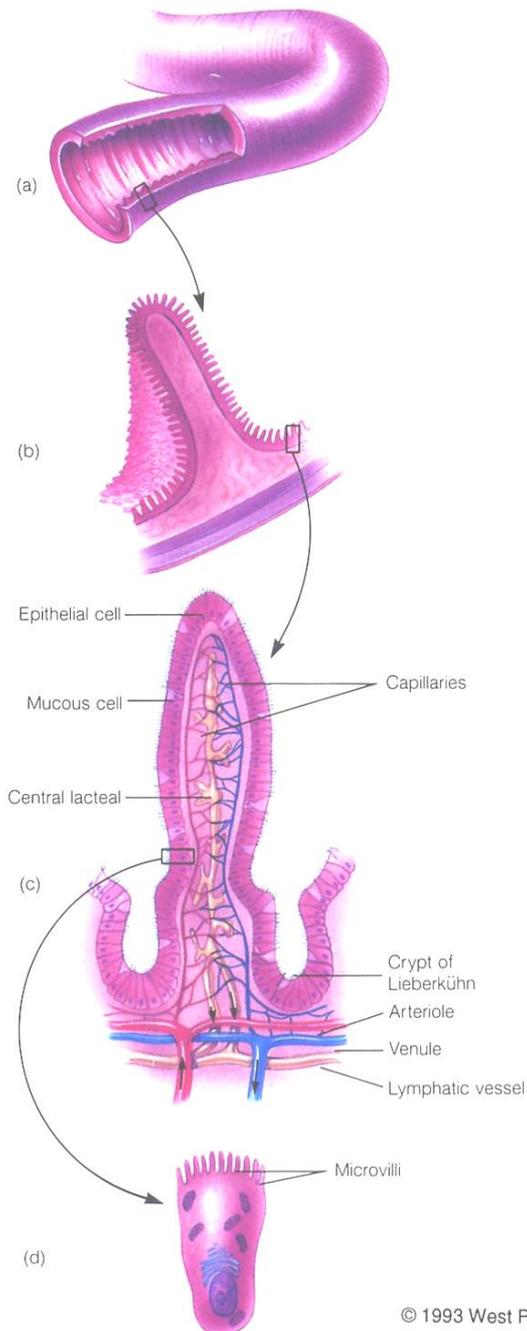


Digestion and Absorption

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

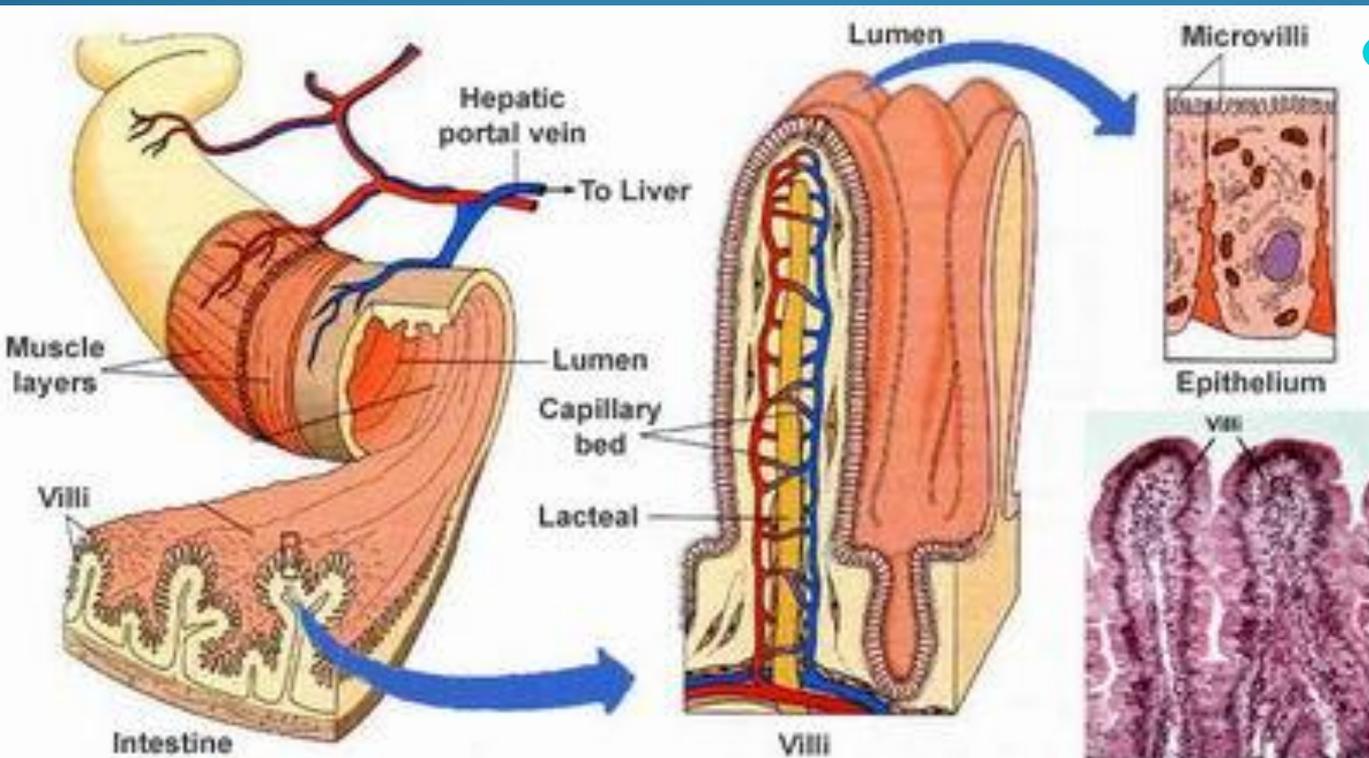
- Folds in mucosa and submucosa (Folds of Kerckring or Circular Folds)
- Villi which increases surface area 10 fold.
- Microvilli which increase surface area 20 fold.

The net increase in the surface area is 600 fold.

