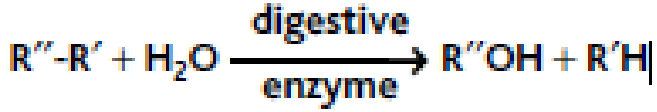
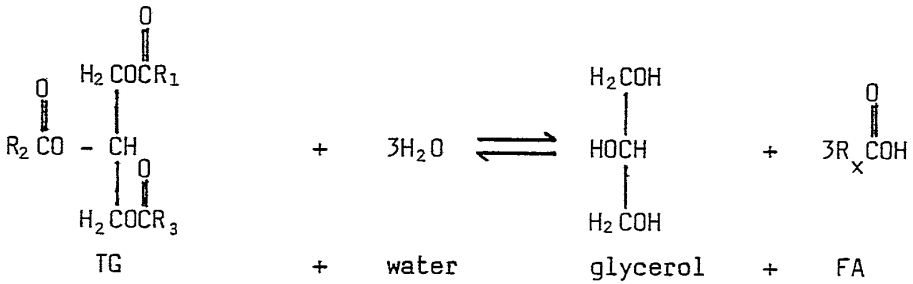
Digestion and Absorption in the Gastrointestinal Tract

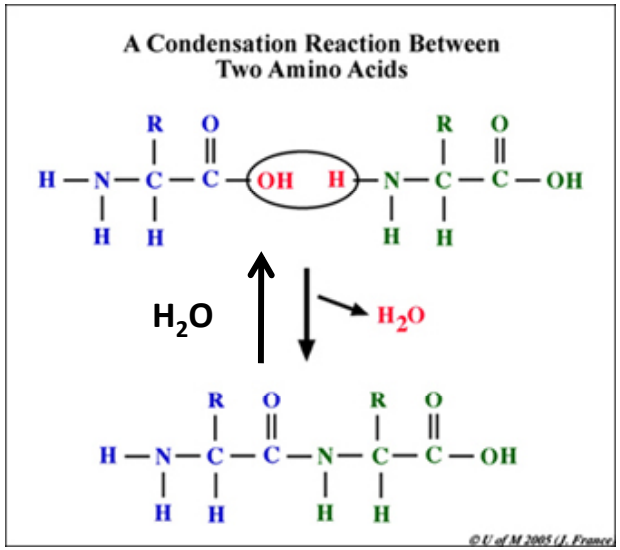
Digestion of the Various Foods by Hydrolysis

Hydrolysis of Carbohydrates: Almost all the carbohydrates of the diet are either large polysaccharides or disaccharides, which are digested to monosaccharides by hydrolysis.



Hydrolysis of fats: the fat-digesting enzymes return three molecules of water to the triglyceride molecule and thereby split the fatty acid molecules away from the glycerol.





Hydrolysis of Proteins. Proteins to peptides and then to amino acids

Digestion of Carbohydrates

3 major sources of carbohydrates exist in the normal human diet.

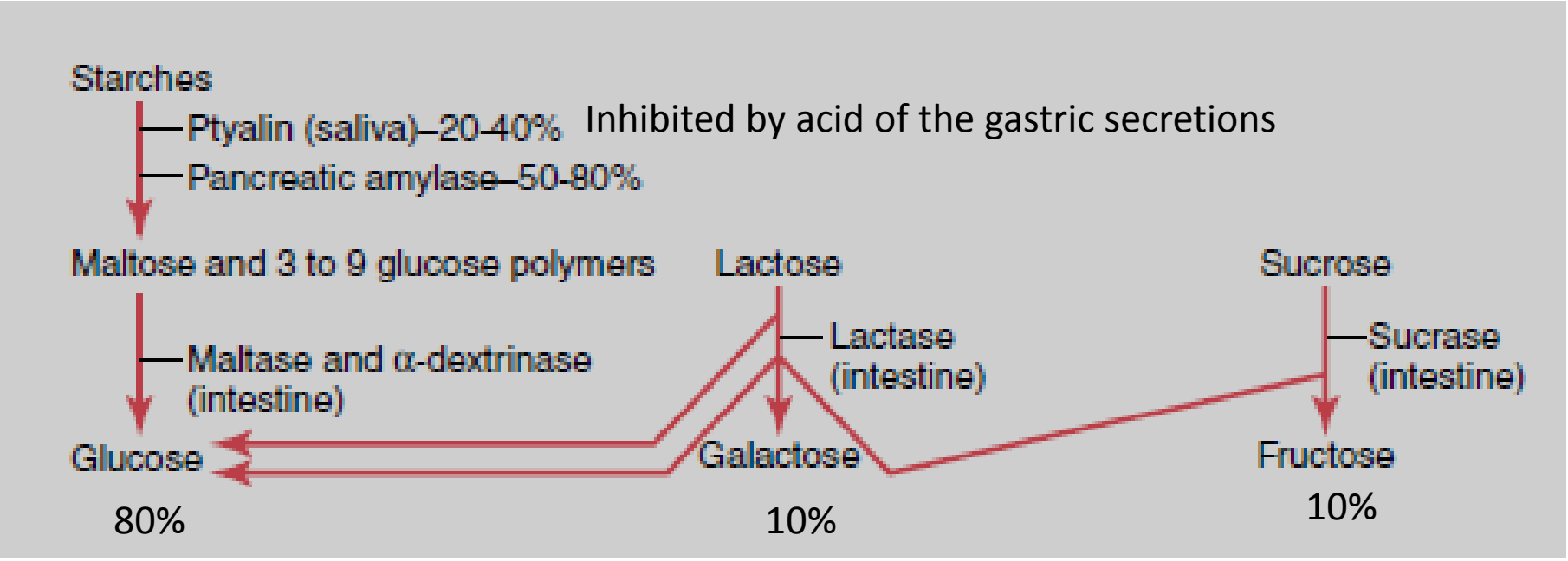
Sucrose*/cane sugar, a disaccharide*
Lactose, *disaccharide* found in milk;
Starches, *large polysaccharides* present in almost all nonanimal foods, particularly
in potatoes and different types of grains.

