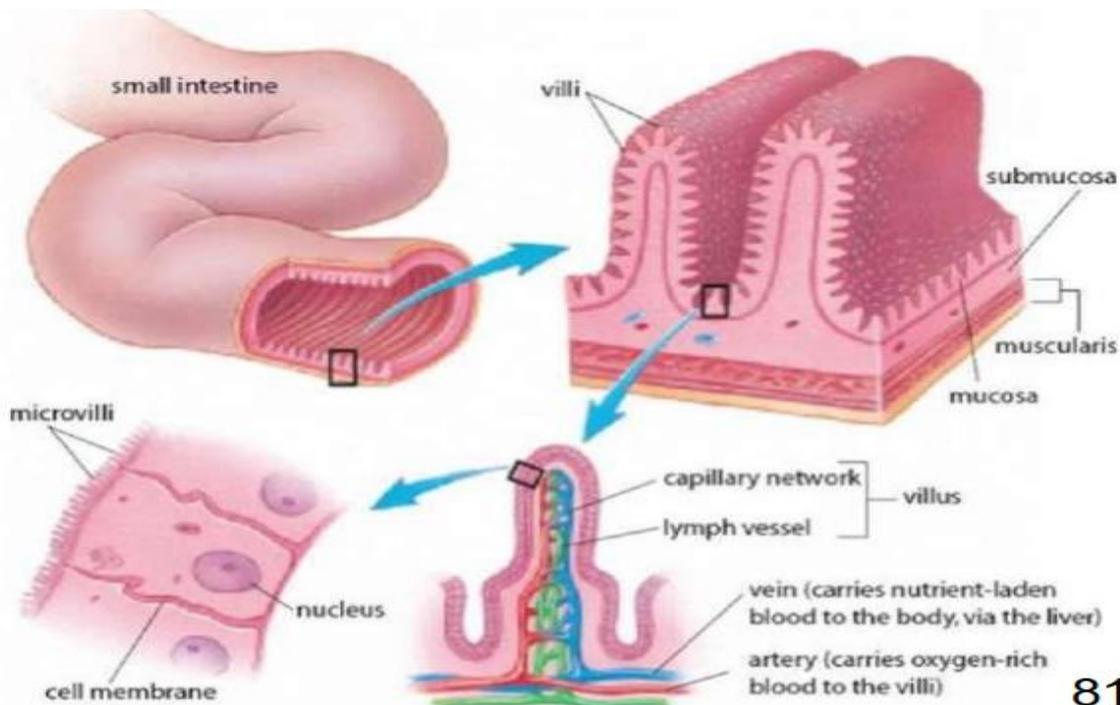
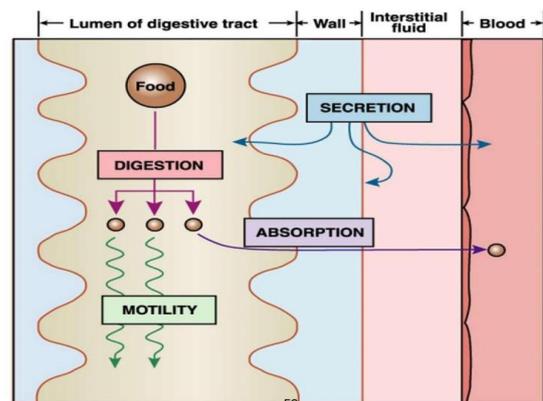
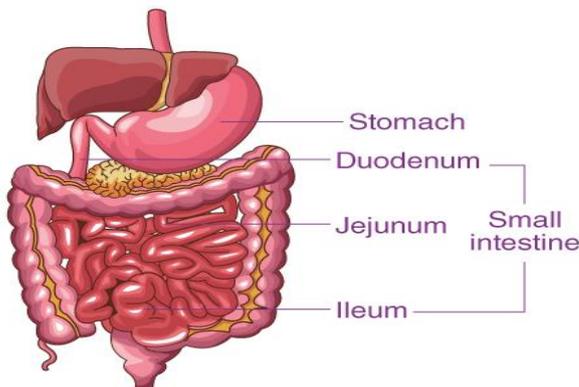


# Small Intestine

<b>Parts:</b>	<ul style="list-style-type: none"> <li>• Duodenum, jejunum and ileum.</li> </ul>
<b>Surface area:</b>	<ul style="list-style-type: none"> <li>• 250m<sup>2</sup> (large) due to Numerous folds of the mucosa.</li> </ul>
<b>Functions:</b>	<p><b>1) Secretory functions:</b></p> <ul style="list-style-type: none"> <li>➤ Intestinal juice (succus entericus).</li> <li>➤ G.I. hormones.</li> </ul> <p><b>2) Digestive functions:</b></p> <ul style="list-style-type: none"> <li>➤ Digestion of food is completed in small intestine</li> </ul> <p><b>3) Absorption.</b></p> <p><b>4) Motor function.</b></p>



