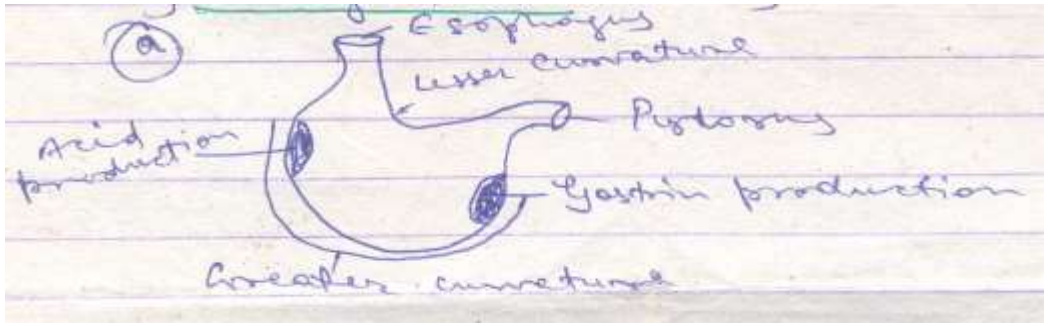
Digestive System

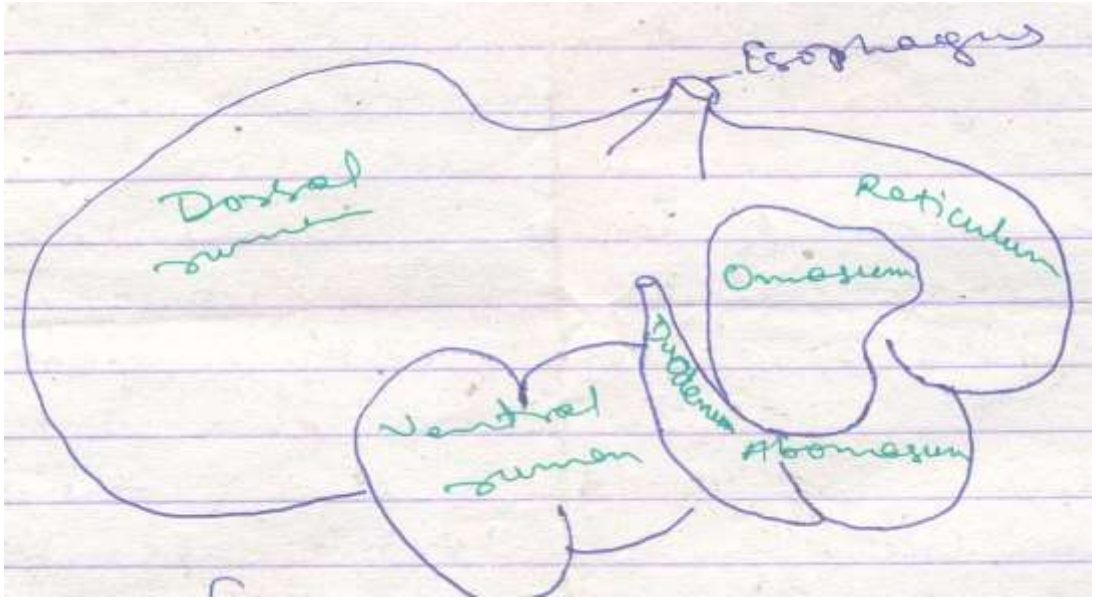
Digestive tract of monogastric & ruminant animal:

- Oral cavity is divided into lips & muzzle, helps in prehension
- Cheek- store food in mouth for mastication
- Tonsil- a gland, determines the status of oral cavity
- Tongue- Helps in prehension of food
- Pharynx- common passage for food & air
- Esophagus- connecting pharynx to the stomach
- Stomach- 2 types, a single & 4 chambered

Monogastric animals stomach: Consists of cardia, fundus, body & pylorus



Polygastric animals stomach: Consists of rumen, reticulum, omasum & abomasum



Esophagus enters stomach at the junction of rumen & reticulum while abomasum is the true stomach.

Functions of stomach compartments:

- **Rumen-** Helps in fermentation, digestion & absorption of end products particularly volatile fatty acids present in micro-flora & micro-fauna
- **Reticulum-** It pushes solid food into rumen & fluidy ingesta into omasum & acts as strainer

Schematic diagram of a cow:

