

Anatomy and physiology of the goat

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Animal Biosecurity and Welfare, NSW DPI

Goat owners need to understand the basic structure and functioning of goats if they are to maintain the health and increase the productivity of their herds.

This brief outline of the goat's anatomy and physiology is a starting point for those who want to begin keeping goats, and for established producers who would like to fine-tune their knowledge.

Anatomy is the branch of biological science that deals with the form and structure of animals.

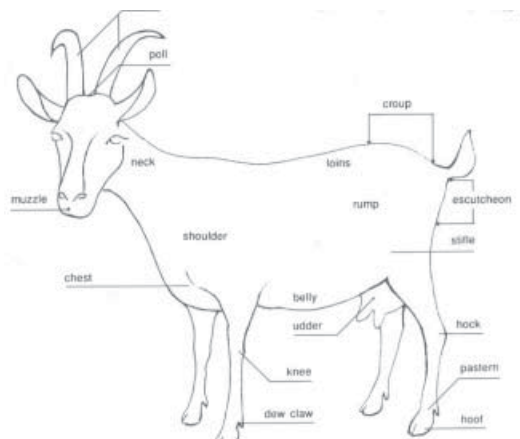
Physiology is the branch that deals with the functions of the body.

Anatomy

Points of a goat

The points of an animal are the salient features that an owner or prospective buyer examines in order to assess its health or its potential as breeding stock.

Figure 1 The points of a female goat



Line drawing by Nagui Henein

The skeleton is made up of the vertebral column, ribs and skull; the limbs; and the joints.

The vertebral column consists of a series of irregularly shaped bones, some fixed and some movable. There are 7 neck (cervical) vertebrae, 13 chest (thoracic) vertebrae, 6 or 7 lumbar vertebrae, 4 pelvic (sacral) vertebrae and between 4 and 8 tail (coccygeal) vertebrae.

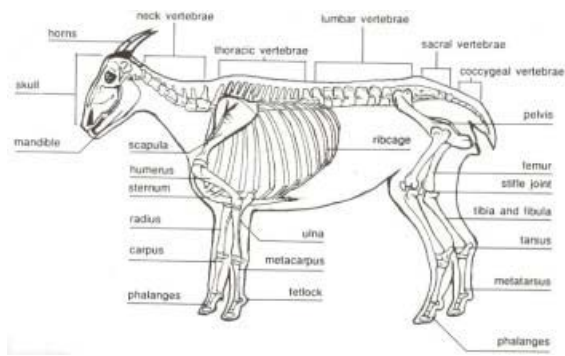
The ribs are elongated, curved bones that form the ribcage, which is the skeleton of the thoracic cavity (chest). There are 13 pairs of ribs attached to each side of the thoracic vertebrae. Most of them are fixed—that is, they are joined to the sternum (breastbone) at the front of the chest—but the last two pairs are not attached at the front and are called floating ribs.

The skull includes all the bones of the head. It consists of a number of flat bones that form immovable joints, most of which disappear with age; and a lower jawbone (mandible), which forms movable joints with the other parts of the skull.

The limbs include forelegs (thoracic limbs) and hind legs (pelvic limbs). The forelegs consist of shoulder, forearm and a lower limb made up of carpus, metacarpus and phalanges. The hind legs consist of pelvic girdle, thigh, and a lower limb made up of tarsus, metatarsus and phalanges.

Skeleton

Figure 2 The skeleton of a goat



Line drawing by Nagui Henein

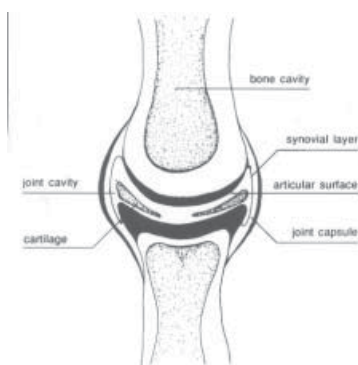
The joints are where two or more bones of cartilages meet. There are two main kinds of joints.

Fixed or immovable joints have no joint cavity and are united by fibrous tissue or cartilage. Many of these are temporary joints which become fixed as calcium accumulates in the flexible tissues and turns to bone (calcifies) with age. Examples are the joints in the skull, the joints of ribs to vertebrae, and the pelvic and mandibular symphyses (midline joints).

Movable joints have a joint cavity surrounded by a joint capsule. There are two opposing bone surfaces, which have smooth surfaces of very dense bone.