# Succus Entericus

## ▪ Composition:

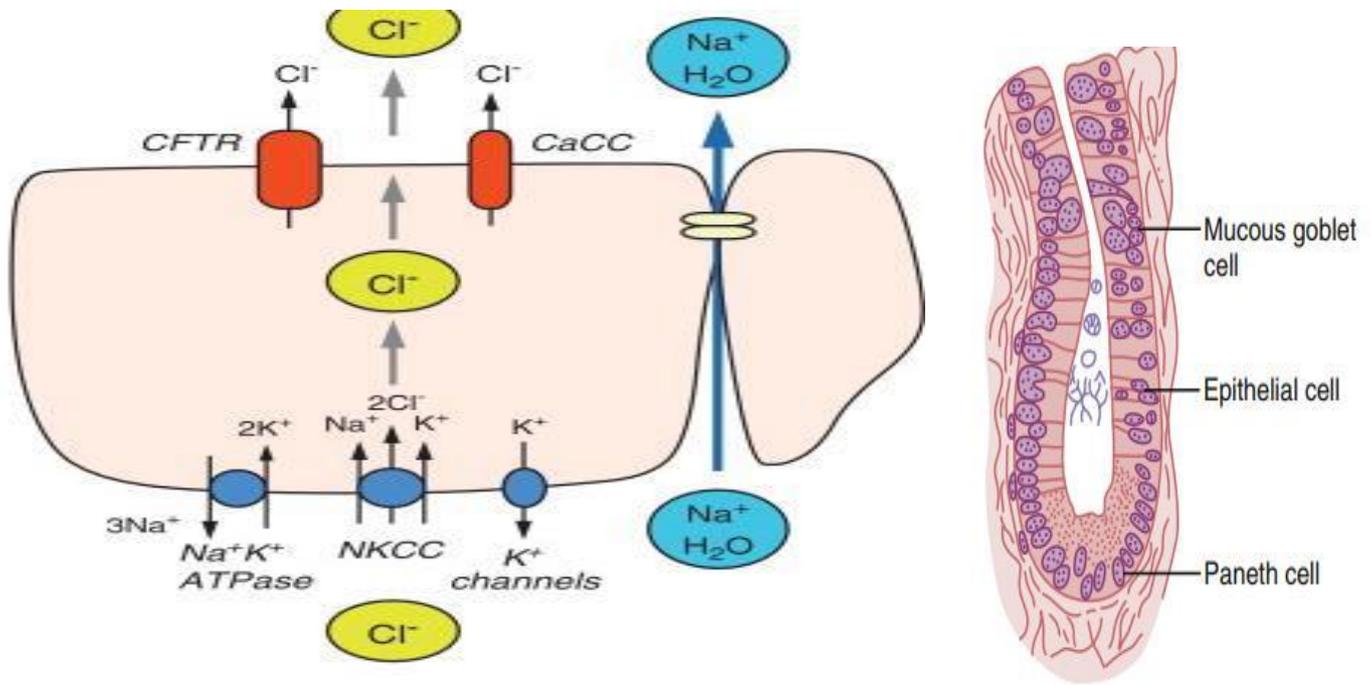
- **Volume:** 2L/day
- **PH:** 7.5-8

## ▪ Component:

1) Alkaline fluid	<ul style="list-style-type: none"><li>• <b>Contain:</b> Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup> &amp; HCO<sup>-3</sup>.</li><li>• It is secreted by the intestinal Crypts</li></ul>
2) Mucus	<ul style="list-style-type: none"><li>• Secreted by Brunner's glands in the duodenum.</li></ul>
3) Enzymes	<ul style="list-style-type: none"><li>• E.g., enterokinase, oligo and disaccharidases and peptidases</li></ul>

## NB:

- Cl is the major ion secreted by the small intestine.
- There are 2 Cl<sup>-</sup> channels in the apical border of the crypt's cell:
  - 1) Cl<sup>-</sup> channel activated by cholinergic stimulation, secretin, glucagon and VIP:
    - Abnormally increased in **some pancreatic tumors** leading to marked secretion of Cl and Na<sup>+</sup> **followed by** water resulting in diarrhea called pancreatic cholera.
  - 2) Cl<sup>-</sup> channel activated by cAMP:
    - It is activated by **cholera toxins** resulting in marked secretion of Cl<sup>-</sup> and Na<sup>+</sup> followed by water causing **watery diarrhea**.



▪ **Regulation of secretion of succus entericus:**

1) **Local myenteric reflex:**

- It is the **main mechanism** of regulation.
- It is initiated by the presence of food in small intestine.
- **Impulses are transmitted to the intrinsic nerve plexus stimulating secretion of succus entericus.**

2) **Nervous regulation:**

Vagal stimulation	Sympathetic stimulation
<b>Stimulates</b> mucus secretion by Brunner's glands	<b>Decrease</b> intestinal secretion

3) **Hormonal regulation:**

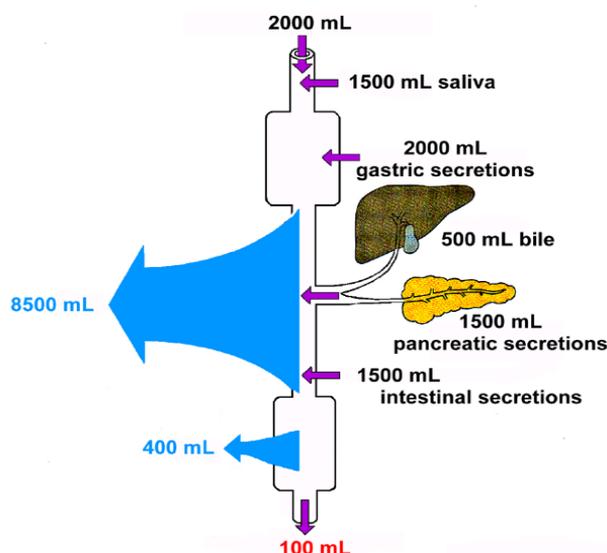
Hormones which stimulate secretion	Hormones which inhibit secretion
<ul style="list-style-type: none"> <li>• VIP (major hormone).</li> <li>• CCK and secretin.</li> <li>• Prostaglandin.</li> </ul>	<ul style="list-style-type: none"> <li>• Adrenaline</li> <li>• Noradrenaline.</li> </ul>

# Absorption of food

<b>Def.:</b>	<ul style="list-style-type: none"> <li>passage of <b>digested food</b> from the lumen of GIT through mucosa to blood stream.</li> </ul>
<b>Routes:</b>	<ul style="list-style-type: none"> <li>The absorbed substances reach blood through <b>blood capillaries</b> or <b>lymph vessels</b>.</li> </ul>
<b>Sites:</b>	<ol style="list-style-type: none"> <li><b>Small intestine (mainly):</b> because of the large mucosal absorptive surface (250 m<sup>2</sup> or more).</li> <li><b>Stomach:</b> alcohol and some drugs which are highly lipid soluble are absorbed from stomach.</li> <li><b>Large intestine:</b> can absorb water, electrolytes, glucose, amino acids and drugs.</li> </ol>

## 1) Absorption of Water

- **By osmosis.**
- The amount of water ingested is about **2 L/d** and the secretions of GIT are about **7 L/d**.
  - **8.5 L/d** are **absorbed** from **small intestine (80-90% of water)**
  - **0.4 L/d** is **absorbed** by **large intestine**.
  - So, about **100 ml/d** water is **excreted in stool**.



