Course: Animal form and function

NUTRITION AND DIGESTION

- Animal strategies for getting and using food
- Diversity in digestive structures of invertebrate and vertebrates
- The mammalian digestive system

ANIMAL STRATEGIES FOR GETTING AND USING FOOD

CONTINUOUS VERSUS DISCONTINUOUS FEEDERS

Continuous feeders

- ✓ Many continuous feeders are slow-moving or completely sessile animals (they remain permanently in one place).
- ✓ **aquatic suspension feeders**, such as **tube worms** and **barnacles**, remain in one place and continuously “strain” small food particles from the water.

Discontinuous feeders

- ✓ tend to be active, sometimes highly mobile, animals.
- ✓ have more digestive specializations than continuous feeders.
- ✓ Many **carnivores**, for example, pursue and capture relatively large prey. carnivores have digestive systems that permit the storage and gradual digestion of large, relatively infrequent meals.
- ✓ **Herbivores** spend more time eating than carnivores do, but they are also discontinuous feeders.

SUSPENSION FEEDERS

Suspension feeding is the removal of suspended food particles from the surrounding water by some sort of capture, trapping, or filtration structure.

This feeding strategy involves three steps:

(1) transport of water past the feeding structure,

(2) removal of nutrients from the water, and

(3) transport of the nutrients to the mouth of the digestive system.

Sponges, ascidians, branchiopods, ectoprocts, entoprocts, phoronids, most bivalves, and many crustaceans, polychaetes, gastropods, and some nonvertebrate chordates are suspension feeders.

DEPOSIT FEEDERS

- Deposit feeding involves primarily omnivorous animals.
- These animals obtain their nutrients from the sediments of soft-bottom habitats (muds and sands) or terrestrial soils.
- Direct deposit feeders simply swallow large quantities of sediment (mud, soil, sand, organic matter).
- The usable nutrients are digested, and the remains pass out the anus. Direct deposit feeding occurs in many polychaete annelids, some snails, some sea urchins, and in most earthworms.
- Other direct deposit feeders utilize tentaclelike structures to consume sediment.
- **Examples:**

sea cucumbers, most sipunculans, certain clams, and several types of polychaetes.

HERBIVORY

Herbivory is the consumption of macroscopic plants.

Although biting and chewing mechanisms evolved within the architectural framework of a number of invertebrate lineages, they are often characterized by the development of hard surfaces (e.g., teeth) that powerful muscles manipulate.

Invertebrates that evolved macroherbivory include:

- ✓ molluscs,
- ✓ polychaete worms,
- ✓ arthropods,
- ✓ sea urchins.

i. molluscs

- Molluscs use the radula to scrape algae off rocks or to tear the leaves off terrestrial plants.

ii. In Polychaetes

- Polychaetes have sets of large chitinous teeth on an eversible proboscis or pharynx that is used to scrape off algae.
- This toothed pharynx is also suitable for carnivory when plant material is scarce.

iii. In Arthropods

- Macroherbivory is found in almost every group of arthropods.

Example:

insects and crustaceans have large, powerful mandibles capable of biting off plant material and subsequently grinding and chewing it before passing the plant material to the mouth.

Predation is one of the most sophisticated feeding strategies, since it requires the capture of live prey.

PREDATION

Motile stalkers

- ✓ pursue their prey
- ✓ **Examples:**
  - Ciliate protozoa,
  - nemerteans,
  - polychaete worms
  - gastropods
  - octopuses
  - squids
  - crabs
  - sea stars
  - many vertebrates.

Lurking predators

- ✓ sit and wait for their prey to come within seizing distance.
- ✓ **Examples:**
  - certain species of praying mantises
  - shrimp
  - crabs
  - spiders
  - polychaetes
  - many vertebrates

Sessile opportunists

- ✓ usually are not very mobile.
- ✓ They can only capture prey when the prey organism comes into contact with them.
- ✓ **Examples:**
  - certain protozoa
  - barnacles
  - cnidarians

Grazing carnivores

- ✓ move about the substrate picking up small organisms.
- ✓ **Examples:**
  - Sponges
  - Ectoprocts
  - Tunicates
  - Snails
  - Worms
  - small crustaceans.

SURFACE NUTRIENT ABSORPTION

They directly absorb nutrients from the external medium across their body surfaces. This medium may be nutrient-rich seawater, fluid in other animals' digestive tracts, or the body fluids of other animals.

For example,

- ✓ Some free-living protozoa, such as **Chilomonas**, absorb all of their nutrients across their body surface.
- ✓ The endoparasitic protozoa, **cestode worms, endoparasitic gastropods, and crustaceans**.
- ✓ A few nonparasitic multicellular animals. Examples include the **gutless bivalves** and **pogonophoran worms**.

FLUID FEEDERS

- ✓ The biological fluids of animals and plants are a rich source of nutrients. Feeding on this fluid is called fluid feeding.

Example:

- ✓ **the sea lamprey** The lamprey uses the funnel like a suction cup to grip its fish host, and then with its tongue, rasps a hole in the fish's body wall and then sucks blood and body fluids from the wound.
- ✓ **Insects** have the most highly developed sucking structures for fluid feeding. For example, **butterflies, moths, and aphids** have tubelike mouthparts that enable them to suck up plant fluids.
- ✓ Blood-sucking mosquitoes
- ✓ Pollen- and nectar-feeding birds
- ✓ vampire bats, such as Desmodus, of tropical South and Central America.
- ✓ Nectar-feeding bats