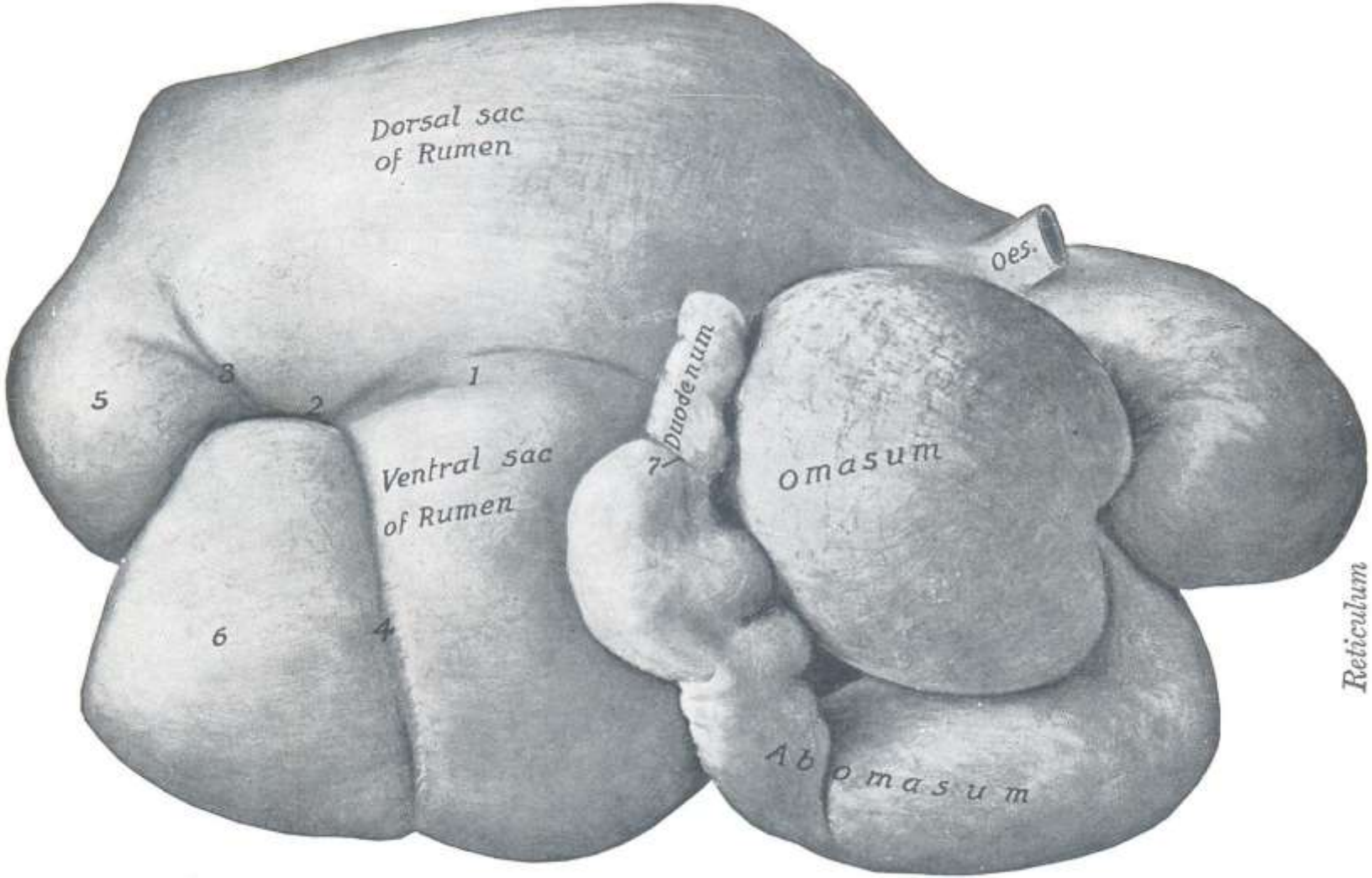
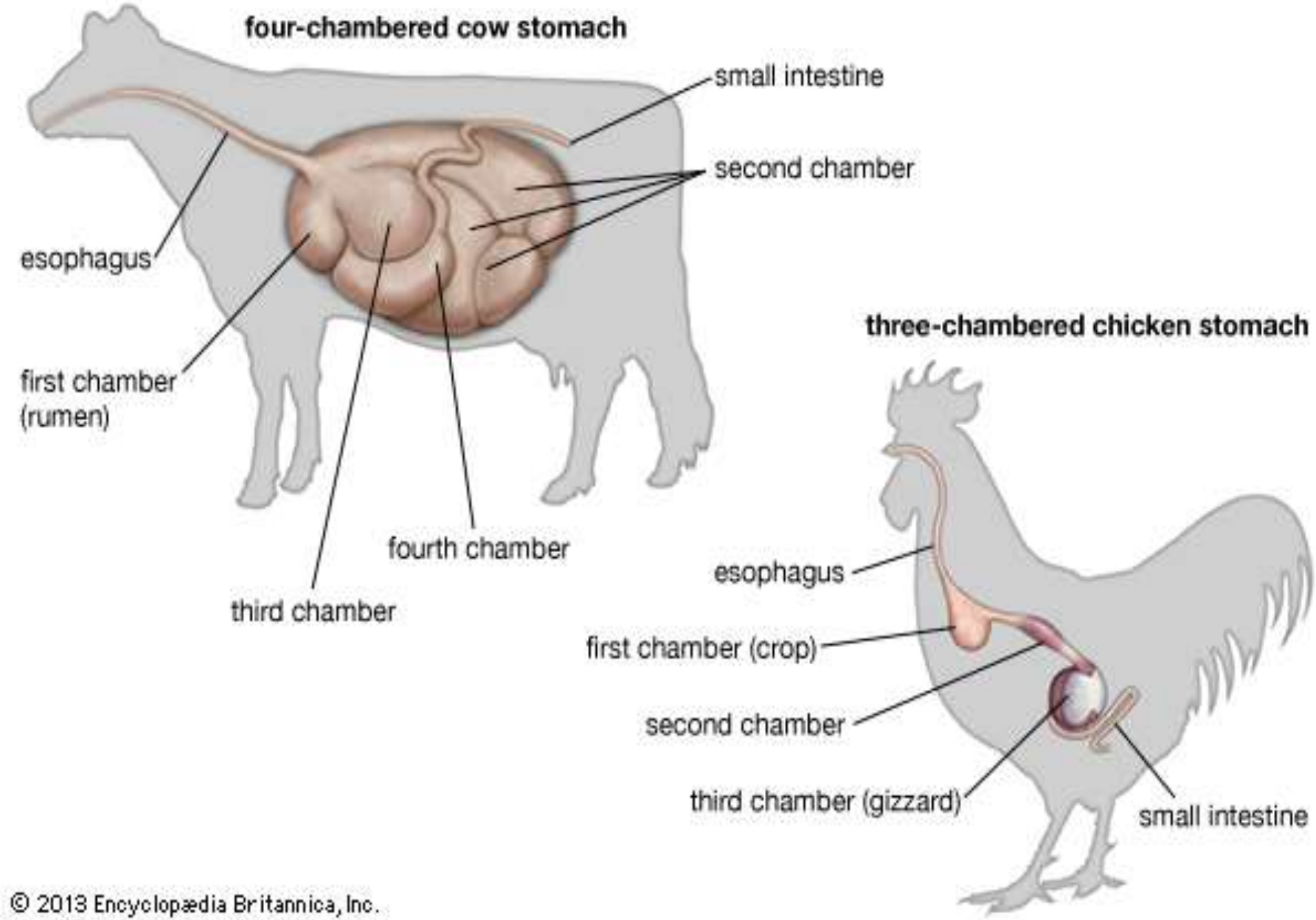