Other carbohydrates ingested to a slight extent are *amylose, glycogen, alcohol, lactic acid, pyruvic acid, pectins, dextrins, and* minor quantities of *carbohydrate derivatives in meats, cellulose (indigestible)*

➢Carbohydrates are almost totally converted into *maltose and/or other small glucose polymers in the mouth and stomach* before passing beyond the duodenum or upper jejunum.

➢The enterocytes lining the villi of the small intestine contain four enzymes (*lactase, sucrase, maltase,* and α-*dextrinase), which splits the disaccharides* lactose, sucrose, and maltose, plus other small glucose polymers, into their constituent monosaccharides.

➢glucose (80%) of the final products of carbohydrate digestion, and galactose and fructose each represent (10 %).

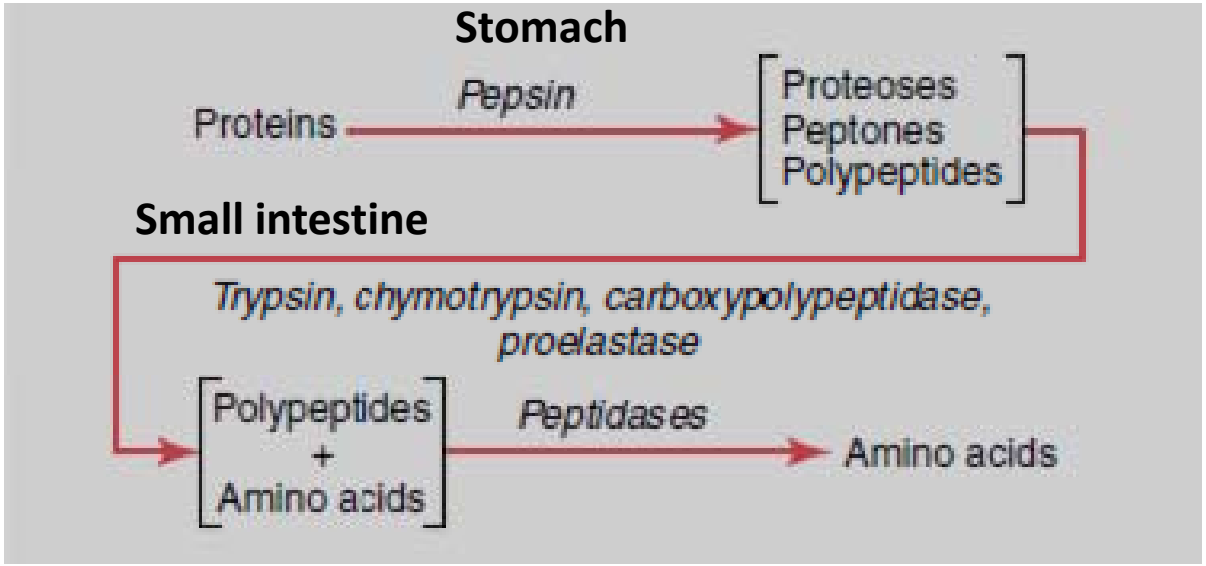


Digestion of Proteins

➢Pepsin secreted in stomach is active at acid pH and can digest the protein *collagen, an albuminoid* type of protein that is affected little by other digestive enzymes. Collagen is a major constituent of the intercellular connective tissue of meats.

➢Most protein digestion occurs in the upper small intestine, in the duodenum and jejunum, under the influence of proteolytic enzymes from pancreatic secretion.

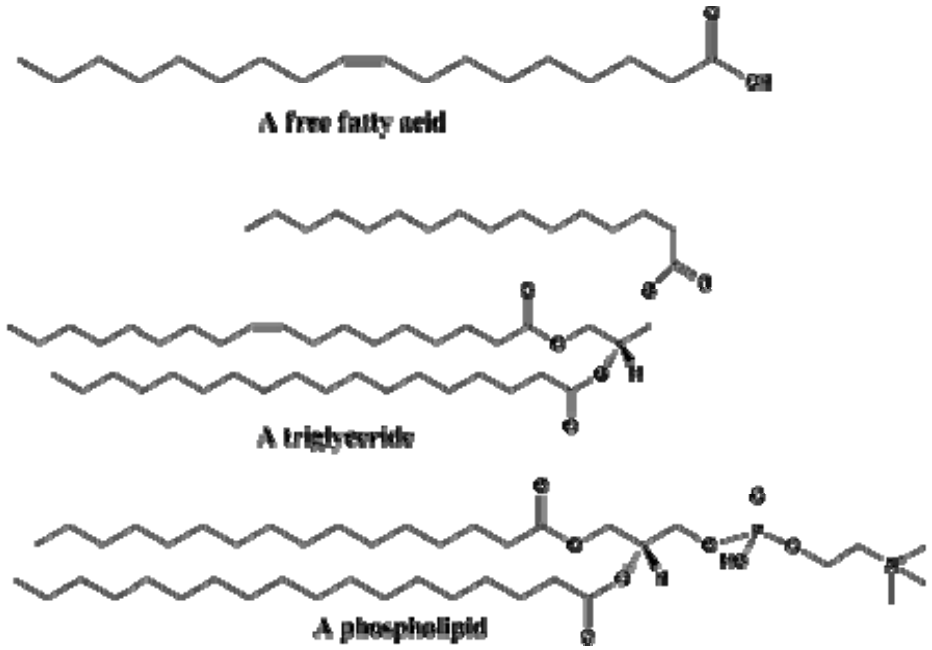
➢*Proelastase is converted into elastase, which then digests elastin fibers that partially* hold meats together.



