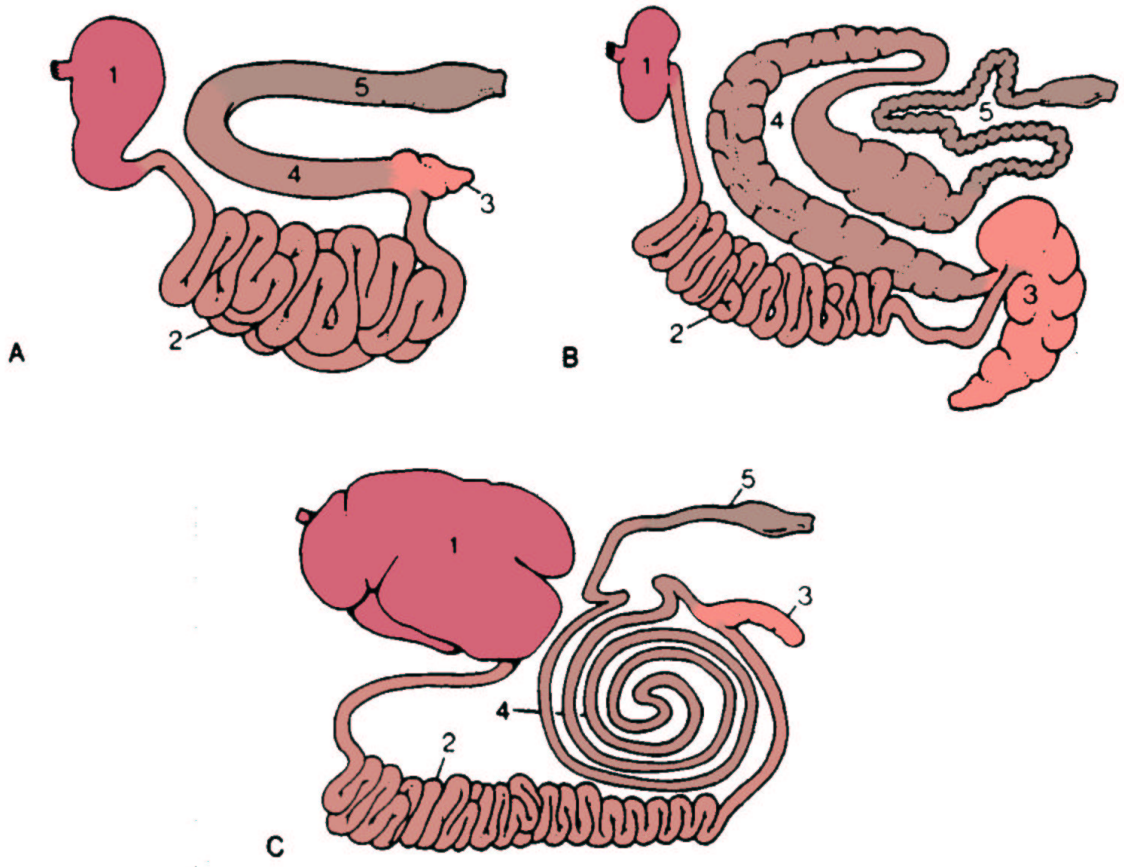
Digestive System
ANS 215
Physiology and Anatomy of Domesticated Animals

I. Digestive Tract

A. Animals are classified according to the diet in their natural state as:
   1. Carnivores
   2. Herbivores
   3. Omnivores

B. Because of the diversity of diet, various parts of the digestive system developed in different ways.



Comparisons of gastrointestinal tracts of, **A**) the dog, **B**) the horse, **C**) and cattle.
1. Stomach; **2**. small intestine; **3**. cecum;
4. ascending colon (dog), large colon (horse), coiled colon (cattle); **5**. descending colon.

C. Mouth
   1. Most cranial part of the digestive system
      a. also referred to as oral cavity
      b. site of reduction of food particle size
      c. teeth and tongue are structures that assist in digestion
      d. salivary enzymes are also added to digesta

2. Teeth
    a. mechanically reduce the size of ingested food
        i. increases surface area
    b. teeth are also used for cutting food (incisors) and defense (canines)
    c. Types of teeth:
        i. identified by location and use
            - incisors
                · most forward
                · used for cutting
                · also called nippers
            - canines
                · also called fangs, eyeteeth, tusks
                · used for tearing
                · located posterior to incisors
            - premolars
                · used for grinding
                · located posterior to canines
            - molars
                · located caudal to premolars
                · used for grinding

Dental Formulas and Eruption Times for Permanent Teeth

Teeth	Horse	Cow	Sheep	Pig	Dog
			Permanent Formula		
	3 1 3 or 4 3	**0 0 3 3**	**0 0 3 3**	**3 1 4 3**	**3 1 4 2**
	2(I-C-P-M-)	**2(I-C-P-M-)**	**2(I-C-P-M-)**	**2(I-C-P-M-)**	**2(I-C-P-M-)**
	3 1 3 3	**4 0 3 3**	**4 0 3 3**	**3 1 4 3**	**3 1 4 3**
			Permanent Eruption		
Incisors					
11	**2½ yr**	**1½ - 2 yr**	**1 - 1½ yr**	**1 yr**	**3 - 5 mo**
12	**3½ yr**	**2 - 2½ yr**	**1½ - 2 yr**	**16 - 20 mo**	**3 - 5 mo**
13	**4½ yr**	**3 yr**	**2½ - 3 yr**	**8 - 10 mo**	**4 - 5 mo**
14		**3½ - 4 yr**	**3½ - 4 yr**		
Canines					
C	**4 - 5 yr**			**9 - 10 mo**	**4 - 6 mo**
Premolars					
P1	**5 - 6 mo**	**2 - 2½ yr**	**1½ - 2 yr**	**12 - 15 mo**	**4 - 5 mo**
P2	**2½ yr**	**1½ - 2½ yr**	**1½ - 2 yr**	**12 - 15 mo**	**5 - 6 mo**
P3	**3 yr**	**2½ - 3 yr**	**1½ - 2 yr**	**12 - 15 mo**	**5 - 6 mo**
P4	**4 yr**			**12 - 15 mo**	**5 - 6 mo**
Molars					
M1	**9 - 12 mo**	**5 - 6 mo**	**43 - 5 mo**	**4 - 6 mo**	**5 - 6 mo**
M2	**2 yr**	**1½ yr**	**9 - 12 mo**	**8 - 12 mo**	**6 - 7 mo**
M3	**3½ - 4 yr**	**2 - 2½ yr**	**1½ - 2 yr**	**18 - 20 mo**	**6 - 7 mo**

I = incisors, C = canines, P = premolars, M = molars, wk = week, mo = month, yr = year

    d. Dental formula
        i. indicates the number of incisors (I), canines (C), premolars

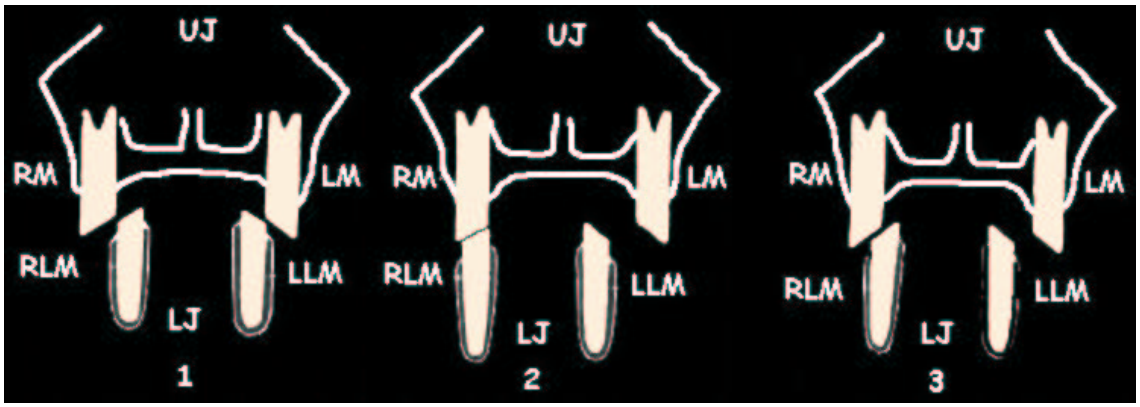
(P), and molars (M) on one side of the mouth

ii. dental formula of the cow is I0/4C0/0P3/3M3/3
- numerator represents upper jaw, denominator is lower jaw
- cow has a firm dental pad instead of incisors in upper jaw

iii. formula represents teeth on one side of the mouth

e. Exposed surface of teeth

i. Several terms are used to describe the exposed surface of a tooth.
- table (grinding surface) – makes contact with the ‘ surface of opposite jaw
- lingual surface – side of tooth next to tongue
- labial surface – outer surface next to lips
- buccal surface – outer surface next to cheeks
- contact surface – next to a neighboring tooth ot the same arcade (row)
- upper arcades of cheek teeth (molars and premolars) are slightly wider apart than the lower arcades of cheek teeth
- upper cheek teeth have a wider table surface than the lower cheek teeth



UJ = upper jaw; LJ = lower jaw; RM = right molar; LM = left molar;
RLM = right lower molar; LLM = left lower molar

Schematic transverse section of the upper and lower jaws of the horse at the level of the fourth molars showing the position of the tables of the teeth during rest and mastication. **1.** Position of the teeth during rest. The outside edge of the lower row is in apposition with the inside edge of the upper. **2.** Jaws fully crossed, masticating from left to right (lower jaw movement). The tables of both upper and lower molars now rest on each other. **3.** Position halfway through mastication. The outer half of the lower teeth wears against the inner half of the upper. Note the potential for developing “points” on the cheek side of the uppers and on the tongue side of the lowers.

