Digestive System of Monogastrics

Prof. Dr. Osman KÜÇÜK

Overview of Digestion

- 2 main groups of organs in the digestive system.
  1. Alimentary Canal (nutrition)
     a. Mouth
     b. Pharynx
     c. Esophagus
     d. Stomach
     e. Small bowel
     f. Large bowel

2. Accessory Digestive Organs
    a. Teeth
    b. Tongue
    c. Gall bladder
    d. Salivary glands
    e. Liver
    f. pancreas

How does "Digestion" occur?

6 step process:

1. Ingestion
2. Propulsion

    Peristalsis – alternate waves of muscular contraction and relaxation in the primary digestive organs. The end result is to squeeze food from one part of the system to the next.

3. Mechanical Digestion

   - physical preparation of food for digestion.

   - Segmentation – mixing of food in the intestines with digestive juices.

4. Chemical Digestion

   - Carbohydrates, Fat, and Proteins are broken down by enzymes.

5. Absorption

   - transfer of the digested portion of food into the blood from the digestive canal.

6. Defecation

   - removal/elimination of the waste products from the body.

The Digestive System

- Function: physically and chemically breakdown food products so that they can be absorbed and transported to cells.
- CARBOHYDRATES are the major source of biochemical energy. They include sugars and starches. These are eventually broken down into MONOSACCHARIDES (simple sugars)

- PROTEINS are broken down to amino acids. AMINO ACIDS are the chemical building blocks of proteins. Proteins are necessary parts of cell membranes and nucleic acids (DNA and RNA).
- LIPIDS are broken down to fatty acids and glycerol. Lipids are very large molecules and cannot be directly absorbed. They are broken down by ENZYMES which are organic CATALYSTS. They are very specific for each chemical reaction and the function to speed up the reaction.

Mouth and Associated Organs

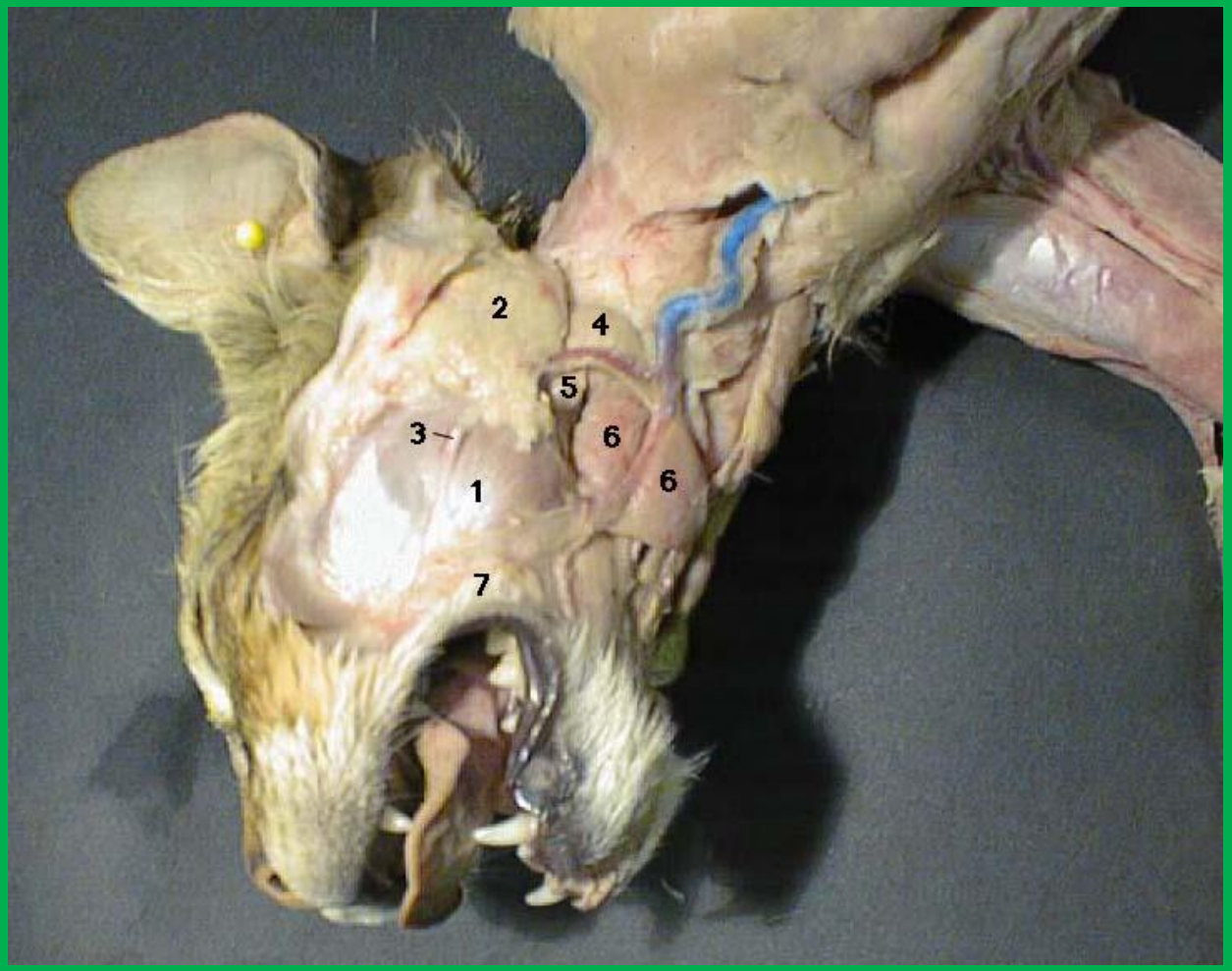
- Food enters the GI tract at the mouth. It is chewed, manipulated by the tongue, and moistened with saliva.

- Tongue

  - skeletal muscle

  - mixes food with saliva into a compact mass known as a BOLUS.

- The PAROTID GLAND produces salivary amylase (ptyalin), a digestive enzyme (break down starches).
- It is the **largest** of the salivary glands.
- The parotid gland is an exocrine gland. Exocrine glands empty via a duct to a specific location (endocrine gland empties directly into the bloodstream).
- SUBMANDIBULAR GLAND (submaxillary) carries saliva into the angle of the lower jaw.



1. Masseter Muscle
2. Parotid Gland
3. Parotid Duct
4. Submandibular Gland
5. Sublingual Gland
6. Lymph Nodes
7. Molar Gland

Teeth

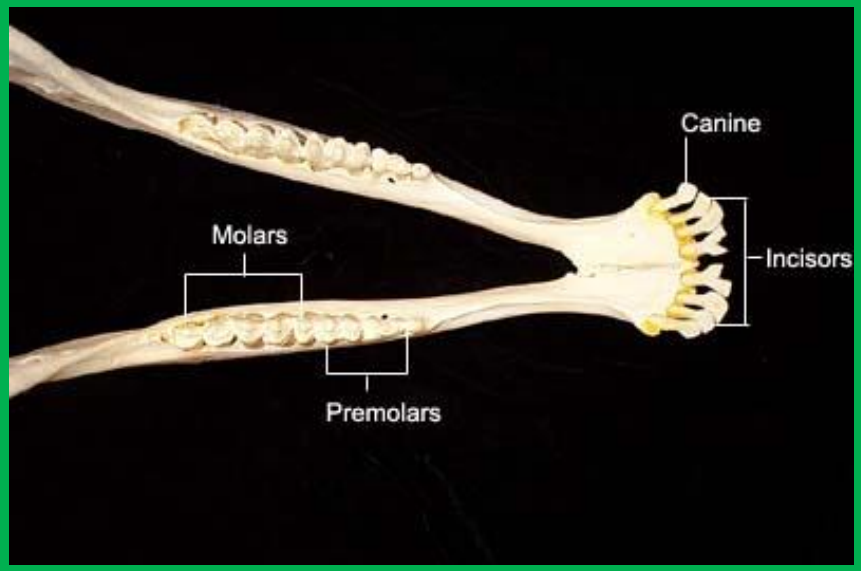
- Very similar to bone.
- Three major components:
  1. hydroxyapatite $Ca_5(PO_4)_3(OH)$
  2. bone collagen
  3. cells

Hidroksiapatit: elmastan sonraki en sert moleküldür

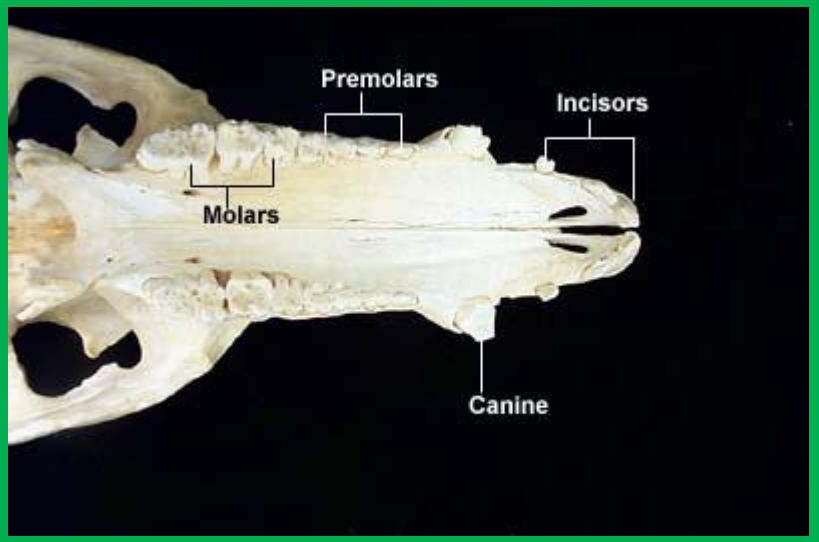
- The pH of the mouth is usually 7.2
- There are acids in the mouth that come from three sources:
    1. stomach acid during vomiting
    2. foods
    3. waste products of mouth bacteria

- INCISORS – chisel shaped for nipping food.
- CANINES – cone shaped for tearing
- PREMOLARS –
- MOLARS - grinding food

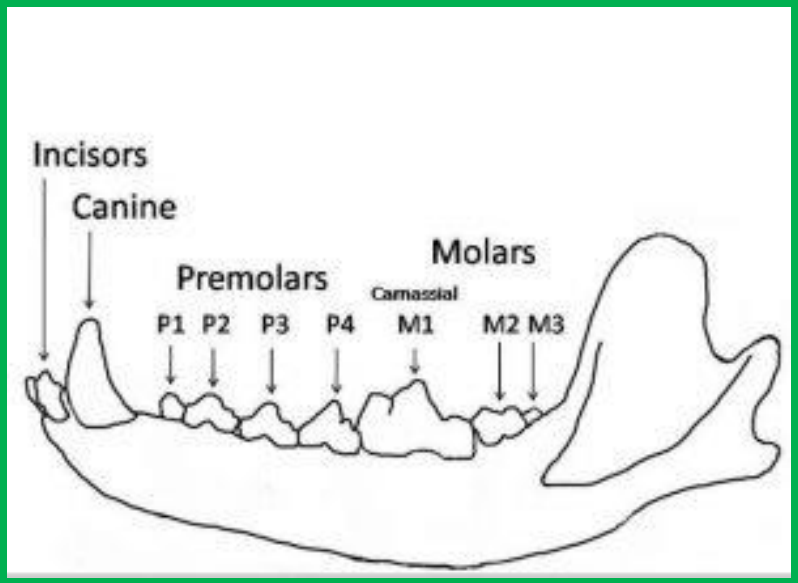
- Her bir hayvan türünde farklı sayıda diş bulunur (geçici ve kalıcı)



