PHYSIOLOGY OF DIGESTION

CHEMICAL DIGESTION

SEMESTER – IV

ZOO CC409

UNIT-1

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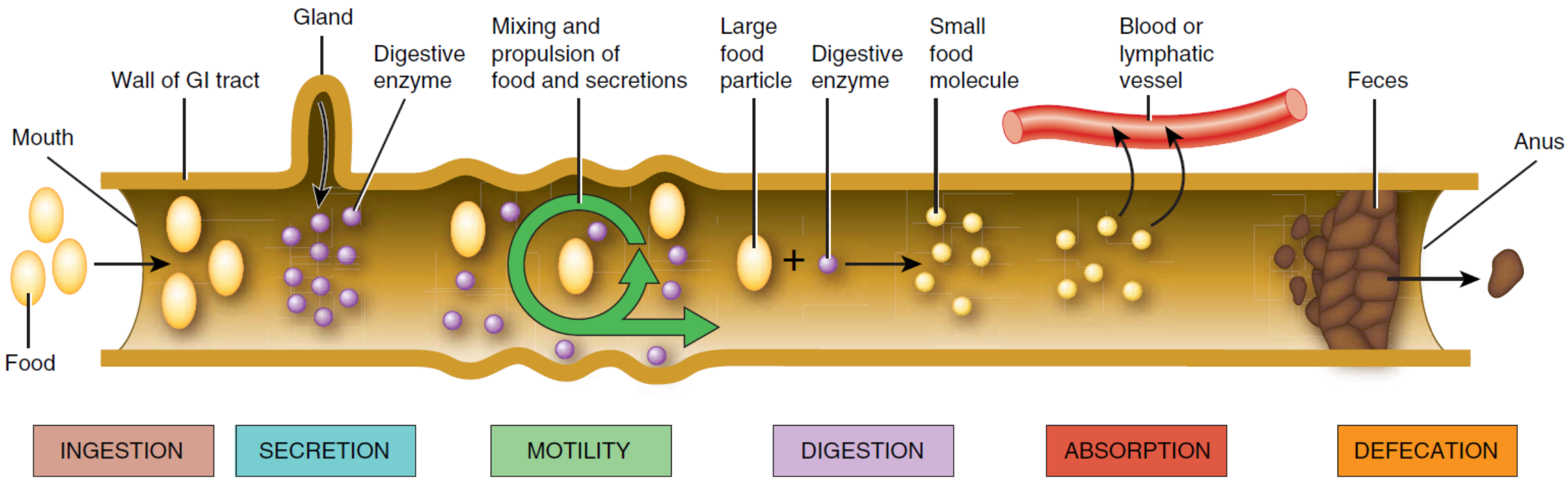
INTRODUCTION

- The gastrointestinal tract is basically a muscular tube that contains and processes food as it moves from the **mouth** to the **anus**.
- The food material is complex and composed of carbohydrate, proteins, fats and other substances. These complex materials are hydrolysed into simpler materials, with the help of enzymes for absorption by the intestinal wall. Overall, the digestive system performs **six** basic processes:
- **Ingestion:** This process involves taking foods and liquids into the mouth (eating).
- **Secretion:** Each day, cells within the walls of the GI tract and accessory digestive organs secrete a total of about 7 liters of water, acid, buffers, and enzymes into the lumen (interior space) of the tract.
- **Motility:** Alternating contractions and relaxations of smooth muscle in the walls of the GI tract mix food and secretions and move them toward the anus. This capability of the GI tract to mix and move material along its length is called **motility.**
- **Digestion: Digestion** is the process of breaking down ingested food into small molecules that can be used by body cells.
- **Absorption:** The movement of the products of digestion from the lumen of the GI tract into blood or lymph is called **absorption.**
- **Defecation:** Wastes, indigestible substances, bacteria, cells sloughed from the lining of the GI tract, and digested materials that were not absorbed in their journey through the digestive tract leave the body through the anus in a process called **defecation.**



The digestive system performs six basic processes: ingestion, secretion, motility, digestion, absorption, and defecation.

Physiology of Digestion

- **Digestion** is the process of breaking down ingested food into small molecules that can be used by body cells. Digestion of food occurs in three phases and all these phases takes place in coordination with each other. Three components of physiology of digestion are:
  - Mechanical digestion
  - Chemical digestion
  - Hormonal control of digestive activities

- In **mechanical digestion** the teeth cut and grind food before it is swallowed, and then smooth muscles of the stomach and small intestine churn the food to further assist the process. As a result, food molecules become dissolved and thoroughly mixed with digestive enzymes.
- In **chemical digestion** the large carbohydrate, lipid, protein, and nucleic acid molecules in food are split into smaller molecules by hydrolysis. Digestive enzymes produced by the salivary glands, tongue, stomach, pancreas, and small intestine catalyse these catabolic reactions.
- Physiology of digestion is under strict action of **hormones** and different **enzymes**.

CHEMICAL DIGESTION

Introduction

- Chemical digestion breaks down food as it moves through the digestive tract.
- Using enzymes and other digestive chemicals, the process reduces food particles into nutrient molecules that can be absorbed.

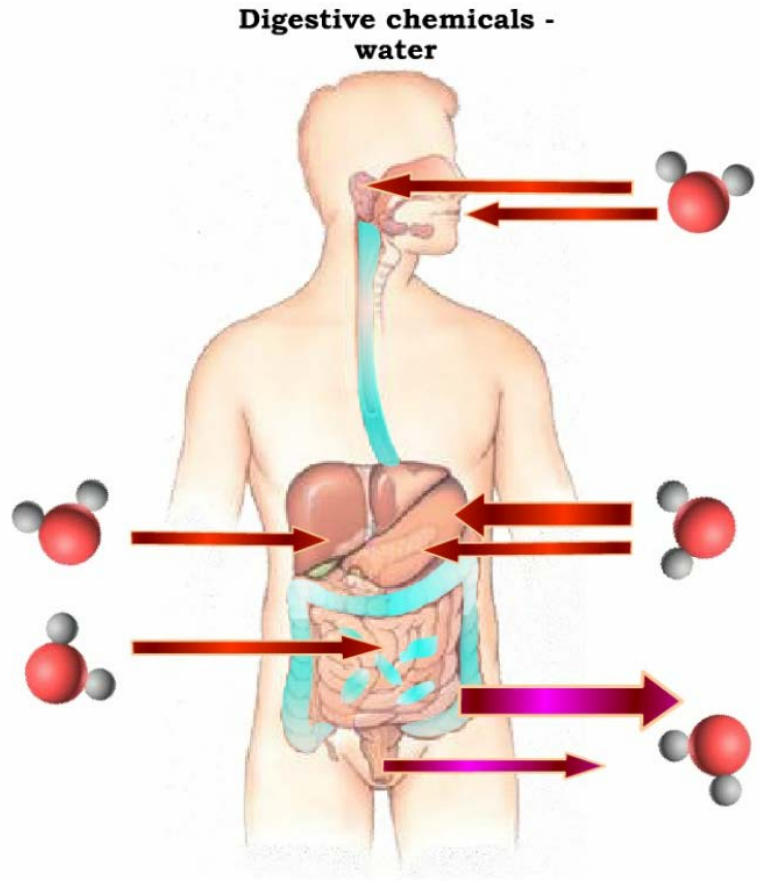
Digestive chemicals - Types

- Most chemical digestion is done by the actions of digestive enzymes.
- Other important digestive chemicals are needed to maintain a proper environment for enzymatic reactions, as well as other functions.
- These chemicals are: **water, Bile , Gastric acid, Bicarbonate**.
- **Digestive chemicals - Enzymes**
- The reactions in chemical digestion are enzyme mediated **hydrolysis reactions**.
- Water and enzymes break down the substrate into products.
- Most enzymes are identified by the substrate that they break down.
- For example, the enzyme **dipeptidase** breaks down dipepetide.

Digestive chemicals

Water

- Water is most abundant molecule in ingested fluids.
- Water plays a primary role in the hydrolytic digestive reactions.
- Help liquefy and transport digestive foodstuffs down the tract.
- Transport secretions from accessory digestive organs to GI tract.
- Aids in the absorption of nutrients.



Gastric acid

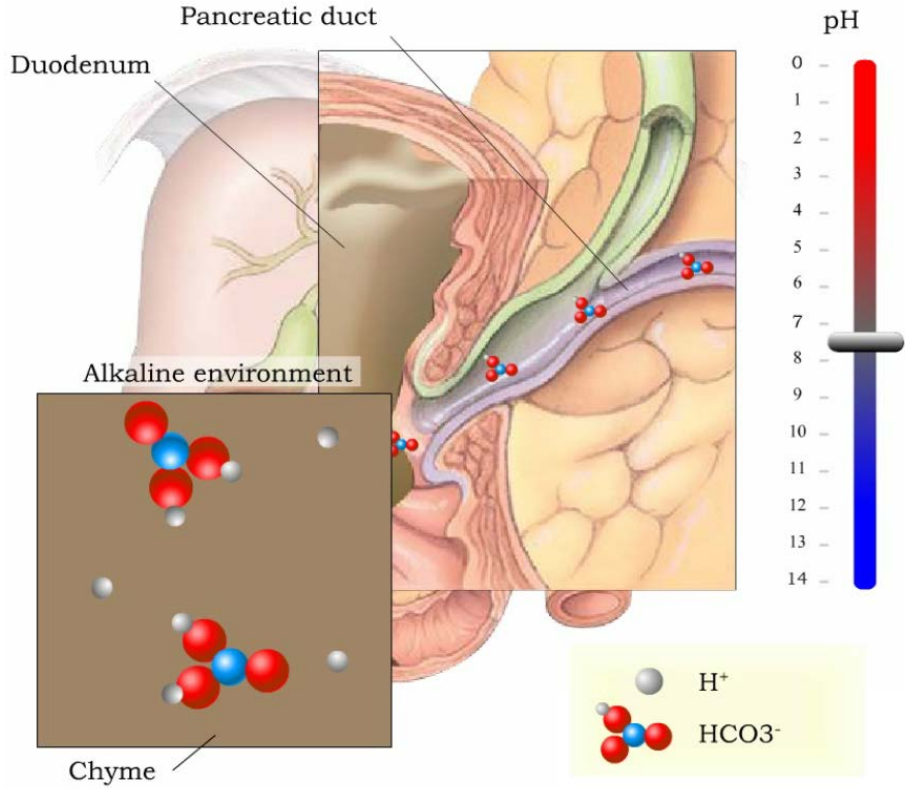
- The stomach mucosa produces **hydrochloric acid**, a strong acid
- Gastric acid breaks hydrogen bonds and alters the globular shape of proteins to promote the :
  - Production of pepsin , the gastric enzyme
  - Destruction of microbial proteins.
- Enzymes more easily break down the resulting polypeptide into smaller peptides.

