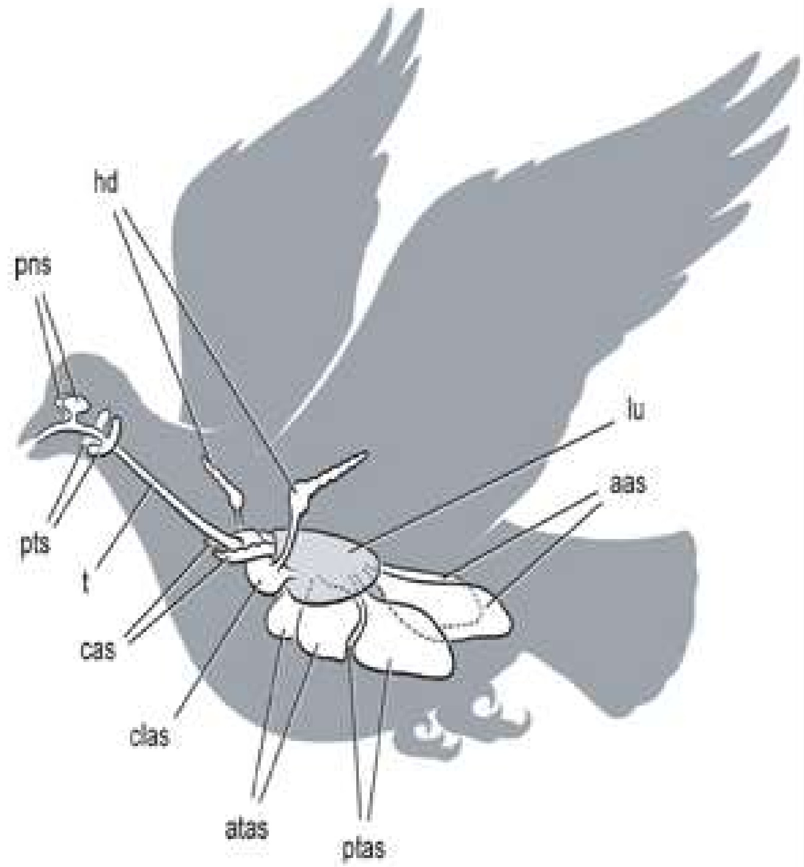

Bird and Animal Anatomy

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