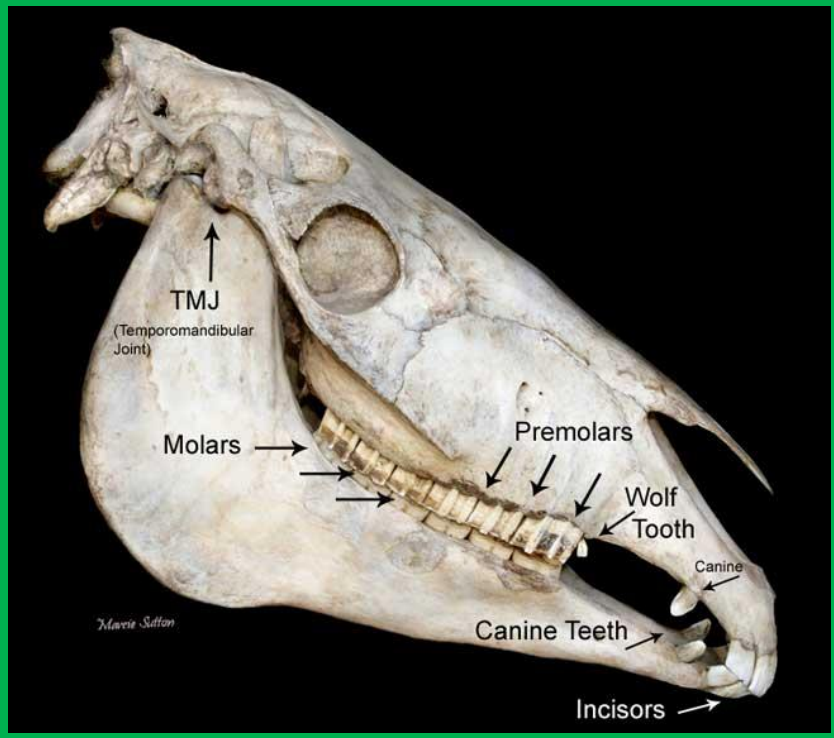
Ruminant



Domuz



Köpek



At

Chewing (Mastication)

- Helps the digestive process by:

  a. Mixes food with digestive enzymes in saliva.
  b. Increases surfaces area of food
  c. Makes moving the food easier

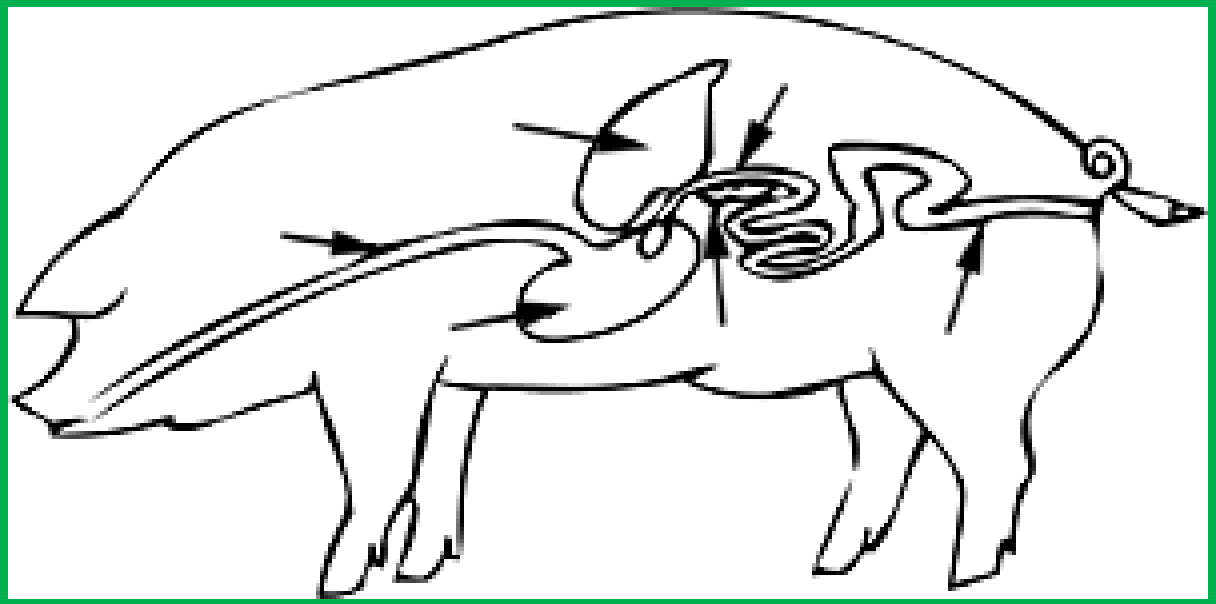
- When the swallowed food reaches the stomach, the pH drops to 3 (very acidic). The ptyalin is no longer active at that pH.
- Once food is swallowed, smooth muscle in the esophagus carries the bolus by PERISTALSIS.
- Once food enters the esophagus, peristalsis is automatic.

Stomach

- Complexity varies
  - Simple in monogastrics (nonruminants)
  - 4-chambered complex stomach of ruminant

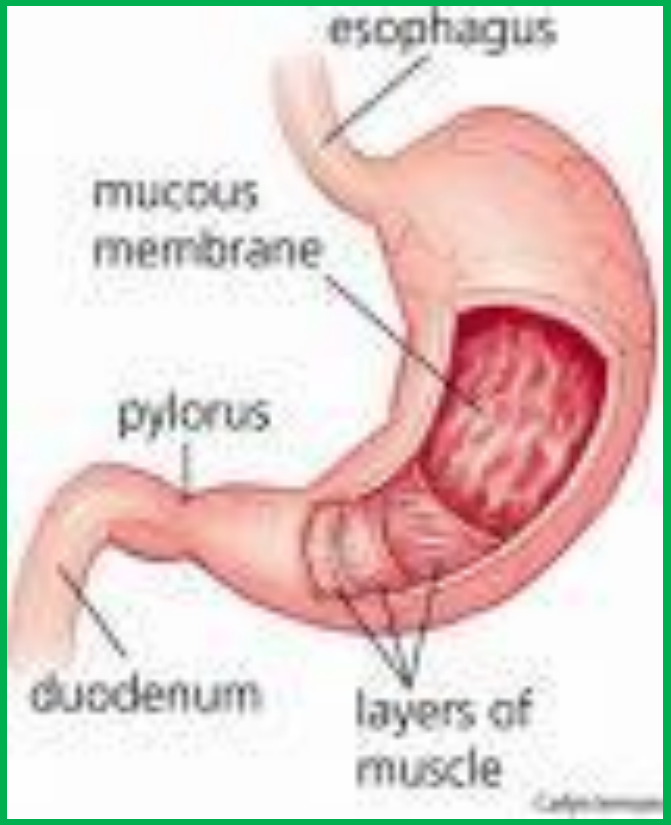
Functions of Stomach

- STORAGE
- Chemical Digestion



Non-Ruminant Stomach

- 4 regions
  - Esophageal
  - Cardiac
  - Fundic
  - Pyloric



Poultry

- "Stomach" is called PROVENTRICULUS (Kursak)

- Has same functions as mammal

Stomach

- Food is temporarily stored here.
- **Gastric juices** are secreted.
- Has layers of muscle that line the inside.
- **Mechanically** and **chemically** breaks down food.

Gastric Juices

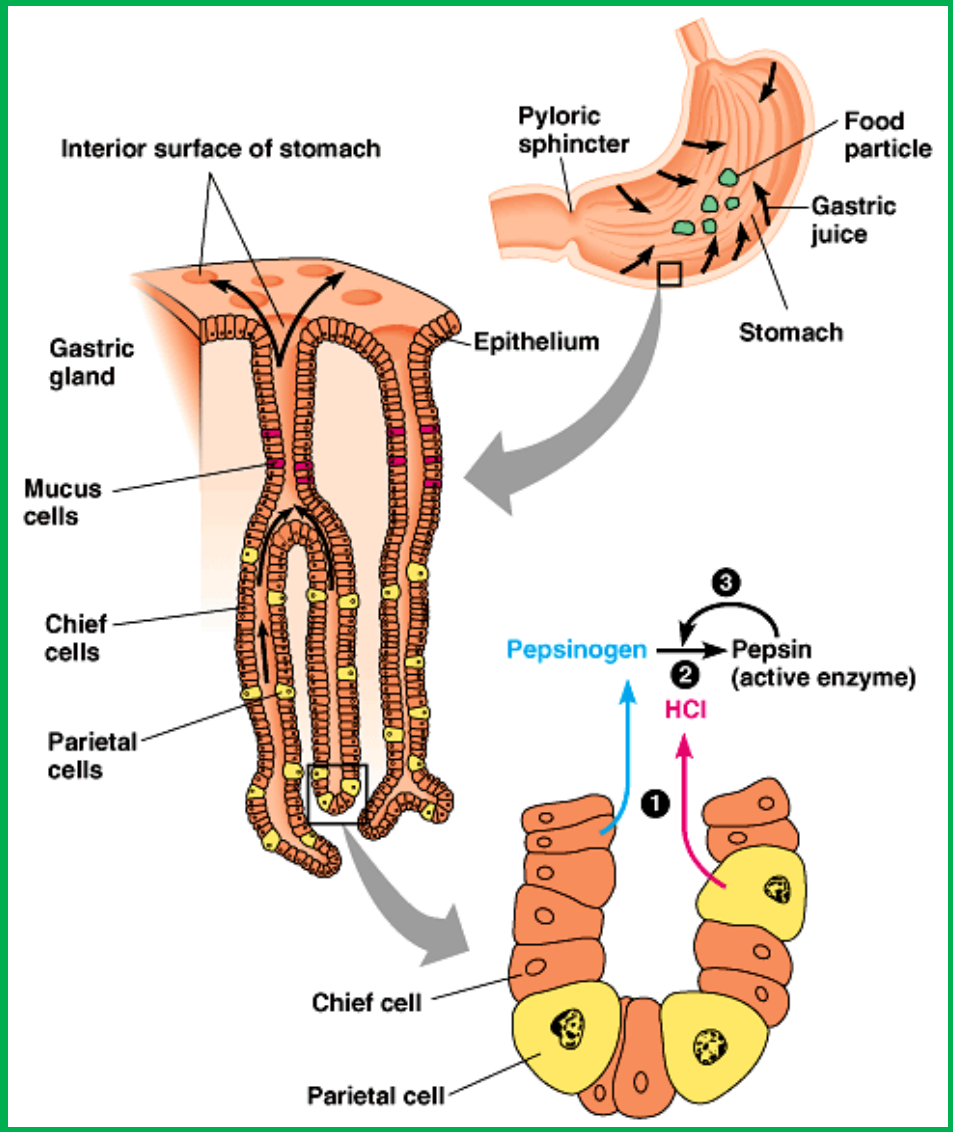
- Secreted by the stomach.
- **Acidic** (pH 1.5-2.5) (HCl).
- **Pepsin-** an **enzyme** that breaks down large **proteins** into **amino acids**.
- Food is further broken down into a thin liquid called **chyme**.

Stomach

- Functions
  - food storage
    - can stretch to fit ~2L food
  - disinfect food
    - HCl = pH 2
      - kills bacteria
  - chemical digestion
    - pepsin
      - enzyme breaks down proteins
      - Endopeptidase (middle)!

But the stomach is made out of protein!
What stops the stomach from digesting itself?