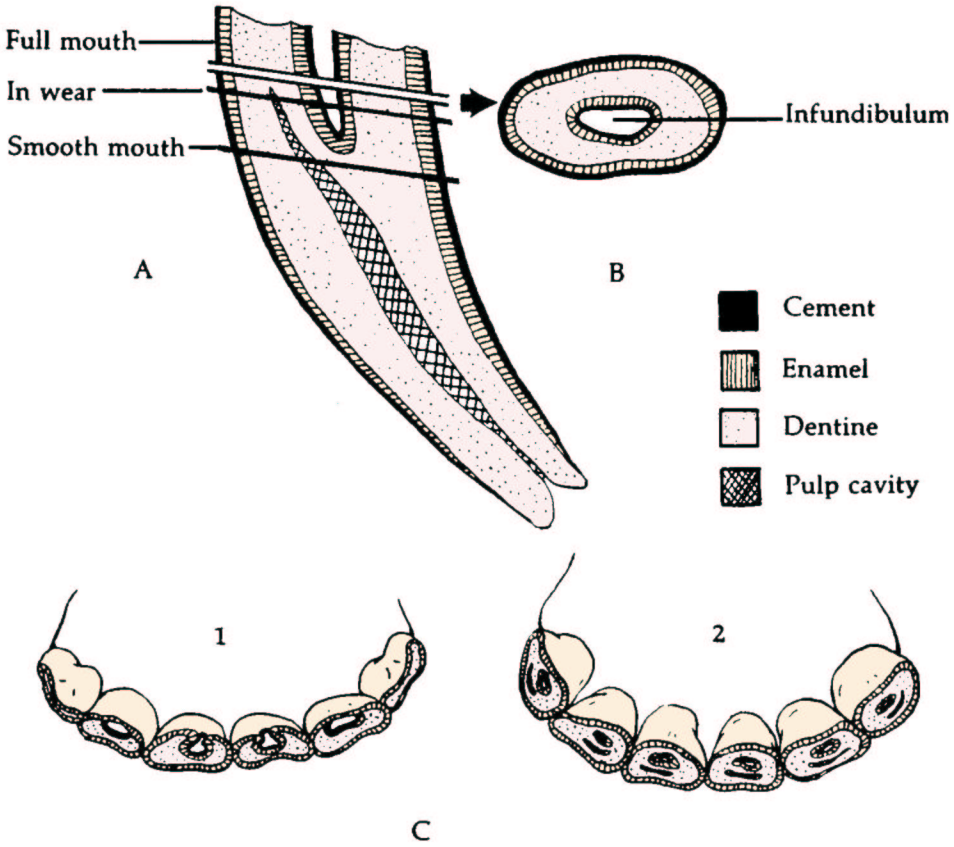
ii. uneven wear of tooth surface

- can develop, particularly in horses
- points can develop on teeth that injure the buccal or lingual membranes causing pain
- filing off points with rasps is called “floating teeth”

iii. age of horses can be approximated by examining lower incisors

- determine if permanent incisors have erupted
  - full mouth includes all 3 incisors

IL 1 = 2 ½ years
IL 2 = 3 ½ years
IL 3 = 4 ½ years

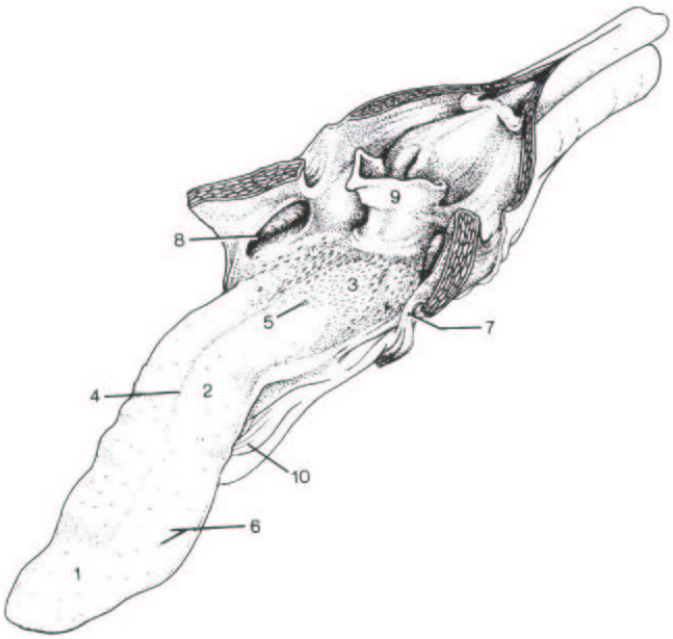


Incisors of the horse showing wear characteristics. **A.** Longitudinal section. **B.** Transverse section. **C.** Table surfaces illustrating full mouth, 1) in wear, 2) smooth mouth

iv. wear characteristics

- mouth is in wear when two complete enamel rings are present on the table surface of each incisor
- approximate ages for each pair of incisors to be in wear are 6, 7, and 8 years for I1, I2, and I3
- judgment is made regarding the loss of the inner enamel ring and appearance of the pulp cavity (dental star)
    - 11, 12, and 13 years for I1, I2, and I3
- a horse has a smooth mouth when these occur in all three pairs of incisors
- rough approximation of horse ages for
    - full mouth 5 years
    - in wear 10 years
    - smooth mouth 15 years

3. Tongue
    a. muscular organ used to maneuver the food mass
    b. tongue can be differentiated from other muscle tissues, because it has fibers oriented in three directions
    c. rough surface of the tongue is provided by numerous projections known as papillae
        i. provide traction for moving the food within the mouth
        ii. help in grooming themselves and offspring
    d. process of digestion is aided by discriminatory taste buds located on the tongue surface within the vallate and fungiform papillae



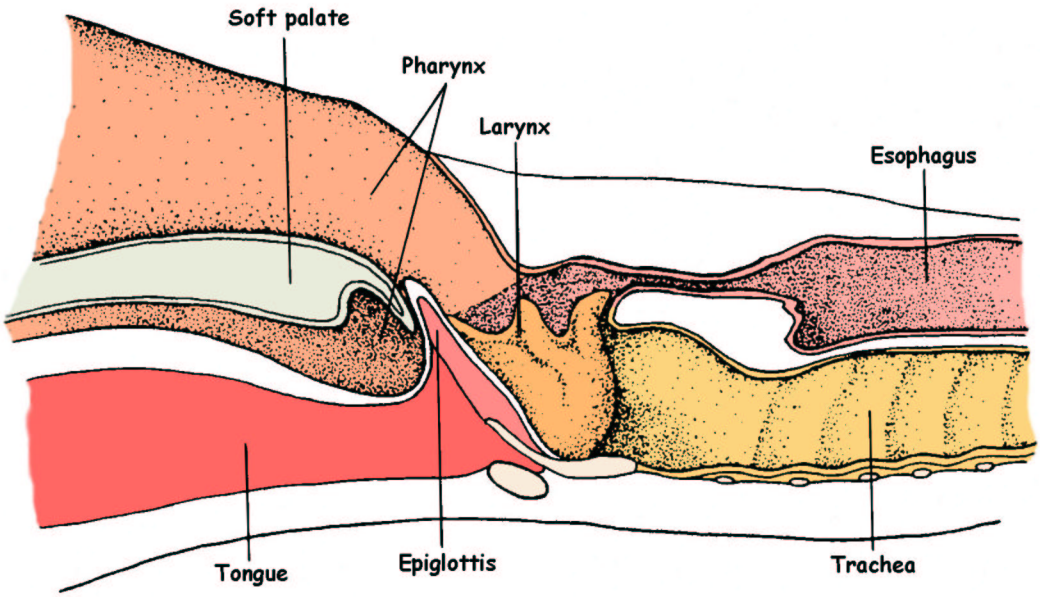
The tongue of a dog: 1 – apex, 2 – body, 3 – root, 4 – median groove, 5 – vallate papilla, 6 – fungiform papillae, 7 – palatoglossal arch, 8 – palatine tonsil in tonsillar fossa, 9 – epiglottis, 10 – frenulum

D. Pharynx
    1. Common passageway for food and air

2. Opens into mouth, nasal cavities, eustachian tubes, larynx and esophagus
3. Passage of food through the pharynx and into the larynx and nasal cavities is prevented due to reflex and mechanical factors.

E. Esophagus

1. Muscular tube extending from the pharynx to the stomach
2. During its course to the stomach, the esophagus traverses the thorax within the mediastinal space.



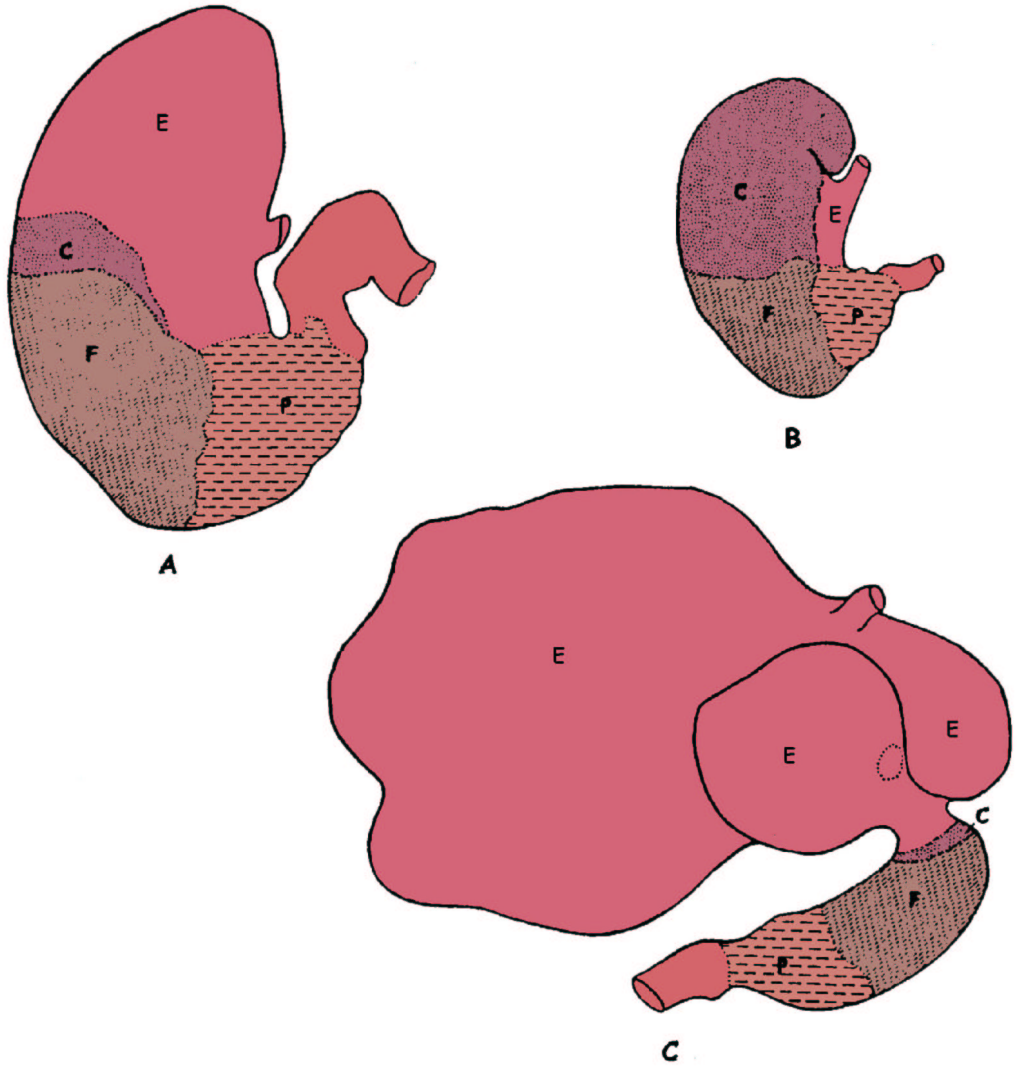
Sagittal section of the pharynx, esophagus, and trachea. The darker stippled areas relate to the route of food intake. Reflexes associated with swallowing facilitate the safe passage of food from the pharynx into the esophagus.