Movable joints have cartilages between the bones to reduce friction and absorb concussion. The inner lining of the joint capsule is the synovial layer, which produces synovial fluid ('joint fluid'). Examples include joints of the limbs, such as the shoulder and the hip, and the joint between the skull and the vertebral column.

Figure 3 Cross-section of a movable joint



Line drawing by Nagui Henein

There are also joints with limited movement and rigid supporting tissues; for example, the joints between the vertebrae in the spinal column.

Digestive system

Teeth. Goats have three groups of teeth:

- four pairs of incisors on the lower jaw only, which bite on to a 'dental pad' on the upper jaw;
- three premolars on each side of the upper and lower jaws;
- three molars on each side of the upper and lower jaws.

The teeth usually erupt at about the times shown below.

	Temporary	Permanent
First incisors	1 st week	13-15 months
Second incisors	2 nd week	18-21 months
Third incisors	3 rd week	22-24 months
Fourth incisors	4 th week	27-32 months
Premolars	2-6 weeks	18-24 months
First molars		3-5 months
Second molars		9-12 months
Third molars		18-24 months

A goat's age can be estimated by examining the permanent teeth that have erupted (see Agfact A7.2.2 *How to tell the age of goats*).

Stomach. The stomach of a goat is very large and consists of four parts: the rumen, the reticulum, the omasum and the abomasum.

The rumen occupies almost all of the left half of the abdominal cavity. It is divided internally into compartments by pillars (large folds of the wall) and lined with many papillae (small projections of tissue). The rumen wall has a layer of muscle.

The reticulum is the foremost part of the stomach. It lies beneath ribs 6–8, just behind the diaphragm and liver. Its lining is arranged in a mesh-like 'honeycomb' pattern.

The omasum is the smallest part of the stomach. It is oval in shape and sits on the right side of the abdominal cavity. Its interior is divided by large longitudinal folds of tissue, like pages in a book.

The abomasum is about twice the size of the reticulum, but elongated in shape. It lies on the right side of the abdominal cavity. The lower end of the abomasum is constricted by the pyloric

sphincter, a strong muscular valve which separates it from the duodenum.

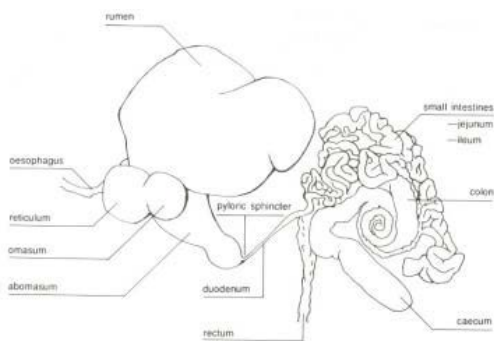
Intestines. The small intestine is about 25m long, with an average diameter of 25mm. The first 60cm forms the duodenum, which is next to the pancreas.

The small intestine lies at the back of the right side of the abdominal cavity. It is made up of the jejunum and the ileum.

The caecum is a blind sac which marks the junction between the small intestine (ileum) and the start of the large intestine. It is about 200mm long and 50mm in diameter.

The colon, or large intestine, is about 5m long. At its beginning it is the same diameter as the caecum, gradually tapering to about the same as the small intestine, when it becomes the rectum.

Figure 4 The stomachs and intestinal tract of a goat



Line drawing by Nagui Henein

Reproductive system—female

The external part of the female genitalia is called the vulva. It seals the opening of the reproductive system to protect against contamination and to prevent the sensitive internal tissues from drying out. It is pinkish grey in colour.

The vulva leads to the vagina, which is a tubular structure with a smooth, moist, glistening lining. The lining is tough and covered with mucus to withstand possible injury and bacterial contamination resulting from natural service.

The cervix is a series of muscular ridges forming a protective block between the uterus (and the developing foetus) and the exterior. To keep out harmful bacteria, foreign debris and undesirable fluids there is a cervical plug of mucus—a thick, tacky secretion from the mucus glands in the lining of the cervix. This plug seals the cervix during pregnancy and when the doe is not on heat.

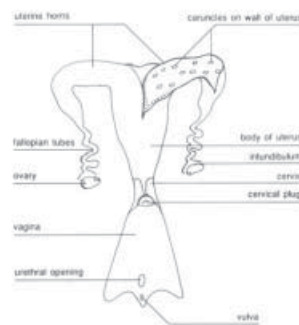
The uterus is often called the womb. When the doe is not pregnant, the uterus is 2–3 cm long. It

has two horns extending from it. The lining of the uterus is dark pink because it is covered with tiny blood vessels that are there to provide nutrients for the growing embryo. The caruncles—small raised areas on the uterine wall—are the points of attachment for the placenta.