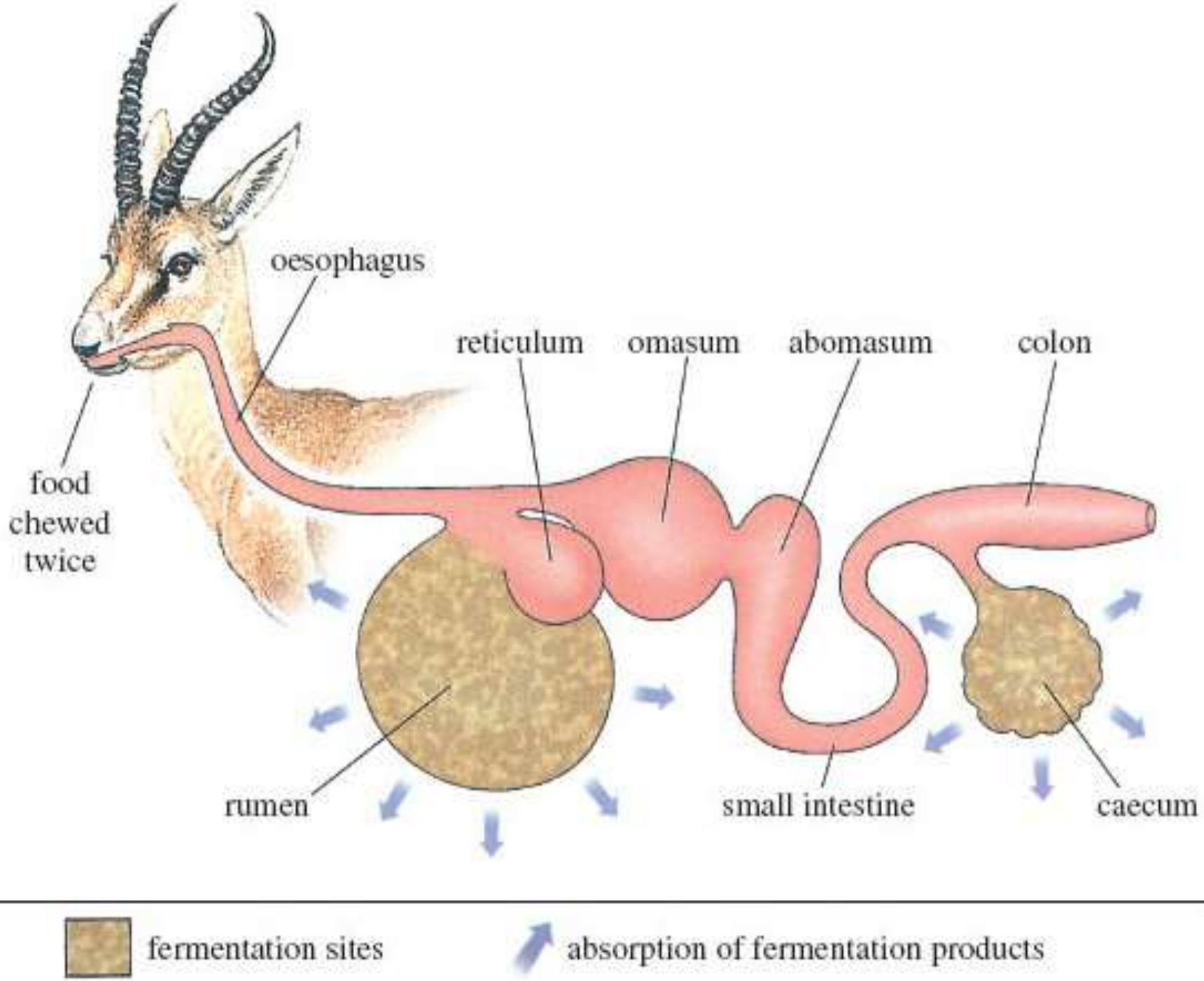