3. esophagus then passes through the diaphragm into the abdominal cavity and enters the stomach
4. Food and fluids are moved from the pharynx to the stomach by muscular waves of contraction.
5. The esophagus is normally closed at the pharyngeal end by the tonic activity of the cranio-esophageal sphincter.
6. The esophagus remains closed at the opening to the stomach (cardia), because of a closure that is physiologic in nature.
7. On its way to the stomach, the esophagus courses along the left side of the trachea. Bolus transport can be observed by watching the left side of the neck (especially in ruminants)

F. Stomach

1. Food is received by the stomach for storage (pending further digestion) and for continuation of digestion.

2. Primary regions as viewed from outside:
    a. cardia
        i. located nearest the esophagus
        ii. continued by the fundus
    b. fundus
        i. dome-shaped part of the stomach
        ii. fundus is adjacent to the corpus
    c. corpus
        i. rounded bae or bottom
    d. antrum
        i. constricted part that joins duodenum

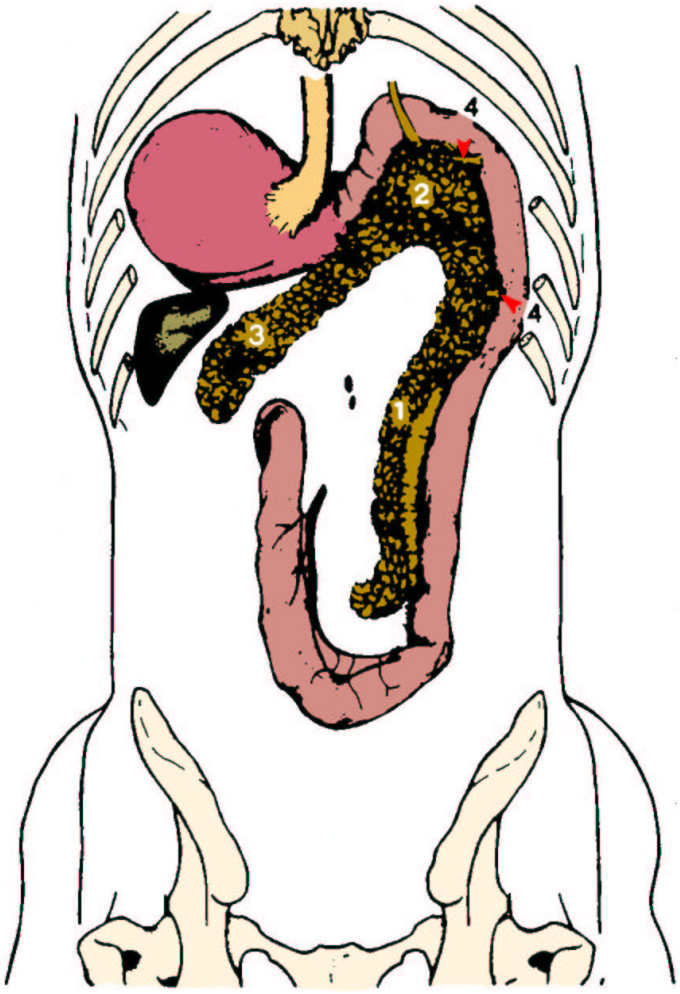


Inner regions of the stomach. **A.** Horse; **B.** Pig; **C.** Ruminant.
E = Esophageal region, C = Cardiac gland region, F = Fundic gland region, P = Pyloric gland region

3. Regions of stomach as defined by cell type (inner aspect)
    a. esophageal gland region
    b. cardiac gland region
        i. secretes mucous

c. fundic gland region
    i. entire space between cardiac and pyloric gland regions
    ii. These glands are sometimes called gastric glands.
    iii. secrete hydrochloric acid and pdpsinogen
d. pyloric gland region
    i. secrete mucous and the hormone gastrin

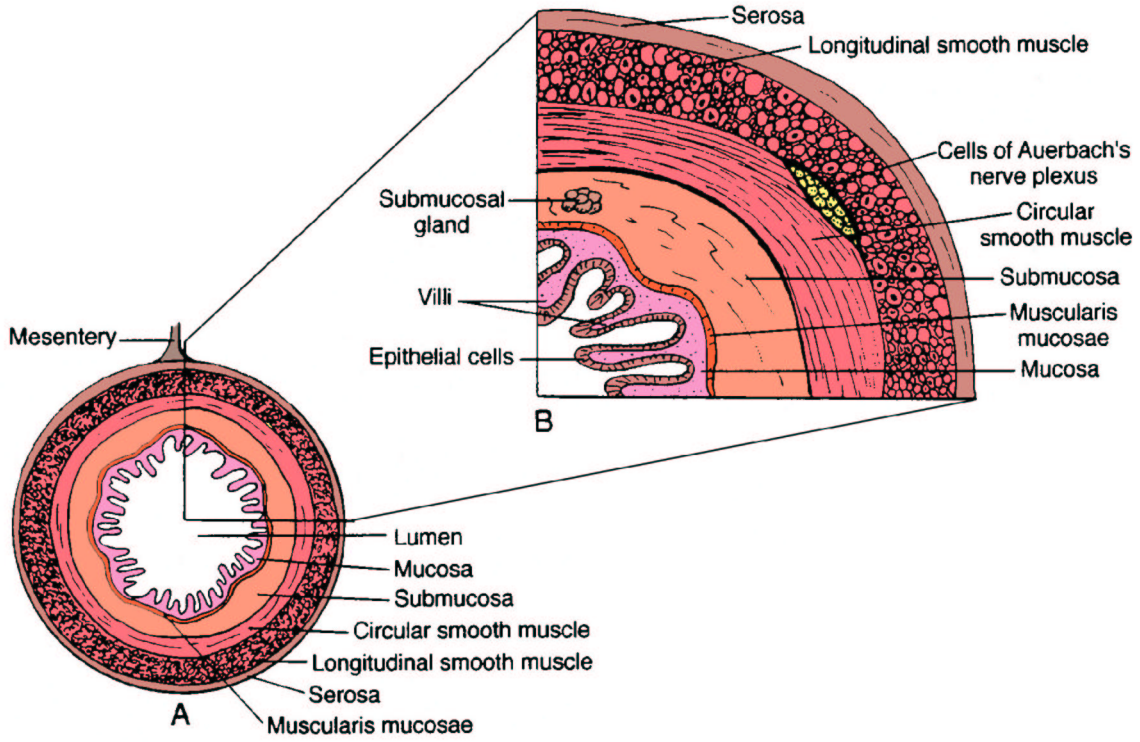
4. Ruminant stomachs
    a. foregut fermentation
    b. includes the rumen, reticulum (omasum) and abomasums
    c. true stomach is the abomasum



Dorsal view of the canine stomach, duodenum, and pancreas.
1. right lobe of pancreas, 2. body of the pancreas, 3. left lobe of the pancreas, 4. pancreatic ducts
The common bile duct is received into the duodenum in close association with the anterior pancreatic duct.

G. Small intestine
1. The contents of the stomach enter the small intestine after their preparation in the stomach.
2. The small intestine is comprised of three segments:

a. duodenum
    i. closely connected to the pancreas
    ii. receives pancreatic secretions
    iii. also receives bile
b. jejunum
c. ilium



Schematic representation of the general organizational features of the mammalian gastrointestinal tract. **A.** Cross-section of small intestine with its mesenteric suspension that envelops the intestine as its serosa. **B.** Section from **A** to show greater detail. The Auerbach nerve plexus controls gastrointestinal movements. Meissner's plexus (not shown) is in the submucosa and it controls secretions and blood flow. The muscularis mucosae produces folds in the mucosa for amplification of surface area.

3. The inner layer of the small intestine, having intimate contact with the contents of the lumen, is composed of an epithelial cell layer known as the mucosa.
4. The submucosa is a connective tissue layer that provides space for blood vessels, lymph vessels, and nerve fibers.
    a. There is also a sparse layer of smooth muscle fibers known as the muscularis mucosa.
        i. individual fibers from the muscularis mucosa attach to villi and cause movement when contracting

    b. A nerve network (Meissner's plexus) in the submucosa is important in controlling secretion s of the epithelial cells and blood flow.
        i. This network also serves a sensory function via stretch receptors.

ii. Another nerve plexus (Auerbach's plexus), between the inner circular and outer longitudinal muscle layers is important in controlling gastrointestinal movement.
- These two nerve plexus are referred to as the enteric nervous system, which extends from the esophagus to the anus.

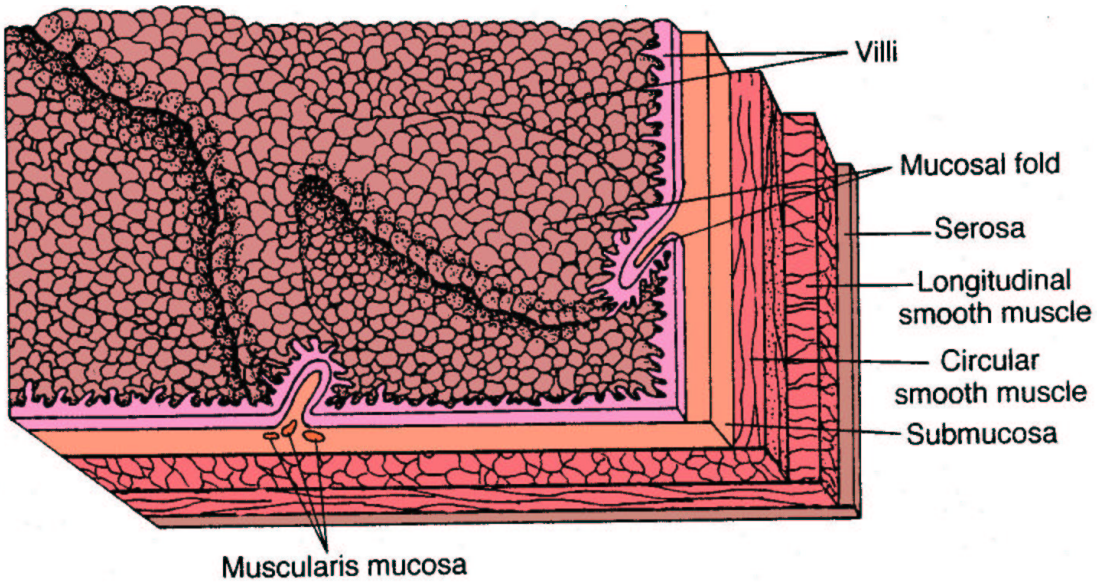
c. The outer layer of the intestine is the serosa. It covers the intestine and is continuous with the mesentery, which suspends the intestine within the abdominal cavity.
i. the mesentery is in turn continuous with the peritoneum

d. The surface are of the intestine is increased by long length and folding of the tissue within the intestine.
i. folds or placations are covered with villi and the individual cells that cover the villi have their own micriovilli
ii. microvilli provide for the greatest amplification of surface area and constitute the brush border
iii. this amplification increases the total surface area of the small intestine about 600 times that of a smooth cylinder of the same size

