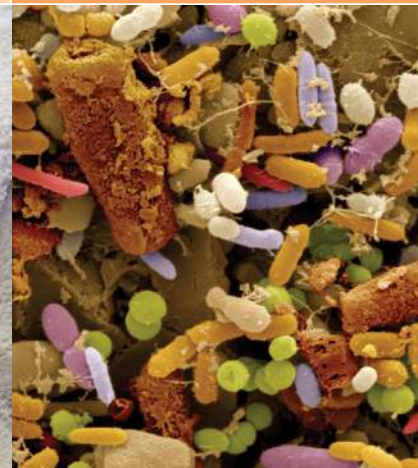
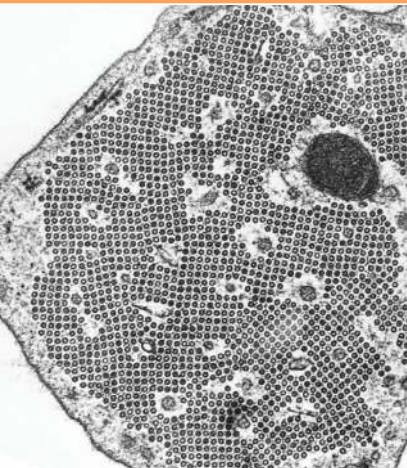


MODULE ONE

Animal nutrition and digestion

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Unit 1

Animal nutrition



Key questions

- What are the different parts of the alimentary canal of the ruminant (cow and sheep)?
- What are the different parts of the alimentary canal of the non-ruminant (fowl and pig)?
- What are the differences between the stomachs of ruminants and non-ruminants?
- What are the functions and adaptations of the various structures of the alimentary canal?
- What is the internal structure of the rumen, reticulum, omasum, abomasum and small intestine?

Animal nutrition is concerned with the way in which animals obtain their food, how the food is broken down during digestion into forms that can be absorbed and utilised to meet the animal's requirements, and how the body gets rid of waste products.

In this unit we are going to look at the alimentary canals (digestive systems or guts) of ruminants such as cows and sheep as well as non-ruminants such as fowl and pigs.

Some animals such as cattle, sheep and goats are herbivores that consume food from plant origin to meet their nutritional requirements. Cattle, sheep and goats are all ruminants.

Other farm animals such as pigs are omnivores that consume feed from both plant and animal origin. They are non-ruminants.

There are also animals that consume food only from animal origin and these are called carnivores. These include wild animals, such as lions and wolves, and animals such as the domesticated cat.

The digestive systems of these different kinds of animals are adapted to suit their specific feed requirements, in order to make the necessary nutritional components accessible for the animal's use. Animals, especially those that are sheltered, must be fed the correct and balanced feeds to fulfil their nutrient requirements.

Proper nutrition is vital for productive and profitable livestock farming. Nutrition is the single most costly component in livestock production.



Organisms that can manufacture their own food are photoautotrophic and those that cannot make their own food are heterotrophic. Animals are heterotrophic. Heterotrophs can either be parasitic (they obtain food from a living host) or saprophytic (they obtain food from dead organisms). Herbivores (feed on plant material), carnivores (feed on animal material) and omnivores (feed on plant and animal material) are all saprophytic.

Fundamental processes in the digestive system

- **Ingestion** is the intake of large food molecules into the mouth where digestion starts.
- **Digestion** is the process in which large complex food molecules are broken down into smaller simpler particles by the digestive enzymes before they can be transported from the alimentary canal into the bloodstream. Digestion consists of:
 - physical processing – breaking down food into smaller particles by chewing (**masticating**) it and then mixing it with saliva to form a bolus to swallow
 - chemical processing – the addition of digestive enzymes to split large food molecules into smaller ones.
- In the process of **absorption** the digested food is absorbed from the alimentary canal into the bloodstream. This involves transporting water, ions and nutrients from the lumen across the epithelium into the blood so that it can be used by the body.
- **Assimilation** is when the ingested food is taken up by the cells of the body.
- **Egestion** is when the indigestible waste products are eliminated from the body.
- In the process of **secretion** digestive juices are secreted by different organs in the digestive tract to break down food into smaller particles. These secretions include saliva, gastric juice, pancreatic juice, bile and intestinal juice.