➢Further digestion of polypeptides by Peptidases (initially in the membrane than cytosolic) in Enterocytes that Line the Small Intestinal Villi, until converted to aminoacids, which then pass on to the basolateral side to the blood.

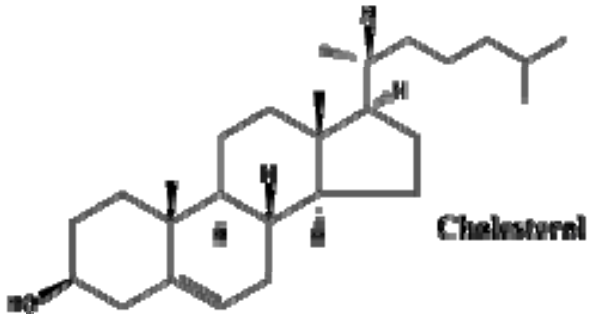
Digestion of Fats

➢By far the most abundant fats of the diet are the neutral fats, also known as ***triglycerides,*** each molecule of which is composed of a glycerol nucleus and three fatty acid side chains,



➢Small quantities of ***phospholipids, cholesterol, and cholesterol esters.*** The phospholipids and cholesterol esters contain fatty acid and therefore can be considered fats.

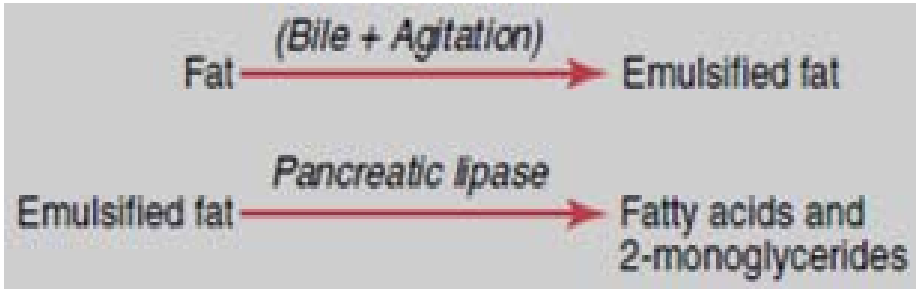
➢Cholesterol, however, is a sterol compound that contains no fatty acid, but it does exhibit some of the physical and chemical Characteristics of fats; plus, it is derived from fats and is metabolized similarly to fats.



➢Therefore, cholesterol is considered, from a dietary point of view, a fat.

➢A small amount of triglycerides is digested ***in the stomach by lingual lipase*** that is secreted by lingual glands in the mouth and swallowed with the saliva (10%). Essentially all fat digestion occurs in the small intestine

➢The first step is physically to break the fat globules into small sizes so that the water-soluble digestive enzymes can act on the globule surfaces. This process is called *emulsification of the fat, and it begins* ***by agitation in the stomach to mix the fat***with the products of stomach digestion.



➢Most in the duodenum under the influence of ***bile, bile salts and lecithin*** act as detergent (polar portion interacting with water and non-polar with fat), forms micelles.

➢Pancreatic lipase hydrolyze emulsified fat, *cholesterol ester hydrolase hydrolyze cholesterol ester, phospholipase A2 hydrolyze phospholipid.*

➢Bile salt micelles also act as a transport medium to carry the monoglycerides and free fatty acids, to the brush borders of the intestinal epithelial cells (Ferrying)

Basic Principles of Gastrointestinal Absorption

- Total quantity of fluid that must be absorbed each day by the intestines is equal to the ingested fluid (about 1.5liters) plus that secreted in the various gastrointestinal secretions (about 7 liters). This comes to a total of 8 to 9 liters.

- About 1.5 liters of this is absorbed in the small intestine, leaving only 1.5 liters to pass through the ileocecal valve into the colon each day.

- Stomach is a poor absorptive area of the GItract , it lacks the typical villus type of absorptive membrane, and also because the junctions between the epithelial cells are tight junctions. Only a few highly lipid-soluble substances, such as alcohol and some drugs like aspirin, can be absorbed in small quantities.

Folds of Kerckring, Villi, and Microvilli Increase the Mucosal Absorptive Area by Nearly 1000-Fold