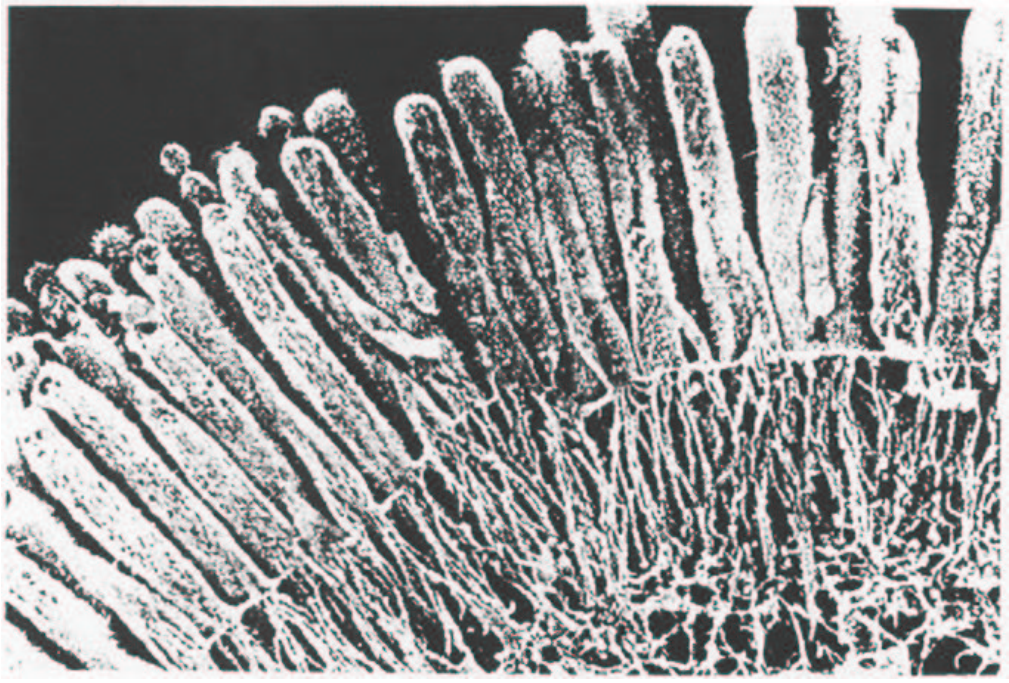
Lengths of Intestinal Parts for Several Species

Animal	Part of Intestine	Relative Length (%)	Average Absolute Length (m)	Ratio of Body Length to Intestine Length

Horse	**Small intestine**	**75**	**22.44**	
	Cecum	**4**	**1.00**	
	Large colon	**11**	**3.39**	**1:12**
	Small colon	**10**	**3.08**	
	Total	**100**	**29.91**	
Ox	**Small intestine**	**81**	**46.00**	
	Cecum	**2**	**0.88**	**1:20**
	Colon	**17**	**10.18**	
	Total	**100**	**57.06**	
Sheep & goat	**Small intestine**	**80**	**26.20**	
	Cecum	**1**	**0.36**	**1:27**
	Colon	**19**	**6.17**	
	Total	**100**	**32.73**	
Pig	**Small intestine**	**78**	**18.29**	
	Cecum	**1**	**0.23**	**1:14**
	Colon	**21**	**4.99**	
	Total	**100**	**23.51**	
Dog	**Small intestine**	**85**	**4.14**	
	Cecum	**2**	**0.08**	**1:06**
	Colon	**13**	**0.60**	
	Total	**100**	**4.82**	
Cat	**Small intestine**	**83**	**1.72**	
	Large intestine	**17**	**0.35**	**1:04**
	Total	**100**	**2.07**	
Rabbit	**Small intestine**	**61**	**3.56**	
	Cecum	**11**	**0.61**	**1:10**
	Colon	**28**	**1.65**	
	Total	**100**	**5.82**	

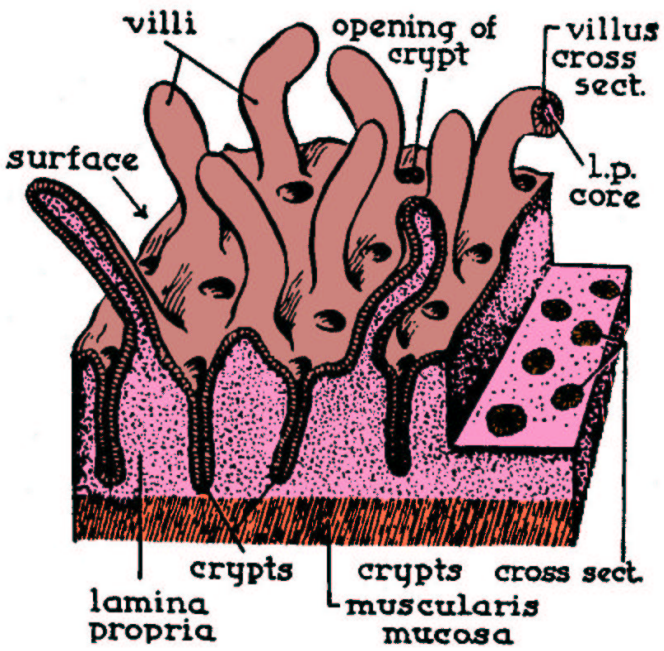


A layered section of intestine as viewed from its inner surface. The folds are produced by strategic contraction of the muscularis mucosa. The projections from the surface represent the villi,, another means of surface amplification.

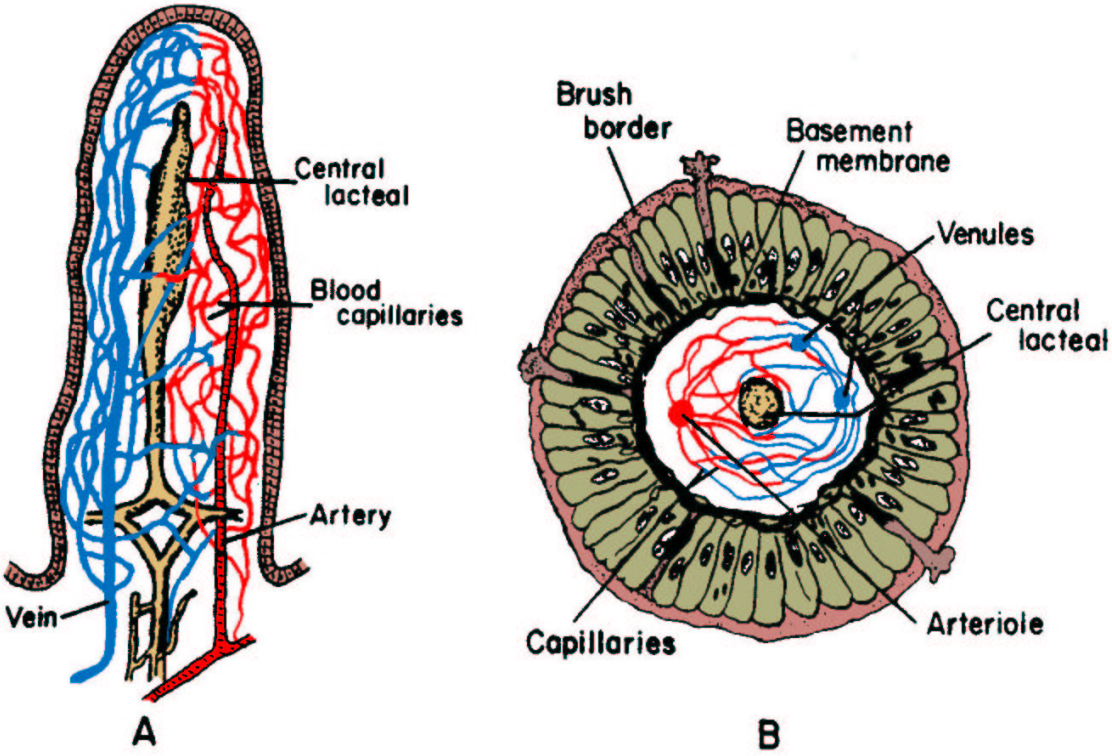


Photomicrograph of microvilli extending from a small intestine epithelial cell.
The cordlike structures extending downward from the microvilli are contractile actin filaments.

e. The crypts of liberkühn are clustered groups of undifferentiated cells between adjacent villi.
    i. only cells of villi to undergo division
    ii. Renewal of cells in the villi is accomplished by migration of new cells away from the crypts.



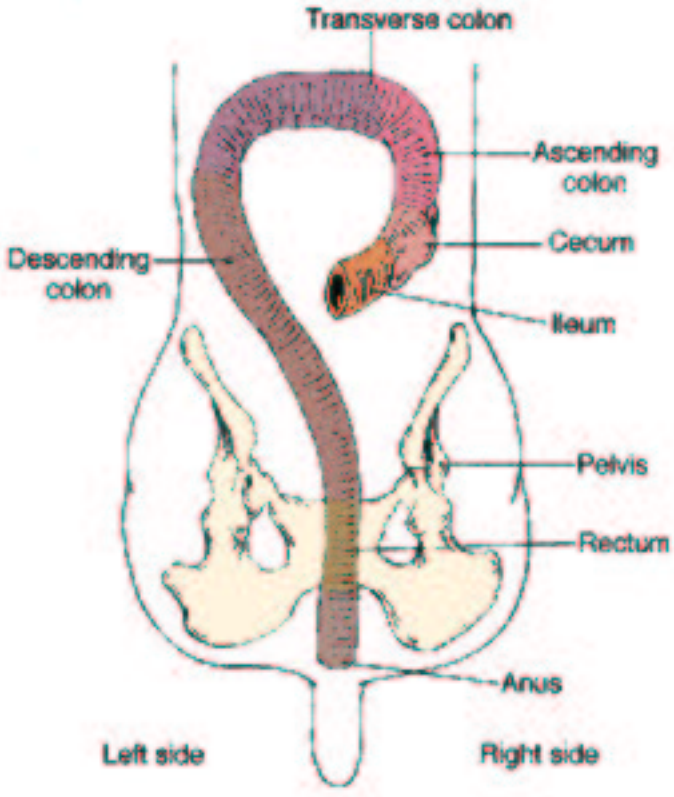
Three-dimensional representation of the small intestine lining.
The vili are finger-like processes with cores of lamina propria that extend into the lumen.
The crypts of Liberkühn are depressions into the lamina propria.



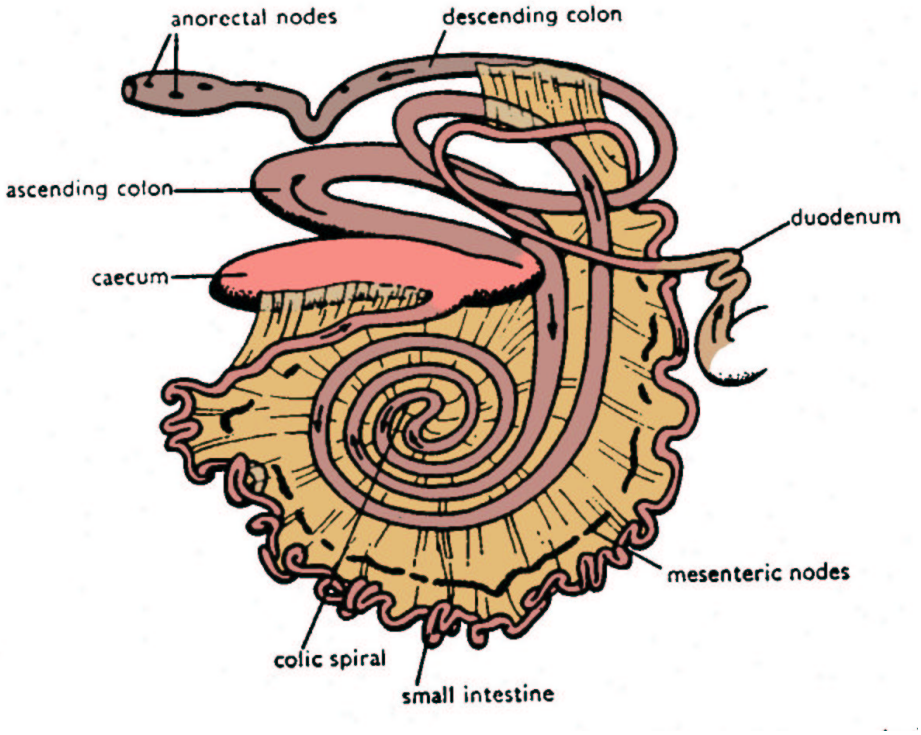
Functional organization of the villus. **A.** Longitudinal section.
B. Cross section showing the epithelial cells and basement membrane.