## 2) Absorption of Na<sup>+</sup> ions

### ▪ At basolateral border:

➤ Na<sup>+</sup> ions are transported across by **Na<sup>+</sup> - K<sup>+</sup> pump**.

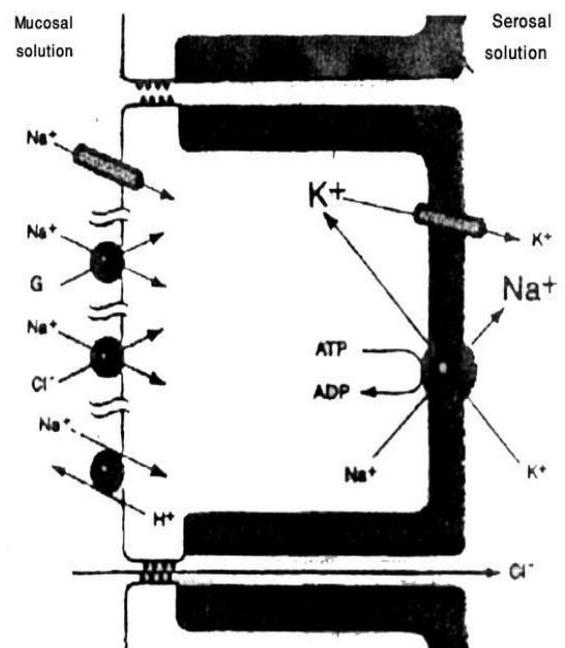
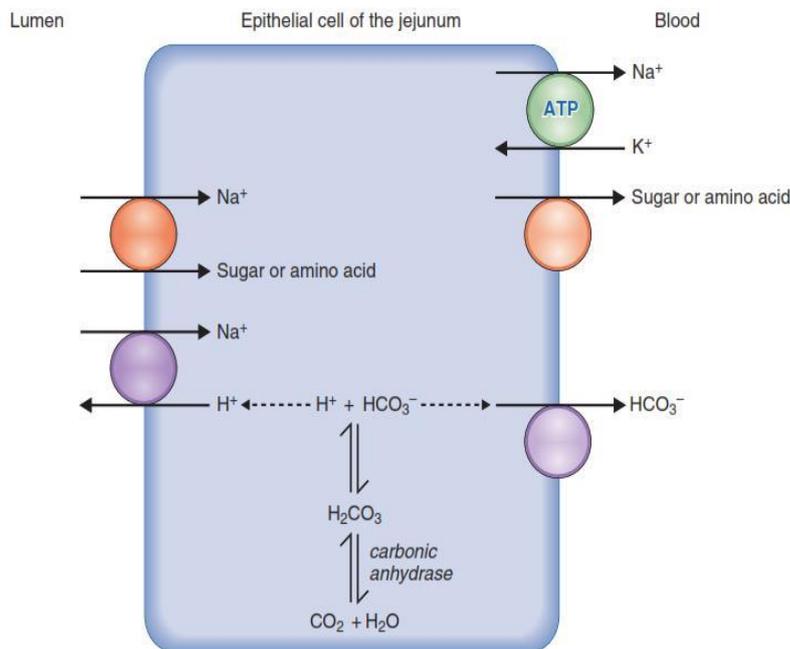
### ▪ Inside Enterocyte:

➤ Na<sup>+</sup> concentration **decreases** inside.

### ▪ At luminal (Apical) border:

➤ Transport of Na<sup>+</sup> from the lumen into the enterocyte by the following ways:

30%	<ul style="list-style-type: none"> <li>• by Na<sup>+</sup>-glucose, Na<sup>+</sup> - amino acid &amp; Na<sup>+</sup> - H<sup>+</sup> transporters.</li> </ul>
30%	<ul style="list-style-type: none"> <li>• by neutral Na<sup>+</sup> - Cl<sup>-</sup> cotransporter</li> </ul>
40%	<ul style="list-style-type: none"> <li>• by special Na<sup>+</sup> channels.</li> </ul>



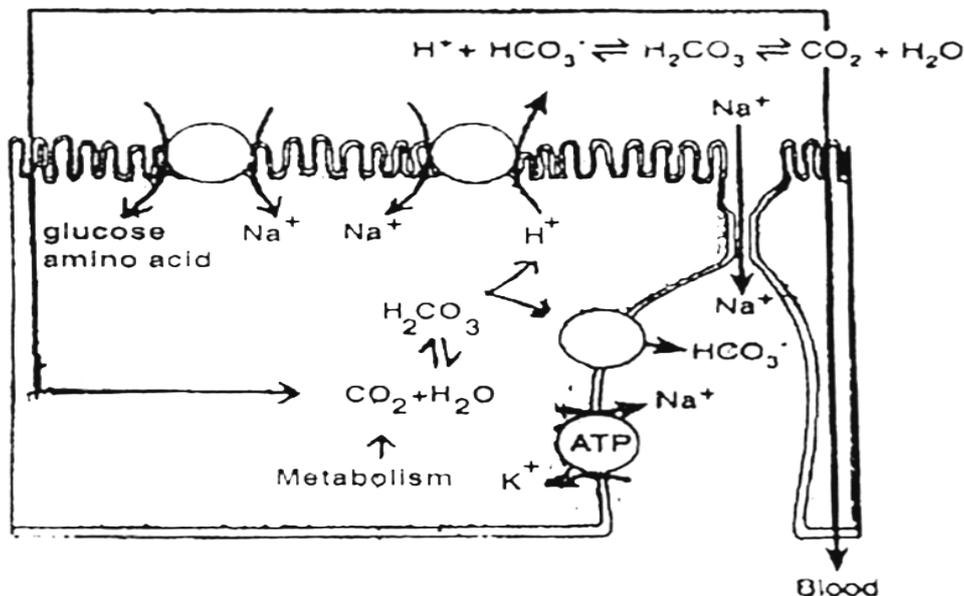
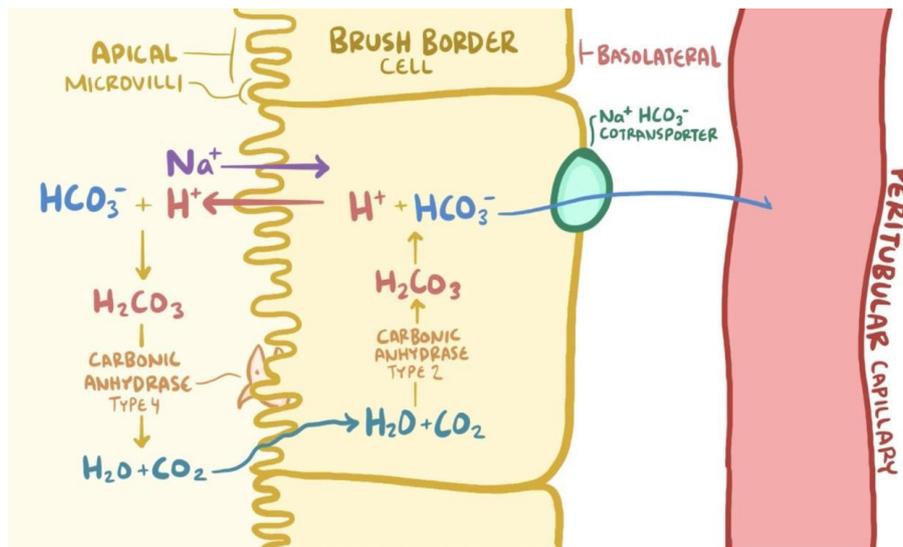
### NB:

- The presence of **glucose** in intestinal lumen facilitates Na<sup>+</sup> absorption because of the presence of common carrier.
- **This is the basis for treatment of Na<sup>+</sup> and water loss in diarrhea** by oral administration of solution containing NaCl and glucose.

### 3) Absorption of $\text{HCO}_3^-$ ions

- Are absorbed actively and by an indirect way:

<p><b>1- Luminal border:</b></p>	<ul style="list-style-type: none"> <li>• Some <math>\text{Na}^+</math> ions are absorbed coupled with counter-transport of <math>\text{H}^+</math> ions.</li> </ul>
<p><b>2- lumen of intestine:</b></p>	<ul style="list-style-type: none"> <li>• <math>\text{H}^+</math> ions combine with <math>\text{HCO}_3^-</math> to form <b>carbonic acid</b> which dissociates into <b>water and <math>\text{CO}_2</math></b>.</li> <li>• <u><math>\text{CO}_2</math>:</u> <ul style="list-style-type: none"> <li>a) Diffuses to blood to be <b>expired through lungs</b> or</li> </ul> </li> <li>• Binds with water intracellular to form <b>carbonic acid</b> again which dissociated to <math>\text{H}^+</math> &amp; <math>\text{HCO}_3^-</math>, the latter diffuses to blood.</li> </ul>



## 4) Absorption of Cl<sup>-</sup> ions

▪ **Method:** Secondary active transport or Passively.

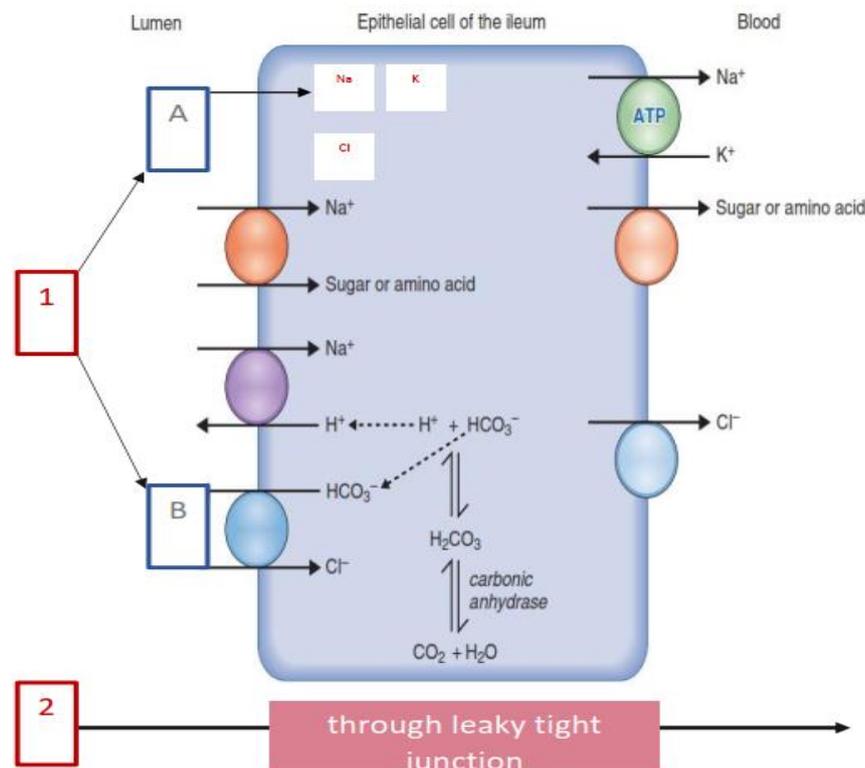
▪ **Steps:**

1) Cl<sup>-</sup> ions are absorbed in small intestine by two secondary active transport mechanisms:

a) Na<sup>+</sup> or K<sup>+</sup> - Cl<sup>-</sup> co-transporter.

b) Cl<sup>-</sup> - HCO<sub>3</sub><sup>-</sup> exchanger (in ileum and colon).

2) Cl<sup>-</sup> ions also diffuse through the **leaky tight junction** between the enterocytes following Na<sup>+</sup> ions.



## 5) Absorption of K<sup>+</sup> ions

▪ There is bidirectional movement of potassium across the intestinal wall, both passive and active.

▪ By passive diffusion through the **tight junctions** and lateral space of the enterocyte when the concentration rises because of absorption of H<sub>2</sub>O.

