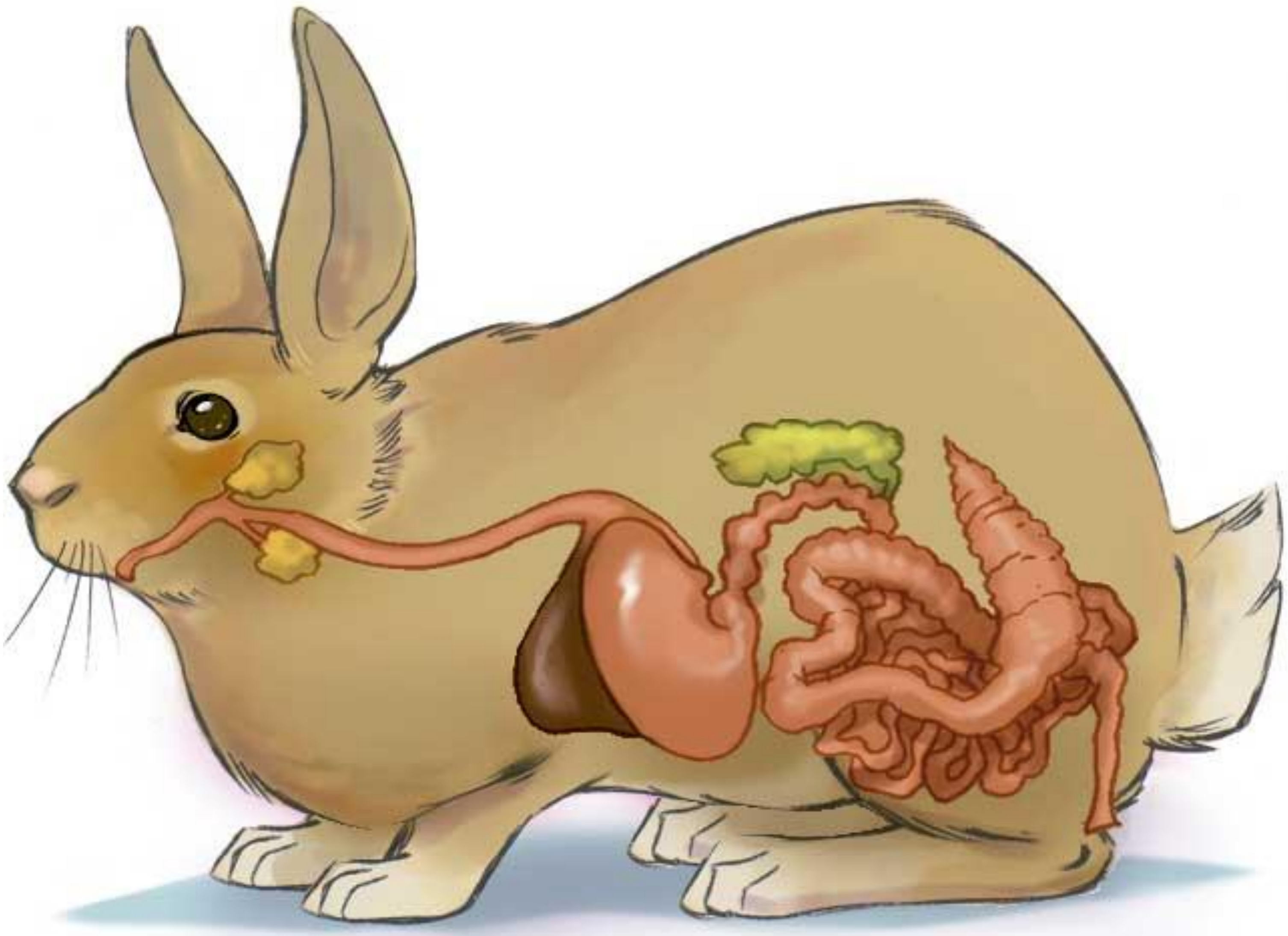
Physiology of Digestive System



Physiology of Digestive System

MOTILITY

SECRETION

DIGESTION

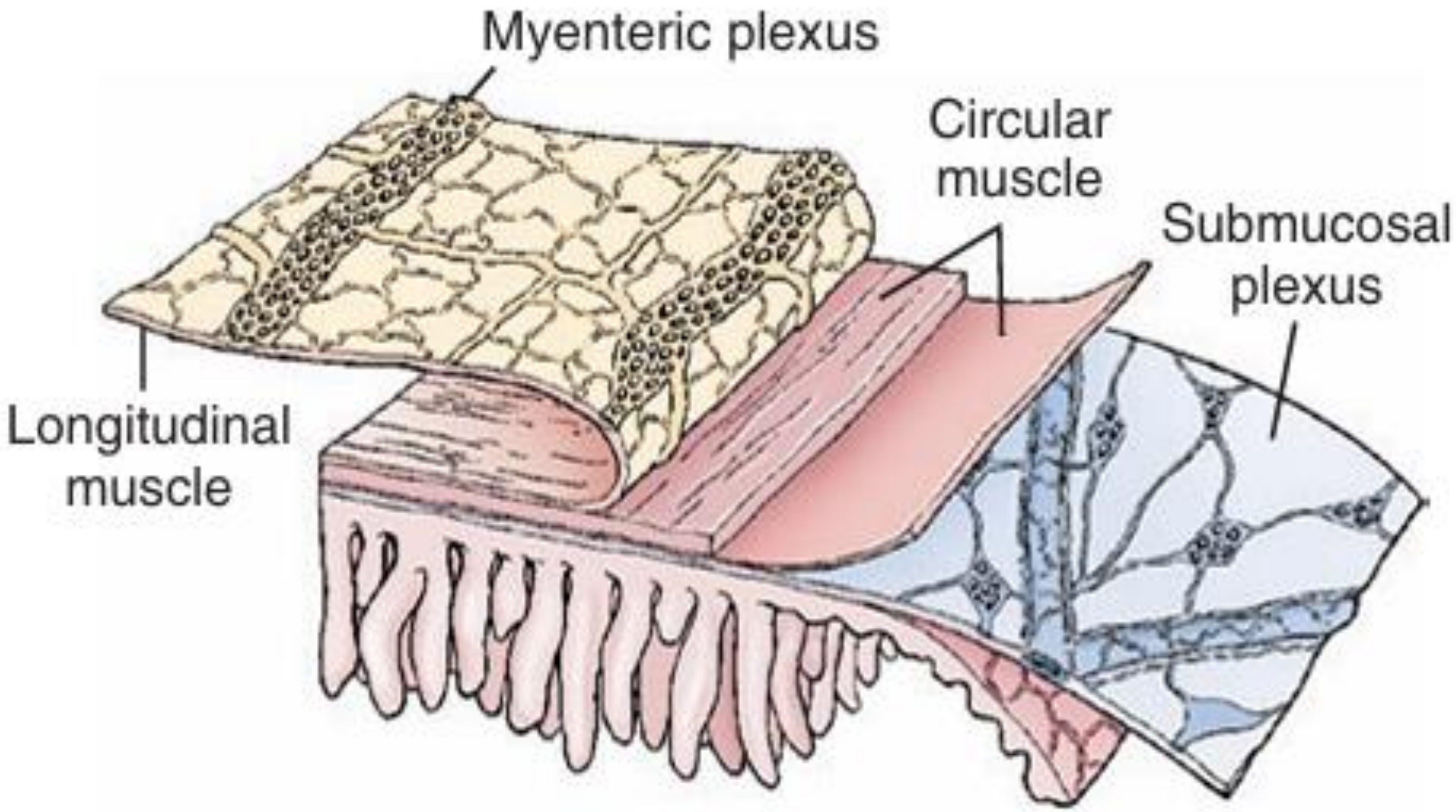
ABSORPTION

Regulation of Motility & Secretion

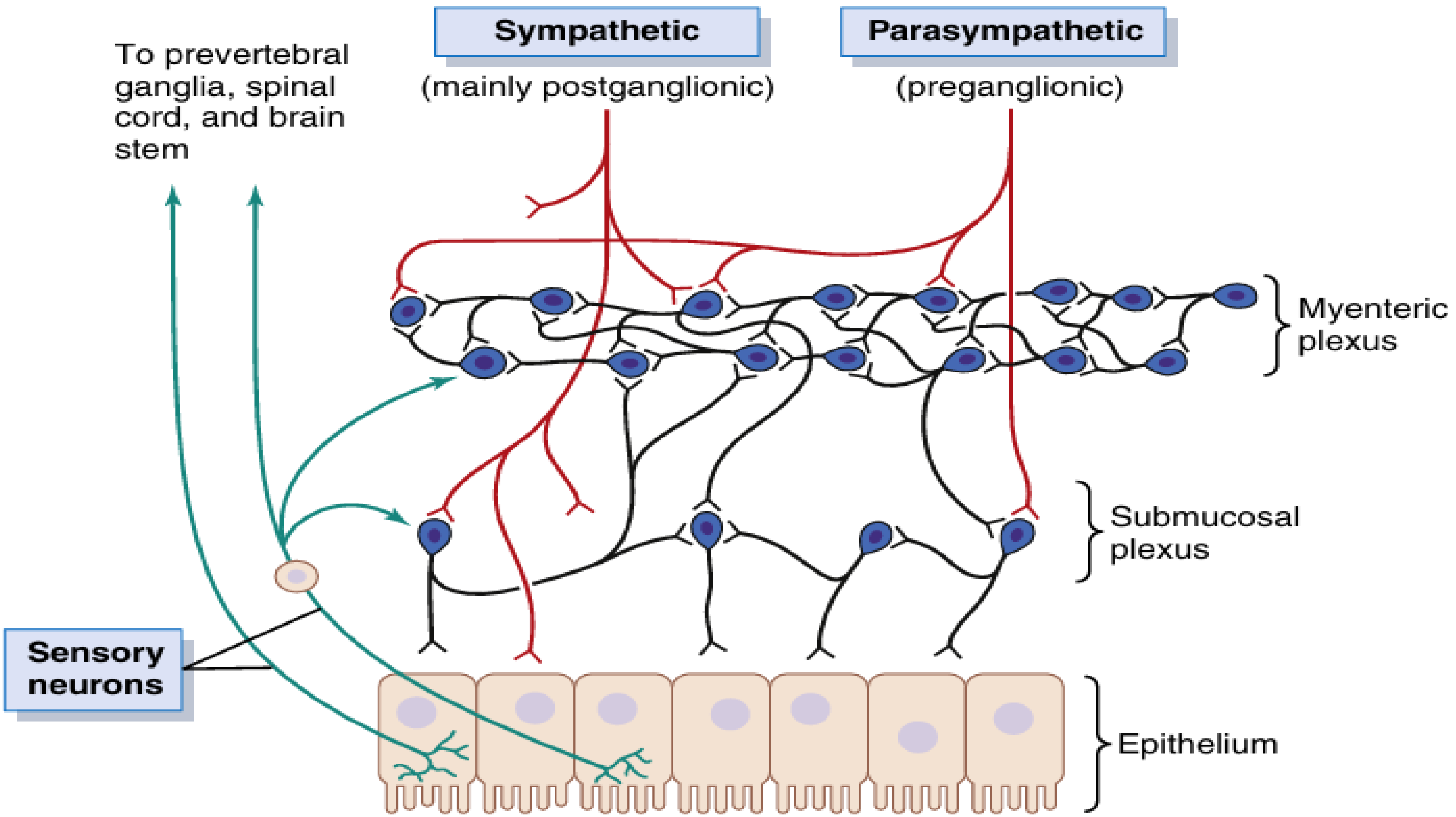
KEY POINTS

1. An independent, intrinsic enteric nervous system lies within the wall of the gut.
2. The enteric nervous system contains receptors, sensory neurons, interneurons, and motor neurons.
3. The gut receives extrinsic innervation from the autonomic nervous system.
4. The gut contains afferent neurons that relay information to the central nervous system.
5. The gastrointestinal system has an intrinsic endocrine system.
6. The immune system participates in regulation of gastrointestinal activity.
7. The regulation of gastrointestinal function is integrated by the interaction of many regulatory molecules acting on multiple cell types in the gut.

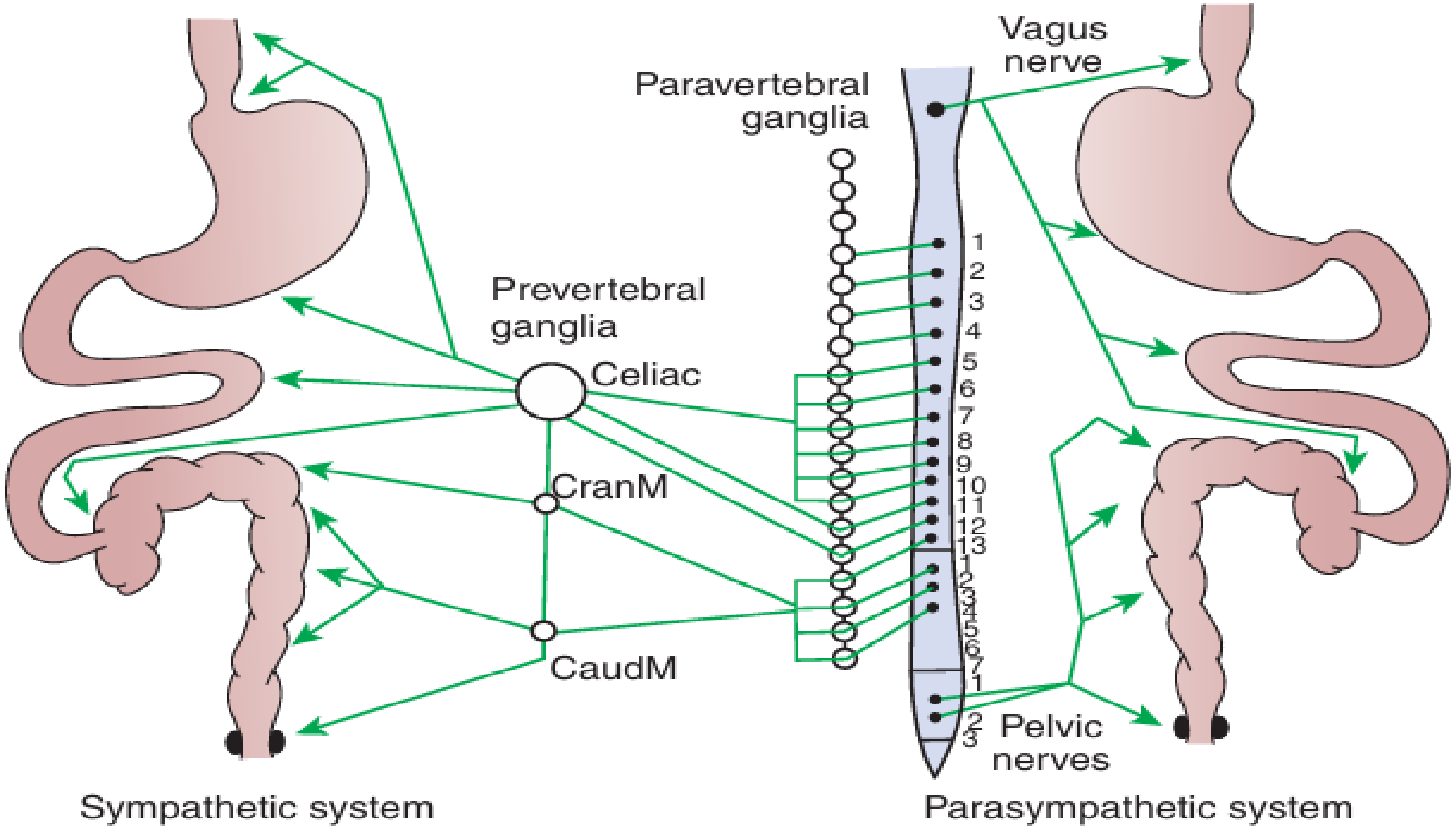
Enteric Nervous System(ENS)



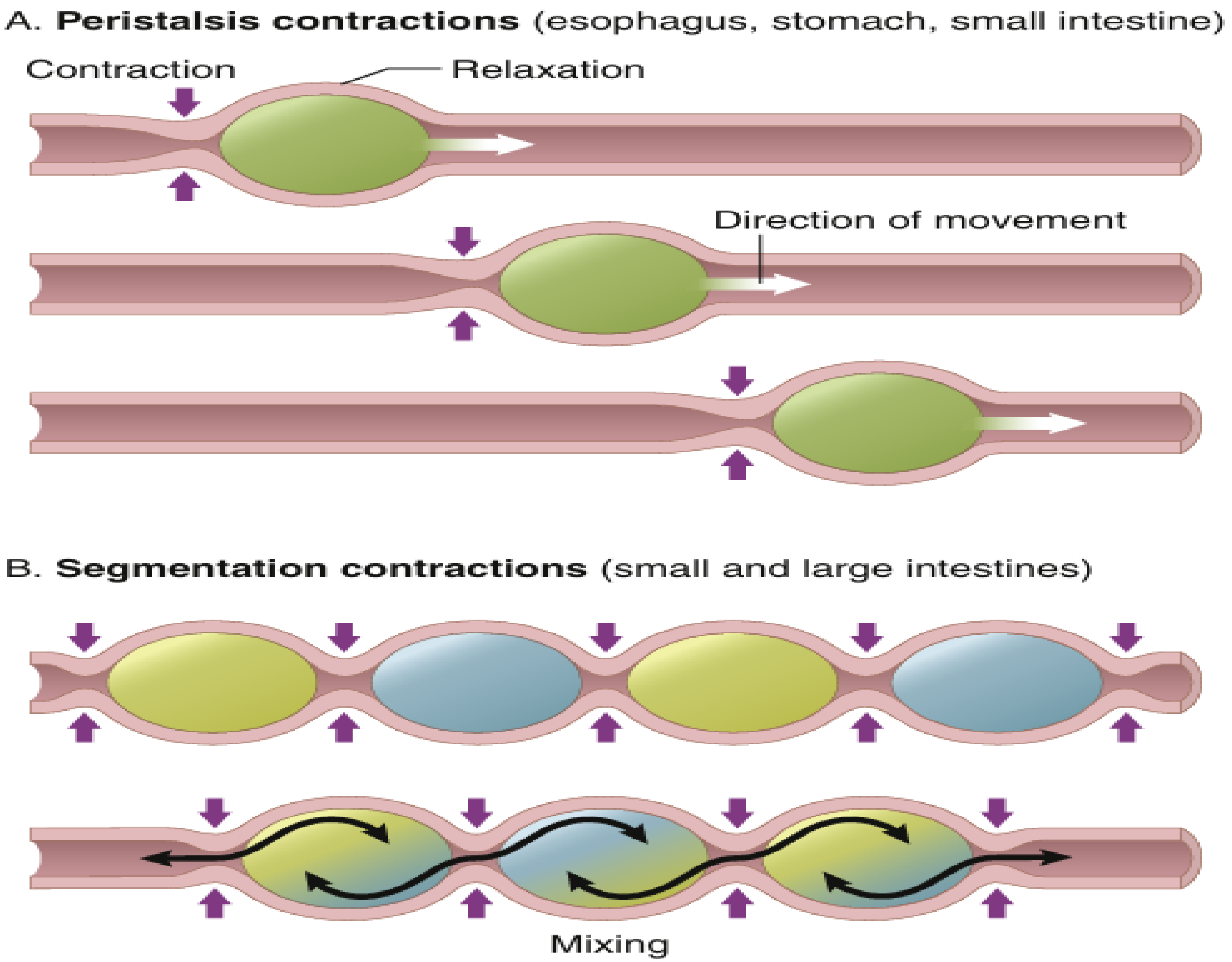
Enteric Nervous System(ENS)



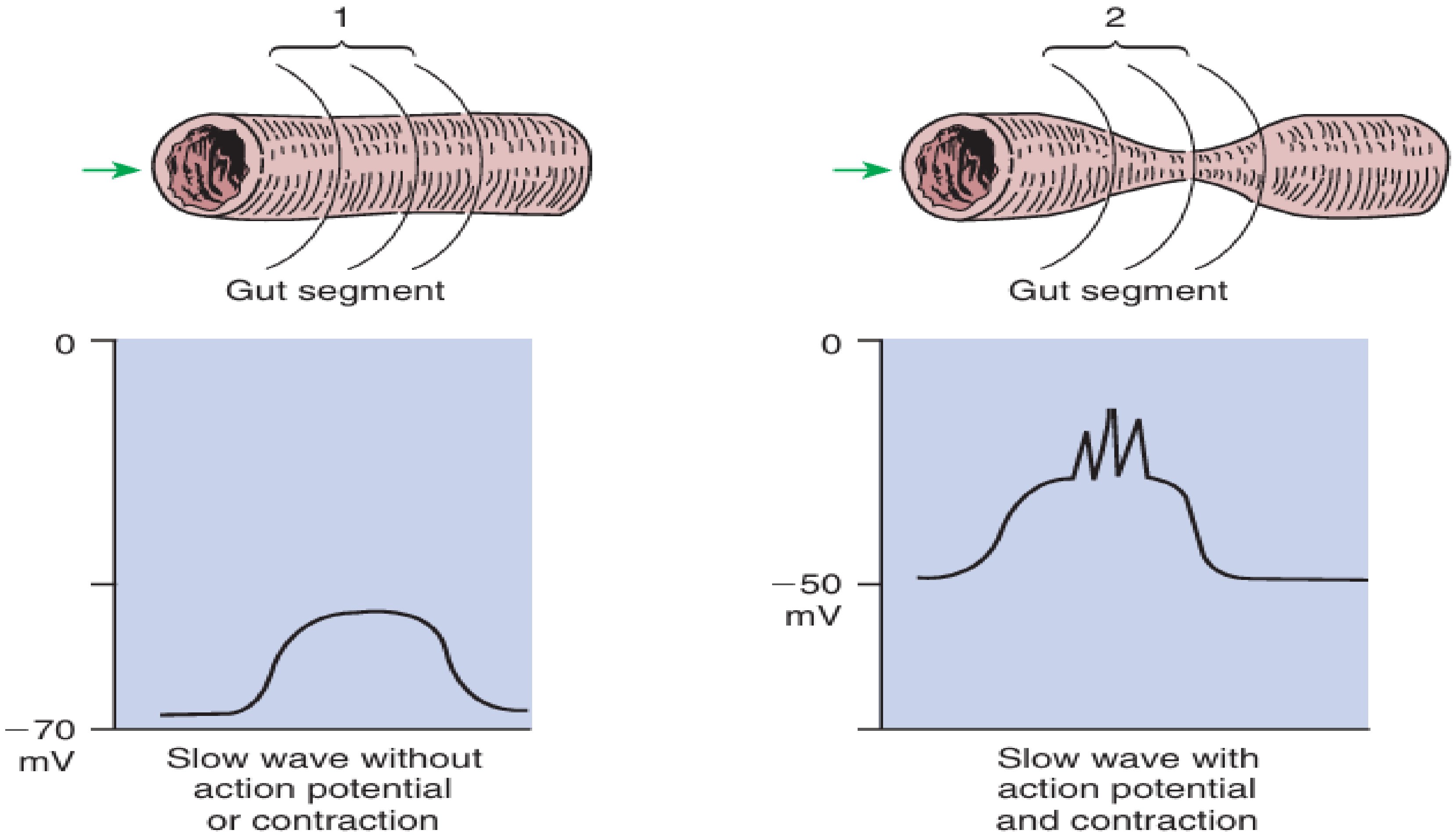
Autonomic Innervation of Digestive System