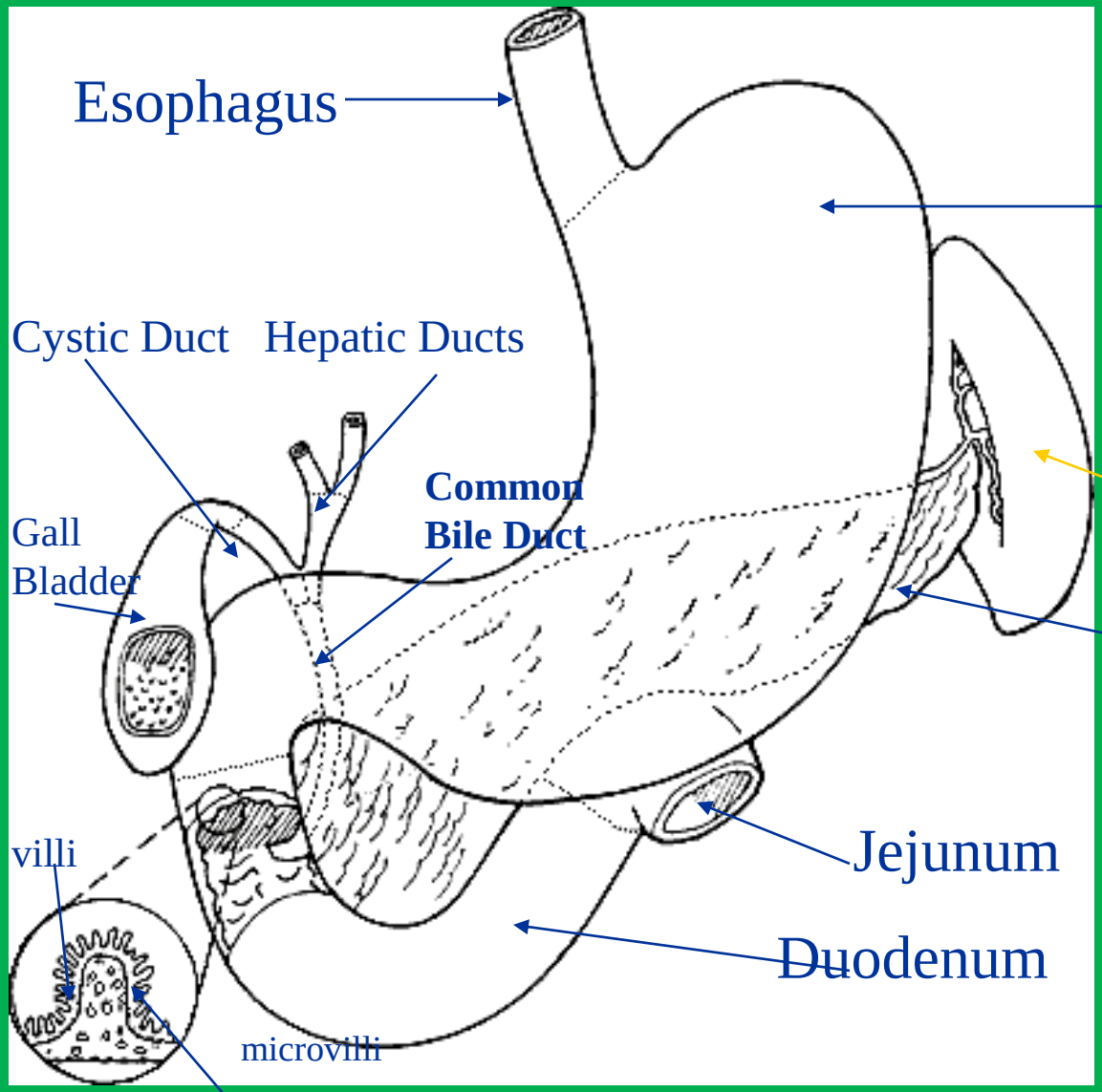
mucus secreted by stomach cells protects stomach lining



Gastric Secretions

1. HCL
    1. Activates pepsinogen to pepsin
    2. Does some digestion itself
2. Gastric Enzymes
    1. Pepsin
    2. Lipase
    3. Renin
3. Mucin
4. Intrinsic Factor (for absorbing B12)

Sources of Intestinal Secretions

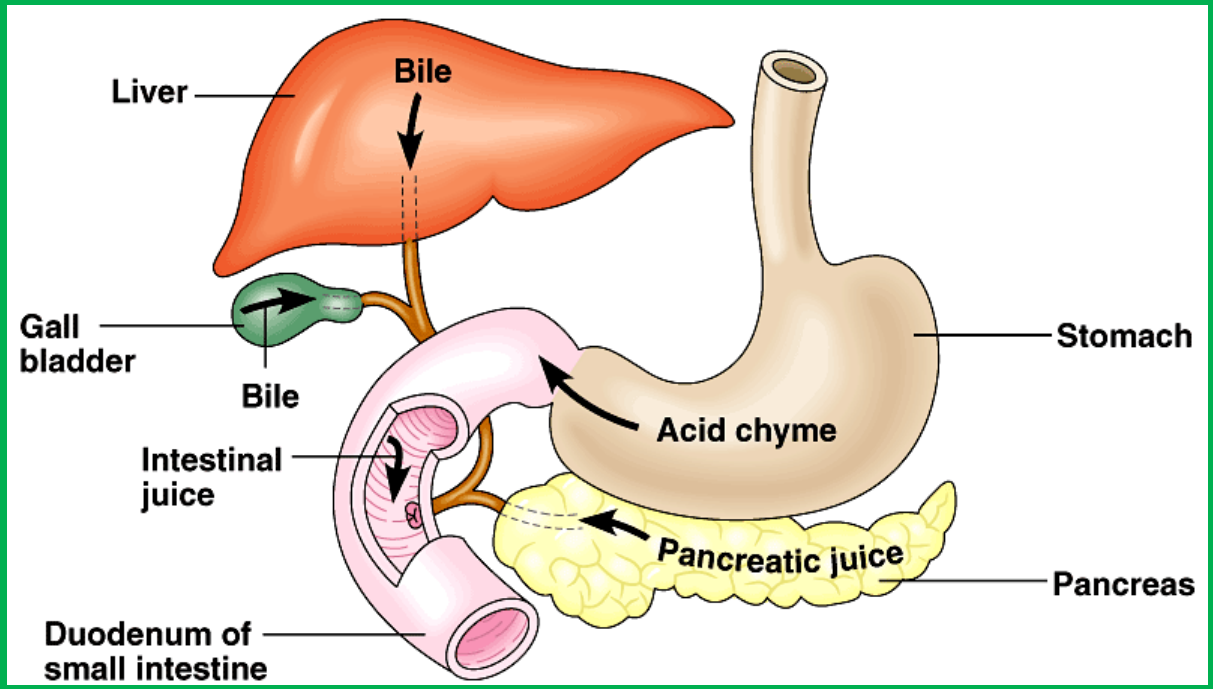


Accessory Organs

- Pancreas
- Gall Bladder
- Liver
- Spleen

Pancreas

- Digestive enzymes
  - digest proteins
    - trypsin, chymotrypsin
  - digest starch
    - amylase
- Buffers
  - neutralizes acid from stomach



Pancreas

- An organ which secretes both digestive enzymes (exocrine) and hormones (endocrine)
- Pancreatic juice digests all major nutrient types.
- Nearly all digestion occurs in the small intestine & all digestion is completed in the SI.

Pancreas

- Produces approx. 10 enzymes which are responsible for digestion.
- The PANCREATIC DUCT carries these enzymes directly into the common bile duct. Sometimes it empties directly into the duodenum (anatomic variance).
- Also secretes BICARBONATE which neutralizes the duodenal contents.
- The ISLETS OF LANGERHANS produce INSULIN and GLUCAGON.

Gall bladder (safra kesesi)

- Pouch structure located near the liver which concentrates and stores bile

- **Bile duct** – a long tube that carries BILE. The top half of the common bile duct is associated with the liver, while the bottom half of the common bile duct is associated with the pancreas, through which it passes on its way to the intestine.

BILE

- Bile emulsifies lipids (physically breaks apart FATS)

- Bile is a bitter, greenish-yellow alkaline fluid, stored in the gallbladder between meals and upon eating is discharged into the duodenum where it aids the process of digestion.

- Bile contains bile salts, water, pigments, cholesterol, and lecithin (a phospholipid)
- Bile salts act like detergents and EMULSIFY fats. Makes fat form into small droplets that are more soluble. Greater surface area makes it more digestible.

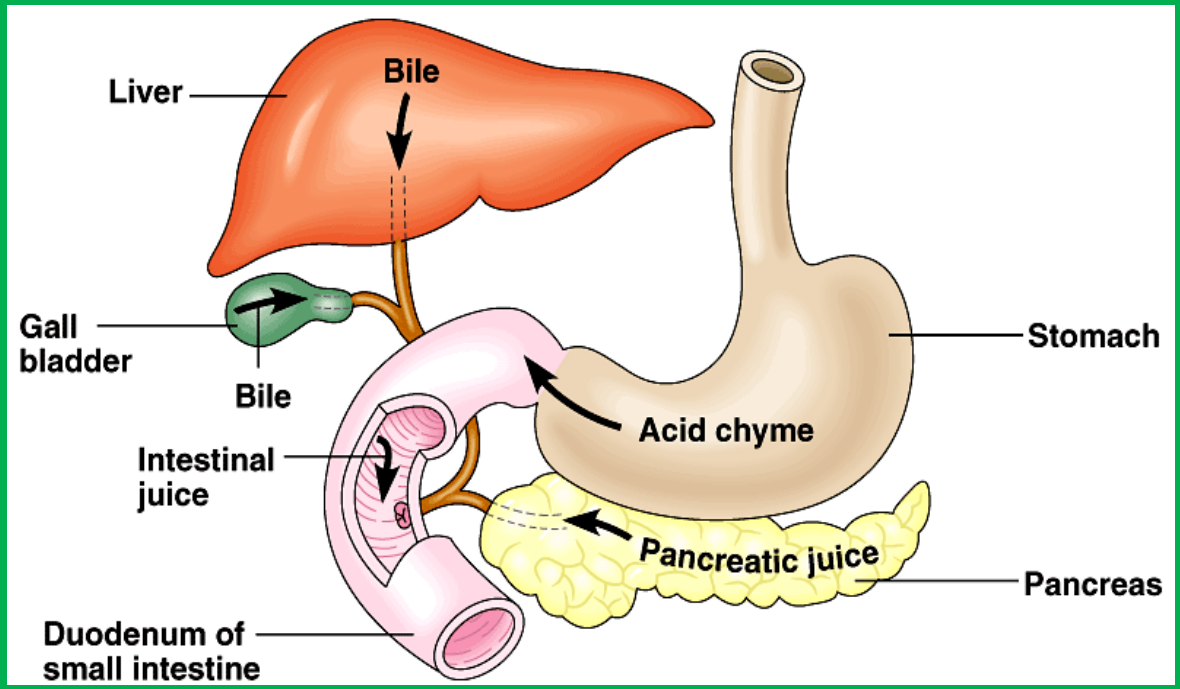
- Bile is stored in the GALL BLADDER where it is concentrated. When fat is detected in the duodenum, the gall bladder contracts and bile is discharged into it.
- The COMMON BILE DUCT comes into the first inch of the duodenum. Its opening is called the AMPULLA OF VATER. This opening is controlled by the SPHINCTER OF ODDI. This sphincter relaxes when the gall bladder contracts.

Liver

- Function
  - produces bile
    - bile stored in gallbladder until needed
    - breaks up fats
      - act like detergents to breakup fats

bile contains colors from old red blood cells collected in liver =

iron in RBC rusts & makes feces brown



Liver

- 5 functions:

1. Detoxification of blood
2. Carbohydrate metabolism
   - -glycogenesis – formation of glycogen from excess glucose in circulation.
   - -glycogenolysis – breakdown of glycogen in times of fasting.
   - -gluconeogenesis-formation of glucose in hepatocytes from raw materials.
3. Lipid metabolism
   - -synthesizes large quantities of cholesterol and phospholipids.
   - -oxidizing triglycerides to produce energy.
4. Protein synthesis
5. Secretion of bile

Spleen

- Stores blood
- Produces WBC
- Part of lymphatic system
- Found midaxillary, deep to ribs 9-11 and superior to the TPL.

Small Intestine

- Most **chemical digestion** takes place here.
- Simple **sugars** and **proteins** are absorbed into the inner lining.
- **Fatty acids** and **glycerol** go to lymphatic system.
- Lined with villi, which increase surface area for absorption, one cell thick.