H. Large intestine

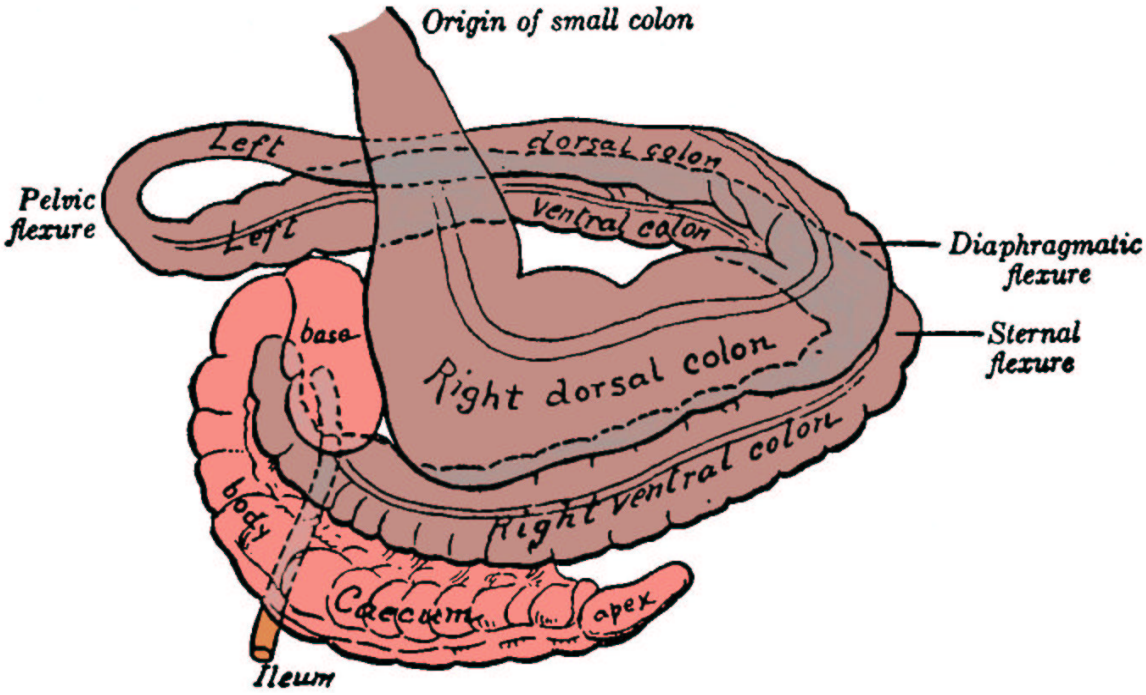
1. Contents from the terminal part of the ileum enter the large intestine at the cecum (ileocecal junction) in the horse, at the colon (ileocolic junction) in the dog, or at the cecumand colon (ileocecolcolic junction) in the ruminant and pig.
2. The large intestine consists of the cecum and colon.
    a. Development of the large intestine varies among animals according to diet.
    b. In ruminants, bacterial and protozoan cells are digested here.
    c. In simple herbivores (e.g. horse) enzymatic digestion precedes fermentation and no microbes or protozoa are available for digestion here.
    d. Food requiring further digestion by fermentation enters or is diverted into the cecum unless it is developed poorly as in the dog.
3. The colon continues from the cecum to its termination at the anus.



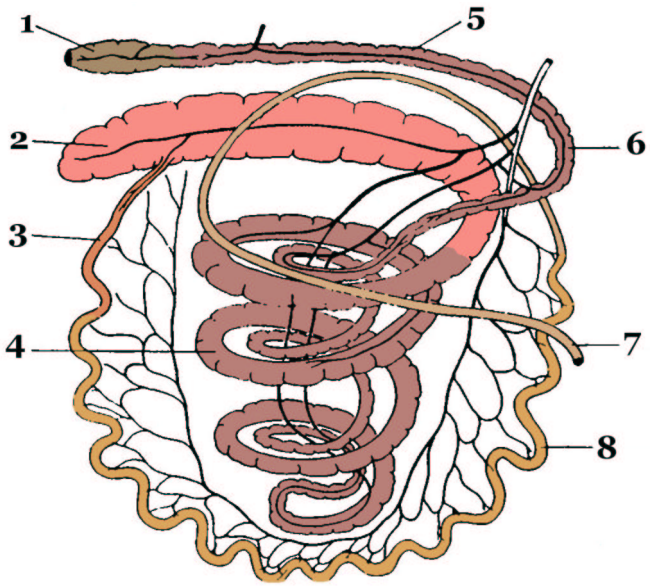
Dorsal view of the dog cecum and colon (large intestine). The dog, a carnivore, has no special arrangement for its ascending colon. The rectum is the pelvic portion of the descending colon that terminates at the anus.



Gastrointestinal tract of the cow showing the colic spiral (asna spiralis).

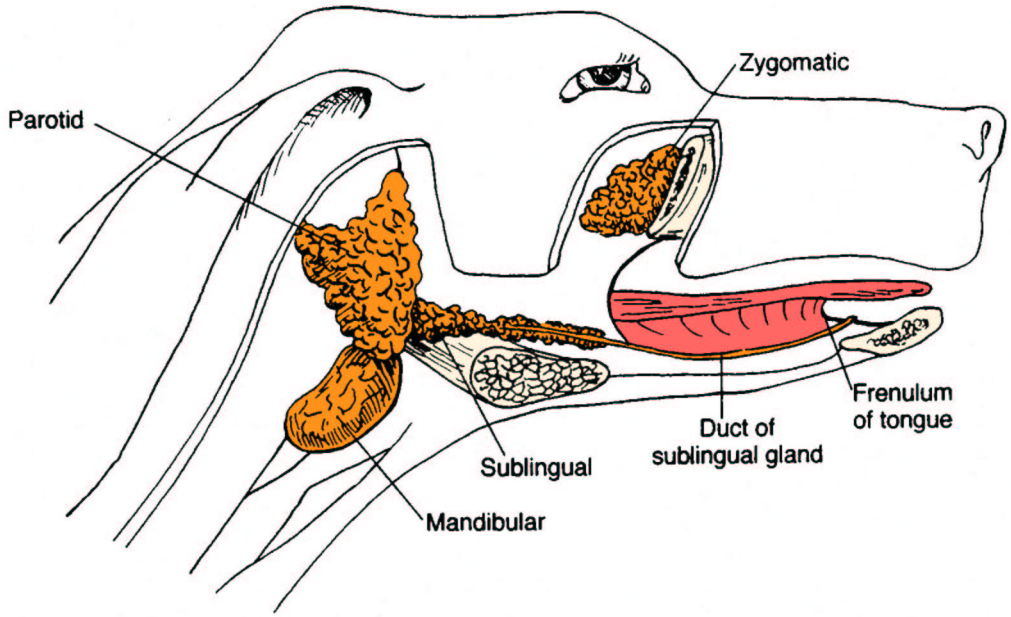


Schematic representation of the cecum and colon of the horse



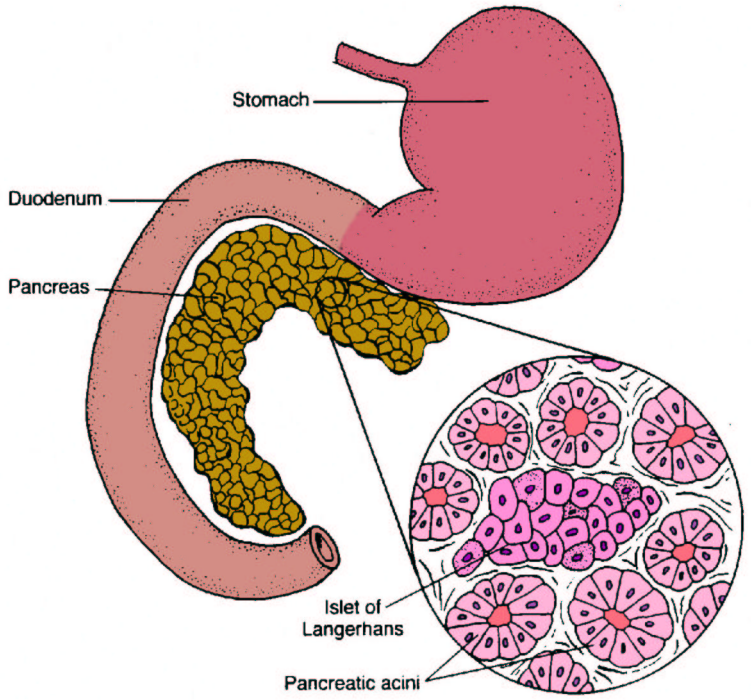
Schematic representation of the intestinal tract of the pig. 1 – rectum, 2 – cecum, 3 – ileum, 4 – ansa spiralis (coiled colon), 5 – descending colon, 6 – transverse colon, 7 – second curve of duodenum, 8 – jejunum.

I. Accessory glands
   1. Salivary glands
      a. three pairs of well-defined glands
      b. glands connected to mouth by ducts
      c. salivary glands are serous, mucous, or mixed depending on secretion
      d. blood vessels and nerves enter each gland where ducts exit
      e. innervation is sympathetic and parasympathetic



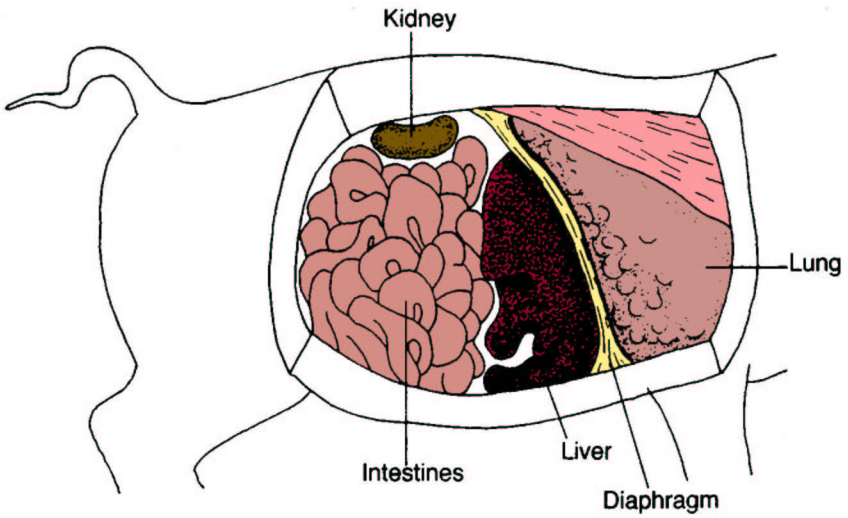
Location of salivary glands in the dog. They are paired glands, and only those on the right side are shown. The right mandible has been removed to show the sublingual salivary gland and its duct. The duct empties on a small papilla located near the anterior end of the frenulum (midventral fold of the tongue).