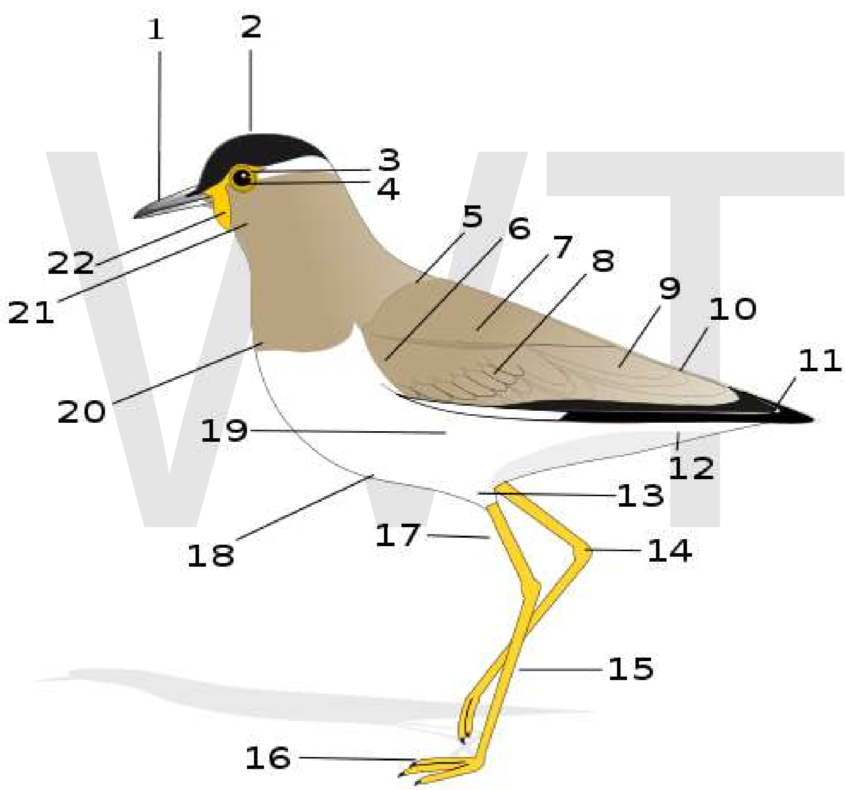
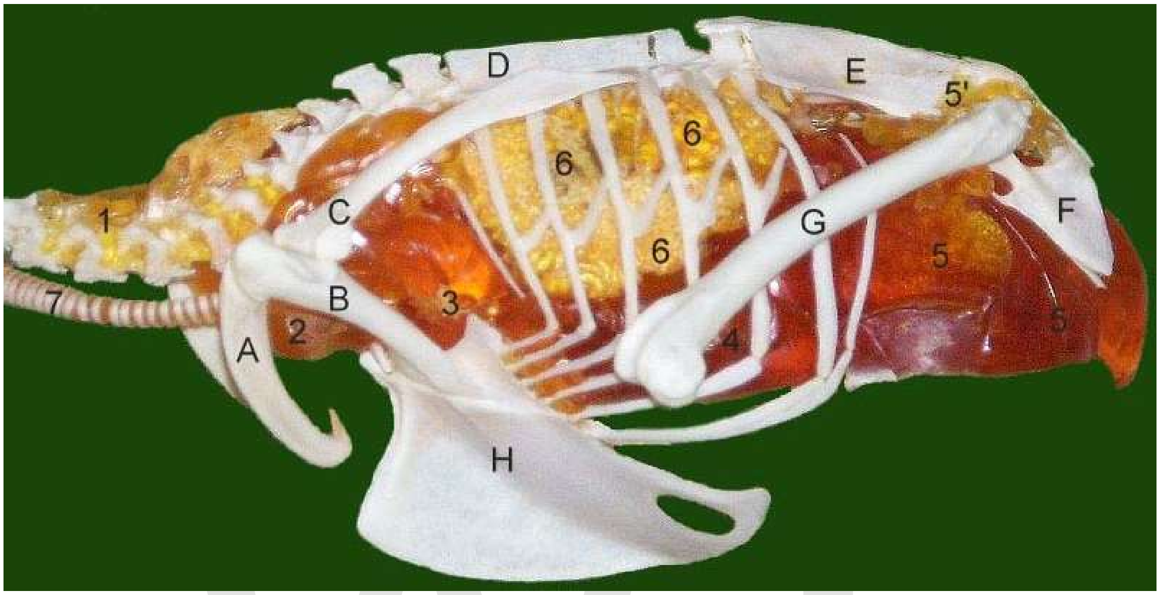
Bird Anatomy