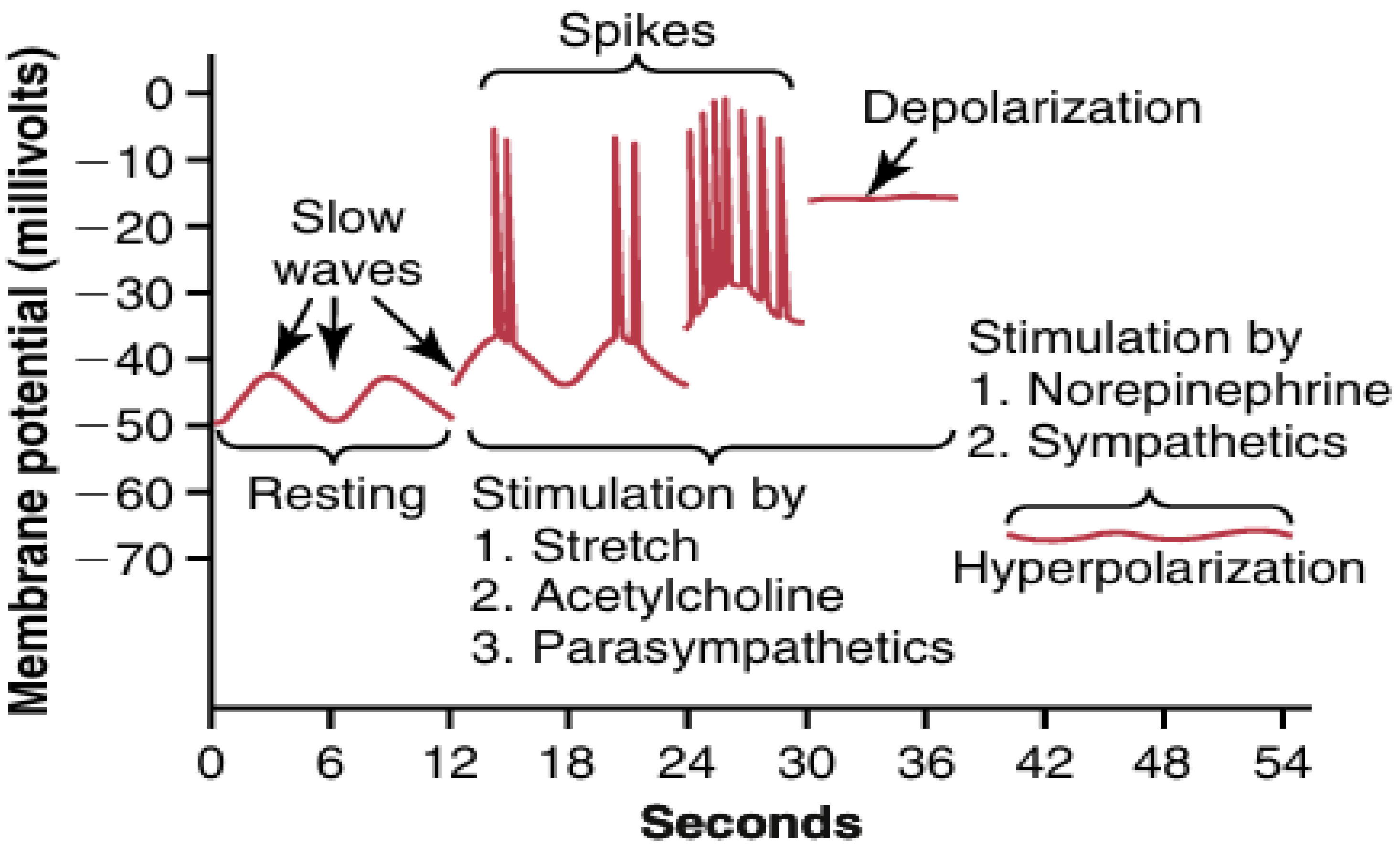
Motility


A. Peristalsis contractions (esophagus, stomach, small intestine)
Contraction
Relaxation
Direction of movement
B. Segmentation contractions (small and large intestines)
Mixing

Motility

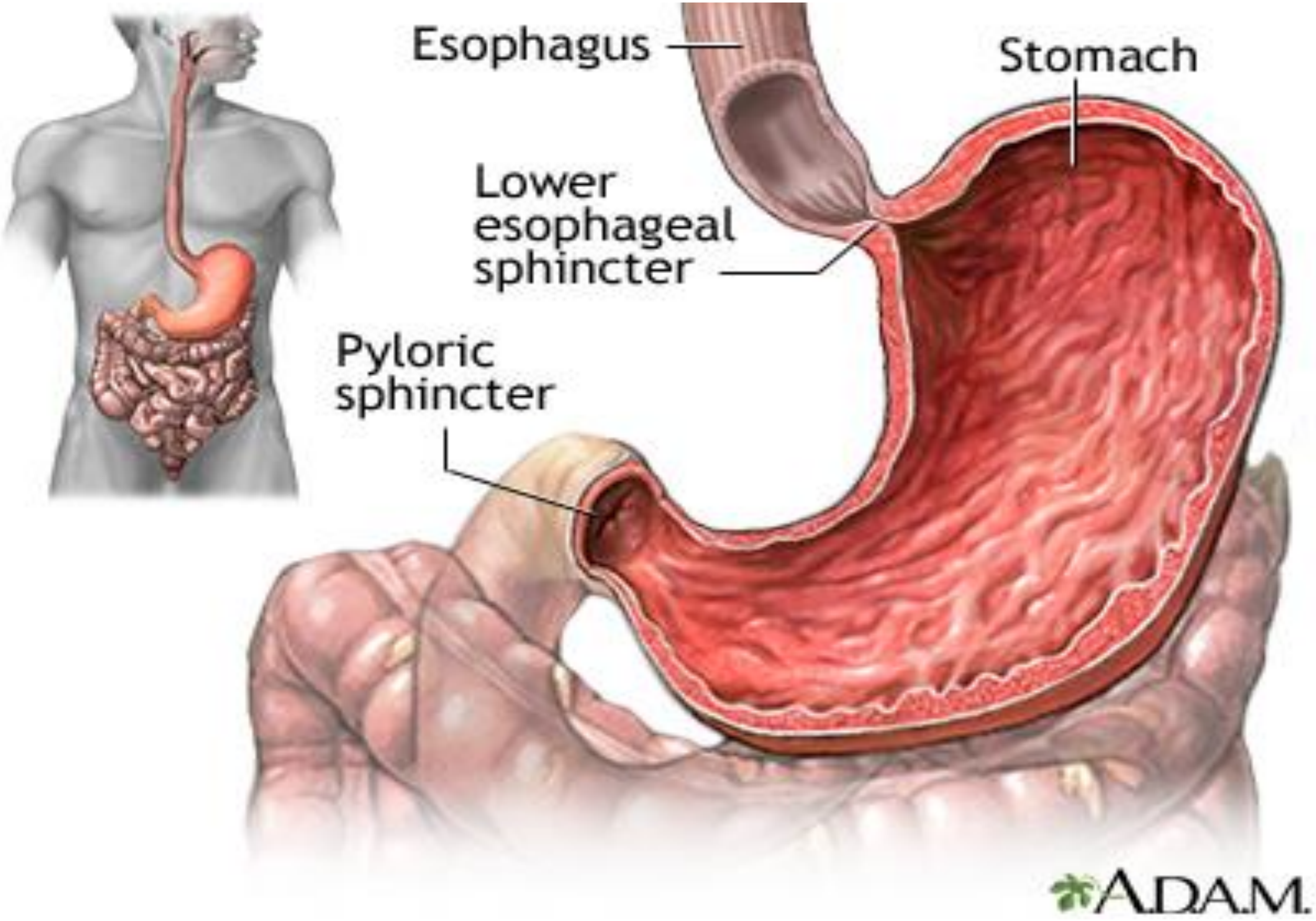

1
Gut segment
0
−70
mV
Slow wave without
action potential
or contraction
2
Gut segment
0
−50
mV
Slow wave with
action potential
and contraction

Motility

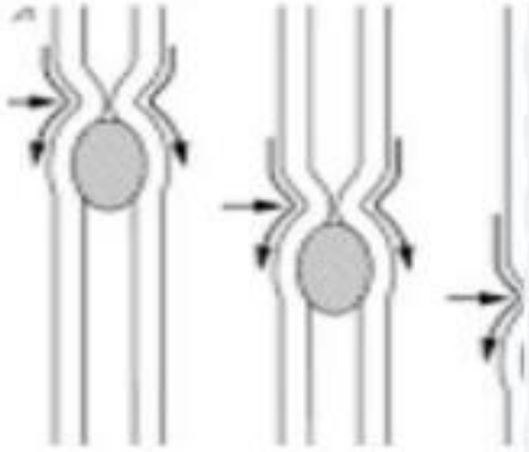


Spikes
Depolarization
Slow
waves
Stimulation by
1. Norepinephrine
2. Sympathetics
Resting
Stimulation by
1. Stretch
2. Acetylcholine
3. Parasympathetics
Hyperpolarization
Membrane potential (millivolts)
0
−10
−20
−30
−40
−50
−60
−70
0
6
12
18
24
30
36
42
48
54
Seconds

Function of Sphincter



Peristalsis & Antiperistalsis



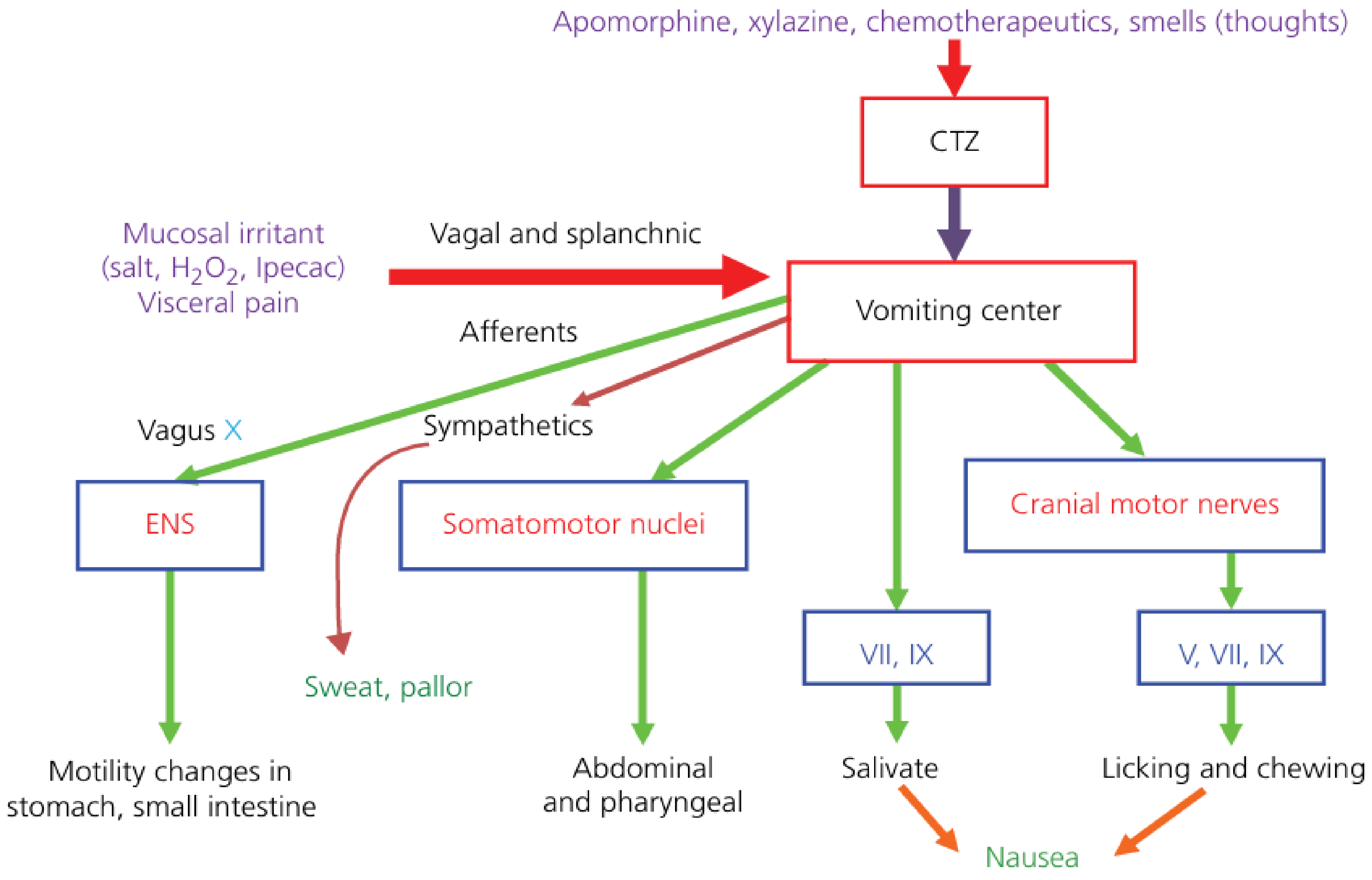
Peristalsis is the downward wave-like movements **of** smooth muscles **of** the GI tracts that propels food bolus from mouth to GI tract. **Antiperistalsis is** the upward or backward wave-like movements **of** smooth muscle that propels food from stomach to mouth

Vomition

A collection of nerve cells in the *reticular formation of the medulla* comprise the *vomiting center*. These neurons receive sensory information directly from the gastrointestinal tract via vagal and sympathetic afferent fibers.

A second collection of nerves within the *floor of the fourth ventricle* forms the *chemoreceptor trigger zone*. These neurons have receptors that recognize blood-borne chemicals or toxins that reach them.

Vomition


Apomorphine, xylazine, chemotherapeutics, smells (thoughts)
CTZ
Mucosal irritant
(salt, H_2O_2, Ipecac)
Visceral pain
Vagal and splanchnic
Afferents
Vomiting center
Vagus X
Sympathetics
ENS
Somatomotor nuclei
Cranial motor nerves
VII, IX
V, VII, IX
Sweat, pallor
Motility changes in
stomach, small intestine
Abdominal
and pharyngeal
Salivate
Licking and chewing
Nausea

Types of Glands & Secretions in Digestive System

Saliva & Salivary Glands

Saliva Moistens, Lubricates, and Partially Digests Food

As food is chewed, it is mixed with salivary secretions that allow it to be molded into well-lubricated boluses that facilitate swallowing. In addition, saliva may have antibacterial, digestive, and evaporative cooling functions, depending on the species.

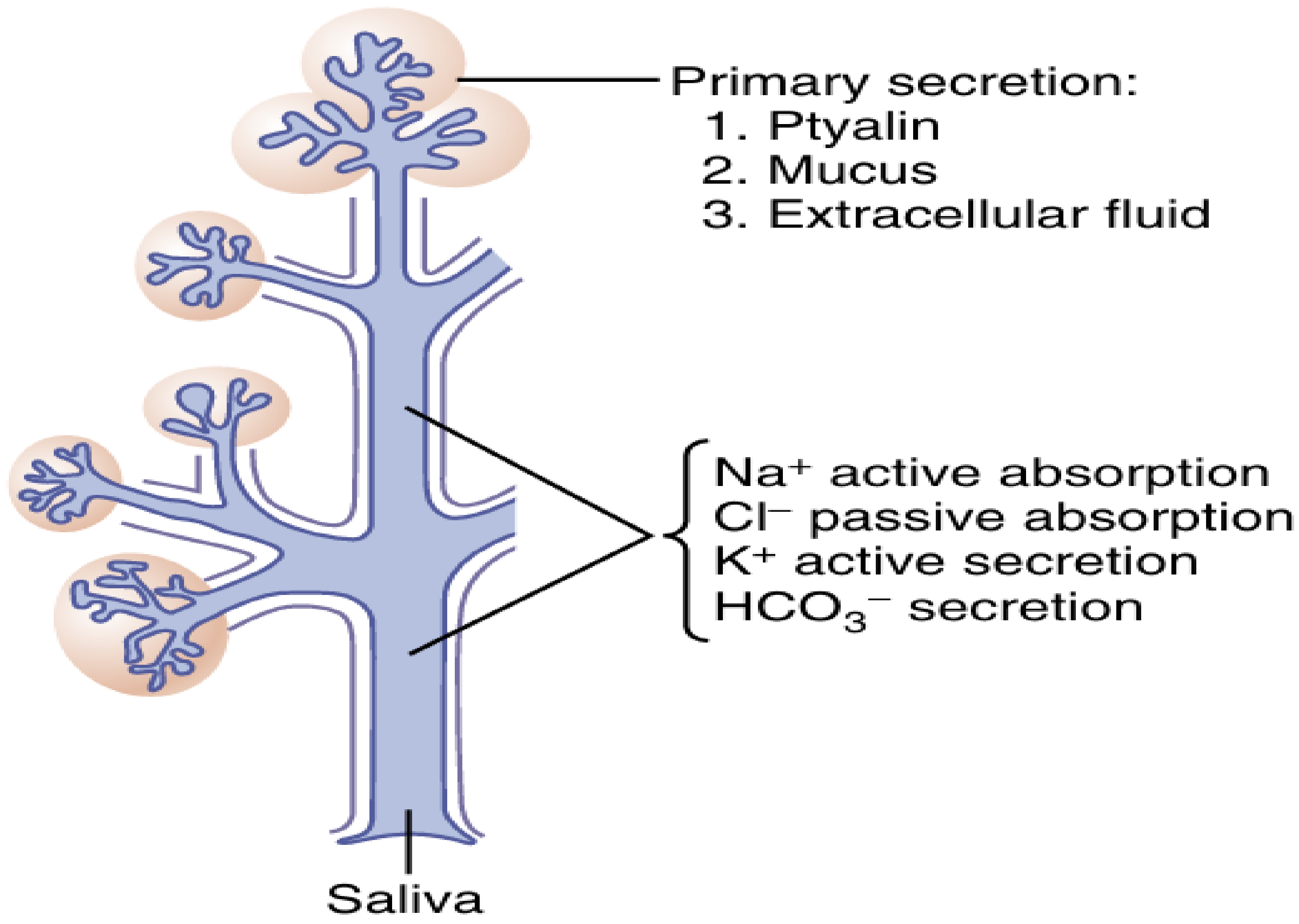
Saliva & Salivary Glands

The antibacterial activity of saliva results from antibodies and antimicrobial enzymes known as *lysozymes*. Initially, you may think that the antibacterial properties of saliva are inefficient because the mouth normally contains a large, thriving population of bacteria. However, saliva aids in keeping this population in check, and animals with impaired salivary function are prone to infectious diseases of the oral cavity.

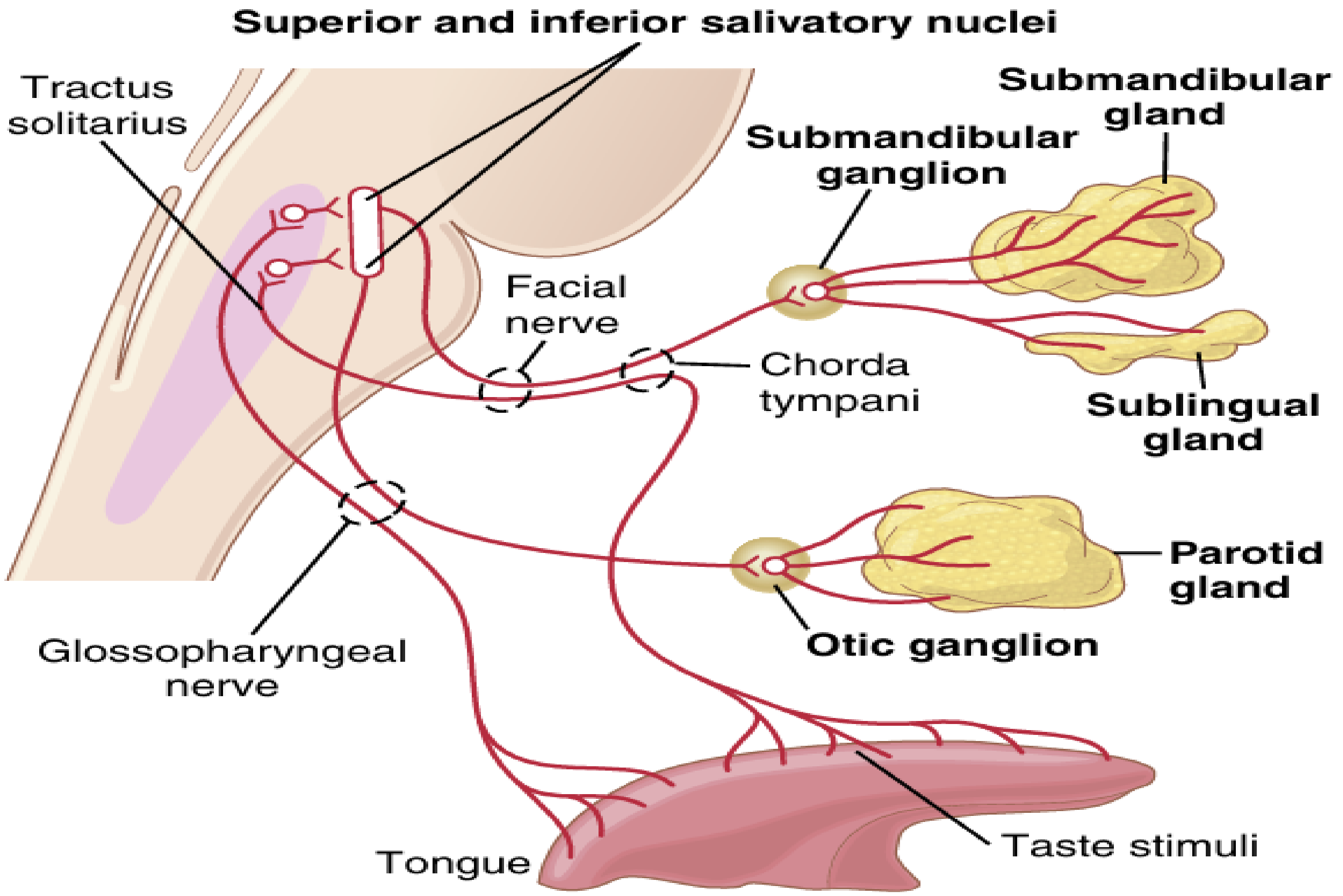
Saliva & Salivary Glands

In omnivorous animals, such as rats and pigs, saliva contains a starch-digesting enzyme known as *salivary amylase*. This enzyme is usually absent from the saliva of carnivorous animals, such as cats. The saliva of some species also contains a fat-digesting enzyme known as *lingual lipase*. This enzyme is frequently present in young animals, such as calves, while they are on a milk diet; the enzyme disappears as they mature.

Saliva & Salivary Glands



Saliva & Salivary Glands



Importance of Saliva in Ruminants

Ruminant Saliva Is a Bicarbonate-Phosphate Buffer Secreted in Large Quantities

The normal composition of ruminant parotid saliva is quite different from the saliva of monogastric animals. Bovine and canine saliva are compared in Fig. 29.2. Ruminant saliva is isotonic and, compared with blood serum, has high concentrations of bicarbonate and phosphate and a high pH. This well-buffered solution is necessary for neutralizing acids formed by fermentation in the rumen, and ruminants secrete it in enormous quantities. An adult cow may secrete 100 to 200 L of saliva per day. This volume is approximately equivalent to the extracellular fluid volume of most adult cattle. It is obvious that much of the water and electrolytes secreted in saliva must be reabsorbed rapidly and recirculated through the total body water, or the animal would die of dehydration in a short period of time. In abnormal circumstances, such as blockage

Esophageal Secretion

Esophageal secretions are entirely mucous and mainly provide lubrication for swallowing. The main body of the esophagus is lined with many *simple mucous glands.* At the gastric end and to a lesser extent in the initial portion of the esophagus, many *compound mucous glands* can also be found. The mucus secreted by the compound glands in the upper esophagus prevents mucosal excoriation by newly entering food, whereas the compound glands located near the esophagogastric junction protect the esophageal wall from digestion by acidic gastric juices that often reflux from the stomach back into the lower esophagus. Despite this protection, a peptic ulcer at times can still occur at the gastric end of the esophagus.