Bile

- Bile is produced by the liver.
- Bile consists mostly of **bile salts** (produced from **cholesterol**) and water.
- Primary functions of bile is emulsification of fatty globules.
- Emulsification facilitates efficient breakdown of fat molecule by lipase enzymes.

Bicarbonate:

- Bicarbonate is secreted into the intestine to:
- Buffer the acidic chyme from the stomach and protect intestinal mucosa.
- Promote an alkaline pH level in the small intestine to create a proper environment for intestinal enzymes to function normally.

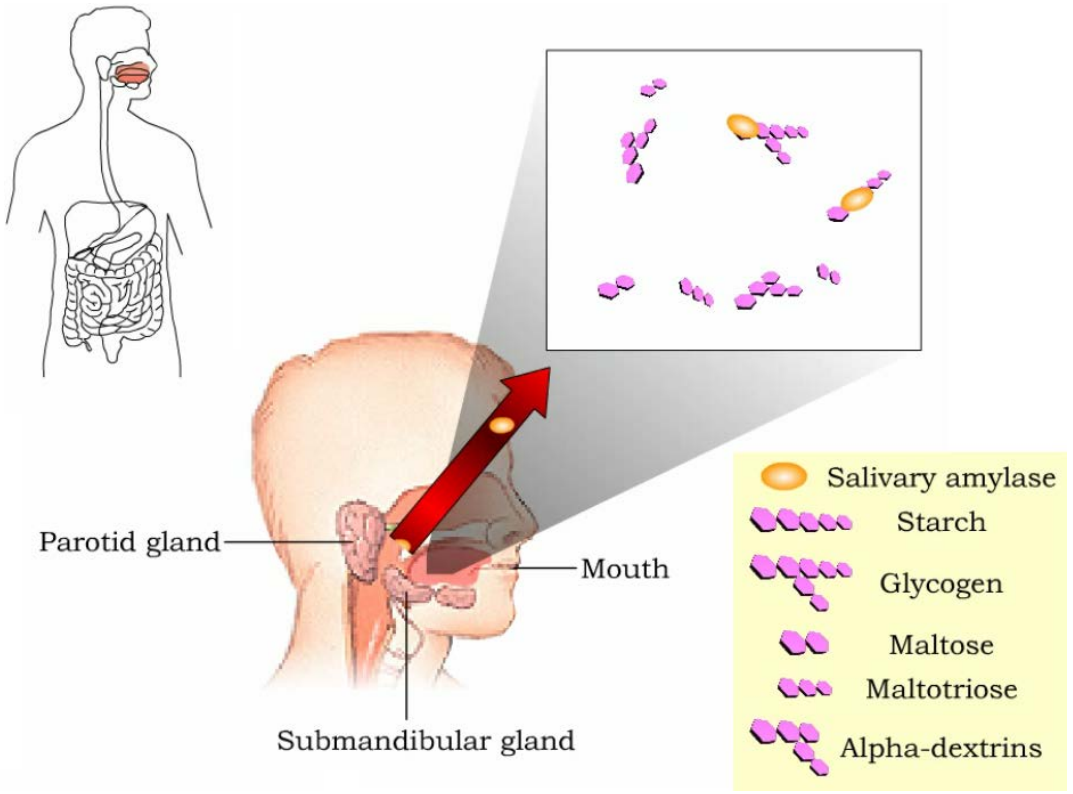


Carbohydrate digestion

- Digestion of complex carbohydrates (starches and glycogen) involves:
  - Amylases produced by the salivary glands and pancreas.
  - Brush-border enzymes in small intestine.

Carbohydrate digestion – mouth and stomach

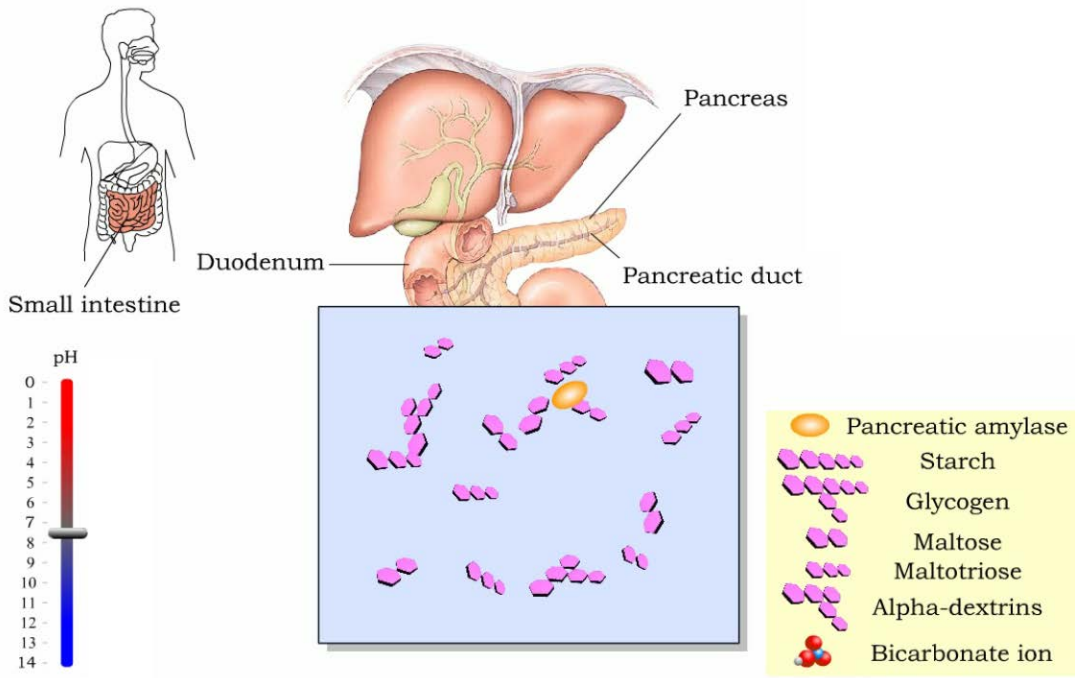
- **In the mouth, amylase** from the **parotid** and **submandibular salivary glands** begins carbohydrate digestion.
- Salivary amylase converts starch and glycogen into following products :
  - Maltose (disaccharide)
  - Maltotriose (trisaccharide)
  - Alpha-dextrins (starch fragments)



- However, only a few starch or glycogen molecules are completely digested into maltose before they enter the small intestine.
- The stomach's acidic pH destroys **salivary amylase**.

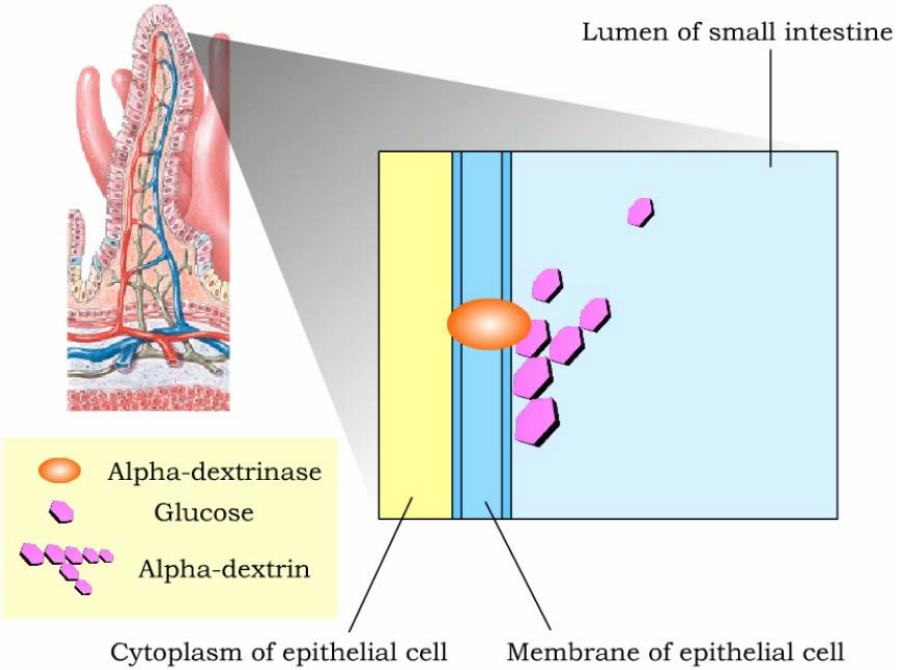
Carbohydrate digestion – Pancreas and small intestine

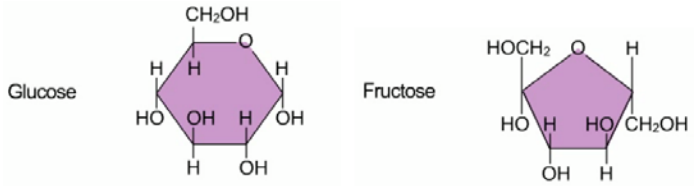
- The **pancreas** secretes **amylase** into the **duodenum**.
- In the small intestine, bicarbonate ions from pancreatic juice neutralizes gastric acid.
- Amylase continues the breakdown of starches and glycogen into maltose, maltotriose, and alpha dextrins.
- **Amylase** does **not** act on **cellulose** an indigestible plant fiber.

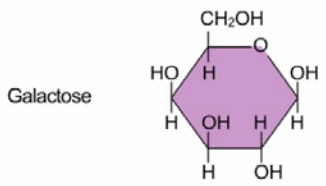


Carbohydrate digestion – brush border enzymes

- Carbohydrate digestion concludes in the microvilli of the small intestine, in brush border epithelial cells.
- Four brush border enzymes are involved:
  - **Alpha dextrinase** breaks down alpha-dextrin chains by removing glucose units.
  - **Sucrase** breaks sucrose into glucose and fructose.
  - **Maltase** breaks maltose and maltotriose into glucose.
  - **Lactase** breaks lactose into glucose and galactose.
- The **final** end **products** of **carbohydrate digestion** are **glucose, fructose,** and **galactose.**