External anatomy (topography) of a typical bird: 1 Beak, 2 Head, 3 Iris, 4 Pupil, 5 Mantle, 6 Lesser coverts, 7 Scapulars, 8 Coverts, 9 Tertials, 10 Rump, 11 Primaries, 12 Vent, 13 Thigh, 14 Tibio-tarsal articulation, 15 Tarsus, 16 Feet, 17 Tibia, 18 Belly, 19 Flanks, 20 Breast, 21 Throat, 22 Wattle

Bird anatomy, or the physiological structure of birds' bodies, shows many unique adaptations, mostly aiding flight. Birds have a light skeletal system and light but powerful musculature which, along with circulatory and respiratory systems capable of very high metabolic rates and oxygen supply, permit the bird to fly. The development of a beak has led to evolution of a specially adapted digestive system. These anatomical specializations have earned birds their own class in the vertebrate phylum.

Respiratory system

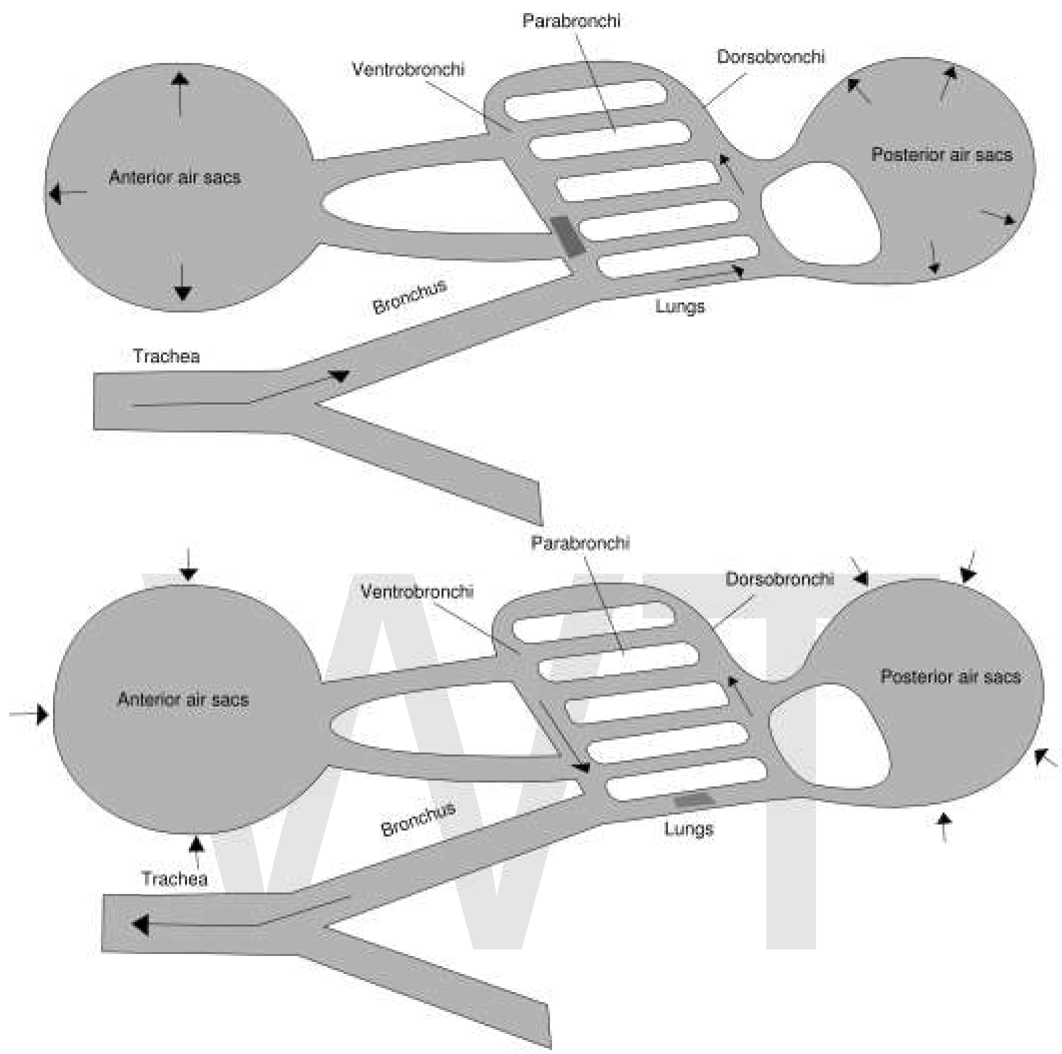


Air always flows from right (posterior) to left (anterior) through a bird's lungs during both inhalation and exhalation. Key to a Common Kestrel's circulatory lung system: 1 cervical air sac, 2 clavicular air sac, 3 cranial thoracic air sac, 4 caudal thoracic air sac, 5 abdominal air sac (5' diverticulus into pelvic girdle), 6 lung, 7 trachea

Due to their high metabolic rate required for flight, birds have a high oxygen demand. Development of an efficient respiratory system enabled the evolution of flight in birds. Birds ventilate their lungs by means of air sacs.

These sacs do not play a direct role in gas exchange, but to store air and act like bellows, allowing the lungs to maintain a fixed volume with fresh air constantly flowing through them.

Three distinct sets of organs perform respiration—the anterior air sacs (interclavicular, cervicals, and anterior thoracics), the lungs, and the posterior air sacs (posterior thoracics and abdominals). The posterior and anterior air sacs, typically nine, expand during inhalation. Air enters the bird via the trachea. Half of the inhaled air enters the posterior air sacs, the other half passes through the lungs and into the anterior air sacs. Air from the anterior air sacs empties directly into the trachea and out the bird's mouth or nares. The posterior air sacs empty their air into the lungs. Air passing through the lungs as the bird exhales is expelled via the trachea. Some taxonomic groups (Passeriformes) possess 7 air sacs, as the clavicular air sacs may interconnect or be fused with the cranial thoracic air sacs.



Birds lungs obtain fresh air during both exhalation and inhalation

As air flows through the air sac system and lungs, there is no mixing of oxygen-rich air and oxygen-poor, carbon dioxide-rich, air as in mammalian lungs. Thus, the partial pressure of oxygen in a bird's lungs is the same as the environment, and so birds have more efficient gas-exchange of both oxygen and carbon dioxide than do mammals. In addition, air passes through the lungs in both exhalation and inspiration, with the air sacs functioning as a reservoir for the next breath of air.

Avian lungs do not have alveoli, as mammalian lungs do, but instead contain millions of tiny passages known as parabronchi, connected at either ends by the dorsobronchi and ventrobronchi. Air flows through the honeycombed walls of the parabronchi into air vesicles, called atria, which project radially from the parabronchi. These atria give rise to air capillaries, where oxygen and carbon dioxide are traded with cross-flowing blood capillaries by diffusion.

