluble than Fe+++ (ferric iron).

Phosphates, oxalates, phytic acid (found in cereals) and pancreatic juice **inhibit** iron absorption.

Mechanisms of Fe++ absorption

- **Active mechanism** of transport

-secretion of ***apoferritin*** → binding to Fe++ (*ferittin*) then →binds to receptors on epith. Cells →endocytosis. (stored in epithelial cells).

As needed → in blood binds to *transferrin*.

If not needed, iron is lost with cell desquamation (**Mucosal Block**).

Absorption of vitamins

- Most vitamins are absorbed in the upper part of the small intestine, but vit. B12 is absorbed in the ileum.

water soluble vitamins

water soluble vitamins are absorbed **passively** except vit. C, vit. B1, and vit. B12.

Absorption of vit. B12 requires the intrinsic factor secreted by the oxyntic cells of the stomach.

Lipid soluble vitamins

(Vit. A, D, E, K).

Follow the same route as lipids.

Solubilized in micelles and chylomicrons.