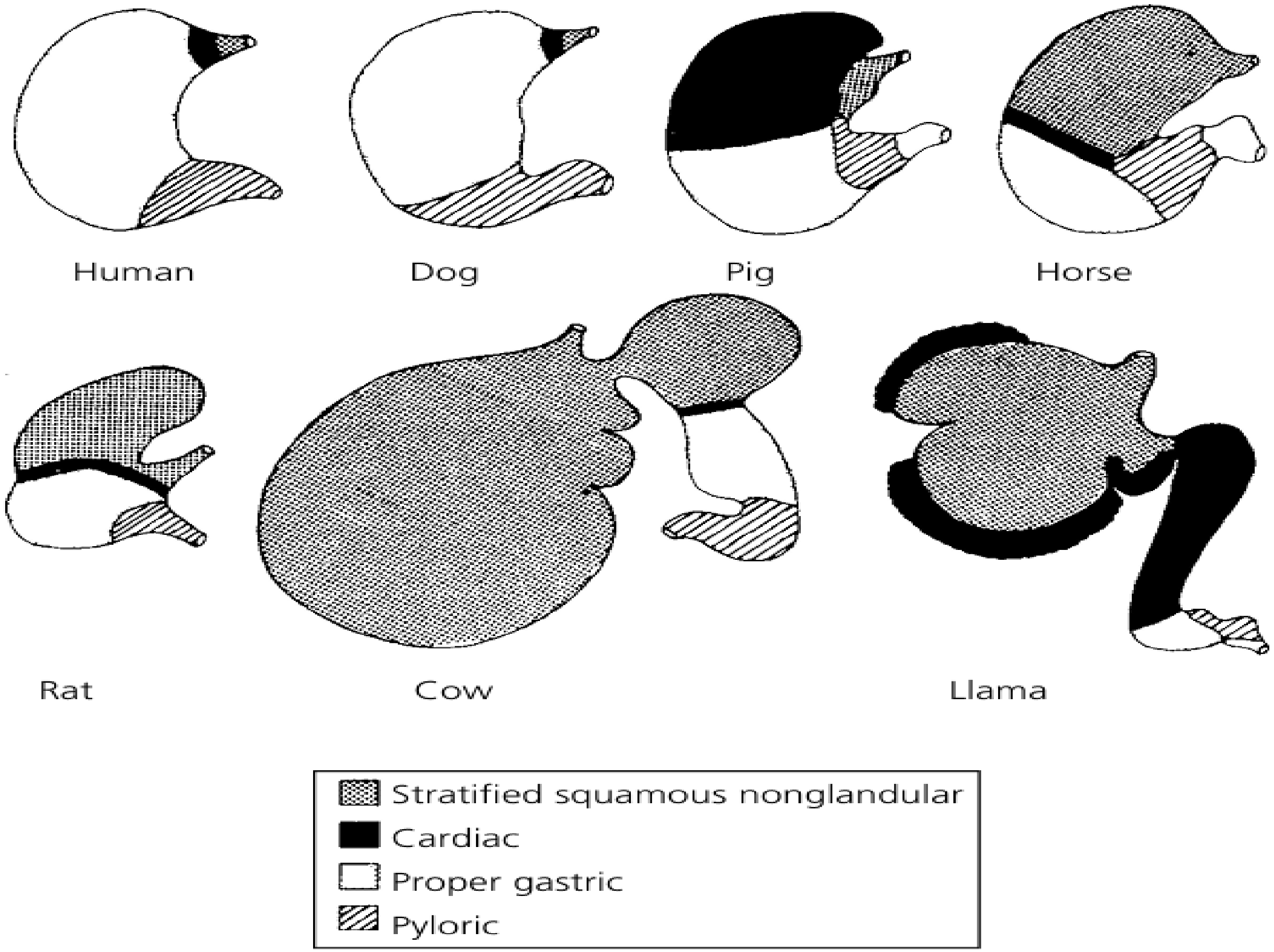
Gastric Secretion

Depending on the Species, There May Be Two General Types of Gastric Mucosa: Glandular and Nonglandular

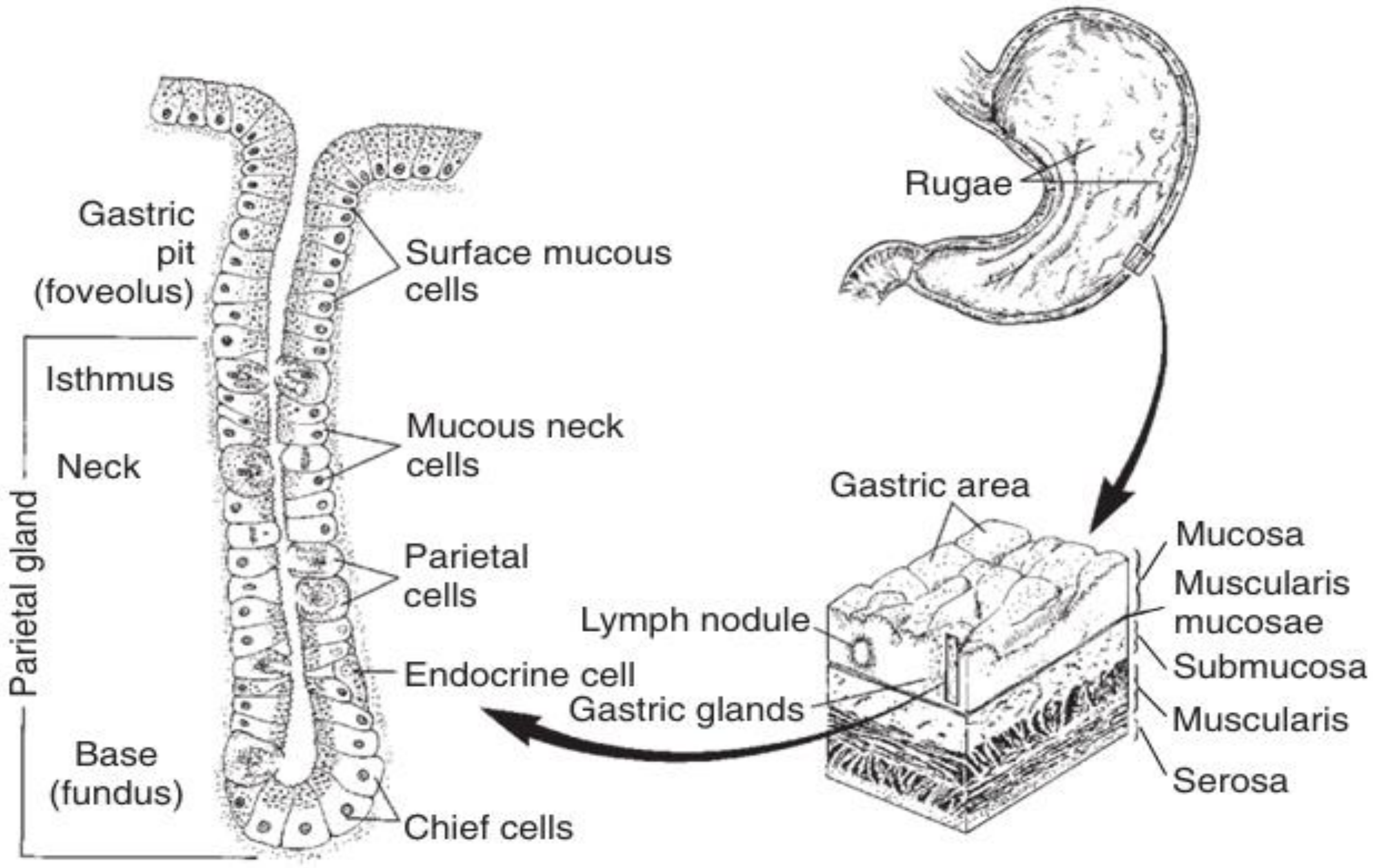
Most domestic, monogastric animals have only glandular mucosa in the stomach, but horses and rats have an area in the proximal portion of their stomachs covered by nonglandular, stratified squamous epithelium. This area is visibly different from the glandular area, to which it adjoins with a sharp line of demarcation. The function of the nonglandular area of gastric mucosa is unclear. The nonglandular area may serve as a place where a small amount of fermentative (rumen-like) digestion could occur. Because there is little mixing activity in the proximal stomach, food in the nonglandular area would be protected from the secretions of the gastric glands. These acid secretions kill bacteria, and thus their presence would prevent fermentation. Fermentative digestion is discussed in detail in Chapter 31.

The glandular area of the stomach is divided into three regions: *cardiac mucosa, parietal mucosa,* and *pyloric mucosa.* These areas contain glands of similar structure but with different types of secretions, as described later. In most species, the cardiac mucosa forms a narrow band around the gastric opening of the esophagus. In the pig, however, the cardiac mucosa covers a substantial portion of the proximal stomach.

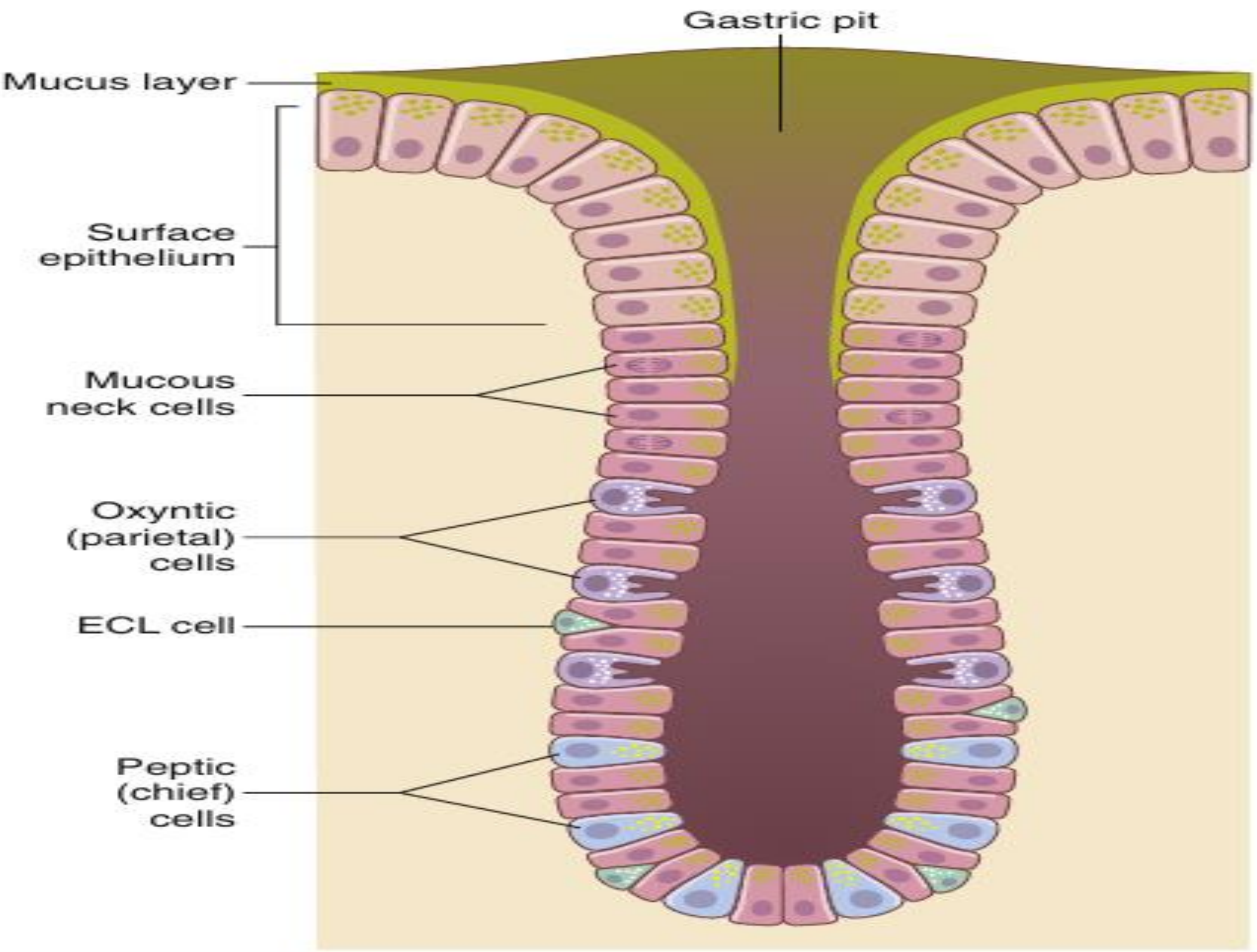
Gastric Secretion



Gastric Secretion



Gastric Secretion



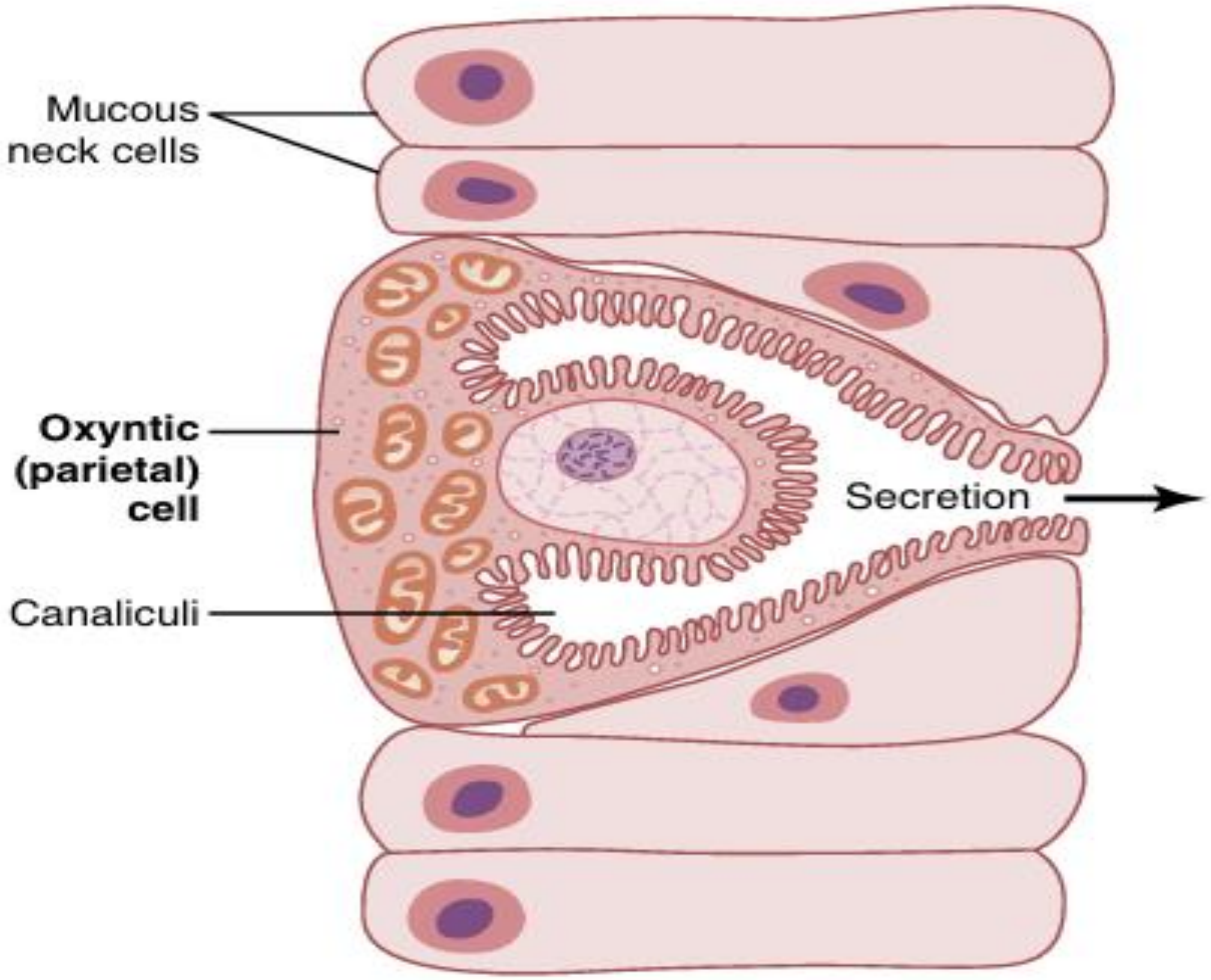
Gastric Secretion

The Parietal Cells of the Gastric Glands Secrete Hydrochloric Acid

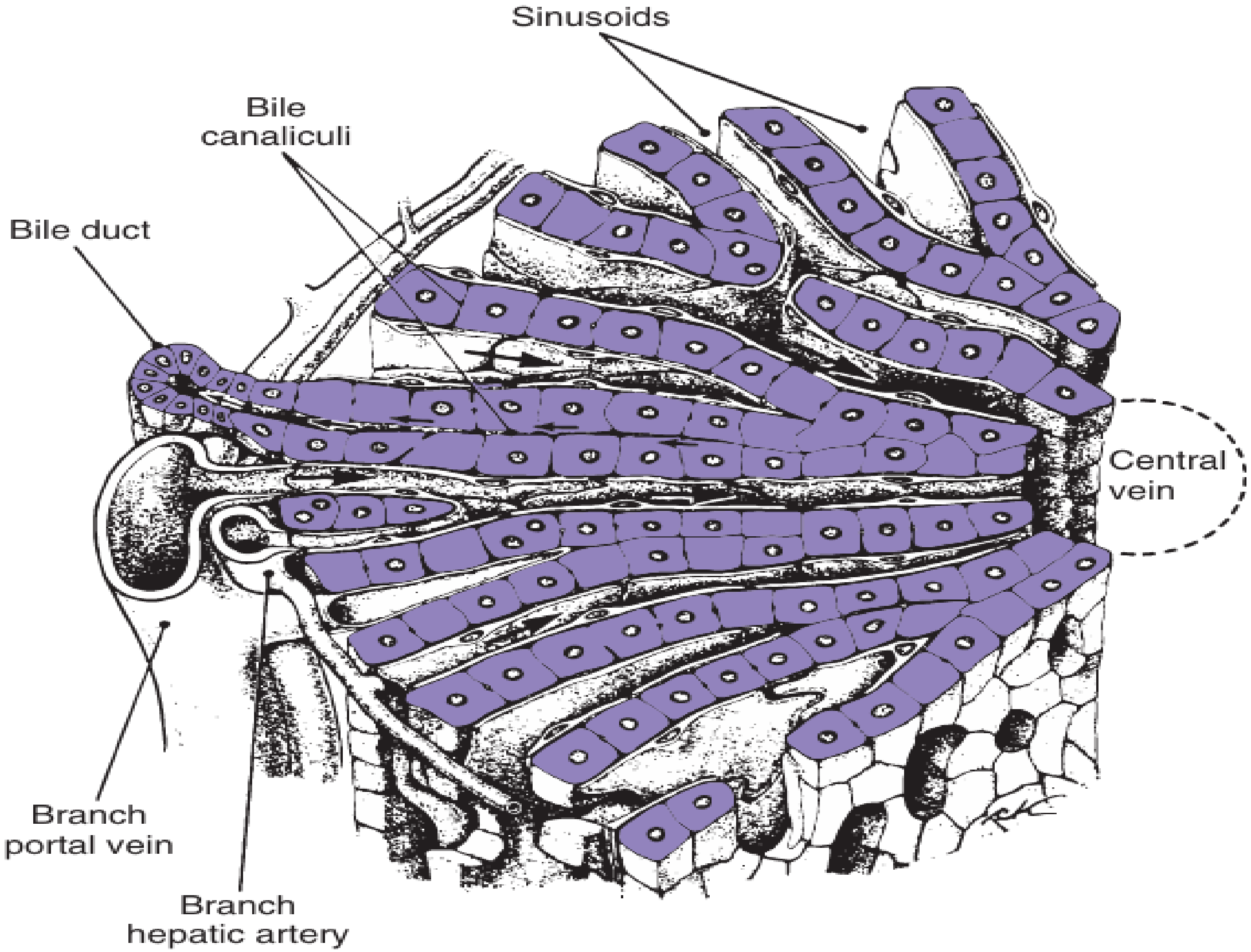
The Parietal Cells Are Stimulated to Secrete by the Action of Acetylcholine, Gastrin, and Histamine

Pepsin Is Secreted by the Chief Cells of the Gastric Glands; It Is Secreted in an Inactive Form and Is Subsequently Activated in the Stomach Lumen

Gastric Secretion



Bile Secretion



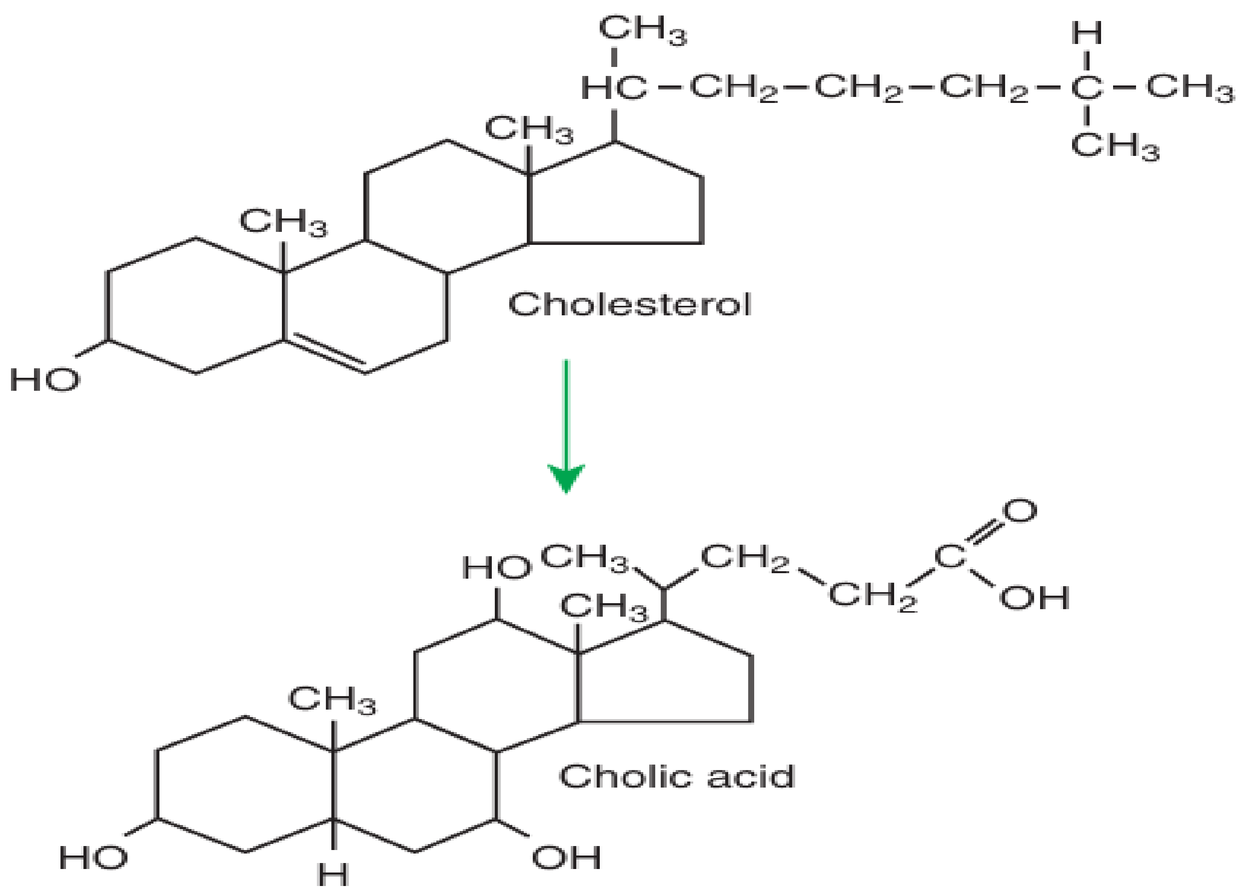
Bile Secretion

Bile Contains Phospholipids and Cholesterol Maintained in Aqueous Solution by the Detergent Action of Bile Acids

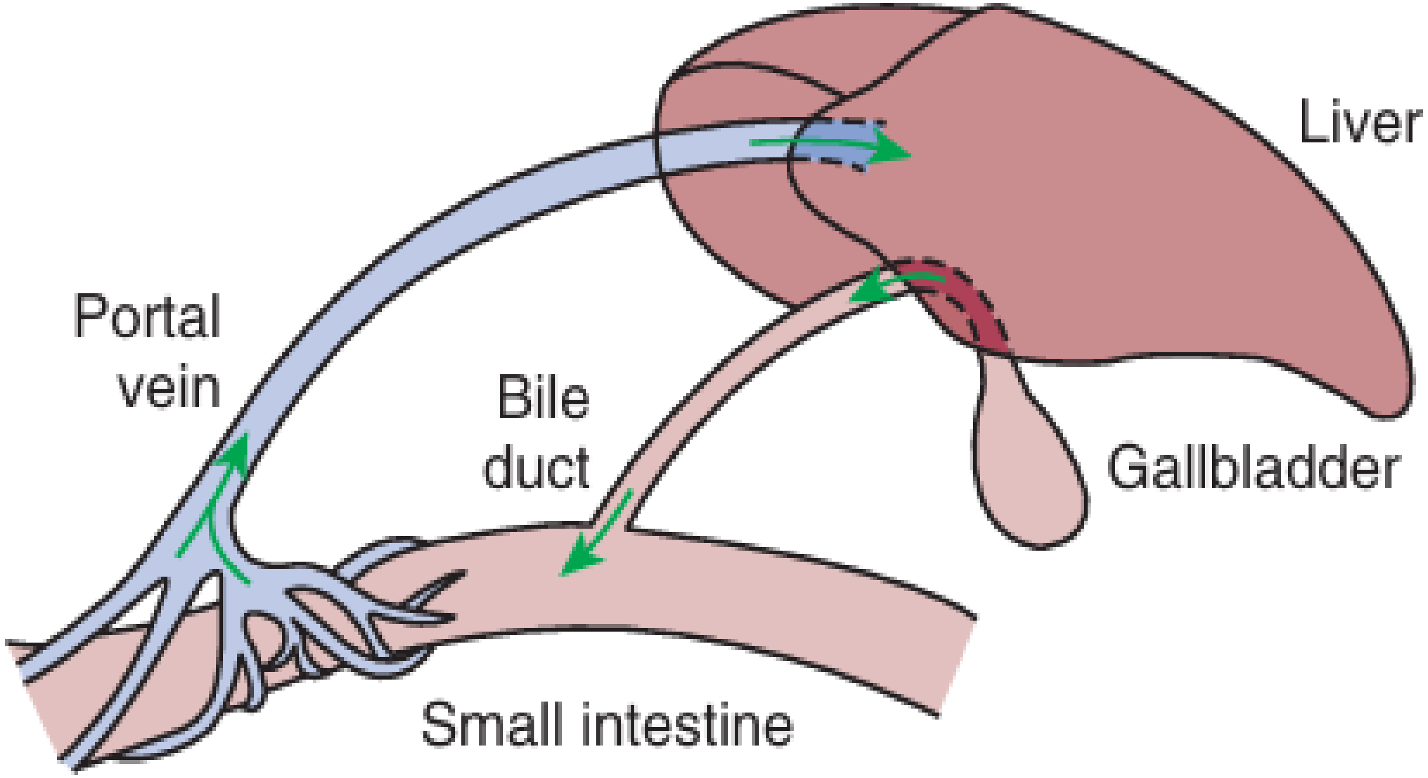
Bile Secretion Is Initiated by the Presence of Food in the Duodenum and Stimulated by the Return of Bile Acids to the Liver

