



## Adaptations of carnivores and herbivores to their diet

The main adaptations described in this Factsheet are:

- dentition in a named herbivore and a named carnivore.
- differences in the digestive systems of herbivores and carnivores with particular reference to ruminants.

### Dentition of the dog

The dog is a carnivore, which means that it mainly eats meat and its teeth are adapted for this purpose. The dog has three incisors, one canine and four premolars on each side of both upper and lower jaws. The upper jaw contains two molars and the lower jaw three molars, on each side. The dental formula is:

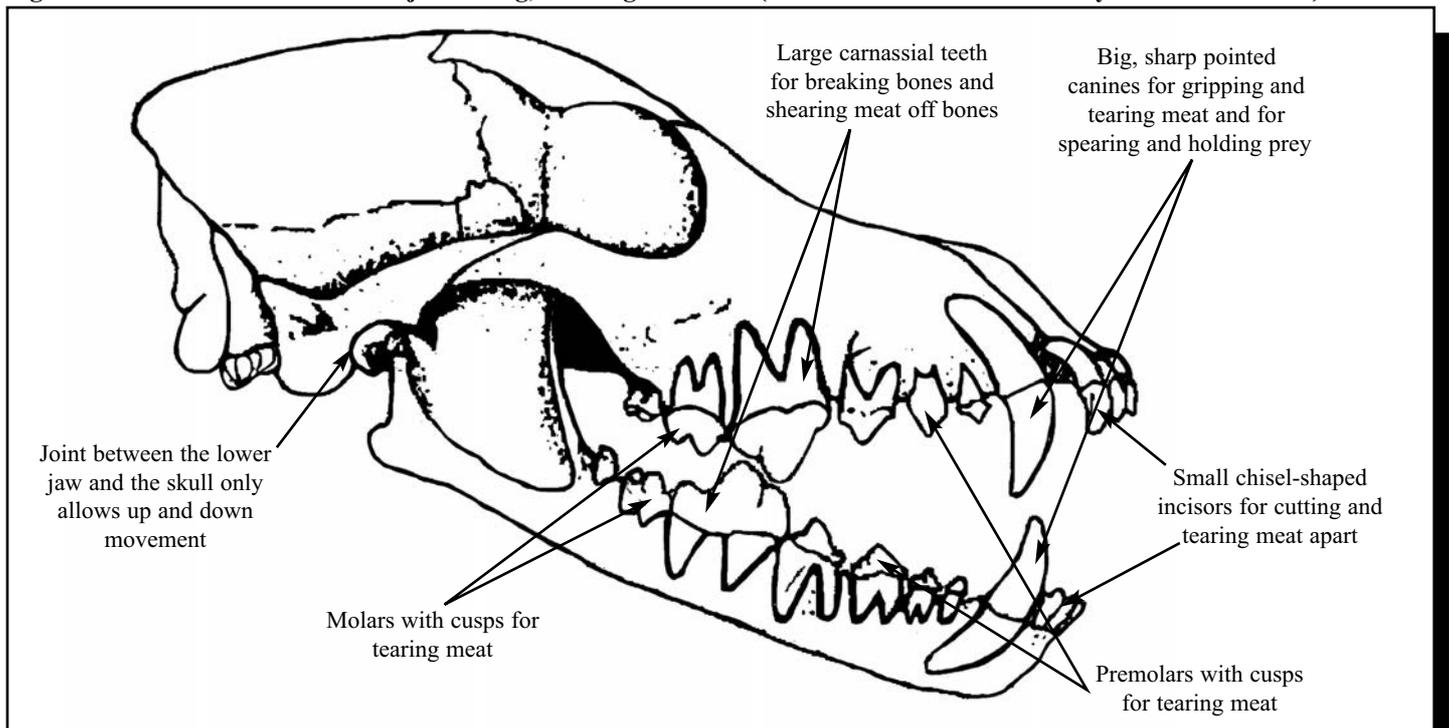
$$i \frac{3}{3} \quad c \frac{1}{1} \quad pm \frac{4}{4} \quad m \frac{2}{3} = 42$$

**Remember:** The dental formula represents the number of each type of tooth in one side of the upper jaw over the number of each type of tooth in one side of the lower jaw. Symbol: *i* = incisors, *c* = canines, *pm* = premolars and *m* = molars. The total number of teeth in the buccal cavity is shown on the right of the equation.