2. Pancreas
    a. has both endocrine and exocrine function
    b. always located near the first part of the duodenum
    c. appears as elongated gland of loosely connected nodules
    d. main pancreatic duct enters duodenum near common bile duct
        i. in sheep and goats, pancreatic duct enters bile duct
    e. endocrine cells are scattered throughout pancreas
        i. islets of langerhans
        ii. alpha cells produce glucagons
        iii. beta cells produce insulin
        iv. cells secrete directly into the bloodstream

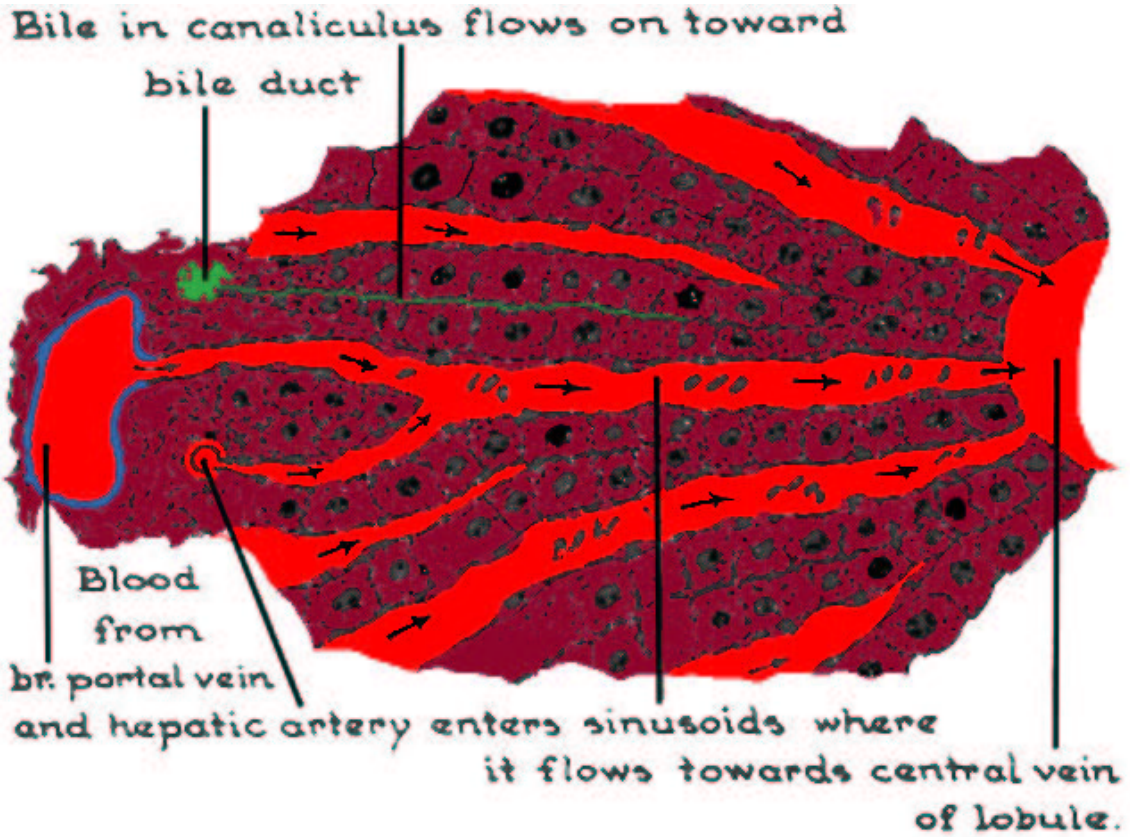


Location of the pancreas and its general appearance. The pancreas is always located near the first part of the duodenum and appears as an elongated gland of loosely connected aggregated nodules. The inset from the pancreas shows an islet of Langerhans (endocrine) situated among a number of pancreatic acini, the exocrine (digestive secretions) portion.

3. Liver
    a. multipurpose organ
    b. always located immediately behind the diaphragm
    c. in ruminants it tends to be on the right side
    d. lobules of the liver are clearly demarcated
    e. liver receives arterial blood through hepatic artery and venous blood through portal vein
        i. portal vein drains stomach, spleen, pancreas, and intestines
        ii. blood from both sources is circulated through the sinusoids
            - here it is detoxified and modified before returning via the hepatic vein to the vena cava



The pig liver and its location relative to other organs. Because of the large amount of interlobular connective tissue, the lobules are mapped out sharply. For this reason, the liver is much less friable (easily broken) than that of other animals.



Portion of a liver lobule (highly magnified). Blood from the portal vein and hepatic artery flows into sinusoids (lined with Küpffer cells) and empties into the central vein. Bile travels in the opposite direction in canaliculi to empty into bile ducts in the triad areas.

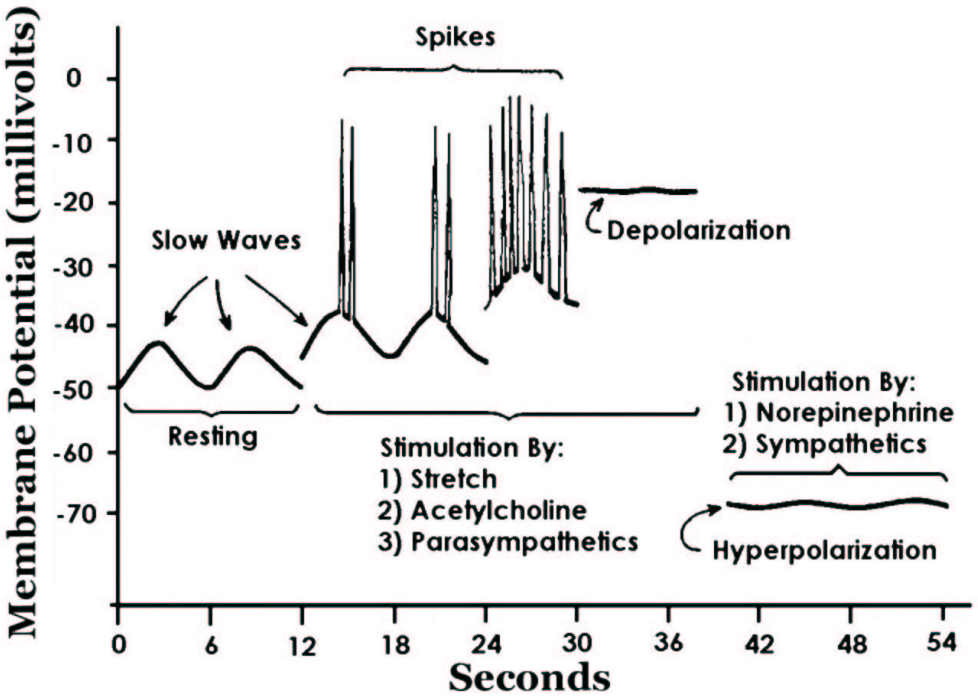
II. Physical and Mechanical Factors

A. Prehension
    1. Seizing and conveying food into the mouth
        a. mouth, tongue, and lips

B. Mastication
    1. mechanical breakdown of food in the mouth
    2. A bolus of food is formed by the mastication process.
    3. bolus is mixed with saliva, which provides adhesiveness

C. Deglutination
    1. act of swallowing
    2. conveys the food mass from the mouth to the stomach
    3. some degree of consciousness is required, because activity is voluntary
        a. inhaling food and vomitus is possible when unconscious

D. Smooth muscle activity
    1. Once food reaches the stomach, its movement is controlled by the activity of the smooth muscles of the stomach and intestine.
    2. muscle activity is spontaneous and controlled by autonomic nervous system
    3. segmentation is represented by contractile waves that travel short distances
    4. peristaltic waves travel longer distances and usually move in and arboreal direction
    5. An important intrinsic reflex for the small intestine is the peristaltic reflex.
        a. initiated by distention of the bowel
        b. hormones gastrin and cholecystokinin are know to stimulate gastrointestinal smooth muscle and affect the rate of passage

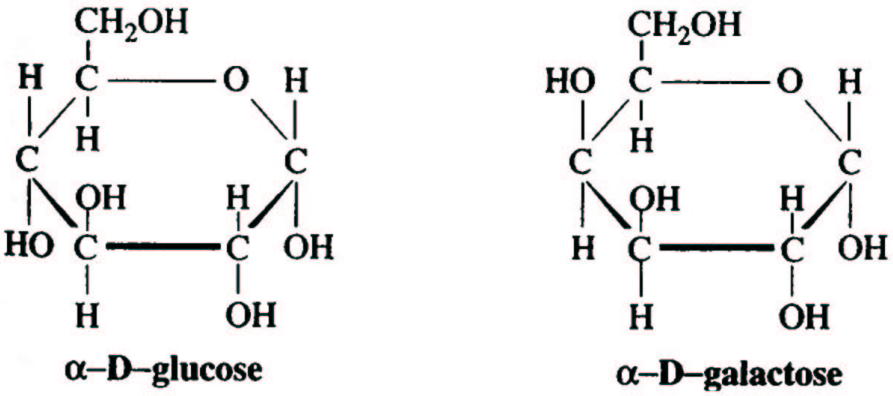


Membrane potentials in mammalian intestinal smooth muscle. Note the slow waves, spike potentials, and directions of depolarization and hyperpolarization.

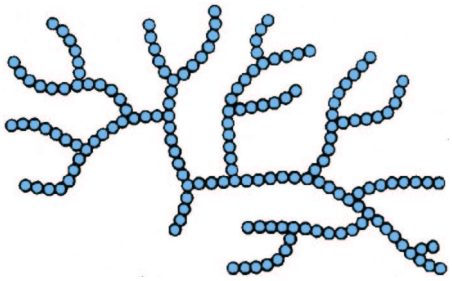
E. Physical functions of the stomach and intestine
    1. mixing food with secretions
    2. control of emptying of its contents
        a. Delay of gastric emptying
            i. Neural mechanism (enterogastric reflex)
                - osmoreceptors detect hypertonicity
                - excessive protein or carbohydrate is also effective in delaying gastric emptying
                - other receptors respond to high hydrogen ion concentrations
                - cholecystokinin slows gastric emptying to aid in fat digestion
                - gastric inhibitory polypeptide (GIP) is secreted by the jejunal mucosa in response to high lipid and carbohydrate content of the diet

III. Composition of Foodstuffs

A. Six basic foodstuffs are classified as:
    1. Carbohydrates
        a. classified as monosaccharides, disaccharides, or polysaccharides depending on number of pentose or hexose carbon units they contain
        b. primary food
        c. glycogen represents principal carbohydrate reserve

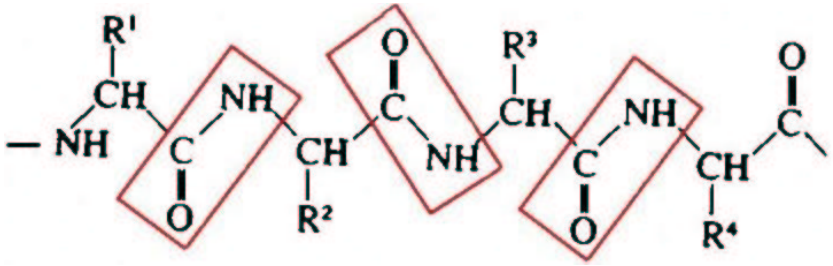


Chemical structure of monosaccharides are represented by glucose and galactose.