Comparison of the external structure of the alimentary canal of a ruminant (cow and sheep) and a non-ruminant (fowl and pig)

There are about 150 different **ruminant** species. Ruminants include domesticated animal species such as cows, goats and sheep as well as wild species such as deer, buffalo and giraffe. They are all hoofed animals. All ruminants are herbivores. They are able to utilise indigestible roughage and low-quality feed that consists predominantly of cellulose. They have the unique ability to extract energy from fibrous plant material (cellulose, hemicelluloses and lignin) as well as other components of plant cells that are indigestible to non-ruminants.

Ruminants swallow their food without chewing it properly and later it is regurgitated and re-chewed before it is re-swallowed and further digested. You will learn more about these processes in Unit 3.



Figure 1.1.1 Ruminants: cow, sheep and goat



Figure 1.1.2 Non-ruminants: pig and fowl

Ruminants can further be classified according to their feeding behaviours into grazers and browsers.

- **Grazers** such as cows and sheep feed on grass and small plants.
- **Browsers** such as goats feed on leaves of bushes and trees. Wild browsers such as deer eat highly nutritious twigs and shrubs where they live in the woods.

Non-ruminants such as pigs, fowl and humans are **monogastric** with a simple single-chambered stomach. They eat, chew and swallow their food only once before it is digested in the alimentary canal. Although non-ruminants cannot digest fibre for energy, they do, however, need fibre to get rid of waste products.

The digestive system of the domestic fowl has a very simple structure and function in comparison with those of ruminants and other non-ruminants. However, it is very efficient and effective when the fowl is fed with the correct diet, in adequate amounts, of high quality and easily digestible feed that is low in fibre. The alimentary canal has layers of longitudinal and circular muscles and it has an inner lining of mucous membrane.