Small Intestine

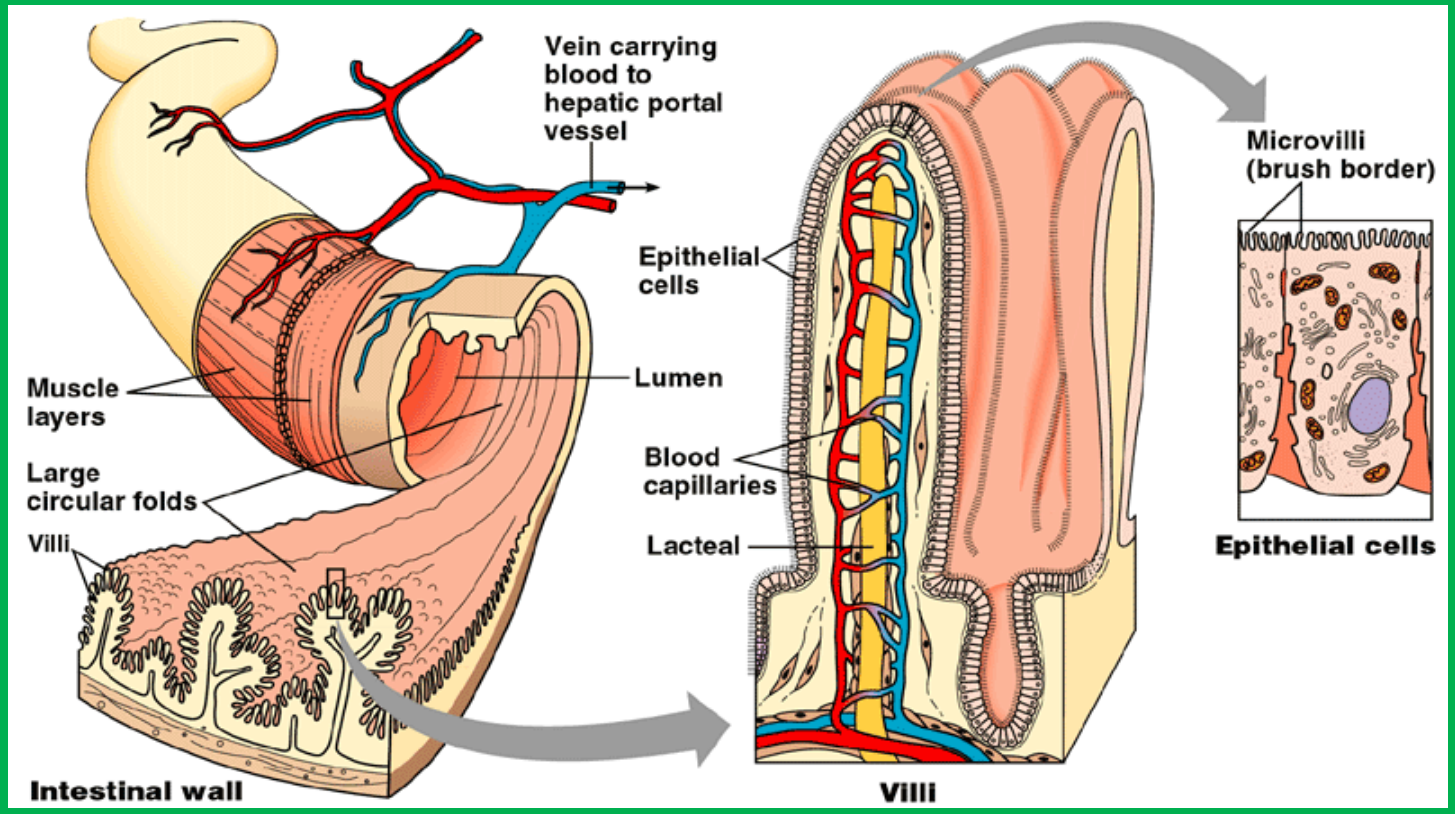
- The small intestine produces 7 enzymes. There are a total of 17 enzymes that are dumped into the duodenum for digestion.
- The small intestine is the area where most digestion occurs.
- It is also the place where 74% of the absorption of nutrients occur.

- The absorptive area is increased by:
    1. circular folds called PLICAE CIRCULARIS.
    2. Microscopic VILLI
    3. MICROVILLI

These structures increase the surface area of the small intestine by 600x

Absorption by Small Intestines

- Absorption through villi & microvilli
  - finger-like projections
  - increase surface area for absorption



Absorption

- Molecules must get from gut lumen into brush border of epithelial cells, then across cells into blood or lymph.
- Occurs by diffusion, facilitated absorption and active absorption.

Absorption in the SI

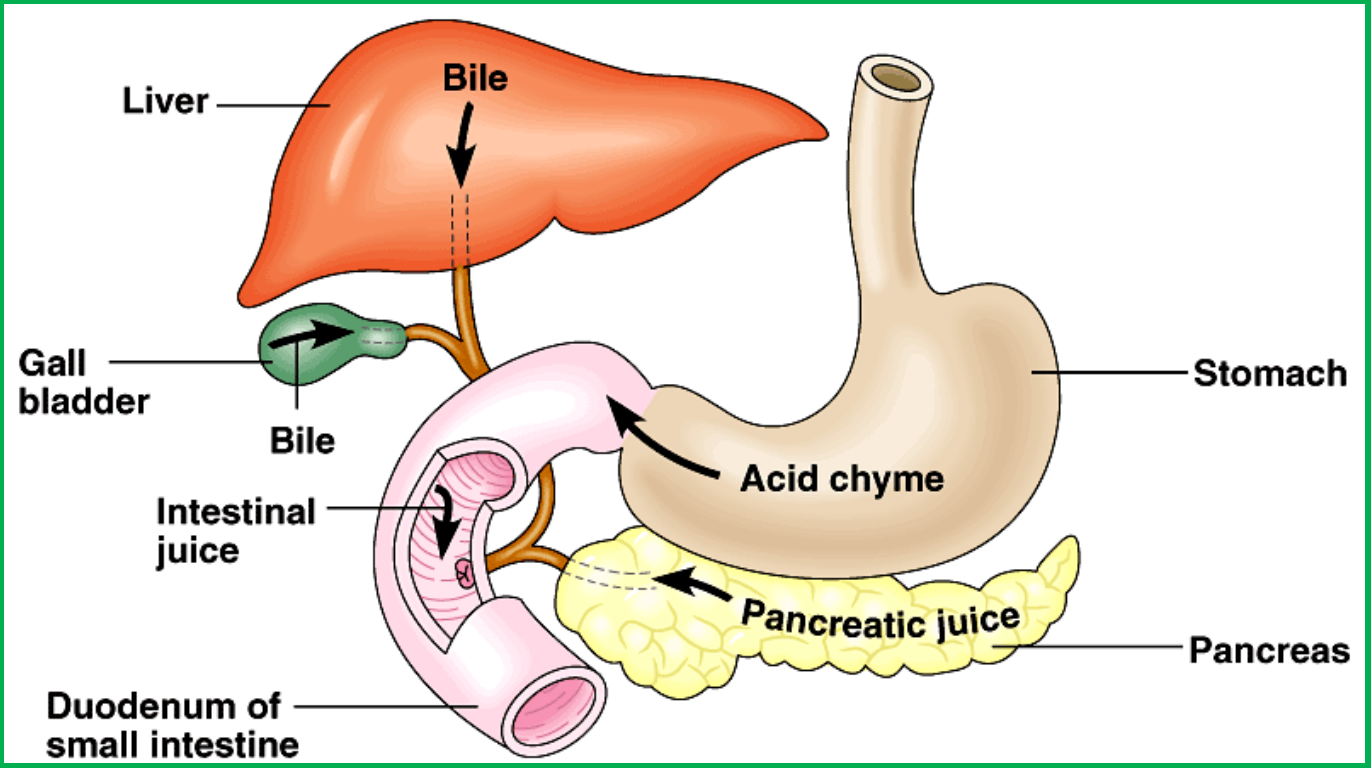
- Much absorption is thought to occur directly through the wall without the need for special adaptations
- Almost 90% of our daily fluid intake is absorbed in the small intestine.
- **Villi** - increase the surface area of the small intestines, thus providing better absorption of materials

Small intestine

- Function
  - chemical digestion
    - major organ of digestion & absorption
  - absorption through lining
    - over 6 meters!
    - small intestine has huge surface area = 300m^2 (~size of tennis court)
- Structure
  - 3 sections
    - duodenum = most digestion
    - jejunum = absorption of nutrients & water
    - ileum = absorption of nutrients & water

Duodenum

- 1st section of small intestines
  - acid food from stomach
  - mixes with digestive juices from:



Digestive Juices

- Bile
  - Produced in the LIVER
  - Stored in the Gall Bladder
- Pancreatic juice
  - Exocrine secretions
    - Sodium carbonate and bicarbonate
    - Enzymes
  - Endocrine secretions
    - Insulin
    - Glucogon

Some Definitions

Secretion

- discharge of materials synthesized by cells.

Excretion

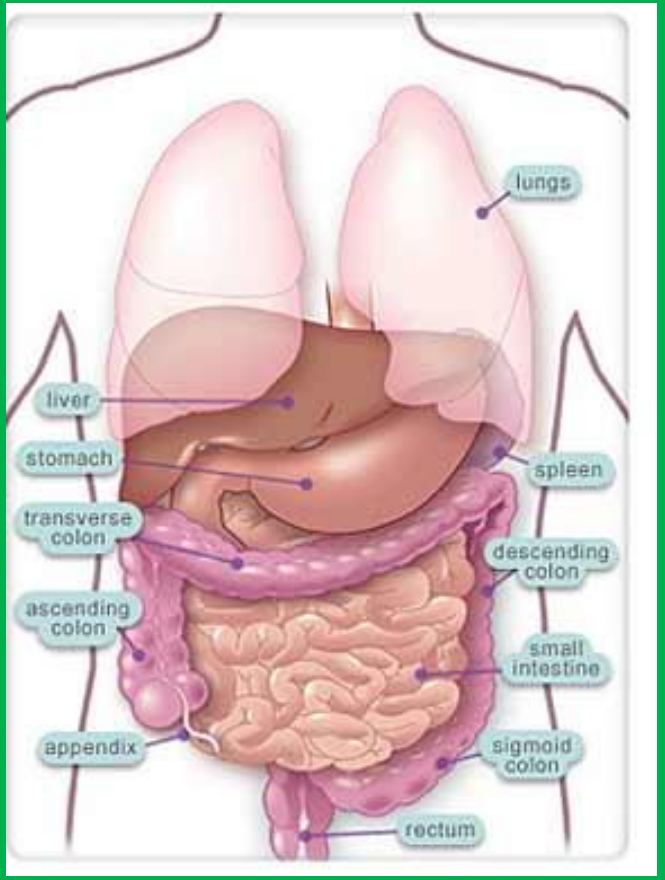
- discharge of metabolic waste products from our cells. Occurs at skin, sweat glands, lungs, feces, and kidneys.

Digestive Juices continued

- Secretions from small intestine wall
  - They digest disaccharides, peptides, etc to forms that can be absorbed

Large intestines (colon)

- Function
  - re-absorb water
    - use ~9 liters of water every day in digestive juices
    - > 90% of water reabsorbed
      - not enough water absorbed
        - diarrhea
      - too much water absorbed
        - constipation

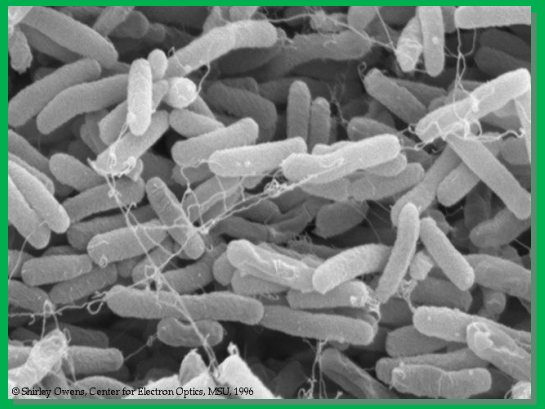


Large Intestine

- **Solid materials** pass through the large intestine.
- These are **undigestible** solids (fibers).
- Water is absorbed.
- **Vitamins K and B** are reabsorbed with the water.
- **Rectum**- solid wastes exit the body.