## 6) Absorption of $\text{Ca}^{++}$ Ions

### Method:

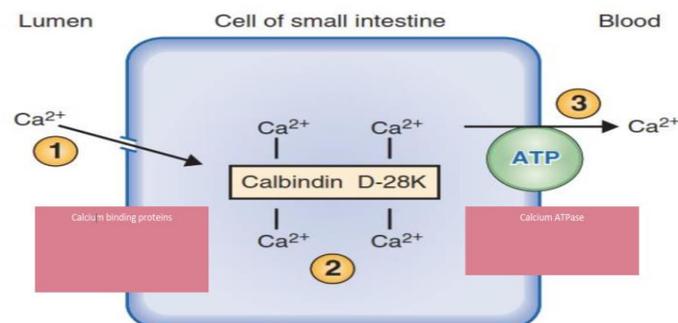
- They are actively transported mainly in **upper small intestine**.
- Absorbed **according to the body needs**.

### Factors affecting:

Increasing Absorption	Decreasing Absorption
<ul style="list-style-type: none"> <li>● <b><u>Low plasma <math>\text{Ca}^{2+}</math>:</u></b> <ul style="list-style-type: none"> <li>➤ Stimulates <b>parathyroid hormone</b> secretion which activates vitamin D in kidney to (<b>1, 25 dihydroxy cholecalciferol</b>).</li> <li>➤ <b><u>1, 25 dihydroxy cholecalciferol increases calcium absorption from intestine by stimulating formation of:</u></b> <ul style="list-style-type: none"> <li>- <b>Calcium binding proteins at the apical border</b></li> <li>- <b>Calcium ATPase, at the basolateral border.</b></li> </ul> </li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>● <b><u>Factors which form insoluble calcium salts in intestine as:</u></b> <ul style="list-style-type: none"> <li>● Oxalates</li> <li>● Phosphates</li> <li>● Phytates</li> <li>● Increase PH</li> <li>● Much fatty acids.</li> </ul> </li> </ul>

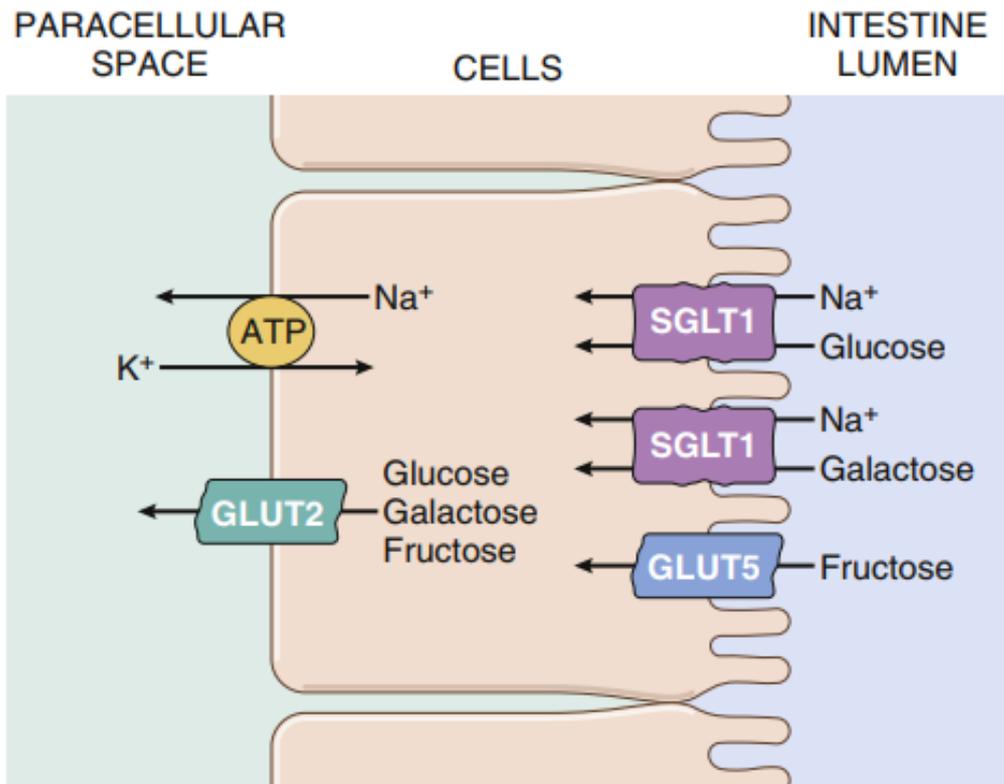
### NB:

- Vitamin D deficiency or chronic renal failure results in inadequate intestinal  $\text{Ca}^{+2}$  absorption, causing **rickets** in children and **osteomalacia** in adults.