Glossary

monogastric an organism with a simple single-chambered stomach

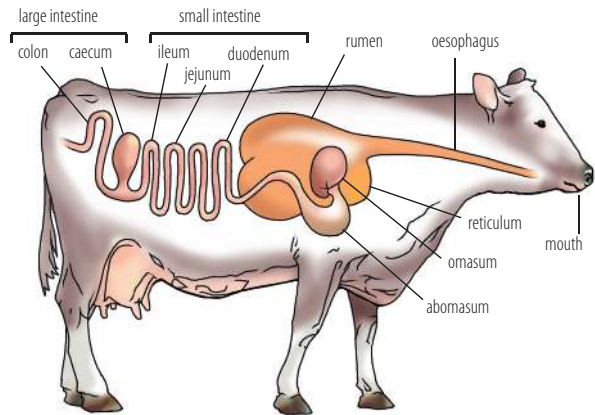


Figure 1.1.3 The external structure of the alimentary canal of the cow

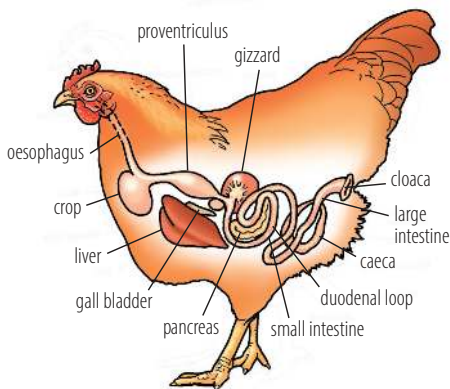


Figure 1.1.4 The external structure of the alimentary canal of the fowl

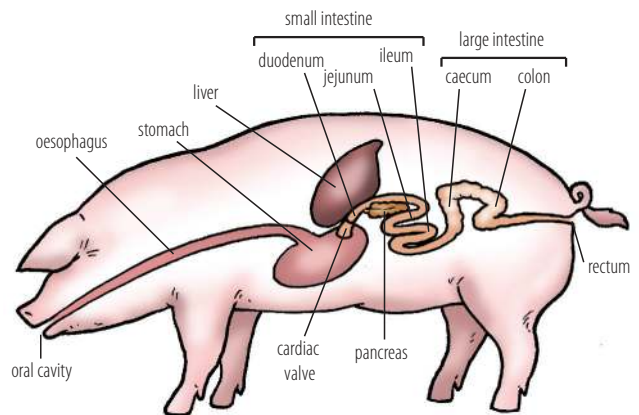



Figure 1.1.5 The external structure of the alimentary canal of the pig

| Organ | Ruminant | Non-ruminant | Pig |
|----------------|--|---|--|
| Mouth | <ul style="list-style-type: none"> Lips of cattle are broad, thick and almost immovable. Tongue is long, thick, muscular and rough and is used to grasp or gather grass. The upper jaw (maxilla) is fixed to the skull and immovable. The lower jaw (mandible) moves with a side to side motion during chewing and rumination. Cattle have 32 teeth. The dental formula of the cow is: $\frac{0.0.3.3}{4.0.3.3}$ There are no incisors or canines in the upper jaw; instead they have a dental pad. The upper and lower jaws both have six premolars and six molars each (making a total of 24 molars). Between the incisors and molars is a large gap that enables cattle to harvest and chew a large amount of fibrous feed. There are three pairs of salivary glands: <ul style="list-style-type: none"> parotid glands – below the ear submandibular glands – below the jaw sublingual glands – below the tongue. Taste buds occur mostly on the posterior side of the tongue. | <ul style="list-style-type: none"> Chickens do not have lips and cheeks; instead they have beaks to peck up food to enter the mouth. Beaks are composed of bone and dense horny skin called keratin. The upper part of the beak (upper maxilla) is fused with the skull and is immovable. The lower part of the beak (lower mandible) is hinged at the jaw, which makes it mobile. They do not have teeth and are unable to chew their food. A chicken has a small, triangular pointed tongue covered with thick horny epithelium and is relatively inflexible. The roof of the mouth is a hard palate with a long narrow split in the middle (where the nasal cavity opens into the mouth). On the hard palate there are five transverse rows of hard conical papillae pointing backwards. The ducts of eight different salivary glands open through the hard palate to release their secretions into the mouth cavity. Taste buds occur on the roof of the mouth and the back of the tongue. | <ul style="list-style-type: none"> The oral cavity is covered with non-keratinised stratified squamous epithelium. The muscular tongue containing taste buds is located on the lower jaw. The muscles used for chewing are attached to the lower jaw (mandible). The upper jaw (maxilla) is immovable. Pigs have 44 teeth. The dental formula is: $\frac{3.1.4.3}{3.1.4.3}$ Pigs have all four kinds of teeth namely incisors, canines, premolars and molars. There are three pairs of salivary glands that secrete saliva: <ul style="list-style-type: none"> parotid glands submandibular glands sublingual glands. The hard palate in the roof of the mouth is a hard bony structure that separates the oral cavity from the nasal cavity. The soft palate is a movable fold underneath the hard palate that closes off the nasal cavity from the oral cavity during swallowing or suckling. The hard and soft palates are covered by mucous membranes. |
| Pharynx | <ul style="list-style-type: none"> This muscular tube plays a role in digestion and respiration. It is longer and wider than the pharynx of the pig. | <ul style="list-style-type: none"> The pharynx is very small. The combined cavity of the mouth and pharynx is sometimes referred to as the oropharynx. | <ul style="list-style-type: none"> This short muscular tube serves as a passageway for food to the oesophagus and air to the trachea. It is usually open to allow air to move in freely. When the animal eats, the trachea is closed off, breathing stops and the animal swallows the food. |

 A dental formula is for one half of the mouth in the following order: incisors, canines, premolars and molars.

| Organ | Ruminant | Non-ruminant | |
|----------------------------|--|---|--|
| | | Fowl | Pig |
| Oesophagus / Gullet | <ul style="list-style-type: none"> This muscular tube connects the mouth to the forestomachs. It is an extension of the pharynx in the back of the oral cavity. It goes down the neck next to the trachea, through the thoracic cavity and diaphragm to the stomach in the abdominal cavity. The walls of the oesophagus have striated muscles. It is lined with squamous epithelium. | <ul style="list-style-type: none"> This wide tube connects the oral cavity with the crop and eventually enters the proventriculus of the stomach. The crop is a sac-like structure on the right side just before the oesophagus enters the thoracic cavity. The wall consists of four tissue layers of which the innermost one is a mucous membrane. | <ul style="list-style-type: none"> This tube connects the pharynx with the single-chambered stomach. At the posterior end is a cardiac sphincter that prevents food from passing from the stomach back into the oesophagus, which is known as gastro-oesophageal reflux. |
| Stomach | <ul style="list-style-type: none"> The cow has a complex stomach consisting of four compartments namely: <ul style="list-style-type: none"> rumen reticulum omasum abomasum. The cardiac sphincter is at the entrance to the stomach and the pyloric sphincter at the exit into the small intestine. | <ul style="list-style-type: none"> The stomach consists of two chambers that are both covered by a fair amount of fat or adipose tissue: <ul style="list-style-type: none"> The proventriculus is the soft, tubular glandular stomach and is relatively small. It is covered with a thick wall composed of five layers. The ventriculus (also known as the gizzard) has a flattened, rounded shape and has thick muscular walls. The interior is lined with horny epithelium. | <ul style="list-style-type: none"> A pig has a simple monogastric stomach consisting of only one chamber. <ul style="list-style-type: none"> It is a muscular sac-like organ. It is connected to the oesophagus at the front end by the cardiac sphincter and to the small intestine at the back end by the pyloric sphincter. It is divided into four different parts: <ul style="list-style-type: none"> oesophageal region cardiac region fundic region pyloric region. |