Fig. 18–9. Stomach of cow, right view. Oes, Esophagus; *1*, right longitudinal groove of rumen; *2*, caudal groove of rumen; *3, 4*, coronary grooves; *5, 6*, caudal blind sacs of rumen; *7*, pylorus. From Sisson and Grossman: The Anatomy of the Domestic Animals. Philadelphia, W.B. Saunders.

Different animal stomachs




oesophagus
reticulum
omasum
abomasum
colon
food
chewed
twice
rumen
small intestine
caecum
fermentation sites
absorption of fermentation products

- **Omasum-** grind food particles, absorb water along with Na & K and flowing VFA
- **Abomasum-** Gastric juice is secreted to regulate chemical & enzymatic digestion. It also regulates the flow of ingesta

Small intestine- Consists three segments i.e. duodenum, jejunum and ileum. They helps in digestion & absorption. It is composed of four layers from outside inward as serous, muscular, outer sub mucosa & inner mucous layer.

Large intestine- consists of 3 parts i.e. cecum, colon & rectum.

- In carnivores, the vitamins, minerals, water & end products escape from small intestine absorption are allow to absorb.
- It absorbs a large quantity of water & make end product digested a semisolid consistency & allow to excrete.

Prehension- Process of feed & water intake by domestic animals are aided by muzzle, lips, cheek, tongue & teeth is called prehension.

Mastication- feed intake is crushed & divided into small pieces for further smooth digestion & absorption by chewing & mastication.

Deglutition- Deglutition or swallowing is conveying of food from mouth through the pharynx & esophagus to stomach. This is under control of a centre in the medulla

Rumination- In polygastric animals, food once swallowed is taken back to the oral cavity for re-mastication & re-ensalivation.

Defecation: Complex reflex act where the feces are excrete or expelled through the anus.

Hunger contraction- These are peristaltic waves travelling from cardia to pylorus. They appear before the stomach has completely or partially emptied.

Thirst- a sensation referred to the mucous membrane of mouth & pharynx

Vomition- the spasmodic ejection of contents of the stomach through esophagus & mouth.

Act of vomition: It comprises following actions

- Relaxation of stomach muscles & esophageal sphincter & closing of pylorus.
- Contraction of abdominal muscles leading to ↑ in intra abdominal pressure
- Expansion of chest cavity with closed glottis
- Opening of upper esophageal sphincter

Saliva- The salivary glands, parotid, sub-mandibular & sub-lingual secretes the alkaline liquid which helps in mixing & collecting of food material.

Composition of saliva-

- colorless, viscid, easily frothing slightly opaque liquid
- average pH is 6.8 & alkaline in nature
- Specific gravity is 1.005
- contains organic & inorganic constituents in small amounts consists of mucin, proteins & ptyalin, desquamated epithelial cells & leucocytes.
- Consists Na, K, chloride, bicarbonate & phosphate

Electrolytes- saliva is hypotonic & contains K^+ & $HCO3^-$ in higher concentrations than Na^+ & CL^-

Proteins- containing amylase and lingual lipase for digestion of starch & fat. Whereas it contains mucin, a glycoprotein for food lubrication.

Secretion of saliva- controlled by ANS reflexes

- Parasympathetic nerve secrete a large volume of watery fluid i.e. high in electrolytes but low in proteins

- Sympathetic nerve stimulation causes secretion of small volume of fluid containing a high content of mucus
- Salivary reflexes are elicited by thought, aroma or by taste or presence of the food in alimentary canal

Functions of saliva:

- **Protection-** cooling hot foods, diluting any unwanted food odor, washing food away from the teeth and destroying harmful bacteria within mouth
- **Digestion-** α amylase (Ptyalin) break down the starch into disaccharides. α amylase is inactivated by low pH of the stomach. Lingual lipase breakdown ingested fat
- **Lubrication-** lubricates the food for easy swallowing & moisten the mouth

Bile: required for digestion & absorption of fats & for the excretion of water insoluble substances (cholesterol and bilirubin)

Regulation- It is formed by liver epithelial cells (hepatocytes) & epithelial cells lining the bile ducts.

- stored in the gallbladder during inter digestive period
- consists of electrolytes & water and controlled by secretin secreted by ductal cells having $HCO3^-$
- Secretion is directly related to amount of bile reabsorbed by the hepatocytes.
- It is not under any direct hormonal or nervous control

Composition-

- synthesized from cholesterol & converted into bile salts by hepatocytes & at ileum they are absorbed actively
- Bilirubin & biliverdin are two principal bile pigments which are metabolites of hemoglobin formed in liver
- conjugated as glucoronides for excretion.
- Phospholipids are abundantly found in bile with Na & K, CL, Zn etc in small amounts & $HCO3^-$.

Intestinal secretion: secretes mainly mucus which serves as a protective role, preventing HCl & chyme from damaging the intestinal wall. The mucus is secreted by

- Brunners gland from duodenum
- Goblets cell from the intestinal epithelium & intestinal crypts (crypts of liberkuhn)
- Some enzymes also secretes from the intestinal epithelial cells to break down & absorption of small peptides & di-saccharides.
- Epithelial cells of the intestine also secrets some electrolytes & water.
- Water acts as solvent for digested products & electrolytes for re-absorption of residual digestive products remain in the intestine.

Pancreatic secretions:

Regulation- Pancreas secretion is divided into three phases

- **Cephalic phase:-** Thought, sight, smell or taste of food produces cephalic phase of pancreatic secretion. Enzyme secreted by acinar cells are stimulated by enteric neurons releases from ACh (vagal stimulation) $HCO3^-$ secreted by ductal cells and stimulated by vagus nerves releases a non-cholinergic & non-adrenergic transmitter

- **Gastric phase:-** enhanced during the distension & food breakdown products. Distension leads to secretion of HCO_3^- & enzymes through ACh (Antrum & corpus). When food breakdown occurs G-cells of the antrum releases gastrin, produces a low volume & high enzyme pancreatic secretion

- **Intestinal phase:-** Major stimulants for pancreatic secretion are CCk & secretin. They are released from endocrine cells in the duodenum & jejunum. Both CCk & secretin along with potentiate secretion of HCO_3^- & produce in significant amount

Composition- secretion consists of electrolytes & enzymes

- **Electrolytes:** Na^+ & K^+ , HCO_3^- & H^+ from the dissociation of H_2CO_3. It also contains small amounts of Ca_2^+, Mg_2^+, Zn_2^+, HPO_4^{2-} (mono-hydrogen phosphate) & SO_4^{2-} (sulfate)
- **Enzymes:** consists of α-amylase which hydrolyzes glycogen, starch to disaccharides except cellulose in carbohydrate. Water soluble esters can be hydrolyzed through pancreatic lipases. Trypsinogen & chymo-trypsinogen is converted to trypsin by enterokinase.