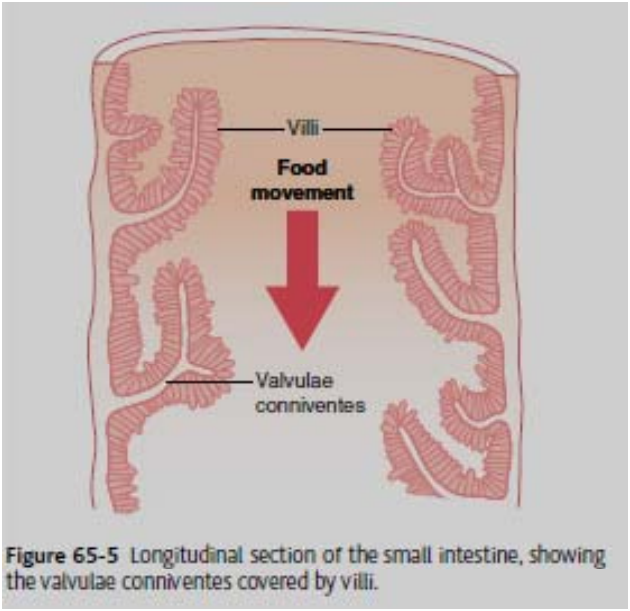


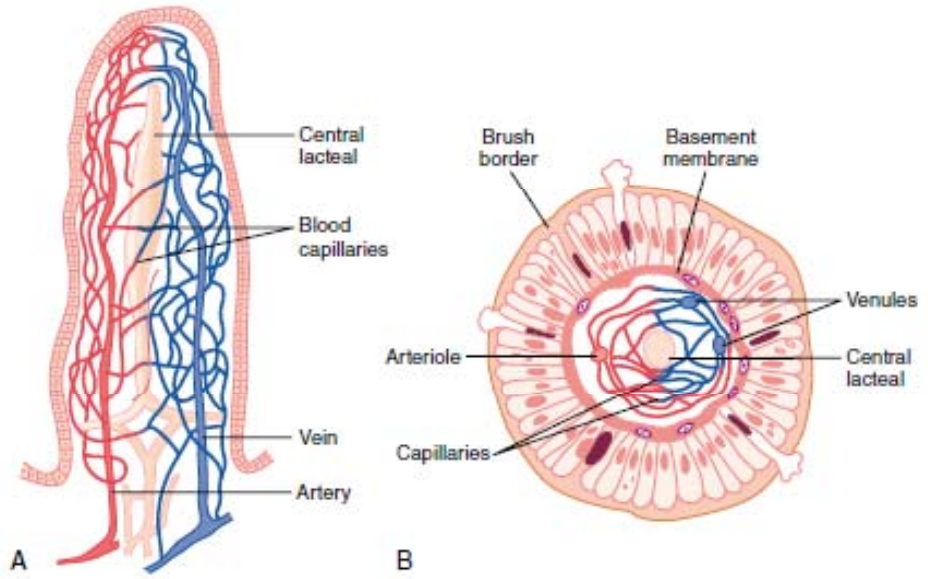
Figure 65-5 Longitudinal section of the small intestine, showing the valvulae conniventes covered by villi.

- Folds of kerckring , well developed in duodenum and jejunum, projecting 8mm into lumen.

- located on the epithelial surface of the small intestineall the way down to the ileocecal valve are millions of small *villi,* 1 mm into lumen.

- Each intestinal epithelial cell on each villus is characterized by a *brush border, consisting of as many as* 1000 *microvilli* .

- Advantageous portal blood and lymph vessel for absorption, some absorption by pinocytosis



Absorption in the Small Intestine

➢Absorption from the small intestine each day consists of several hundred grams of carbohydrates, 100 or more grams of fat, 50 to 100 grams of amino acids, 50 to 100 grams of ions, and 7 to 8 liters of water.

➢The absorptive capacity of the normal small intestine is far greater than this.

➢The large intestine can absorb still additional water and ions, although very few nutrients.

Absorption of Water by Osmosis

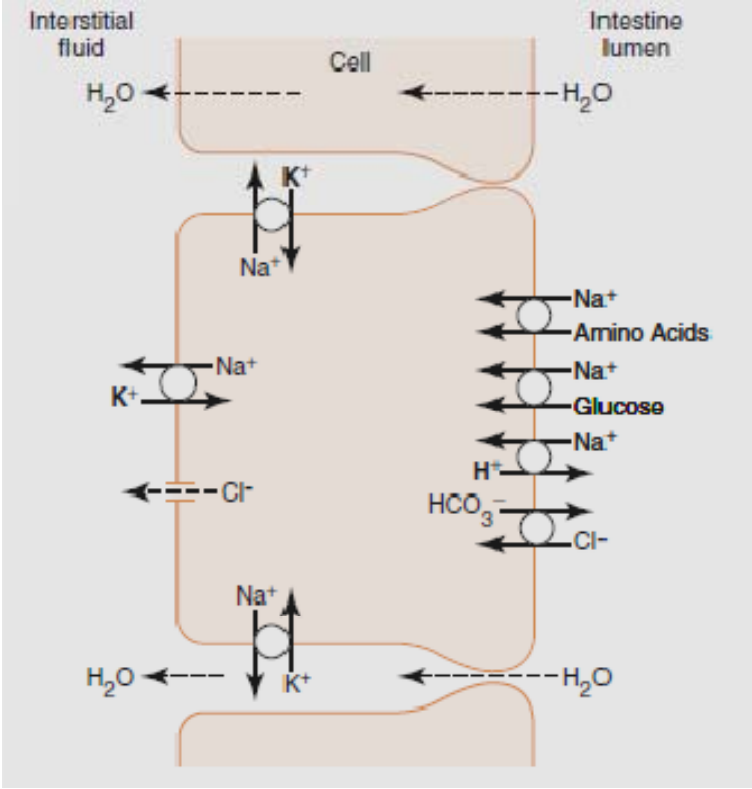
Water is transported through the intestinal membrane entirely by osmosis:

➢When the chyme is dilute enough, water is absorbed through the intestinal mucosa into the blood of the villi.

➢When hyperosmotic solutions are discharged from the stomach into the duodenum., osmosis from plasma to chyme occurs.

Absorption of Ions

Sodium Ions: Each day 20-30 g of Na+ secreted in the intestinal secretions , diet 5 to 8 g Na+, prevent loss into the feces, the intestines absorbs 25 to 35 g of Na+ each day. **Extreme diarrhea, Na+ reserves of the body can sometimes be depleted to lethal levels within hours.**



➢Na+ absorption by active transport from inside the epithelial cells through the basal and lateral walls of these cells into paracellular spaces. Partly absorbed along with negatively charged chloride ions.