Microorganisms

- Living in the large intestine is a community of helpful bacteria
  - *Escherichia coli* (*E. coli*)
    - produce vitamins
      - vitamin K; B vitamins
    - generate gases
      - by-product of bacterial metabolism
      - methane, hydrogen sulfide



Large Intestine

- Ascending, transverse and decending colon
- FUNCTIONS:
  - Storage
  - Absorption of water
- Special role of cecum

Cecum

- Blind pouch at junction of small and large intestine
- Developed in nonruminant herbivores (horses, rabbits)
- Provides post-absorptive fermentation vat
  - Digests cellulose, Does NOT provide protein

Rectum

- The sphincter ani is an involuntary smooth muscle.
- The DEFECATION REFLEX which is kept in control by the sigmoid flexure and peristaltic activity.
- When peristalsis occurs the sphincter ani relaxes. An EXTERNAL SPHINCTER (skeletal muscle) can oppose the sphincter ani. This allows you to "hold it in" until you find a bathroom!
- The first part and part of the second third of the esophagus are also made of skeletal muscle. The rest of the GI tract is smooth muscle.

CHO metabolism

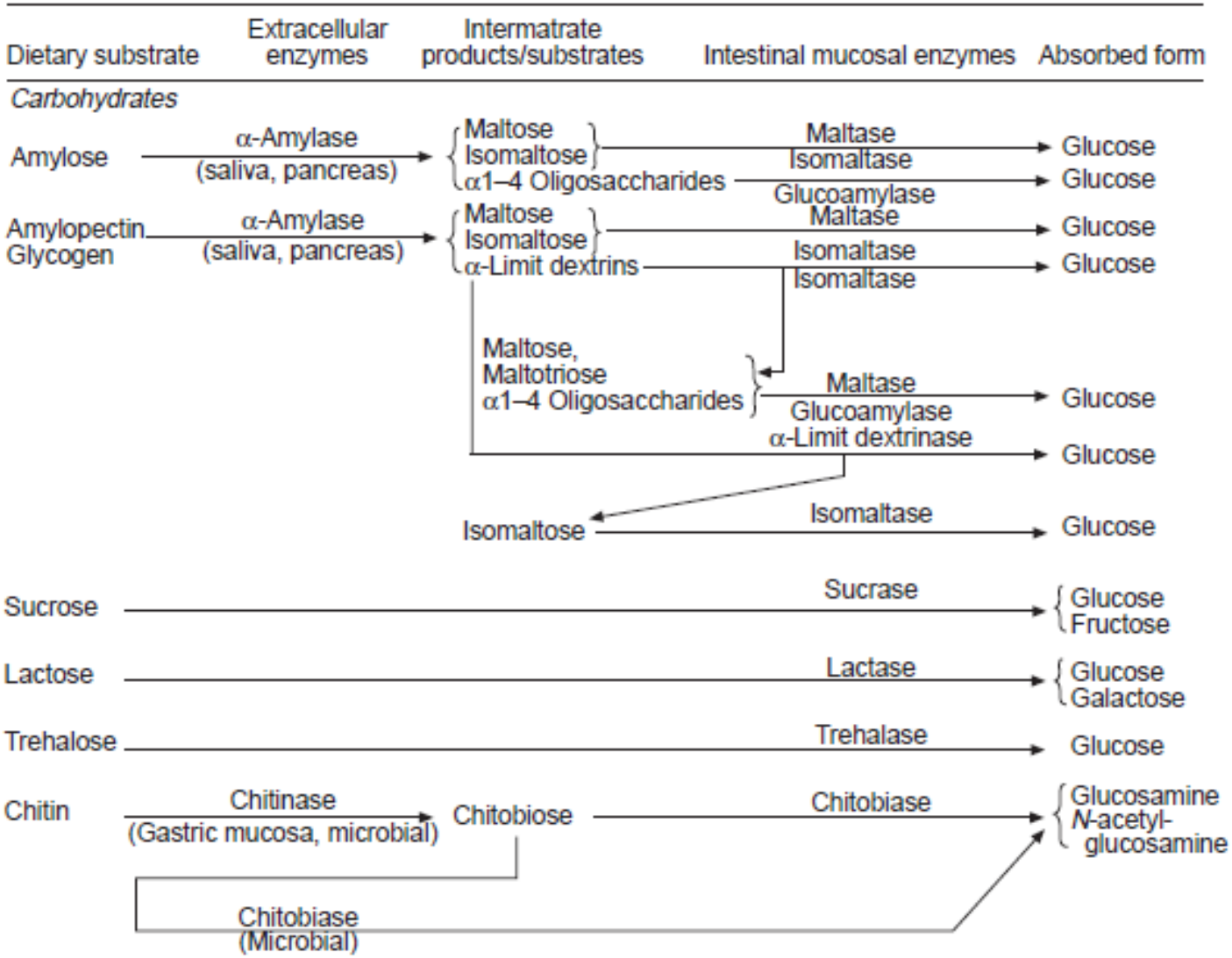
Soluble: present
only 5% in feeds,
but citrus pulp contains 30%.
Corn plant harvested for silage
has high amount but fermentation
uses almost all, little left.

Table 6.1. Classification of carbohydrate by dietary form.

I. Free – not associated with the cellular structure of food
   A. Lactose – milk
   B. Fructose – honey
   C. Trehalose – haemolymph
II. Intracellular – inside the cell
   A. Soluble – dissolved in the cytosol of cell
   B. Storage polysaccharide
      a. Starches
         1. Amylose, α1–4 glucose polymer
         2. Amylopectin α1–4 and α1–6 glucose polymer
         3. Glycogen, α1–4 and α1–6 glucose polymer
      b. Fructans
         1. Levans, β2–6 fructose polymer
         2. Inulins, β2–1 fructose polymer
III. Cell wall
   A. Cellulose, β1–4 glucose polymer
   B. Hemicellulose, β1–4 xylose polymer
   C. Pectin, α1–4 galacturonic acid
   D. Gums, β1–4 and β1–3 polymers of various sugars
   E. Lignin, phenylpropenoid polymers (not carbohydrate)
IV. Chitin, β1–4 *N*-acetylglucosamine polymer
   A. Exoskeleton
   B. Cell wall

CHO metabolism

Table 6.2. Summary of carbohydrate digestion in direct absorbers.



CHO metabolism

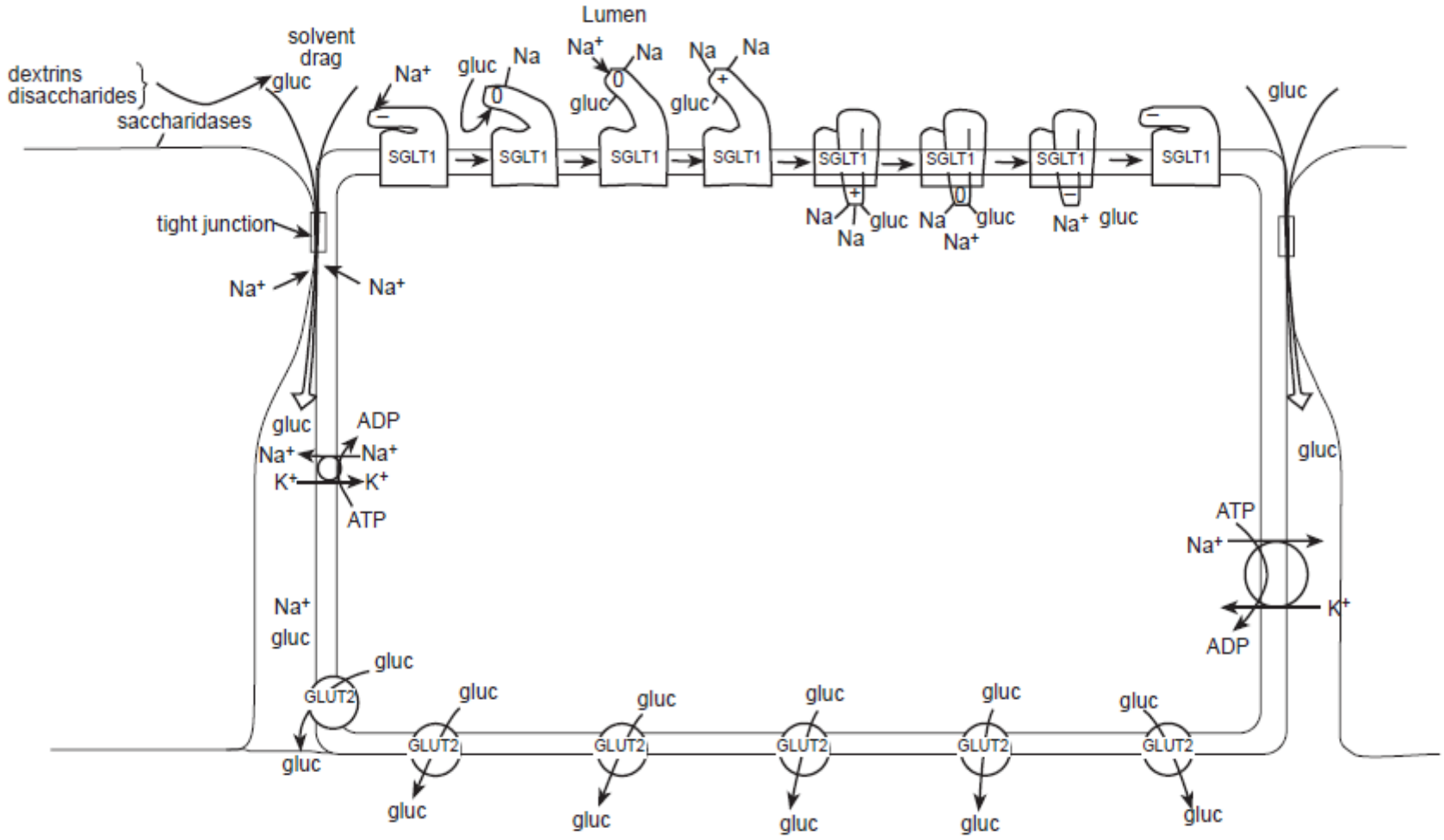


Fig. 6.1. Absorption of glucose through the small intestine.

