

# Absorption in the Gastrointestinal Tract

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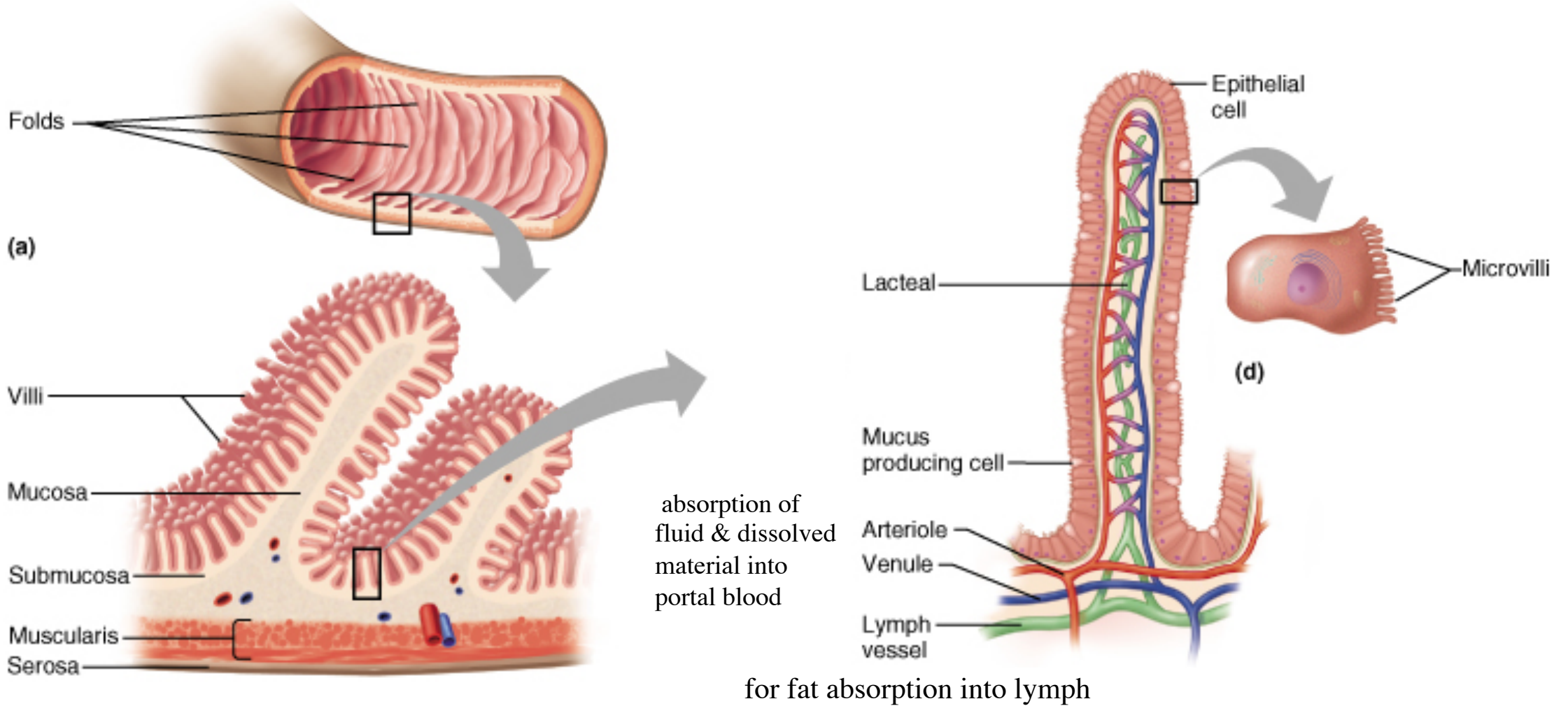
# Absorptive surface of SI mucosa