The two uterine horns are linked by a thin, web-like ligament until they curve downward and backward, when they separate and taper off into the fallopian tubes. These lead to the ovaries, to which they are attached by funnel-shaped structures called infundibula.

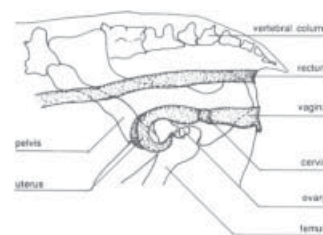
The infundibula and the fallopian tubes are lined with tiny, hair-like projections called cilia, which wave in unison to create currents in the flow of mucus. The sperm find the egg by swimming directly against this current.

Figure 5 Schematic diagram showing the anatomy of the doe's reproductive tract



Line drawing by Nagui Henein

Figure 6 Schematic diagram showing the approximate positions of the doe's reproductive organs



Line drawing by Nagui Henein

Reproductive system—male

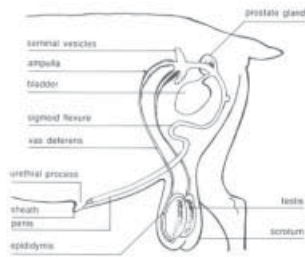
The scrotum is the sac of skin which contains the two testicles (testes). The testes are ovoid in shape. They grow to about 10cm long and usually weigh 250–300 grams.

The epididymis runs from the top of the testicle down the side to the bottom (or tail), then upwards again through the inguinal canal to become the vas deferens. The epididymis and the vas deferens transport semen.

The penis has a sigmoid (S-shaped) flexure which allows it to lengthen during mating. The urethra extends (as the urethral process) 2–3 cm beyond the end of the penis.

The accessory sex organs—the seminal vesicles, the prostate gland and the ampullae—are attached to the vas deferens and lie next to the bladder.

Figure 7 Anatomy of the buck's reproductive tract



Line drawing by Nagui Henein

Skin

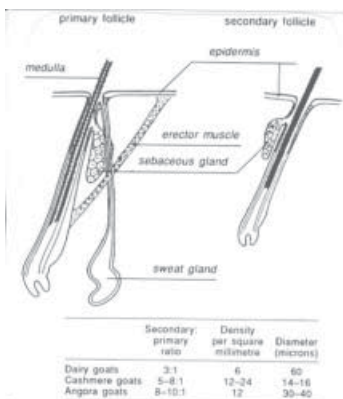
The follicles are the fibre-bearing structures of the skin. They are formed in the foetus during pregnancy.

The primary follicles have hair fibres at birth, and the secondary follicles start to produce fibre during the first few months of the goat's life.

The primary follicles secrete sweat from the sudoriferous glands and wax from the sebaceous glands.

The S/P ratio is the ratio of secondary follicles to primary follicles. Each primary follicle has an associated group of secondary follicles. The density of the follicles is the number of follicles (primary and secondary) per square millimetre of skin. Density indicates the potential fleece production.

Figure 8 Section through goat skin showing a primary and secondary follicle

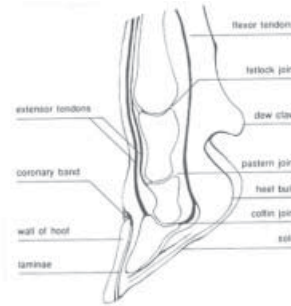


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Feet

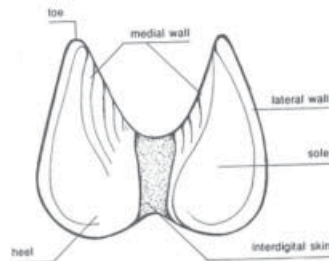
The wall of the hoof is horn tissue produced by the horn bud cells around the coronary band (the junction of the skin and the wall of the hoof). The horn grows downward as the wall wears away during walking. The weight of the goat falls on the wall of the hoof.

Figure 9 Cross-section of the lower leg and foot of a goat



Line drawing by Nagui Henein

Figure 10 Ground surface view of a goat's foot

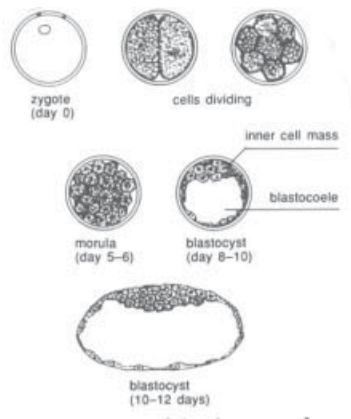


Line drawing by Nagui Henein

Embryology

The zygote is a fertilised egg (ovum). The morula is a 16 or 32 cell structure formed by the division and redivision of the zygote. The blastocyst is a structure with a fluid-filled cavity (blastocoele) surrounded by the cells formed into a layer. The inner cell mass is the layer of cells pushed to the side wall by the fluid; this is the mound of cells that will form the embryo.