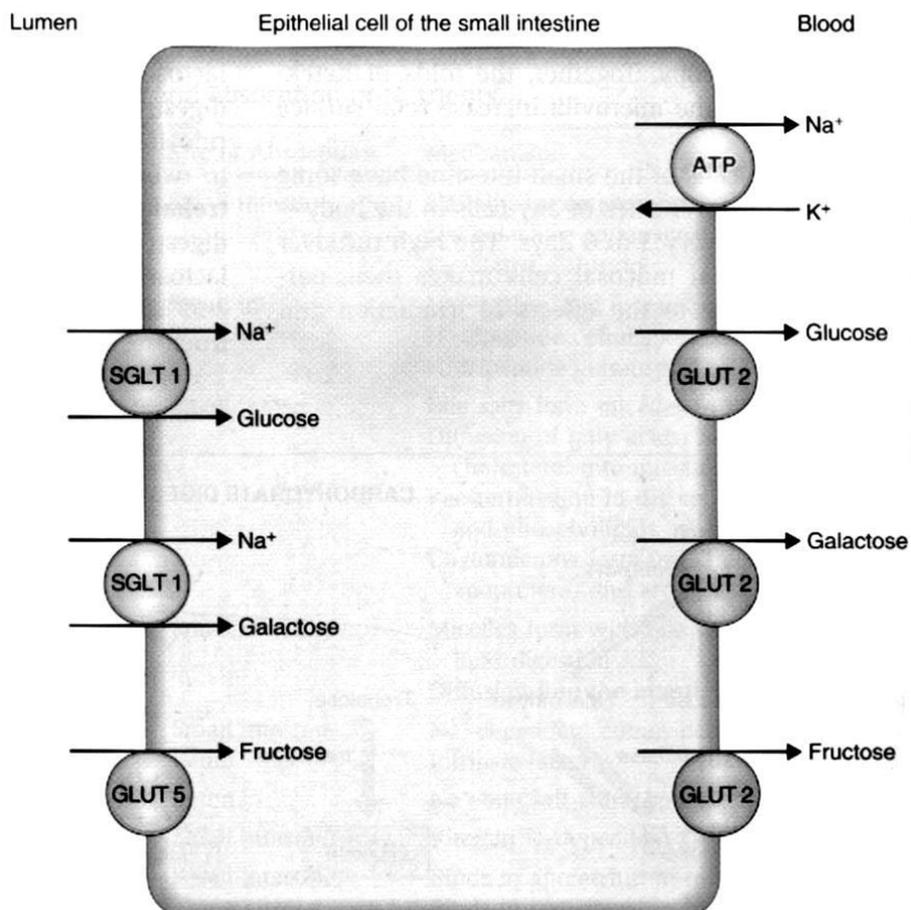


## 7) Absorption of carbohydrates

	Glucose & galactose	Fructose	Pentose
<b>1- Luminal border:</b>	<p><u>Through Na<sup>+</sup> dependent secondary active transport (the transporter is SGLT1).</u></p> <ul style="list-style-type: none"> <li>• <b>Steps:</b> <ol style="list-style-type: none"> <li>A) <b>SGLT1</b> has 2 receptor sites, one for Na<sup>+</sup> &amp; the other for glucose or galactose.</li> <li>B) As a result of active transport of Na<sup>+</sup> through the basolateral membrane, the concentration of Na<sup>+</sup> <b>decreases</b> inside cell.</li> <li>C) These favors <b>facilitated cotransport</b> of Na<sup>+</sup> and glucose or galactose.</li> </ol> </li> </ul>	<ul style="list-style-type: none"> <li>• Is absorbed by <b>Facilitated diffusion</b> (the transporters are <b>GLUT5</b>).</li> <li>• Its absorption is <b>independent</b> of Na<sup>+</sup>.</li> </ul>	<b>By simple diffusion.</b>
<b>2- Enterocyte:</b>	<ul style="list-style-type: none"> <li>• The increase in concentration of glucose or galactose helps their <b>facilitated diffusion</b> out of the cell into blood capillaries.</li> </ul>	<ul style="list-style-type: none"> <li>• Most of it is converted into <b>glucose</b>, so its concentration is continuously <b>decreased</b> maintaining a high concentration gradient for diffusion of fructose from the lumen.</li> </ul>	
<b>3- Baso-lateral border:</b>	<p>Leave to the blood by <b>facilitated diffusion</b>. (The carrier is GLUT2)</p>	<p>Absorbed by <b>Facilitated diffusion</b> (Through GLUT2).</p>	



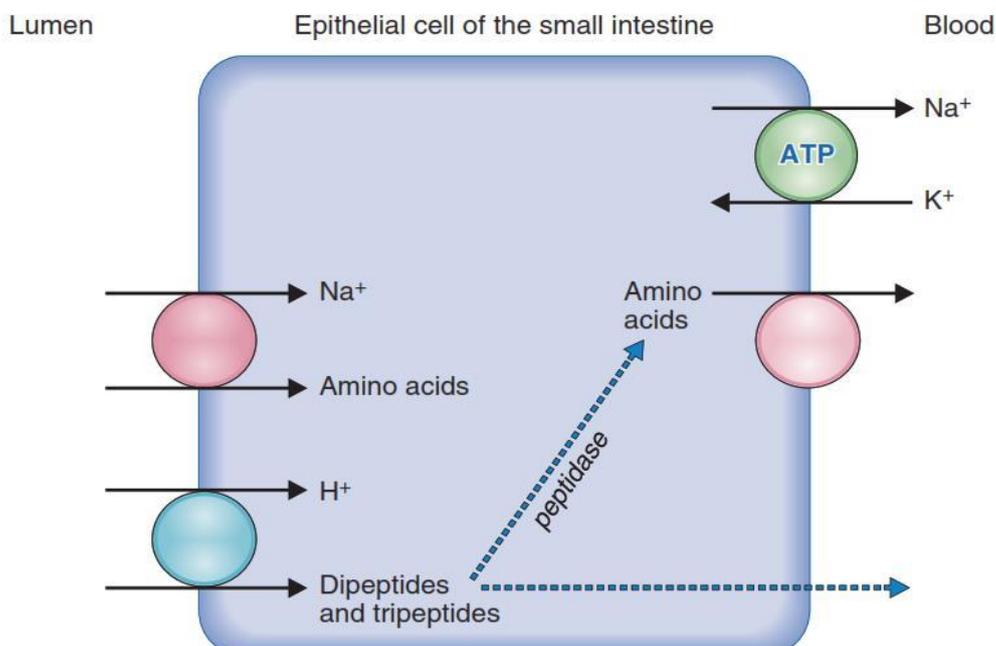
**Figure 66-9.** Absorption of glucose, galactose, and fructose through the intestinal epithelium. ATP, Adenosine triphosphate; GLUT2, Glucose transporter 2; GLUT5, glucose transporter 5; SGLT1, sodium-glucose co-transporter 1.