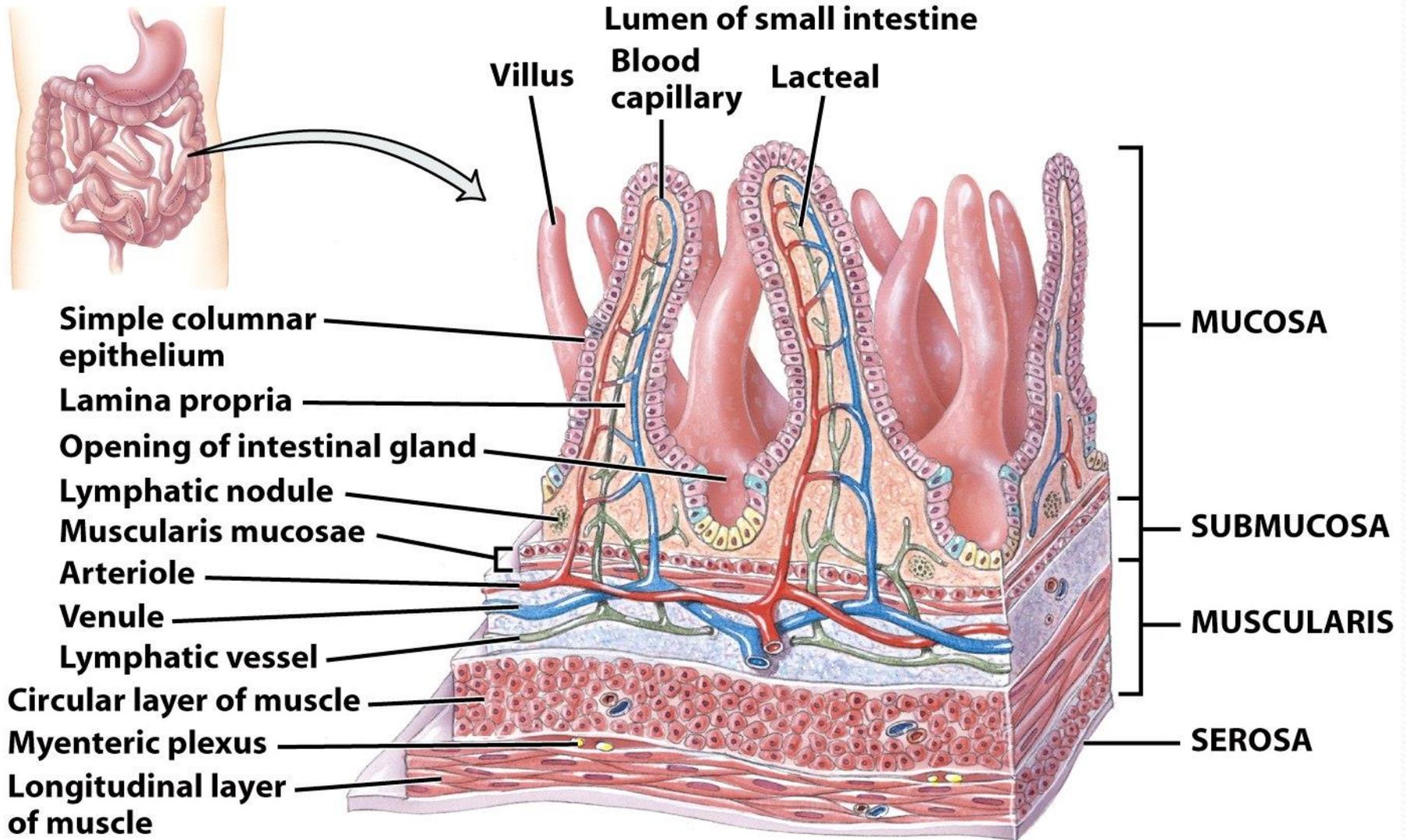
Intestinal specialization

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:

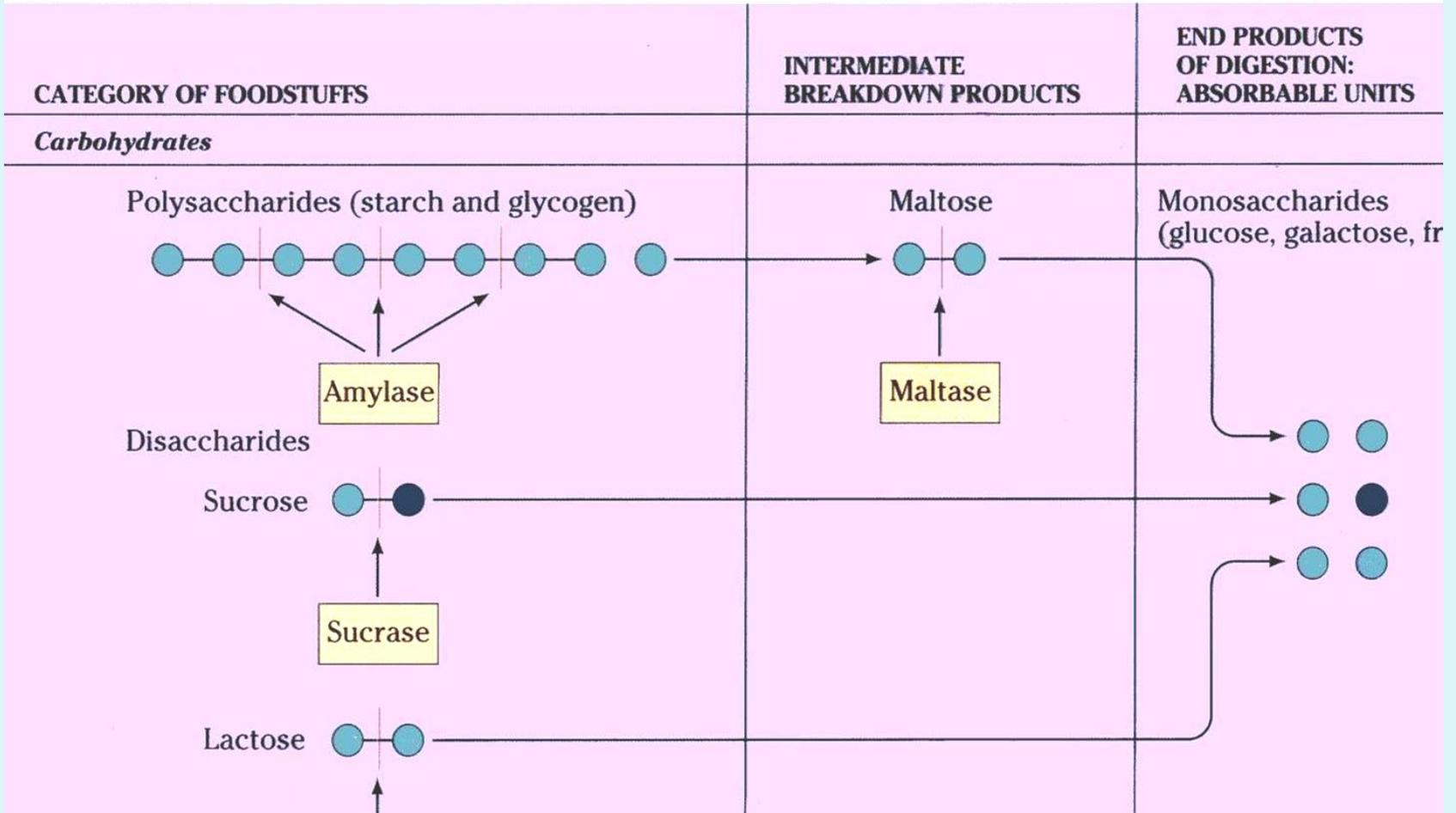
Lactase split lactose → glucose + galactose

Sucrase split sucrose → fructose + glucose.