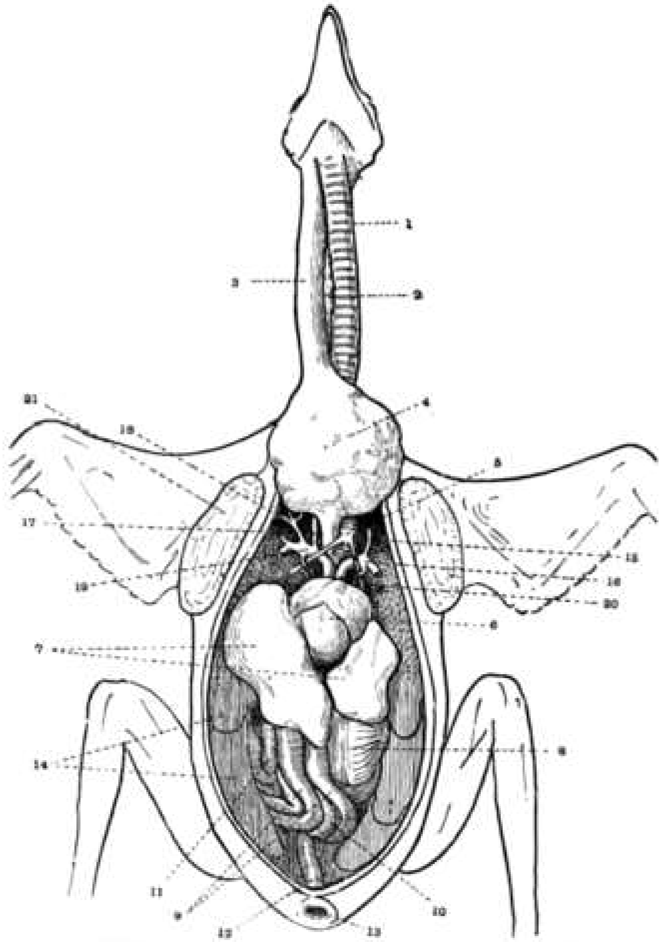
Birds also lack a diaphragm. The entire body cavity acts as a bellows to move air through the lungs. The active phase of respiration in birds is exhalation, requiring muscular contraction.

The syrinx is the sound-producing vocal organ of birds, located at the base of a bird's trachea. As with the mammalian larynx, sound is produced by the vibration of air flowing through the organ. The syrinx enables some species of birds to produce extremely complex vocalizations, even mimicking human speech. In some songbirds, the syrinx can produce more than one sound at a time.

Circulatory system

Birds have a four-chambered heart, in common with humans, most mammals, and some reptiles (namely the crocodilia). This adaptation allows for an efficient nutrient and oxygen transport throughout the body, providing birds with energy to fly and maintain high levels of activity. A Ruby-throated Hummingbird's heart beats up to 1200 times per minute (about 20 beats per second).

Digestive system



The chief Viscera of the Pigeon, *Columba livia*

1. Trachea. 2. Thymus gland. 3. Oesophagus. 4. Crop. 5. Syrinx. 6. Heart. 7. Liver. 8. Gizzard. 9. Duodenum. 10. Pancreas. 11. Small intestine. 12. Rectum. 13. Cloaca. 14. Air-sacs. 15. Left carotid. 16. Left subclavian. 17. Right carotid. 18. Brachial artery. 19. Right subclavian. 20. Muscles of syrinx. 21. Pectoralis major muscle cut across.

Alimentary canal of the bird exposed.

Sharp tooth-like structures in this rooster's mouth called papillae help birds hold and move food around

Many birds possess a muscular pouch along the esophagus called a crop. The crop functions to both soften food and regulate its flow through the system by storing it temporarily. The size and shape of the crop is quite variable among the birds. Members of the order Columbiformes, such as pigeons, produce a nutritious crop milk which is fed to their young by regurgitation. Birds possess a *ventriculus*, or gizzard, composed of four muscular bands that rotate and crush food by shifting the food from one area to the next within the gizzard. The gizzard of some species contains small pieces of grit or stone swallowed by the bird to aid in the grinding process of digestion, serving the function of mammalian or reptilian teeth. The use of gizzard stones is a similarity between birds and dinosaurs, which left gizzard stones called gastroliths as trace fossils.

Drinking behavior

There are four general ways in which birds drink.