## 1. Valvulae Conniventes/ folds of Kerckring → circular folds

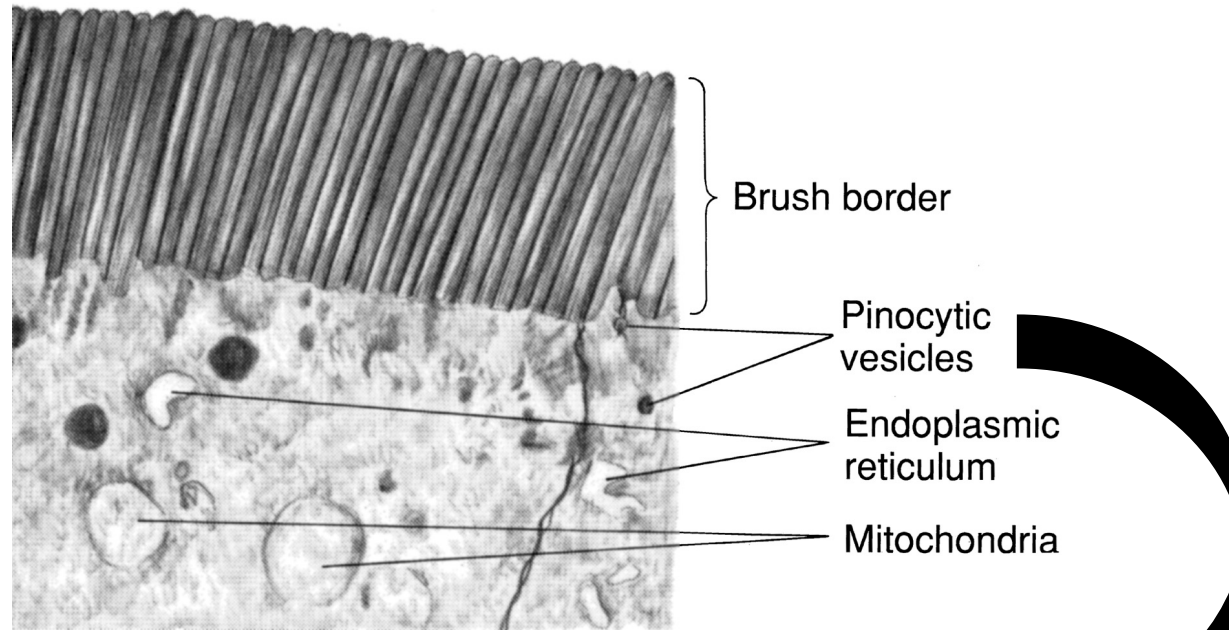
- ✓ Increase surface area of absorptive mucosa 3X.
- ✓ Well developed in D & J, protrude up to 8 mm into the lumen.

## 2. Villi → 1 mm projections from mucosa

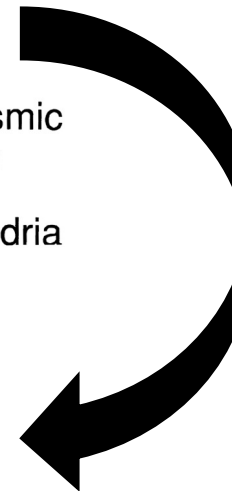
- ✓ Condensed in upper SI , less profuse in distal SI
- ✓ Increase surface area of absorptive mucosa 10X
- ✓ Epithelial cell on each villus is characterized by brush border.
- ✓ Brush border includes 1000 microvilli 1um length x 0.1 um diameter
- ✓ Brush border increases surface by 20-fold.
- ✓ Actin filaments contract rhythmically causing continual movement of microvilli exposing them to intestinal fluid.



**Folds Of Kerckring, Villi, And Microvilli Increase The Mucosal Absorptive Area By Nearly 1000-fold Making Total Area Of 250 Or More Square Meters For Entire SI**



infolded enterocyte membrane  
forming vesicles of  
absorbed fluids (pinocytosis)



# Absorption in SI

## Absorption from SI/day

- ✓ Several hundred g carbohydrates
- ✓  $\geq 100$  g fat
- ✓ 50 -100 g amino acids
- ✓ 50 -100 g ions
- ✓ 7 - 8 L of H<sub>2</sub>O

## Absorptive capacity of SI is far greater than this

- ✓ several kilograms carbohydrates
- ✓ 500 g fat
- ✓ 500 -700 g proteins
- ✓  $\geq 20$  L of H<sub>2</sub>O