Figure 11 The stages of development of a fertilised egg



Line drawing by Nagui Henein

The cells differentiate to form the specific organs in layers of primitive cells:

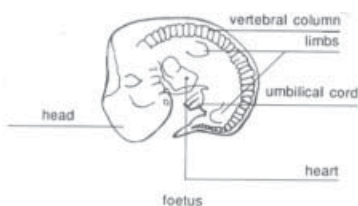
- The ectoderm (outer layer), from which form the nervous system (including the brain), sense organs, skin, hooves, hair and mammary glands;
- The mesoderm (middle layer), from which form the circulatory system (including the heart), skeleton, muscles, kidneys and the reproductive tract;
- the endoderm (inner layer), from which form the digestive system, liver and lungs.

The amnion and the allantochorion are membranes around the outside of the embryo. The amnion contains fluids in which the embryo is suspended. The allantois-a sac which accumulates waste products in fluid-combines with the chorion (the outer layer of membrane) to form the allantochorion. The allantochorion attaches to the lining of the uterus to form the placenta.

The cotyledons are the points of attachment of the placenta to the uterine wall. They include the caruncles, which are extensions of the uterine wall.

After differentiation of the tissues and organs, the embryo becomes known as a foetus. The circulatory system develops rapidly, and by the third week an embryonic heartbeat is detectable.

Figure 12 A foetus taking form



Line drawing by Nagui Henein

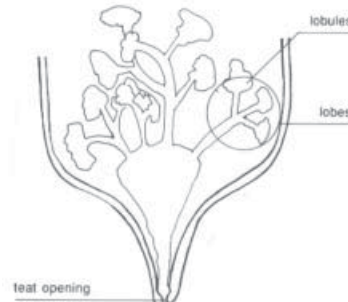
Dizygous (non-identical) twins form from the fertilisation of two ovulations in the same oestrus cycle; monozygous twins result from the fertilisation of a single ovum and are genetically identical.

Udder

The goat's udder is in the inguinal region (the groin). It has two glands, one on either side of the midline. Each gland has a single teat and each teat has a single orifice (opening). The glands are separate units.

The internal divisions of the glands are represented in figure 13. The milk-producing cells are grouped into lobes, and within these are lobules. These are further divided into alveoli, which are tiny sac-like structures. They have an internal cavity called a lumen, and are lined by milk-secreting epithelial cells. Each alveolus is surrounded by muscle cells which contract during 'milk letdown'.

Figure 13 Section through the udder of a doe



Line drawing by Nagui Henein

Physiology

Liver functions

- To excrete bile, which passes into the gall bladder and thence into the small intestine to aid digestion.
- To store glycogen, the source of energy.
- To store minerals such as copper and iron.
- To break down aged red blood cells.
- To break down toxic substances.
- To break down waste products from body metabolism.

Kidney functions

- To filter out and excrete waste and excess materials from the bloodstream.
- To maintain the fluid status of the body by removing or retaining fluid, and to maintain the correct pH level and chemical balance.

Reproduction

Goats mature sexually at 5–8 months of age. Reproduction depends on successful deposition of the buck's semen in the vagina of the doe at the correct time in her oestrus cycle.

Every 18–25 days a fluid-filled follicle containing oestrogen develops in the ovary. The oestrogen is carried throughout the body by the bloodstream. It brings the doe on heat by affecting certain tissues that lining the cervix, which produce a clear stringy mucus and an attractive (to the buck) odour. Also, oestrogen stimulates in the brain of the doe a desire to accept the buck. Heat usually lasts for 24–36 hours.

Ovulation usually occurs towards the end of heat. The egg is released from the follicle to enter the fallopian tube, with the assistance of the funnel-shaped infundibulum. For successful fertilisation, the sperm must travel from the cervix through the uterus and along the uterine horn to the fallopian tube into which the egg is extruded.