The dentition of the dog is designed for gripping the prey, cutting and tearing meat off bones and for crushing bones (Fig. 1).

- The incisors, at the front of the jaw, are small but are shaped like chisels and are sharp. They are used to snip or gnaw meat off bones and to cut lumps of meat up.
- The canines, behind the incisors, are very long, sharp and spear-shaped. They are used to impale and grip the prey and to tear the meat.
- The last upper premolar and the first lower molar are very large with sharp upper surfaces and vertical sides. They are called **carnassial teeth** and fit together when the mouth is closed. When the dog is eating they work together like a pair of scissors, snipping meat off bones and also crushing bones.
- The other molars and premolars are smaller than the carnassial teeth but have strong pointed cusps for cutting and tearing meat. A dog cannot masticate (chew) the meat and has to swallow whole lumps of it. It cannot chew since the lower jaw can only move against the upper jaw in an up and down plane. This is due to the shape of the temporo-mandibular joint between the temporal bone of the skull and the mandible (lower jaw).
- To withstand the considerable stresses incurred when eating, all the teeth have strong roots anchored deeply into the jawbones. Incisors and canines have one root per tooth. Premolars and molars may have two or three roots per tooth.
- The condyle (articulating joint surface) of the lower jaw is situated in a very deep groove in the skull. This ensures that the temporo-mandibular joint does not become dislocated due to struggling movements of the prey.
- The jaw muscles are very powerful, enabling a bite strong enough to crack bones.

Fig 1. Side view of skull and lower jaw of dog, showing the teeth. (Some bone has been cut away to show the roots).



**Dentition of the sheep**

The sheep is a herbivore and eats mainly grass or other available vegetation and so its dentition is adapted for this purpose. The sheep has no incisors or canines on each side of the upper jaw but has three incisors and one canine on the lower jaw. There are three premolars and three molars on each side of both upper and lower jaws. The dental formula is:

$$i \frac{0}{3} \quad c \frac{0}{1} \quad pm \frac{3}{3} \quad m \frac{3}{3} = 32$$

The dentition of the sheep is designed for cutting off the grass from the plant, when grazing, and for grinding the grass efficiently to smash the cellulose cell walls of plant cells thus releasing the digestible plant cell contents. The dentition of the sheep is shown in Fig. 2.