Most birds are unable to swallow by the "sucking" or "pumping" action of peristalsis in their esophagus (as humans do), and drink by repeatedly raising their heads after filling their mouths to allow the liquid to flow by gravity, a method usually described as "sipping" or "tipping up". The notable exception is the Columbiformes; in fact, according to Konrad Lorenz in 1939,

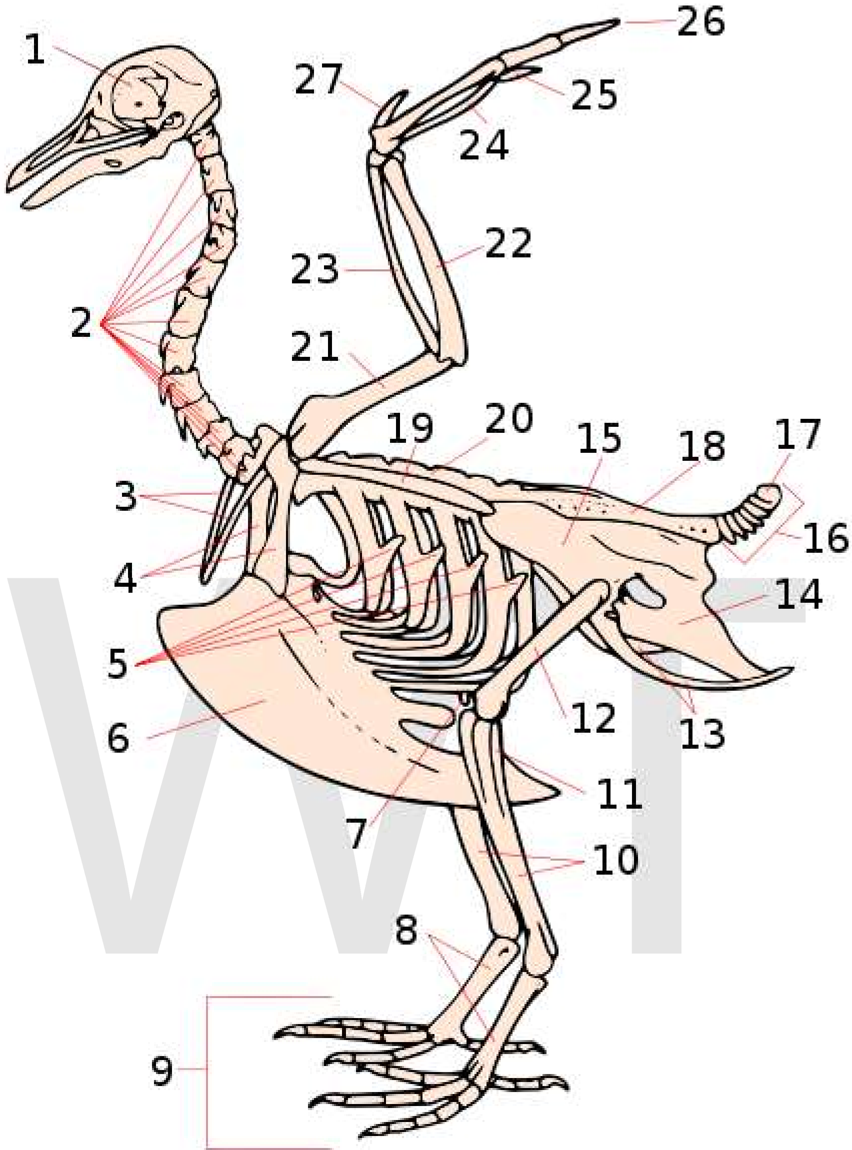
"one recognizes the order by the single behavioral characteristic, namely that in drinking the water is pumped up by peristalsis of the esophagus which occurs without exception within the order. The only other group, however, which shows the same behavior, the Pteroclidae, is placed near the doves just by this doubtlessly very old characteristic."

Although this general rule still stands, since that time, observations have been made of a few exceptions in both directions.

In addition, specialized nectar feeders like sunbirds (Nectariniidae) and hummingbirds (Trochilidae) drink by using protrusible grooved or trough-like tongues, and parrots (Psittacidae) lap up water.

Many seabirds have glands near the eyes that allow them to drink seawater. Excess salt is eliminated from the nostrils. Many desert birds get the water that they need entirely from their food. The elimination of nitrogenous wastes as uric acid reduces the physiological demand for water.