Functions-

- Endocrine cells secrete insulin, glucagon, somatostatin & pancreatic polypeptide.
- Exocrine cells into acini produces 4 digestive enzyme peptidases, lipases, amylases & nucleases, which are responsible for digestion of proteins, fats, carbohydrates & nucleic acids respectively.

- Ductal cells consist of high concentration of HCO_3^- which neutralizes gastric acid & regulates pH of upper intestine
- Failure to neutralize the chyme & undergoes to intestine can cause duodenal ulcers.

Digestion in ruminant stomach:

- have microbial fermentation of ingesta by hydrolysis & anaerobic oxidation
- Microbes generate ATP for hydrolysis & fermentation to absorb the end products i.e., VFA but in case of non ruminants, it is glucose
- Ruminant stomach is highly vascularized & blood flow $\uparrow^{es}$ when absorption of end products are being going on
- innervations are by vagal & splanchnic nerves provides sensory & motor pathways

Mechanism of absorptions of carbohydrate, protein & fat:

- Ruminal microbes consists of yeast, fungi & mixed but independent population of bacteria
- CH_2O in diet consists of starch, sucrose, lactose & fiber
- In lumen, pancreatic α-amylase combines disaccharides & tri-glysaccharides & α-limit dextrins
- Intra-luminal products of CH_2O digestion with the dietary disaccharides can`t be absorbed by mucosa
- further breakdown into mono-saccharides being transported into the epithelial cells by Na-dependent co-transport & facilitated diffusion process & enters into the blood stream
- Protein hydrolysis begins in stomach but digestion occurs in proximal small intestine

- Amino acids, di-peptides & tri-peptides are the remaining products after pancreatic digestion
- Peptides are further hydrolsed by brush border hydrolases (junction between intestinal lumen & cytoplasm)
- 10% of peptides escape hydrolysis & diffuse to baso-lateral membrane having neuro-active properties contains non nutritional value
- Amino acids are absorbed by Na-dependent co-transport & diffuse across the baso-lateral membrane into portal vein
- Dietary fat consists of water insoluble triglycerides, emulsified in the stomach
- In duodenum, pancreatic lipase acts at oil-water interface of the emulsion particles releasing β-monoglycerides & 2 free fatty acids (amphipaths)
- Bile salts act as detergent & bring the water insoluble into micelle & get dissolved into micelle core in jejunum

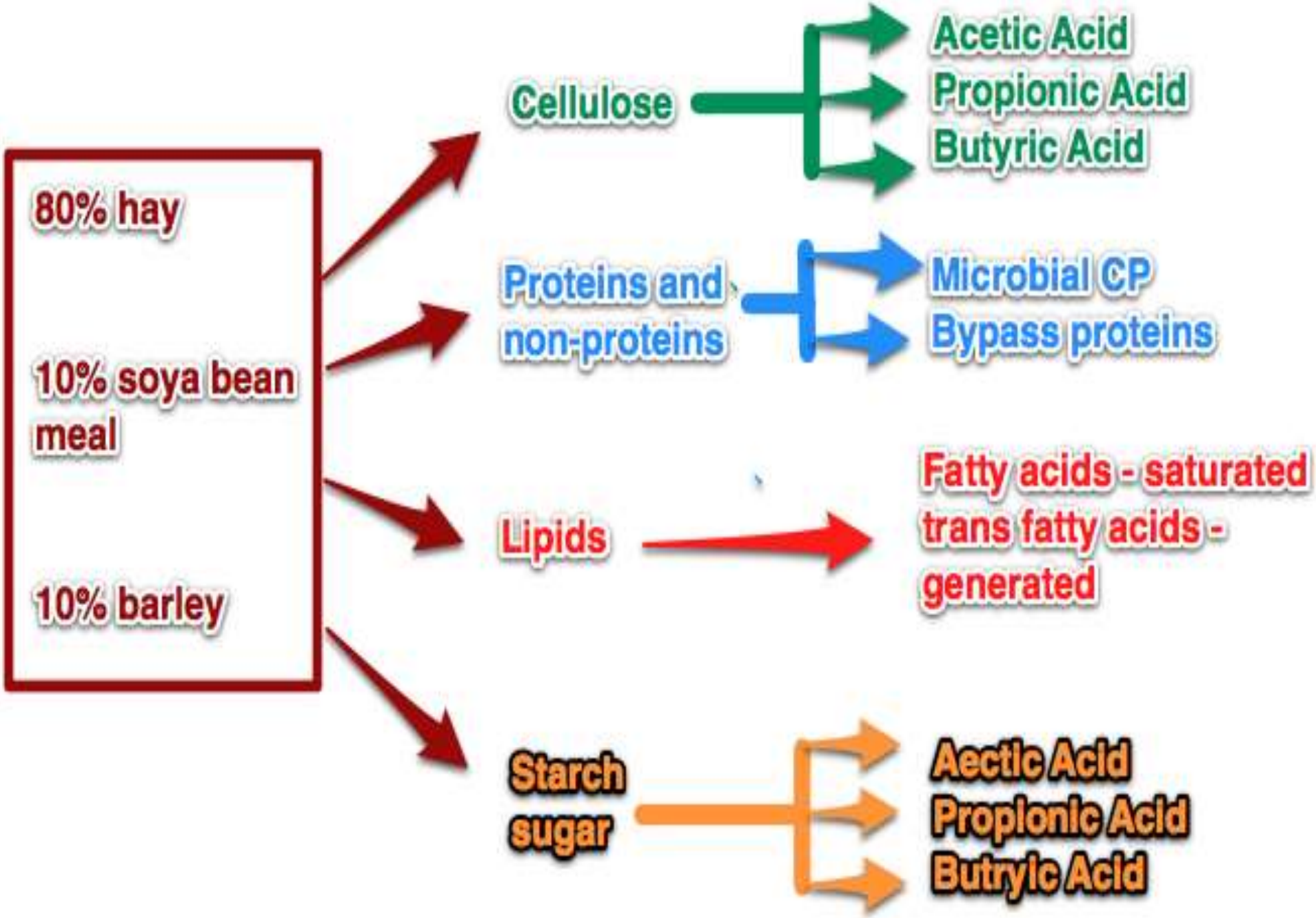
- **Amphipaths-** part polar-water insoluble & non polar-lipid soluble
- **Micelle** (-vely charged aggregates)- to form micelles, need bile acids, 2mM
- Micelles diffuse from the emulsion particle to the brush border where fat releases for diffusion across the lipid membrane into cell
- Fat soluble vitamins absorbed when incorporated into micelle
- Chylomicrons facilitate transport of water insoluble triglycerides & without protein coat, fat is unable to leave the cell