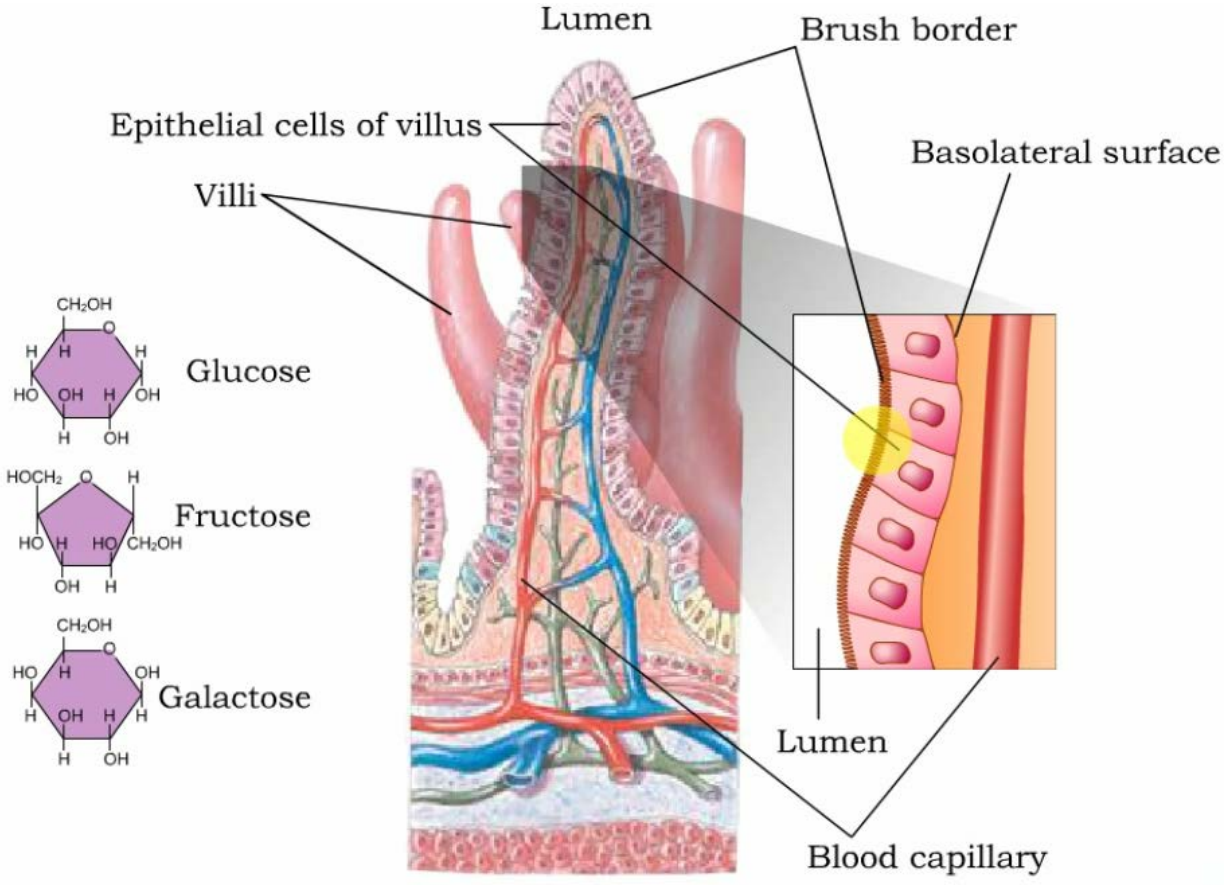






Carbohydrate absorption – end products

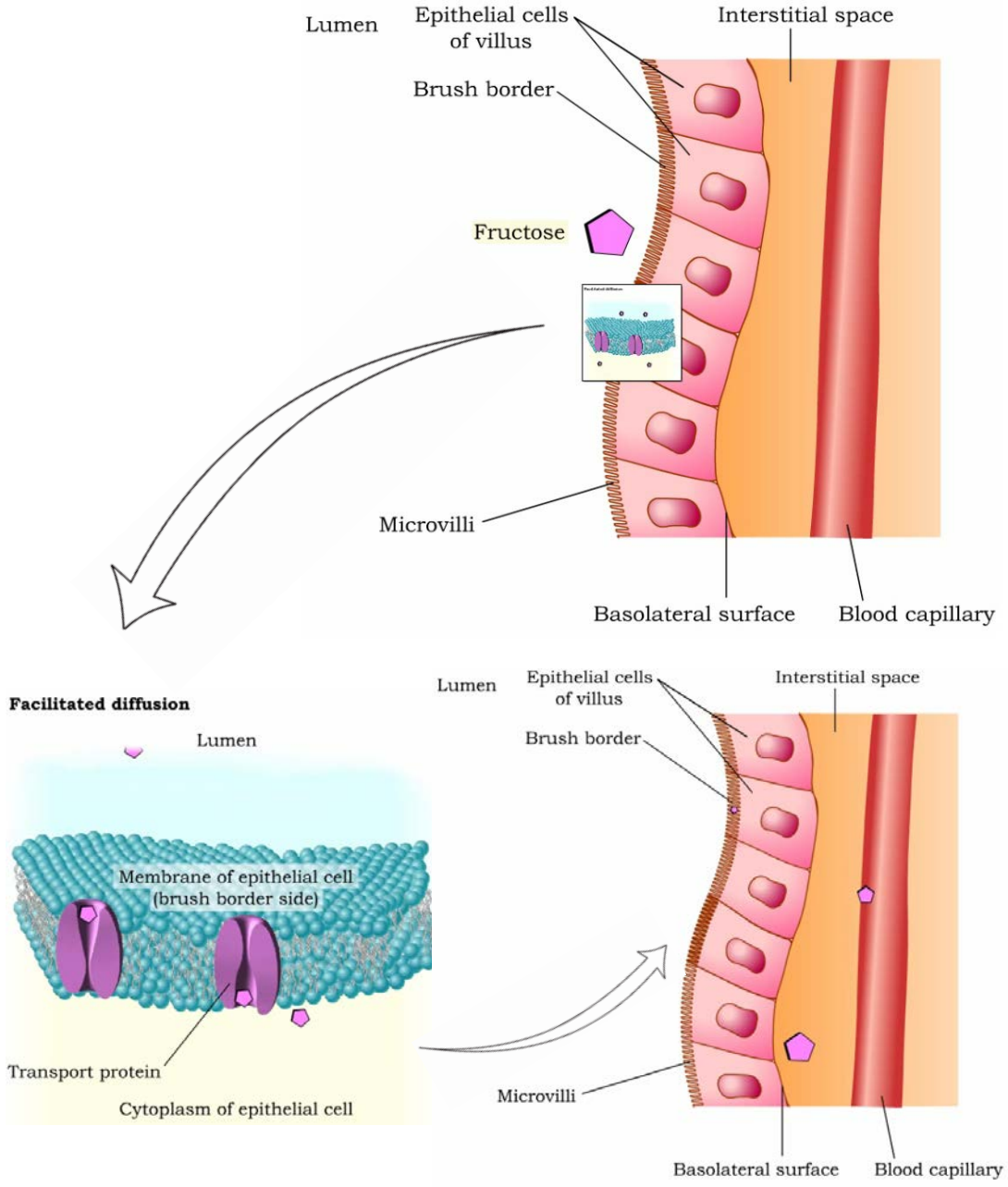
- All end products of carbohydrate digestion (glucose, fructose and galactose) are absorbed as monosaccharides.
- Carbohydrate are ultimately absorbed into capillaries of the villi.



Carbohydrate absorption

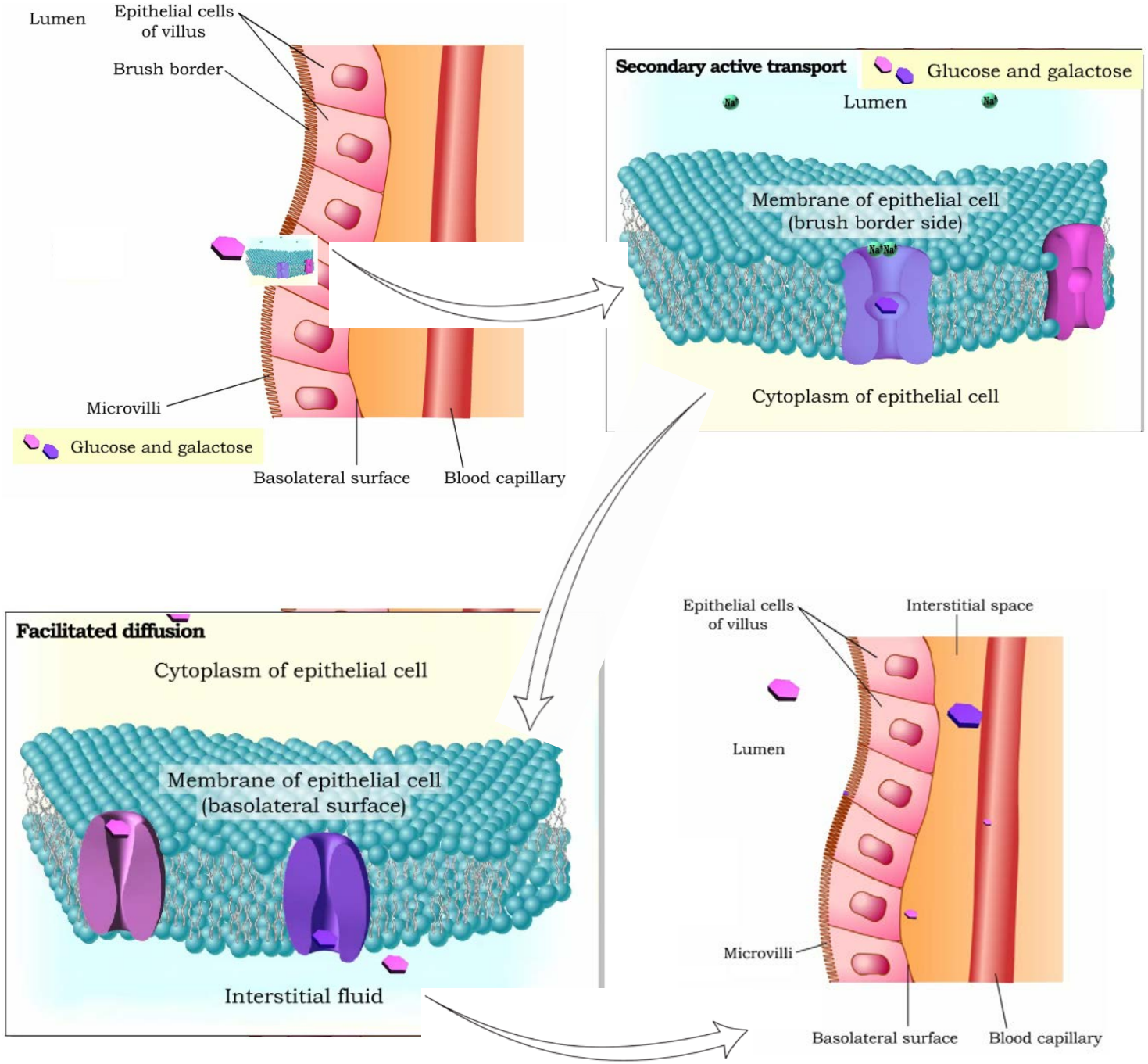
Fructose

- Facilitated diffusion:
  - Transport fructose from lumen into epithelial cells of intestinal villi.
  - Transport monosaccharides out of epithelial cells into the interstitial fluid.
  - The monosaccharide eventually diffuses into the blood stream without using ATP in the process.