Skeletal system

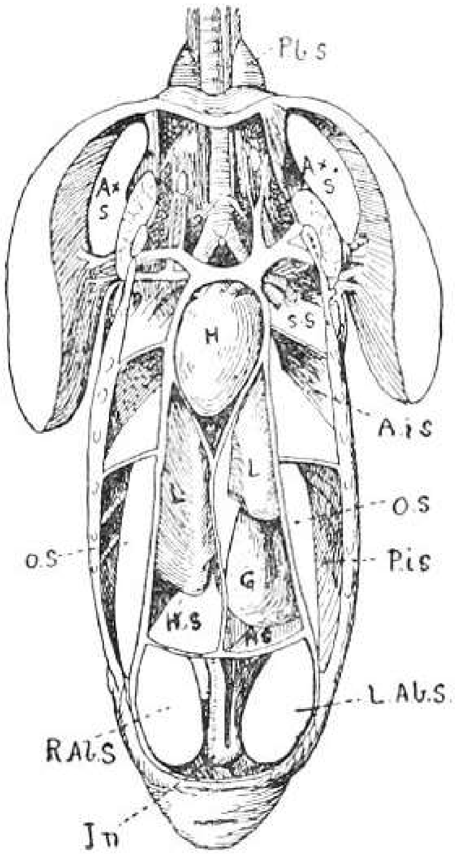


A stylised dove skeleton. Key:
1. skull
2. cervical vertebrae
3. furcula
4. coracoid
5. uncinate processes of ribs
6. keel
7. patella
8. tarsometatarsus
9. digits
10. tibia (tibiotarsus)
11. fibia (tibiotarsus)

12. femur
13. ischium (innominate)
14. pubis (innominate)
15. illium (innominate)
16. caudal vertebrae
17. pygostyle
18. synsacrum
19. scapula
20. lumbar vertebrae
21. humerus
22. ulna
23. radius
24. carpus
25. metacarpus
26. digits
27. alula

The bird skeleton is highly adapted for flight. It is extremely lightweight but strong enough to withstand the stresses of taking off, flying, and landing. One key adaptation is the fusing of bones into single ossifications, such as the pygostyle. Because of this, birds usually have a smaller number of bones than other terrestrial vertebrates. Birds also lack teeth or even a true jaw, instead having evolved a beak, which is far more lightweight. The beaks of many baby birds have a projection called an egg tooth, which facilitates their exit from the amniotic egg.

Birds have many bones that are hollow (pneumatized) with criss-crossing struts or trusses for structural strength. The number of hollow bones varies among species, though large gliding and soaring birds tend to have the most. Respiratory air sacs often form air pockets within the semi-hollow bones of the bird's skeleton. Some flightless birds like penguins and ostriches have only solid bones, further evidencing the link between flight and the adaptation of hollow bones.



DISSECTION SHOWING THE LUNGS AND AIR-SACS OF A BIRD

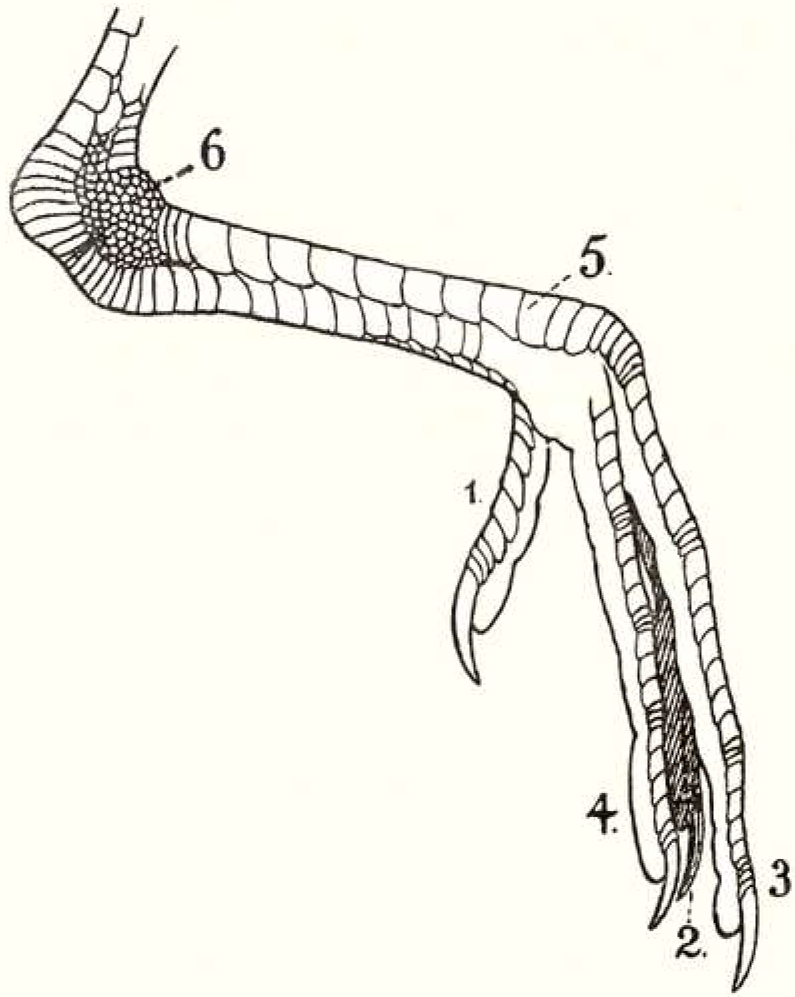
Pb. s. = Pre-bronchial sac. Ax. = Axillary sac bounded externally by the breast-muscles, seen here in section. S. s. = Partition dividing anterior intermediate sac (A.i.s.) from the sub-bronchial sac. P.i.s. = Posterior intermediate sac. O.s. = Oblique septum. H.s. = Horizontal septum. L. Ab. s. = Left abdominal sac. H. = Heart. G. = Gizzard. L. = Liver. In. = Intestine. (After Strasser.)