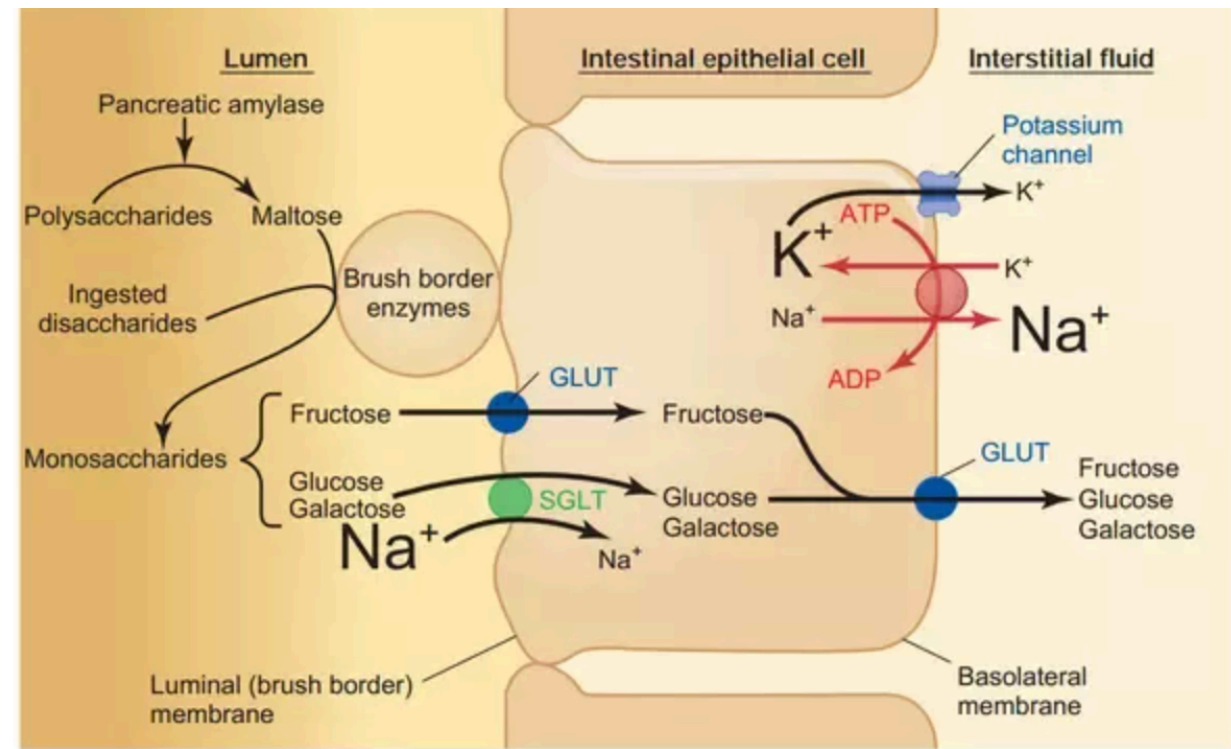
**Large intestine can absorb more water and ions, but very few nutrients.**

# Absorption of Carbohydrates

- Carbohydrates absorbed as monosaccharides
- Small fraction absorbed as disaccharides
- None absorbed as larger carbohydrate compounds.
- The most abundant absorbed monosaccharides is glucose (80 %)
- 20 % galactose & fructose
- All **monosaccharides** absorbed by secondary active transport process.
- Glucose absorption occurs in a co-transport mode with active transport of Na

# Absorption of Carbohydrates

- Glucose absorption is dependent on Na absorption
- The transport of Na through I membrane;
- ✓ Active transport of Na through basolateral membranes of epithelium → interstitial fluid → ↓[Na epithelium] → Na from lumen → brush border by secondary active transport combining glucose
- ✓ Once inside epithelium, other transport proteins and enzymes cause facilitated diffusion of glucose into blood.
- Galactose – same as glucose
- Fructose – facilitated diffusion.
- Inside the cell → phosphorylated & converted to glucose → absorbed into blood.
- Rate of fructose transport is ½ of glucose or galactose.