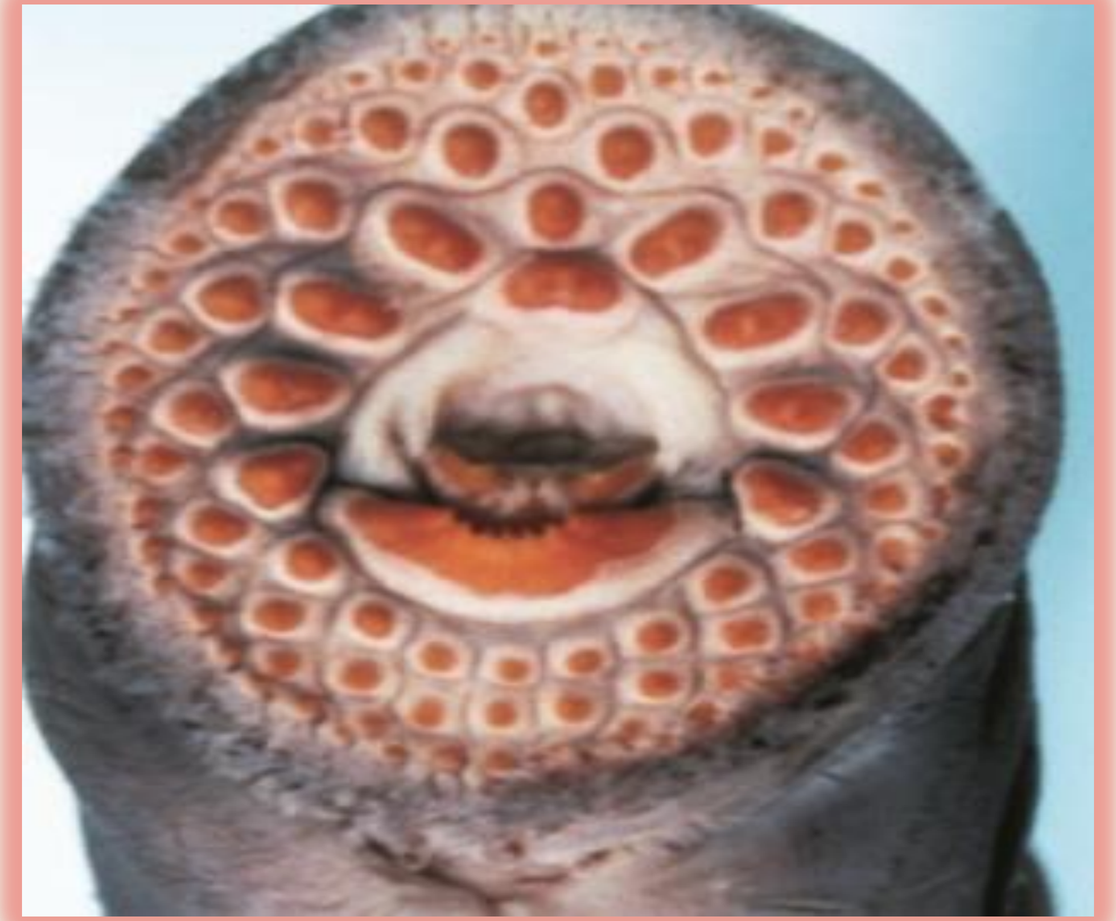


Fig: Rasping tongue and mouth of a lamprey.

DIVERSITY IN DIGESTIVE STRUCTURES: INVERTEBRATES

The development of the anus and complete digestive tract in the aschelminths was an evolutionary breakthrough. A complete digestive tract permits the one-way flow of ingested food without mixing it with previously ingested food or waste. Complete digestive tracts also have the advantage of progressive digestive processing in specialized regions along the system. Food can be digested efficiently in a series of distinctly different steps.

Three examples illustrate digestive systems in protozoa and invertebrates:

(1) the incomplete digestive system of a ciliated protozoan is an example of an intracellular digestive system;

(2) the bivalve mollusc is an example of an invertebrate that has both intracellular and extracellular digestion; and

(3) In insect is an example of an invertebrate that has extracellular digestion and a complete digestive tract.

PROTOZOA

- Protozoa may be autotrophic, saprozoic, or heterotrophic.
- Ciliated protozoa are good examples of protists that utilize heterotrophic nutrition.
- Ciliary action directs food from the environment into the buccal cavity and cytostome.
- The cytostome opens into the cytopharynx, which enlarges as food enters and pinches off a food-containing vacuole.
- The detached food vacuole then moves through the cytoplasm.
- During this movement, excess water is removed from the vacuole, the contents are acidified and then made alkaline and a lysosome adds digestive enzymes.
- The food particles are then digested within the vacuole and the nutrients absorbed into the cytoplasm. The residual vacuole then excretes its waste products via the **cytopyge.**