The Gallbladder Stores and Concentrates Bile During the Periods Between Feeding

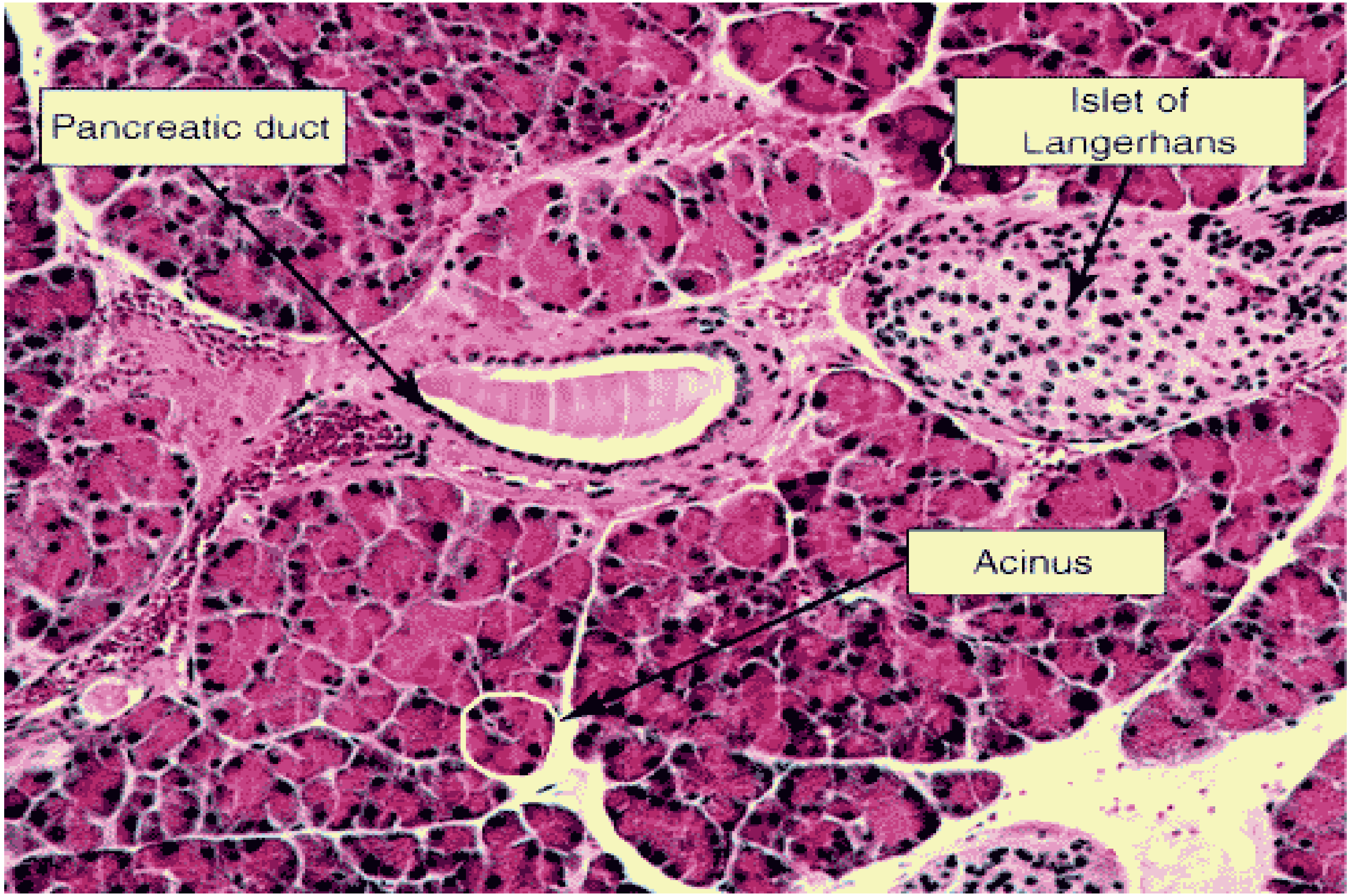
Bile Secretion



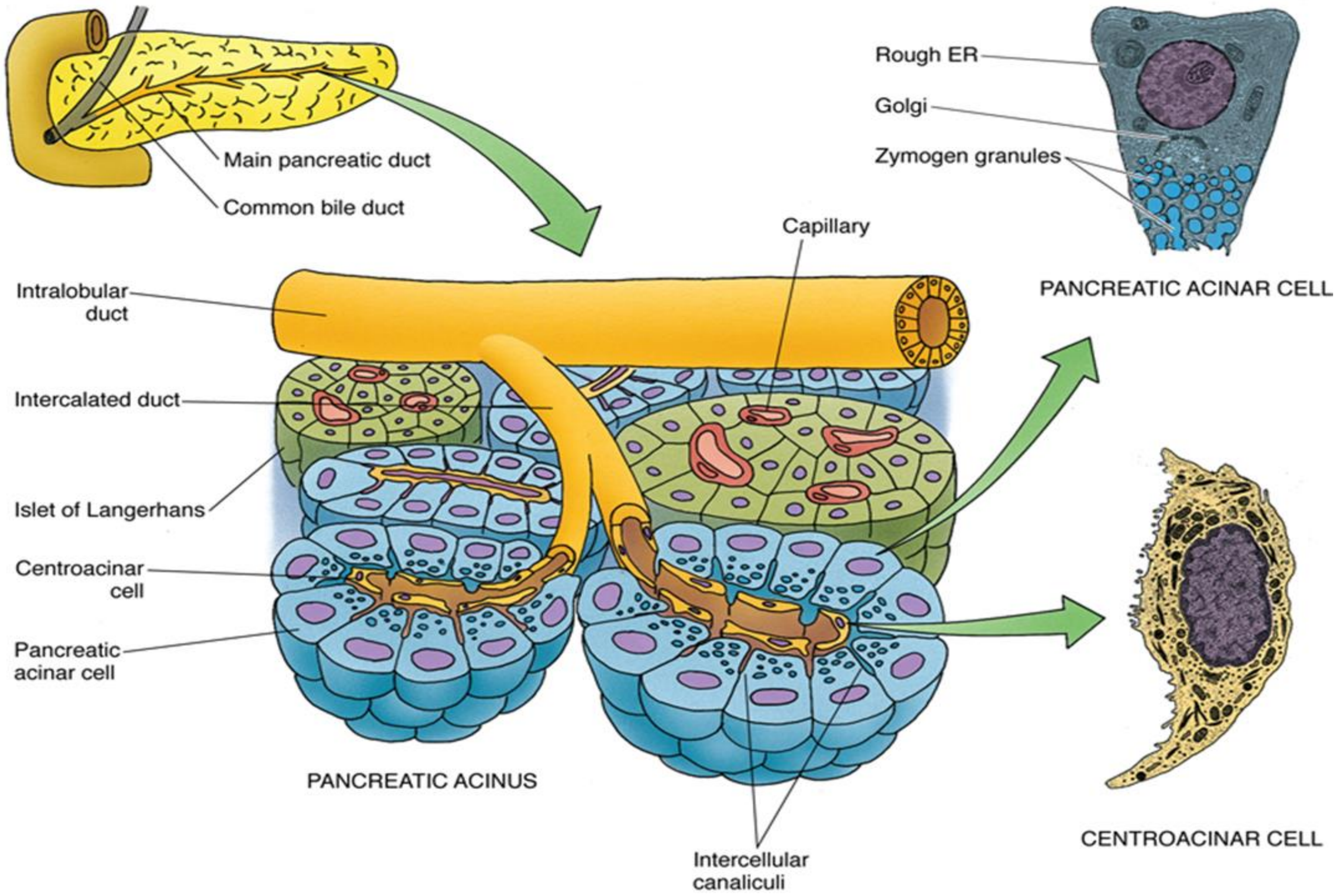
Enterohepathic Cycle



Pancreatic Exocrine Secretion



Pancreatic Exocrine Secretion



Pancreatic Exocrine Secretion

Pancreatic Exocrine Secretions Are Indispensable for Digestion of Complex Nutrients: Proteins, Starches, and Triglycerides

Acinar Cells Secrete Enzymes, Whereas Centroacinar Cells and Duct Cells Secrete an Electrolyte Solution Rich in Sodium Bicarbonate

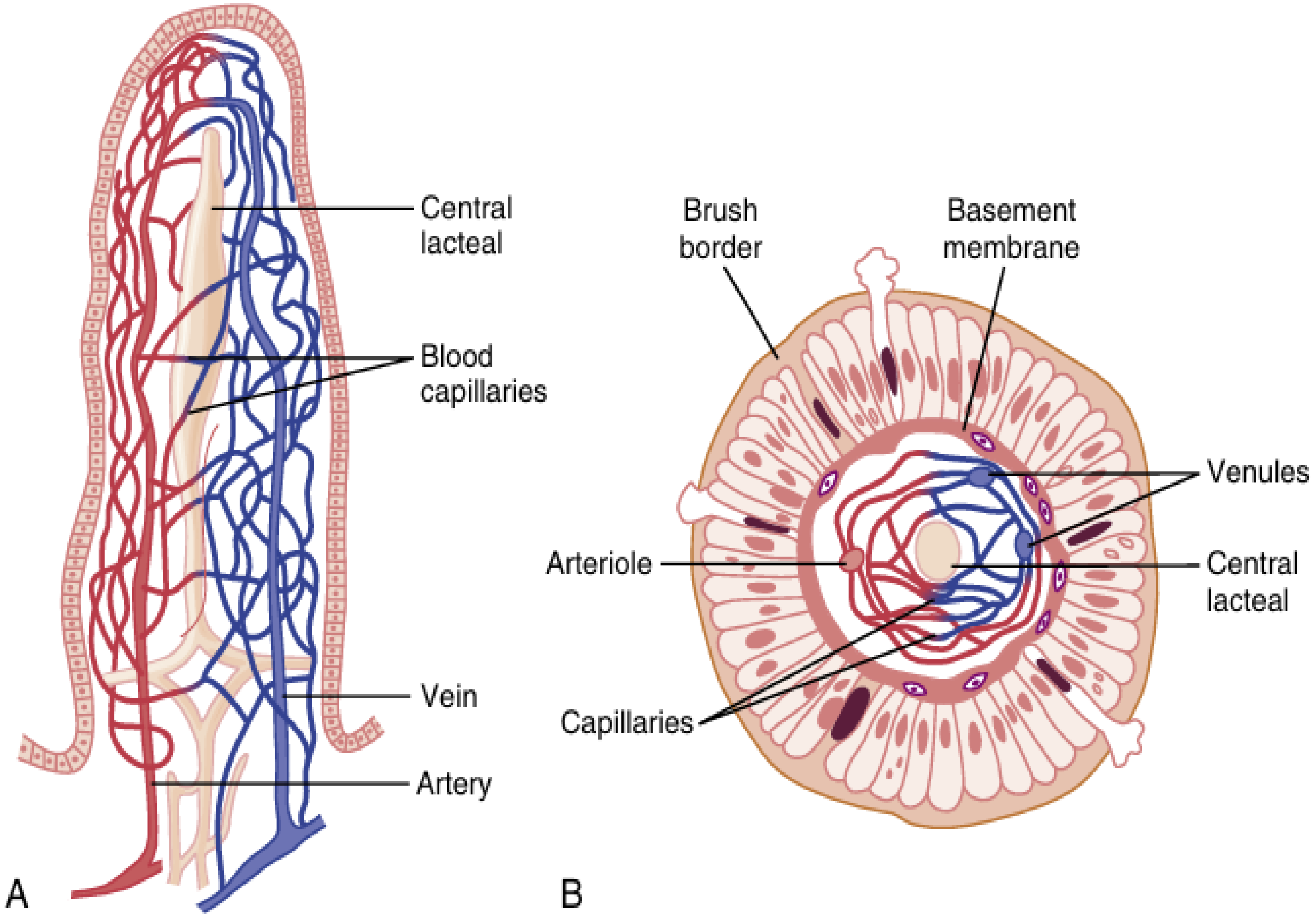
Pancreatic Cells Have Cell Surface Receptors Stimulated by Acetylcholine, Cholecystokinin, and Secretin

The Nonfermentative Processes of Digestion (Physical, Chemical, Luminal, Membranous D.)

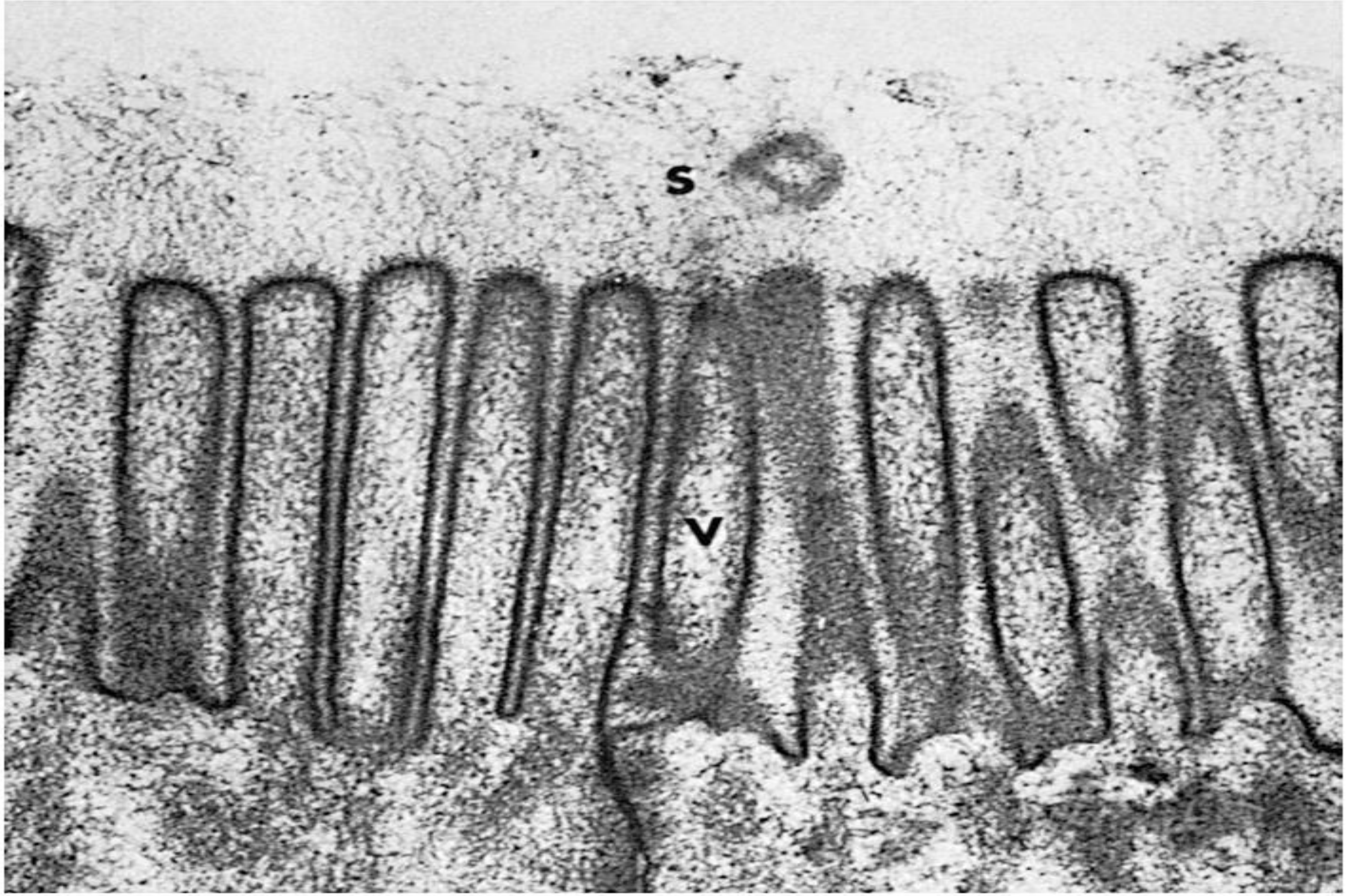
Digestion

1. Breaking down food particle size by physical action is an important part of the digestive process.
2. Chemical digestion results in the reduction of complex nutrients into simpler molecules.
3. Luminal-phase carbohydrate digestion results in the production of short-chain polysaccharides.
4. Luminal-phase digestion of carbohydrates applies only to starches, because sugars are digested in the membranous phase.
5. Proteins are digested by a variety of luminal-phase enzymes.
6. Membranous-phase digestive enzymes are a structural part of the intestinal surface membrane.
7. Membranous-phase digestion occurs within the microenvironment of the unstirred water layer, intestinal mucus, and glycocalyx.
8. A specific membranous-phase enzyme exists for the digestion of each type of polysaccharide.
9. Complete digestion of peptides to free amino acids takes place both on the enterocyte surface and within the cells.

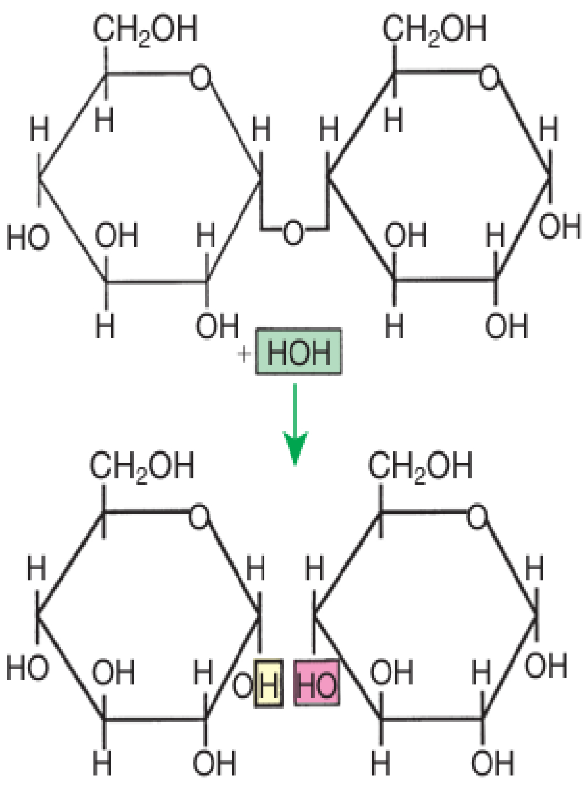
The Nonfermentative Processes of Digestion



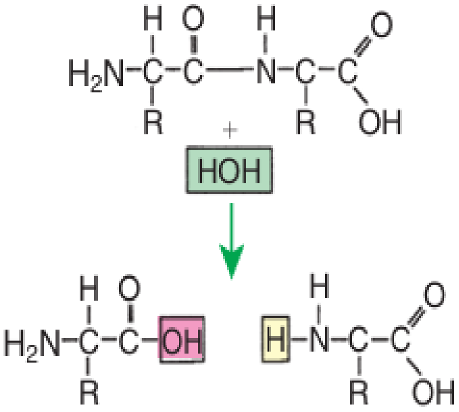
The Nonfermentative Processes of Digestion



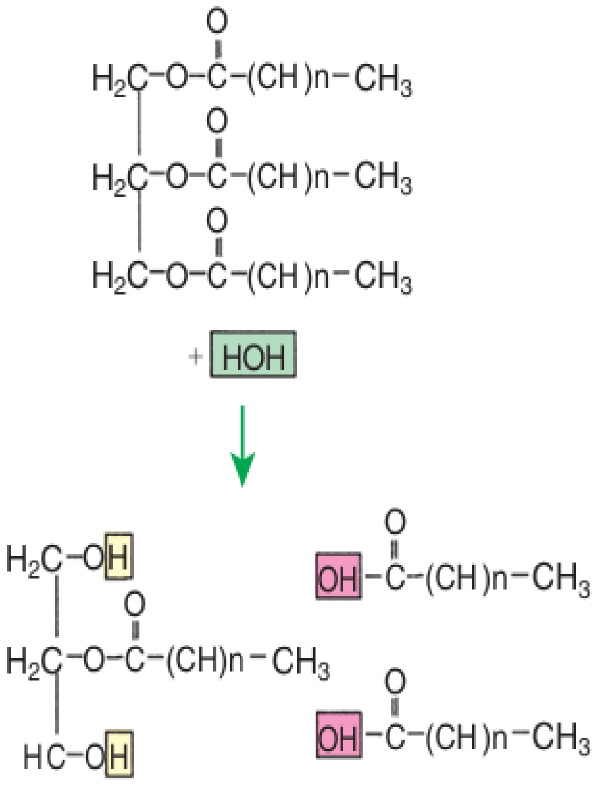
The Nonfermentative Processes of Digestion
HYDROLYSIS