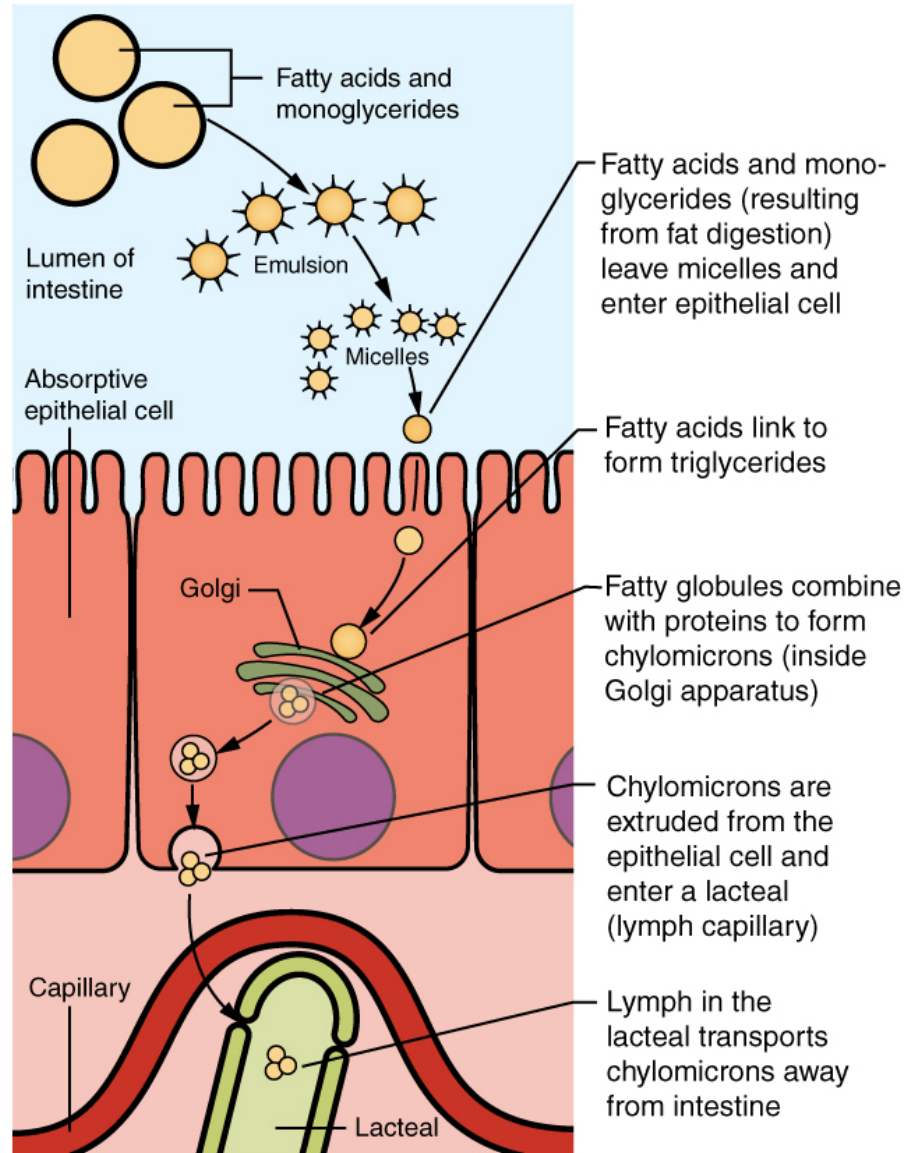


# Absorption of Proteins

- In the form of dipeptides, tripeptides & free amino acids
- Sodium co-transport mechanism (secondary active transport)
- Few amino acids via facilitated diffusion
- 5 types of transport proteins for transporting amino acids and peptides have been found in the luminal membranes of intestinal epithelial cells



# Absorption of Fats



# Absorption of Fats

- Fats are digested to monoglycerides & free fatty acids → dissolved in bile micelles → carried to microvilli of brush border → penetrate into the recesses among the moving, agitating microvilli.
- Monoglycerides & fatty acids diffuse immediately out of micelles into epithelial cells leaving bile micelles in chyme (where they function again and again)
- In the presence of abundance of bile micelles, about 97% of the fat is absorbed - in the absence of the bile micelles, only 40-50 % can be absorbed

# Absorption of Fats

- After entering epithelial cell → fatty acids and monoglycerides → smooth ER → triglycerides formation → released in form of **chylomicrons** through the base of the epithelial cell → thoracic lymph duct → blood circulation
- Short and medium chain fatty acids (more water-soluble) are absorbed directly into the portal blood

## Fluid absorption in the GIS

- Total quantity of fluid absorbed/day (8-9 L) = ingested (1.5 L) + GI secretions (7 L)
- Stomach: poor absorption lacks typical villus + tight junctions between epithelial cells
- ✓ Only few substances: alcohol & aspirin
- Most is absorbed in SI, leaving only 1.5 L to colon/day.