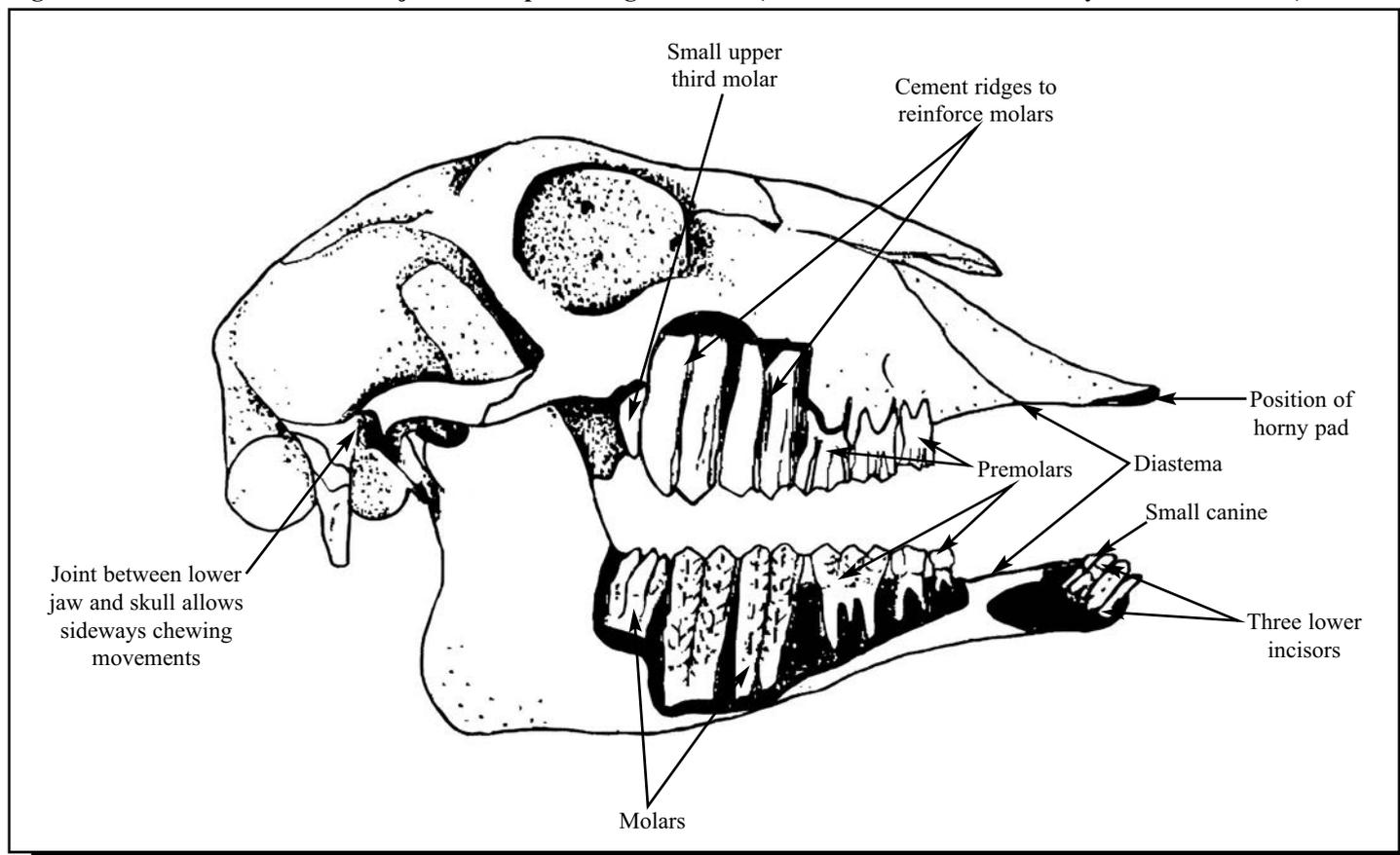
- The incisors in the lower jaw are sharp and bite against a **horny pad** on the upper jaw. This enables the vegetation to be snipped off the plants during feeding.
- There is no upper canine and the lower canine is very small in size. This leaves a space between the horny pad and the upper premolars and between the lower canine and the lower premolars. This space is called the **diastema** and is characteristic of herbivorous mammals. The animal fills the space with extra grass during feeding and then can stop feeding until the grass is chewed and swallowed, thus emptying the diastema. This behaviour lets it look around frequently to watch for predators.
- The temporo-mandibular joint between the lower jaw and the skull has flattened articulating surfaces which enable fairly free movement of the lower jaw sideways and slightly forwards or backwards. Thus a circular grinding movement can be achieved. However, the joint could be easily dislocated but this is unlikely to happen by eating vegetation.

**Remember:** The dentine is the bony substance which makes up the bulk of the tooth. The enamel is the hard, acid resistant substance which coats the crown of the tooth. The cement is a substance which anchors the tooth into the jawbone.