Hydrolysis of glycosidic bond

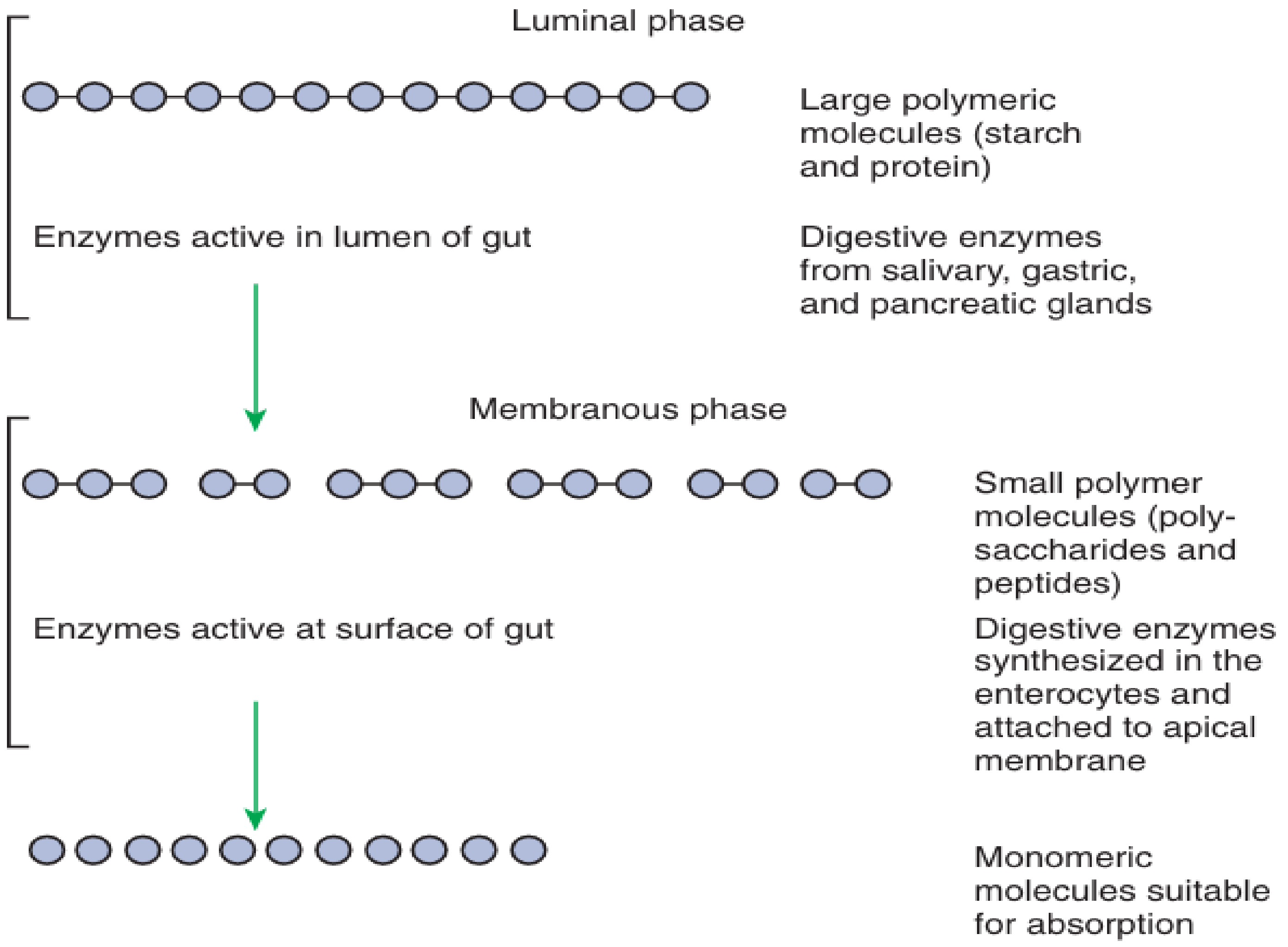


Hydrolysis of peptide bond

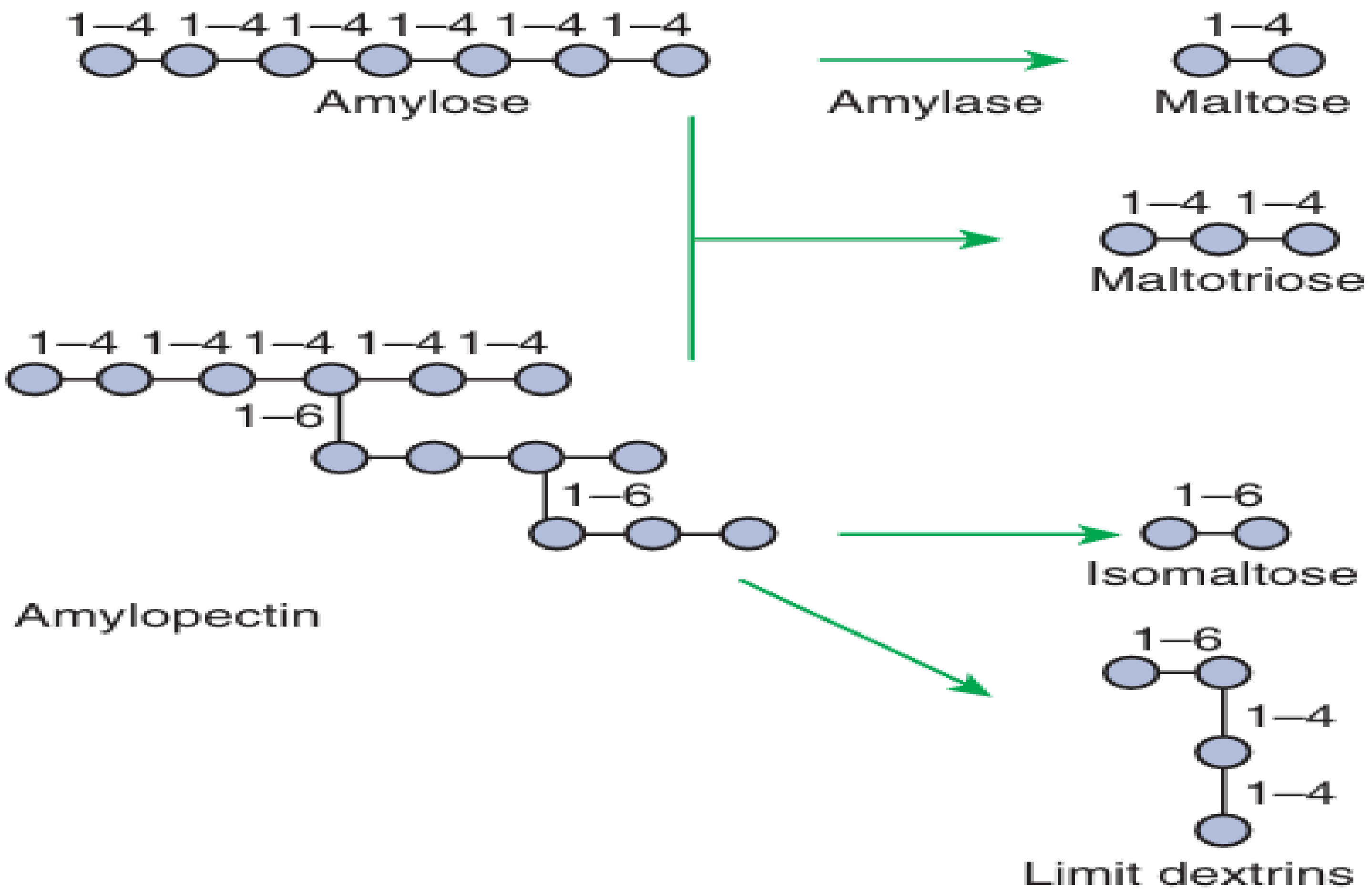


Hydrolysis of two ester bonds in a triglyceride molecule

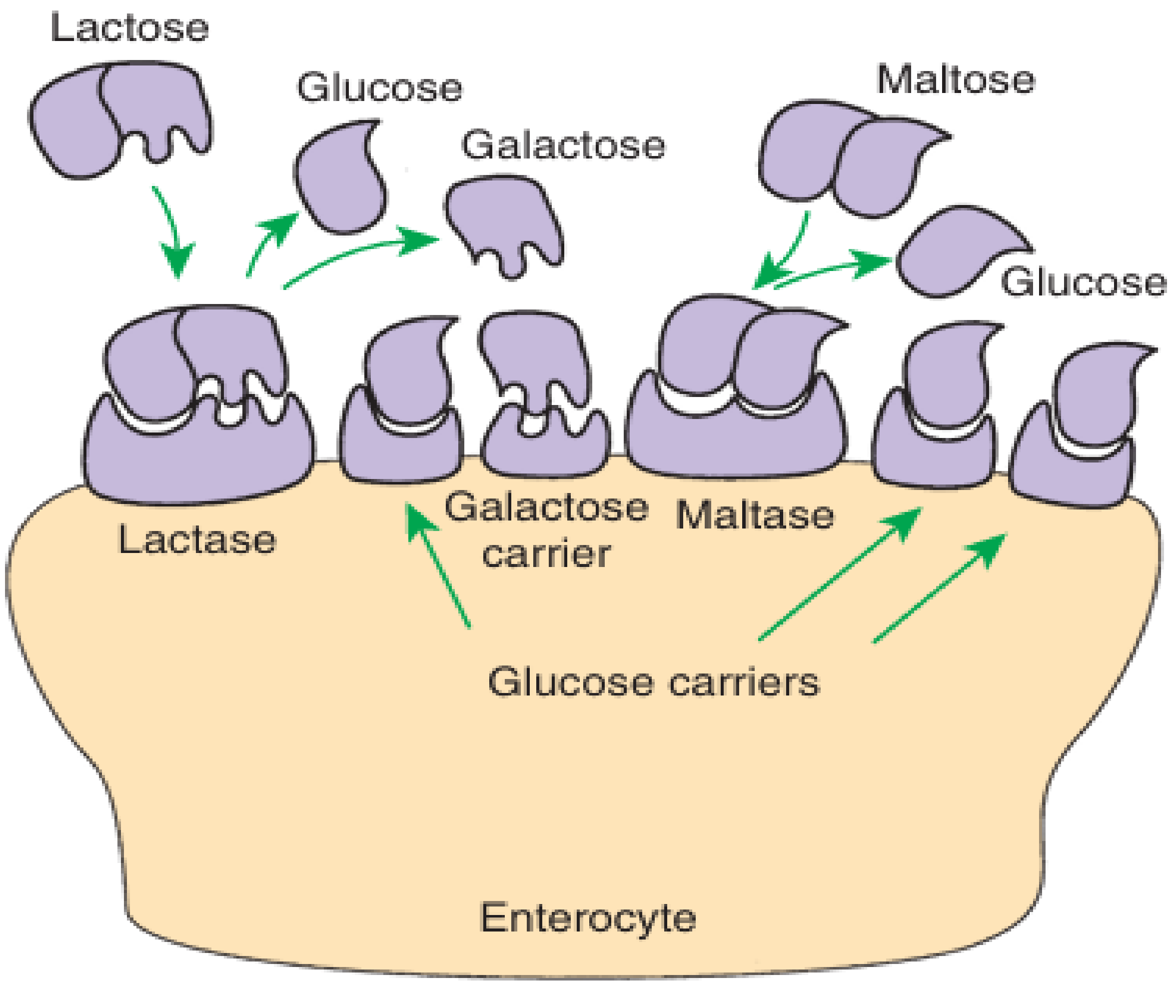
The Nonfermentative Processes of Digestion



The Nonfermentative Processes of Digestion



The Nonfermentative Processes of Digestion

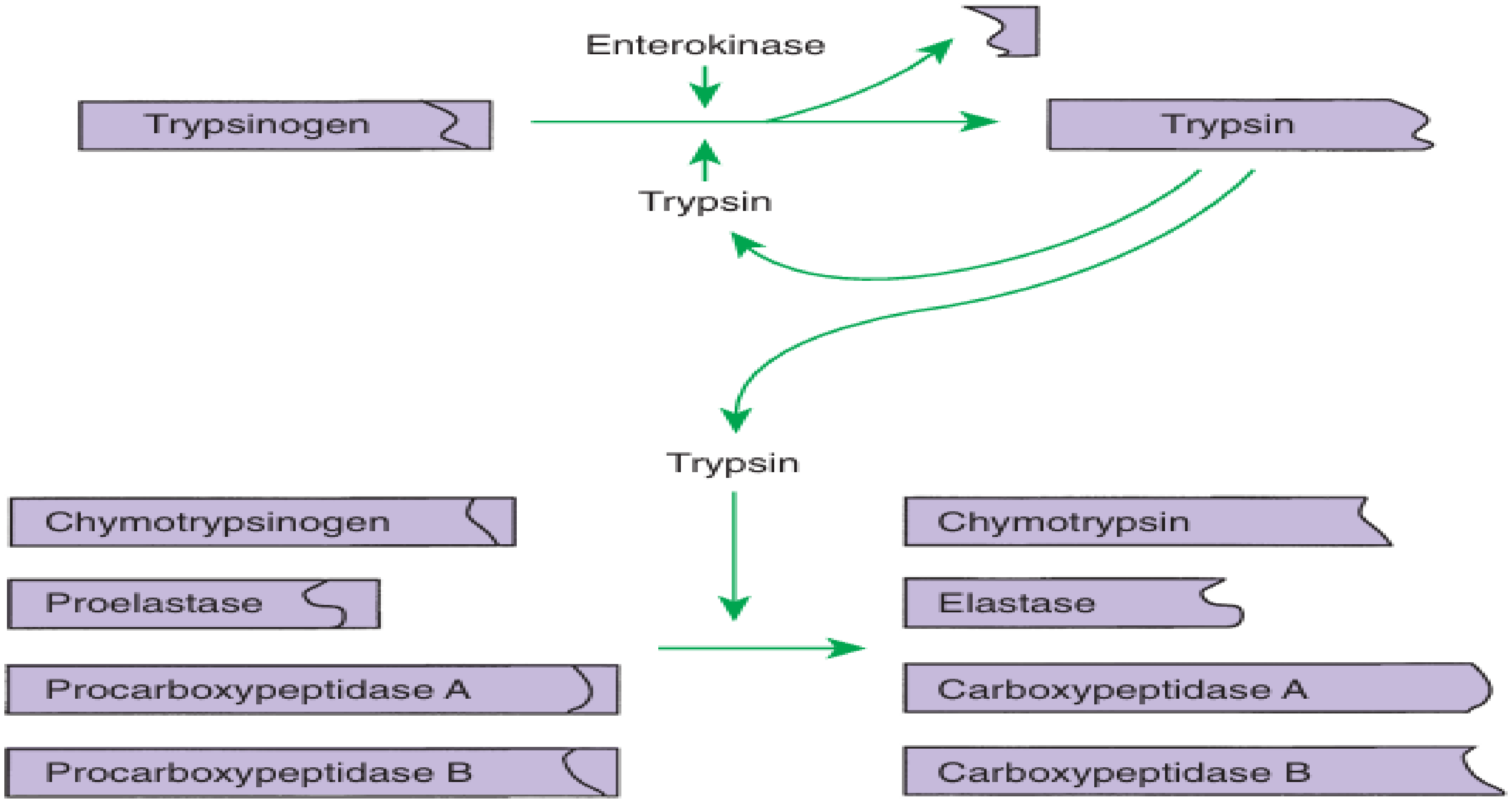


The Nonfermentative Processes of Digestion

TABLE 30.1 Luminal-Phase Enzymes of Protein Digestion

Enzyme	Action	Source	Precursor	Activator
Pepsin	Endopeptidase	Gastric glands	Pepsinogen	Hydrochloric acid, pepsin
Chymosin (rennin)	Endopeptidase	Gastric glands	Chymosinogen	Unknown
Trypsin	Endopeptidase	Pancreas	Trypsinogen	Enterokinase, trypsin
Chymotrypsin	Endopeptidase	Pancreas	Chymotrypsinogen	Trypsin
Elastase	Endopeptidase	Pancreas	Proelastase	Trypsin
Carboxypeptidase A	Exopeptidase	Pancreas	Procarboxypeptidase A	Trypsin
Carboxypeptidase B	Exopeptidase	Pancreas	Procarboxypeptidase B	Trypsin

The Nonfermentative Processes of Digestion

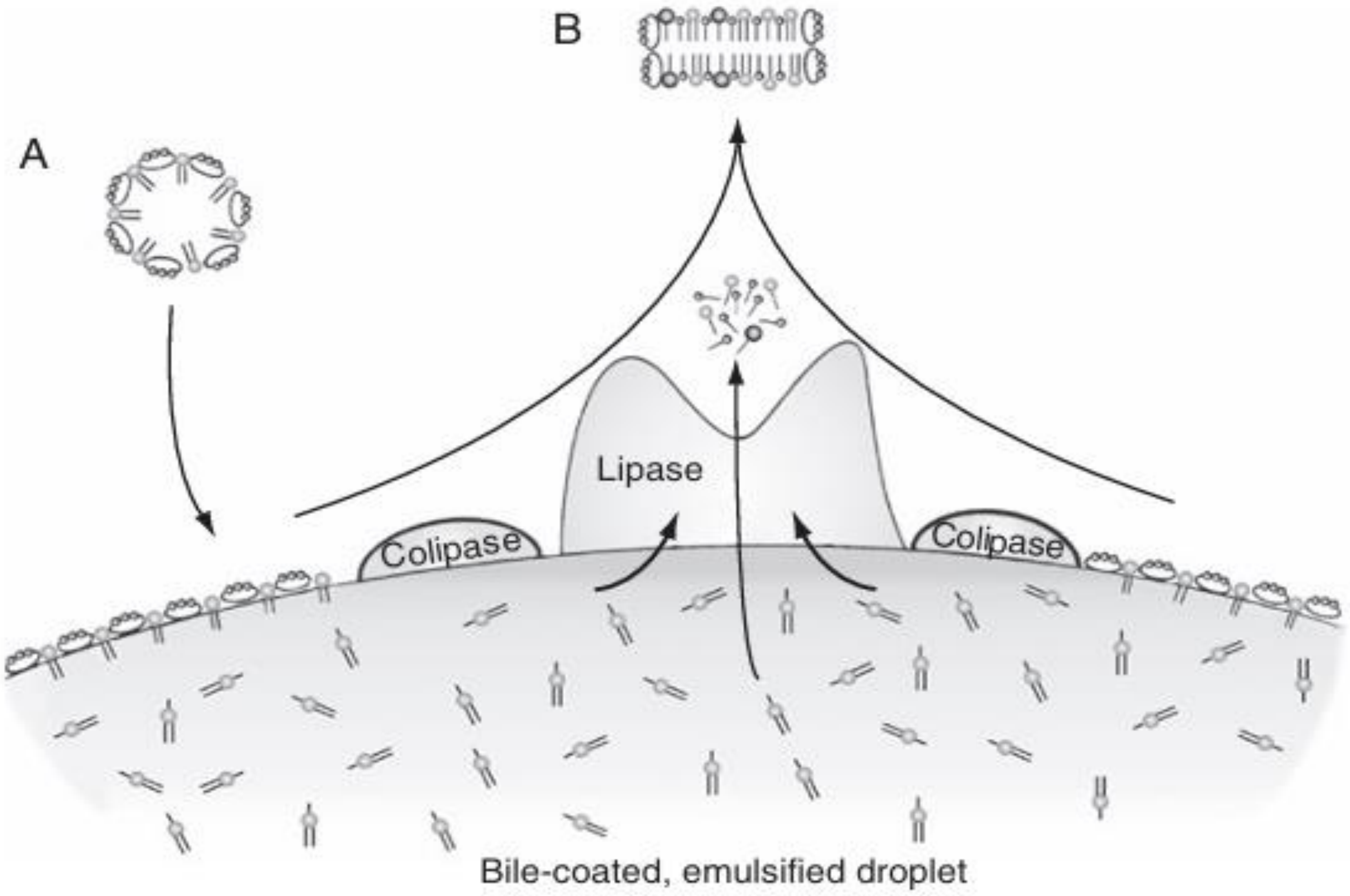


The Nonfermentative Processes of Digestion

While in the bile-coated, or emulsified-droplet, stage, the lipids are subject to the actions of hydrolytic enzymes. Hydrolysis of triglyceride, the major dietary lipid component, occurs because of the combined action of the pancreatic enzymes *lipase* and *colipase*. Lipase is an enzyme secreted, in its active form, from the pancreas. However, lipase cannot directly attack the emulsified lipid droplets in the gut because it cannot penetrate the coat of bile products surrounding the droplets. The function of colipase, a relatively short peptide, is to "clear a path" through the bile products, giving lipase access to the underlying triglycerides. Lipase cleaves the fatty acids off each end of the triglyceride molecule but does not attack the central fatty acid, resulting in the formation of two *free* (or *nonesterified*) *fatty acids* and a *monoglyceride* from each molecule of triglyceride hydrolyzed (Fig. 30.26).

Other lipid-digesting pancreatic enzymes are *cholesterol esterase* and *phospholipase*. The products of these enzymes are nonesterified fatty acids, cholesterol, and lysophospholipids.

The Nonfermentative Processes of Digestion



The Fermentative Processes of Digestion

Microbial Ecosystem of Fermentative Digestion

1. The microbes responsible for fermentative digestion include bacteria, fungi, and protozoa.
2. Cooperation and interplay among the many species of microbes give rise to a complex ecosystem in the forestomach and hindgut.

The Fermentative Processes of Digestion

Substrates and Products of Fermentative Digestion

1. Plant cell walls are important substrates for fermentative digestion and significant nutrient sources for many species.
2. Nutrients other than cell walls are also subject to fermentative digestion.
3. Anaerobic conditions in the rumen result in metabolic activities leading to the production of volatile fatty acids.
4. Volatile fatty acids are important energy substrates for the host animal.
5. Fermentative digestion of protein results in the deamination of a large portion of amino acids.
6. When protein and energy availability in the forestomach are well matched, rapid microbial growth and efficient protein utilization result.
7. Microbial protein can be synthesized in the rumen from nonprotein nitrogen sources.

The Fermentative Processes of Digestion

• BOX 31.1 Grouping of Rumen Bacterial Species According to Type of Substrates Fermented

Major Cellulolytic Species
Bacteroides succinogenes
Ruminococcus flavefaciens
Ruminococcus albus
Butyrivibrio fibrisolvens

Major Hemicellulolytic Species
Butyrivibrio fibrisolvens
Bacteroides ruminicola
Ruminococcus species

Major Pectinolytic Species
Butyrivibrio fibrisolvens
Bacteroides ruminicola
Lachnospira multiparus
Succinivibrio dextrinosolvens
Treponema bryantii
Streptococcus bovis

Major Amylolytic Species
Bacteroides amylophilus
Streptococcus bovis
Succinimonas amylolytica
Bacteroides ruminicola

Major Ureolytic Species
Succinivibrio dextrinosolvens
Selenomonas species
Bacteroides ruminicola
Ruminococcus bromii
Butyrivibrio species
Treponema species

Major Methane-Producing Species
Methanobrevibacter ruminantium
Methanobacterium formicicum
Methanomicrobium mobile

Major Sugar-Utilizing Species
Treponema bryantii
Lactobacillus vitulinus
Lactobacillus ruminis

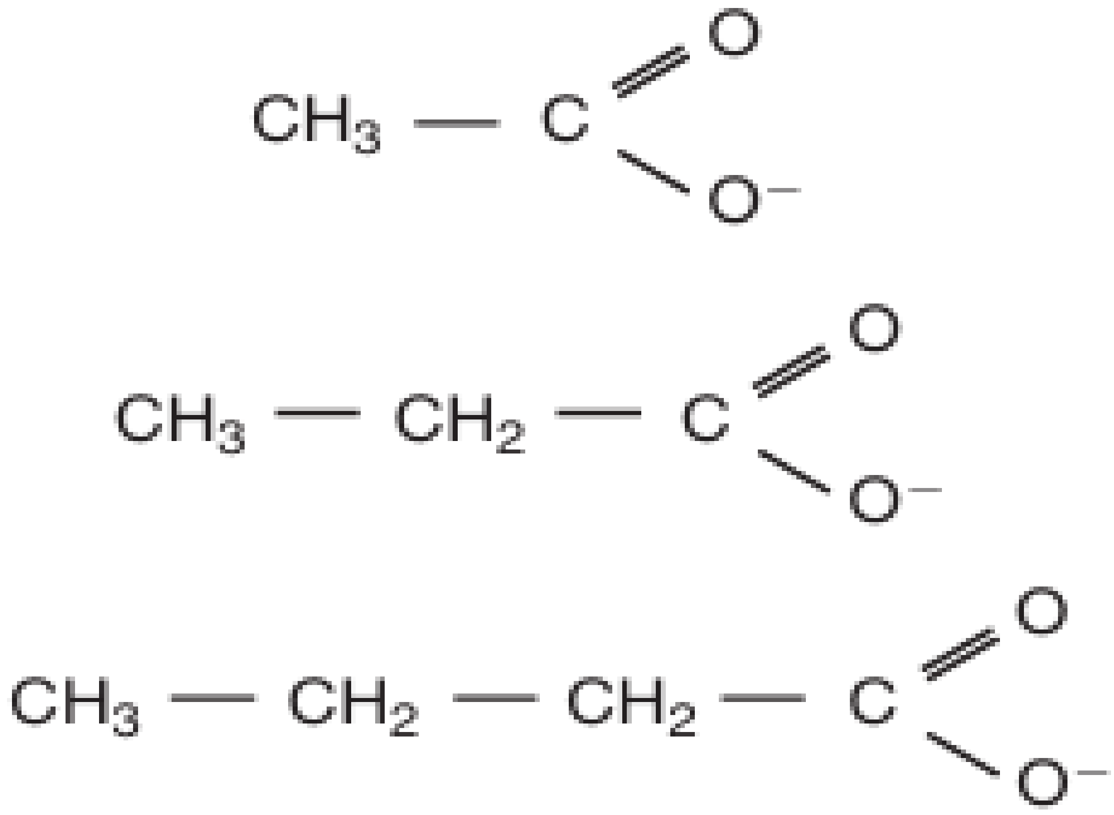
Major Acid-Utilizing Species
Megasphaera elsdenii
Selenomonas ruminantium

Major Proteolytic Species
Bacteroides amylophilus
Bacteroides ruminicola
Butyrivibrio fibrisolvens
Streptococcus bovis

Major Ammonia-Producing Species
Bacteroides ruminicola
Megasphaera elsdenii
Selenomonas ruminantium

Major Lipid-Utilizing Species
Anaerovibrio lipolytica
Butyrivibrio fibrisolvens
Treponema bryantii
Eubacterium species
Fusocillus species
Micrococcus species

Volatile Fatty Acids(VFA)