# Absorption of Water

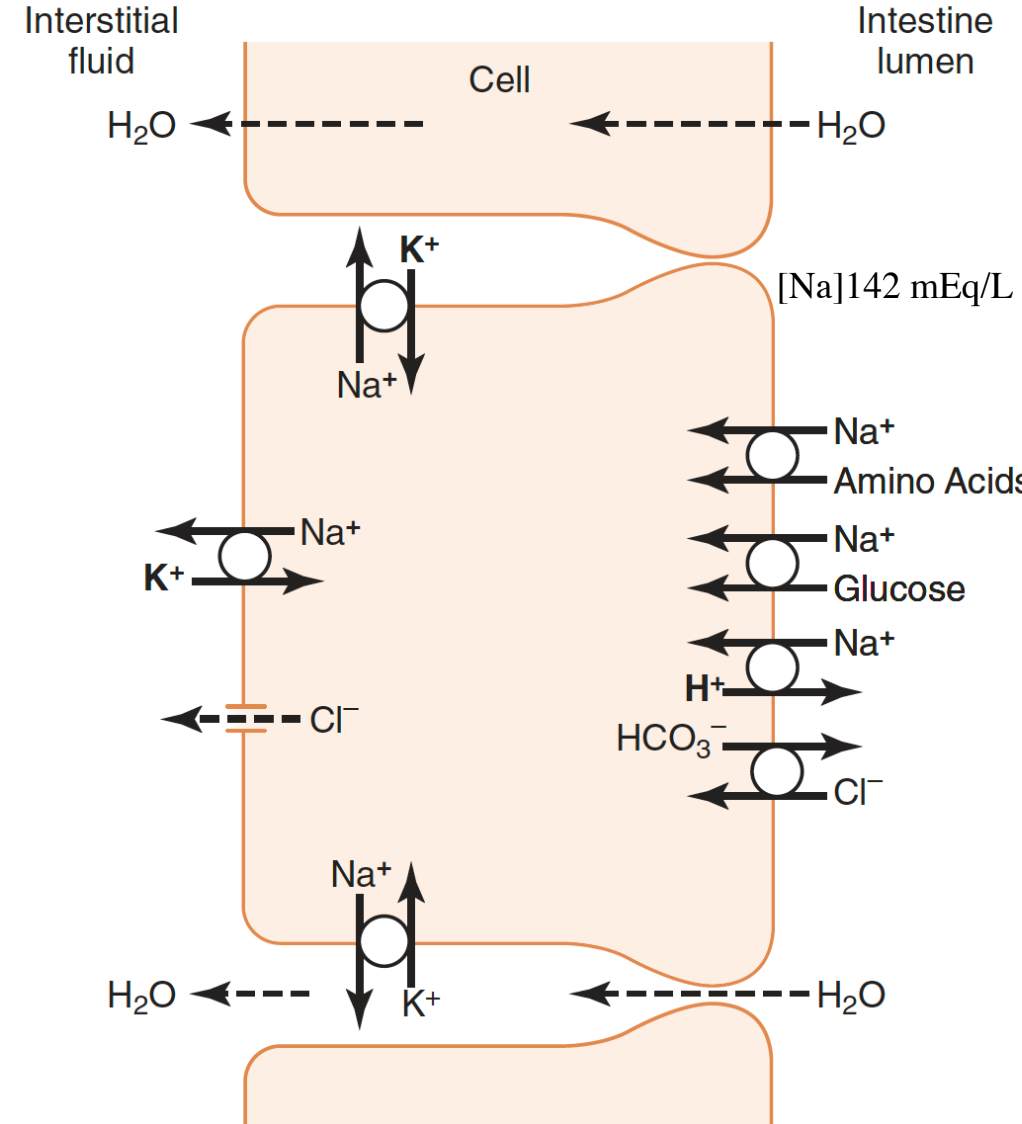
- Isosmotic Absorption/Diffusion - usual laws of osmosis
- When chyme is dilute enough, water is absorbed through the intestinal mucosa into blood of villi almost entirely by osmosis
- When hyperosmotic solutions are discharged from the stomach into the duodenum - water usually will be transferred by osmosis to make the chyme isosmotic with the plasma
- Chyme is isosmotic with plasma except in colon.
- Stool water is hypertonic.

# Absorption of Na

- 30 g of Na are secreted in I secretions/day.
- 5 - 8 g ingested/ day
- Intestines must absorb 25-35g (1/7 of all body Na) of Na/day
- Diarrhea – Na can be depleted to lethal levels within hours

# Sodium Absorption

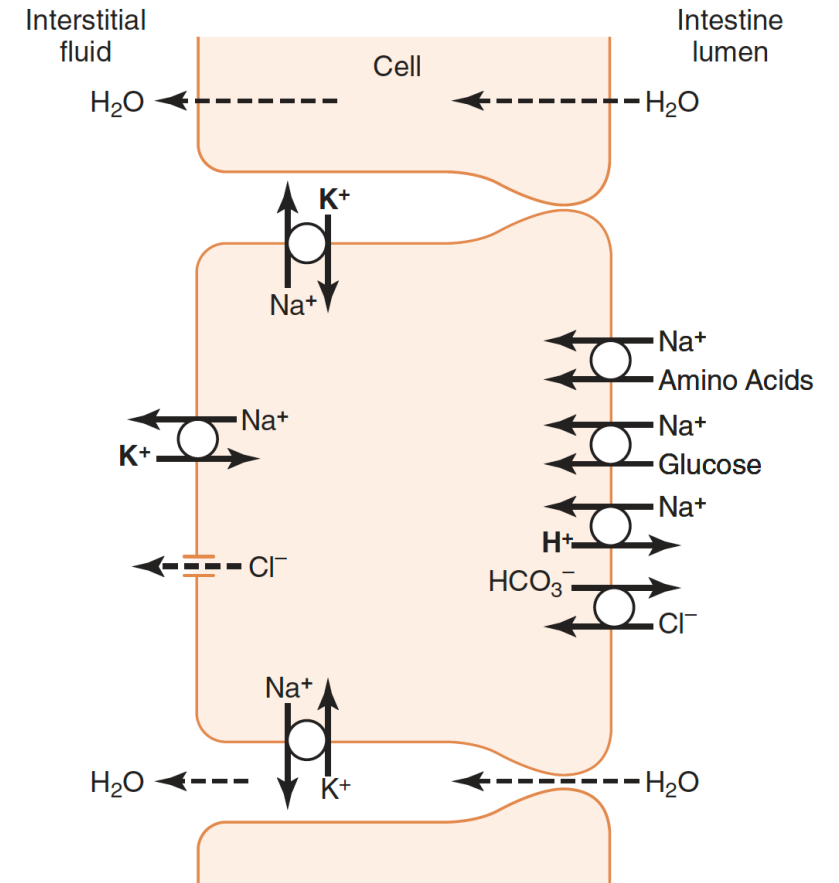
- Na absorption is powered by active transport (ATP)
- Na is absorbed by epithelial cells (enterocytes) of SI.
- Na uptake creates negative electrical potential in gut lumen, that provides gradient for Cl uptake.
- Water follows Na and Cl by osmosis (through cell/tight junctions).