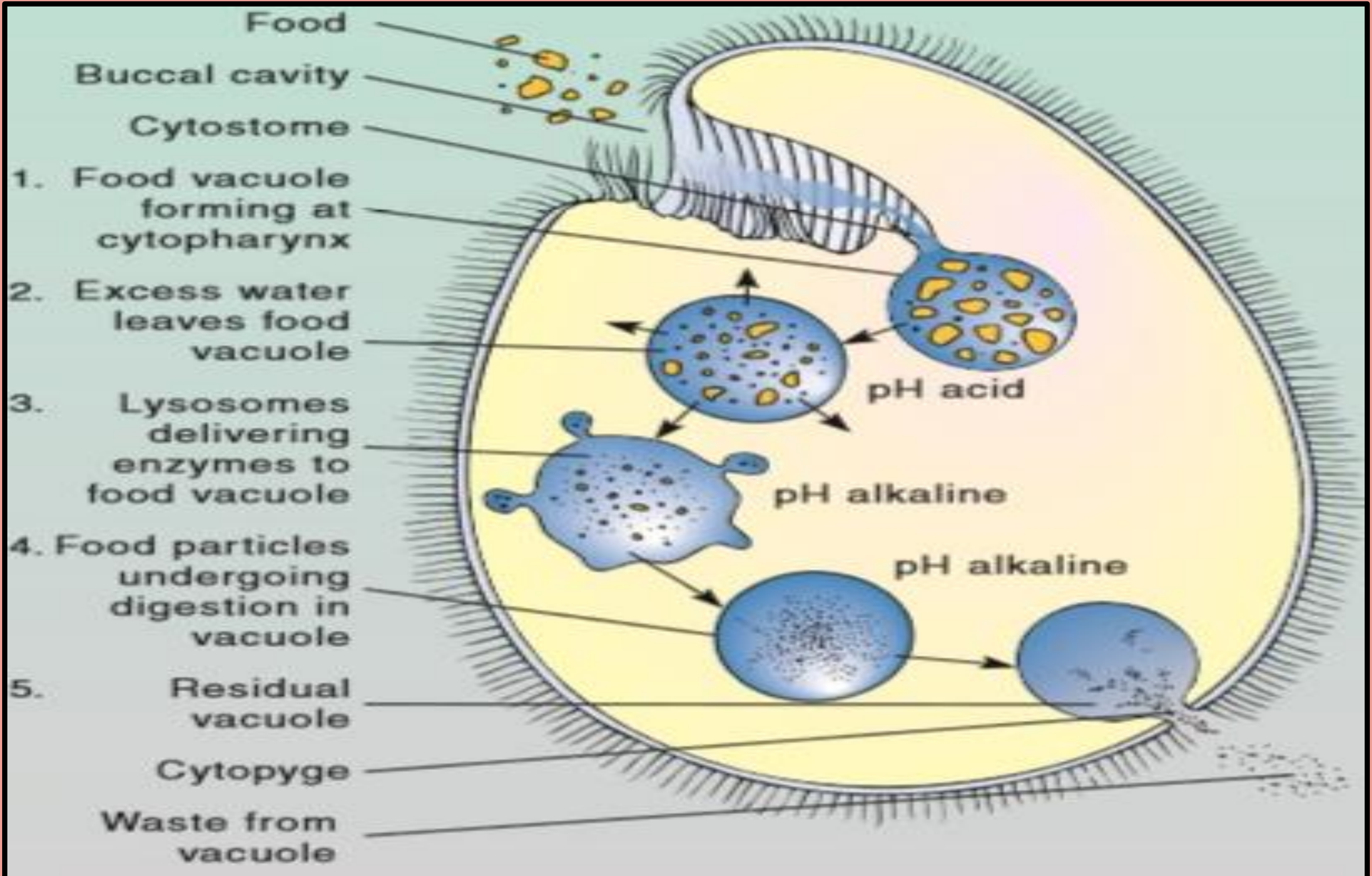


Fig: Intracellular Digestion in a Ciliated Protozoan. Cilia direct food toward the cytostome ("mouth''). The food enters the cytopharynx, where a food vacuole forms and detaches from the cytopharynx. The detached vacuole undergoes acidic and alkaline digestion, and the waste vacuole moves to the cytopyge ("anus'') for excretion.

BIVALVE MOLLUSCS

- Many bivalve molluscs suspension feed and ingest small food particles.
- The digestive tract has a short esophagus opening into a stomach, midgut, hindgut, and rectum.
- The stomach contains a crystalline style, gastric shield, and diverticulated region.
- These diverticulae are blind-ending sacs that increase the surface area for absorption and intracellular digestion.
- The midgut, hindgut, and rectum function in extracellular digestion and absorption
- Digestion is a coordination of three cycles: **(1) feeding, (2) extracellular digestion, and (3) intracellular digestion.**
- Intracellular digestion releases the nutrients into the blood and produces the fragmentation spherules that both excrete wastes and lower the pH for optimal extracellular digestion.

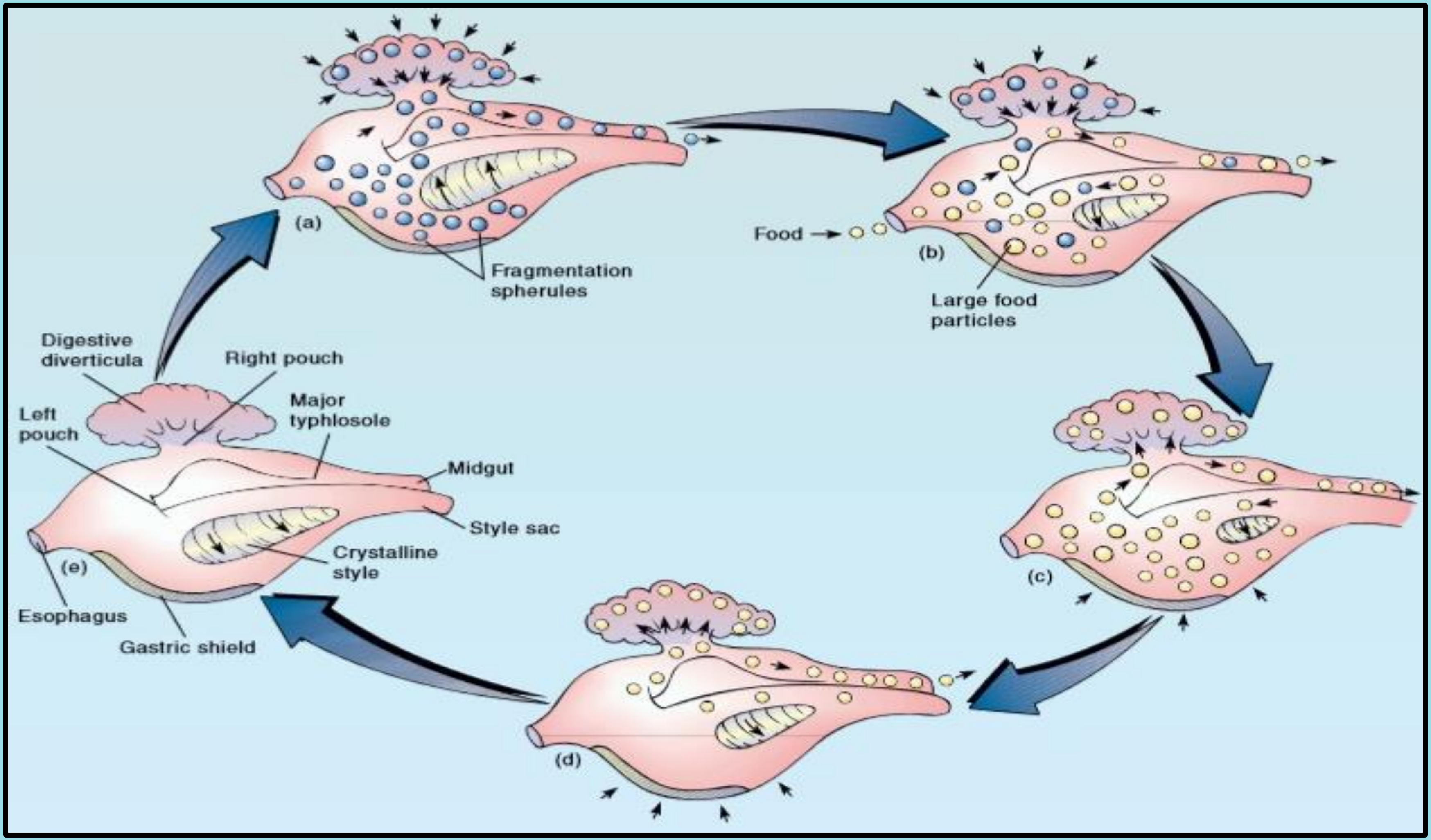


Fig: Extracellular and Intracellular Digestion in a Bivalve Mollusc. (a) Extracellular digestion begins before food ingestion by the dissolving of the crystalline style and the formation of fragmentation spherules in the stomach. **(b)** As food enters the stomach, the rotating style and the enzymes released by the gastric shield mechanically and enzymatically break it down. **(c)** The small food particles then move into the digestive diverticulae for intracellular digestion. **(d)** A progressive passage of food particles from the stomach to the digestive diverticulae follows cessation of feeding. **(e)** During this resting phase, the stomach empties and the style reforms, while intracellular digestion in the diverticulae is completed, and fragmentation spherules begin to form again. The movement of fragmentation spherules starts the next feeding cycle.