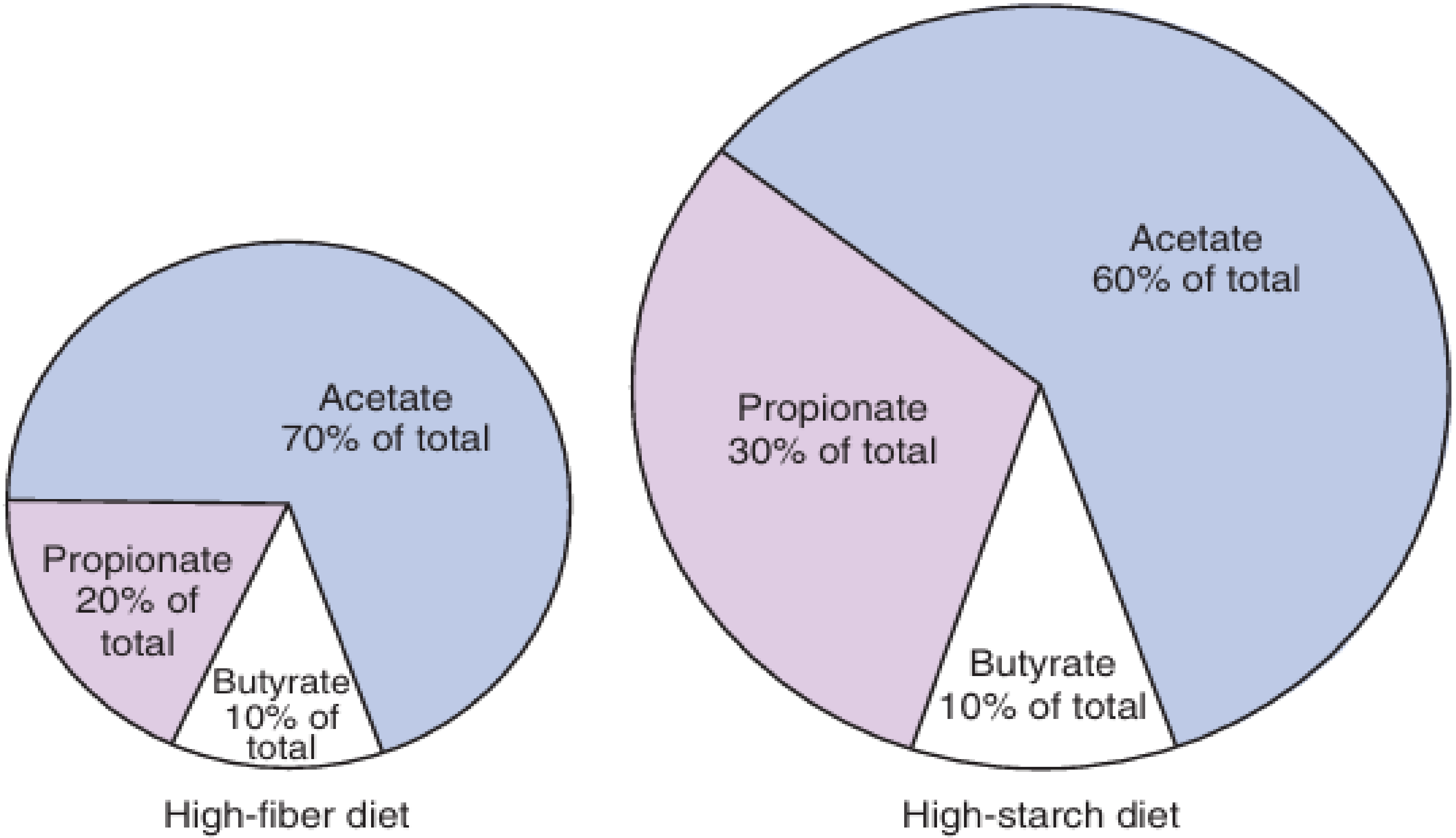


Acetate

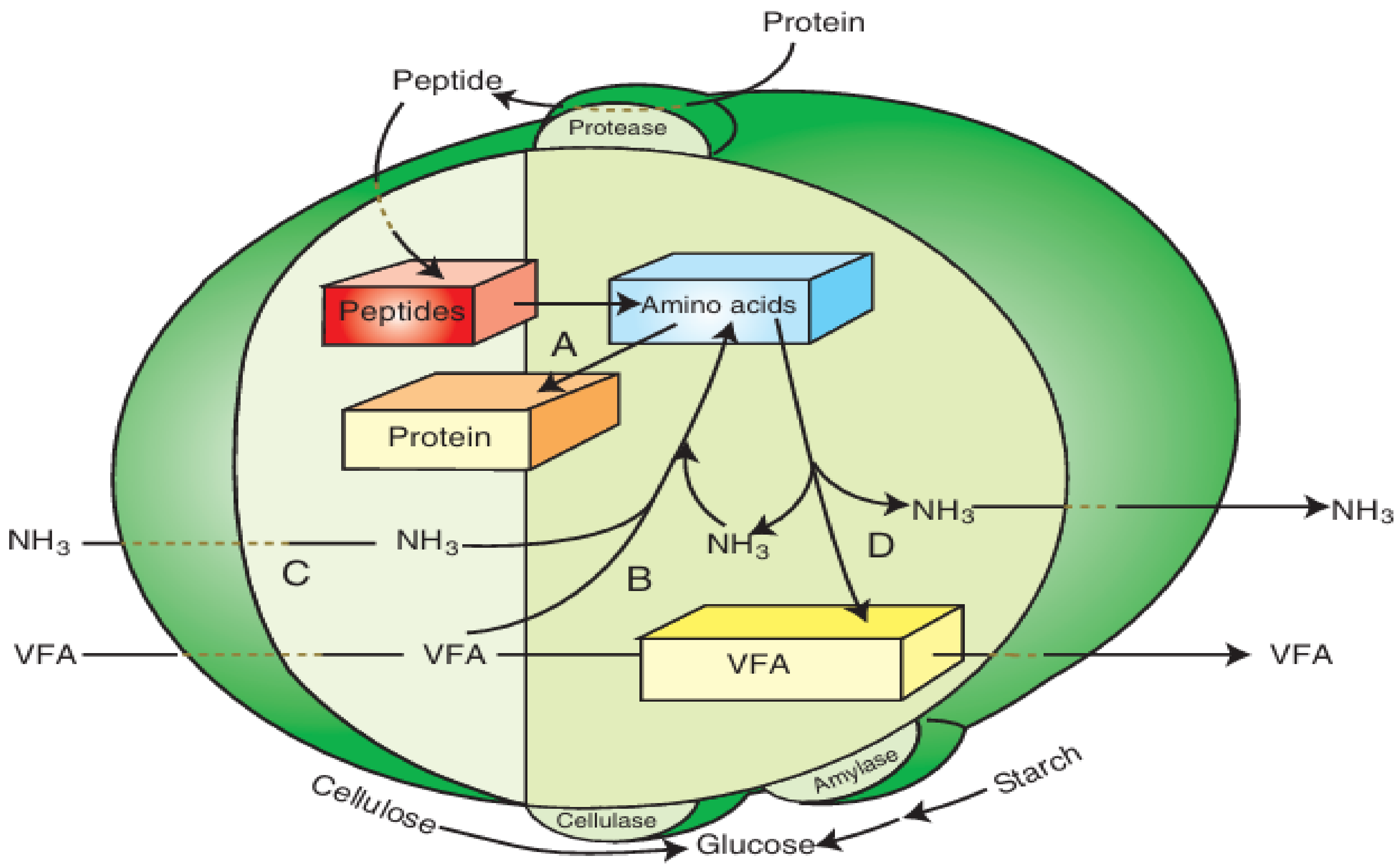
Propionate

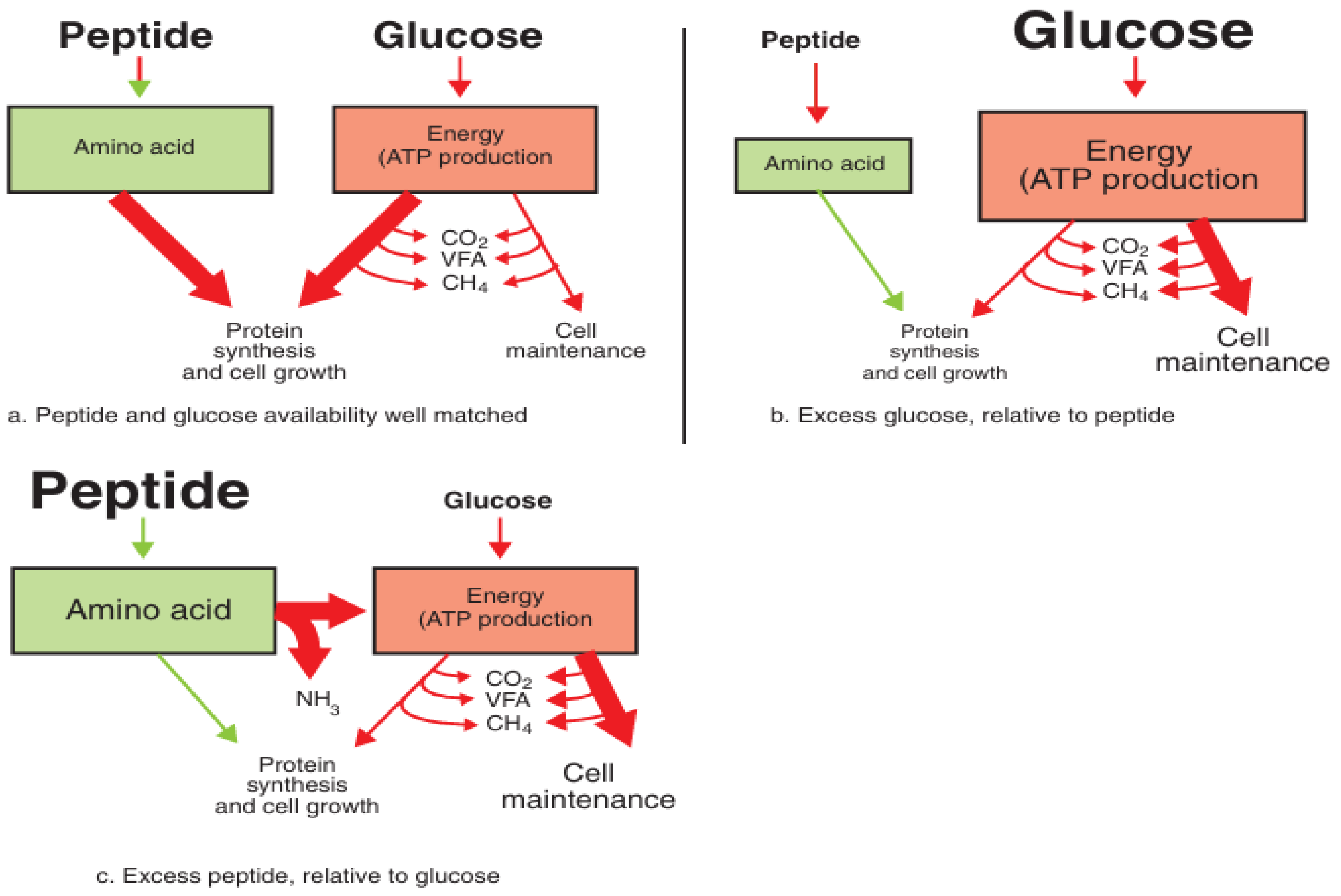
Butyrate

Volatile Fatty Acids(VFA)

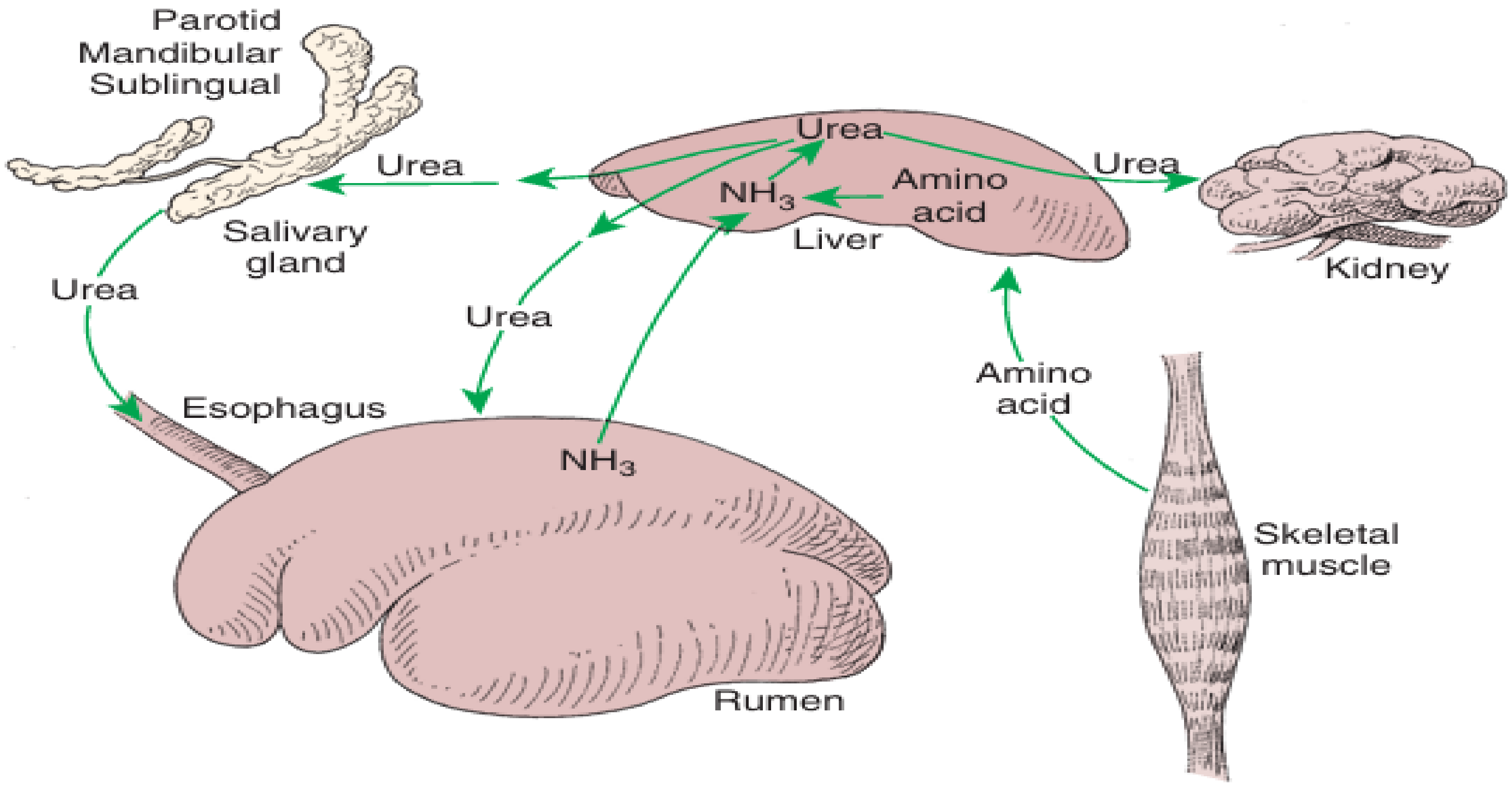


Protein Metabolism by Rumen Microbes

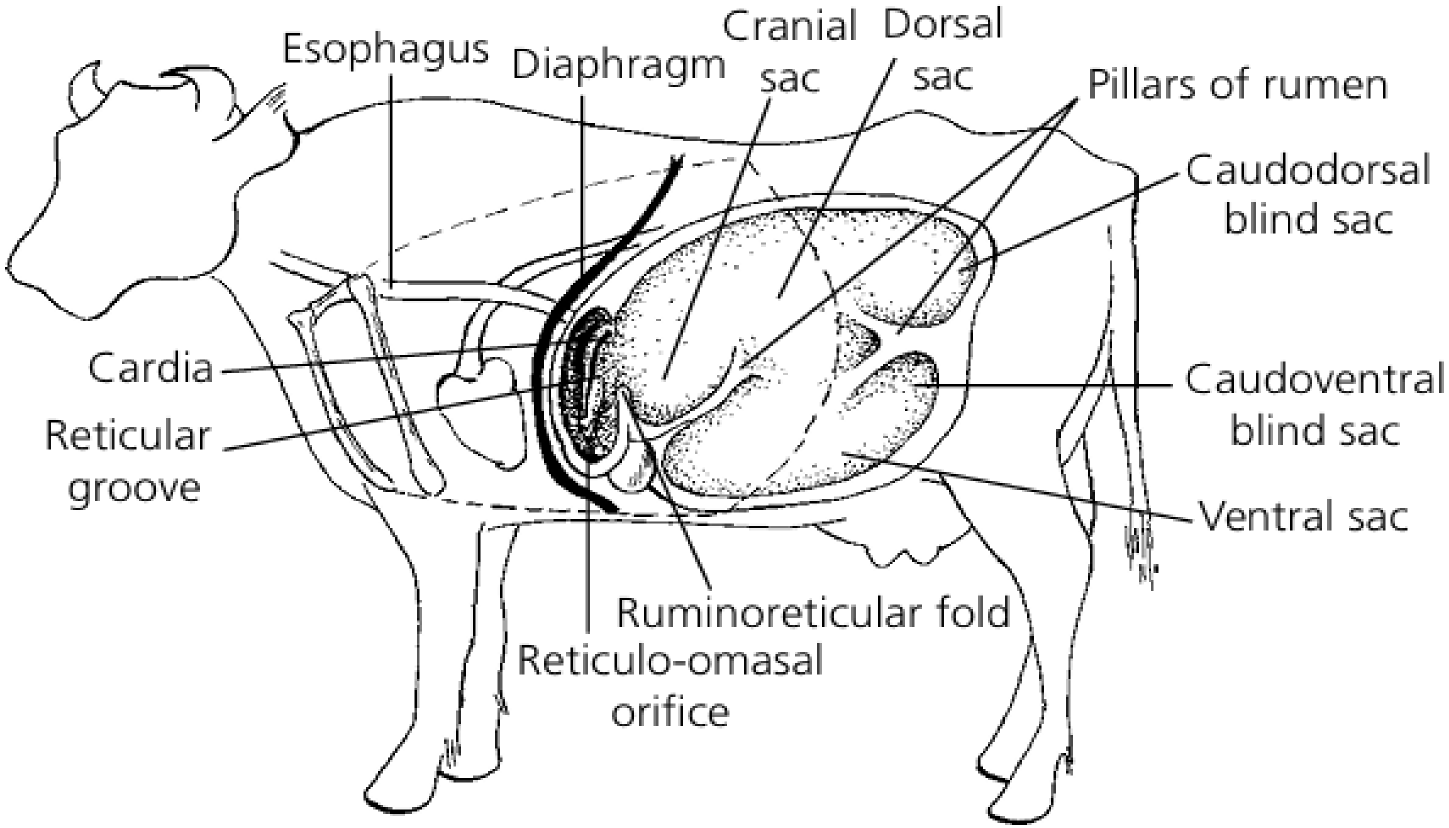



Peptide
Glucose
Amino acid
Energy (ATP production
CO_2
VFA
CH_4
Protein synthesis and cell growth
Cell maintenance
a. Peptide and glucose availability well matched
Peptide
Glucose
Amino acid
Energy (ATP production
CO_2
VFA
CH_4
Protein synthesis and cell growth
Cell maintenance
b. Excess glucose, relative to peptide
Peptide
Glucose
Amino acid
Energy (ATP production
NH_3
CO_2
VFA
CH_4
Protein synthesis and cell growth
Cell maintenance
c. Excess peptide, relative to glucose

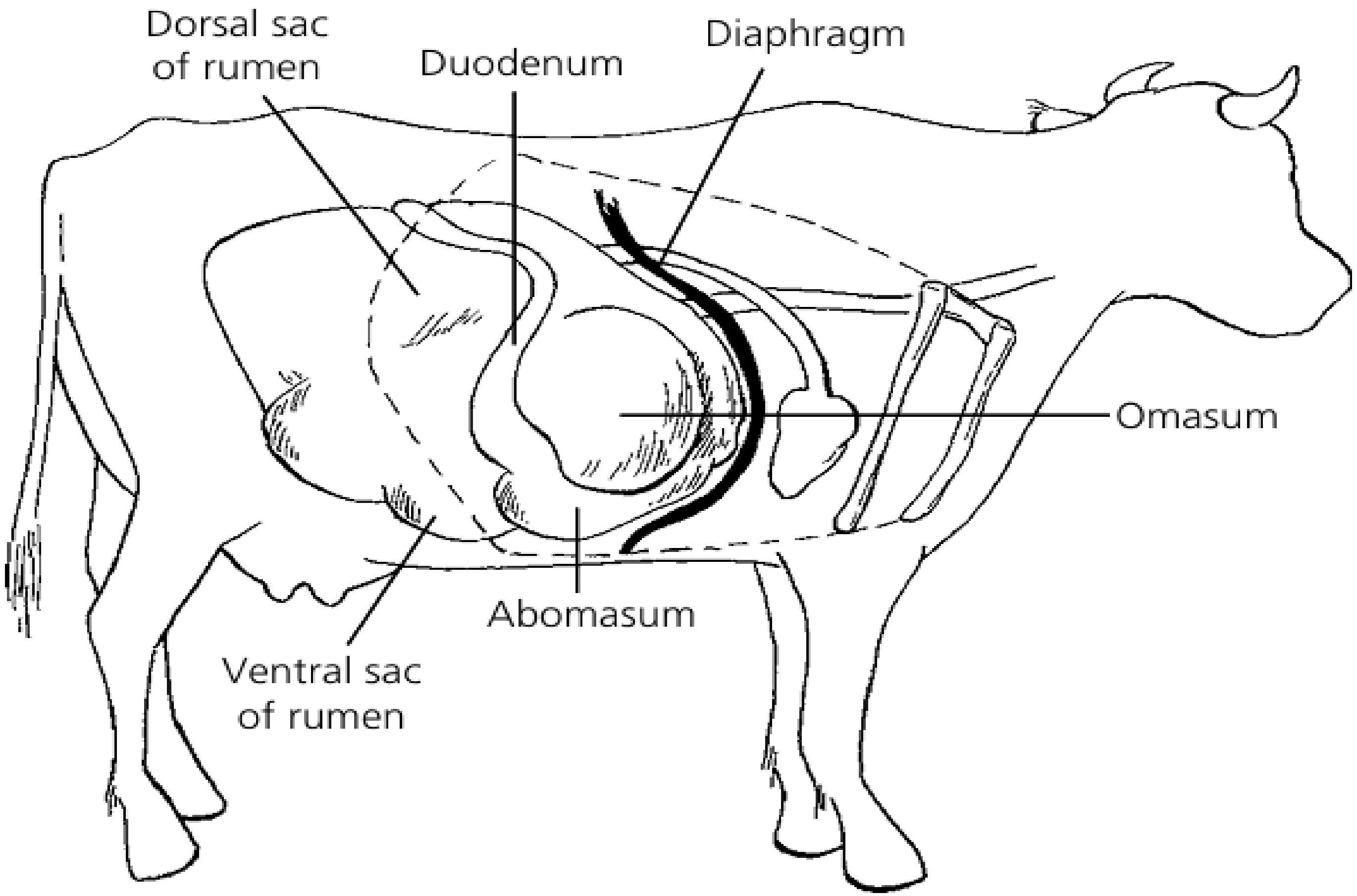
Interorgan Nitrogen Cycling in Ruminants