# Na absorption in small intestine

- Na is absorbed across apical cell membrane by several mechanisms -

1. Diffusion - through water-filled channels
2. Co-transport - with AA
3. Co-transport - with glucose
4. Co-transport - with chloride
5. Counter-transport - in exchange for H<sup>+</sup>





# Absorption of Ions

When person *dehydrated*, large amounts of *aldosterone* secreted by adrenal glands



Increased activation of **enzyme and transport mechanisms** for all aspects of Na absorption by intestinal epithelium



Increased Na absorption in turn causes secondary increases in absorption of **chloride ions, water**

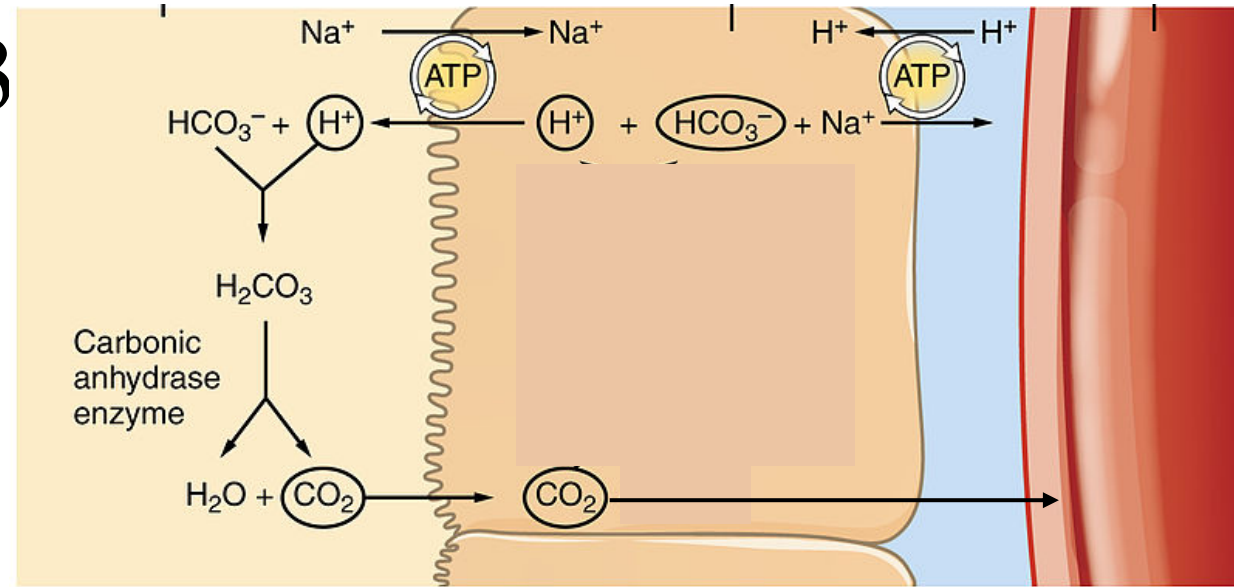
This effect of aldosterone is important in colon because it allows virtually no loss of NaCl in feces + little water loss.

# Absorption of Ions

- Absorption of Cl in Duodenum & Jejunum
- Cl absorption is rapid by *diffusion*
- Absorption of Na ions through epithelium creates electronegativity in chyme and electropositivity in the paracellular spaces between the epithelial cells.
- Cl move along this electrical gradient to “*follow*” the sodium ions
  - Chloride also absorbed across brush border of parts of ileum & LI by Cl-HCO<sub>3</sub> exchanger.
  - Cl exits the cell on the basolateral membrane through chloride channels.