Glucose and Galactose

- Secondary active transport :
  - Transport glucose and galactose into epithelial cells of intestinal villi.
  - Couples transport of glucose or galactose with that of sodium ions.
  - Transports materials in the same direction, down the concentration gradient for at least one substance.
- Glucose and Galactose are then transported from epithelial cells to the interstitial fluid and eventually into the blood via facilitated diffusion

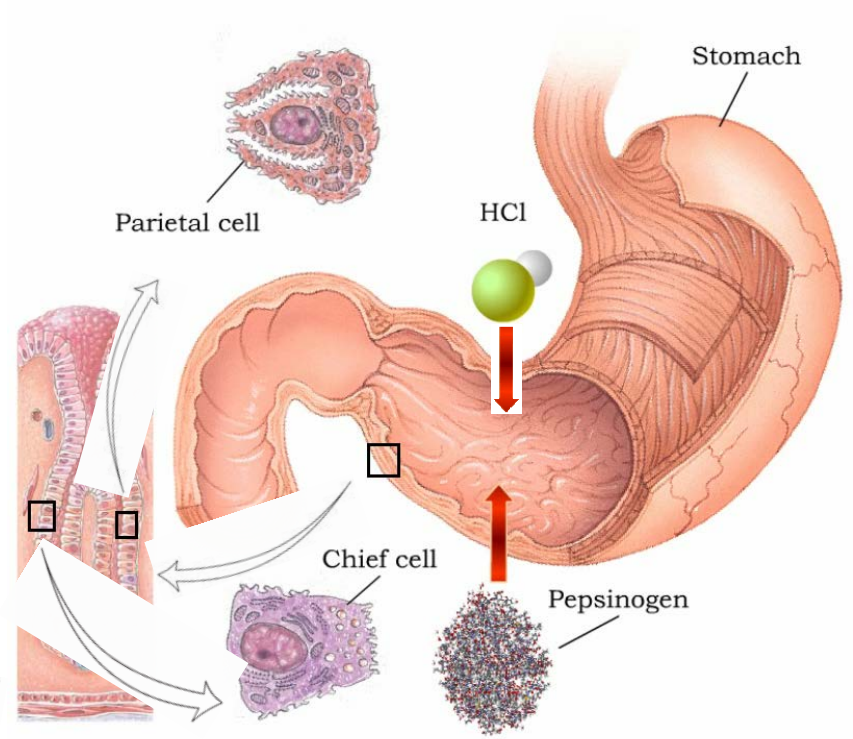


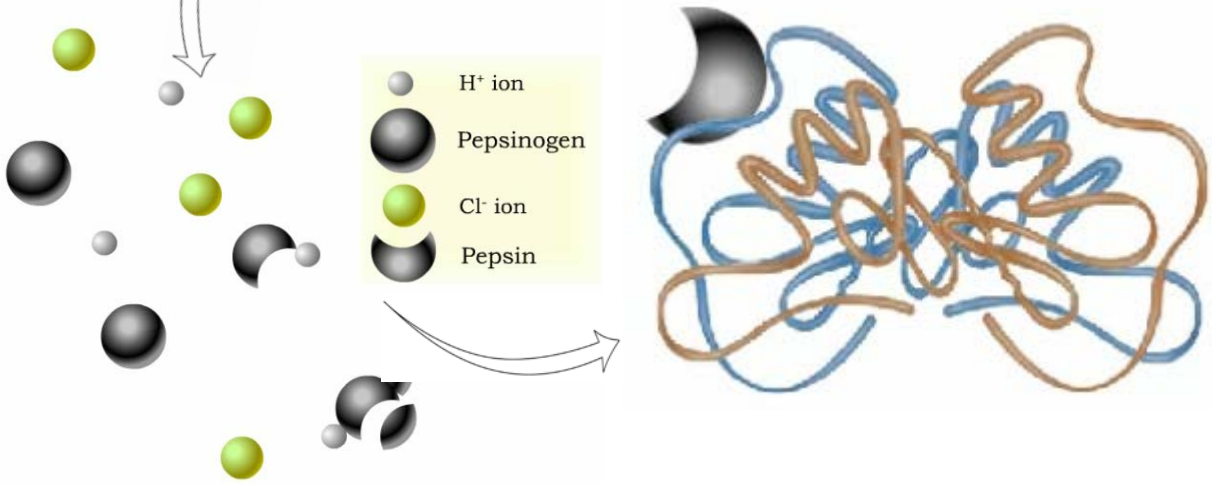
Protein Digestion

- Protein digestion occurs in the stomach and small intestine.
- The stomach enzyme pepsin initiates the process.
- Pancreatic and intestinal brush border enzymes complete the digestive process.

Protein Digestion - Stomach

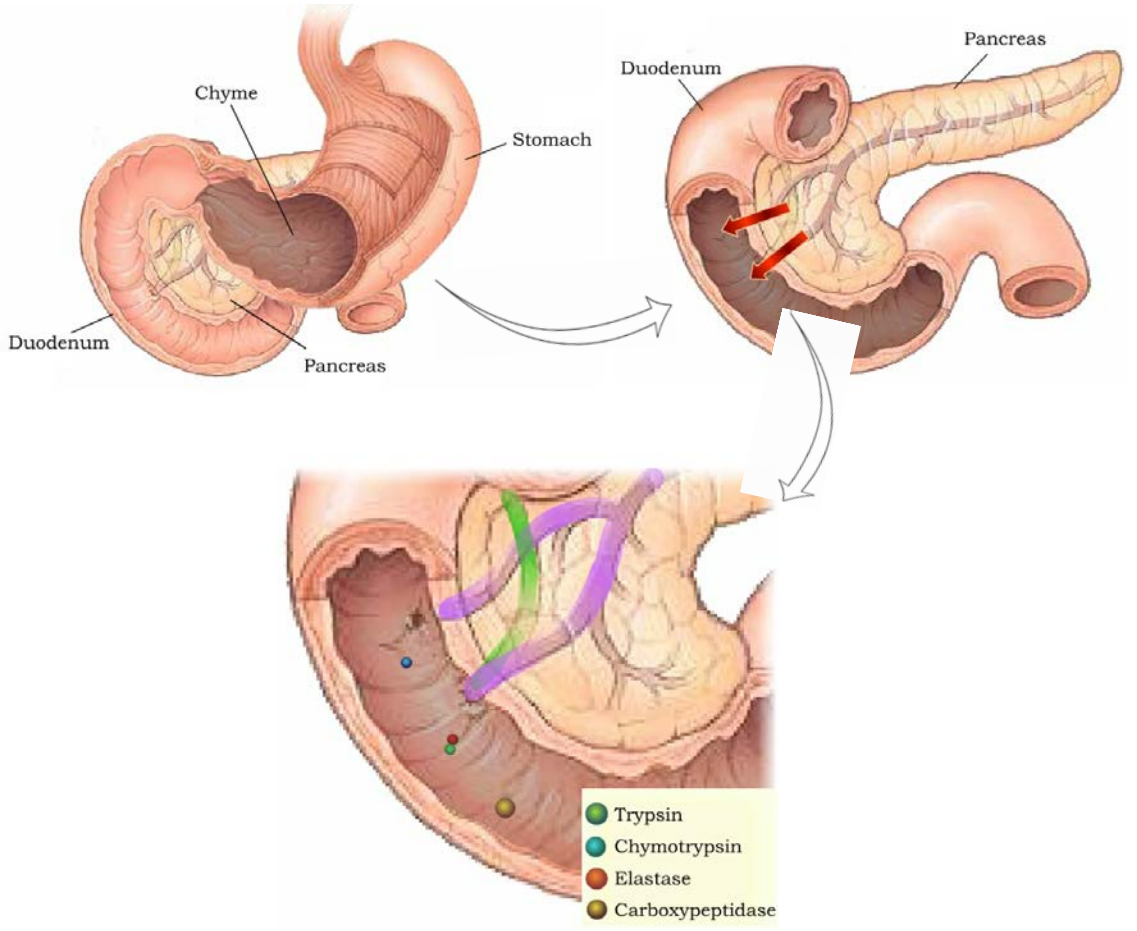
- In the stomach, pepsin is created from pepsinogen in the presence of pH- lowering hydrochloric acid (HCl).
- Newly produced pepsin molecules then catalyze the production of more pepsin.
- Pepsin molecules begin to break down proteins into peptides.



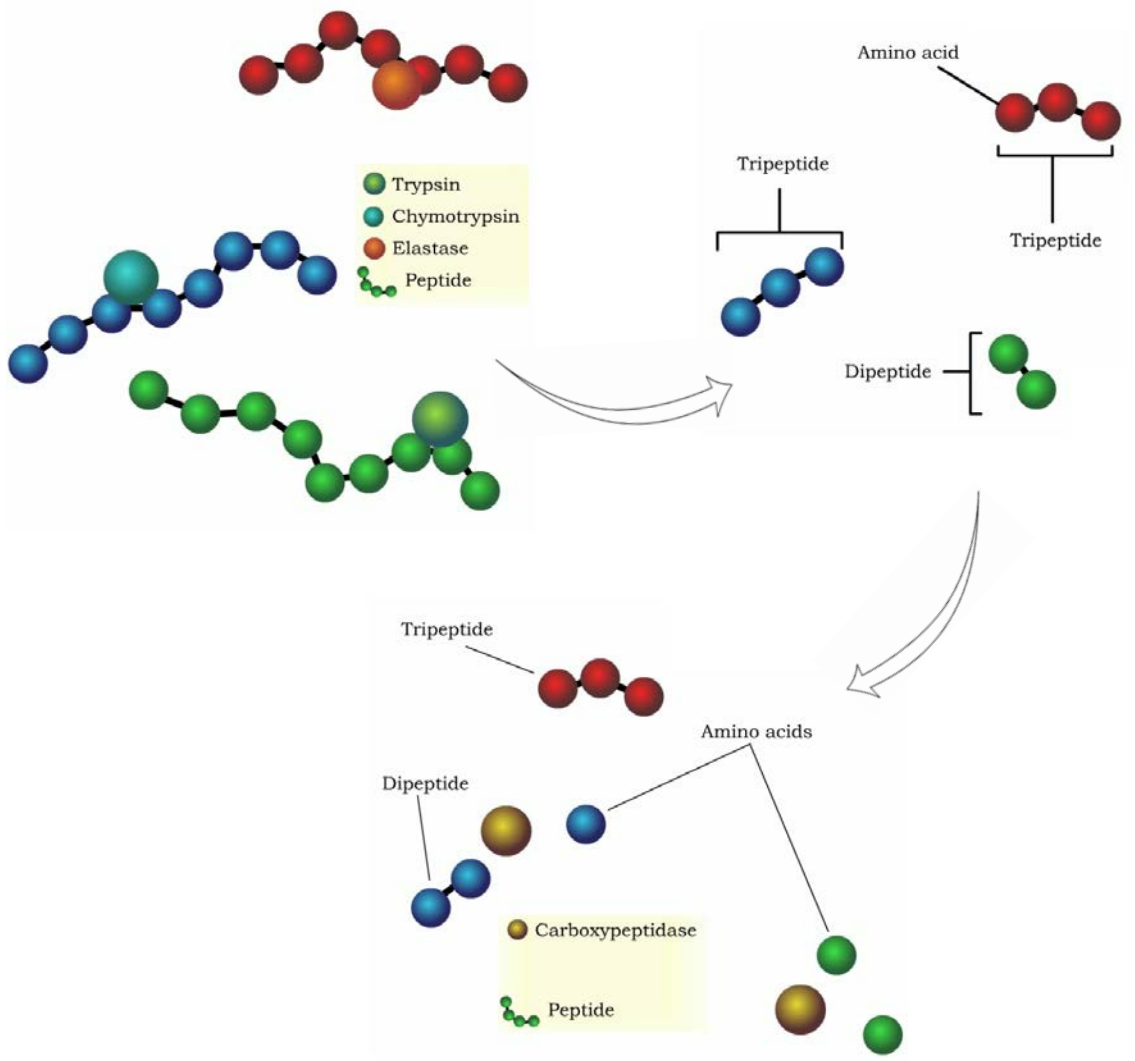


Protein Digestion – Small Intestine

- Protein continues to be broken down in the small intestine.
- In the duodenum , chyme interacts with pancreatic juice, a mixture of fluid and several enzymes.
- Protein digesting enzymes in pancreatic juice are:
  - Trypsin
  - Chymotrypsin
  - Elastase
  - Carboxypeptidase.