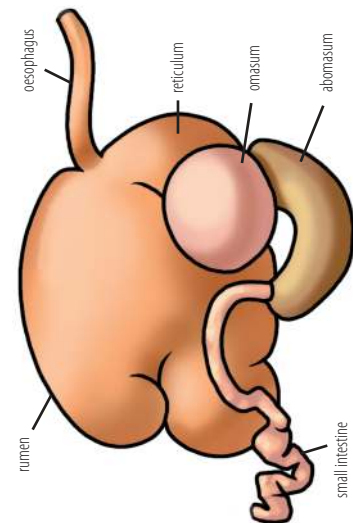


Figure 1.1.6 The four compartments of the stomach of a ruminant

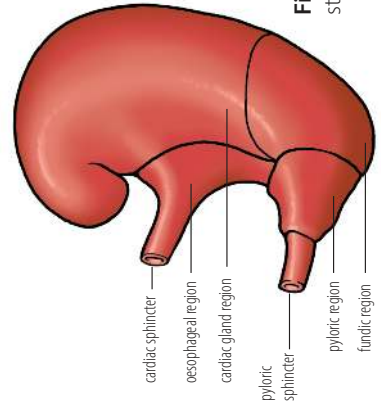


Figure 1.1.7 The stomach of the pig

| Organ | Ruminant | Non-ruminant | Pig |
|------------------------|--|--|--|
| Small intestine | <ul style="list-style-type: none"> This tube runs from the abomasum to the large intestine. The small intestine of a ruminant is about 20 times longer than the length of the animal, so a cow that is two metres long will therefore have a small intestine about 40 m in length. It is divided into three parts: <ul style="list-style-type: none"> - duodenum - jejunum - ileum. The ileum is the longest section of the small intestine. | <p>Fowl</p> <ul style="list-style-type: none"> In the mature chicken the small intestine is about 125 cm long and comprises about 50% of the digestive tract. It is divided into three parts: <ul style="list-style-type: none"> - duodenum - jejunum - ileum. Only the duodenum can be easily distinguished. It starts at the exit of the gizzard and forms an elongated loop. (The pancreas is located between the arms of the loop.) The small intestine forms a coil after the duodenum. The jejunum and ileum cannot easily be differentiated. The jejunum is suspended from the dorsal wall of the abdominal wall by a thin membrane – the mesentery. The jejunum and ileum are suspended in the mesentery. There is a small projection called Meckel's Diverticulum on the outer surface of the small intestine. This is where the yolk sac was attached during embryo development. | <p>Pig</p> <ul style="list-style-type: none"> In a mature pig the small intestine is about 18 m in length. It is a tube consisting of three parts namely: <ul style="list-style-type: none"> - duodenum - jejunum - ileum. |
| Large intestine | <ul style="list-style-type: none"> The large intestine is the last part of the digestive system between the ileum and the rectum. It is shorter but wider than the small intestine. It consists of two parts: <ul style="list-style-type: none"> - The caecum is a blind-ended pouch just below the ileo-caecal valve that connects the large intestine to the ileum of the small intestine. - The colon is the longest part of the large intestine and can be divided into the ascending, transverse, descending and sigmoid segments. The large intestine ends in the rectum. | <ul style="list-style-type: none"> The large intestine is very short (about 10 cm). It ends at the cloaca. Fowl have two caeca (blind-ended pouches/guts) with a length of about 16–18 cm in mature chickens. The caeca are attached at the junction between the small intestine and the large intestine. The caeca are closely attached lengthwise to the small intestine by the mesentery. Each consists of three parts: <ul style="list-style-type: none"> - thick-walled narrow base at the ileo-caecal valve - thin-walled middle part - thick-walled wide blind apex. The rectum is the terminal point of the digestive tract. | <ul style="list-style-type: none"> The large intestine consists of two parts: <ul style="list-style-type: none"> - caecum - colon. The caecum is sac-like and opens into the alimentary tract. The colon is divided into the ascending, transverse, descending and sigmoid parts. At the terminal end of the large intestine is the rectum. |
| Rectum | <ul style="list-style-type: none"> The rectum is the short terminal segment that continues into the anal canal. | <ul style="list-style-type: none"> The rectum is the terminal point of the digestive tract. | <ul style="list-style-type: none"> The large intestine ends in the rectum. |
| Anus/ Cloaca | <ul style="list-style-type: none"> The alimentary canal ends in the anus. The anus opens and closes by a sphincter to release the undigested food in the form of faeces. | <ul style="list-style-type: none"> The opening of the anus of a fowl is known as a cloaca. It is tubular and is the opening to the exterior of the body. The posterior opening is called the vent, which is the common opening for the digestive and uro-genital tract. | <ul style="list-style-type: none"> The anus is guarded by external and internal sphincter muscles. |