Cellular fermentative digestion-

- Due to low metabolic rate, fermentation of cellulolytic bacteria occurs slow
- optimum pH is 6.2 to 6.8 of cellulolytic bacteria (methanogenic bacteria)
- requires CO_2 & 2H supply to produce methane & amino acids supply to get their protein requirements
- These mixed microbes leads to produce VFA, CO_2 & CH_4

Fermentative digestion of Starch:

- Starch & simple sugar degradation is performed by various primary amylolytic bacteria
- Bacteria`s have faster fermentative rates & low pH 5.5 to 6.6
- require NH_3 & amino acid for synthesis of protein


80% hay
10% soya bean meal
10% barley
Cellulose
Acetic Acid
Propionic Acid
Butyric Acid
Proteins and non-proteins
Microbial CP
Bypass proteins
Lipids
Fatty acids - saturated
trans fatty acids - generated
Starch sugar
Aectic Acid
Propionic Acid
Butryic Acid

Fermentative digestion of Protein:

- Proteolytic bacteria degrades 15 to 35% of dietary protein in the rumen
- Bacterial proteolysis produce peptides which are absorbed & further hydrolyze within the cell of bacteria
- End products are amino acids taken up by some other microbes & rest are used to produce ammonia & certain metabolic acids
- end products are further fermented to VFA`s required as nutrition for cellulolytic bacteria
- After conversion of dietary & NPN compounds & de-amination, results in production of ammonia
- Ammonia is an important substrate for microbial protein synthesis to provide energy needed for synthetic reaction
- During fermentation of dietary protein, recycling of dead microbes protein continues

Fermentative digestion of Lipids:

- Ruminal microbes hydrolyze dietary lipids, using the unsaturated fatty acids as hydrogen acceptors which converts mostly into stearic acid
- From VFA`s ruminal microbes synthesize microbial lipids
- Protozoa absorb PUFA in their own structure to protect them from hydrogenation
- During intestinal digestion, protozoa`s comes from rumen, release their content of PUFA as main source for ruminants

Absorption of food stuffs:

VFA`s- absorbed by passive diffusion through the granulosum cells of the fore-stomach epithelium

Lactic acid- absorbed by fore-stomach epithelium

Digestion in Birds:

Regulation of food intake-

- complex process involves both peripheral & central control regulation
- Peripheral regulation involves GI tract and liver
- Crop and gizzard monitored ingestion of food by distention sensitive receptors
- Meal termination is associated by distention of gizzard less by crop
- Termination of feed in crop and intestine, various receptors act like glucose, osmotic and intestinal amino acid when stimulated by glucose, hypertonic saline or amino acids
- By the hepatic portal blood system, liver absorbs nutrient from the intestinal tract
- Information regarding absorption is communicated by brain via signals through the vagus nerve
- For ingestion of food CCk, bombesin, gastrin and neurotensin peptides are responsible, produced by avian intestinal tract