Maltase split maltose, glucose polymers → glucose.

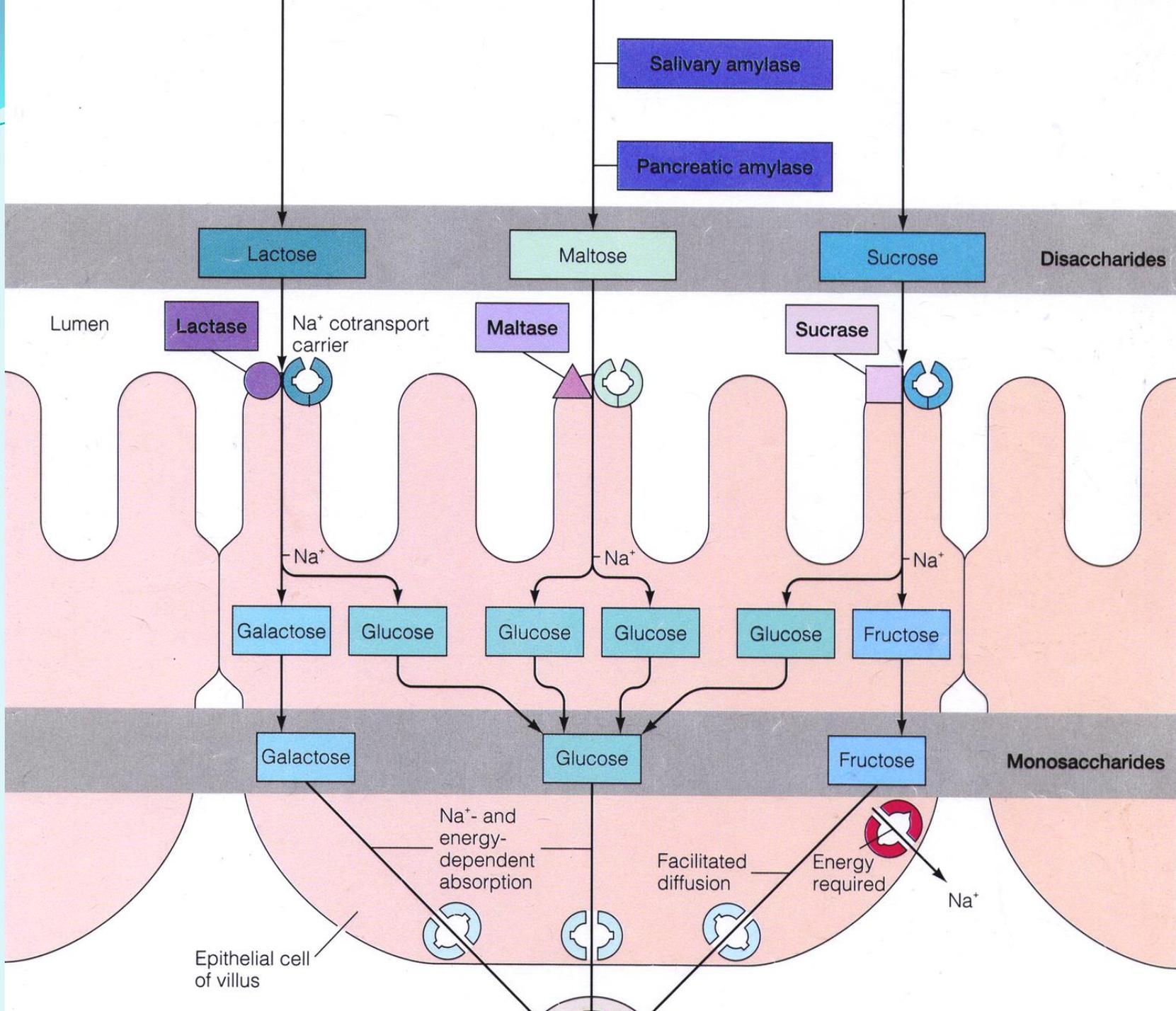
α -Dextrinase attack at alpha 1,6 linkage.

Process of Digestion



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

glucose, fructose, galactose.



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

Absorption of Carbohydrates

Glucose

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

- Absorption with solvent drag through the tight junction.

