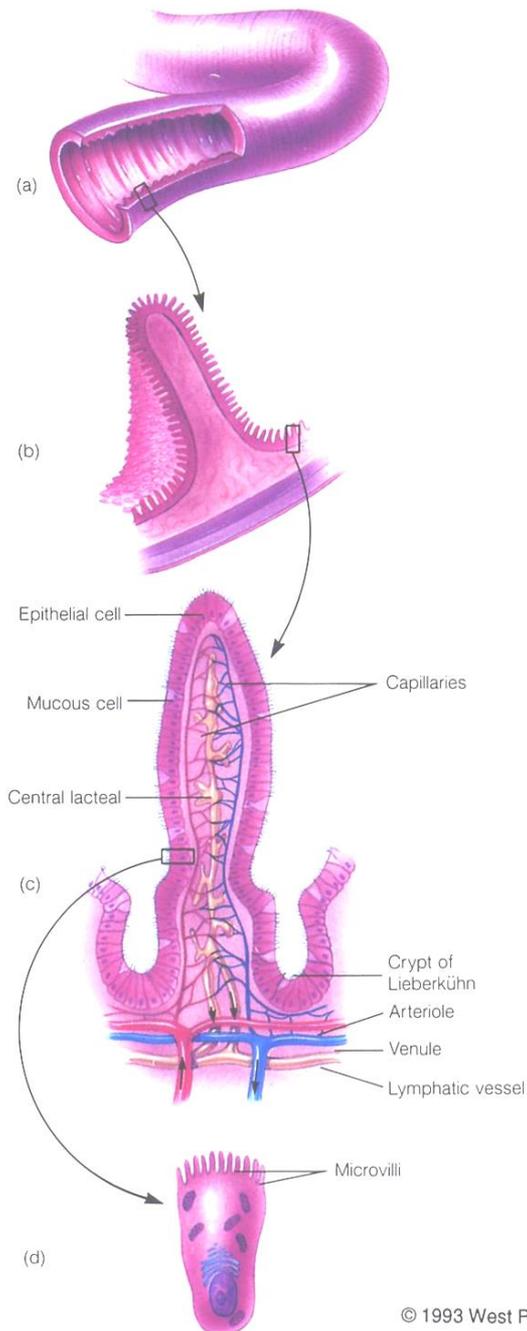


Digestion and Absorption

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

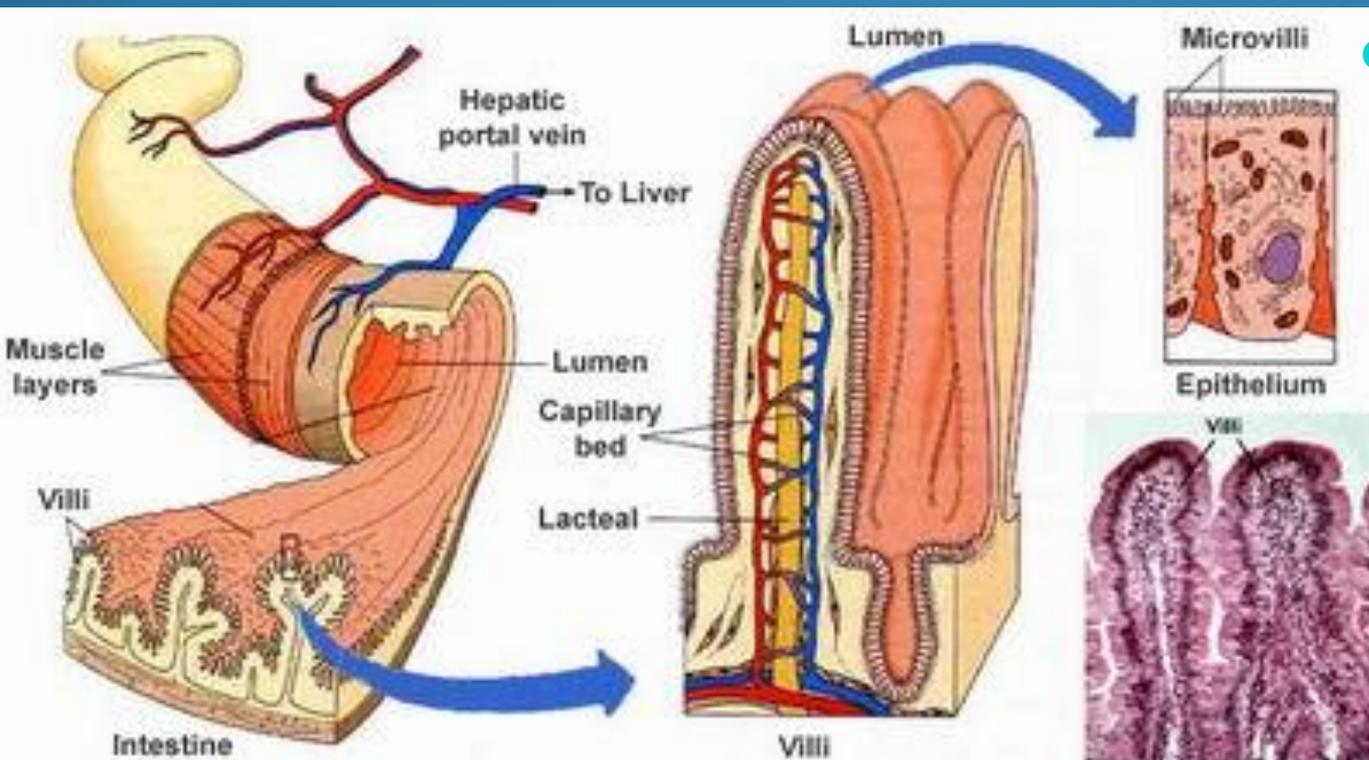
- Folds in mucosa and submucosa (Folds of Kerckring or Circular Folds)
- Villi which increases surface area 10 fold.
- Microvilli which increase surface area 20 fold.

The net increase in the surface area is 600 fold.