INSECTS

The grasshopper is a representative insect with a complete digestive tract and extracellular digestion

- ✓ During feeding, the mandibles and maxillae first break up (masticate) the food, which is then taken into mouth and passed to the crop via the esophagus.
- ✓ During mastication, the salivary glands add saliva to the food to lubricate it
- ✓ Saliva contains the enzyme amylase, which begins the enzymatic digestion of carbohydrates.
- ✓ The midgut secretes other enzymes (carbohydrases, lipases, proteases) that enter the crop.
- ✓ Food passes slowly from the crop to the stomach
- ✓ Large particles are returned to the crop for further processing; the small particles enter the gastric cecae, where extracellular digestion is completed.
- ✓ Most nutrient absorption then occurs in the intestine.
- ✓ Undigested food is moved along the intestine and passes into the rectum, where water and ions are absorbed.

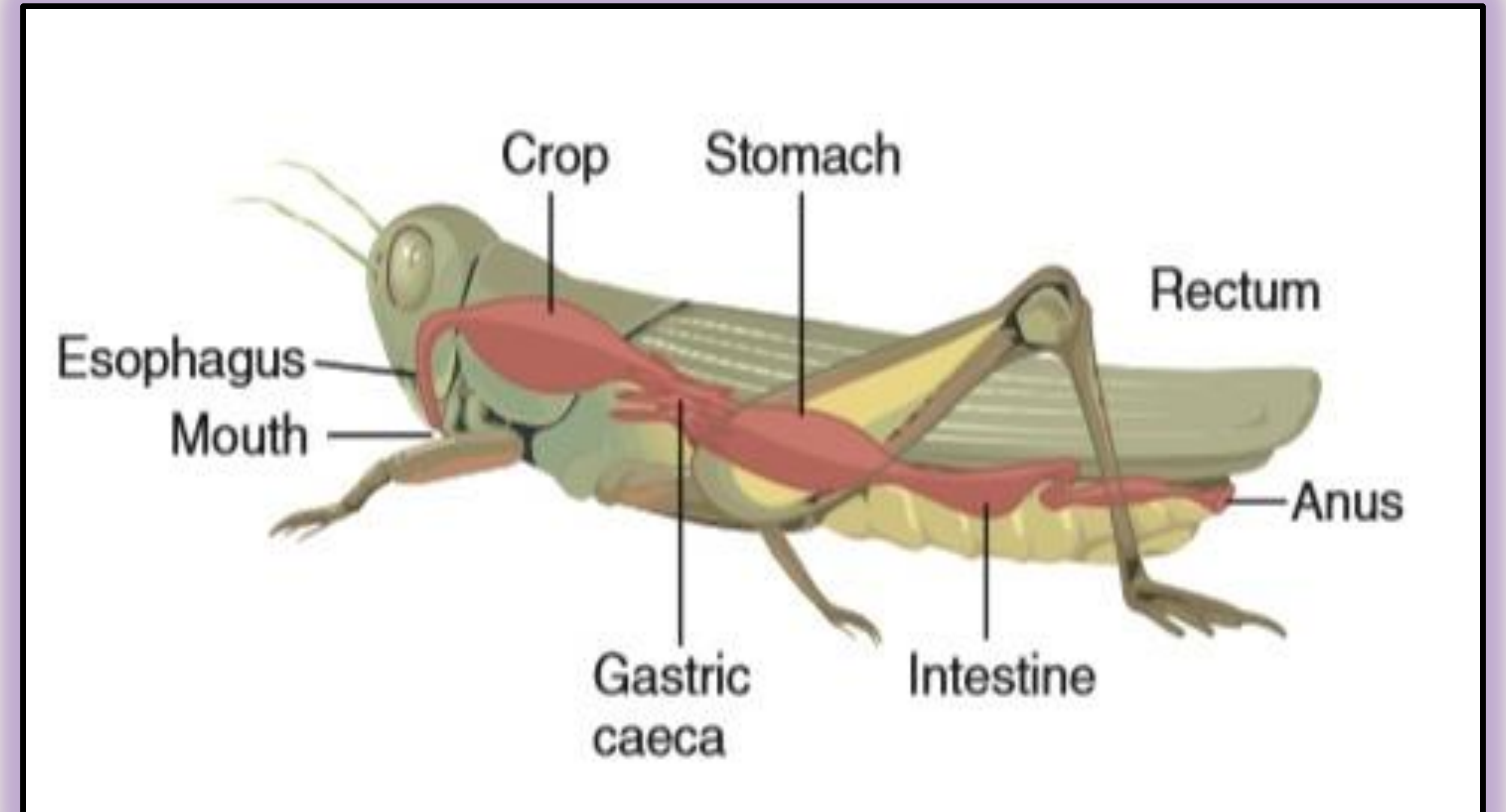


Fig: The complete digestive tract of an insect (grasshopper) has an expanded region called a crop that functions as a food storage organ.

DIVERSITY IN DIGESTIVE STRUCTURES: VERTEBRATES

The complete vertebrate digestive tract (gut tube) is highly specialized in both structure and function for the digestion of a wide variety of foods. The basic structures of the gut tube include the buccal cavity, pharynx, esophagus, stomach, small intestine, large intestine, rectum, and anus/cloaca.

In addition, three important glandular systems are associated with the digestive tract:

(1) the salivary glands;

(2) the liver, gallbladder, and bile duct; and

(3) the pancreas and pancreatic duct.

The oral cavity (mouth), teeth, intestines, and other major digestive structures usually reflect the way an animal gathers food, the type of food it eats, and the way it digests that food.

TONGUES

- ✓ A tongue or tonguelike structure develops in the floor of the oral cavity in many vertebrates.
- ✓ For example,
- ✓ a **lamprey** has a protrusible tongue with horny teeth that rasp its prey’s flesh.
- ✓ **Fishes** may have a primary tongue that bears teeth that help hold prey; however, this type of tongue is not muscular.
- ✓ **Tetrapods** have evolved mobile tongues for gathering food.
- ✓ **Frogs and salamanders** and some lizards can rapidly project part of their tongue from the mouth to capture an insect.
- ✓ A **woodpecker** has a long, spiny tongue for gathering insects and grubs.
- ✓ **Ant- and termite-eating mammals** also gather food with long, sticky tongues.
- ✓ Spiny papillae on the tongues of **cats and other carnivores** help these animals rasp flesh from a bone.