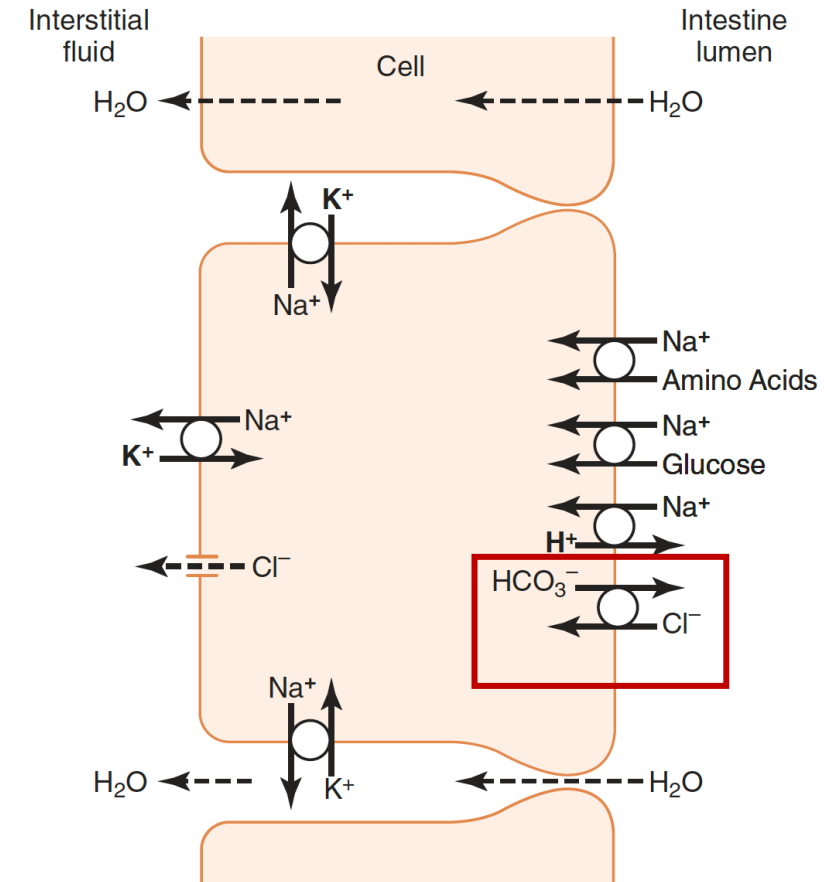
# Active absorption of $\text{HCO}_3^-$

- Large quantities of  $\text{HCO}_3^-$  must be reabsorbed from D & J because large amounts of  $\text{HCO}_3^-$  secreted into D in *both pancreatic secretion & bile*
- $\text{HCO}_3^-$  is absorbed in *indirect way*:
- When Na is absorbed, amounts of  $\text{H}^+$  are secreted into lumen in exchange for Na
- These  $\text{H}^+$  combine with  $\text{HCO}_3^-$  to form carbonic acid ( $\text{H}_2\text{CO}_3$ ), which then dissociates to form  $\text{H}_2\text{O}$  &  $\text{CO}_2$
- $\text{H}_2\text{O}$  remains as part of chyme,  $\text{CO}_2$  is absorbed into blood and expired through the lungs



# Secretion of $\text{HCO}_3^-$ in Ileum and Large Intestine

- Epithelial cells on villi of I & LI have capability of secreting  $\text{HCO}_3^-$  in exchange for absorption of  $\text{Cl}^-$
- It provides alkaline  $\text{HCO}_3^-$  that neutralize acid products formed by bacteria in the large intestine