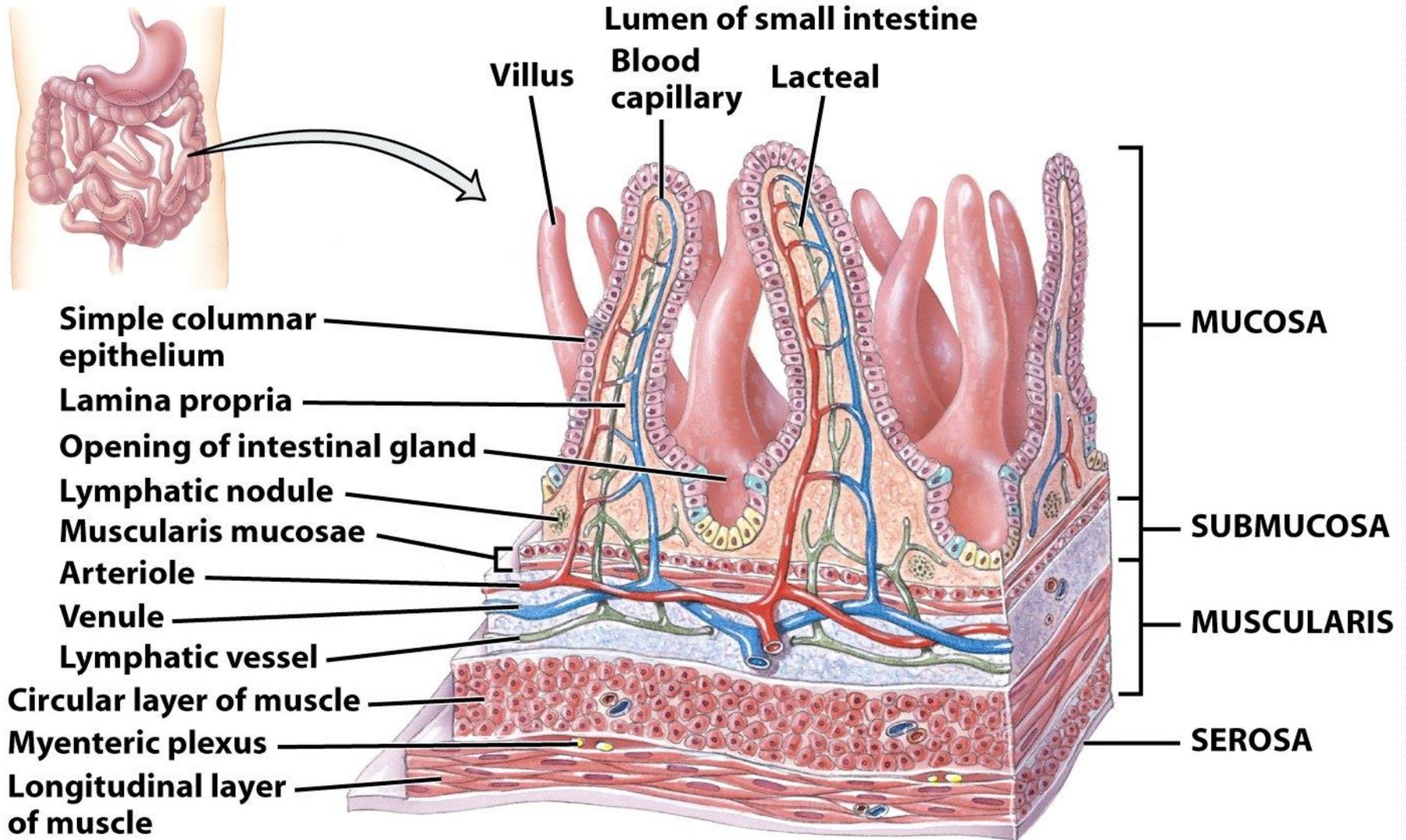
Intestinal specialization

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

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 **dimers**:
 - **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 dextrans.

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

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

Enzymes

Brush border enzymes:

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

4 enzymes:

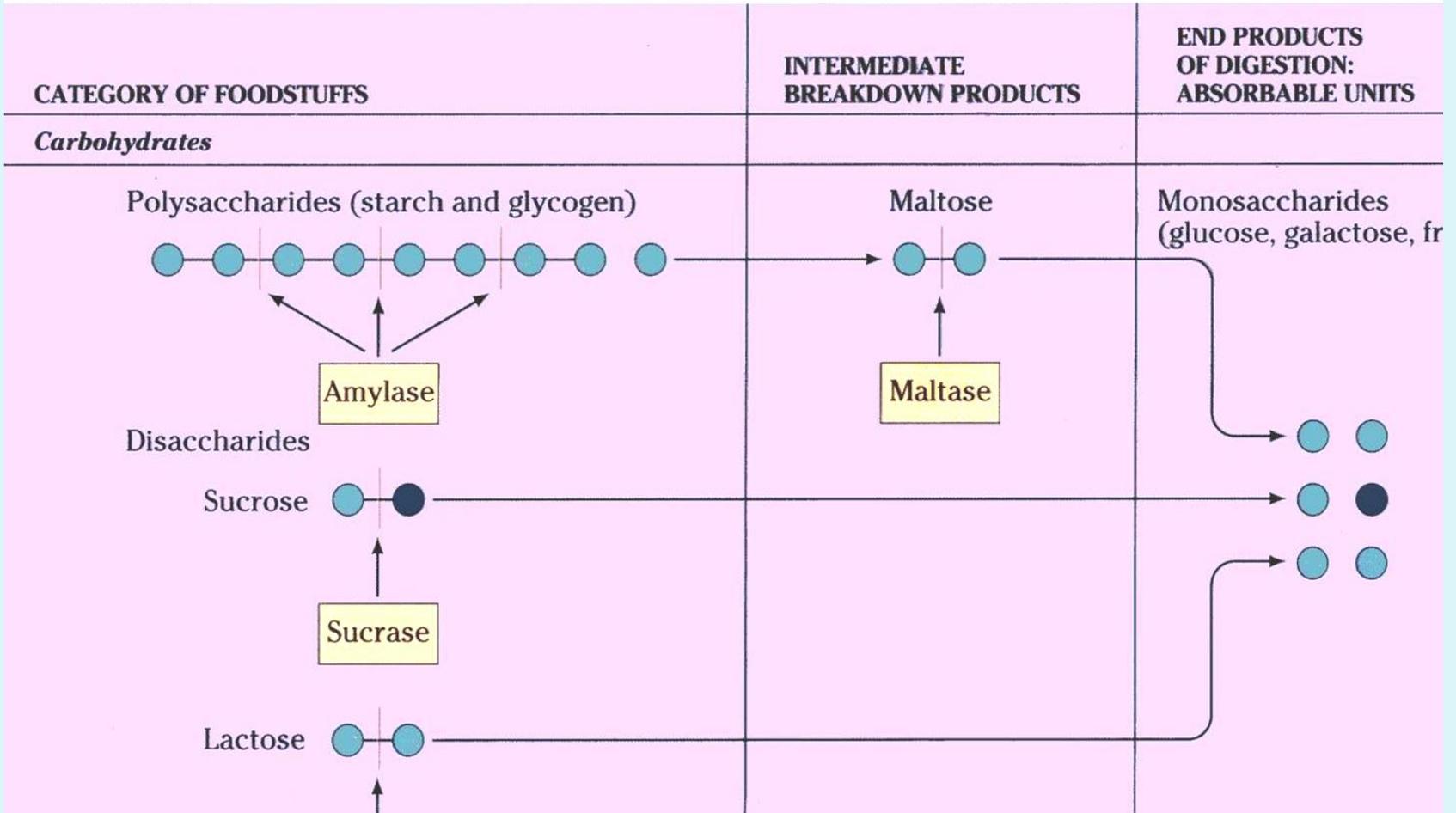
Lactase split lactose → glucose + galactose

Sucrase split sucrose → fructose + glucose.