CHO metabolism

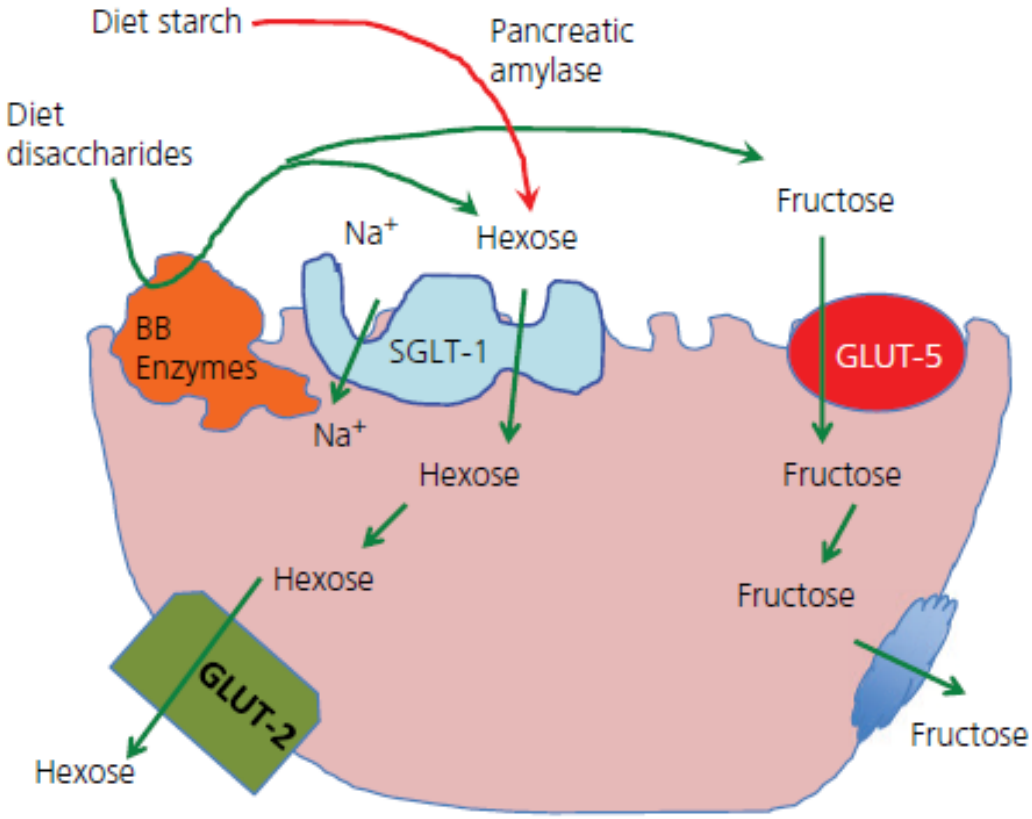


Figure 44.11 Starch is converted to glucose, maltose, and limit dextrins by amylase in the lumen of the intestine. Brush border enzymes (BB enzymes) such as maltase, lactase, sucrase, and dextrinase convert dietary disaccharides (e.g., maltose, lactose, sucrose) and limit dextrins to single hexose (glucose and galactose) or pentose (fructose) molecules. Hexoses in the brush border are brought into the cell using a Na^+-linked glucose transporter (SGLT-1). Pentose sugars use a Na^+-independent facilitated transporter (GLUT-5). At the basolateral membrane, both hexose (GLUT-2 transporter) and pentose sugars use facilitated transport diffusion to enter the extracellular fluid down their concentration gradient.

Lipid metabolism

Lipids consumed by non-ruminant animals are predominantly triacylglycerols (triglycerides), with the exception of herbivorous animals such as horses and rabbits that may consume considerable amounts of galactolipids from vegetative material.

Salivary lipase possesses significant hydrolytic activity at pH 3.5, near that of the stomach. Gastric lipase is present at higher activities in neonatal animals and has higher hydrolytic activity toward milk triacylglycerols than does pancreatic lipase (Jensen *et al.*, 1997). Gastric lipase attacks primarily short- and medium-chain fatty acid linkages on the *sn*-3 position of triacylglycerol, such as those prevalent in milk of ruminants and swine.

Lipid metabolism

Bile is essential for further lipid digestion and absorption in the small intestine (Brindley, 1984). The primary components of bile necessary for lipid digestion are the bile salts and phospholipids. Bile salts, which are responsible for emulsification of lipid droplets, are synthesized from cholesterol in hepatocytes of the liver. The bile salts are conjugated by the liver with the amino acids taurine or glycine, which increases the water solubility and decreases the cellular toxicity of the bile salts. Pigs conjugate bile salts to both taurine and glycine, whereas poultry only produce taurine conjugates (Freeman,

Pancreatic secretions into the small intestine are also critical for lipid digestion and absorption. Dispersion of lipid by bile salts enables attachment of the pancreatic polypeptide colipase, which attracts pancreatic lipase and enables it to interact at the surface of the lipid droplet (Brindley,

Lipid metabolism

Absorption of fatty lipids into intestinal epithelial cells is an energy-independent process that is facilitated by maintenance of a concentration gradient into the cells.

Most absorption of fatty acids and monoacylglycerols takes place in the jejunum in mammals. In fowl, some fatty acid absorption has been demonstrated in both the duodenum and the ileum. The

Fatty acid digestibility is high in non-ruminants, with values often >80% in pigs and poultry and >90% in pre-ruminant calves (Doreau and Chilliard, 1997). Intestinal fatty acid digestibility decreases with increasing chain length and increases with increasing unsaturation. Absorption

Lipid metabolism

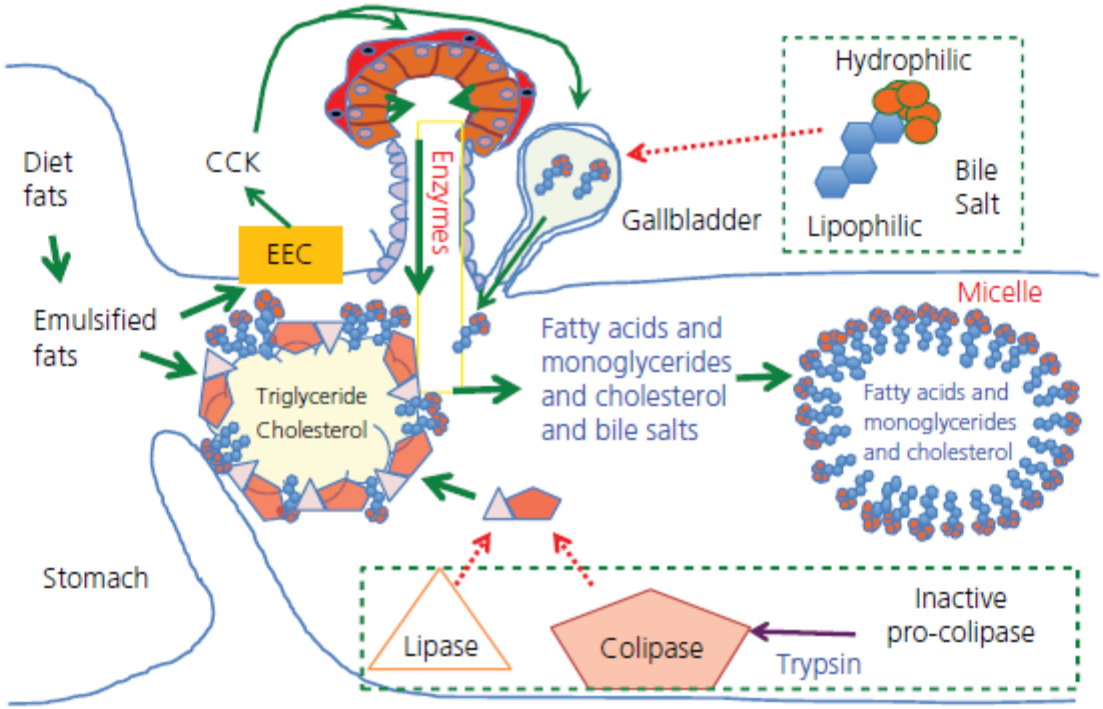


Figure 44.12 Luminal phase of fat digestion. Churning of the stomach emulsifies dietary lipids. As these fats enter the duodenum they stimulate enteroendocrine cells (EEC) to secrete cholecystokinin (CCK). CCK stimulates the pancreas to release digestive enzymes including lipase and pro-colipase needed for fat digestion. CCK also stimulates the gallbladder to contract causing secretion of bile salts into the lumen. Pro-colipase is cleaved by trypsin to form active colipase, which is a cofactor needed for full activity of lipase. Lipase, colipase, and the bile salts work together on the emulsified fat to convert the triglycerides to monoglycerides and free fatty acids. The liberated fatty acids and monoglycerides, as well as cholesterol and fat-soluble vitamins, are surrounded by bile salts to form micelles. Micelles are several hundred fold smaller than the emulsified fat droplet.

Lipid metabolism

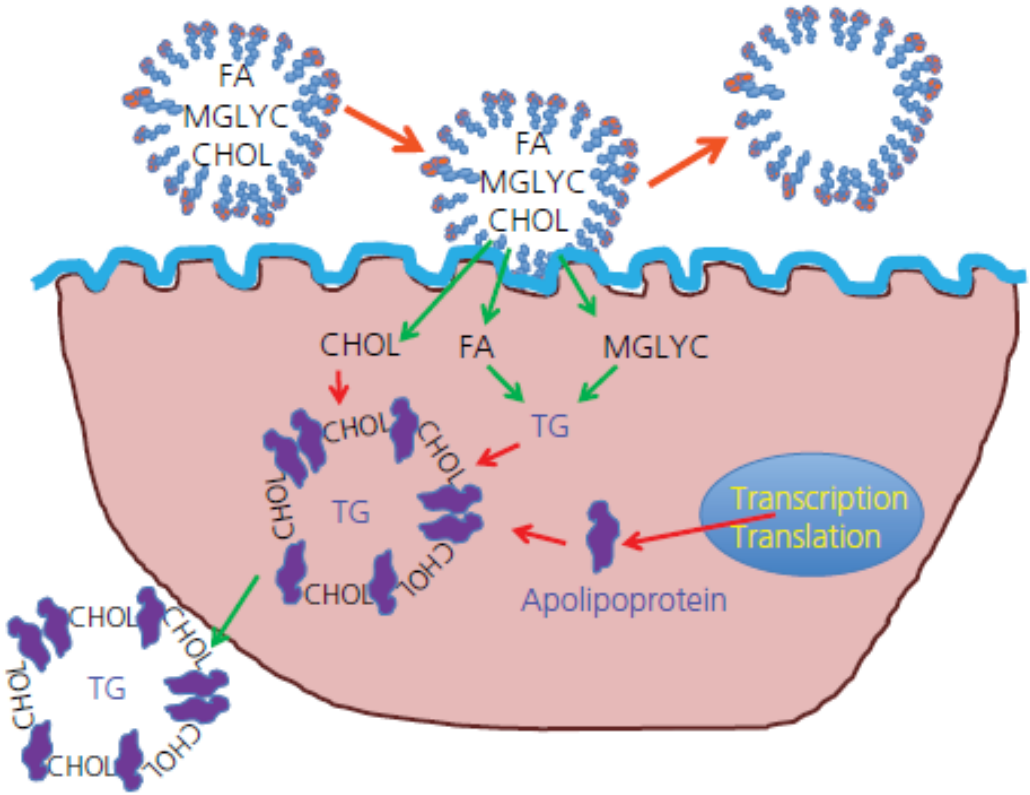


Figure 44.13 Brush border phase of lipid digestion and absorption. Lipids packaged into the micelle are able to cross the unstirred water layer above the enterocytes. On making contact the fatty acids (FA), monoglycerides (MGLYC), cholesterol (CHOL), and fat-soluble vitamins diffuse across the apical membrane to the cytosol. The FA and MGLYC are combined to reform triglycerides (TG), encouraging further diffusion of FA and MGLYC from the micelle. The empty micelle bile salts return to the lumen to collect another load of FA and MGLYC. The enterocyte produces apolipoproteins that are combined with cholesterol to form a chylomicron structure which surrounds cytosol TG and fat-soluble vitamins. The chylomicron is then exocytosed across the basolateral membrane. It is too large to enter venules so it enters the lacteal and lymphatics to reach the thoracic duct.

Protein metabolism

Proteins in the diet tend to be very large molecules and often consist of hundreds of amino acids linked by peptide bonds. For example, casein, the major protein in milk, has a molecular weight of 23,000 and is about 200 amino acids in length. These molecules need to be broken down to at least the dipeptide and tripeptide level before they can cross the enterocytes. Protein digestion begins in the stomach. Here the very acidic environment alone can hydrolyze some of the peptide bonds. The chief cells of the gastric glands secrete **pepsinogen**, an inactive proteolytic enzyme. It is secreted in an inactive form to prevent autodigestion of the chief cells and gastric gland cells. Gastric gland acid mixes with the pepsinogen and cleaves off a fragment of the pepsinogen to form pepsin, the active enzyme. Pepsin cleaves peptide bonds next to hydrophobic amino acids with aromatic side chains (phenylalanine, tryptophan, tyrosine). **Rennin** is another enzyme produced by chief cells. It cleaves between phenylalanine and methionine residues on proteins, and is especially important for digestion of casein by neonatal

Protein metabolism

mammals. Both pepsin and rennin function optimally when the pH is between 2 and 3. The net result is that proteins that were hundreds of amino acids long when they entered the stomach enter the duodenum as fragments that may be 25–100 amino acids long.