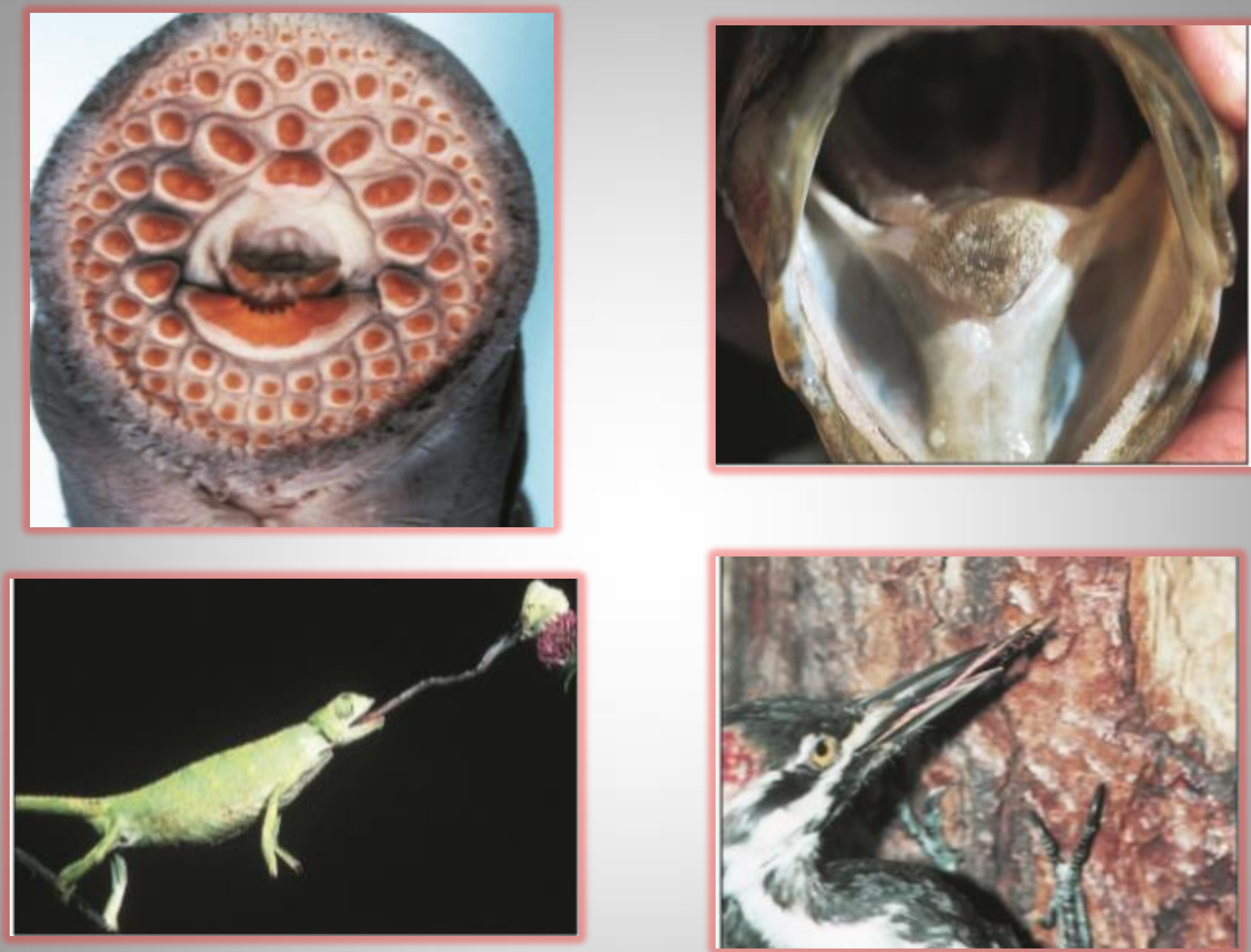


Fig: Tongues. (a) Rasping tongue and mouth of a lamprey. (b) Fish tongue. (c) Tongue of a chameleon catching an insect. (d) The tongue of a woodpecker extracts insects from the bark of a tree.

TEETH

Teeth are specialized, depending on whether an animal feeds on plants or animals, and on how it obtains its food.

- ✓ With the exception of birds, turtles, and baleen whales, most vertebrates have teeth. Birds lack teeth, probably to reduce body weight for flight.
- ✓ The **teeth of snakes** slope backward to aid in the retention of prey while swallowing
- ✓ The **canine teeth of wolves** are specialized for ripping food
- ✓ **Elephant** has two of its upper, front teeth specialized as weapons and for moving objects
- ✓ **Humans, pigs, bears, raccoons**, and a few other mammals are omnivores, they have teeth that can perform a number of tasks—tearing, ripping, chiseling, and grinding