Maltase split maltose, glucose polymers → glucose.

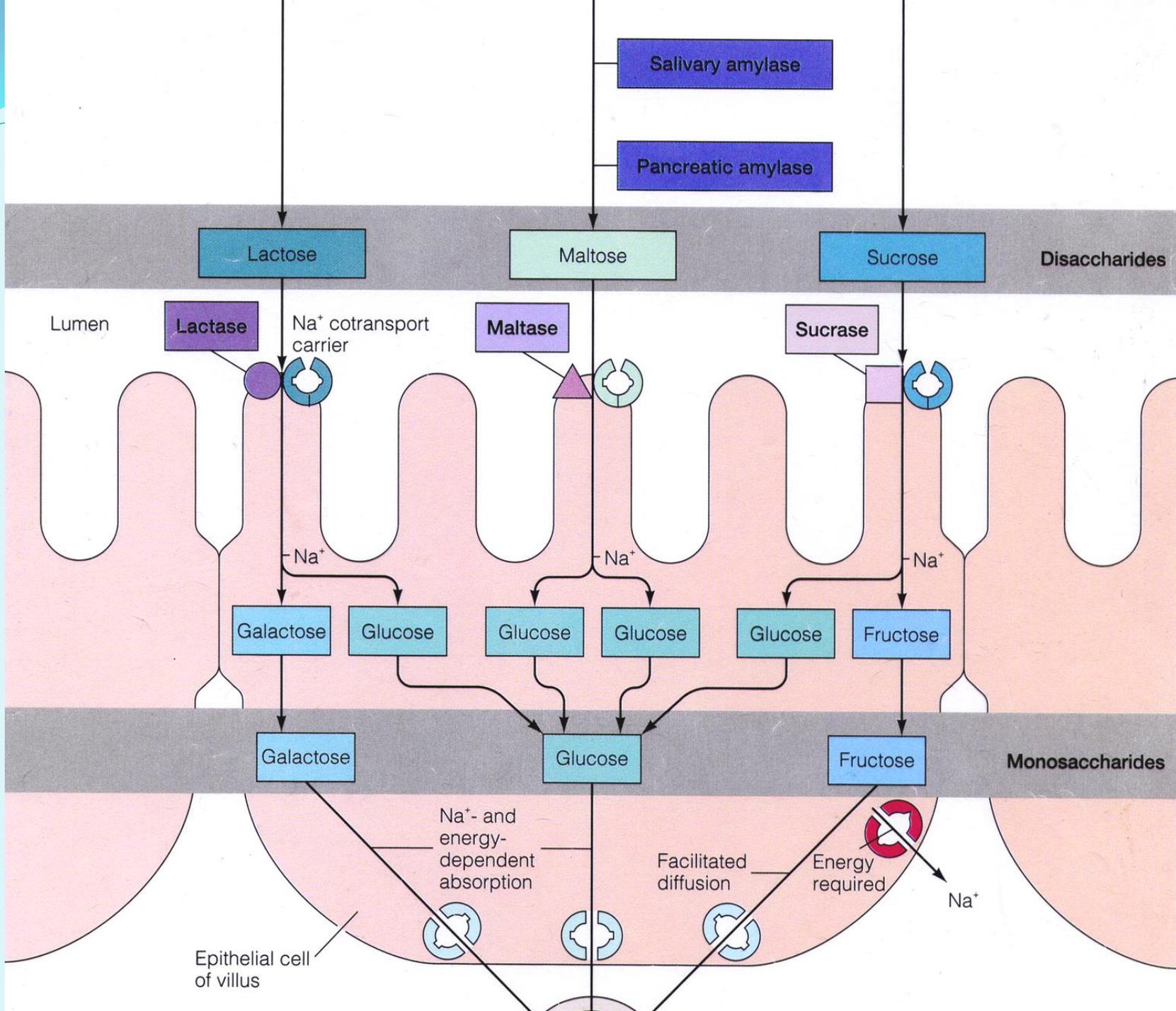
α -Dextrinase attack at alpha 1,6 linkage.

Process of Digestion



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

glucose, fructose, galactose.



Absorption of Carbohydrates

Glucose

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

- Absorption with solvent drag through the tight junction.

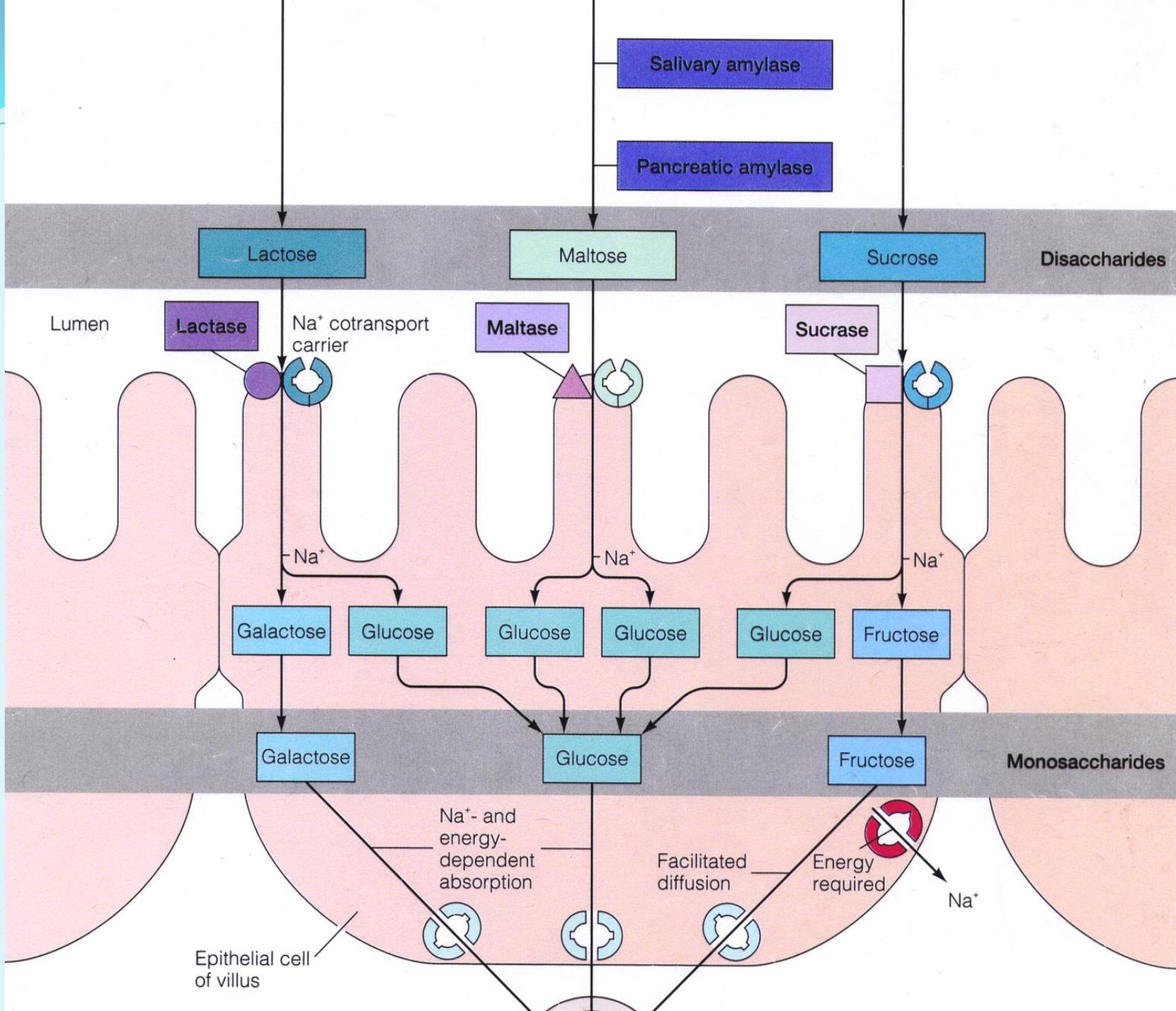
Increased glucose concentration in chyme → increased absorption → increased osmotic pressure in the paracellular space → increased fluid flow through the tight junction which carries anything dissolved.