Air-sacs and their distribution

Birds also have more cervical (neck) vertebrae than many other animals; most have a highly flexible neck consisting of 13-25 vertebrae. Birds are the only vertebrate animals to have a fused collarbone (the furcula or wishbone) or a keeled sternum or breastbone. The keel of the sternum serves as an attachment site for the muscles used for flight, or similarly for swimming in penguins. Again, flightless birds, such as ostriches, which do not have highly developed pectoral muscles, lack a pronounced keel on the sternum. It is noted that swimming birds have a wide sternum, while walking birds had a long or high sternum while flying birds have the width and height nearly equal.

Birds have uncinate processes on the ribs. These are hooked extensions of bone which help to strengthen the rib cage by overlapping with the rib behind them. This feature is also found in the tuatara *Sphenodon*. They also have a greatly elongate tetradiate pelvis as in some reptiles. The hindlimb has an intra-tarsal joint found also in some reptiles. There is extensive fusion of the trunk vertebrae as well as fusion with the pectoral girdle. They have a diapsid skull as in reptiles with a pre-lachrymal fossa (present in some reptiles). The skull has a single occipital condyle.

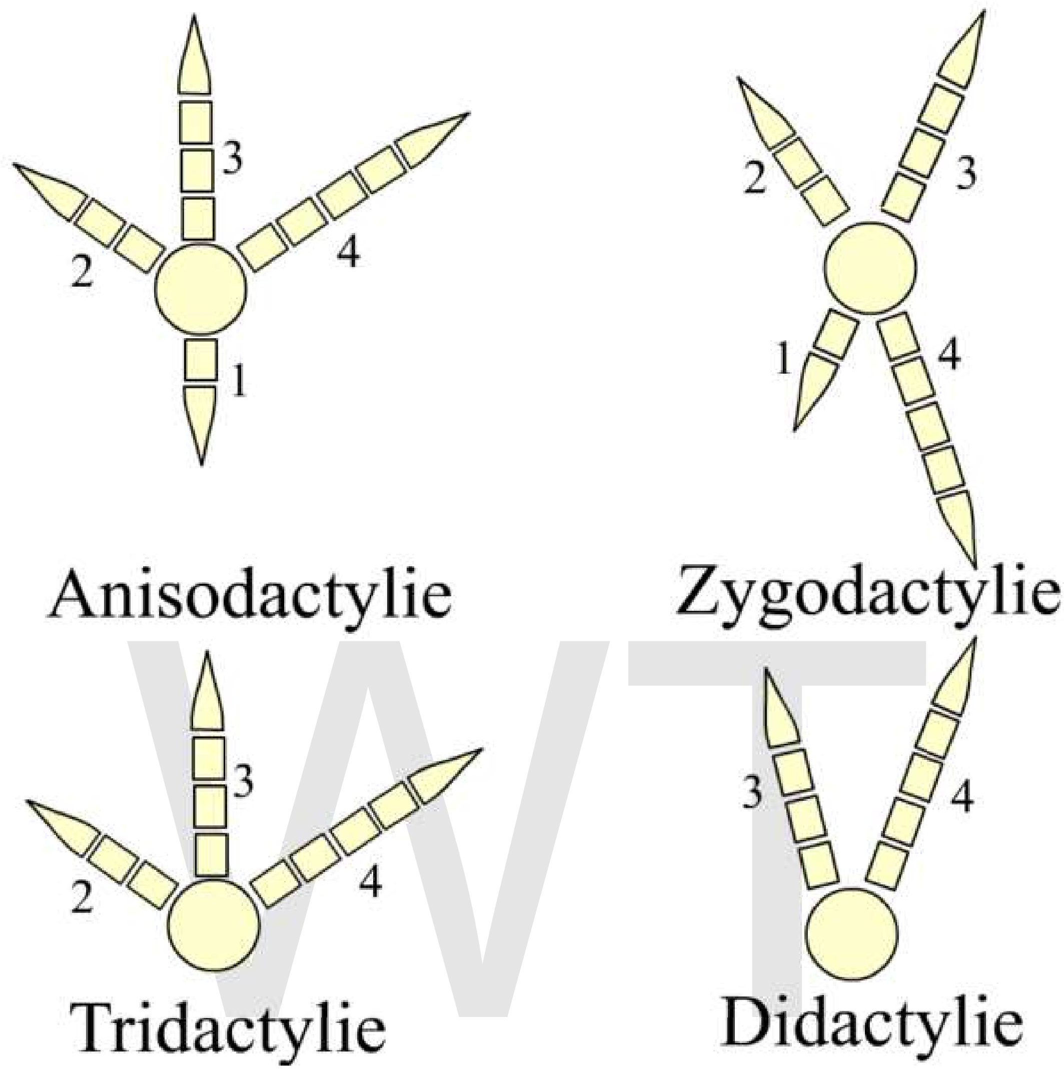
Skeleton



Side view of Right Foot of a Purple Gallinule (*Porphyrio*) to show the composition of the horny covering (*podotheca*).