## 8) Absorption of proteins

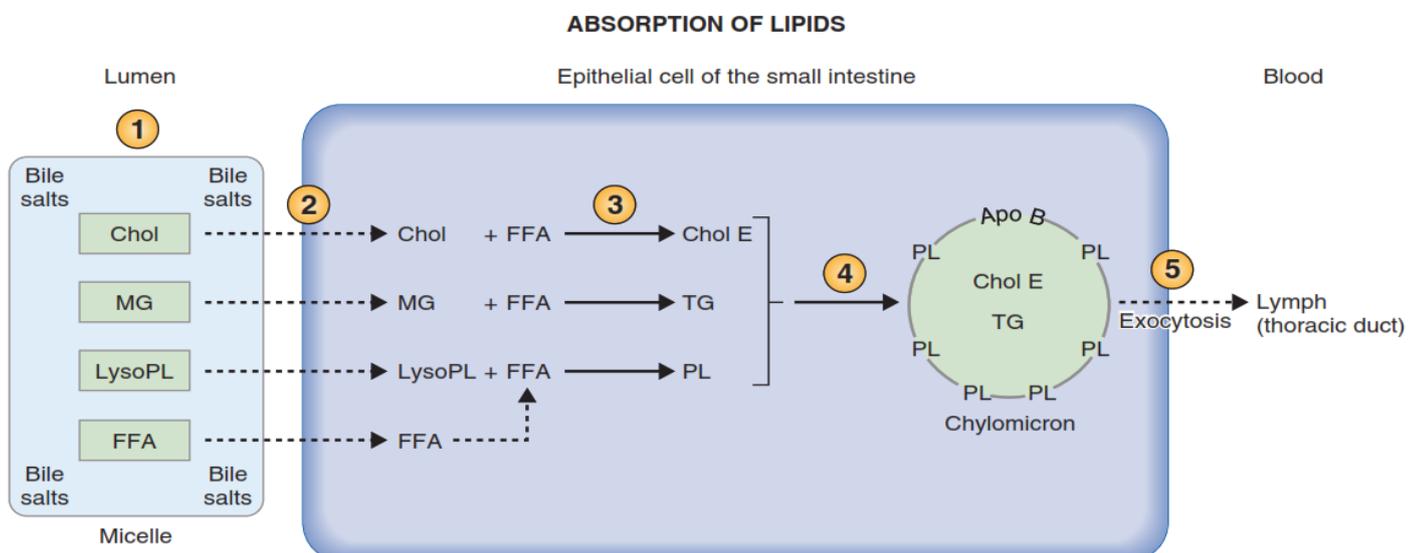
- Almost **all proteins are absorbed as amino acids**.
- Small quantities of small (**di & tri**) peptides are also absorbed unchanged.
- **Separate carriers** are present for absorption of basic, acidic, neutral, di-and- tri-peptides.
- **Mechanism:**

	<b>Amino acids</b>	<b>Di &amp; tri-peptides</b>	<b>Whole proteins</b>
<b>Luminal border:</b>	<b>By Na<sup>+</sup> dependent secondary active transport.</b>	<b>By H<sup>+</sup> dependent co transporter.</b>	<ul style="list-style-type: none"> <li>• Extremely minute quantities can be absorbed by <b>Pinocytosis</b>.</li> <li>• <b>E.g.,</b> maternal antibodies in claustrum and foreign proteins producing allergic symptoms after eating certain foods.</li> </ul>
<b>Enterocyte:</b>	_____	<ul style="list-style-type: none"> <li>• Hydrolyzed to <b>amino acids</b> by cytosolic peptidase.</li> </ul>	
<b>Baso-lateral border:</b>	<b>By facilitated diffusion into portal blood.</b>		



## 9) Lipid Absorption

<p><b>In the intestinal lumen:</b></p>	<ul style="list-style-type: none"> <li>• <b>Micelles</b> bring the products of lipid digestion into contact with the absorptive surface of the intestinal cells.</li> <li>• Glycerol is <b>hydrophilic</b> and is not contained in the micelles.</li> </ul>
<p><b>At brush border:</b></p>	<ul style="list-style-type: none"> <li>• Fatty acids, mono-glycerides, and cholesterol diffuse <b>across the luminal membrane</b> into the cells.</li> </ul>
<p><b>In the intestinal cells:</b></p>	<ul style="list-style-type: none"> <li>• <b>Esterification:</b> <ul style="list-style-type: none"> <li>➤ The products of lipid digestion are <b>re-esterified</b> to triglycerides, cholesterol ester, and phospholipids and, with apoproteins, form <b>chylomicrons</b>.</li> </ul> </li> </ul>
<p><b>At Baso-lateral border:</b></p>	<ul style="list-style-type: none"> <li>• Chylomicrons are transported out of the intestinal cells by <b>exocytosis</b>.</li> <li>• Because chylomicrons are too large to enter the capillaries, they are transferred to <b>lymph vessels</b> and are added to the bloodstream <b>via the thoracic duct</b>.</li> <li>• <b>NB: Lack of apo-protein B</b> results in the inability to transport chylomicrons out of the intestinal cells and causes <b>abetalipoproteinemia</b>.</li> </ul>



## 10) Iron Absorption

- It is **actively transported** mainly in upper small intestine, duodenum and jejunum.
- **Factors affecting Iron Absorption:**

Decreased by	Helped by
<ul style="list-style-type: none"><li>• Oxalates, phosphates, phytates and tannin.</li></ul>	<ul style="list-style-type: none"><li>• <b>Vitamin C</b> which reduces <math>Fe^{+3}</math> to <math>Fe^{+2}</math></li><li>• <b>Gastric HCl</b> which breaks insoluble iron complexes.</li></ul>

- **Mechanism:**

1) Iron is transported through the brush border as  **$Fe^{+2}$  or heme** carried by different transport carrier proteins.

2)  $Fe^{+2}$  is released from heme intracellularly by **heme oxygenase**.

3) Most of  $Fe^{+2}$  intracellular is **actively transported** across the basolateral membrane and enters blood where it is bound in the  $Fe^{+3}$  form to apotransferrin forming **transferrin**.