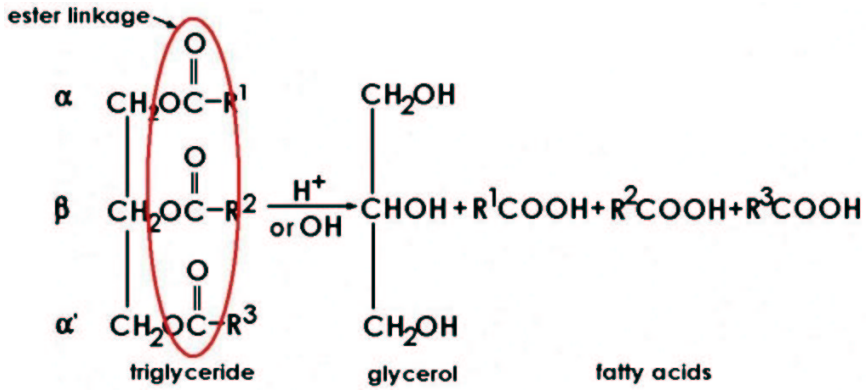
Schematic representation of the highly branched glycogen molecule.
Each bead of the chain represents a glucose molecule.

2. Proteins
    a. complex, high molecular weight, large, colloidal molecules that contain a high percentage of amino acids; important source of nitrogen – primary food
    b. Essential amino acids are those that cannot be synthesized at all or rapidly enough to permit normal growth. They must be acquired in the diet.
    c. Non-essential amino acids are those that the animal can synthesize.

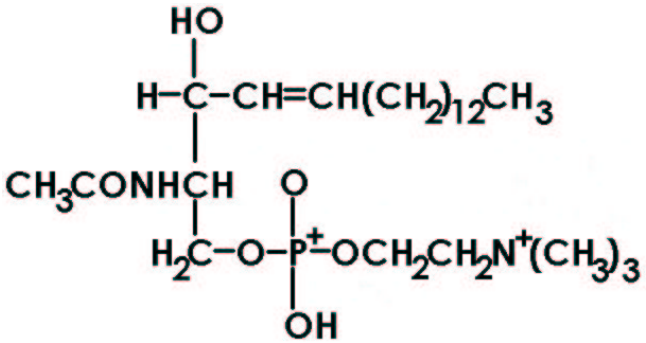


A polypeptide chain, the basic primary structure of a protein. The peptide bonds are shown by the areas boxed by the red boxes.

3. Lipids
    a. include fat and related substances – primary food



Hydrolysis of a simple lipid. Three molecules of long-chain fatty acids and one molecule of glycerol are released when a triglyceride molecule is hydrolyzed. The great majority of lipids are triglycerides. Lipids are esters of glycerol and fatty acids. The ester linkages are shown within the area circumscribed by the red circles.



Sphingomeylin, this phospholipid is common to myelin sheaths of nerve fibers.

4. Water
    a. Water is considered an accessory food, but it is essential to live.
5. Inorganic salts
    a. minerals are required for skeletal development and many chemical reactions that occur during metabolism
    b. minerals only required in trace amounts are called trace minerals
    c. combined amount of mineral in the diet is determined by ashing (burning) of the food source
    d. considered an accessory food
6. Vitamins
    a. group of chemically unrelated organic compounds
    b. generally function as metabolic catalysts usually in the form of coenzymes
    c. considered an accessory food

IV. Digestive Secretions and Their Functions

A. Saliva – facilitates mastication and deglutition
1. volume varies considerably among species
2. cow can produce 25 – 50 gallons per day
3. can perform cooling function
4. contains amylase for starch digestion

B. Gastric secretions
1. mucous – protective function
2. pepsinogen – converted to pepsin by HCl
3. gastrin – stimulates secretion of HCl
4. hydrochloric acid
5. rennin – in young ruminants – coagulates milk protein

C. Pancreatic secretions
1. HCO_3^- neutralizes HCl content of stomach contents entering the duodenum
2. enzymes included all those needed for digestion of fat, protein, and carbohydrates
    a. amylase
    b. trypsinogen
    c. chymotrypsinogen
    d. elastase
    e. carboxypeptidase
    f. pancreatic lipase

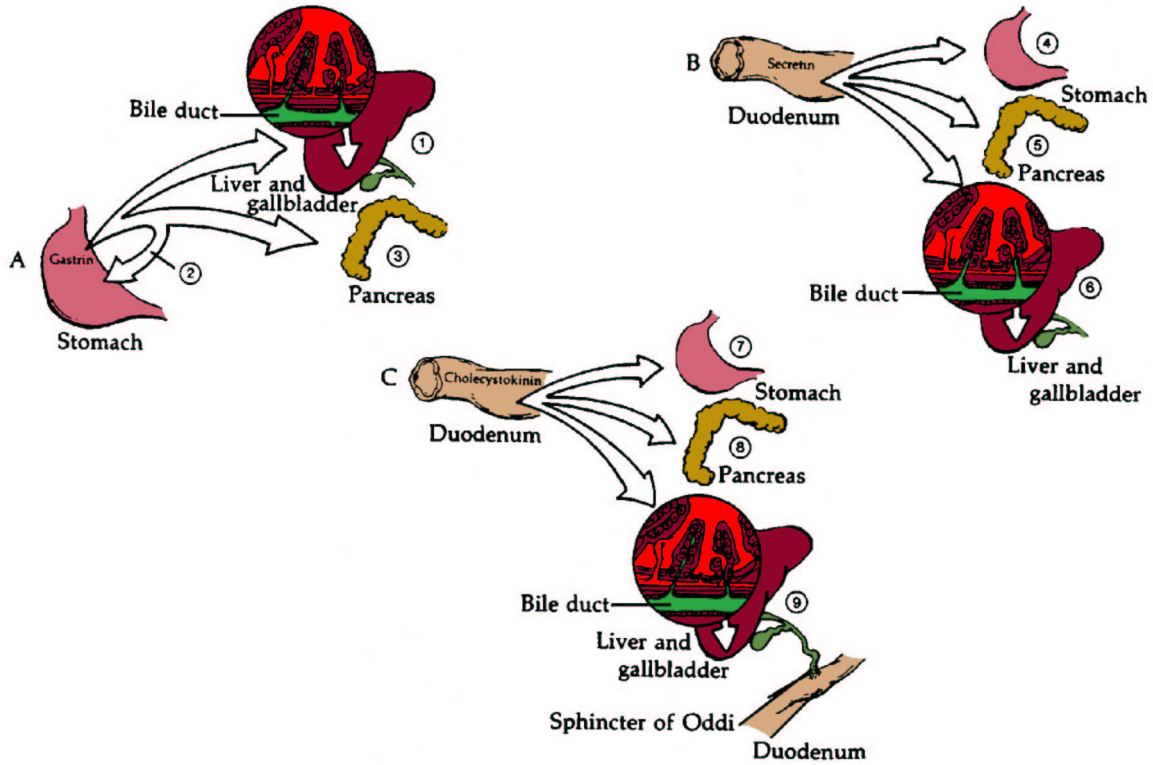
D. Biliary secretion
1. Bile is a greenish-yellow solution of bile salts, bilirubin, cholesterol, lecithin, and electrolytes.
2. Bile salts are produced continuously by the liver, but the amount required for digestion far exceeds production, therefore they are recirculated from the intestine to the hepatic cells (portal circulation)
3. Bile salts are synthesized from cholesterol
4. The only domestic animal without a gallbladder is the horse.
5. Fat in the intestine is emulsified by bile salts and lecithin.

V. Breakdown and Absorption of Carbohydrates, Proteins, and Fats

A. Most digestion of carbohydrates, proteins, and fats occurs in the small intestine

(except in ruminants).

1. Carbohydrate
    a. amylase breaks down starch to maltose
    b. maltose is further degraded by maltase to monosaccharides
    c. fructose, glucose, and sucrose are all absorbed at brush border
2. Protein
    a. gastric and pancreatic proteases hydrolyze proteins into smaller units
    b. oligopeptidases at the brush border break down oligopeptides to individual amino acids for absorption
    c. amino acids are actively transported into the blood
3. Fat
    a. dietary triglycerides are emulsified by bile salts
    b. triglycerides broken down into glycerol and fatty acids by lipase



The major mammalian gastrointestinal hormones and their association with gastric, pancreatic, and biliary secretions. **A.** Gastrin: 1 – stimulates secretion of HCO_3^- and H_2O from bile duct epithelium, 2 – stimulates HCl and pepsinogen secretion, 3 – stimulates secretion of pancreatic enzymes. **B.** Secretin: 4 – inhibits HCL secretion and stimulates pepsinogen secretion, 5 – stimulates secretion of HCO_3^- and H_2O from pancreas, 6 – stimulates secretion of HCO_3^- and H_2O from bile duct epithelium. **C.** Cholecystokinin: 7 – inhibits HCl secretion, 8 – stimulates secretion of pancreatic enzymes, 9 – stimulates contraction of gall bladder and relaxation of sphincter of Oddi, and stimulates secretion of HCO_3^- and H_2O by bile duct epithelium.

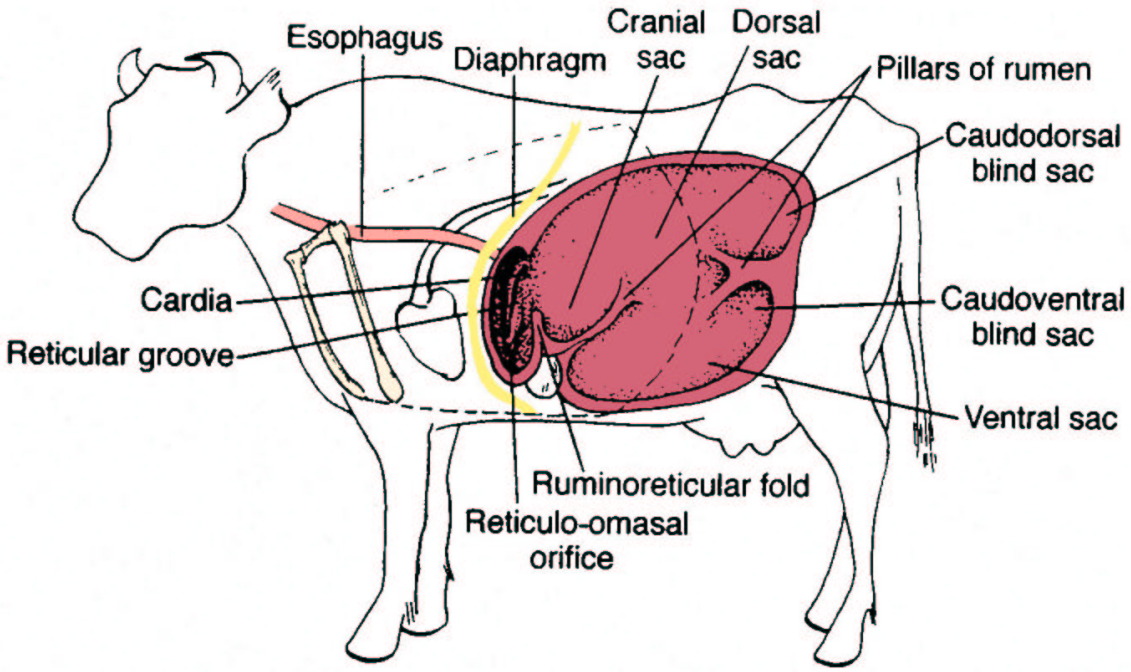
VI. Microbial Digestion in the Large Intestine

A. No enzymatic digestion occurs in the large intestine of mammals.

B. Digestion that occurs results from microbial action which is significant for non-ruminant herbivores and omnivores
C. End products of digestion are volatile fatty acids (VFA's)
    1. acetate
    2. proprionate
    3. butyrate
D. Horses obtain as much as 75% of their energy requirement from large intestinal absorption of VFA's.
E. Large intestine fermentation salvages otherwise lost calories as VFA's and decreases the effective osmotic pressure of the large intestine contents, so that water can be reabsorbed.