Galactose

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

Fructose

- **Facilitated diffusion** by using a Na^+ independent carriers



Salivary amylase

Pancreatic amylase

Lactose

Maltose

Sucrose

Disaccharides

Lumen

Lactase

Na^+ cotransport carrier

Maltase

Sucrase

Galactose

Glucose

Glucose

Glucose

Glucose

Fructose

Galactose

Glucose

Fructose

Monosaccharides

Na^+

Na^+

Na^+

Na^+ - and energy-dependent absorption

Facilitated diffusion

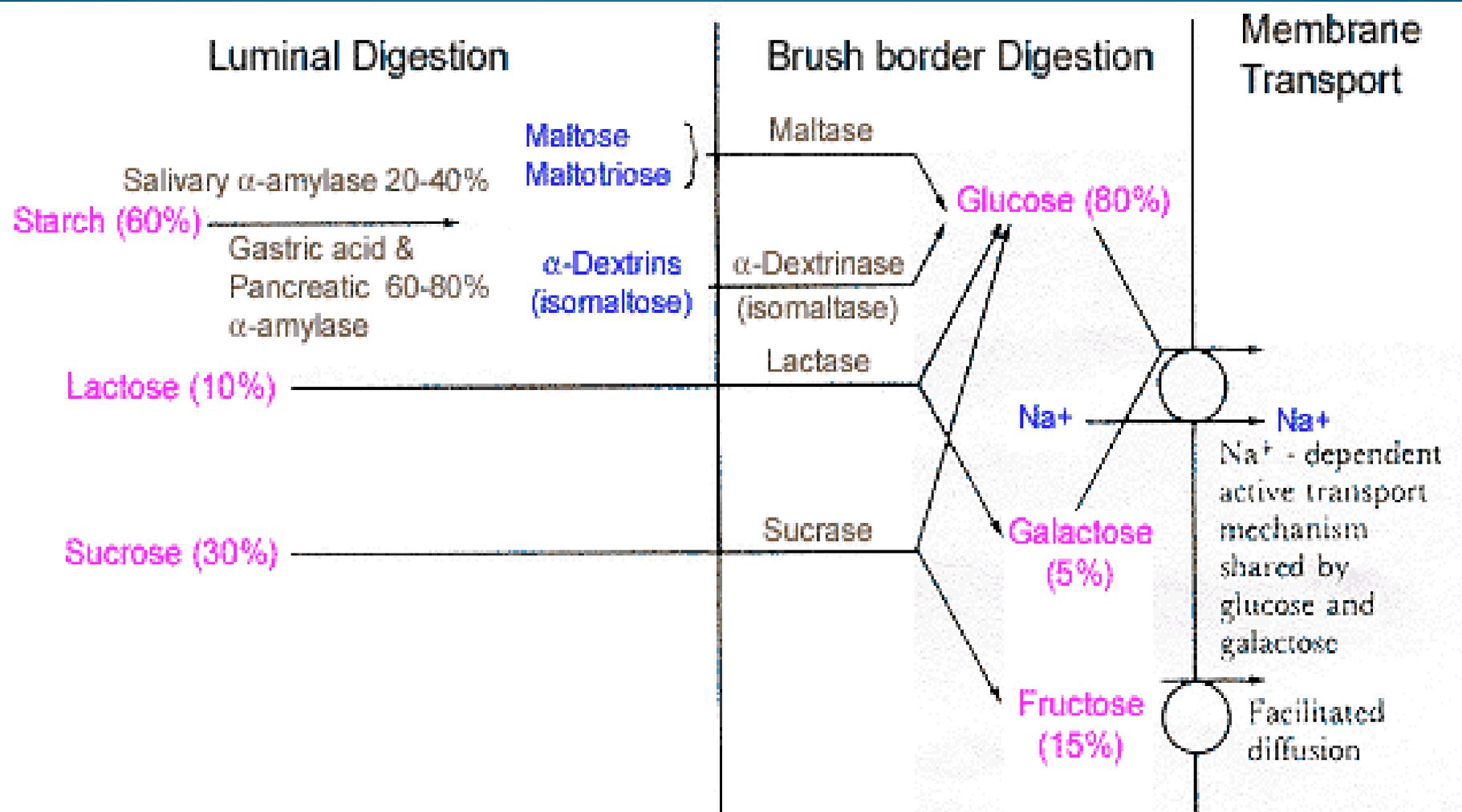
Energy required

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**.