The Fermentative Digestion in Ruminants

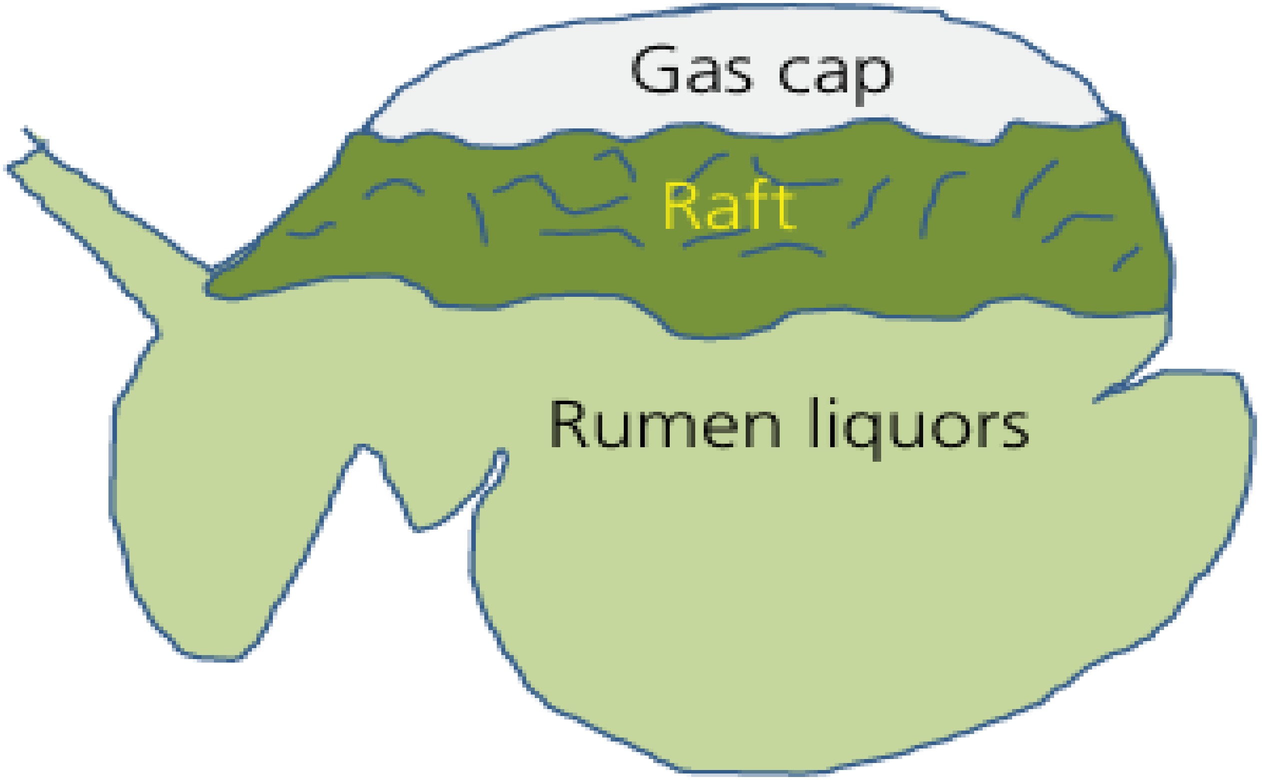


The Fermentative Digestion in Ruminants

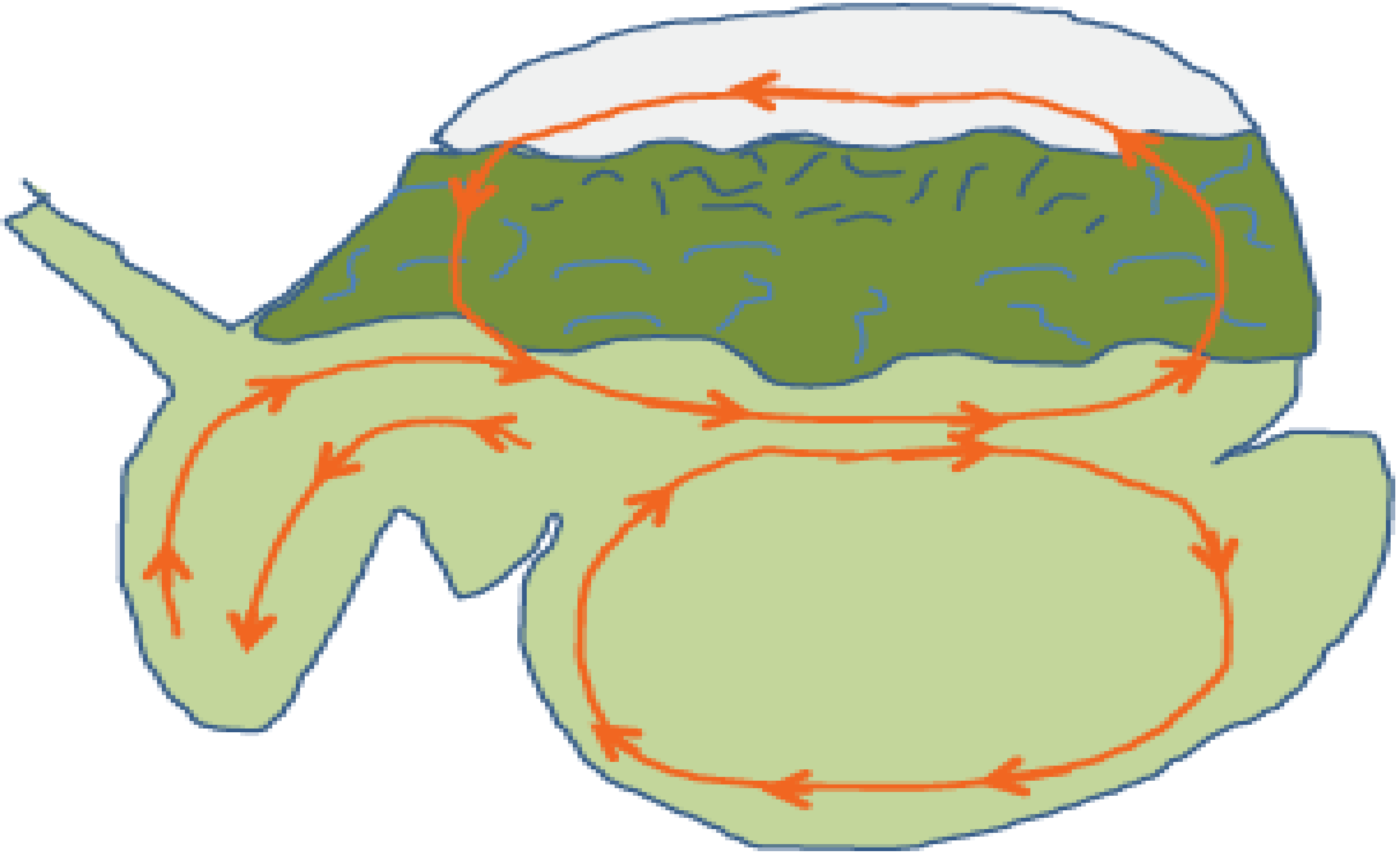


Mucosal Surface of Forestomachs in Ruminant

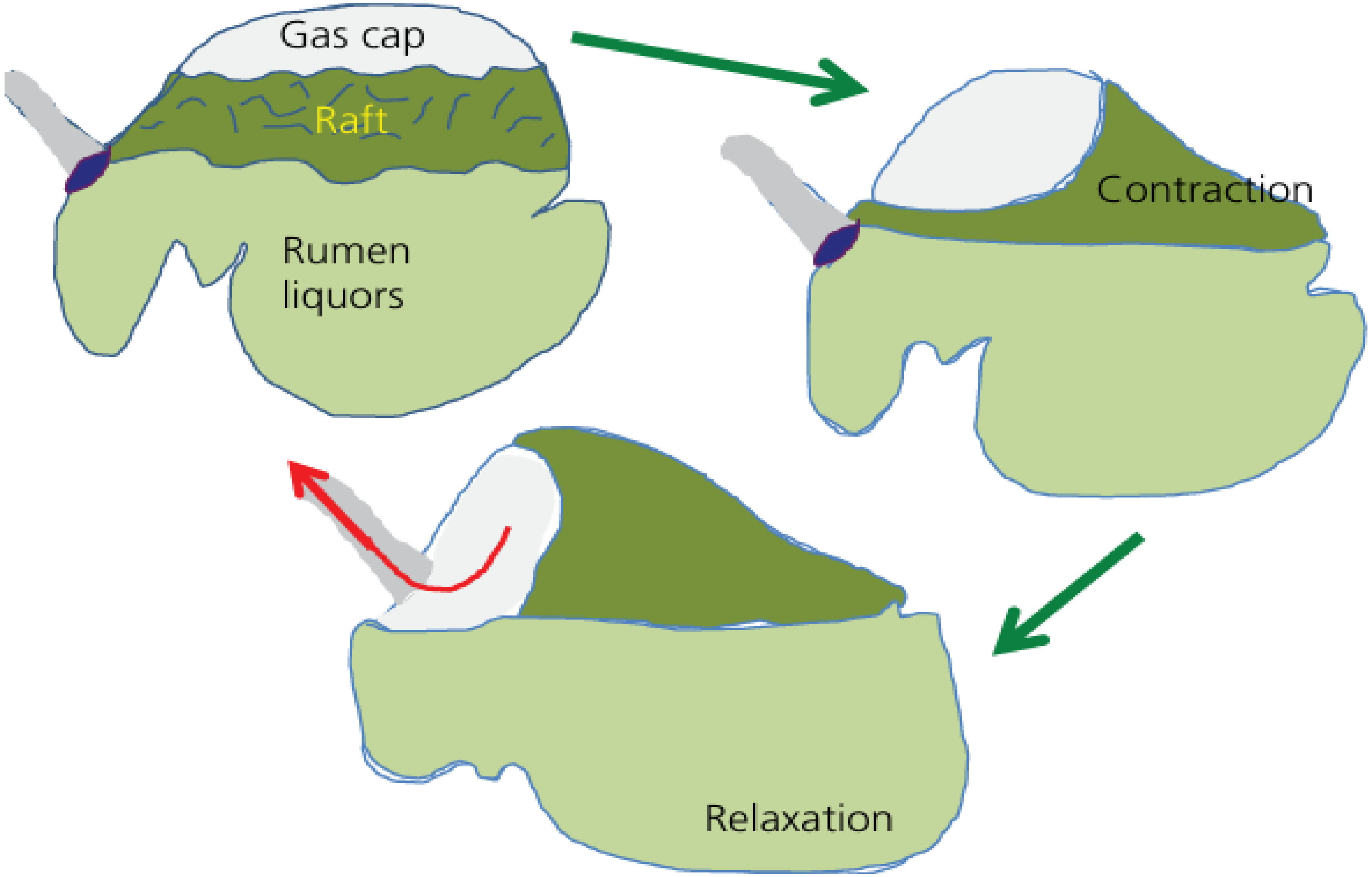
Layers of Ingesta in Rumen



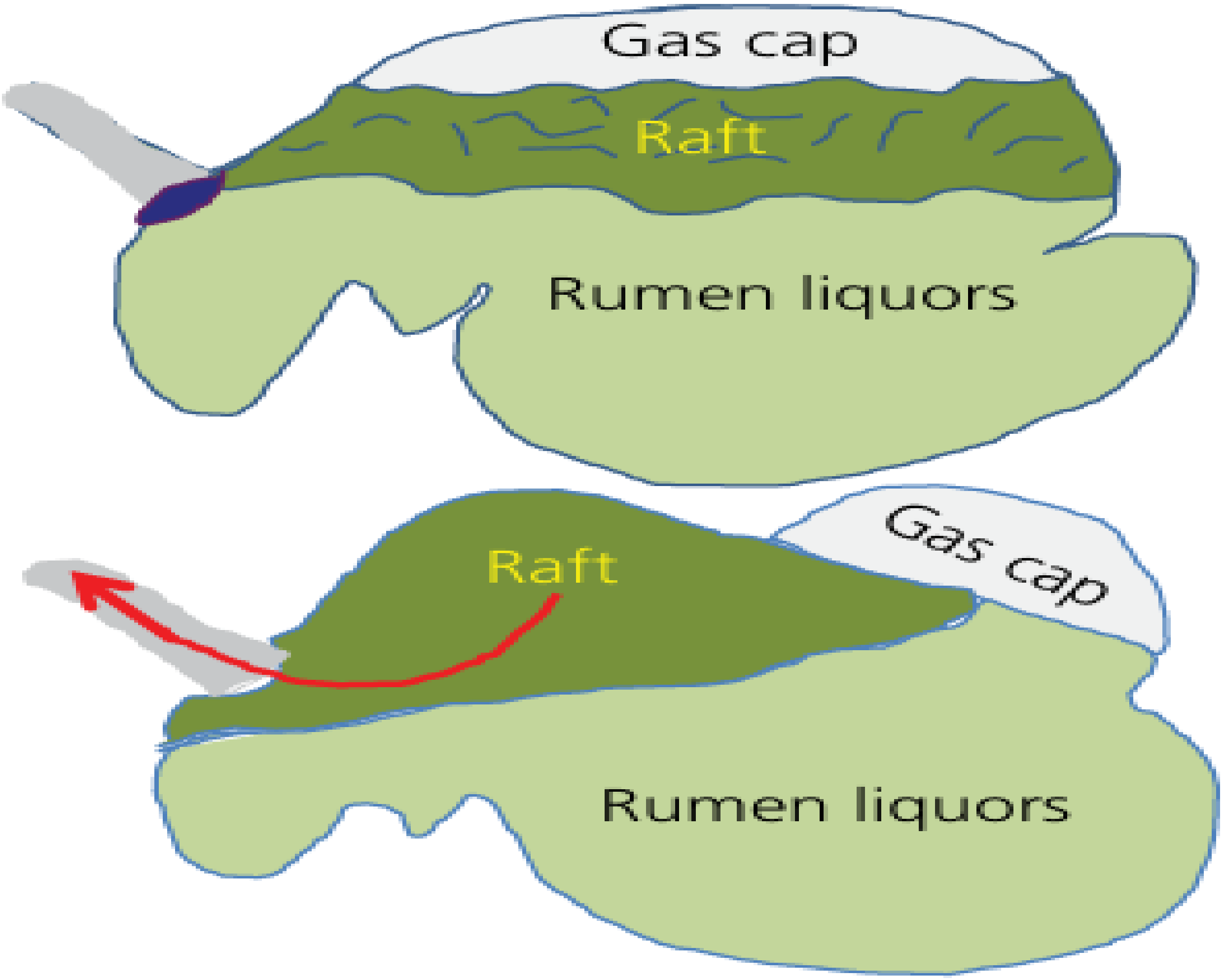
Mixing Contractions



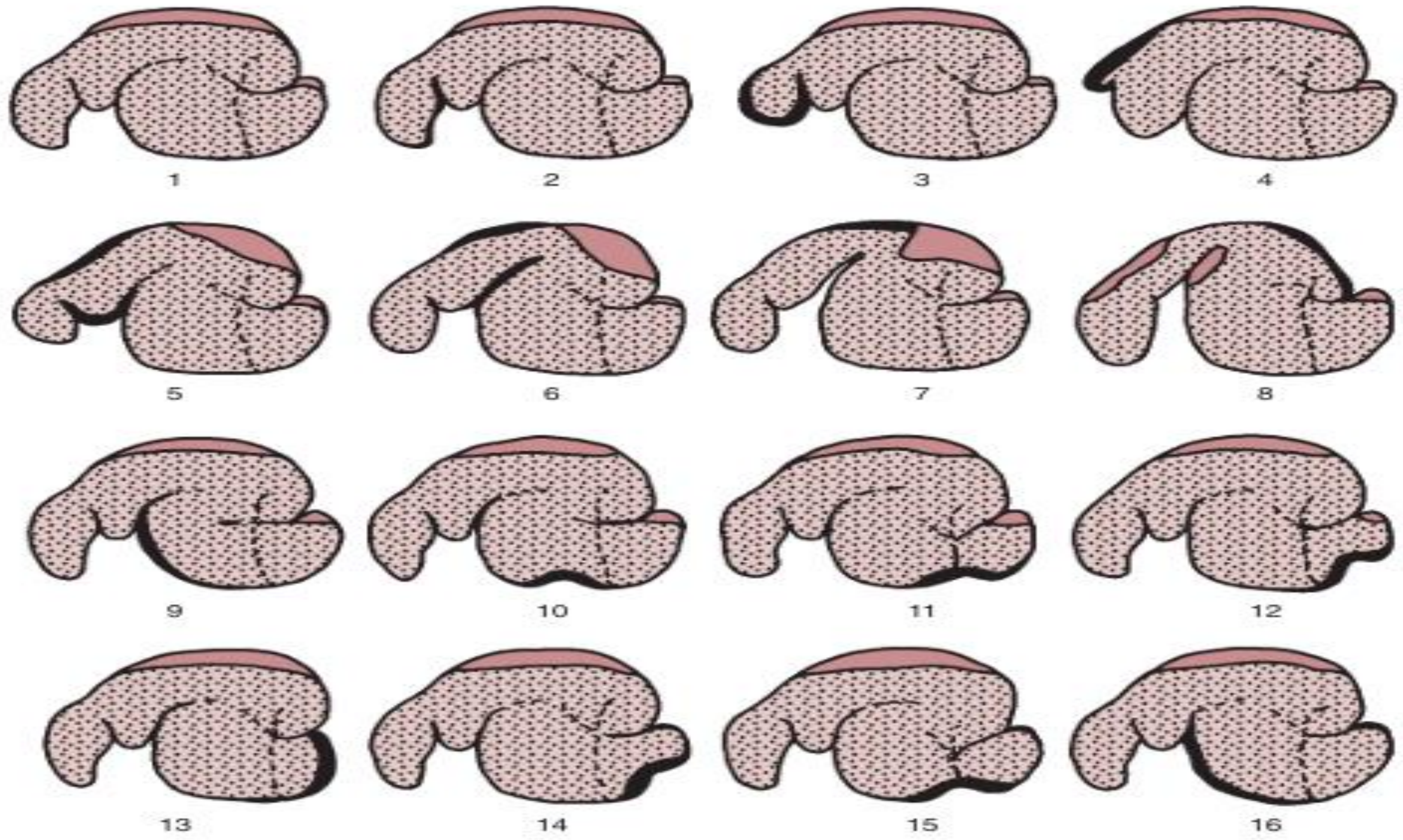
Eructation Reflex



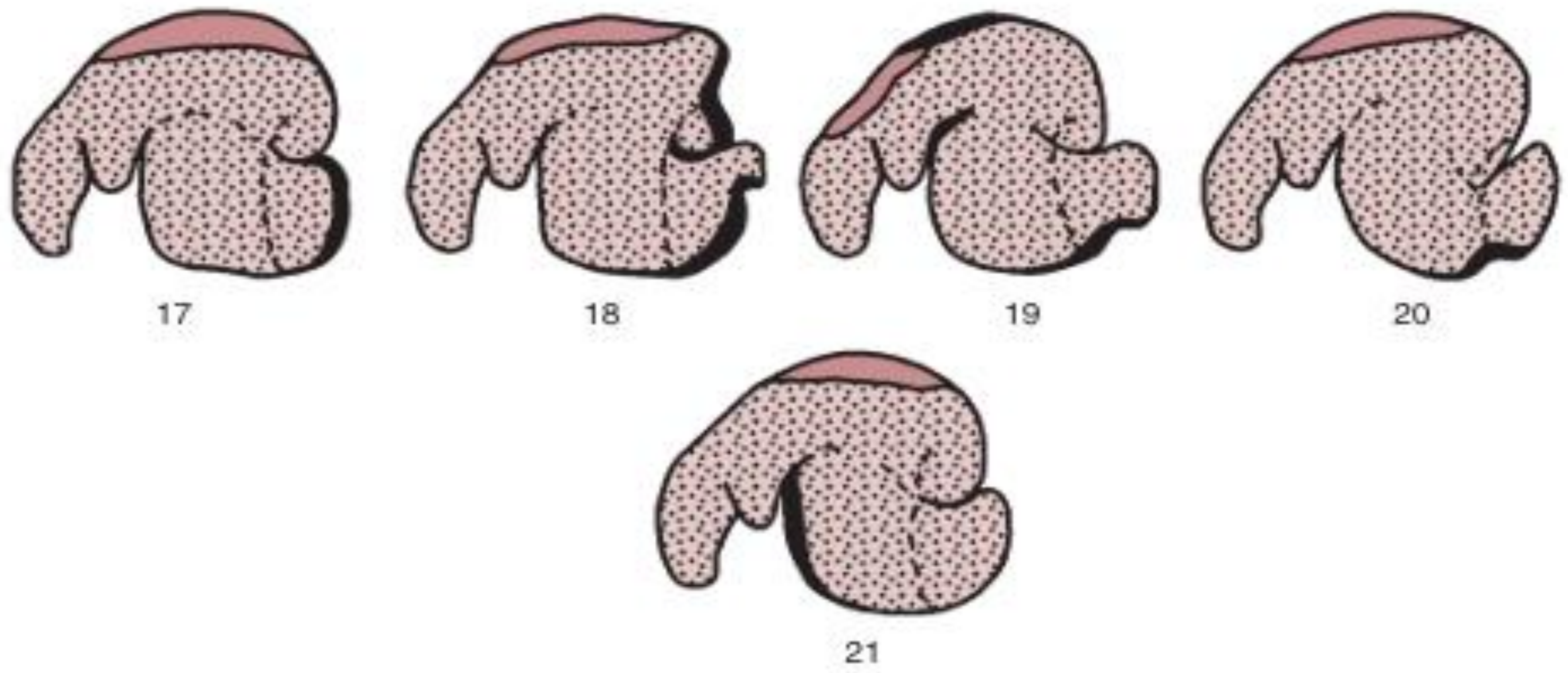
Rumination and Regurtigation Reflex



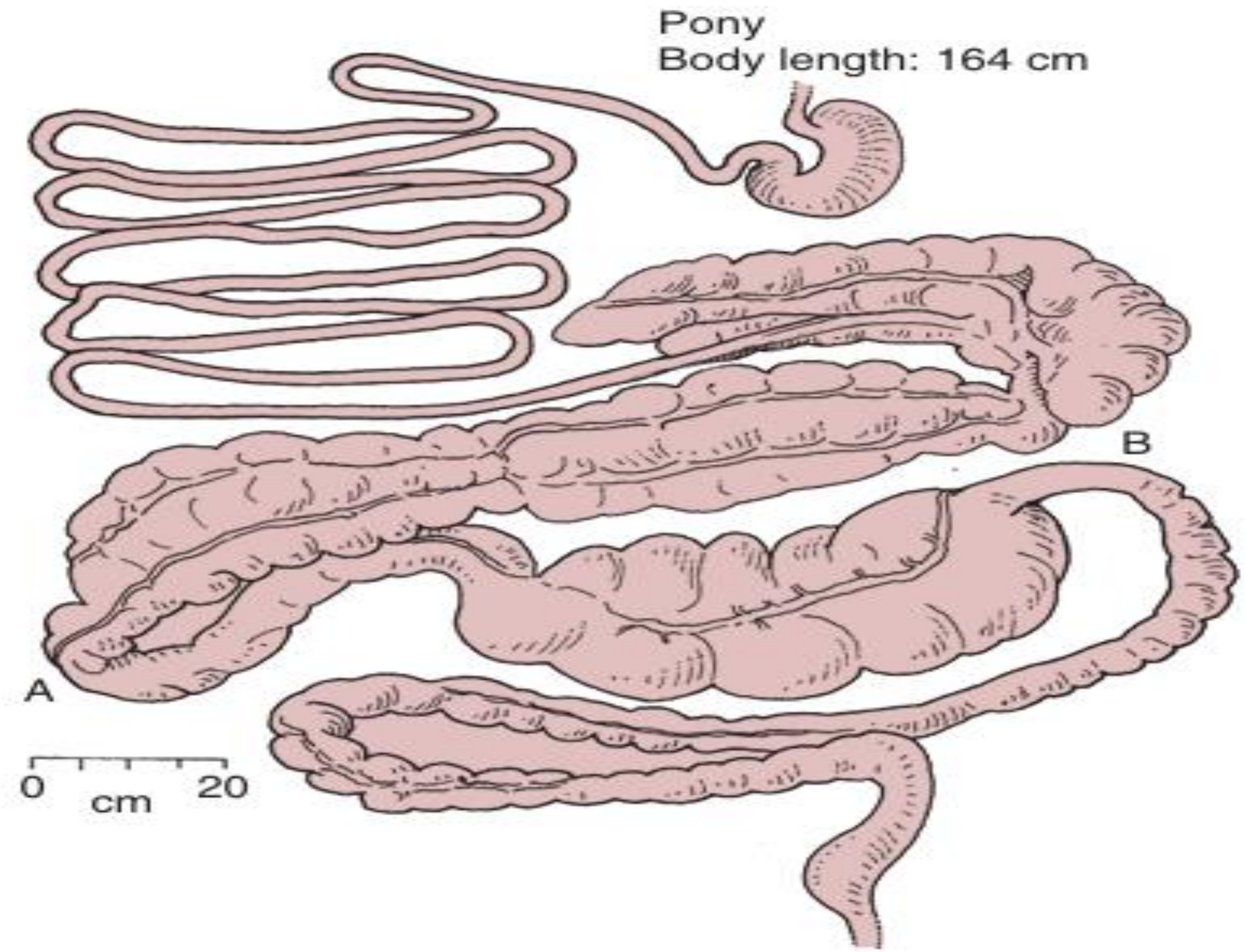
Reticuloruminal Contractions(Primary C.)



Reticuloruminal Contractions(Secondary C.)