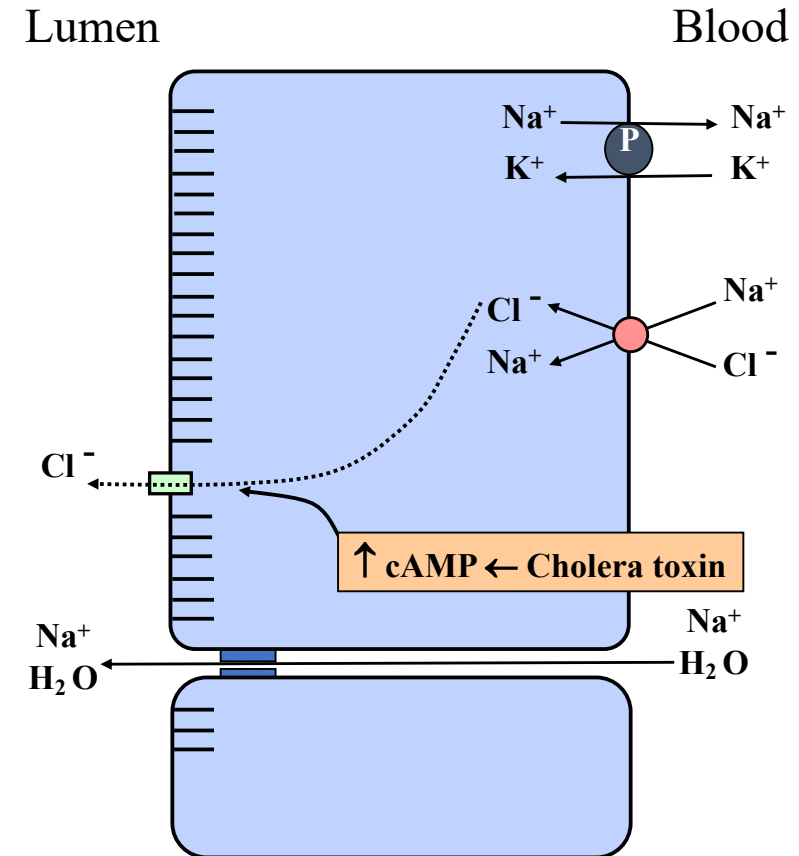
# Absorption of Ions

New epithelial cells secrete NaCl & H<sub>2</sub>O into lumen - This secretion is reabsorbed by older epithelial cells → absorbing digested nutrients

Toxins of *cholera* and of some other types of diarrheal bacteria can stimulate the secretion so greatly → *secretion often becomes much greater than can be reabsorbed*

*Cholera toxin* – ↑cAMP – opening of Cl channels – active Na pump – water osmosis

Rx - NaCl solution



# Absorption of Ions

- Ca are actively absorbed into the blood especially from the duodenum – PTH, vitaminD-controlled by daily need of the body
- Iron ions are also actively absorbed from the small intestine – controlled by body need for Hb
- Potassium, magnesium, phosphate can also be actively absorbed through the intestinal mucosa
- *Monovalent* (Na,K,Cl) easily absorbed than *Divalent* (Ca)

# Absorption of vitamins

- Most of the vitamins are absorbed in upper part of small intestine and vitamin B12 is absorbed in ileum.
- Absorption of water-soluble vitamins is faster than fat soluble vitamins (A and D).

# Absorption in Large Intestine

- About 1500 milliliters of chyme normally pass into the large intestine/day
- Most of water and electrolytes in this chyme are absorbed in the colon, usually leaving less than 100 ml of fluid & 1-5 mEq each of Na and Cl to be excreted in the feces
- Proximal half of the colon - absorbing colon
- Distal colon - storage colon



# Absorption in Large Intestine

- Active absorption of Na → electrical potential gradient causes Cl absorption
- Tight junctions between the epithelial cells of large intestinal epithelium - prevents significant amounts of back diffusion of ions
- Aldosterone: absorb Na more completely
- Secretion of HCO<sub>3</sub> – absorption of Cl
- Absorption of Na & Cl creates an osmotic gradient across large intestinal mucosa, which in turn causes absorption of water.
- LI can absorb a max of 5 - 8 L of fluid & electrolytes /day

## Bacterial Action in the Colon

- Colon bacilli are present normally in absorbing colon.
- Capable of digesting small amounts of cellulose→ providing a few calories
- Other substances formed as a result of bacterial activity:
  - ✓ Folic acid
  - ✓ Vitamin K (very imp: daily ingested amount of this vitamin is not sufficient to) maintain adequate blood coagulation
  - ✓ Vitamin B12
  - ✓ Thiamine
  - ✓ Riboflavincontributes in erythropoietic activity & blood clotting mechanism.
- ✓ Gases: CO<sub>2</sub>, H<sub>2</sub> & methane (contribute to flatus in colon)

# Dietary fiber/roughage

- Food particles escape digestion at stomach and SI
- Provides substrate for microflora of LI & ↑ bacterial mass
- Some components of fiber are broken down by bacteria & absorbed and other are excreted through feces.
- Components of dietary fiber :
  - ✓ **Partially degradable** → Cellulose, hemicelluloses and pectin
  - ✓ **Indigestible** → D-glucans, lignin and gums
  - ✓ **Others** minerals, antioxidants and chemicals
- Sources :fruits, vegetables, cereals, bread & wheat grain

# Significance of Dietary Fiber

- Delays emptying of stomach
- Increases formation of bulk and soft feces →eases defecation
- Contains antioxidants and other useful substances.
- Diet with high fiber content tends to be low in energy → reducing the body weight.
- Treatment or prevention of constipation and bowel syndrome, diabetics, cancer, ulcer, etc.

## Composition of the Feces

- 3/4<sup>th</sup> water
- 1/4<sup>th</sup> solid
  - 30% dead bacteria
  - 30% undigested fiber from the food, bile pigment and sloughed epithelial cells
  - 10-20% fat
  - 10-20% inorganic matter
  - 2 -3% protein
- Colour due to stercobilin, urobilin (derivatives of bilirubin)
- Odor :products of bacterial action-odoriferous products include indole, skatole, mercaptans and hydrogen sulfide.

# Absorption in Large Intestine

Large intestine plays an important role in the absorption of various substances such as:

1. Water
2. Electrolytes
3. Organic substances
4. Alcohol
5. Drugs like anesthetic agents, sedatives and steroids