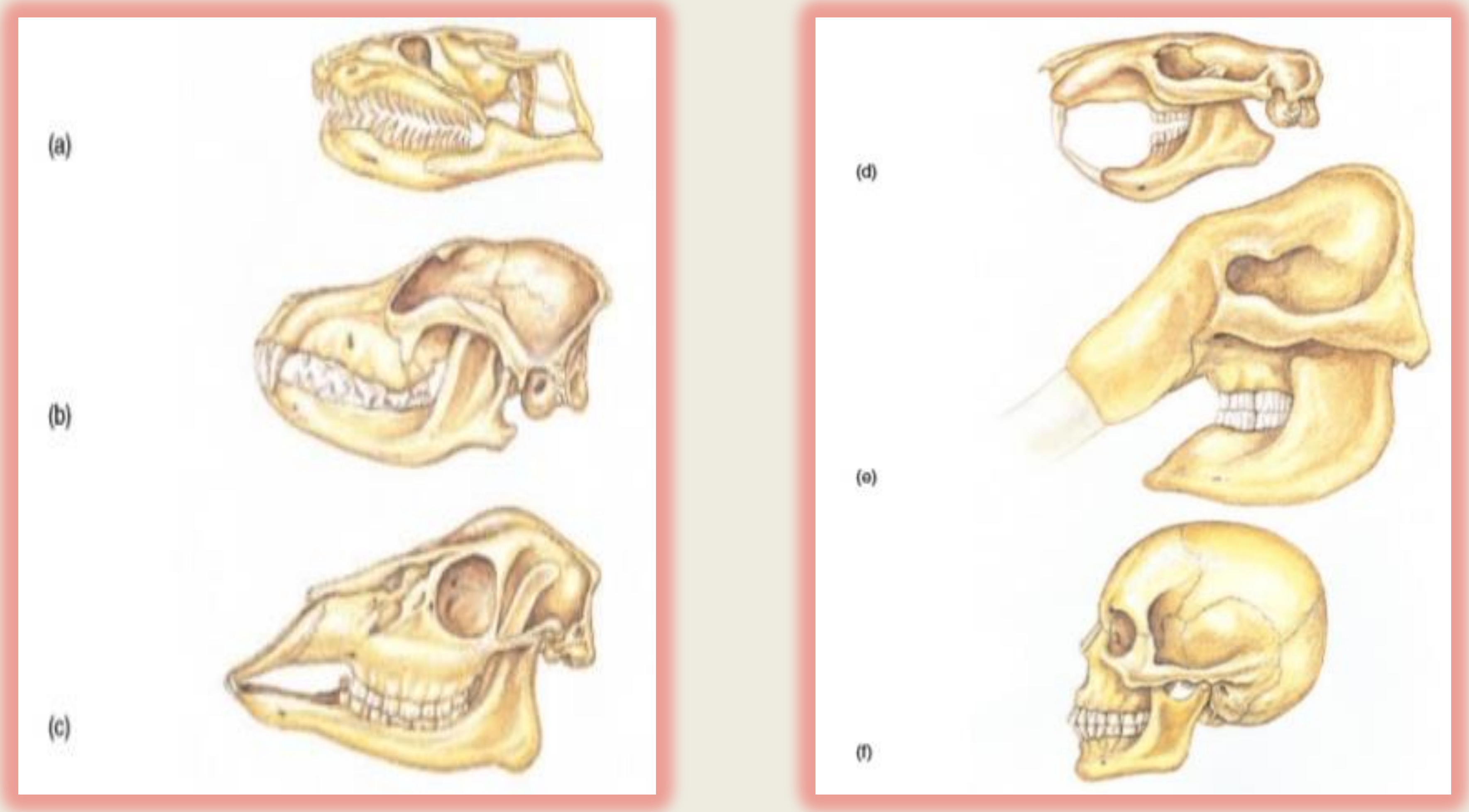


Fig: Arrangement of Teeth in a Variety of Vertebrates. (a) Snake. (b) Wolf. (c) Deer. (d) Beaver. (e) Elephant. (f) Human.

SALIVARY GLANDS

- ✓ Most fishes lack salivary glands in the head region.
- ✓ **Lampreys** are an exception because they have a pair of glands that secrete an anticoagulant needed to keep their prey's blood flowing as they feed.
- ✓ Modified salivary glands of some **snakes** produce venom that is injected through fangs to immobilize prey.
- ✓ Because the secretion of oral digestive enzymes is not an important function in **amphibians** or **reptiles,** salivary glands are absent.
- ✓ Most **birds** lack salivary glands, while all mammals have them.

ESOPHAGI

- ✓ The esophagus (pl., esophagi) is short in **fishes and amphibians**, but much longer in **amniotes** due to their longer necks.
- ✓ **Grain and seed-eating birds** have a crop that develops from the caudal portion of the esophagus.
- ✓ Storing food in the crop ensures an almost continuous supply of food to the stomach and intestine for digestion.
- ✓ This structure allows these **birds** to reduce the frequency of feeding and still maintain a high metabolic rate.

STOMACHS

- ✓ The stomach is an ancestral vertebrate structure that evolved as vertebrates began to feed on larger organisms that were caught at less frequent intervals and required storage.
- ✓ Some zoologists believe that the gastric glands and their production of hydrochloric acid (HCl) evolved in the context of killing bacteria and helping preserve food.
- ✓ The enzyme pepsinogen may have evolved later because the stomach is not essential for digestion.

GIZZARDS

- ✓ Some fishes, some reptiles such as crocodilians, and all birds have a gizzard for grinding up food.
- ✓ The bird's gizzard develops from the posterior part of the stomach called the ventriculus.
- ✓ Pebbles (grit) that have been swallowed are often retained in the gizzard of grain-eating birds and facilitate the grinding process.

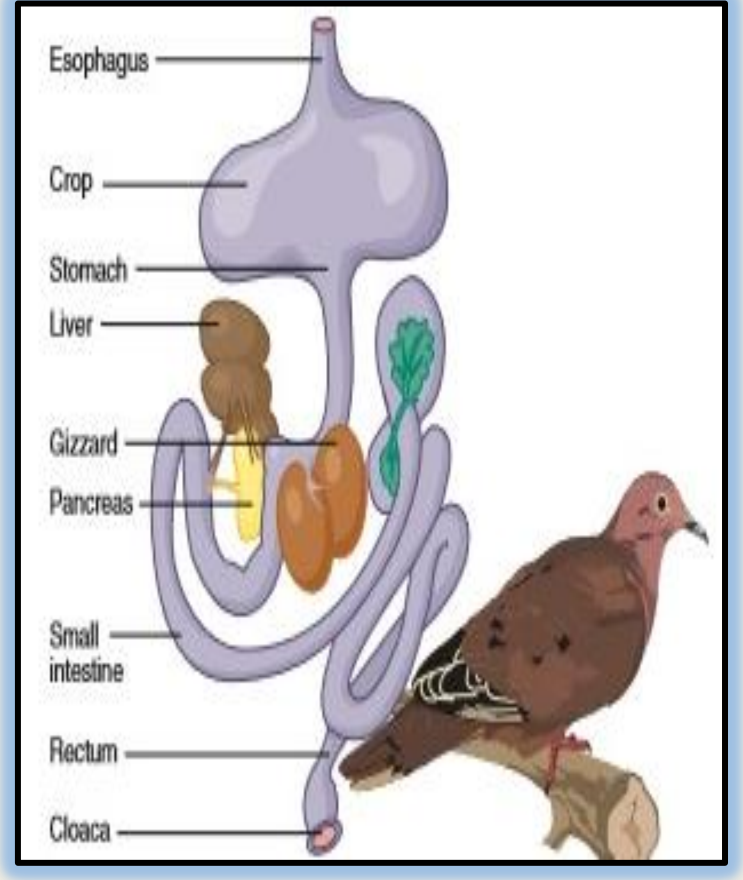


Fig: Arrangement of Stomach and Intestine in a Pigeon

RUMENS

Ruminant mammals—animals that “chew their cud,’’ such as cows, sheep, and deer—show some of the most unusual modifications of the stomach.

ruminant stomach

- ✓ the ruminant stomach provides an opportunity for large numbers of microorganisms to digest the cellulose walls of grass and other vegetation.
- ✓ Gut microorganisms can produce **cellulase**, they have made the herbivorous lifestyle more effective.
- ✓ In ruminants, the upper portion of the stomach expands to form a large pouch, the **rumen**, and a smaller **reticulum.**
- ✓ The lower portion of the stomach consists of a small antechamber, the **omasum**, with a “true’’ stomach, or **abomasum**, behind it.