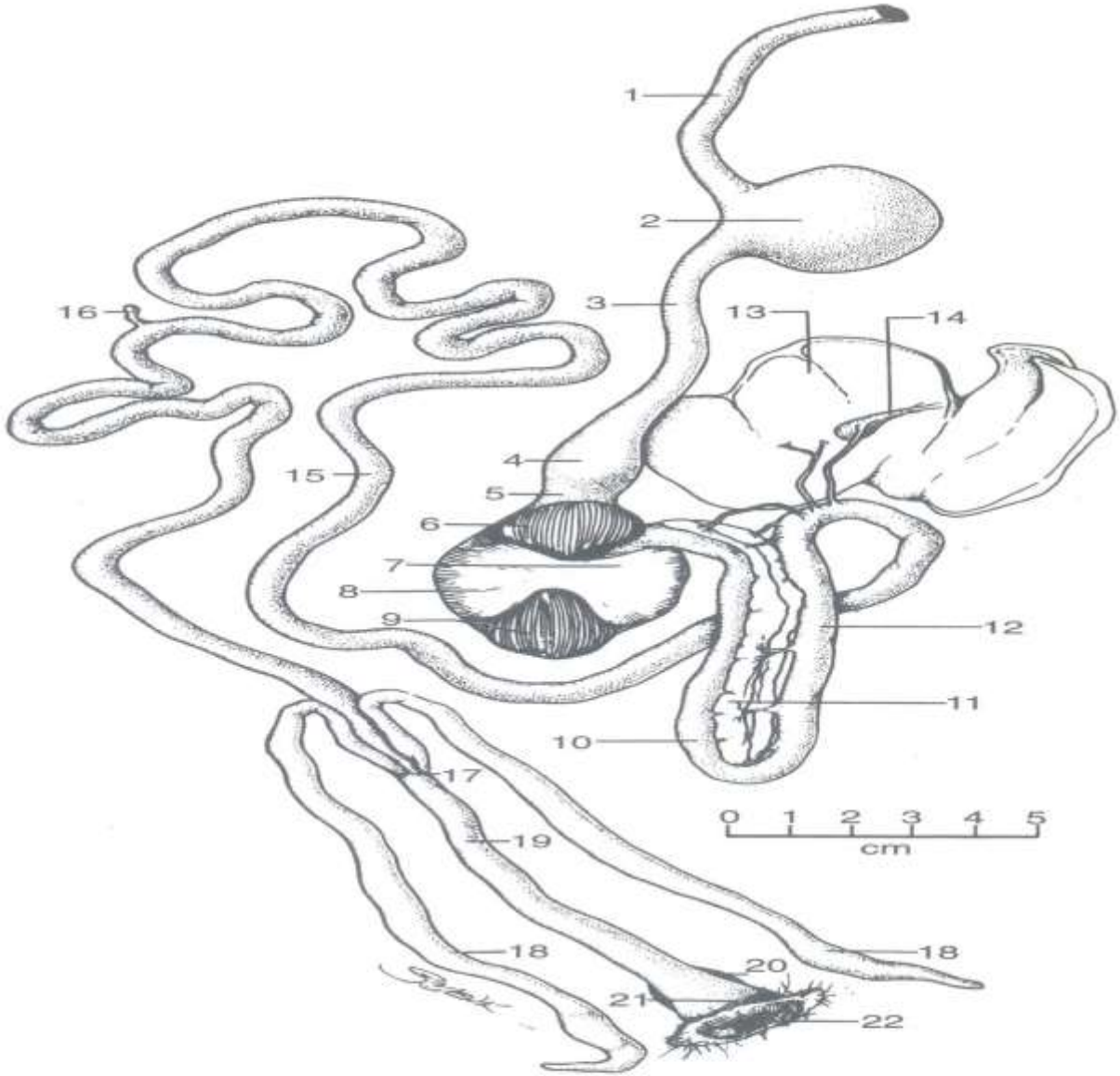


Figure 29.1. Digestive tract of a 12-week-old turkey weighing 2.24 kg. 1, precrop esophagus; 2, crop; 3, postcrop esophagus; 4, proventriculus (glandular stomach); 5, isthmus; 6, thin craniodorsal muscle; 7, thick cranioventral muscle; 8, thick caudodorsal muscle; 9, thin caudoventral muscle (6–9, ventriculus—muscular stomach, gizzard); 10, proximal duodenum; 11, pancreas; 12, distal duodenum; 13, liver; 14, gallbladder; 15, jejunum; 16, Meckel's diverticulum; 17, ileocecocolic junction; 18, ceca; 19, colon; 20, bursa of Fabricius; 21, cloaca; 22, vent. The cloaca consists of three chambers: coprodeum (cranial, receives colon contents); urodeum (middle, receives urinary and reproductive tract contents); and proctodeum (caudal, opens externally through the vent).

Central regulation of food intake includes the systems:

Sl No.	Nerves	systems
1	Trigeminal	Mandibulation
2	Gustatory	Taste
3	Olfactory	Smell
4	Visual	See or sight
5	A.N.S.	Parasympathetic division

- Cholecystokinin and melatonin acts as reduction factor for food intake while ↑^{ed} temperature, ↑^{ed} energy diet level & ↑ protein diet levels also act as external factors.

Gastro-intestinal tract motility:

- Food is swallowed by the stimulation of tongue & muscles reflex causes entering into the esophagus by peristalsis
- For gastro-duodenal contraction, a sequence of 3 rhythm occurs which contracts the ventriculus & passes peristaltic waves through duodenum
- Contraction of gizzard muscle causes contraction of pylorus & isthmus
- Esophagus, crop, pro-venticulus & gizzard are innervated by vagal nerves
- Colonic motility occurs continous & are anti-peristalsis causes