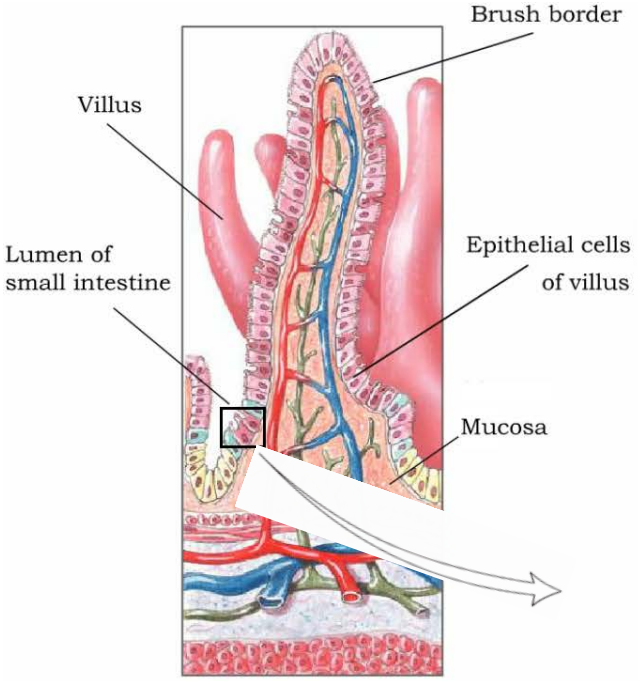
- Each enzyme effectively breaks a particular peptide bond to produce smaller peptides or amino acids.
- **Trypsin, chymotrypsin, and elastase** help break down larger peptides into smaller peptides.
- **Carboxypeptidase** breaks the bond between the terminal amino acid and the carboxyl end of the peptide .

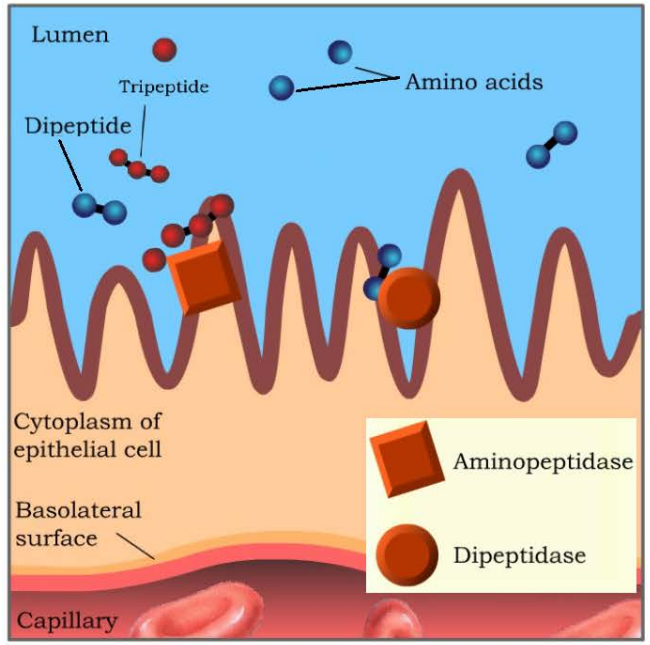


Protein Digestion – brush border enzymes

- Digestion is completed in the brush border by two active enzymes:
  - **Aminopeptidase**- breaks peptide bond that attaches terminal amino acid to the amino end of the peptide.
  - **Dipeptidase**- splits dipeptides into single amino acids.

- End product of protein digestion
  - amino acids
  - Dipeptide
  - tripeptides



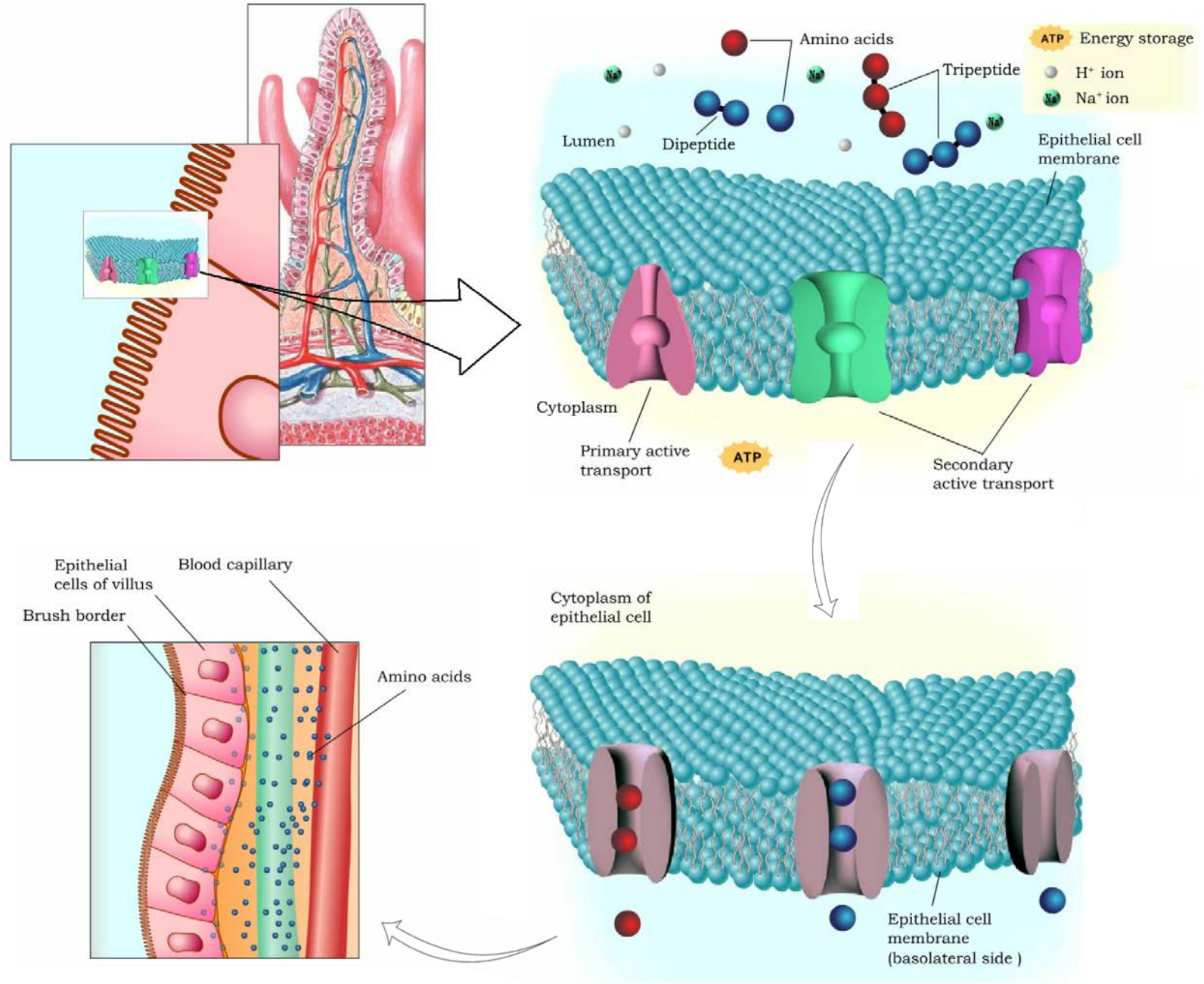


Protein Absorption

- End product of protein digestion – amino acids, dipeptide, tripeptides .
- The end products , amino acids, dipeptides and tripeptides are absorbed at the intestinal villus.
- Absorption depends upon three mechanisms:
  - **Active transport.**
  - **Na+- dependent secondary active transport.**
  - **H+ dependent secondary active transport.**

Protein Absorption – transport mechanisms

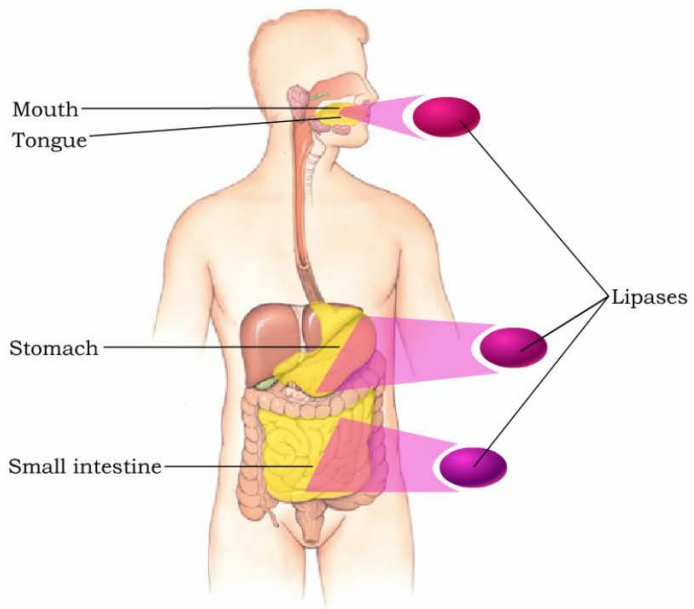
- Most amino acids enter epithelial cells via active transport.
- Some amino acids enter epithelial cells via Na+ dependent secondary active transport.
- Dipeptides and tripeptides enter epithelial cells via H+ dependent secondary active transport.
- The peptides are then hydrolyzed to single amino acids inside of the epithelial cells.
- Amino acids can diffuse out of the epithelial cells, through the intestinal fluid, and enter the blood capillaries of the villus .