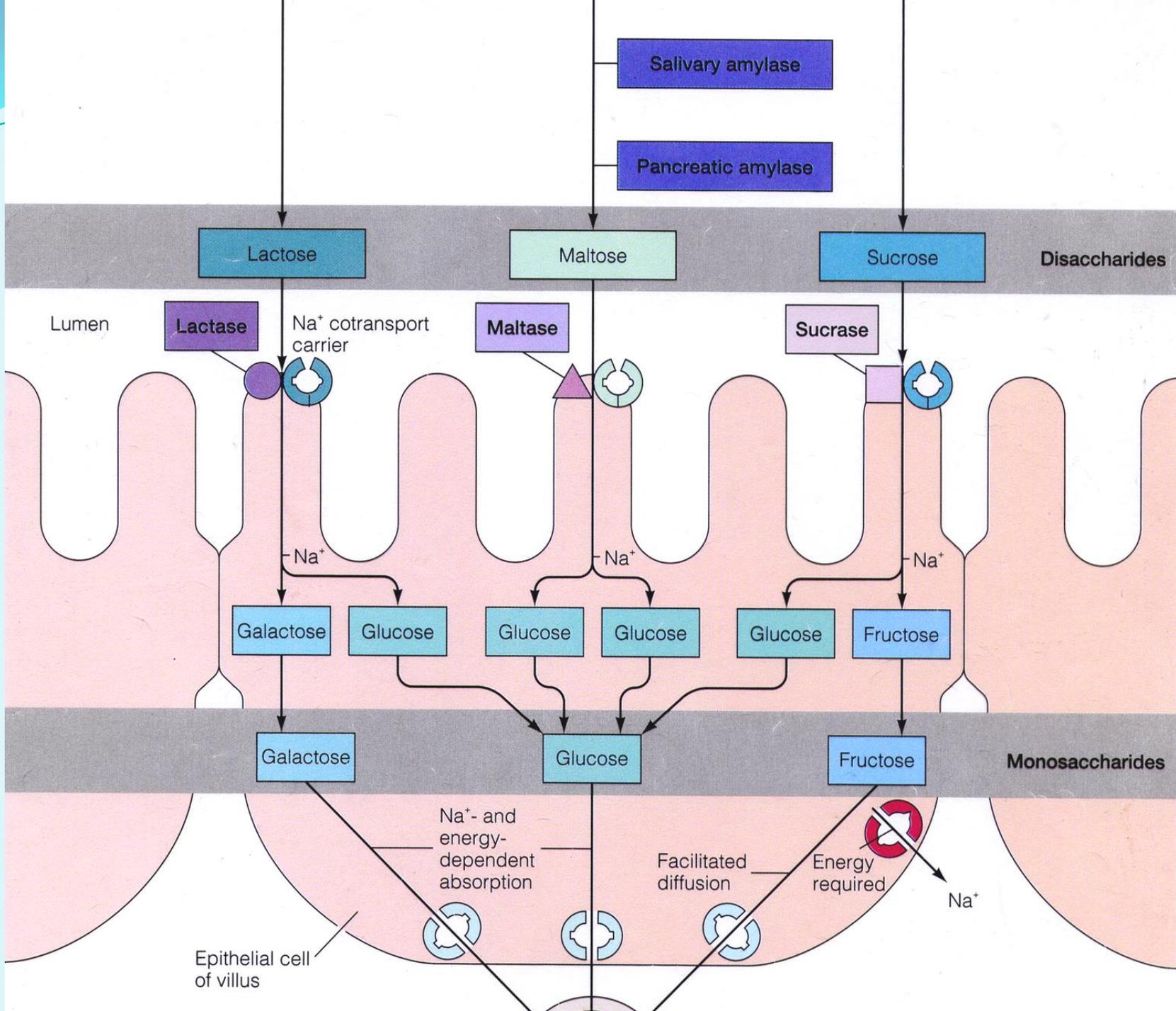
Increased glucose concentration in chyme → increased absorption → increased osmotic pressure in the paracellular space → increased fluid flow through the tight junction which carries anything dissolved.

Galactose

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

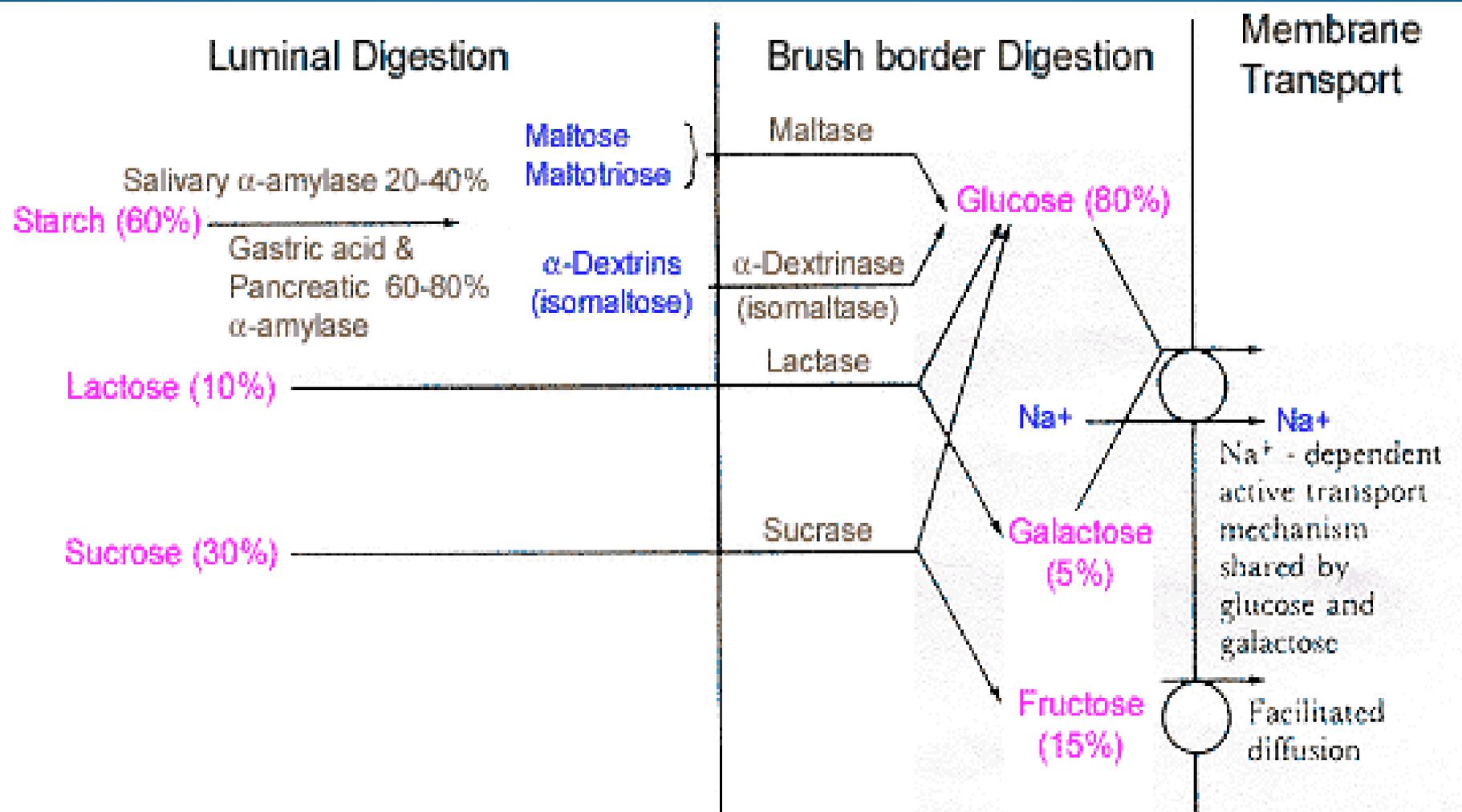
Fructose

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



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**.