Functions and adaptations of various structures of the alimentary canal



Camelids (camels, llamas and alpacas) are also ruminants. However, they have only three compartments in their stomachs and are thus called pseudo-ruminants. The reticulum has gland-like cells and the omasum is tubular and almost indistinct.

The alimentary canals of different animal species are adapted to digest and absorb the specific feed types that they consume.

Ruminants such as cows and sheep are herbivores that depend directly on food of plant origin. Their digestive tracts are adapted to digest carbohydrates and other nutrients produced by plants. Since plant foods are more difficult to digest, the digestive tracts of herbivores are longer to ensure efficient digestion and absorption of the nutrients. Their molar teeth are able to grind and crush the plant material. When chewing the lower jaw moves with a sideways motion to further help with the grinding of the plant food.

The tongue is used to grasp or gather the grass. The food is then pinched off between the incisors and the dental pad with a jerk. The lips are used when the cattle graze or eat smaller feeds such as grains. Cattle cannot bite off the grass very well because they do not have upper incisors.

Non-ruminants such as pigs are often omnivores. They have shorter digestive tracts than herbivores so that they can digest both plant and animal feed. Pigs use their snouts to dig for food, the lips are used to hold the food and the cheeks help with mastication and mixing. Pigs use their flat molars and sharp teeth to grind and tear off food.

Both ruminants (such as cows and sheep) and non-ruminants (such as pigs) have three pairs of salivary glands secreting saliva into the mouth. The saliva is mixed with the food to moisten it and to make swallowing easier. Saliva of non-ruminants contains the enzyme amylase to help with the digestion of starches into sugars. However, the saliva of cows does not contain salivary amylase. You will learn more about these salivary glands in Unit 2.

Fowl are also non-ruminants. They do not have teeth so they are unable to chew their food. Chickens have eight different salivary glands. The saliva also contains the enzyme amylase to help with the digestion of starch. The beak is used to grasp, tear and scoop up food. The tongue is used to push the feed to the back of the mouth so that it can be swallowed easily.

At the back of the mouth of many animals is a cone-shaped epiglottis, which is a flap of skin that is covered with a mucous membrane. It covers the glottis (a slit-like opening that leads to the trachea) and prevents food and liquid from entering the trachea during swallowing. This prevents the animal from choking during eating, drinking and swallowing. Fowl do not have an epiglottis which means that aspiration of food is more likely.

Contraction and relaxation of longitudinal and circular muscles in the walls of the digestive tract aid with the movement of food down the alimentary canal.



Did you know that newly hatched chickens have an 'egg tooth' that they use to hatch from the egg? It disappears after a day or two.

Glossary

aspiration occurs when food, liquid or other material enter your airway or lungs by accident or when you normally have trouble swallowing. This may lead to serious health problems such as pneumonia.

Mouth

Functions of the mouth

- The mouth is primarily the organ for the intake of food into the oral cavity.
- Inside the mouth the teeth chew and grind the ingested coarse food into finer particles before it can be swallowed. However, ruminants swallow their food without properly chewing it. You will learn more about this in Unit 3.
- The salivary glands in the mouth secrete saliva that moistens and softens the food for easy swallowing.
- In cows and pigs the lower jaws (lower part of the beak in fowl) are movable and used to aid with chewing and grinding of the food.