➢Na+ is also co-transported through the brush border membrane by several specific carrier proteins, including (1) sodium-glucose co-transporter, (2) sodium amino acid co-transporters, and (3) sodium-hydrogen exchanger.

➢Provide secondary active absorption of glucose and amino acids, powered by the active Na+-K+ ATPase pump on the basolateral membrane.

➢Water osmosis occurs through the tight junctions between the apical borders of the epithelial cells (paracellular pathway) & through the cells themselves (transcellular pathway), causing flow of fluid into and through the paracellular spaces, finally into the circulating blood of the villus.

Aldosterone Greatly Enhances Sodium Absorption.

- On dehydration large amounts of aldosterone almost always are secreted by the adrenal cortex.

- Within 1 to 3 hours this aldosterone causes increased activation of the enzyme and transport mechanisms for all aspects of sodium absorption by the intestinal epithelium.

- Increased Na^+ absorption in turn causes secondary increases in absorption of Cl^-, water, and some other substances.

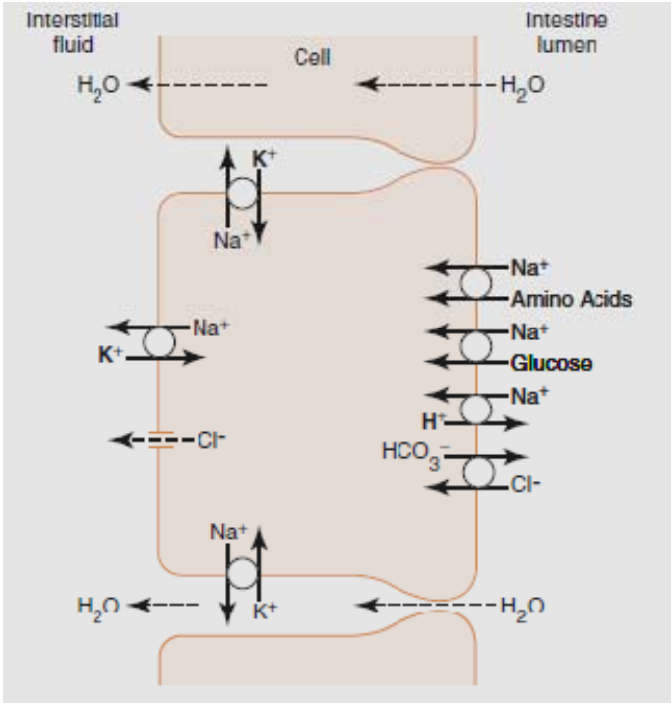
- This effect of aldosterone is especially important in the colon because it allows virtually no loss of NaCl in the feces and also little water loss.

- Thus, the function of aldosterone in the intestinal tract is the same as that achieved by aldosterone in the renal tubules, which also serves to conserve NaCl and water in the body when a person becomes dehydrated.

Absorption of Chloride Ions in the Small Intestine.

➢In the upper part of the small intestine, Cl- absorption is rapid and occurs mainly by diffusion (i.e., absorption of sodium ions through the epithelium creates electronegativity in the chyme and electropositivity in the paracellular spaces between the epithelial cells).

➢Cl- is also absorbed across the brush border membrane of parts of the ileum and large intestine by a brush border membrane Cl-/HCO3- exchanger.



Absorption of Bicarbonate Ions in the Duodenum and Jejunum.

HCO3- is absorbed (active absorption) in an indirect way as follows:

➢When Na+ are absorbed, moderate amounts of H+ are secreted into the lumen of the gut in exchange.

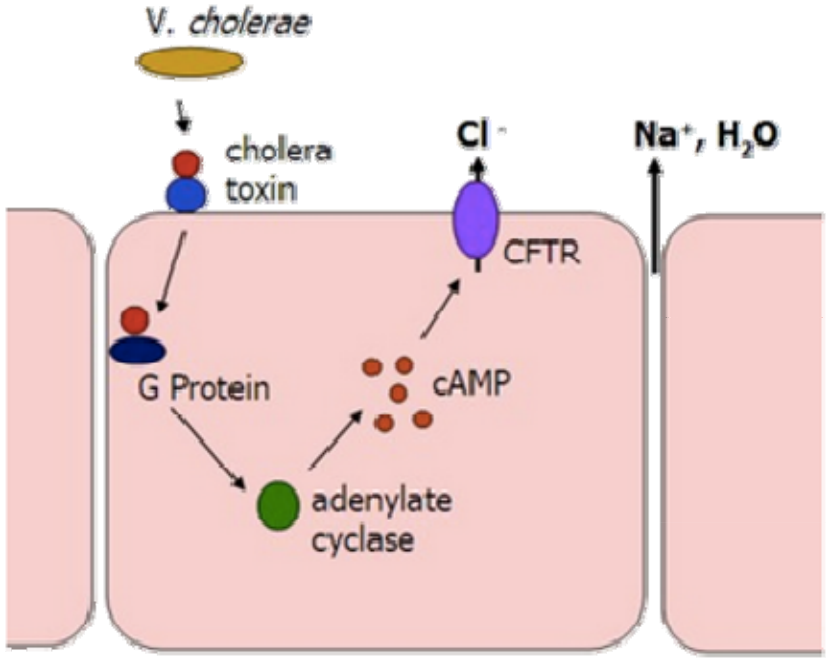
➢ These H+ in turn combine with the HCO3-to form H2CO3, which then dissociates to form H_2O & CO_2.

➢Water remains as part of the chyme in the intestines, but the CO_2 is readily absorbed into the blood and subsequently expired through the lungs.

Extreme Secretion of Chloride Ions, Sodium Ions, and Water from the Large Intestine Epithelium in Some Typesof Diarrhea.