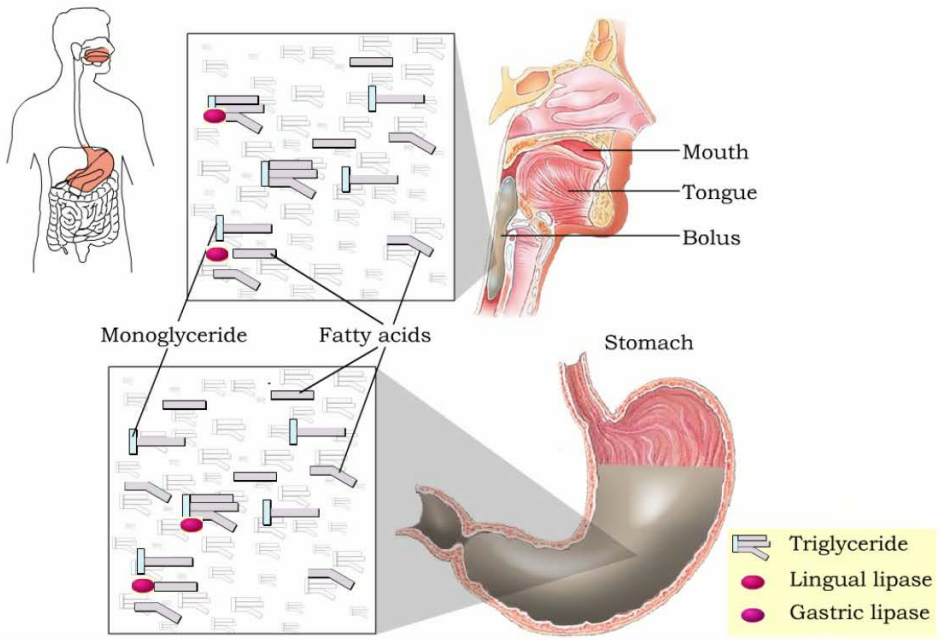


Protein Absorption

Lipid Digestion

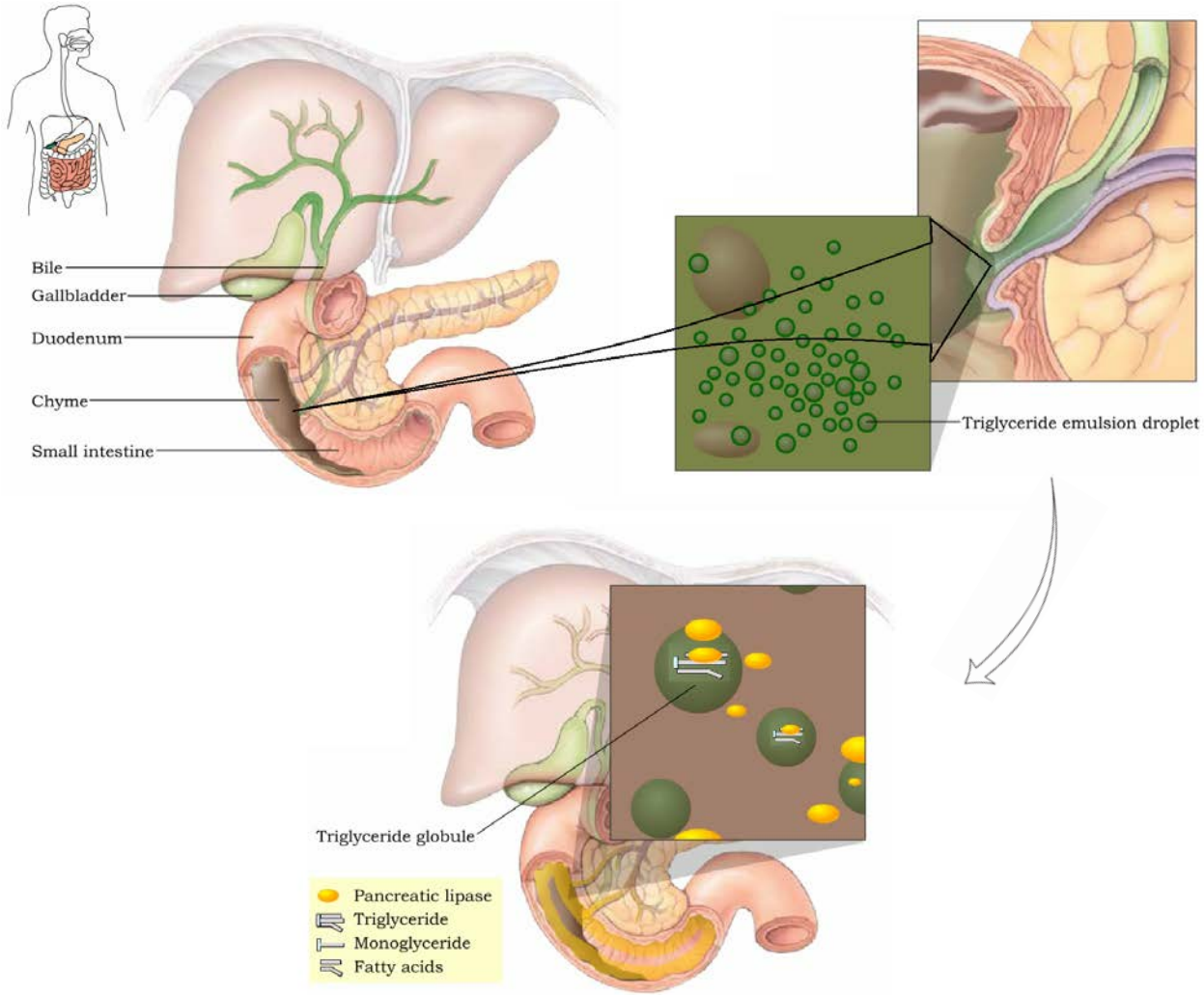
- Lipid digestion takes place primarily in the **small intestine** :
- **some** occurs **in** the **mouth and stomach**.
- Lipases are enzymes that break down triglycerides ad phospholipids.
- Lingual and gastric lipases hydrolyze a small amount of triglycerides.
- End products are fatty acids and monoglycerides.





Lipid Digestion - small intestine

- In the duodenum, triglycerides interact with bile salts and pancreatic juice.
- Bile salts cling to mono, di, and triglycerides of fat globules.
- The breakup of the fat globules results in triglyceride emulsion droplets.
- **Pacreatic lipase:**
  - is produced by pancreatic acinar cells.
  - Attaches to triglyceride molecules of the emulsion droplets.
  - Catalyze the breakup of the triglyceride of molecules into monoglycerides ad fatty acids.
  - Break down most triglycerides in the duodenum of the small intestine.