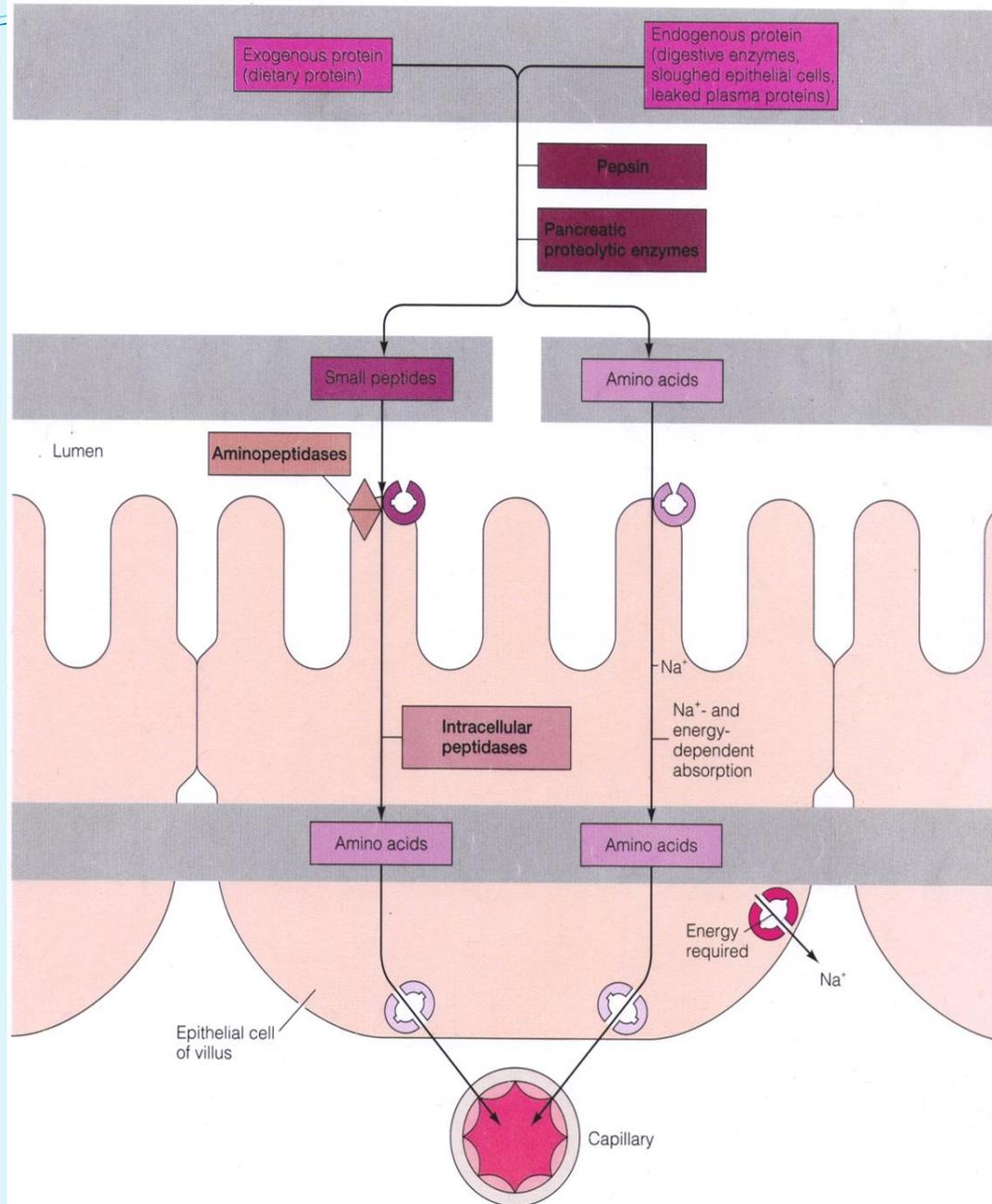
After absorption

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

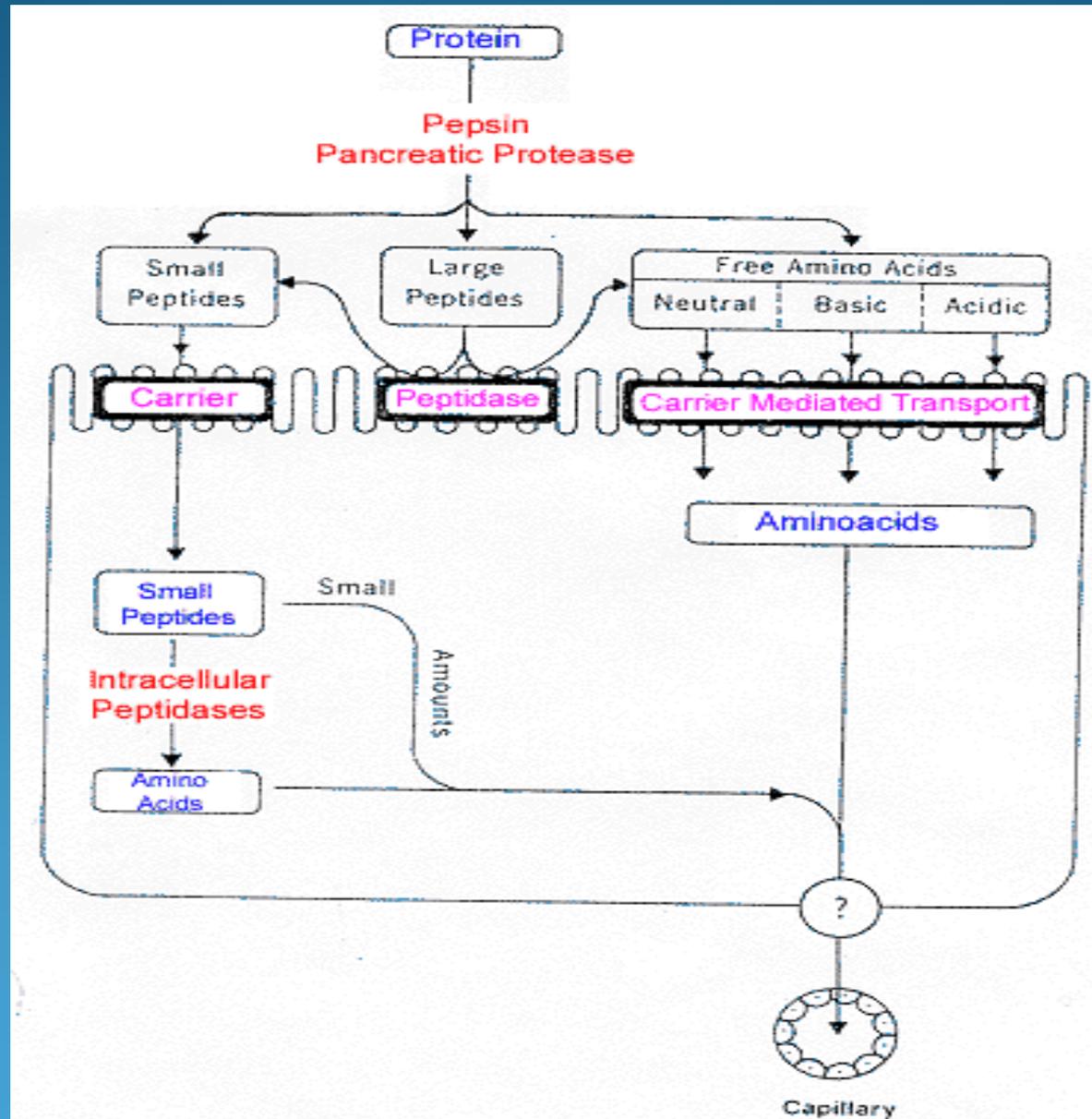
Transported by a membrane bound carriers:

* Na^+ dependent carriers: 3 different carriers:

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

* Na^+ independent carriers: for basic and neutral amino acids.