As peptides reach the small intestine they activate receptors of enteroendocrine cells lining the duodenum crypts, stimulating them to secrete cholecystokinin (CCK). The CCK enters the circulation and reaches the pancreatic acinar cells and myoepithelial cells surrounding each acinus. This triggers secretion of pancreatic enzymes into the upper duodenum via the pancreatic ducts (Figure 44.9). The proteolytic enzymes of the pancreas are produced and secreted into the pancreatic ducts in an inactive form. This prevents autodigestion of the pancreas and pancreatic ducts. The proteolytic proenzymes secreted by the pancreas incude trypsinogen, chymotrypsinogen, pro-elastase, and pro-carboxypeptidases A and B.

Protein metabolism

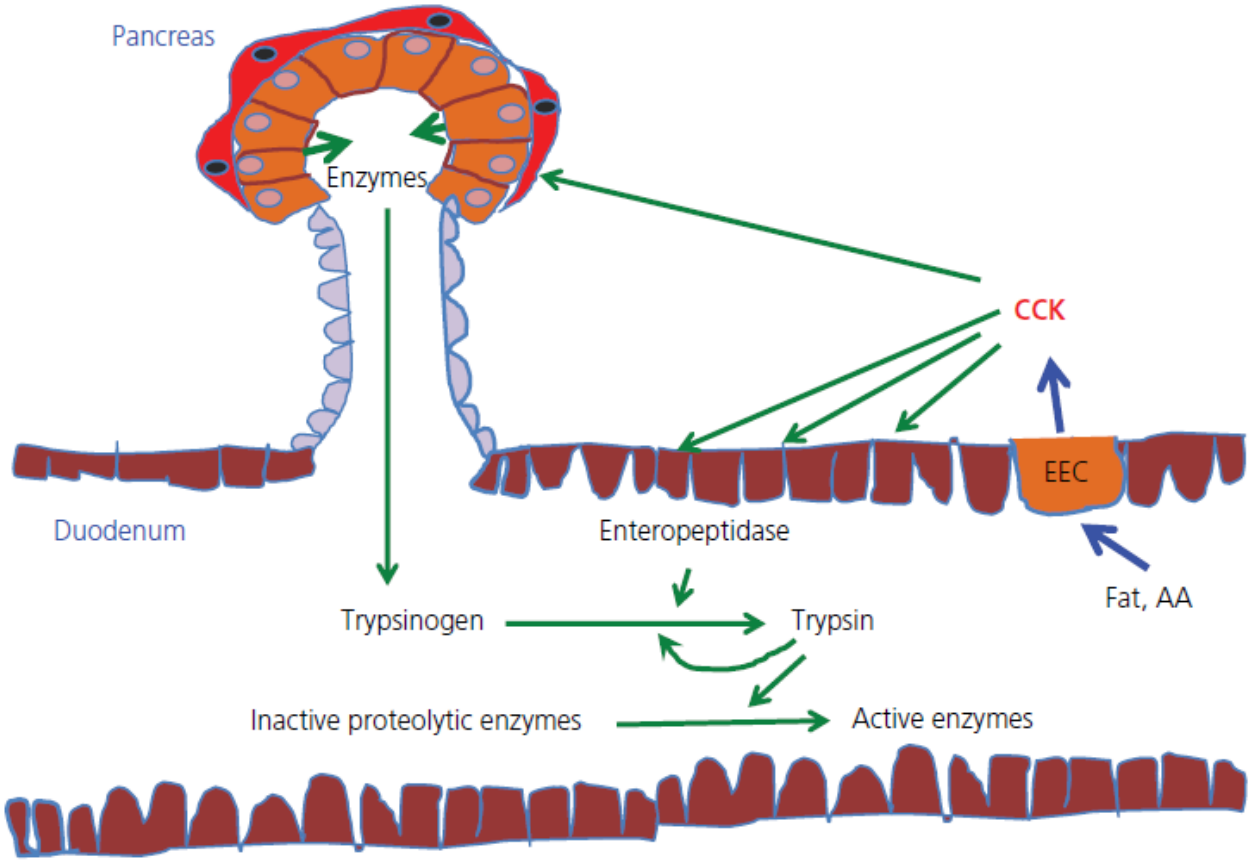


Figure 44.9 Many of the enzymes secreted by the pancreas are in an inactive form. Activation begins when an enteroendocrine cell (EEC) secretes cholecystokinin (CCK) in response to the presence of fats or amino acids (AA) in the duodenum. The CCK stimulates the pancreas to secrete enzymes, many of which are in an inactive form. The CCK also acts on nearby villous enterocytes and causes them to secrete enteropeptidase. Enteropeptidase converts pancreatic trypsinogen to the active enzyme trypsin. Trypsin then cleaves off portions of all the other inactive pancreatic enzymes allowing them to become active in the intestinal lumen. Trypsin can also cleave trypsinogen to form more trypsin enzyme.

Protein metabolism

The CCK secreted by crypt enteroendocrine cells in response to peptides (and fats) entering the duodenum also reaches the villous enterocytes. This causes the enterocytes to secrete an enzyme called enteropeptidase (also called enterokinase) into the lumen of the duodenum. Enteropeptidase seeks out trypsinogen that has entered the duodenum and cleaves off a fragment to form the active proteolytic enzyme trypsin. Trypsin then cleaves off portions of each of the other proteolytic enzymes secreted by the pancreas causing them to become active as well. Trypsin can actually convert trypsinogen to active trypsin in an example of positive feedback regulation. The action of

Protein metabolism

enteropeptidase quickly causes all the inactive proteolytic enzymes in the pancreatic secretions to become active in the lumen of the gut. Each of these different proteolytic enzymes (trypsin, chymotrypsin, elastase, and the carboxypeptidases) cleave peptide bonds between specific amino acids so that when the luminal phase of digestion is finished the protein has been converted to peptides that are generally just 1–12 amino acids long.

These single amino acids and longer peptides then move to the brush border. They are very soluble in water and have no problem crossing the unstirred water layer and entering the glycocalyx, adhering to the microvilli forming the brush border of the villous enterocytes. Several intestinal peptidases project from the brush border into the glycocalyx, but these enzymes are not released into the lumen of the intestine. These intestinal peptidases hydrolyze the peptide bonds, reducing the length of the peptides to no more than three amino acids in length. The next obstacle to their absorption is moving across the apical membrane of the villous enterocyte.

Protein metabolism

Crossing the apical membrane of villous enterocytes

The single amino acids develop a large concentration gradient above the apical membrane of duodenal and jejunal villous cells following ingestion of a meal. Thanks to the secretory efforts of the crypt enterocytes, high amounts of sodium are also found above the apical membrane. At least four facilitated carriers are known to exist in the apical membrane of the villous cells. These transporters seem to be specific for the basic, acidic, or neutral amino acids.

Proline seems to have its own unique carrier. All these single amino acid carriers are facilitated carriers that bind the amino acid and a Na^+ atom (Figure 44.10). The combined force of the amino acid moving down its concentration gradient and Na^+ moving down its electrical and concentration gradient helps drive the large amino acid molecule across the apical membrane.

The dipeptides and tripeptides at the brush border can be absorbed by active transport mechanisms. They are so large that it takes the force supplied by an ATP molecule along with a transporter protein to pump them across the apical membrane. Research suggests that the bulk of amino acids is transported across the apical membrane in the form of dipeptides and tripeptides. Once these arrive in the cytosol of the villous enterocyte they are hydrolyzed to single amino acids by intracellular peptidases.

Protein metabolism

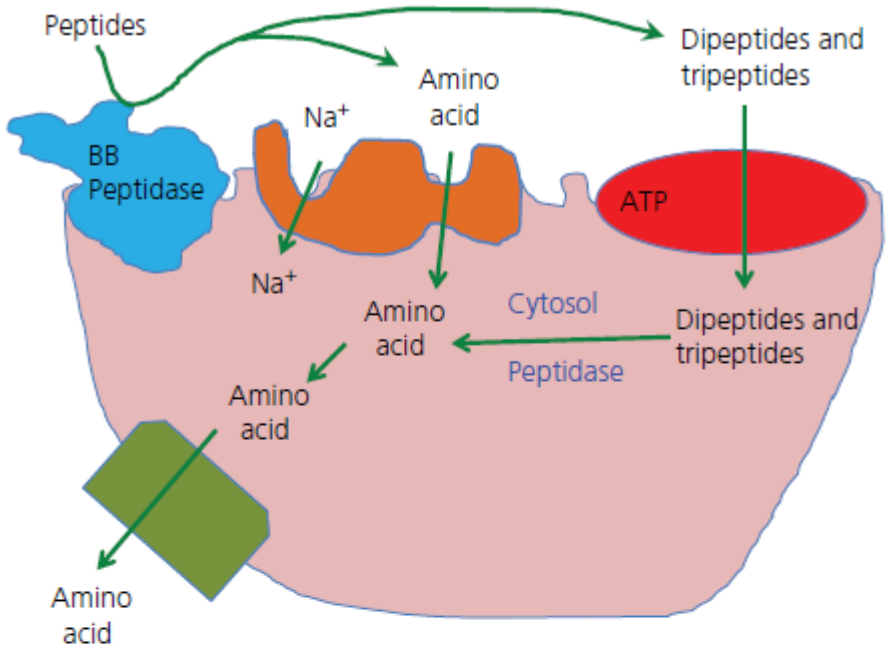


Figure 44.10 Brush border digestion and absorption of proteins and amino acids. A brush border peptidase (BB peptidase) of villous cells can break down any peptides greater than three amino acids that reach the glycocalyx. Single amino acids then use one four known types of Na^+/amino acid cotransporters to cross the apical membrane. These facilitated diffusion carriers utilize the driving forces provided by the high concentration of amino acid in the lumen following a meal and high lumen Na^+ provided by crypt cell secretions to move the large charged amino acids across the brush border. Dipeptides and tripeptides can be transported by special active transport proteins that do not require Na^+, but do expend an ATP to move such large molecules across the membrane. Once inside the cell the dipeptides and tripeptides are converted to single amino acids by intracellular peptidases. Transporters unique to the basolateral membrane then facilitate diffusion of the amino acids into the extracellular fluid.

Protein metabolism

Crossing the basolateral membrane of the villous enterocyte

As the single amino acids accumulate at the basolateral side of the enterocytes, their concentration becomes much higher than that of free amino acids in the extracellular fluid. Transporters unique to the basolateral membrane facilitate the diffusion of amino acids across the basolateral membrane, independent of Na^+. The amino acids enter the extracellular fluid and are transported in the portal circulation to the liver. The Na^+ ions that accompanied the single amino acids across the apical membrane are pumped into the extracellular fluid by the $3Na^+/2K^+$

electrogenic pump residing in the basolateral membrane at the expense of an ATP. The sodium may be removed from the blood by crypt secretory cells and returned to the lumen to assist facilitated transport of other amino acids by villous cells.