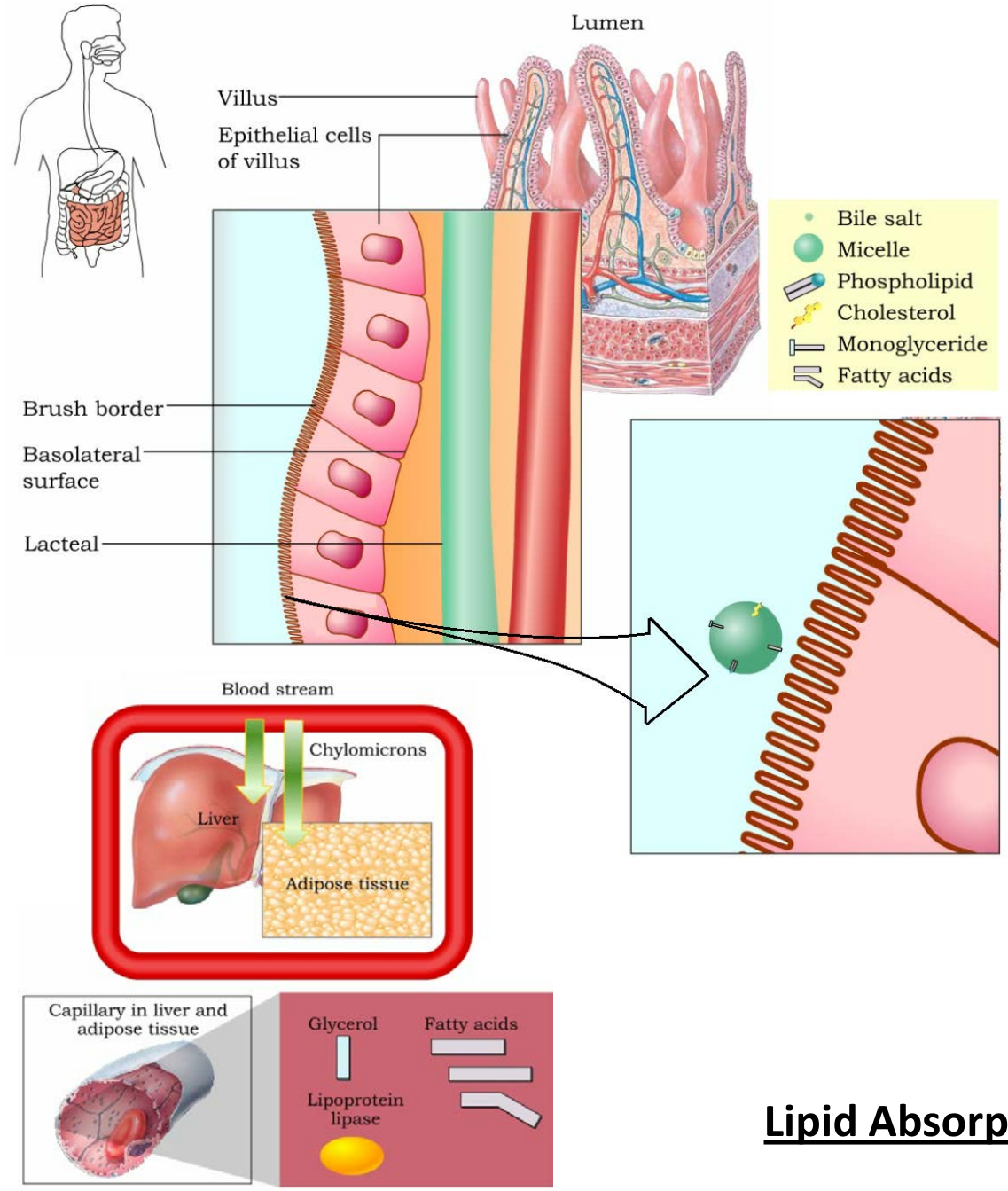


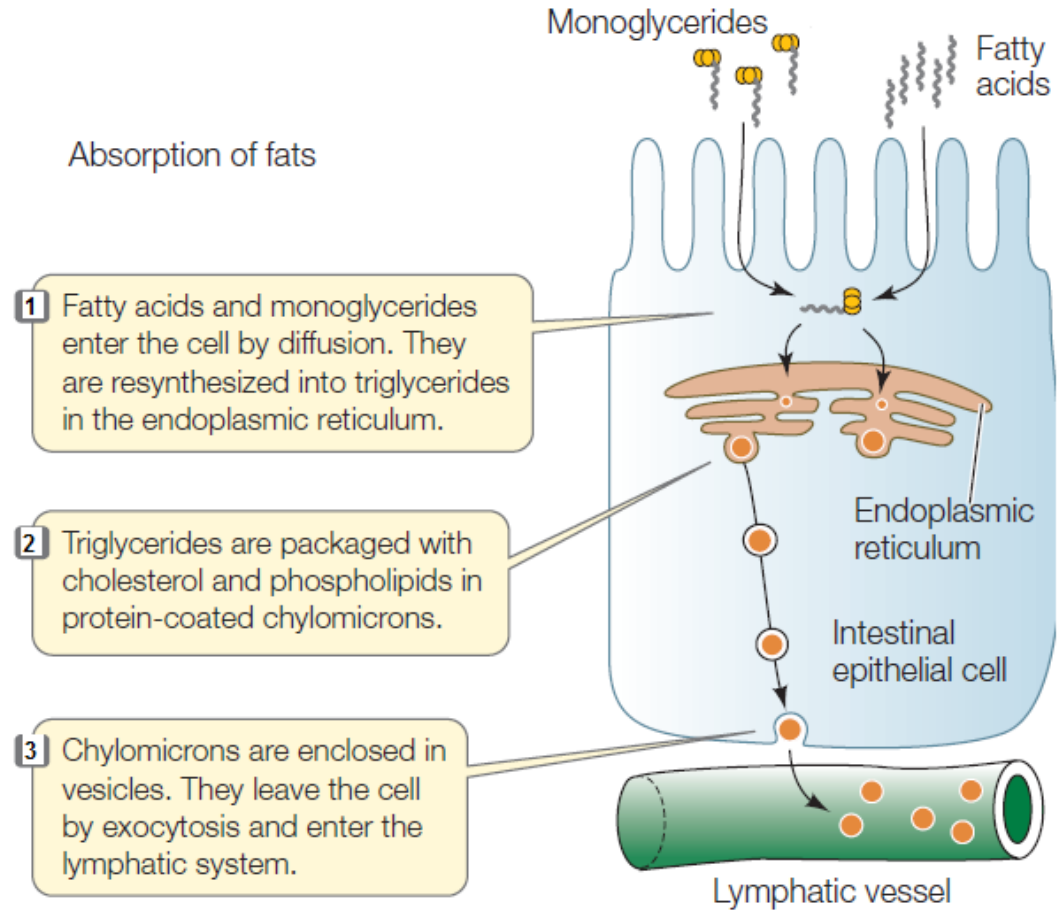
Lipid Absorption

- The end products fatty acids ad monoglycerides, depend on bile salts for absorption.

Lipid Absorption – transport mechanism

- Bile salts from micelles which ferry fatty acids and monoglycerides to epithelial cells.
- Free fatty acids, monoglycerides and some phospholipids and cholesterol molecules , diffuses freely into epithelial cells.
- **Micelles** diffuse back into the chyme and continue transporting end products.
- Monoglycerides are commonly digested further by lipases, producing glycerol and fatty acids.
- Glycerol and fatty acids then recombine to form triglycerides.
- Triglycerides then aggregate with phospholipids and cholesterol to form chylomicrons.
- **Chylomicrons** are the coated with proteins and leave the epithelial cell via **exocytosis**.
- Chylomicrons are too bulky to enter blood capillaries directly.
- They enter lacteals, travel through lymphatic vessels and enter the bloodstream at the left subclavian vein.
- Chylomicrons are quickly removed from the blood and broken down by lipoprotein lipases in capillary endothelial cells in the liver and adipose tissue.





The products of fat digestion are absorbed by intestinal mucosal cells, where they are resynthesized into triglycerides and exported to lymphatic vessels.

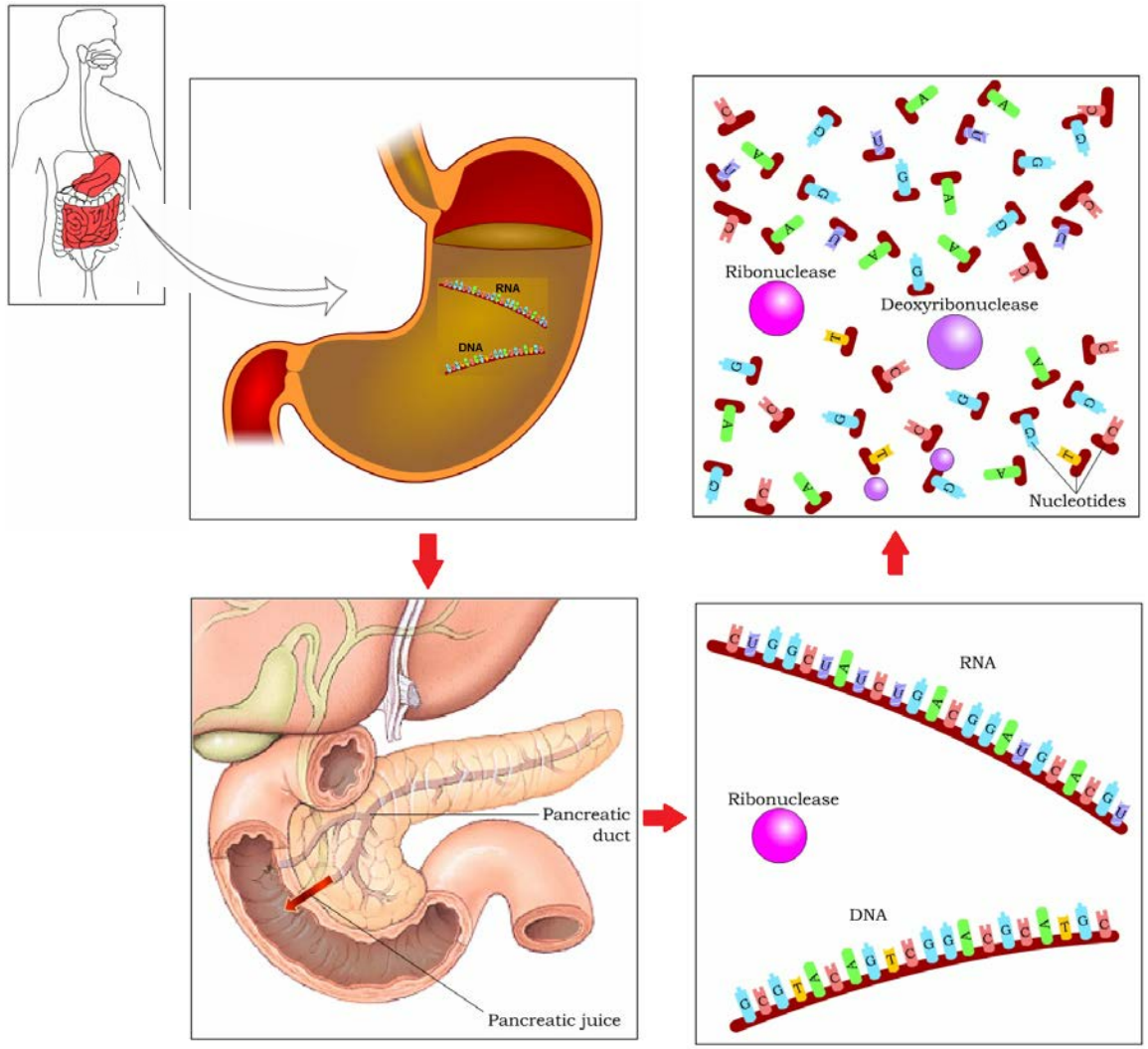
Lipid Absorption

Nucleic Acid Digestion

- Nucleic acid digestion, which takes place in the small intestine, involves:
  - Pancreatic nuclease,
  - Brush border enzymes in the small intestine.

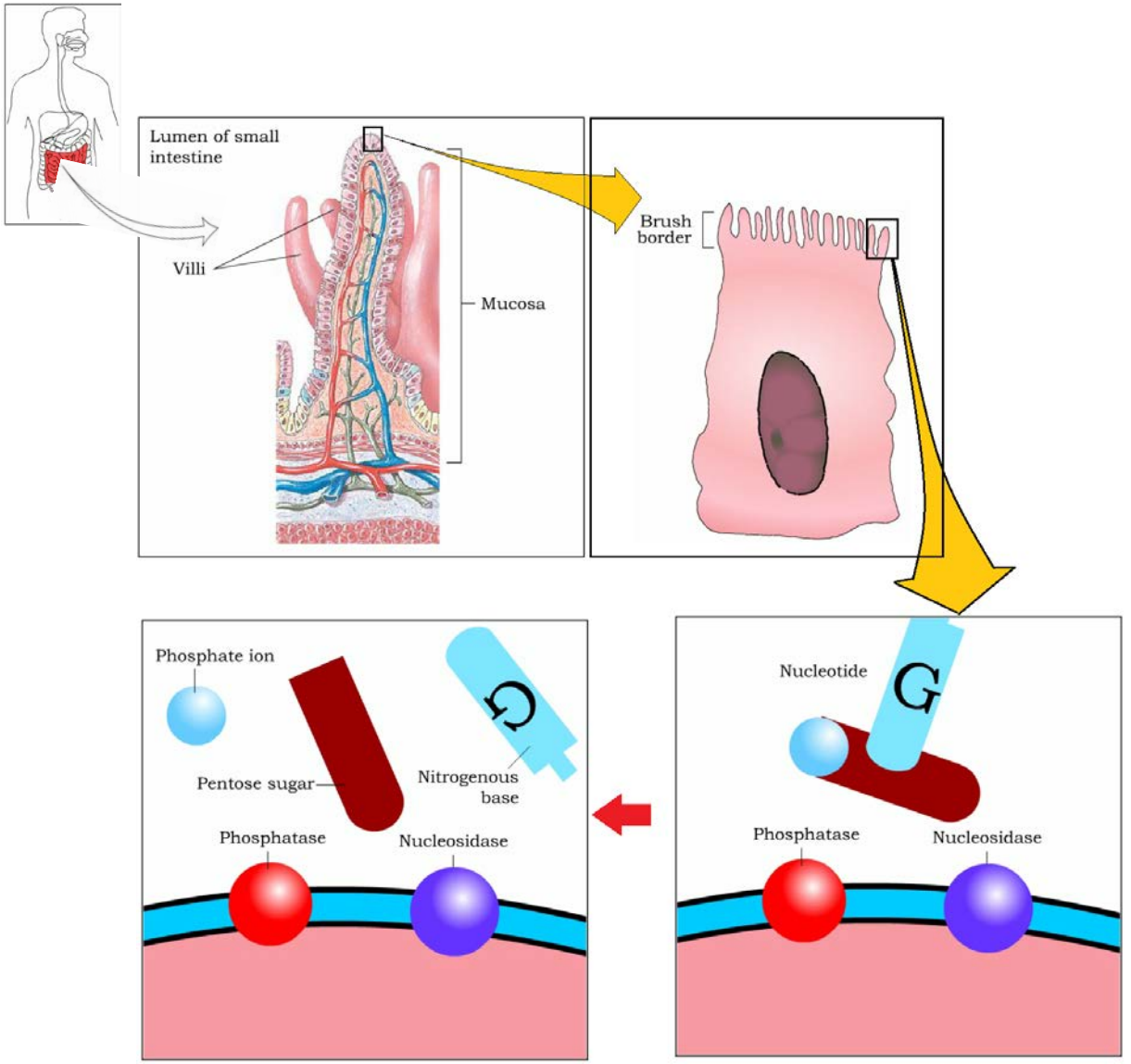
Nucleic Acid Digestion – small intestine

- Nucleic acids enter the small intestine dissolved in gastric chyme.
- As gastric chyme enters the duodenum of the small intestine, pancreatic juice also delivers two nucleases
  - **Ribnuclease,** which catalyzes the breakdown of RNA into ribonucleotides.
  - **Deoxyribouclease**, which catalyzes the breakdown of DNA into deoxyribonucleotides.