Summary of protein digestion and absorption



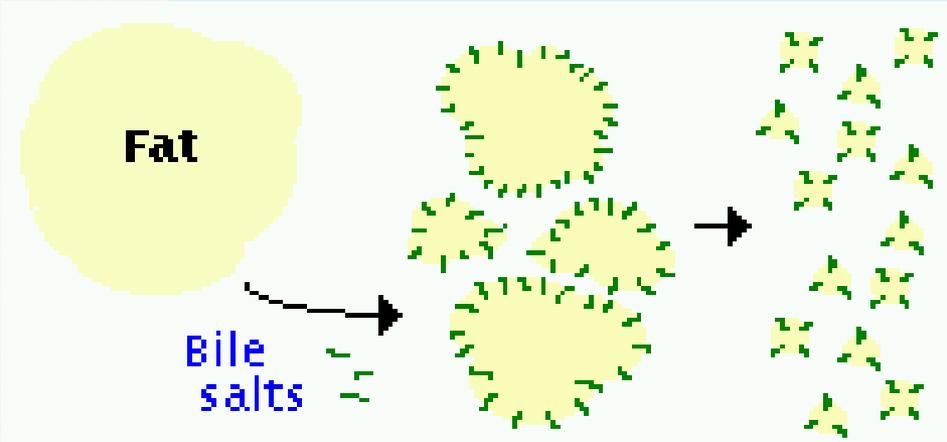
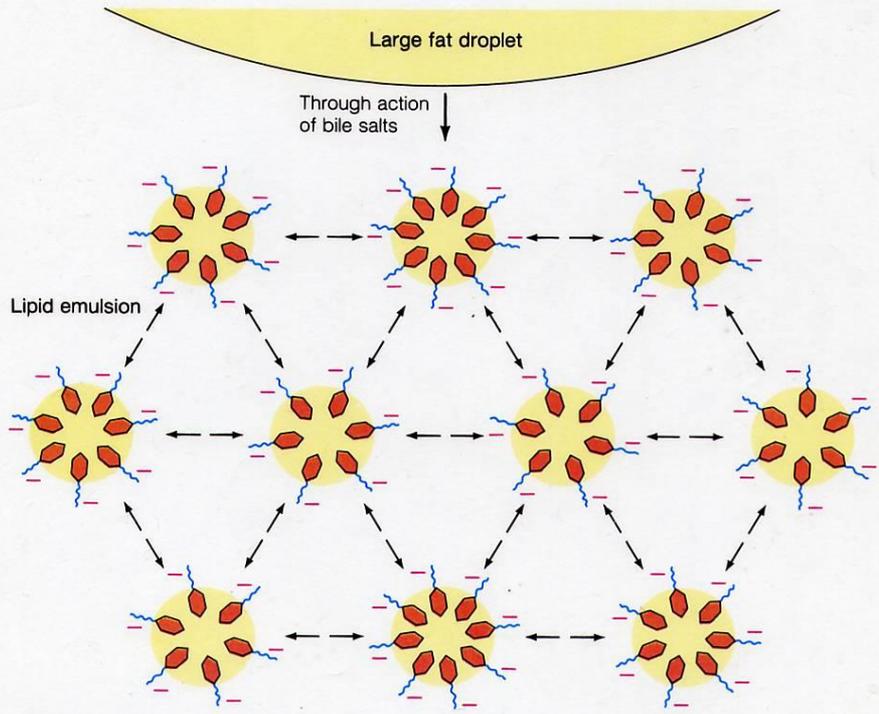
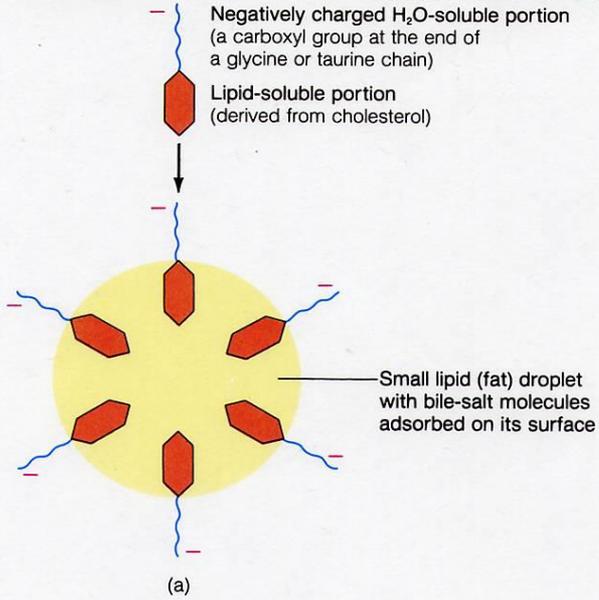
Lipid Digestion and Absorption