➢The toxins of cholera and of some other types of diarrheal bacteria can stimulate the epithelial fold secretion so greatly that this secretion often becomes much greater than can be reabsorbed,.

➢Sometimes causing loss of 5 to 10 liters of water and sodium chloride as *diarrhea each day. Within 1 to 5 days, many* severely affected patients die from this loss of fluid alone.



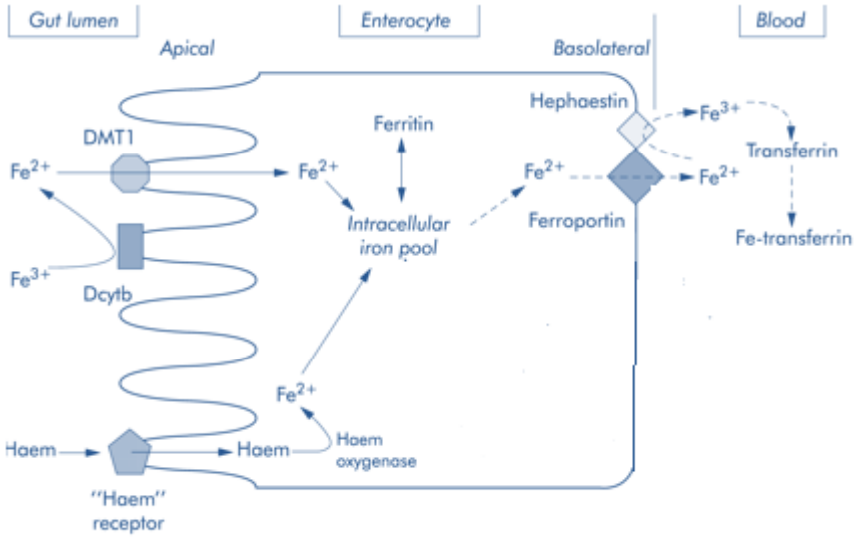
Cystic fibrosis transmembrane conductance regulator (**CFTR**)

the mucus in various organs becomes thick and sticky. In the lungs, the mucus clogs the airways and traps germs, like bacteria, leading to infections, inflammation, respiratory failure, and other complications.

Active Absorption of Calcium, Iron, Potassium, Magnesium, and Phosphate.

Calcium ions: One important factor controlling calcium absorption is **parathyroid hormone** secreted by the parathyroid glands, and another is **vitamin D**. Parathyroid hormone activates vitamin D, and the activated vitamin D in turn greatly enhances calcium absorption.

Iron ions are also actively absorbed from the small intestine.



Potassium, magnesium, phosphate, and probably still other ions can also be actively absorbed through the intestinal mucosa.

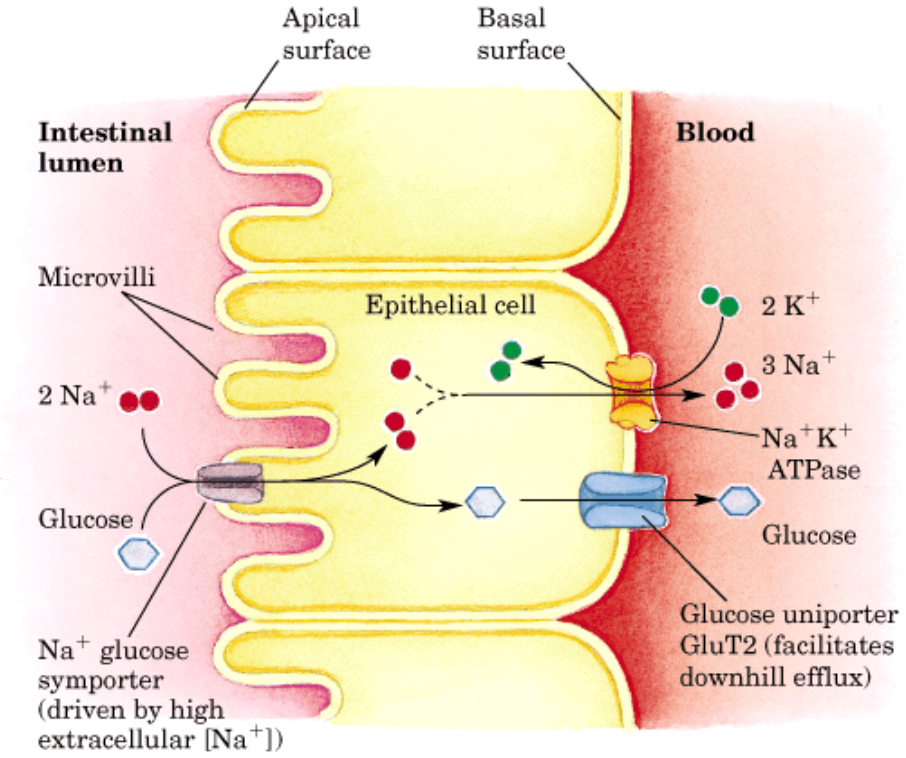
In general, the monovalent ions are absorbed with ease and in great quantities. Conversely, bivalentions are normally absorbed in only small amounts;

Absorption of Nutrients

Carbohydrates Are Mainly Absorbed as Monosaccharides by active transport process
(80% glucose & 20 % (Galactose & Fructose)

Glucose *Is Transported by a Sodium Co-Transport Mechanism.*

In the absence of sodium transport through the intestinal membrane, virtually no glucose can be absorbed.



Galactose is transported in a smilar manner.

Fructose is transported by facilitated diffusion , on entering the cell, becomes phosphorylated, then converted to glucose, and finallytransported in the form of glucose the rest of the way into the blood.