Functions of the tongue

- It is a taste organ that helps the animal to distinguish between the tastes of different feeds.
- The cow has a prehensile tongue that is used to wrap around and grasp grass for intake into the mouth.
- It moves the food towards the teeth for the chewing process.
- It rolls the food into a ball and helps to mix it with saliva to form a bolus.
- The formation of a bolus of food makes swallowing easier.
- It can feel foreign objects in the mouth, which helps prevent the animal from swallowing them.
- The tongue is also used to drink water.
- It is used by the young to suck milk during lactation.

Pharynx

The pharynx is closed off by the epiglottis to prevent food from entering the trachea during swallowing. It is lined internally with stratified squamous epithelium.

Functions of the pharynx

- It plays a role in digestion as it is a passageway for the food from the mouth to the oesophagus. When food is swallowed, the animal stops breathing and the larynx closes the trachea off to prevent food passing into the lungs. The muscles of the pharynx contract to force the bolus of food down into the oesophagus when it is swallowed.
- It plays a role in respiration for the exchange of gases during inhalation and exhalation.
- Feed that is swallowed moves down the pharynx into the oesophagus by contraction and relaxation of the muscular walls.

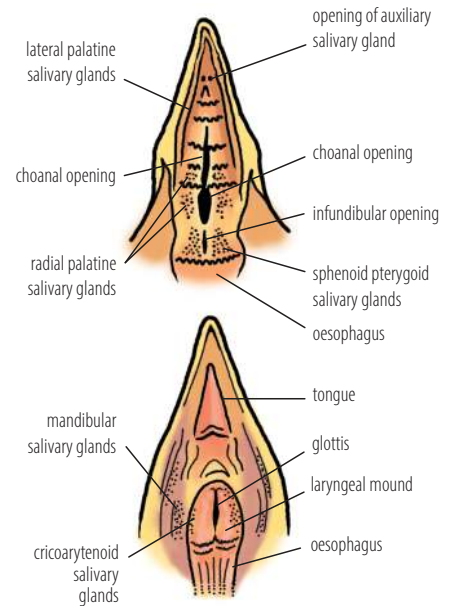


Figure 1.1.8 Internal structure of the mouth of a fowl

Oesophagus

The oesophagus is an extension of the pharynx in the back of the oral cavity. It goes down the neck next to the trachea, through the thoracic cavity and diaphragm to the stomach in the abdominal cavity.

The walls of the oesophagus have striated muscles that contract and relax to move the food downwards into the stomach. It is lined with stratified squamous non-keratinised epithelium. The main part of the oesophagus is lined with small mucous glands.

The functions of the oesophagus are controlled by oesophageal sphincters. The upper sphincter is relaxed during swallowing to allow the food to enter the oesophagus. It pulls the larynx forward and helps with pushing the food into the oesophagus and not into the trachea. The lower sphincter muscle surrounds the oesophagus where it enters the stomach.

Functions of the oesophagus

- The oesophagus connects the mouth to the forestomachs of ruminants and the single-chambered stomach of non-ruminants.
- It is a passageway for boluses of food from the mouth to the stomach. Food is pushed forward by the involuntary contraction and relaxation of the longitudinal and circular muscles in the walls creating a series of wave-like movements called **peristalsis**. There is virtually no absorption of food in the oesophagus.
- Reverse peristalsis or retro-peristalsis also takes place, which means that food is regurgitated from the rumen back through the oesophagus to the mouth to be re-chewed. This only happens in ruminant animals such as cows.
- The mucus secreted by the mucous membranes lubricates the food for easy passage along the alimentary canal.

You will learn more about peristalsis in Unit 3.

Crop of the fowl

The crop of the fowl is an enlarged extension of the oesophagus. It is a temporary storage organ where food is moistened and softened before it moves further down the alimentary canal to be digested. It extends when the chicken is eating to make space for the food being swallowed.

Functions of the crop of the fowl

- Very little digestion takes place in the crop of the fowl.
- The crop stores food materials temporarily.
- The food is moistened and softened.

Stomach

Stomach of the ruminant

The stomach occupies about three-quarters of the abdominal cavity. It fills almost all of the left side and also extends significantly into the right side.

Glossary

peristalsis the involuntary constriction and relaxation of the muscles of the intestine or another canal