Digestion in Ruminants

Food first enters the rumen, where it encounters the microorganisms

Aided by copious fluid secretions, body heat, and churning of the rumen, the microorganisms partially digest the food and reduce it to a pulpy mass

the pulpy mass moves into the reticulum, from which mouthfuls are regurgitated as “cud”

food is thoroughly chewed for the first time.

When reswallowed, the food enters the rumen, where it becomes more liquid in consistency

When it is very liquid, the digested food material flows out of the reticulum and into the omasum and then the glandular region, the abomasum

digestive enzymes are first encountered, and digestion continues

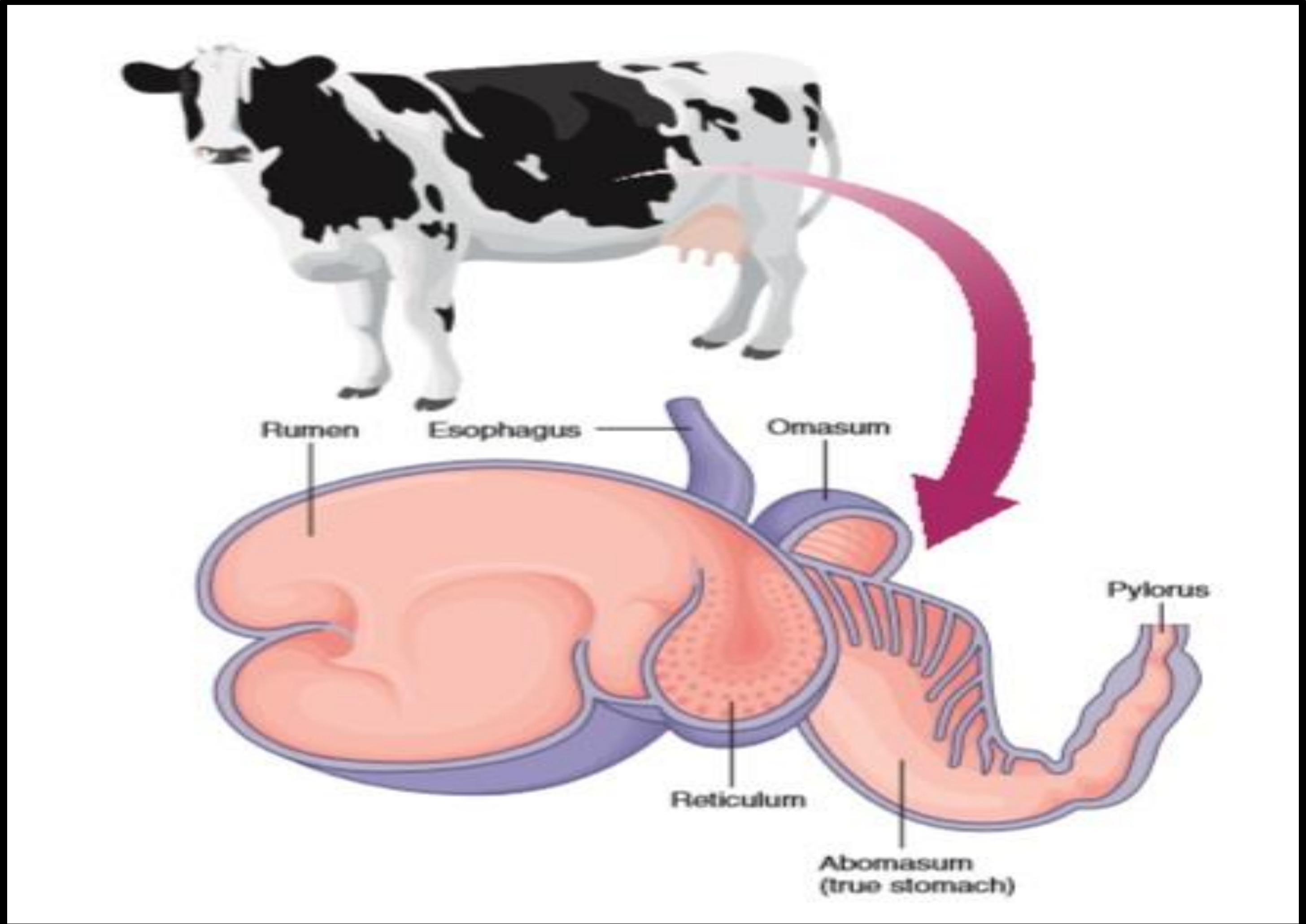


Fig: Ruminant Mammal. Four-chambered stomach of a cow, where symbiotic microorganisms digest cellulose.

CECA

- ✓ Microorganisms attack the food of ruminants before gastric digestion, but in the typical nonruminant herbivore, microbial action on cellulose occurs after digestion.
- ✓ Rabbits, horses, and rats digest cellulose by maintaining a population of microorganisms in their unusually large cecum, the blind pouch that extends from the colon.
- ✓ Adding to this efficiency, a few non-ruminant herbivores, such as mice and rabbits, eat some of their own feces to process the remaining materials in them, such as vitamins.

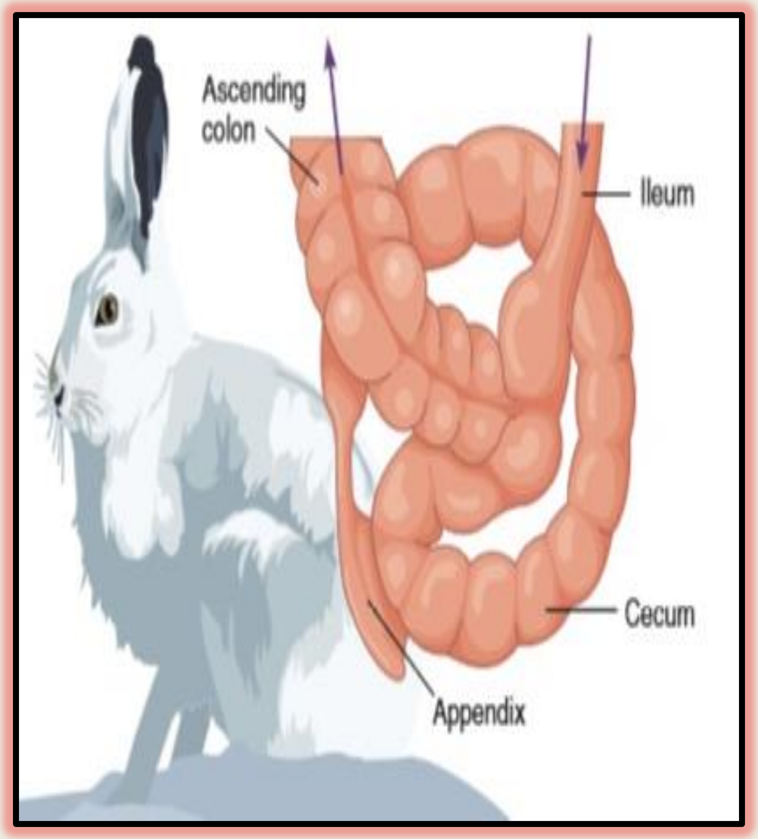


Fig: Extensive Cecum of a Nonruminant Herbivore, Such as a Rabbit. The cecum contains microorganisms that produce digestive enzymes (e.g., cellulase that helps break down cellulose).