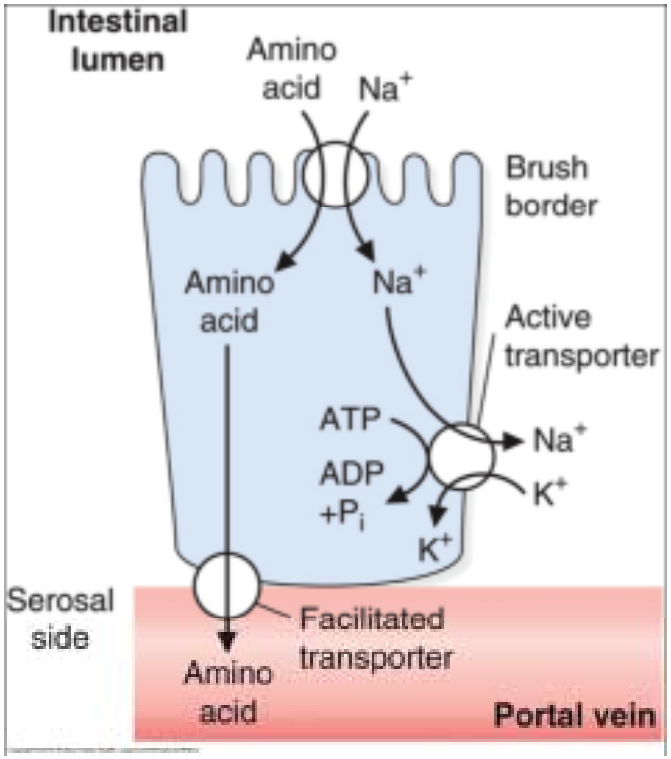
Absorption of Proteins as Dipeptides, Tripeptides, or Amino Acids

Co-transport (or secondary active transport) :

Most peptide or amino acid molecules bind in the cell's microvillus membrane with a specific transport protein that requires sodium binding before transport can occur.

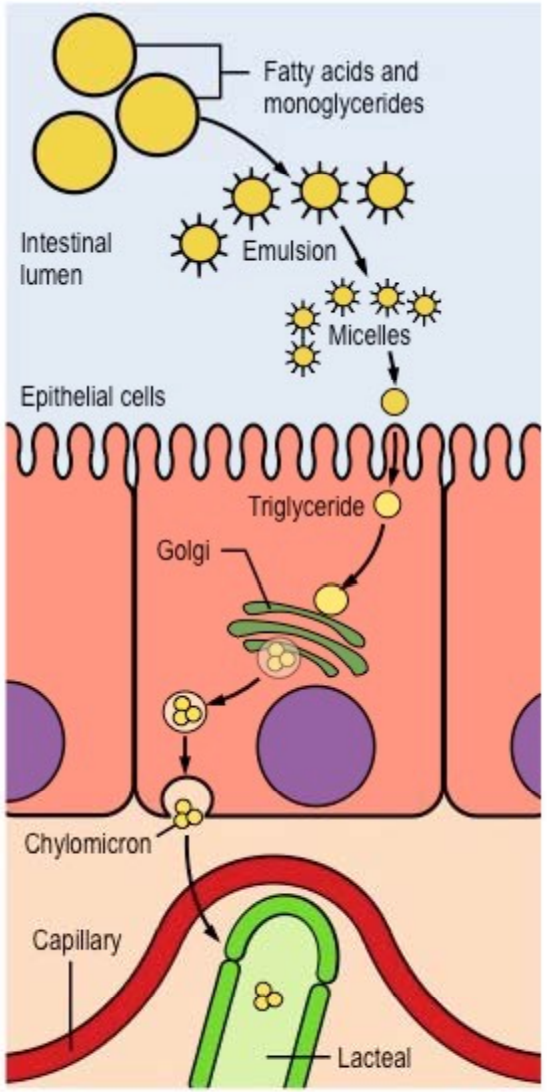
After binding, the sodium ion then moves down its electrochemical gradient to the interior of the cell and pulls the amino acid or peptide along with it.

A few amino acids do not require this sodium co-transport mechanism but instead are transported by special membrane transport proteins in the same waythat fructose is transported, by facilitated diffusion.



At least five types of transport proteins for transporting amino acids and peptides have been found in the luminal membranes of intestinal epithelial cells. This multiplicity of transport proteins is required because of the diverse binding properties of different amino acids (cationinc,anionic, neutral) and peptides

Absorption of Fats



Fatty acids and monoglycerides are emulsified by bile salts to form micelles

Fatty acids enter the epithelial cells and link to form triglycerides

Triglycerides combine with proteins inside the Golgi body to form chylomicrons

Chylomicrons enter the lacteal and are transported away from the intestine

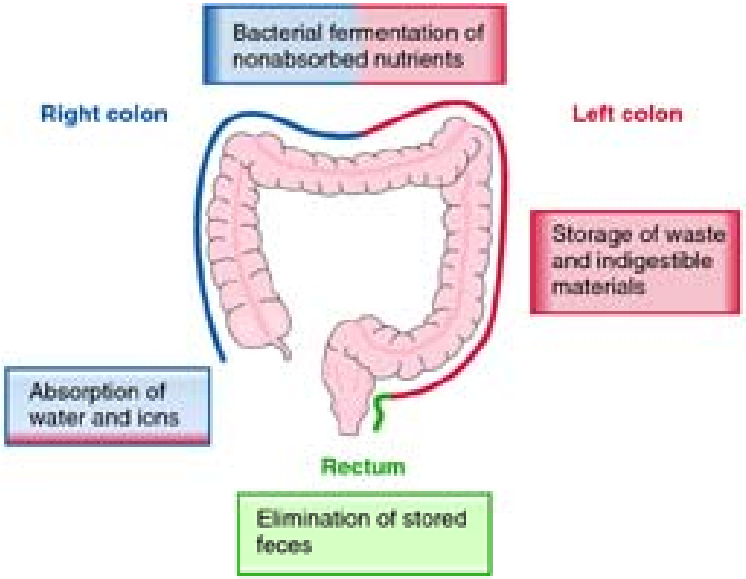
Small quantities of short- and medium-chain fatty acids are absorbed directly into the portal blood rather than being converted into triglycerides and absorbed by way of the lymphatics.