Protein metabolism

Absorption of intact proteins

In rare instances some very specific proteins can be absorbed intact across the intestinal villous cells. The most important of these are the colostral antibodies that provide passive immunity for the neonatal mammal. In the case of colostral immunoglobulins, the antibodies found in colostrum have unique properties that allow them to resist degradation by stomach acid and the proteolytic enzymes. Neonatal proteolytic enzyme secretion and activation processes do not seem to be fully developed, which also helps the protein avoid digestion. Villous cells of the neonate have specific receptors that recognize the immunoglobulins. Once the immunoglobulin binds its receptor, it activates endocytosis of the immunoglobulin: it is enclosed in a section of the apical membrane, transported to the basolateral membrane, and released into the extracellular fluid by exocytosis. The presence of these receptors on the neonatal villous enterocytes is short-lived: most mammals lose these immunoglobulin receptors and stop absorbing immunoglobulin within 24 hours of birth.

Vitamin metabolism

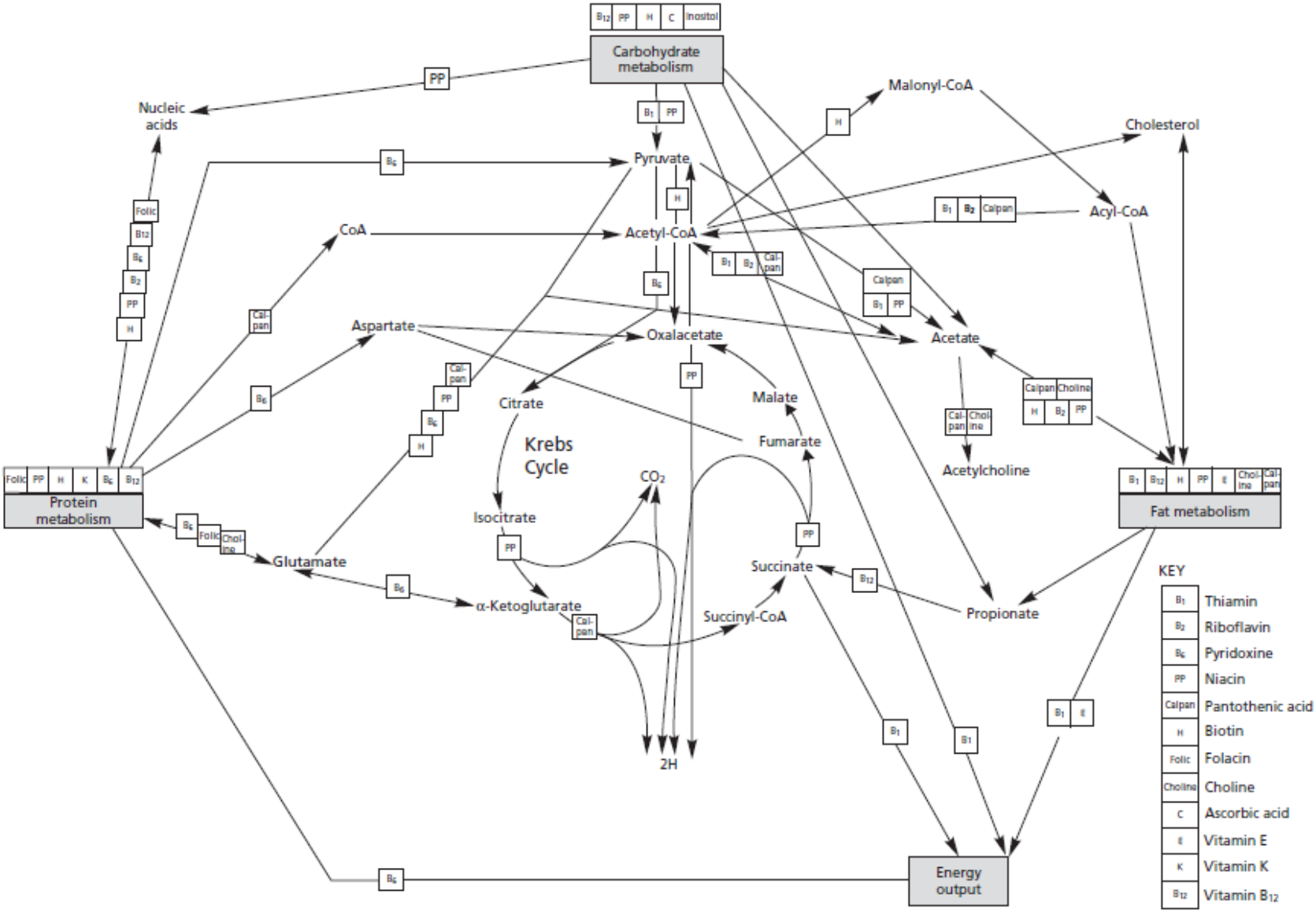


Fig. 5.1 Diagram showing the involvement of vitamins in biochemical pathways.

Adapted from *Roche Vitec Animal Nutrition and Vitamin News* 1: A1–10/2 November 1984.

Vitamin metabolism

Vitamins are involved in metabolic pathways as coenzymes, and some act as protectors in antioxidant and immune systems. The sources and functions of individual vitamins, and the disorders caused by their deficiencies, are summarised below.

Vitamin	Source	Actions	Deficiency symptoms
A, retinol	Fish-liver oil	Sight, epithelial tissues	Blindness, epithelial infection
D_3, cholecalciferol	Fish-liver oil, sun-dried roughage	Calcium absorption	Rickets
E, a-tocopherol	Green foods, cereals	Antioxidant	Muscle degeneration, liver damage
K, menadione	Green foods, egg yolk	Prothrombin synthesis	Anaemia, delayed clotting
B_1, thiamin	Seeds	Carbohydrate and fat metabolism	Poor growth, polyneuritis
B_2, riboflavin	Green foods, milk	Carbohydrate and amino acid metabolism	Poor growth, curled toe paralysis
Nicotinamide	Yeast, liver, tryptophan	Hydrogen transfer (NAD and NADP)	Poor growth, dermatitis
B_6, pyridoxine	Cereals, yeast	Amino acid metabolism	Poor growth, convulsions
Pantothenic acid	Liver, yeast, cereals	Acetate and fatty acid metabolism (coenzyme A)	Poor growth, scaly skin, 'goose-stepping' in pigs
Folic acid	Green foods, cereals, oilseed meals	Metabolism of single carbon compounds	Poor growth, anaemia, poor hatchability
Biotin	Liver, vegetables	Carbon dioxide transfer	Foot lesions, hair loss, FLKS
Choline	Green foods, cereals, methionine	Component of lecithin	Poor growth, fatty liver, perosis
B_{12}, cyanocobalamin	Microorganisms, liver	Propionate metabolism	Poor growth, anaemia, poor coat/feathering
C, ascorbic acid	Citrus fruits, leafy vegetables	Oxidation–reduction reactions	Reduced resistance to infection

FLKS = fatty liver and kidney syndrome.

Mineral metabolism

Minerals fulfil physiological, structural and regulatory functions. Mineral supplements take various forms: mineral salts, rumen boluses, 'organic' compounds and pasture applications. The roles of individual mineral elements, and the effects of their deficiencies, are summarised below:

Mineral element	Role	Effects of deficiency
Calcium	Bone and teeth, transmission of nerve impulses	Rickets, osteomalacia, thin eggshells, milk fever
Phosphorus	Bone and teeth, energy metabolism	Rickets, osteomalacia, depraved appetite, poor fertility
Potassium	Osmoregulation, acid–base balance, nerve and muscle excitation	Retarded growth, weakness
Sodium	Acid–base balance, osmoregulation	Dehydration, poor growth, poor egg production
Chlorine	Acid–base balance, osmoregulation, gastric secretion	Alkalosis
Sulphur	Structure of amino acids, vitamins and hormones, chondroitin	Equivalent to protein deficiency (urea-supplemented diets)
Magnesium	Bone, activator of enzymes for carbohydrate and lipid metabolism	Nervous irritability and convulsions, hypomagnesaemia
Iron	Haemoglobin, enzymes of electron transport chain	Anaemia
Copper	Haemoglobin synthesis, enzyme systems, pigments	Anaemia, poor growth, depigmentation of hair and wool, swayback
Cobalt	Component of vitamin B_{12}	Pining (emaciation, anaemia, listlessness)
Iodine	Thyroid hormones	Goitre; hairless, weak or dead young
Manganese	Enzyme activation	Retarded growth, skeletal abnormality, ataxia
Zinc	Enzyme component and activator	Parakeratosis, poor growth, depressed appetite
Selenium	Component of glutathione peroxidase, iodine metabolism, immune function	Myopathy, exudative diathesis

Electrolyte metabolism

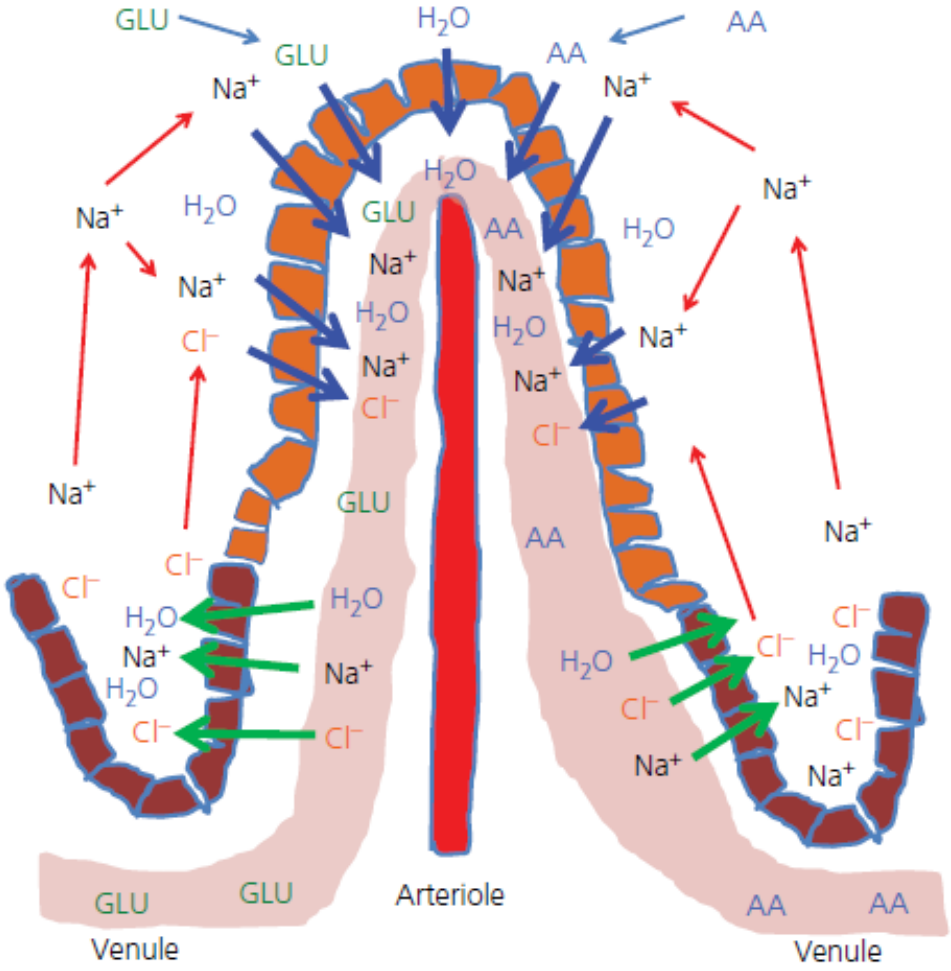


Figure 44.16 Electrolyte circulation from crypt to villus and back to crypt. Crypt cells pump extracellular fluid Cl^- into the lumen. The Cl^- is followed by Na^+ and water. The Na^+ diffuses to the villous cell area where it is utilized to help drive facilitated diffusion of hexose sugars (GLU) and amino acids (AA) across the apical membrane of villous cells. Some of the Na^+ and Cl^- are cotransported across the villous cells and enter the venous blood of the villus. As the venous blood flows past the crypt area, the crypt cells can pump the Cl^- out into the lumen and cause the Na^+ and water to again enter the lumen to be reused to absorb more GLU and AA.