LIVERS AND GALLBLADDERS

The liver manufactures bile, which the gallbladder then stores. Bile is a fluid containing bile salts and bile pigments.

Function of Bile:

- ✓ They emulsify dietary fat, breaking it into small globules (emulsification) on the surface of which the fat-digesting enzyme lipase can function.
- ✓ Bile pigments result from phagocytosis of red blood cells in the spleen, liver, and red bone marrow.
- ✓ Phagocytosis cleaves the hemoglobin molecule, releasing iron, and the remainder of the molecule is converted into pigments that enter the circulation.
- ✓ These pigments are subsequently extracted from the circulation in the liver and excreted in the bile as **bilirubin (“red bile’’) and biliverdin (“green bile’’).**
- ✓ Because of the importance of bile in fat digestion, the gallbladder is relatively large in carnivores and vertebrates, in which fat is an important part of the diet.

PANCREATA

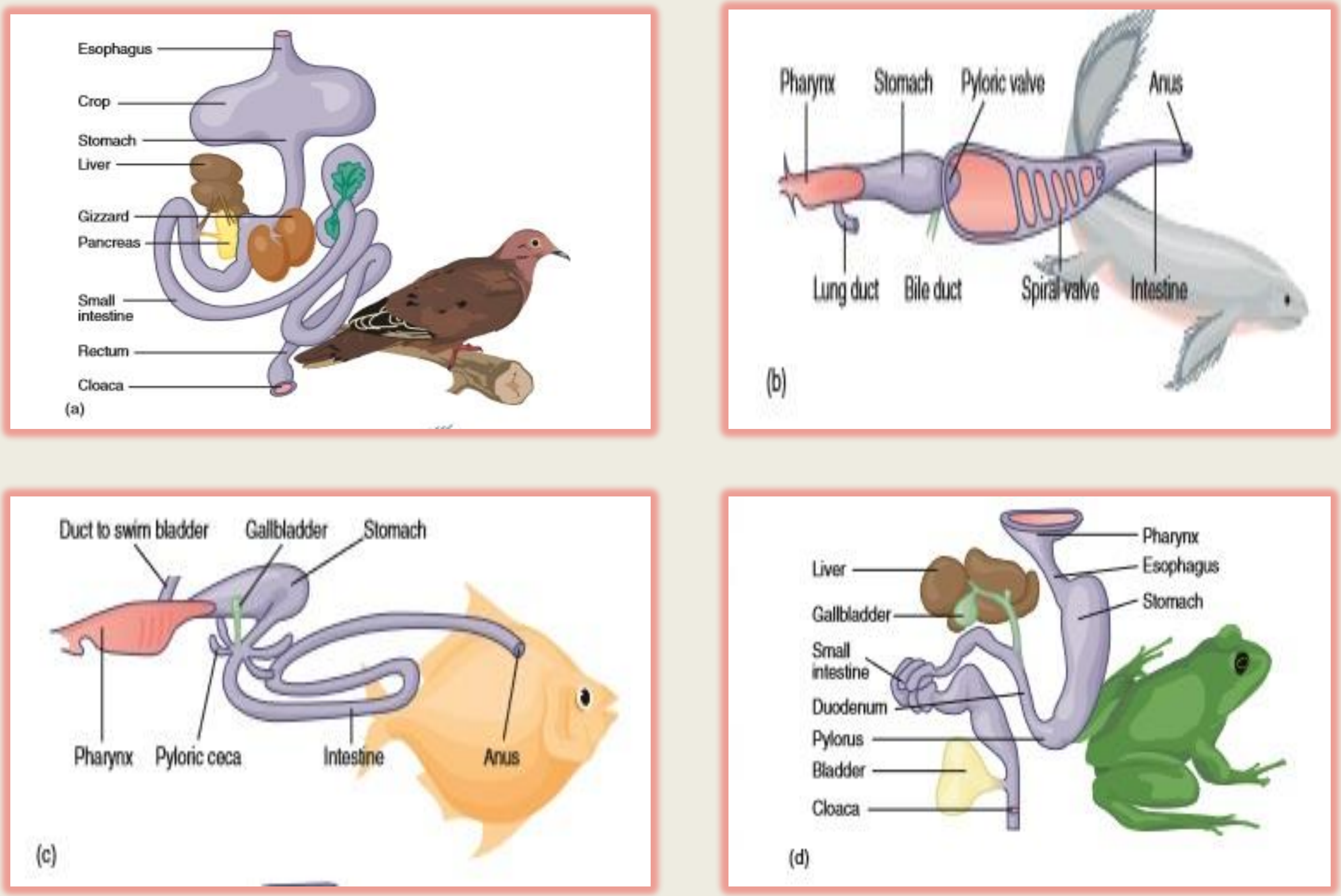
- ✓ Every vertebrate has a pancreas (pl., pancreata); however, in lampreys and lungfishes it is embedded in the wall of the intestine and is not a visible organ.
- ✓ Both endocrine and exocrine tissues are present, but the cell composition varies.
- ✓ Pancreatic fluid containing many enzymes empties into the small intestine via the pancreatic duct

INTESTINES

Intestines are closely related to the animal's type of food, body size, and levels of activity.

For example,

- **cyclostomes, chondrichthian fishes**, and primitive bony fishes have short, nearly straight intestines that extend from the stomach to the anus.
- In more **advanced bony fishes**, the intestine increases in length and begins to coil.
- The intestines are moderately long in most **amphibians and reptiles**
- In **birds and mammals**, the intestines are longer and have more surface area than those of other tetrapods.
- Birds typically have two ceca, and mammals have a single cecum at the beginning of the large intestine.
- The large intestine is much longer in mammals than in birds, and it empties into the cloaca in most vertebrates.



Arrangement of Stomachs and Intestines in a Variety of Vertebrates. (a) Pigeon. (b) Lungfish. (c) Teleost fish. (d) Frog.