VII. The Ruminant Stomach

A. Animals that regurgitate and remasticate their food are called ruminants.
B. The ruminant stomach is adapted for fermentation of ingested food by bacterial and protozoan microorganisms.
C. Mammalian digestive enzymes cannot digest cellulose, however microbial enzymes CAN digest cellulose.

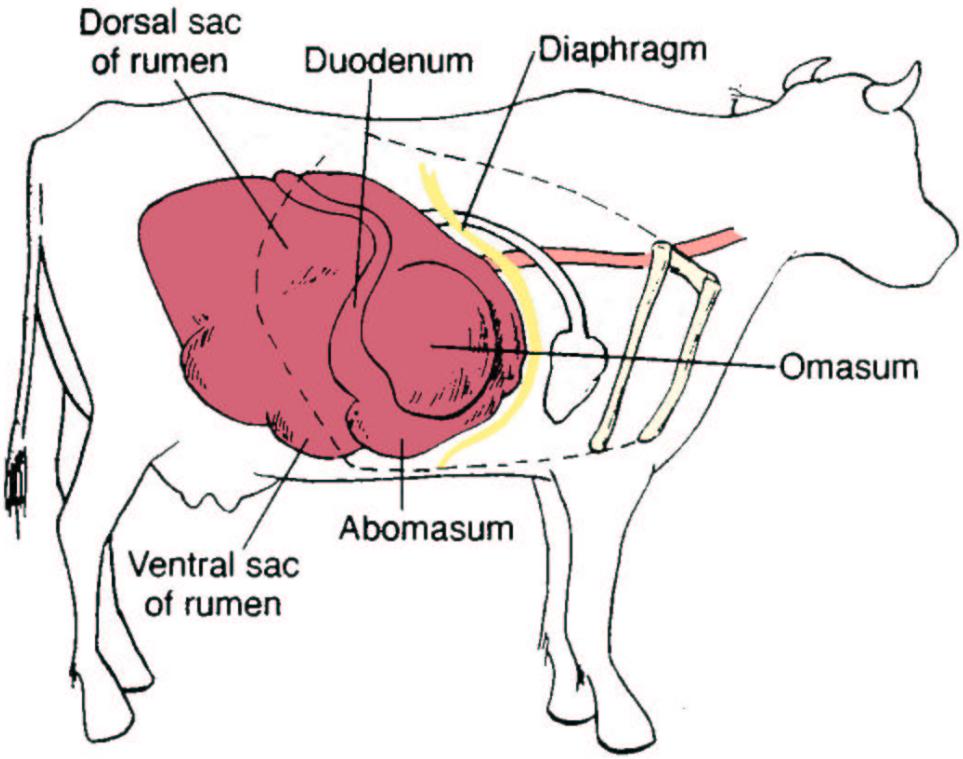


The stomach of cattle (left view). The rumen and reticulum (shown) are two of three compartments of the forestomach that precede the true stomach (abomasum). The reticu.oomasal orifice is the passageway to the third compartment known as the omasum. The rumen is divided into a number of sacs by muscular pillars. Pillar contraction is essential for movement of rumen content.
The dashed line illustrates the extent of the rib cage.

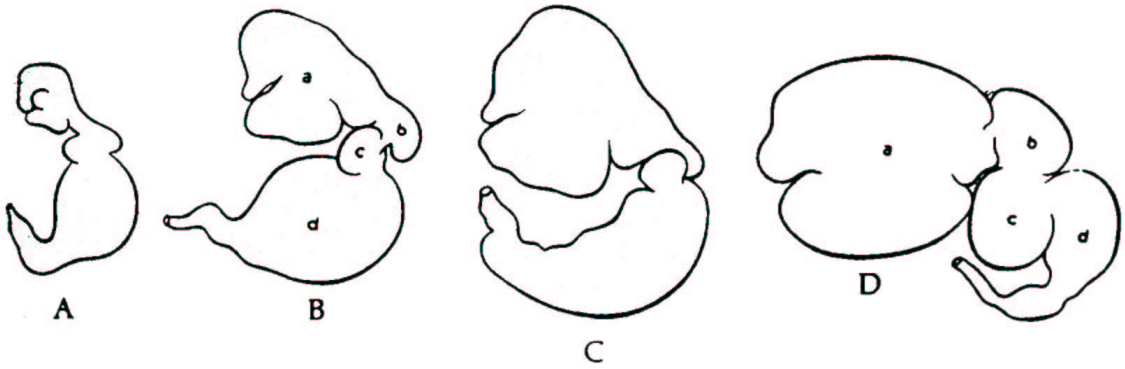
D. Ruminant stomach has four compartments
    1. rumen (paunch) allows for soaking and fermentation of bulk fibrous food,

contents are continually mixed

2. reticulum (honeycomb) serves as pump that causes liquid to flow in and out of the rumen
3. omasum (many plies) provides for continued fermentation and absorption
4. abomasum (true stomach)



The stomach of cattle (right view). The omasum is the third compartment of the forestomach that has a short omasal canal which connects the reticulo-omasal orifice with the omasoabomasal orifice. The dashed line illustrates the extent of the rib cage.



Relative sizes of the bovine stomach compartments at various ages. **A.** 3 days old. **B.** 4 weeks old. **C.** 3 months old. **D.** Adult. a – rumen, b – reticulum, c – omasum, d – abomasum.

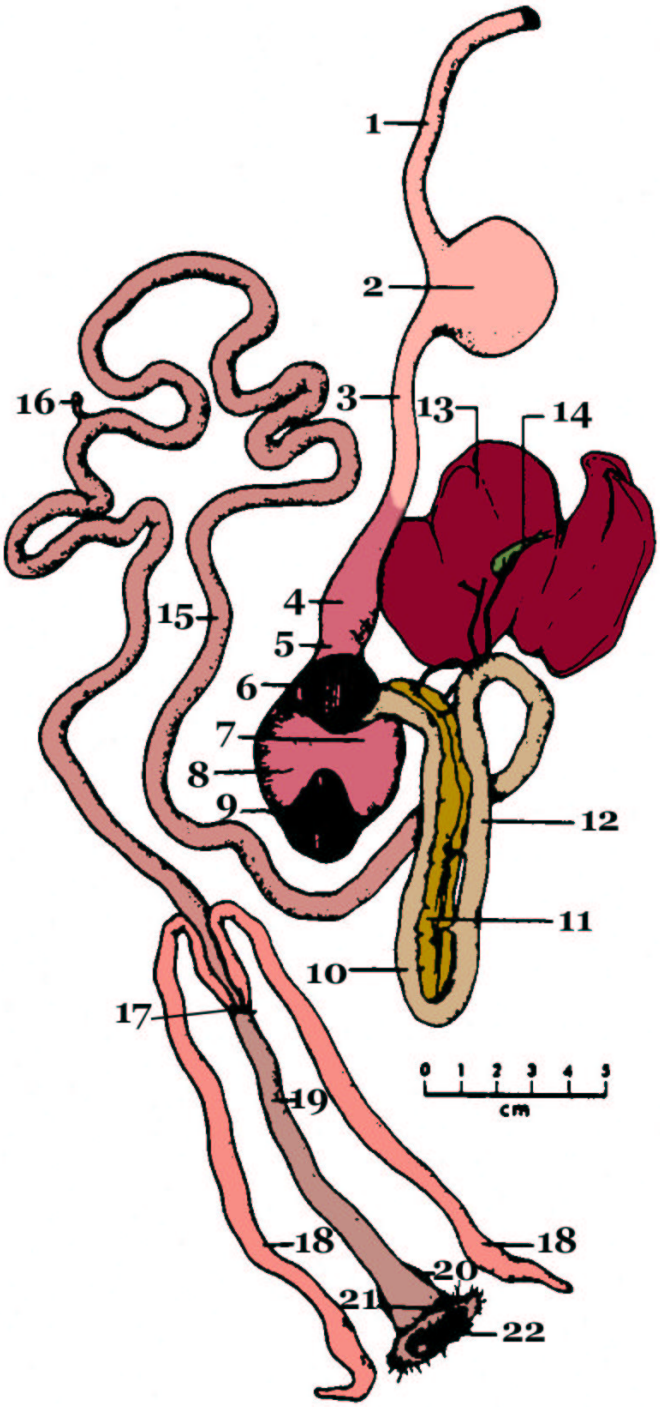
E. Process of rumination
   1. regurgitation

2. remastication
3. reinsalivation
4. redeglutition

F. Byproducts of fermentation
    1. methane (30 – 40% of rumen gas)
    2. carbon dioxide (60 – 70% of rumen gas)
        a. gases mostly eliminated by eructation
    3. volatile fatty acids
    4. protozoa
    5. bacteria

VIII. Avian Digestion

A. Birds have no teeth, therefore the mechanical breakdown of their ingested food is accomplished by the beak and gizzard.
B. Salivary glands are present in birds and well developed in species which consume dry food.
C. The esophagus is divided into precrop and postrcrop segments.
D. The crop is a dilation of the esophagus and has a food storage function.
E. The proventriculus is located between the postcrop, esophagus, and gizzard.
F. The gastric secretions HCl and pepsinogen as well as mucus are secreted by the proventriculus
G. The small intestine has a well-defined duodenum with the pancreas located between its loops, but there is no distinction between6the jejunum and ileum.
H. The ceca, which are paired structures, are located at the junction of the small and large intestine. Here microbial digestion of cellulose occurs.
I. Digestive tract ends with the cloaca, the site that is common to the digestive, urinary, and reproductive tracts in birds.



Digestive tract of a turkey. 1 – precrop esophagus, 2 – crop, 3 – postcrop esophagus, 4 – glandular stomach (proventriculus), 5 – isthmus, 6 – 9 – muscular stomach (gizzard), 10 – proximal duodenum, 11 – pancreas, 12 – distal duodenum, 13 – liver, 14 – gallbladder, 15 – ileum, 16 – Meckel's diverticulum (remnant of yolk sac), 17 – ileocecocolic junction, 18 – ceca, 19 – colon, 20 – bursa of Fabrious, 21 – cloaca, 22 – vent.