- The premolars and molars are similar in structure although the molars are larger than the premolars. Their sides are strengthened with ridges of cement which also help to prevent the edges of the teeth from being chipped away by abrasive food. Their upper surfaces make a very effective grinding surface consisting of ridges and grooves. The structural substances of the teeth, dentine and enamel, wear away at different rates and so leave concentric patterns of sharp, very hard ridges of enamel with slightly less hard depressions of dentine between the ridges. As the lower jaw moves sideways during chewing, the grass is ground by a circular motion between the ridges of the upper and lower premolars and molars. This effectively breaks open the cellulose walls of plant cells.
- Unlike the dog dentition, where the tooth root cavities become closed so limiting the blood supply and so preventing further growth, the root cavities of sheep premolars and molars remain open throughout life. This means a good blood supply is maintained to the teeth which can therefore grow throughout life. The advantage is that as the teeth are worn down on their upper surfaces by grinding they are built up by further growth.

**Exam Hint:** Examiners are likely to ask you to relate the dog or sheep dentition to their different diets or to compare the dentition of dog and sheep in relation to their diets. You could be asked to draw a skull with teeth from a photograph as a test of your skill in accurately recording biological material. You would not be asked to draw a skull and teeth from memory.

**Fig 2.** Side view of skull and lower jaw of sheep showing the teeth. (Some bone has been cut away to show the roots).



**Chewing the cud (rumination)**

Rumination or 'chewing the cud' is the ability to regurgitate plant material from the stomach in order to chew it again. The food is then swallowed again. Mammals that possess this ability are called 'ruminants'. Examples include cows, sheep and deer.

- Sheep (and cows) have this ability to chew their food several times. This behaviour increases the breakdown of cellulose cell walls in the grass thus increasing the release of digestible cell contents. Grasses also contain some abrasive siliceous (silica based) material in their cells and the extra grinding by chewing the cud helps to break this down.
- The sheep will start feeding at daybreak and will feed for several hours until the rumen (a large chamber in the stomach) is full. It will then sit down and chew the cud for several hours until the food in the rumen has been broken down into a consistency that enables it to pass further along the gut. It will then feed again.
- The rumen is attached to the buccal cavity by the oesophagus. To enable food to be regurgitated at will, the muscle in the oesophagus is all voluntary muscle. Carnivores and omnivores have a mixture of voluntary and involuntary muscle tissues in their oesophagus.

**The sheep stomach**

Herbivore guts tend to be longer than carnivore guts. This is because:

1. Plant material needs more time and enzyme action to be broken down than animal material.
2. More space is required to accommodate the bulkier plant material.