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

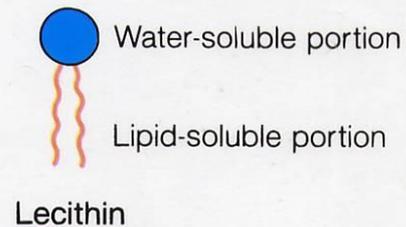
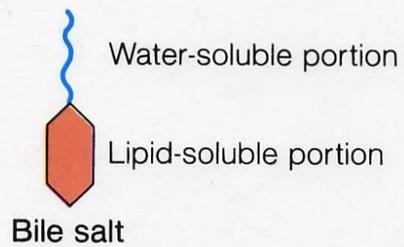
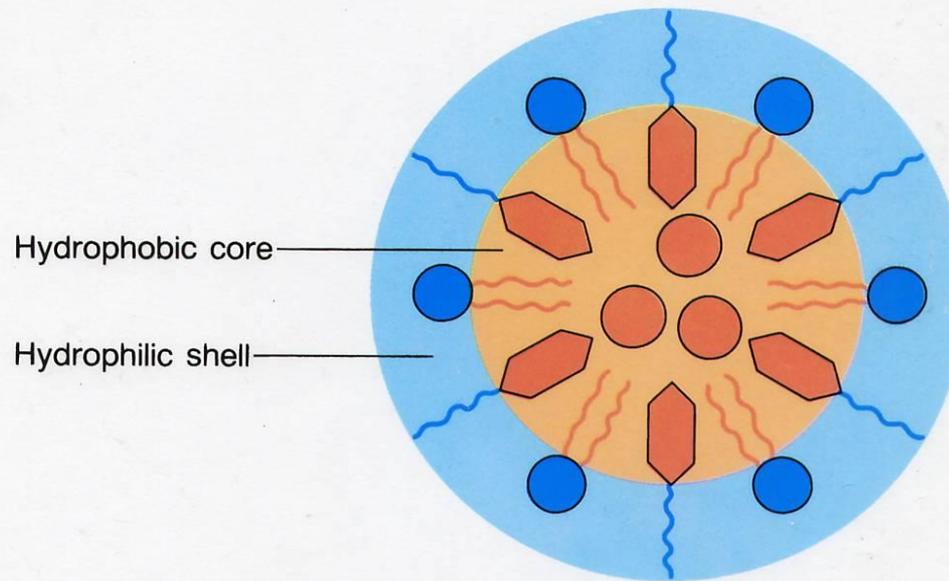
*Intestine:

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

Schematic Structure and Function of Bile Salts



Schematic Representation of a Micelle



Lipid absorption

-Absorption across the luminal membrane
simple diffusion.