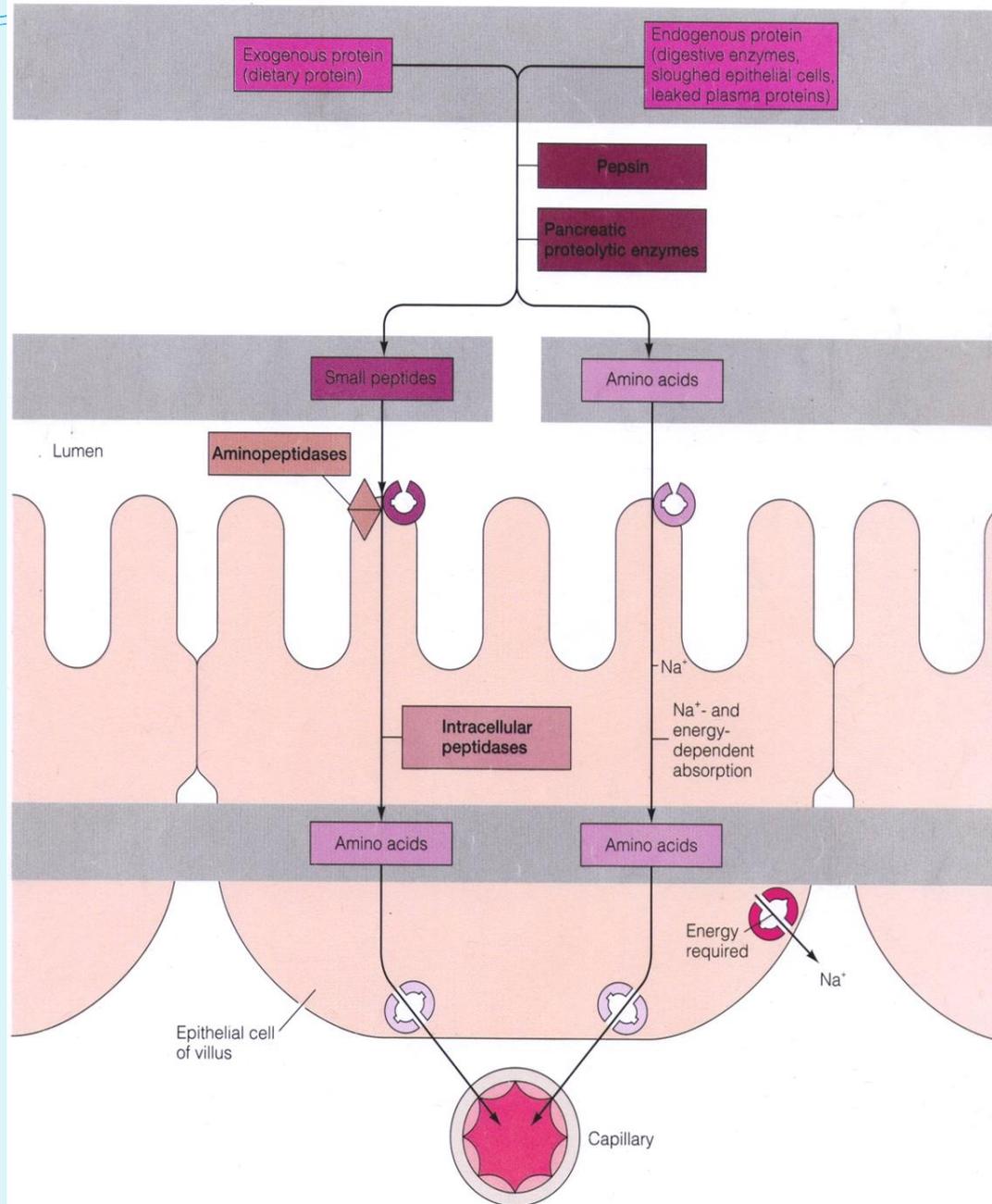
After absorption

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

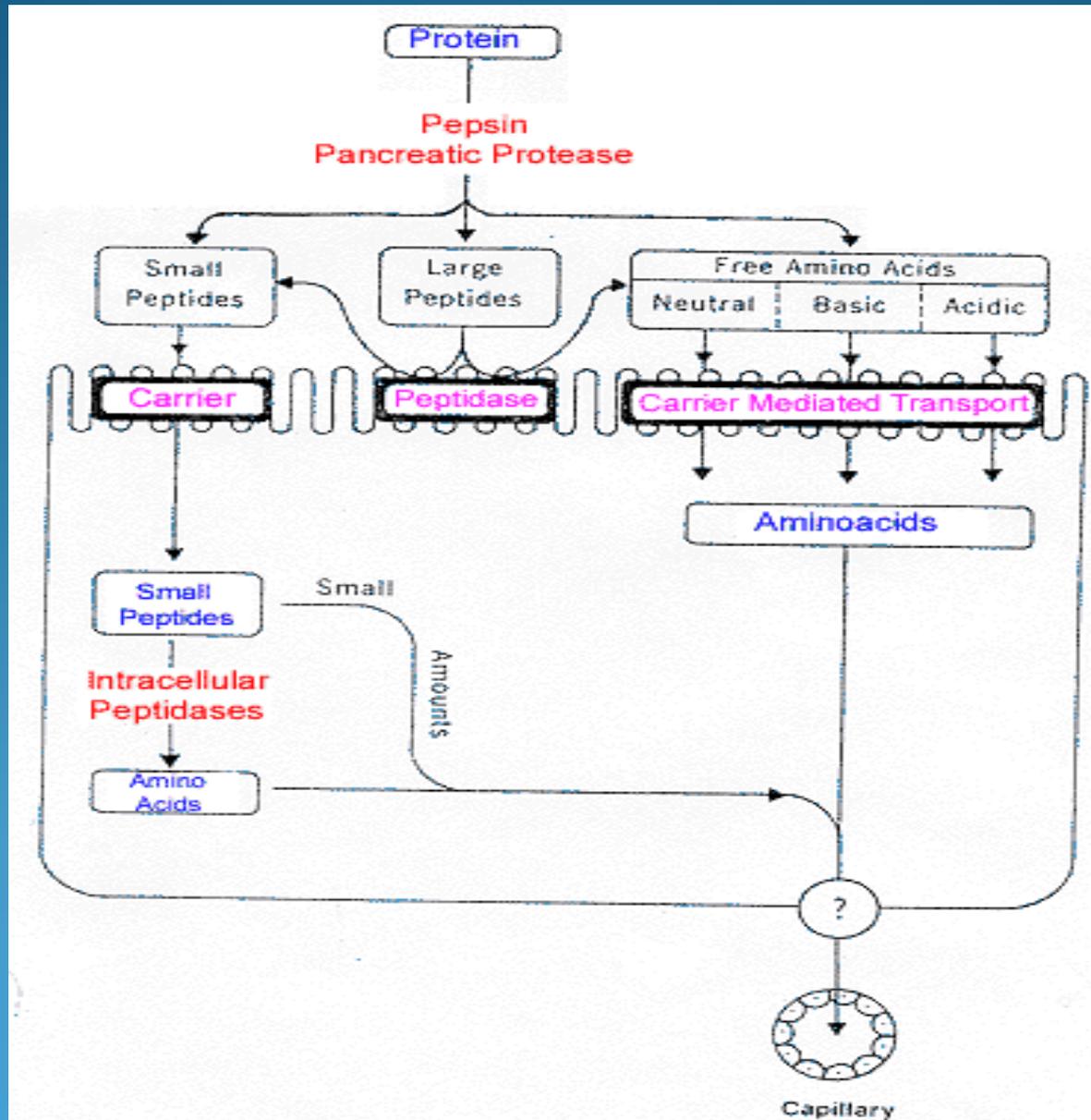
Transported by a membrane bound carriers:

* 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



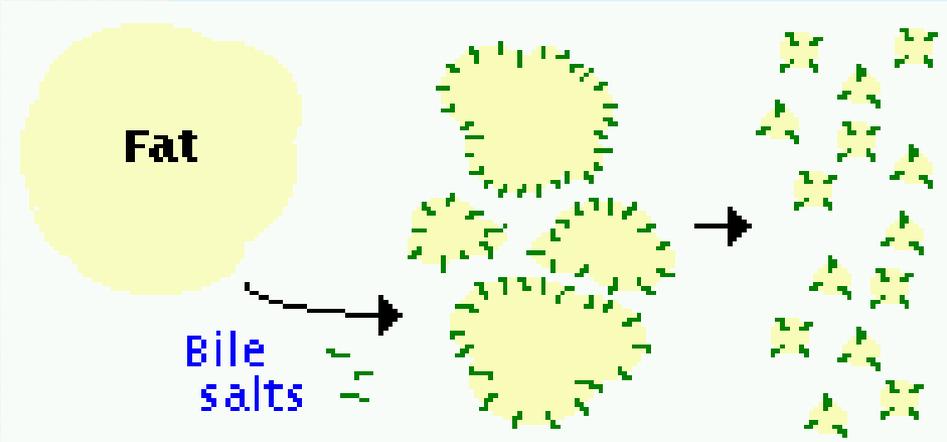
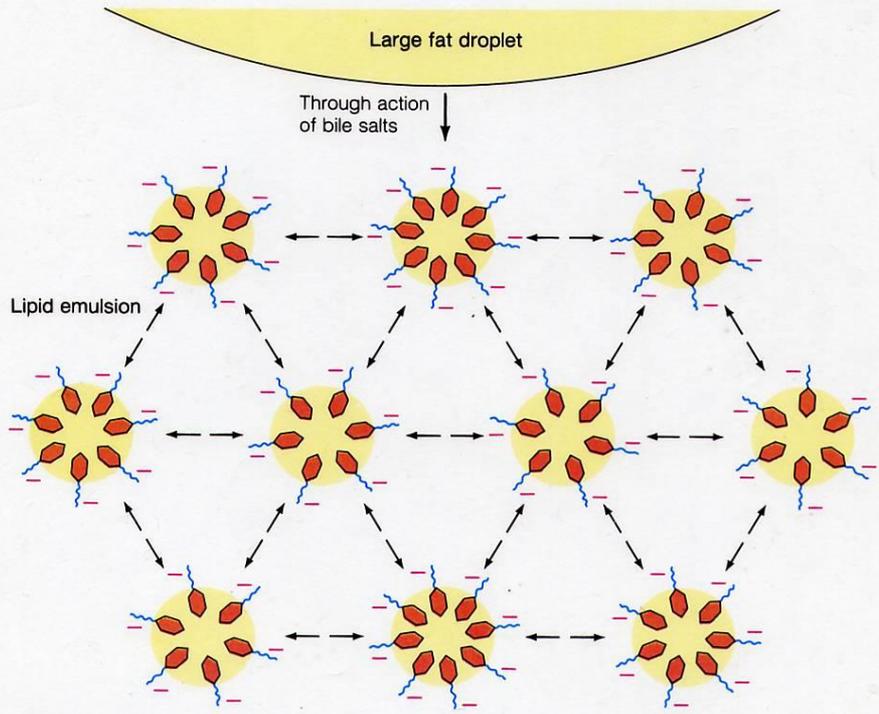
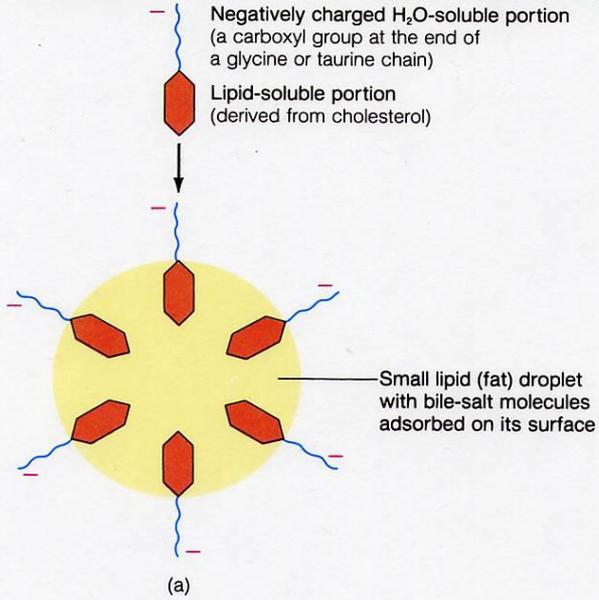
Lipid Digestion and Absorption

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

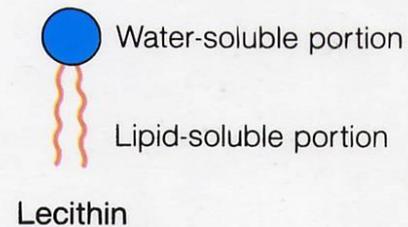
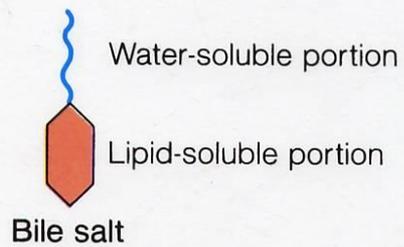
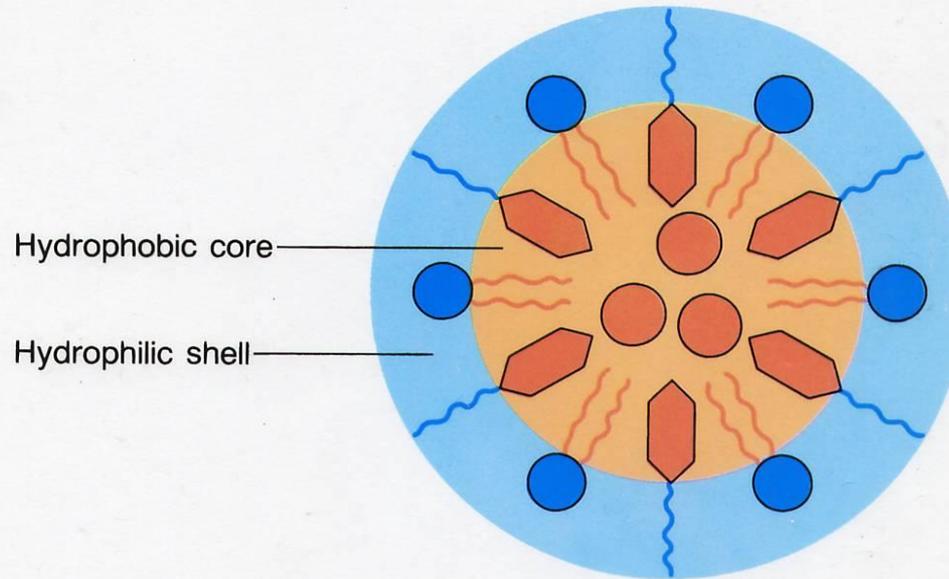
*Intestine:

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

Schematic Structure and Function of Bile Salts



Schematic Representation of a Micelle



Lipid absorption

-Absorption across the luminal membrane
simple diffusion.

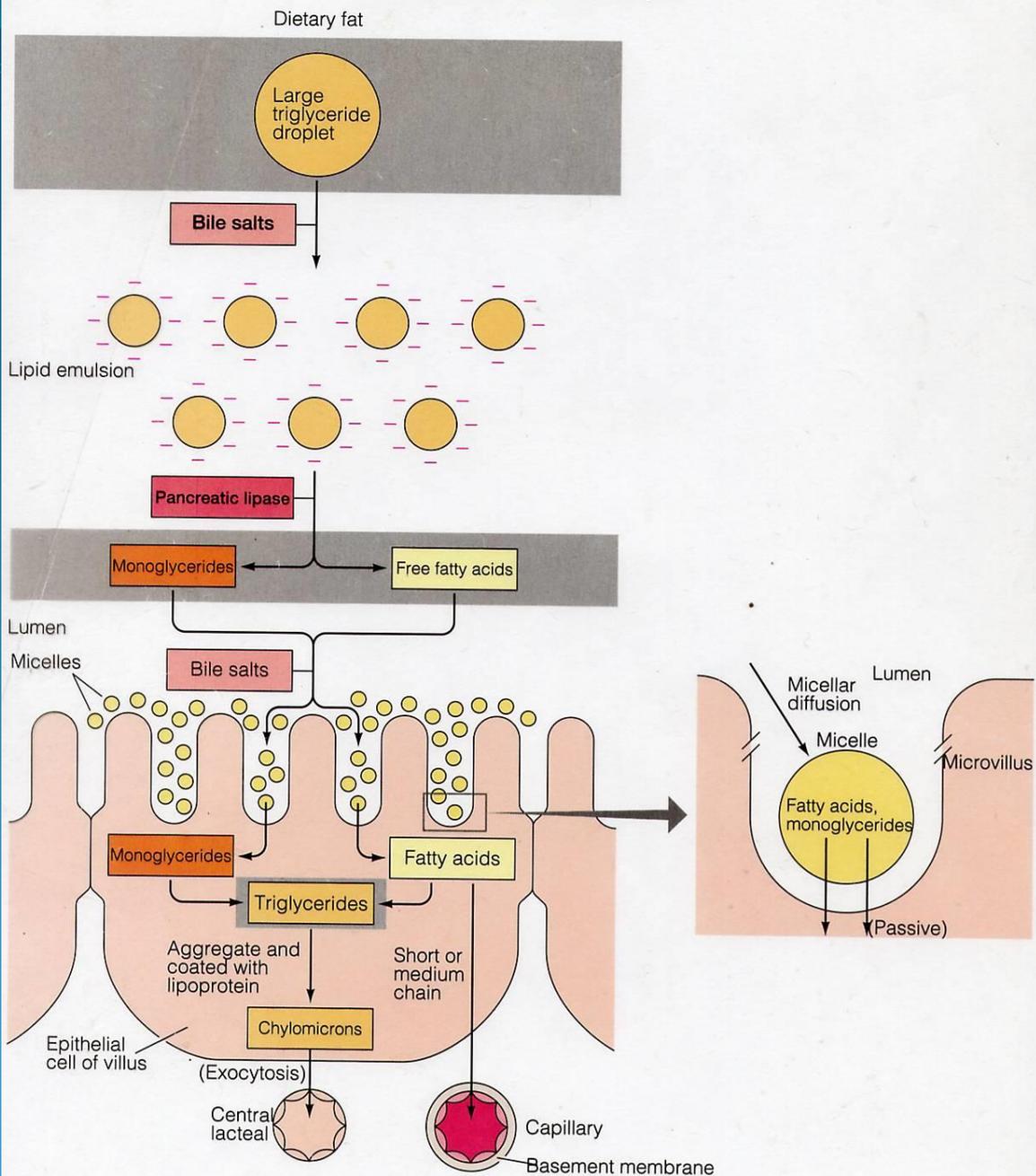
-Once inside the epithelium,

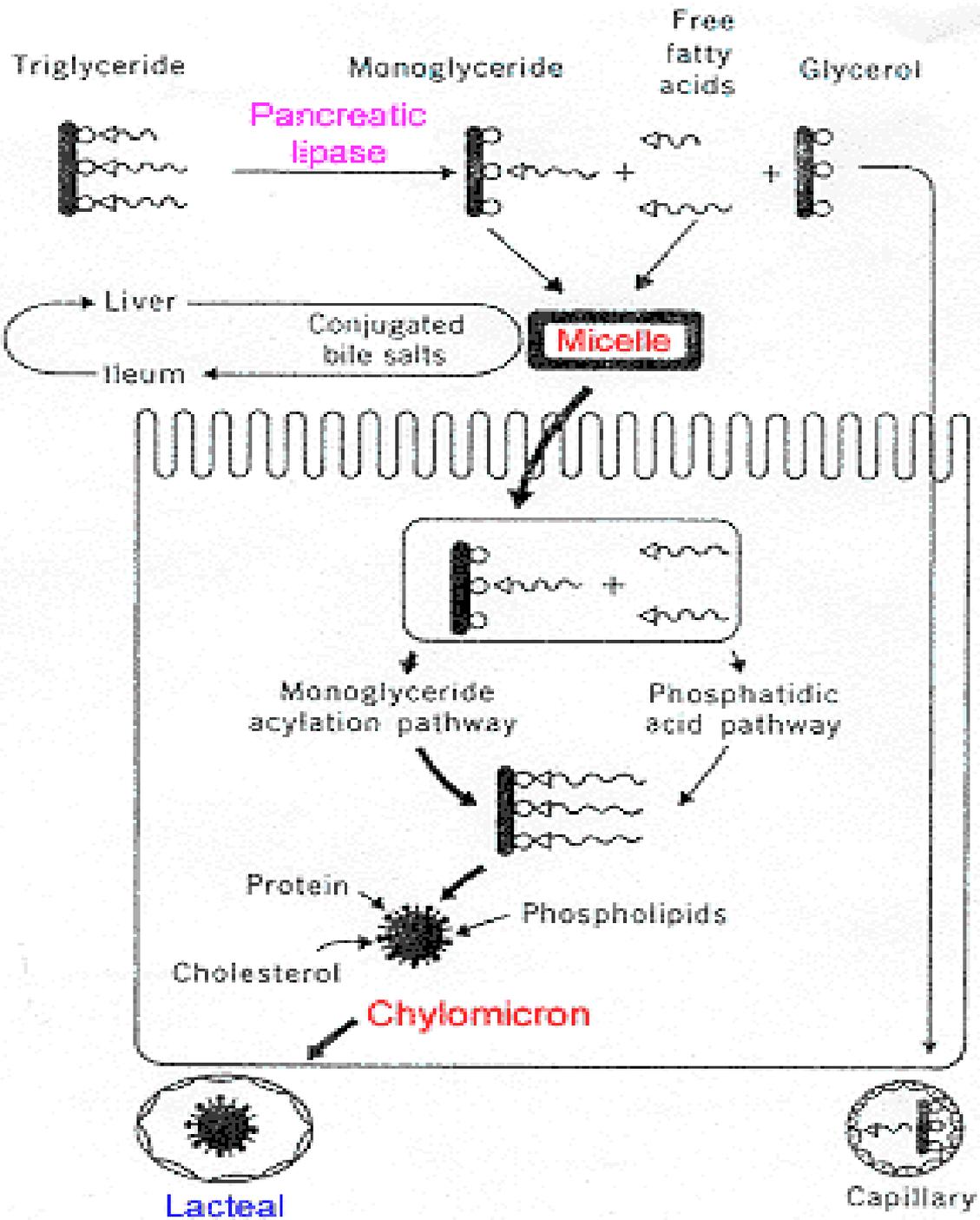
FFA + monoglycerides → *Triglycerides*.