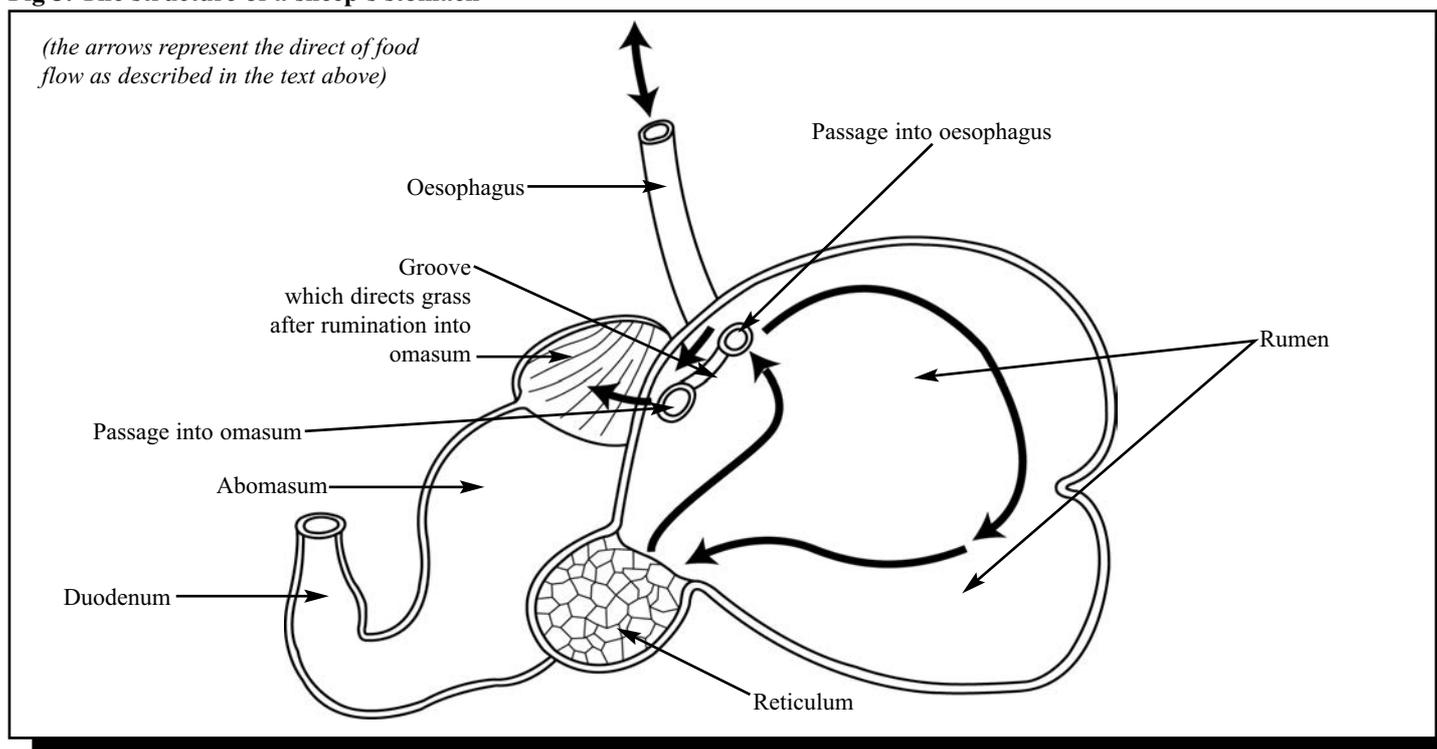
This is illustrated by the structure of the sheep (and cow) stomach. The structure of a sheep's stomach is shown in *Fig. 3*. Whereas a dog has a simple, one-chambered stomach, a sheep has a stomach divided into four chambers. These are, the **rumen**, the **reticulum**, the **omasum** and the **abomasum**. In a fully grown cow the rumen is huge – it can hold about 50 gallons (228 litres) of grass.

Mammals generally do not secrete cellulases (enzymes for digesting cellulose into  $\beta$ -glucose molecules). Many herbivorous mammals possess cellulase-secreting bacteria in certain regions of the gut and these break down the cellulose plant cell walls thus supplementing the mechanical breakdown of cellulose by the teeth.

- In ruminants, the bacteria are mainly in the rumen and reticulum. After feeding and initially chewing the food it is passed into the rumen, where neutral (pH) juices are added and where bacterial fermentation commences. The products of fermentation include  $\beta$ -glucose and large quantities of short chain fatty acids, for example, acetic, propionic and butyric acids. These form a major energy source for the animal.
- From the rumen the food passes into the smaller reticulum. Here the mucosa (inner lining) is folded like a honeycomb, and bacterial digestion proceeds further. The food is then regurgitated from the reticulum back into the buccal cavity for 'chewing of the cud'. When the food is reswallowed, if it is in small enough pieces, it is stopped from re-entering the rumen, by the closure of a groove on the side of the reticulum. This groove makes a channel which channels the liquid cud into the omasum. (See flow arrows on *Fig. 3*)
- The omasum has a mucosa which is folded into vertical ridges. (These resemble the pages of a psalter (book of psalms) - hence the alternative name of psalterium for the omasum). In the omasum the food is churned about, allowing further bacterial fermentation and then is passed to the abomasum (true stomach) which produces the typical acid and secretions of all mammalian stomachs.
- Any bacteria which enter the abomasum are killed by the acid secretions and their protoplasm is digested. The bacteria can build up bacterial protein from non-protein nitrogen present in the grass or stomach, for example, urea and amides. This bacterial protein becomes available to the host animal by the digestion of the bacteria which pass into the abomasum.