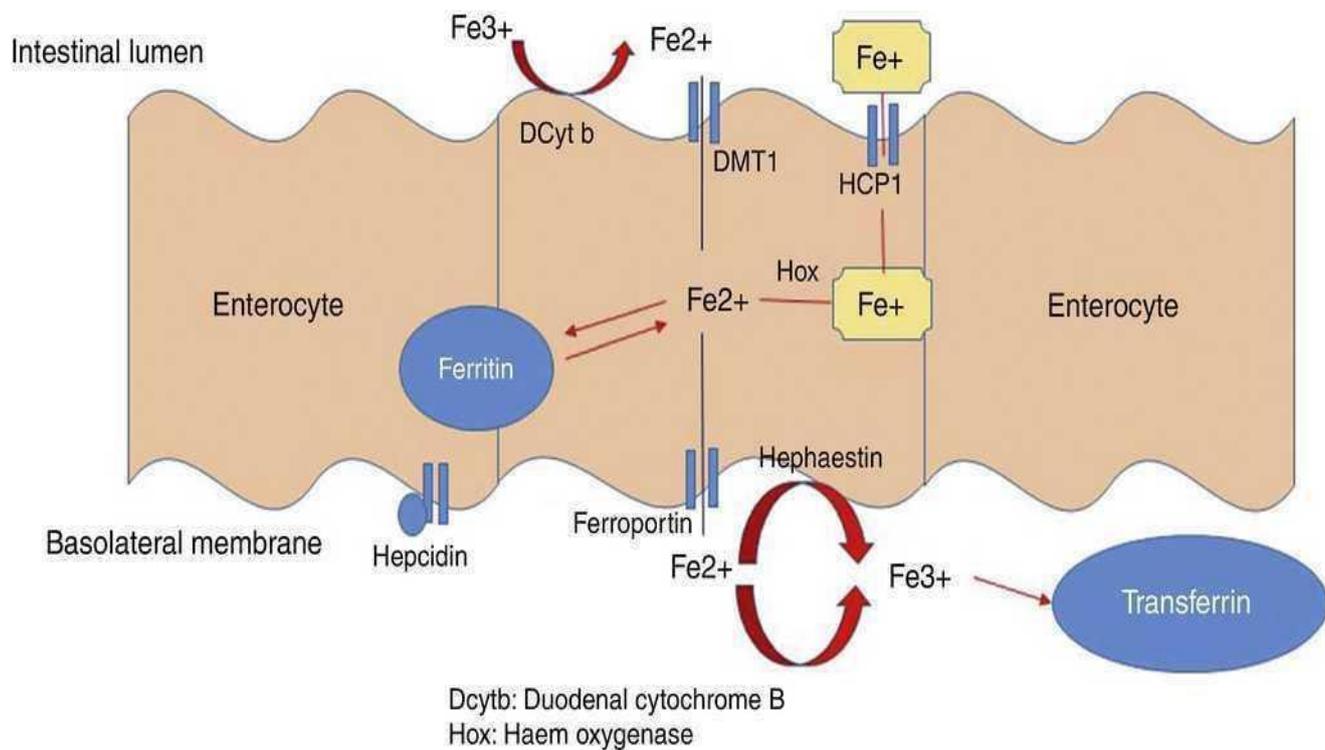
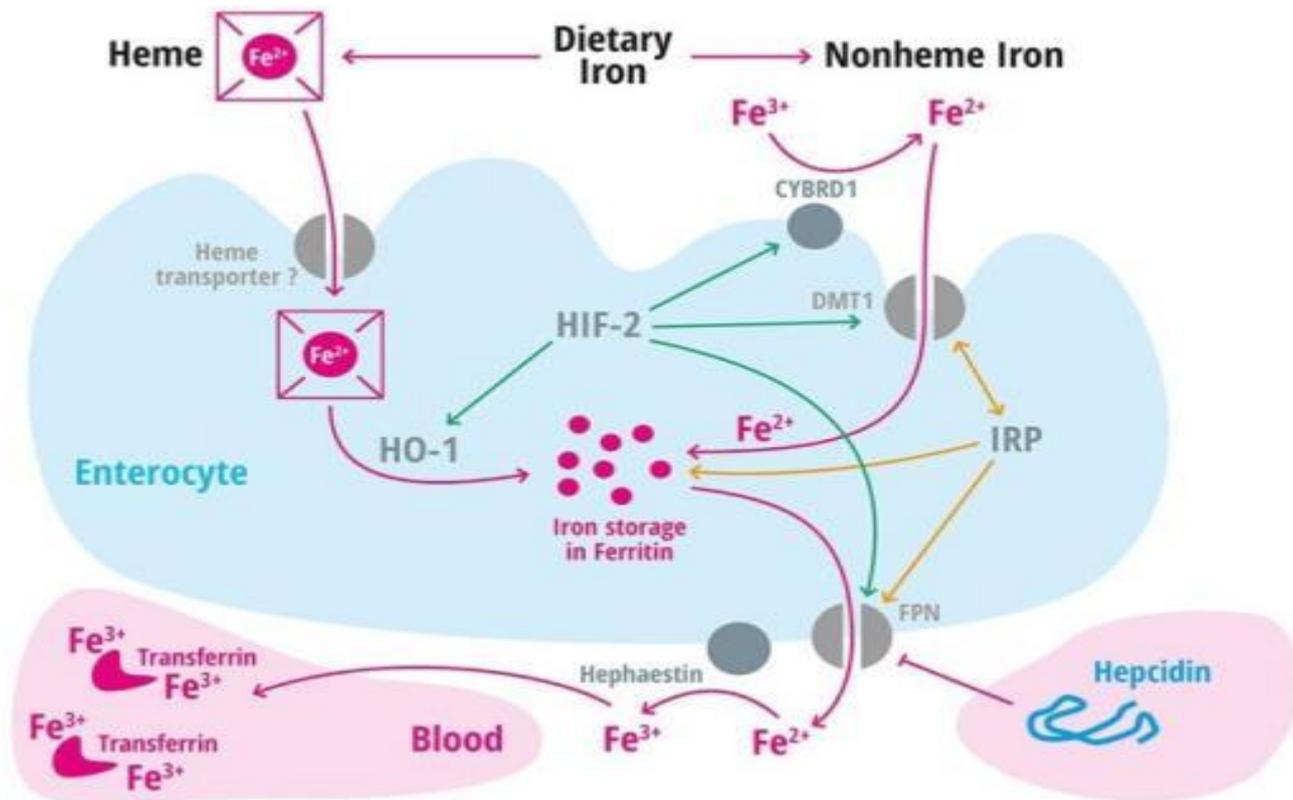
4) Some of  $Fe^{+2}$  intracellular is oxidized to  $Fe^{+3}$  and bound to apoferritin forming irreversible **ferritin**.

- **Iron is absorbed according to the body needs:**

➤ When all apoferritin in the body is saturated with iron, iron is **not released** from transferrin and **further uptake** from the enterocyte is inhibited.

➤ The excess iron in the mucosal cell form **irreversible ferritin** which is lost in the shedded cells.

➤ This **prevents** excess absorption of iron.



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