Absorption in the Large Intestine: Formation of Feces

➢~1.5 L of chyme normally pass through the ileocecal valve into the large intestine each day.

➢Most of the water and electrolytes in this chyme are absorbed in the colon, usually leaving less than 100 ml of fluid to be excreted in the feces.

➢Essentially all the ions are absorbed, leaving only 1 to 5 mEq each of sodium and chloride ions to be lost in the feces.

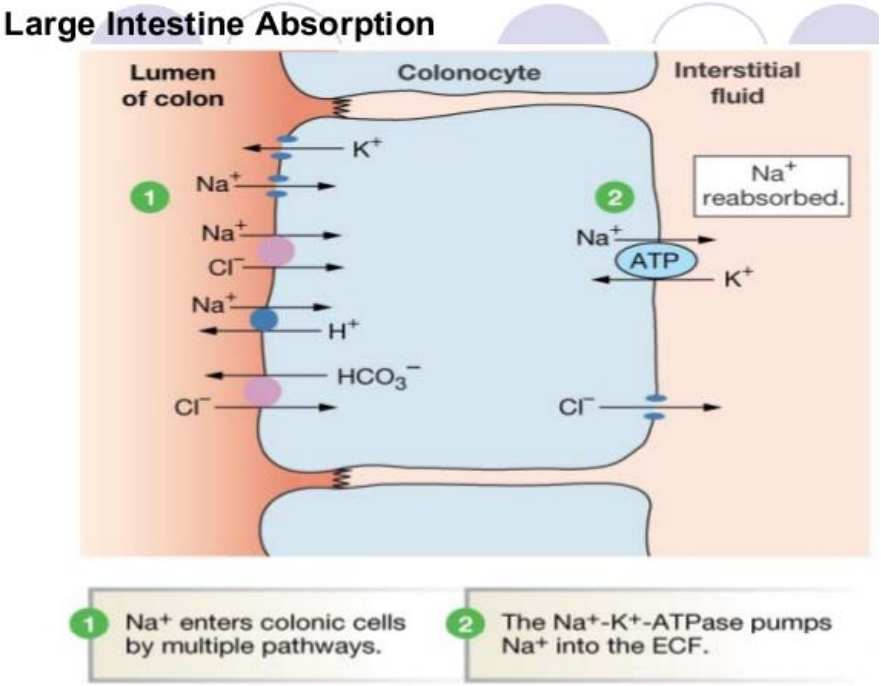


➢Most of the absorption in the large intestine occurs in the proximal one half of the colon, giving this portion the name *absorbing colon, whereas the distal colon functions* principally for feces storage until a propitious time for feces excretion and is therefore called the *storage colon.*

Absorption and Secretion of Electrolytes and Water.

➢The mucosa of the large intestine, like that of the small intestine, has a high capability for active absorption of Na+, and the electrical potential gradient created by absorption of the Na+ causes Cl-absorption as well.

➢ The tight junctions between the epithelial cells of the large intestinal epithelium are much tighter than those of the small intestine. This prevents significant amounts of back-diffusion of ions through these junctions, thus allowing the large intestinal mucosa to absorb Na+ far more than small intestine.



➢In addition, as occurs in the distal portion of the small intestine, the mucosa of the large intestine secretes *HCO3- while it simultaneously absorbs an equal* number of Cl- in an exchange transport process.

➢Absorption of Na+ and Cl- creates an osmotic gradient across the large intestinal mucosa, which in turn causes absorption

Bacterial Action in the Colon.

➢*Numerous bacteria, especially colon bacilli, are present even normally in the absorbing colon.*

➢*They are capable of digesting small amounts of cellulose,* in this way providing a few calories of extra nutrition for the body.

➢In herbivorous animals, this source of energy is significant, although it is of negligible importance in humanbeings.

➢Other substances formed as a result of bacterial activity are vitamin K, vitamin B12, thiamine, riboflavin, and various gases that contribute to *flatus in the colon, especially carbon* dioxide, hydrogen gas, and methane.

➢The bacteria-formed vitamin K is especially important because the amount of this vitamin in the daily ingested foods is normally insufficient to maintain adequate blood coagulation.

Composition of the Feces.

➢The feces normally are about three-fourths *water and one-fourth solid matter* that is composed of about 30 % *dead bacteria, 10* to 20 % *fat, 10 to 20 % inorganic matter, 2 to 3 % protein, and 30 % undigested roughage from* the food and dried constituents of digestive juices, such as bile pigment and sloughed epithelial cells.

➢ The brown color of feces is caused by *stercobilin and urobilin, derivatives* of bilirubin. (markers of feacal pollution in rivers), Bilirubin in liver conjugated to form bilirubin diglucuronide, secreted into the small intestine as bile, bacterial enzymes in the terminal ileum convet it back to bilirubin, further converted to colorless urobilinogen, reduced to stercobilinogen and finally oxidized to stercobilin.

➢The odor is caused principally by products of bacterial action; these products vary from one person to another, depending on each person's colonic bacterial flora and on the type of food eaten.

➢The actual odoriferous products include *indole, skatole, mercaptans,* and *hydrogen sulfide.*