Equine Fermentative Digestion



Equine Fermentative Digestion

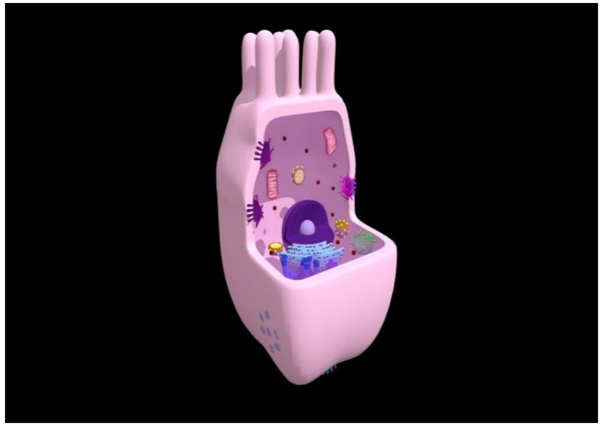
The Equine Hindgut Has a Great Capacity for Fermentation

The Types of Substrate and Fermentation Patterns Are Essentially Identical for Forestomach and Hindgut Fermentation

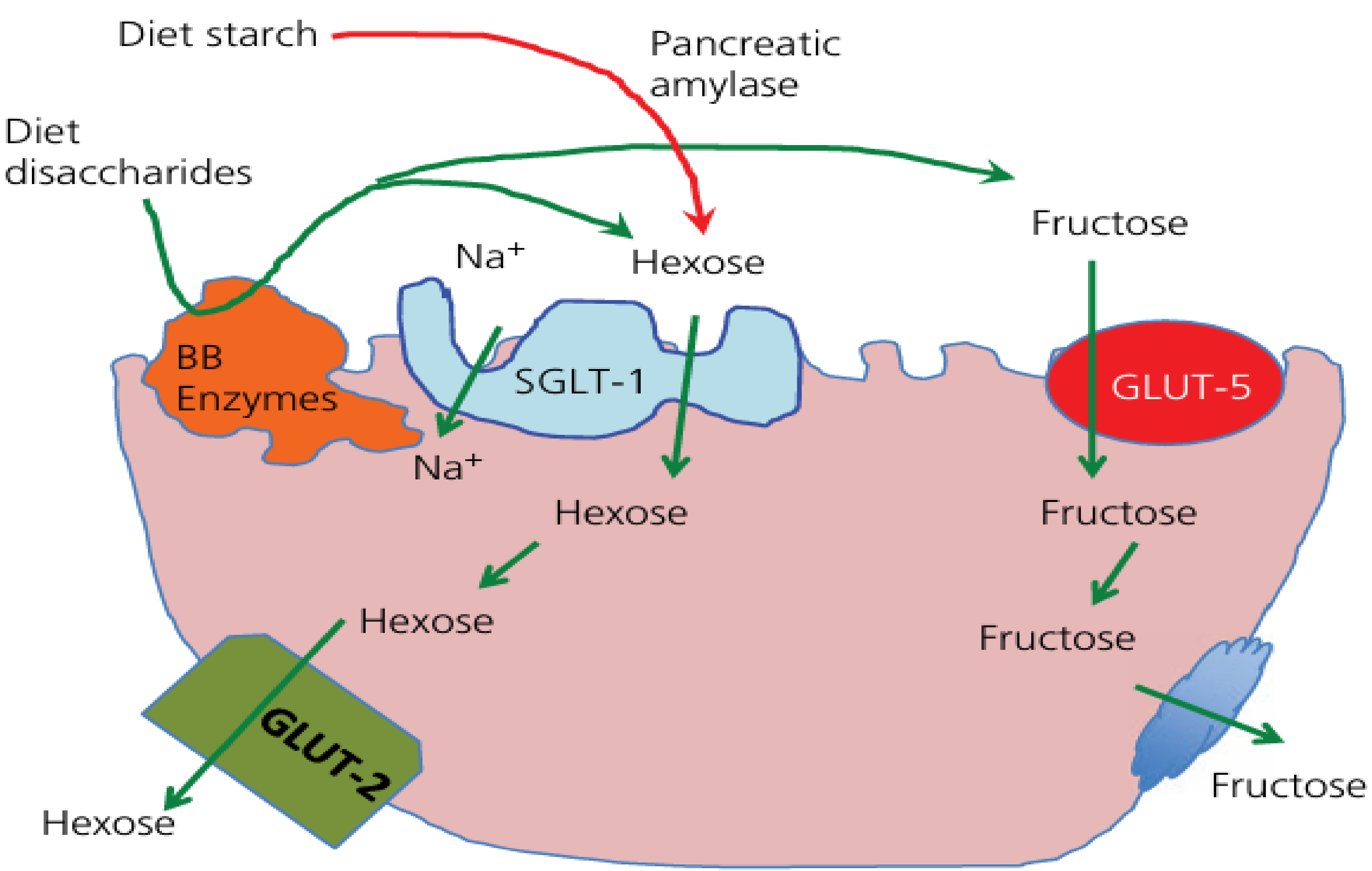
The Rate of Fermentation and Volatile Fatty Acid Production in the Equine Colon Is Similar to That in the Rumen

Absorption

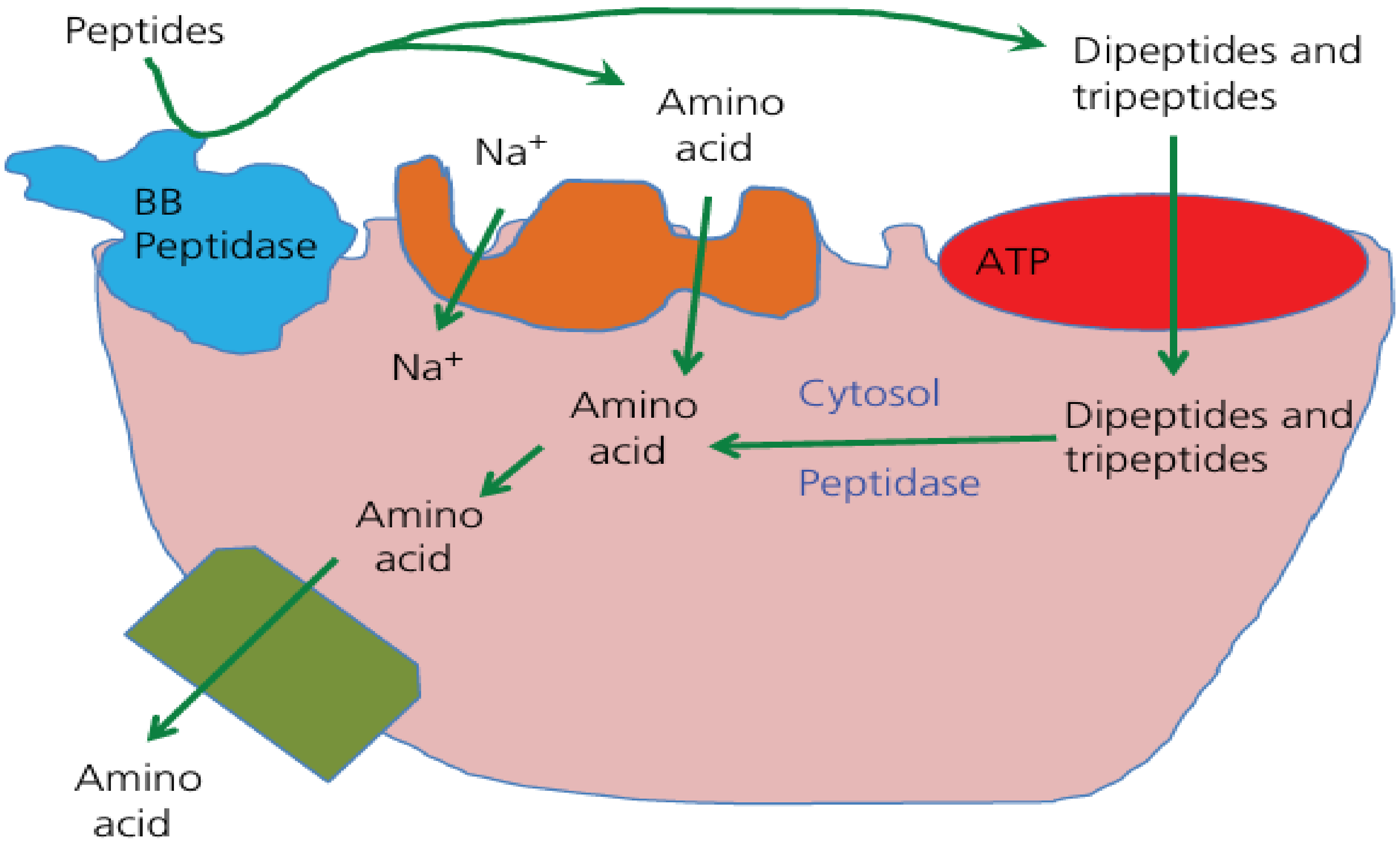
Specialized Nutrient Transport Systems Exist in the Apical and Basolateral Membranes



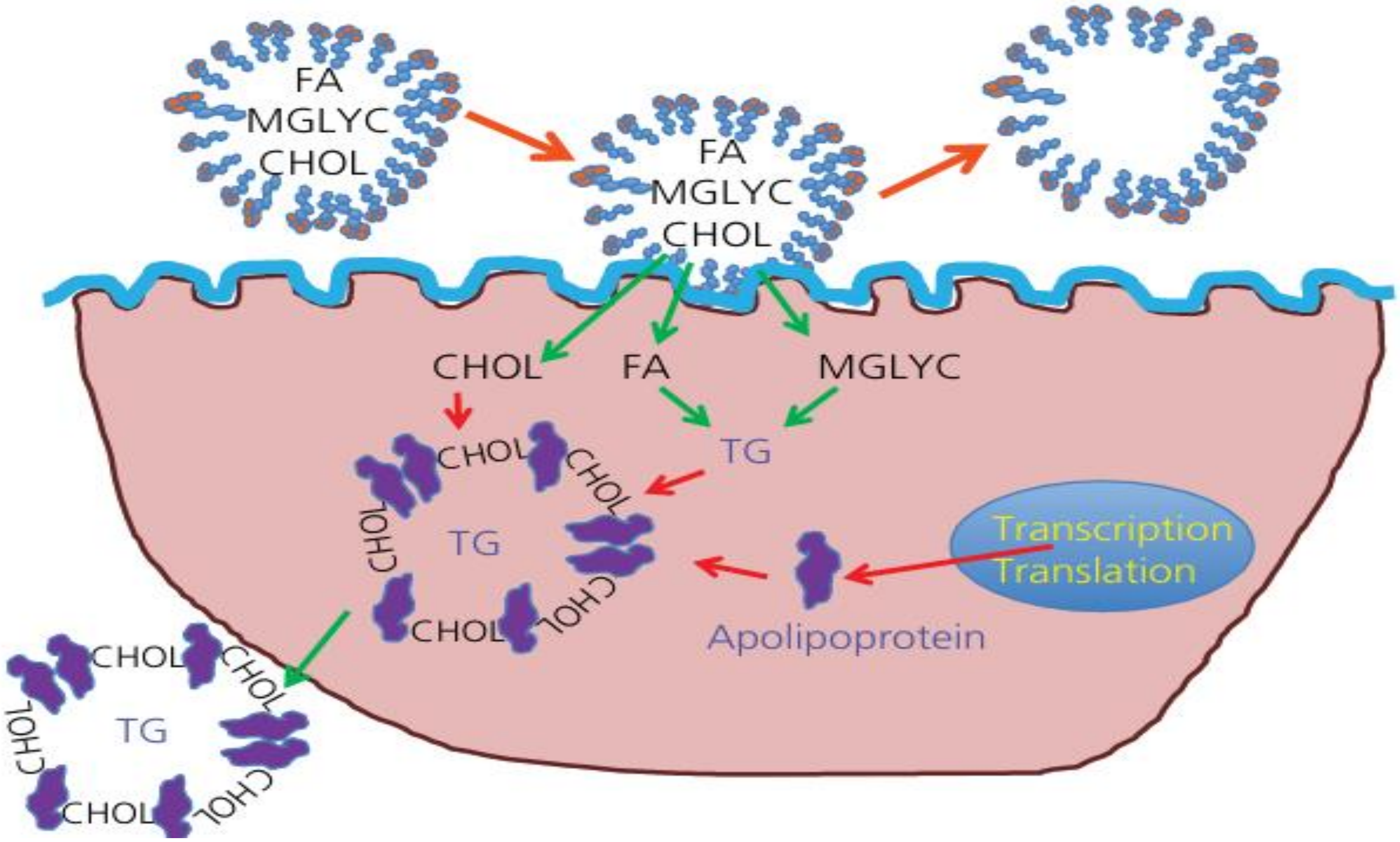
Absorption of Carbohydrates



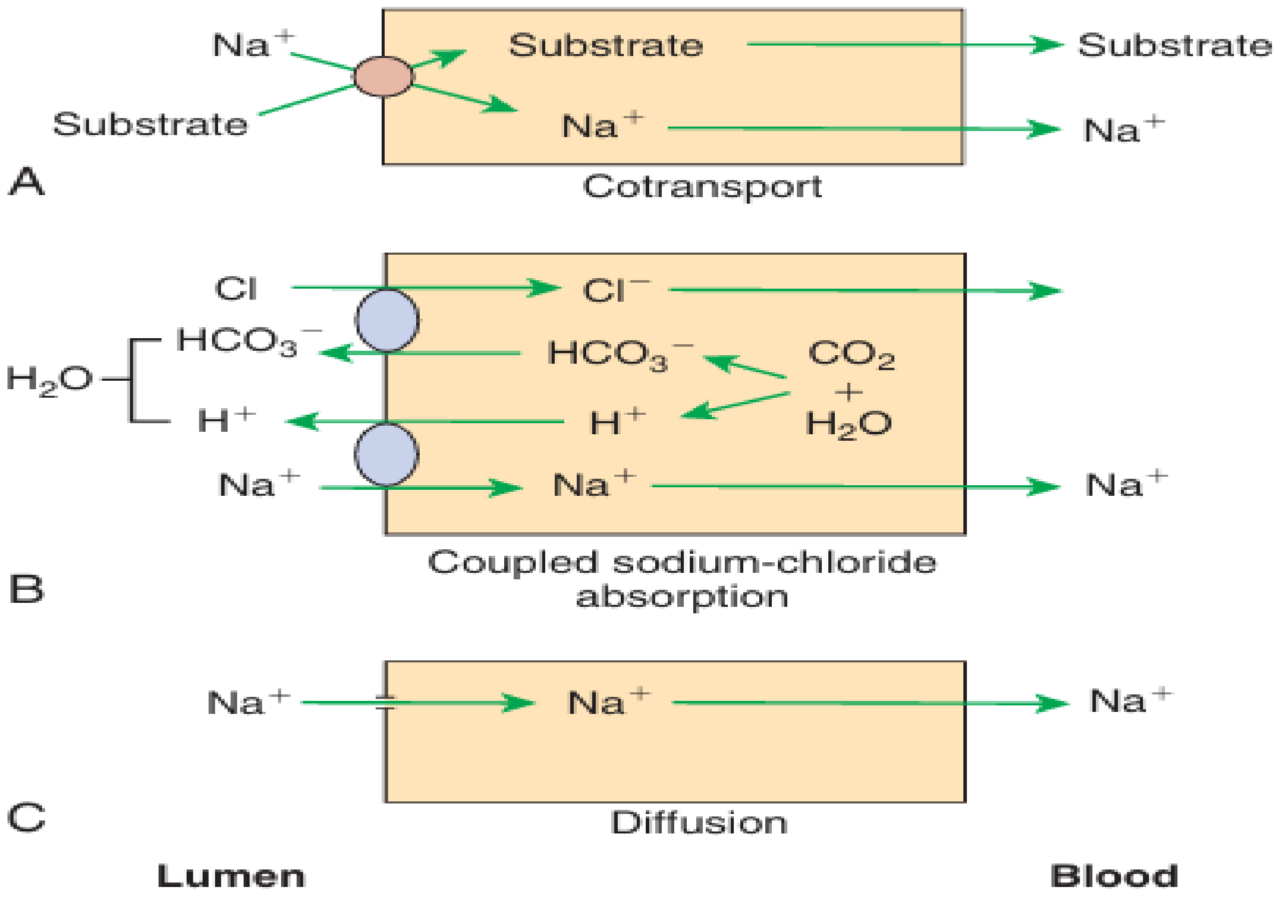
Absorption of Proteins



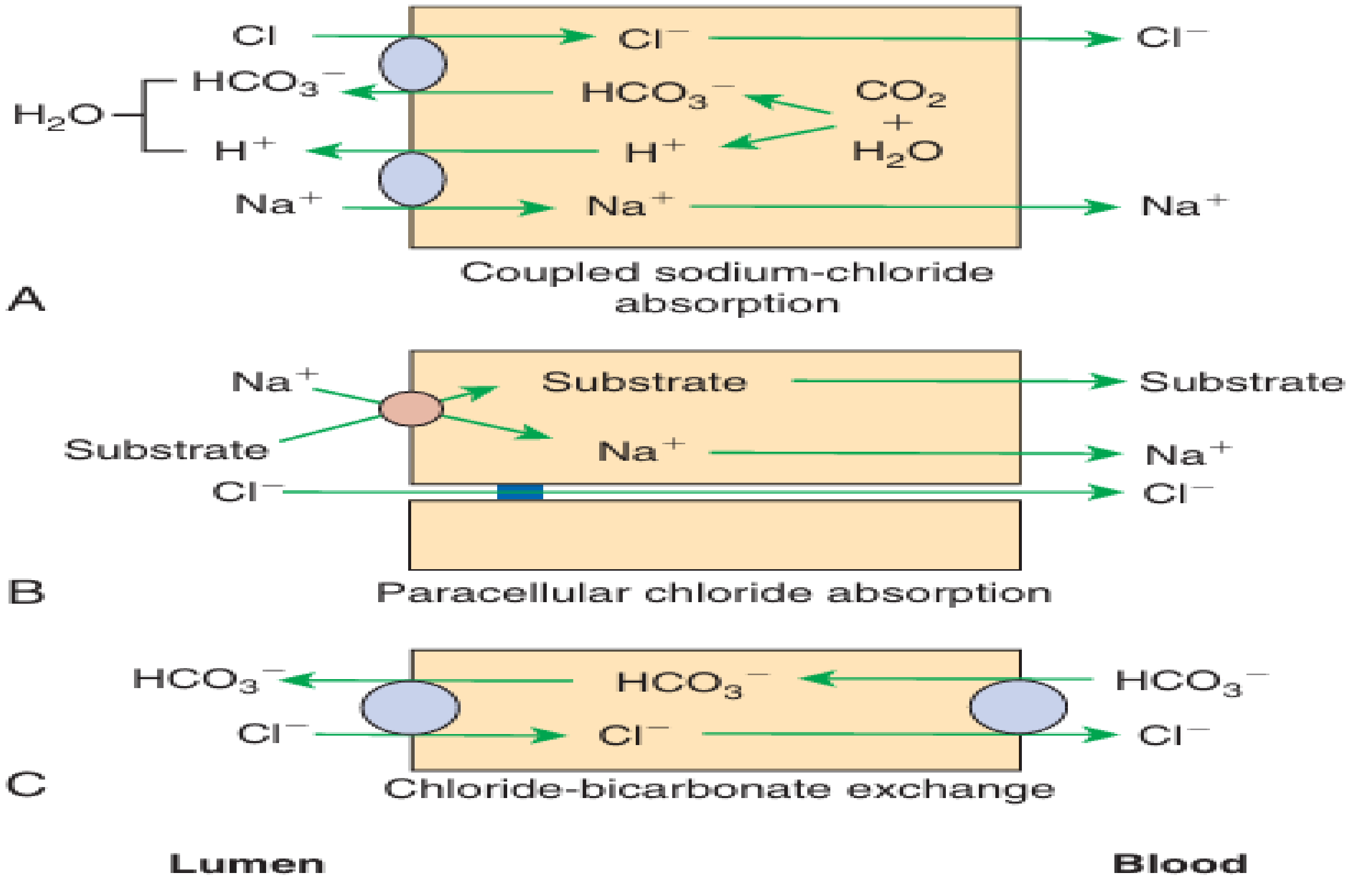
Absorption of Lipids



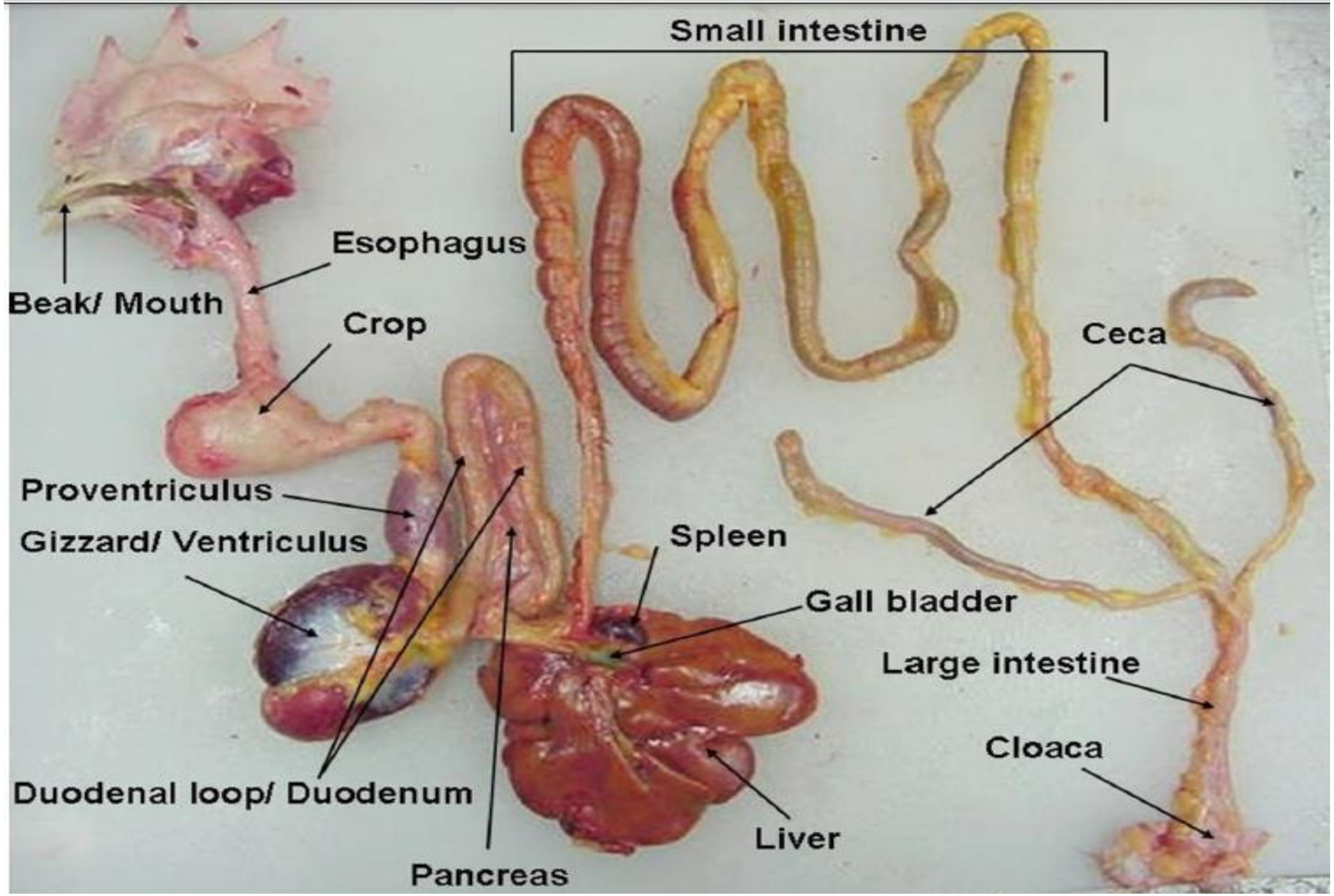
Absorption of Sodium



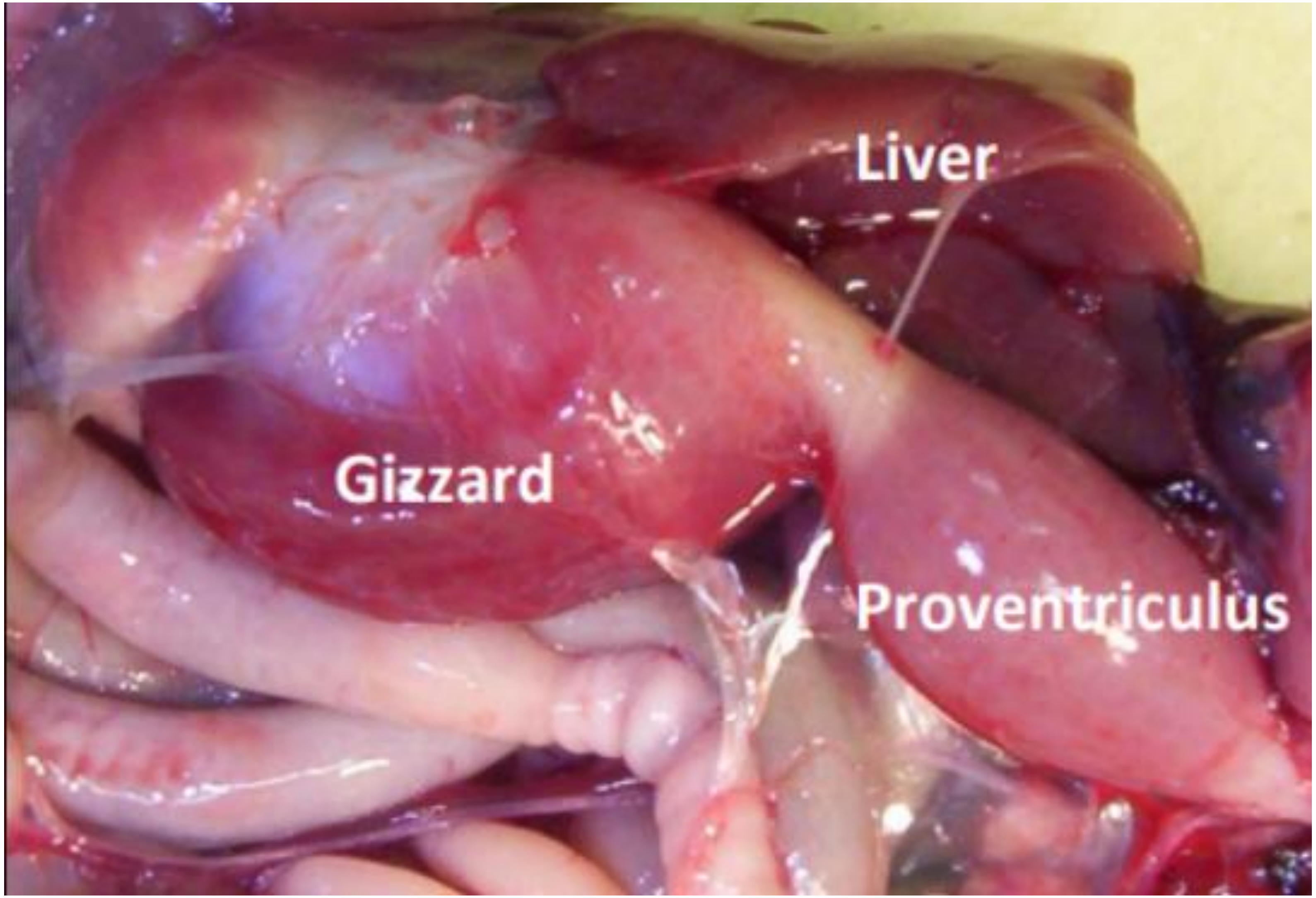
Absorption of Chloride



Avian Digestive System



Avian Digestive System



Avian Digestive System