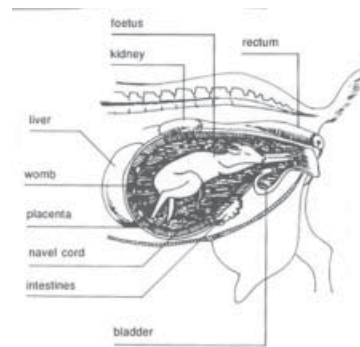
If the heat periods are not regular, ovulation is unlikely to coincide with them and conception becomes difficult. The function of the ovary is to produce an egg every 20 days (normal range 19–21 days), and the regular onset of heat to prepare the doe at this interval is essential. One part of this preparation is the action of oestrogen on the muscle fibres in the uterus, making them sensitive to the hormone oxytocin, which in turn makes the muscles contract in a wave-like action. This helps the sperm to reach the egg.

This assistance for the sperm is essential, since its average life span in the female genital tract is about 24 hours. The sperm travels against the flow of the uterine mucus, and would certainly perish without reaching the fallopian tubes if its only method of propulsion was the wriggle of its tail. So the wavelike action moves the sperm up the genital tract against the flow of mucus and towards the ovary. Once released, the egg perishes within 12 hours if it is not fertilised.

After ovulation the cells in the ovary produce a different hormone, progesterone. This takes the doe out of heat, stops the wave-like muscle contractions and helps to prepare the uterine wall for implantation of the fertilised zygote. Progesterone is produced in the cavity left by the ruptured follicle, which fills with cells to form the yellow body (corpus luteum). This continues to secrete progesterone for 13–14 days. If the egg is fertilised, the corpus luteum goes on to play a part in early gestation.

However, if fertilisation does not take place the uterine wall secretes prostaglandin, a substance which causes the corpus luteum to regress. This occurs between day 16 and day 18, thus completing a full cycle. A new follicle begins to develop and produce oestrogen over these days to bring the doe into heat again at about day twenty. (See Agfact A7.4.1, *Goat reproduction: joining, pregnancy and kidding*.)

Figure 14 The normal position of the foetus in the doe's abdomen (cross-section)



Line drawing by Nagui Henein

Digestion

Goats are ruminants. They eat plants, including pastures (grazing) and many weeds, shrubs and trees (browsing). Digestion is the process of breaking down this plant material in the stomach and intestines into components which can be absorbed and used by the goat.

The rumen works by:

- muscular action—contractions of the muscular walls of the rumen break down newly ingested grass and mix it with rumen liquor; and
- microbial action—bacteria and protozoa secrete enzymes which set up a chemical breakdown process commonly referred to as fermentation.

The walls of the rumen secrete no digestive juices. Any changes to ingested material which occur in the rumen are the result of digestion by the microbes that live in the animal's gut.

- Carbohydrates (consisting of sugars, starches and digestible cellulose) are converted into fatty acids such as acetic, propionic and butyric acids. These have simple chemical structures and are known as volatile fatty acids. Many of these acid molecules are absorbed directly into the blood through the walls of the rumen. Later they can be used for immediate energy production or converted into fat for energy storage.

- Proteins are broken down into their constituent parts, called amino acids. These amino acids are further broken down into fatty acids and ammonia, which can be used by micro-organisms to build microbial protein. This protein may contain some amino acids which were not present in the dietary protein.
- Non-protein nitrogen, such as urea, is broken down in the rumen to yield ammonia. This is later absorbed by micro-organisms to make microbial protein.

the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of the Department of Primary Industries or the user's independent advisor.

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The fermentation processes in the rumen produce large amounts of gas, mainly in the forms of carbon dioxide and methane. These are normally expelled by belching.

Strong muscular contractions of the rumen cause the rumen liquor to spill into the reticulum in small amounts at a time. This liquor contains digested food particles which pass through the reticulum and into the omasum.

The omasum has leaf-like partitions which line its walls and absorb water from the ingested material which passes into it. For this reason its contents are very dry.

The abomasum is the ruminant's only true stomach. It secretes gastric juice containing hydrochloric acid, which kills the rumen microbes and begins to break them down. The gastric juice also contains pepsin, which starts the digestion of proteins.

In the small intestine, enzymes from the pancreas and the walls of the small intestine act on ingested matter and the microbial cells contained in it. The nutrients are then absorbed.

It has often been said that ruminants live not on pasture but on dead rumen microbes which have predigested the pasture.

More information

Tel: 1800 680 244, Animal Biosecurity and Welfare, Department of Primary Industries at biosecurity@dpi.nsw.gov.au,

Local Land Services, Tel: 1300 795 299 To view details of your LLS region: <http://www.lls.nsw.gov.au/>

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