  (a) movement of urine from the cloaca into colon & ceca for absorption of H_2O

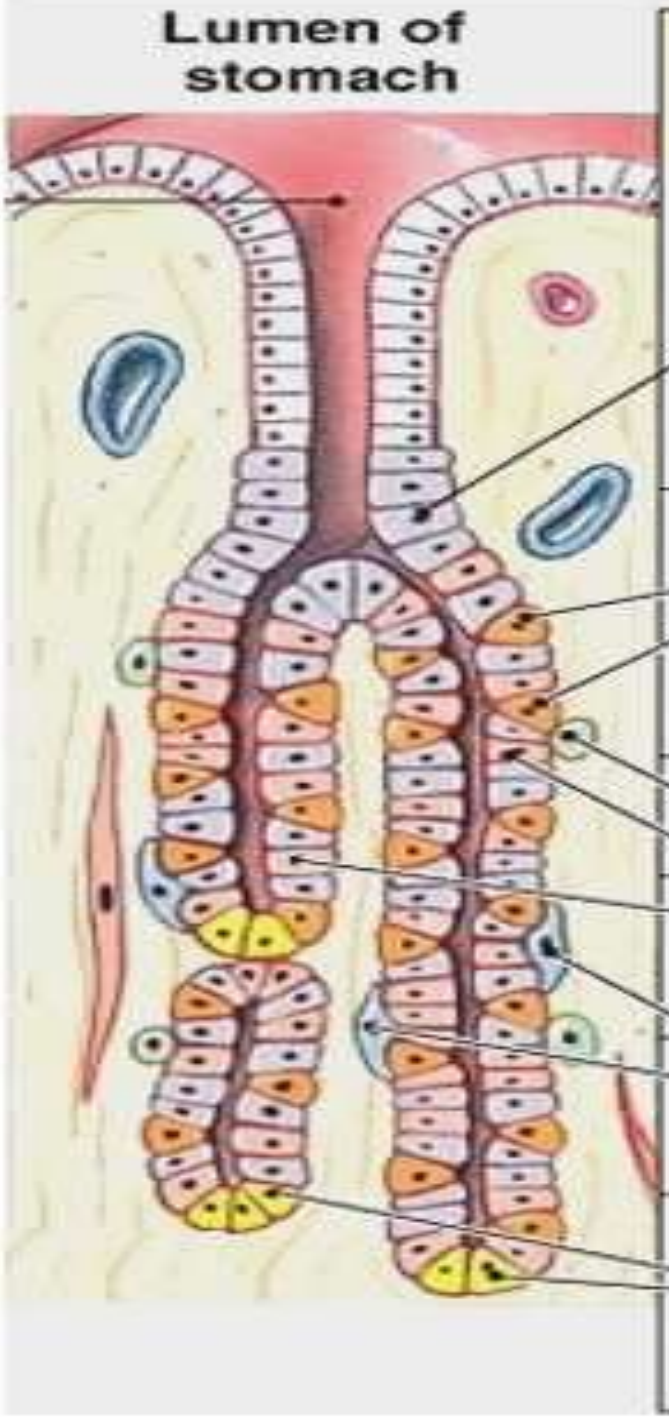
  (b) filling of the ceca

- Anti-peristalsis contraction ceases just before defecation
- Rate of food passage is influenced by consistency, fat content, hardness, water content of the food & amount absorb
- Age & metabolic rate is associated with them are factors which influenced the food passage rate
- Slower rate of food passage is directly related with the ↑^{ed} microbial fermentation of fibrous feed stuffs in ceca & thus utilizes its extreme in adult birds.

Secretion & Digestion:

- Secretion of mucus in buccal cavity and crop tends to moisten & lubrication of the food
- starch digestion occurs in the crop. Amylase is secreted in very few amounts for carbohydrate digestion
- In pro-venticulus, simple mucosal gland secrete mucus & compound sub-mucosal glands secrete mucus as well as HCl & pepsinogen

- **Compound glands = chief + parietal cell** of the mammalian stomach
- Protein digestion initiates in ventriculus on acidic medium
- Pro-venticulus secrete pepsin to hydrolyse protein molecule
- Gizzard breakdowns food material into small pieces & mixes with digestive fluids
- pH ranges between 0.5 to 2.5
- 1 ml of gastric juice/Kg b.wt./hour is secreted by poultry
- Chemical digestion starts in the large intestine
- Exocrine cells of pancreas in the intestinal lumen & membrane digestion of saccharides occurs via the action of digestive enzyme
- large protein molecules hydrolyze into oligo-peptides & di-peptide fragments by the secretion of pancreatic trypsin and chymotrypsin in the intestinal lumen



Cell Types	Substance Secreted
Mucous neck cell	Mucus (protects lining)
	Bicarbonate
Parietal cells	Gastric acid (HCl)
	Intrinsic factor (Ca++ absorption)
Enterochromaffin-like cell	Histamine (stimulates acid)
Chief cells	Pepsin(ogen)
	Gastric lipase
D cells	Somatostatin (inhibits acid)
G cells	Gastrin (stimulates acid)

- Free amino acids being released by the pancreas & aminopeptidase in the brush border membrane of enterocytes transported to microvillus membranes & perform membrane hydrolysis of oligopeptide & dipeptide fragments
- Pancreatic α-amylase in intestinal lumen cleaves maltose units leaving α-dextrins limit in amylopectin
- Maltose, maltotriose & α-limit dextrins are water soluble & diffuse through an aqueous dispersion of mucin absorbed by the glycocalyx covering the microvilli of enterocytes
- Maltose & sucrase-isomaltose in the apical membranes hydrolyse into glucose & absorbed by enterocytes
- mucin layer protects the enterocyte from degradation by pancreatic proteases
- Intestinal pH ranges from 5.6 to 7.2
- Bile salts emulsify fat particles for further digestion and reabsorbed in the lower ileum & re-circulated to the liver to be used again as in mammals

- Proximal ceca has ability to transport mono-saccharides & amino acids against a concentration gradient
- Microbial digestion of cellulose also occurs in ceca
- Reflex of urine into ceca exposes cecal microflora to urea & uric acid for degradation
- Cecal microflora uses the recycled nitrogen
- Microbial synthesis of vitamins-B occur in ceca but are not absorbed by birds
- Feces of chickens are source of vitamin B_{12} & other vit-B`s

Regulation of G.I. tract motility and secretion:

- presence of food, its smell & taste gives secretion of saliva into the buccal cavity, esophagus & crop
- The motility rises due to presence of food goes descend & is controlled by reflex
- Gastric activities including gastric motility & secretion are regulates via cephalic and gastric phase

- Vagus stimulation cause pro-venticular secretion & motility of pro-venticulus & gizzard
- Neural & humoral mechanism act to ↓ gastric secretions & motility
- Serotonin acts as humoral mediator in avian gastric regulation
- There is less inhibition of gastric secretion after duodenal distention & this is blocked by serotonin
- intestinal secretion & motility is ↑^{ed} by vagal stimulation & latter part is ↑^{ed} by distention of the duodenum
- Avian secretion stimulates ↑^{ed} pancreatic secretion (aqueous component) but not ↑^{ed} enzyme secretion
- secretion of pancreatic enzymes initiates on the release of CCk
- On feed, the poultry have ↑^{ed} bile secretion due to CCk

Absorption: dietary fatty acids, carbohydrates & amino acids occurs in the duodenum & proximal part of jejunum.