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^+ .

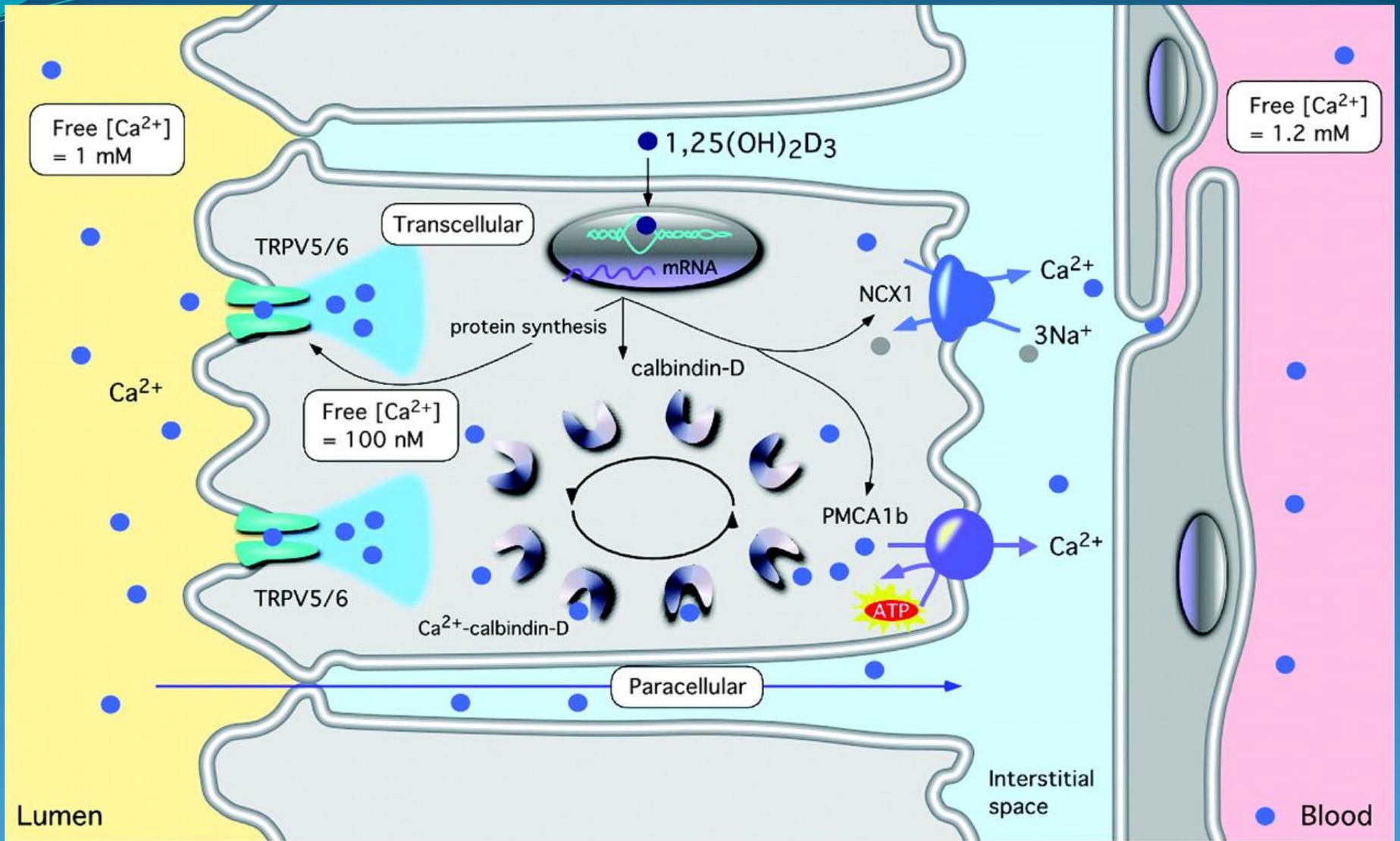
- Ca^{++} : (active absorption)

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.

Physiology

- Register your attendance with your university number
- Make sure that the settings of your phone allow tracking location

Go to settings > privacy > location > services > make sure that location services is ON