**Remember:** The association between the cellulose-digesting bacteria and the sheep or cow is an example of mutualism. Both types of organism benefit from the association.

**Fig 3. The structure of a sheep's stomach**



**Specimen questions**

1. Suggest why:
- (a) (i) molars generally have two or three roots but incisors only have one root. **2**  
(ii) sheep molars have ridges but dog molars have cusps. **2**
- (b) Suggest why dogs have large canine teeth but sheep only have lower canine teeth which are reduced in size. **3**
- (c) Animals can metabolise either alpha or beta-isomers of glucose. Suggest why much of the glucose in the sheep is absorbed from the intestines to the blood in the beta form. **3**
- Total 10 marks**
2. (a) Briefly describe and explain two behavioural adaptations of the sheep related to its diet. **4**  
(b) Briefly describe the carnassial teeth and their functions in the dog. **3**  
(c) Sheep molars have 'open roots'. What does this mean and what feeding advantages does this give to the sheep? **3**
- Total 10 marks**
3. Each of the following groups has one correct statement. For each indicate whether statement **A**, **B**, **C** or **D** is correct.
- (a) the passage of food through the sheep stomach goes through:  
**A** rumen reticulum abomasum omasum  
**B** omasum abomasum reticulum rumen  
**C** rumen reticulum omasum abomasum  
**D** abomasum omasum reticulum rumen **1**
- (b) the bacterial fermentation in the stomach of the sheep:  
**A** digests cellulose producing alpha-glucose and short-chain fatty acids  
**B** produces beta-glucose, acetic acid and proprionic acid  
**C** occurs in the rumen, reticulum and abomasum  
**D** requires an acidic environment **1**
- (c) ruminants:  
**A** are herbivores like sheep and pigs which chew the cud  
**B** regurgitate their food several times to masticate it more  
**C** have involuntary muscle in the wall of the oesophagus  
**D** possess a diastema and cusped molars **1**

**Total 3 marks****Mark scheme**

1. (a) (i) incisors only cut/snip food but molars grind food/shear meat off bones/break bones; therefore attachment of molars to the jawbones must be much stronger than incisor attachment; **2**  
(ii) ridges make a good grinding surface for breaking down plant food in (sheep); cusps make a good cutting surface for shearing meat into bits/off bones (in dogs); **2**
- (b) dogs have large canines for tearing meat/impaling and holding prey; sheep have lost/reduced the canines to make the diastema; diastema is a space for holding extra grass (during feeding); **3**
- (c) bacteria in the rumen/stomach secrete cellulases/cellulose splitting enzymes;  
to breakdown cellulose of plant cell walls into beta-glucose molecules;  
because cellulose is a polymer of beta-glucose molecules; **3**
- Total 10 marks**
2. (a) animal regurgitates food to chew it several times/chews the cud; so that more cellulose cell walls are broken liberating the digestible protoplasm from the cells;  
when feeding the animal quickly fills the diastema with grass; then looks around watching for predators while chewing the food from the diastema before swallowing it; **4**
- (b) last upper premolar and first lower molar; very large teeth bearing strong sharp cusps;  
upper and lower carnassial teeth act like scissors, shearing meat off bones/breaking bones; **3**
- (c) the openings to the pulp/root cavities remain open wide during the life of the tooth; allowing free access of blood supply to the tooth enabling continual growth;  
thus as the tooth is worn down by continual grinding of grass lost tooth substances are replaced by growth (and so the sheep can go on feeding when old); **3**
- Total 10 marks**
3. (a) C;  
(b) B;  
(c) B;

**Total 3 marks****Acknowledgements:**

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Curriculum Press, Unit 305B, The Big Peg, 120 Vyse Street, Birmingham B18 6NF

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