Nucleic Acid Digestion – brush border enzymes

- Further digestion occurs at the microvilli of the epithelial cells of the villi in the small intestine.
- Two brush border enzymes completes nucleic acid digestion
  - **Phosphatases** which catalyzes the cleavage of a phosphate to form a nucleoside(nitrogenous base and pentose sugar).
  - **Nucleosidases**, which catalyze the breaking of the covalent bond that holds the nitrogenous base to the pentose sugar.
- The final end products of nucleic acid digestion are
  - Nitrogeous base
  - Pentose sugars (Ribose and Deoxyribose sugar)
  - Phosphate ions.

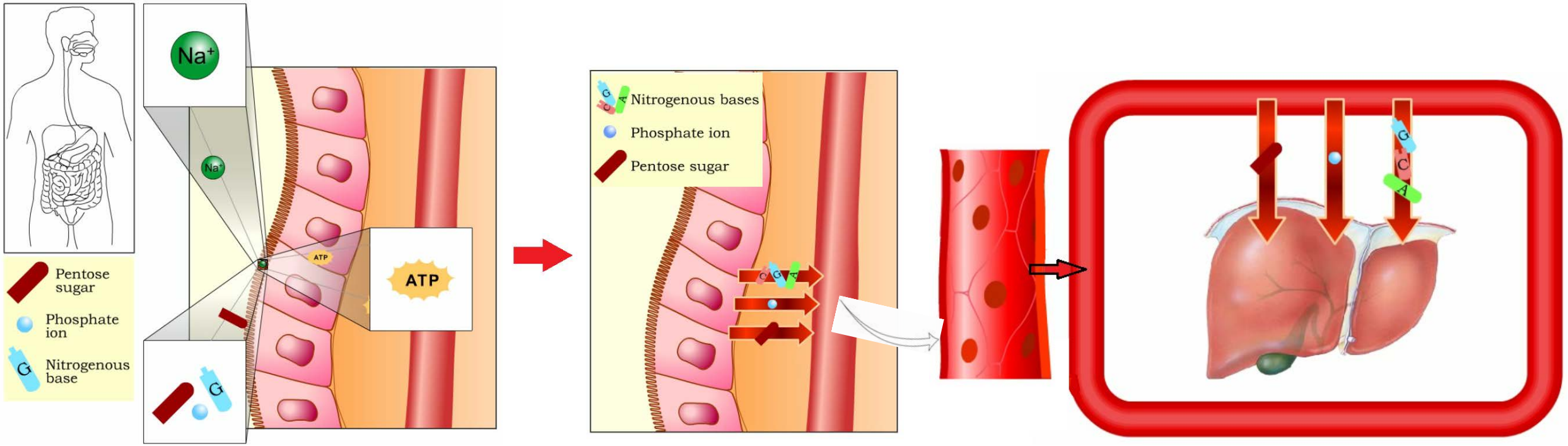


Nucleic Acid Absorption

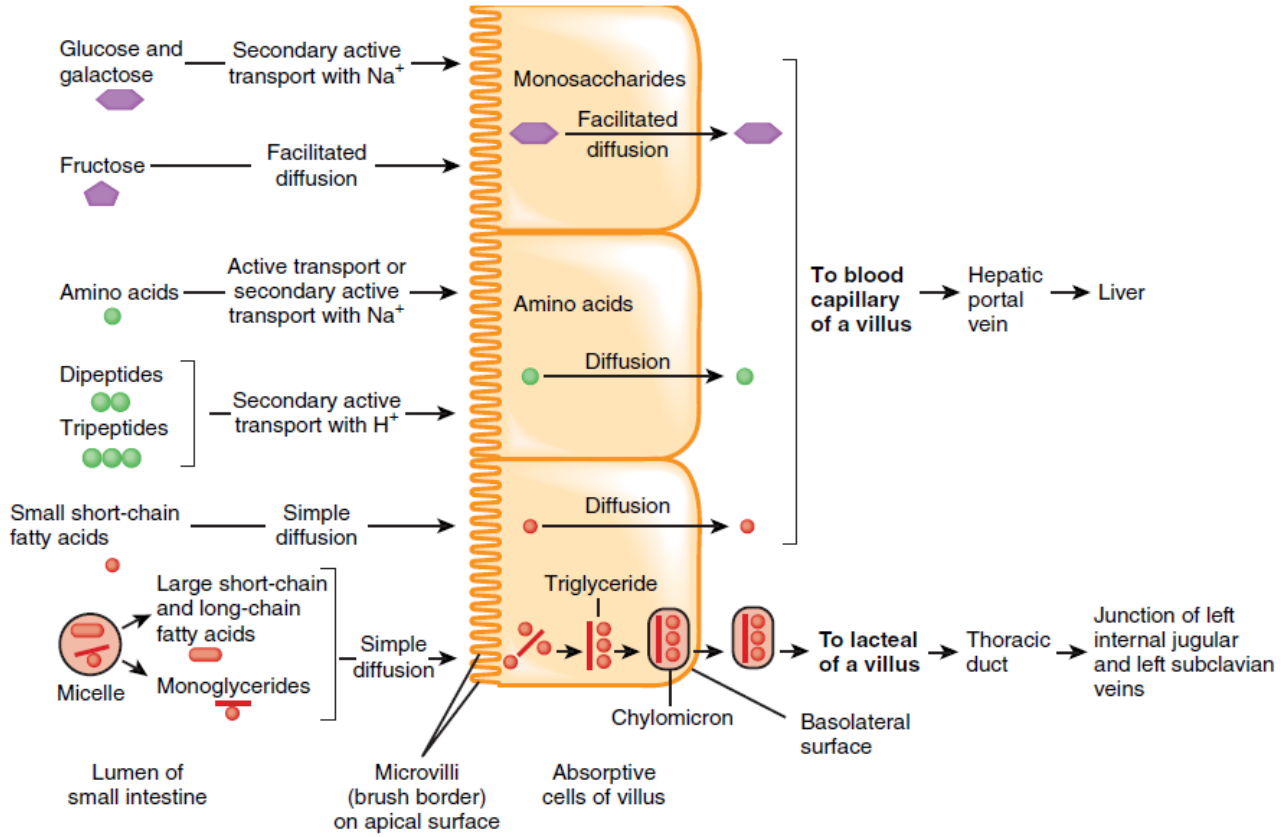
- Absorption of nucleic acid mainly occurs in the duodenum and jejunum of the small intestine.
- At the intestinal villus , all nucleic acid are absorbed as:
  - Nitrogenous base (A, C, T, G, U)
  - Pentose sugar (Ribose and Deoxyribose sugar)
  - Phosphate ions.

Nucleic Acid Absorption -Transport mechanism

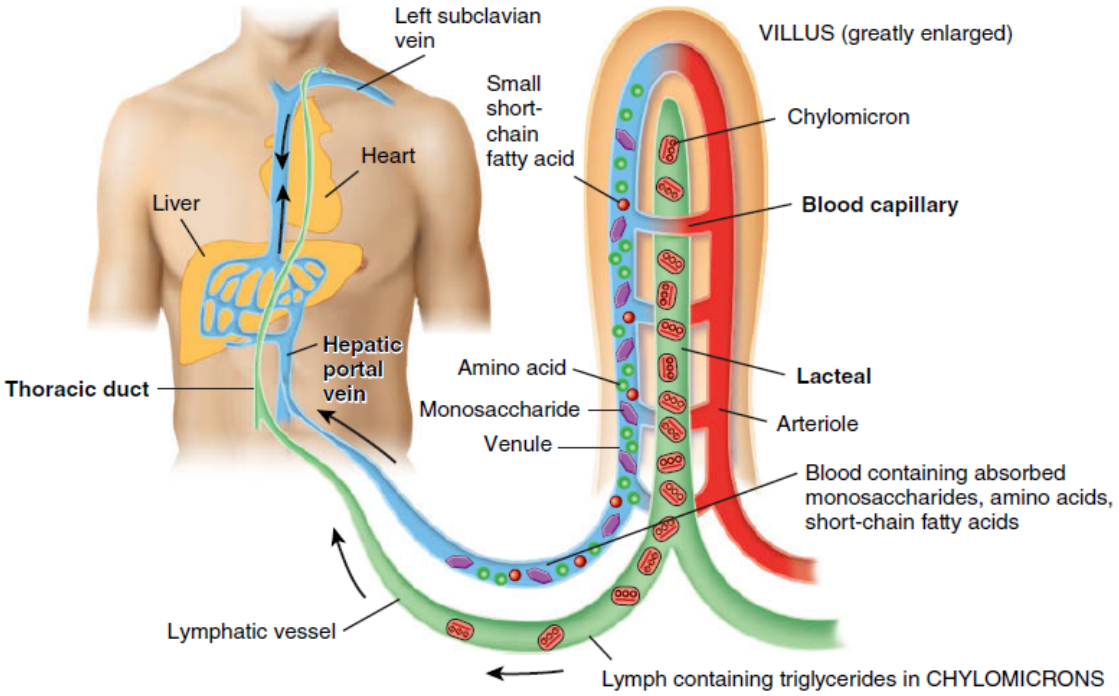
- Membrane transport proteins carry the products of nucleotide digestion into epithelial cells from the lumen.
- **Some** involves **active transport** ; some involve **secondary active transport**.
- Through diffusion the products of nucleotide digestion are transported from intestinal epithelial cells;
  - Across the basolateral membrane
  - Into the interstitial fluid
  - And finally into the blood
- The nucleotide digestion products are transported by blood circulation to the liver and other tissue where they undergo further degradation.



Nucleic Acid Absorption



(a) Mechanisms for movement of nutrients through absorptive epithelial cells of villi



(b) Movement of absorbed nutrients into blood and lymph

Absorption of different digested nutrients in the small intestine