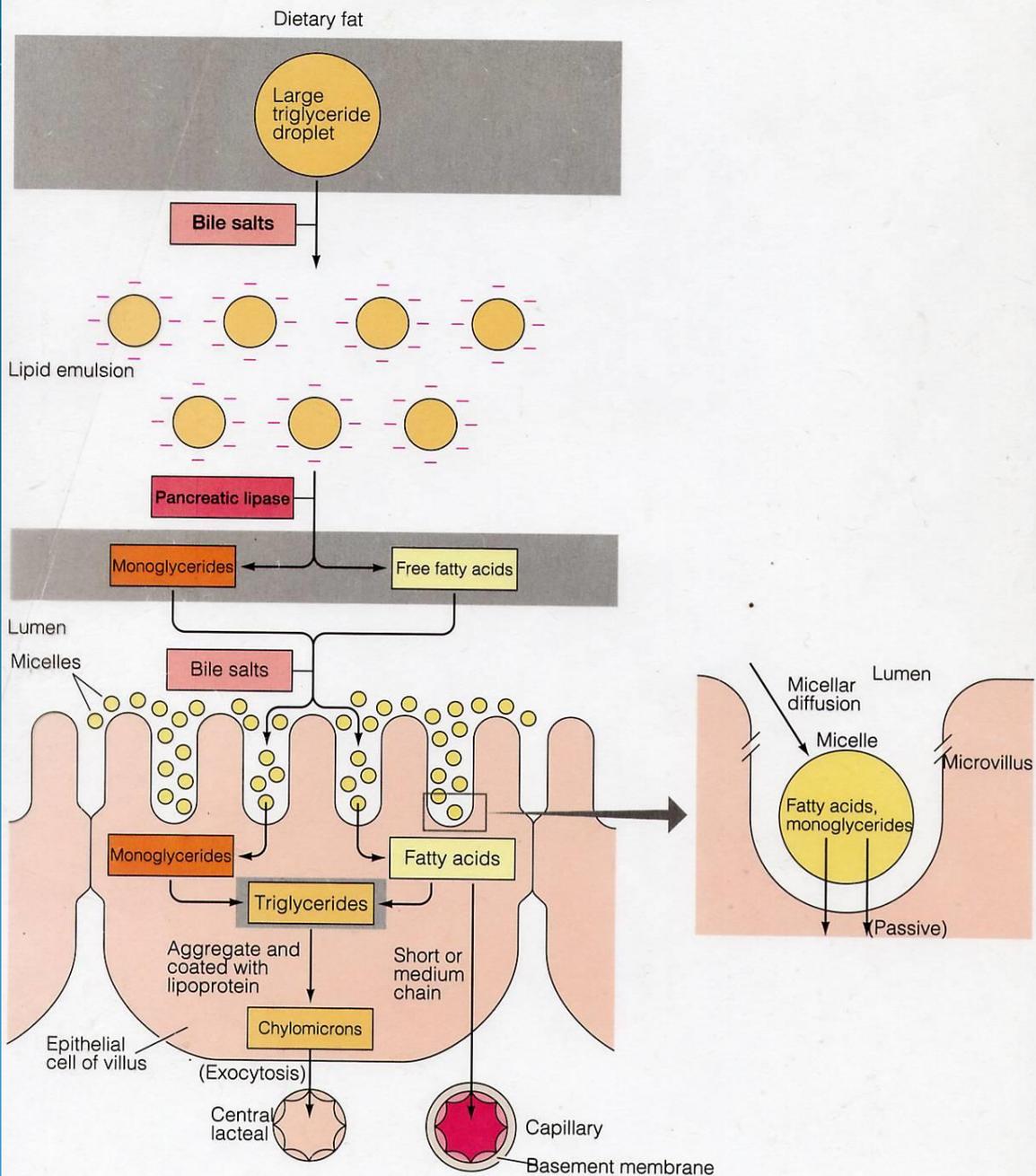
-Once inside the epithelium,

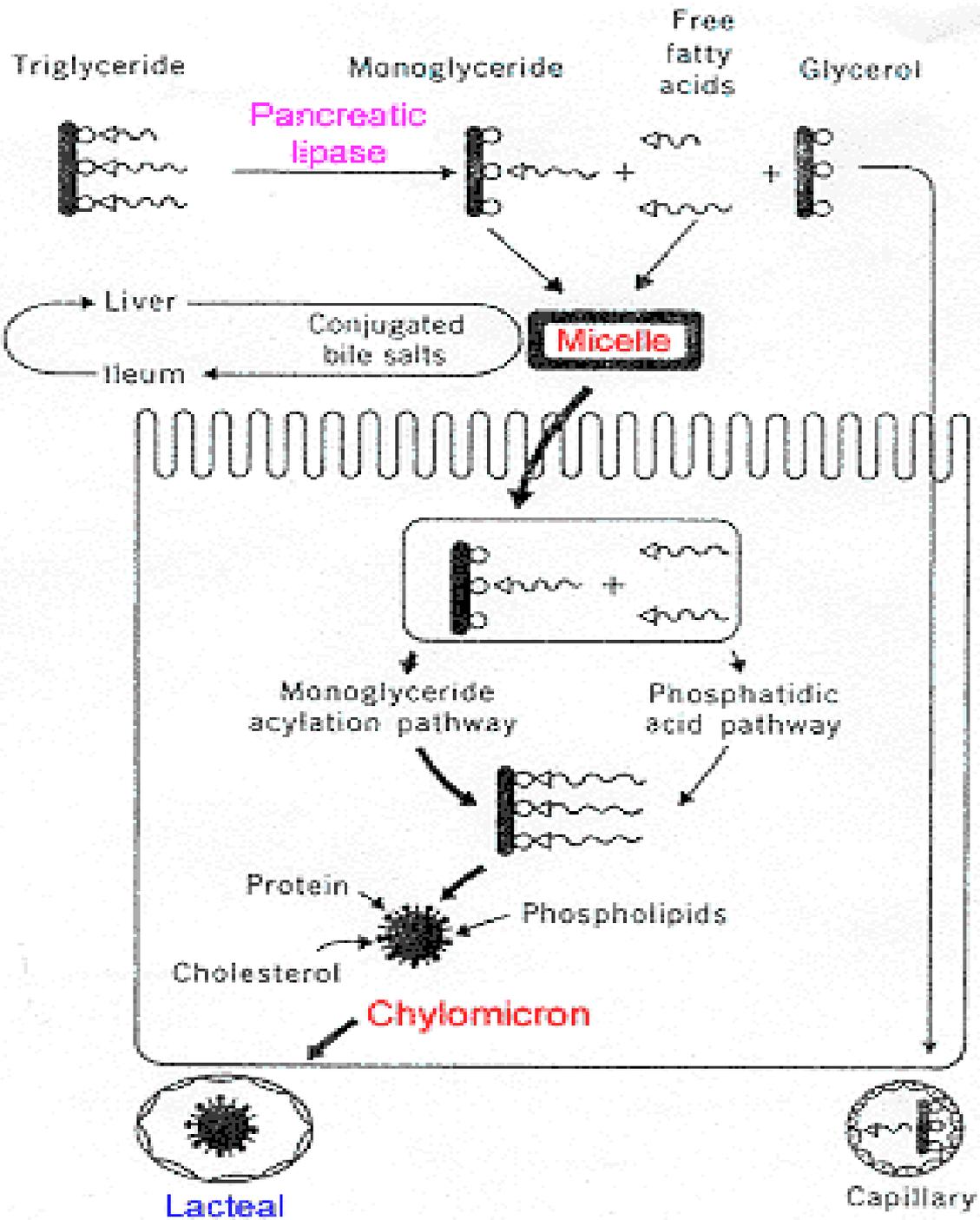
FFA + monoglycerides → *Triglycerides*.

Triglycerides (80-90%) + cholesterol (3%) +
phospholipids (10%) + B- lipoprotein (5%)

are combined → *chylomicrons* (60-
750nm diameter). → expelled by **exocytosis**

Fat Digestion and Absorption





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^+ .

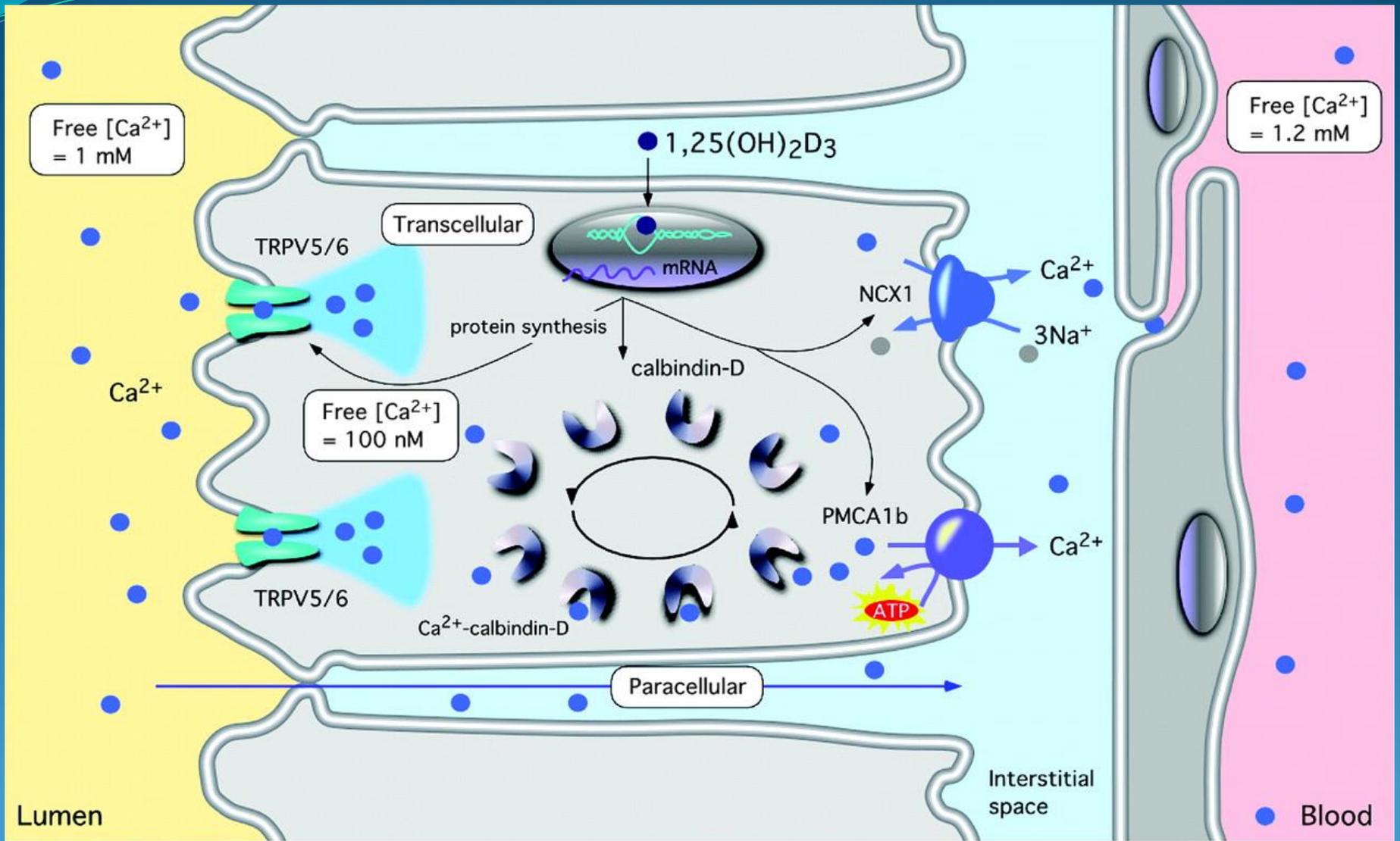
- Ca^{++} : (active absorption)

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

- Once Ca^{++} is inside it binds 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.



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.