1. Hallux or hind toe.
2. Inner toe.
3. Middle toe.
4. Outer toe.
5. Scales (*Scutellæ*).
6. Reticulate scales.

Scalation and structure of the leg



Types of bird feet

The skull consists of five major bones: the frontal (top of head), parietal (back of head), premaxillary and nasal (top beak), and the mandible (bottom beak). The skull of a normal bird usually weighs about 1% of the birds total bodyweight.

The vertebral column consists of vertebrae, and is divided into three sections: cervical (13-16) (neck), Synsacrum (fused vertebrae of the back, also fused to the hips (pelvis)), and pygostyle (tail).

The chest consists of the furcula (wishbone) and coracoid (collar bone), which two bones, together with the scapula (see below), form the pectoral girdle. The side of the chest is formed by the ribs, which meet at the sternum (mid-line of the chest).

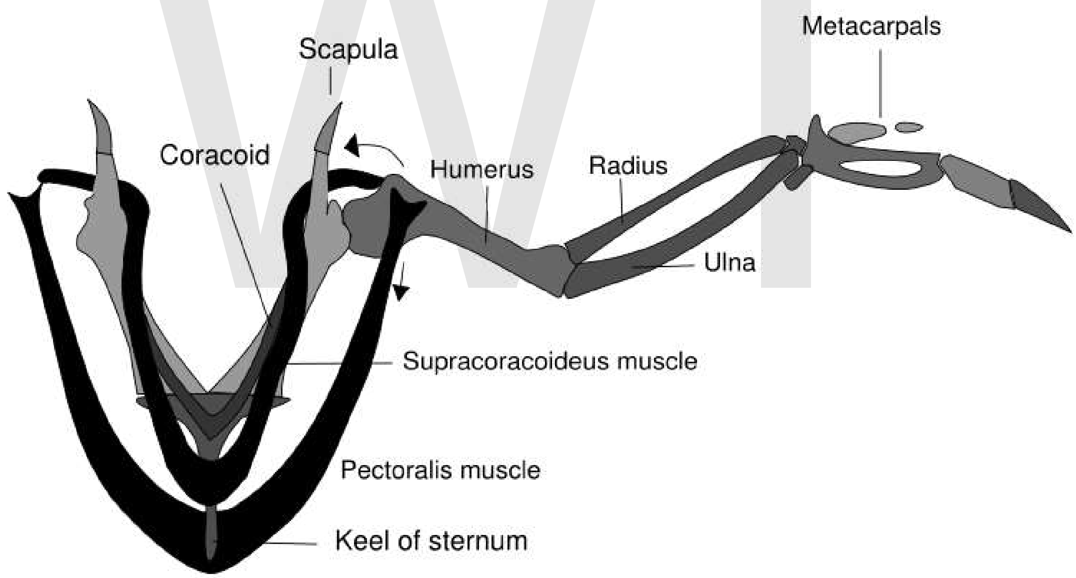
The shoulder consists of the scapula (shoulder blade), coracoid, and humerus (upper arm). The humerus joins the radius and ulna (forearm) to form the elbow. The carpus and metacarpus form the "wrist" and "hand" of the bird, and the digits (fingers) are fused together. The bones in the wing are extremely light so that the bird can fly more easily.

The hips consist of the pelvis which includes three major bones: Illium (top of the hip), Ischium (sides of hip), and Pubis (front of the hip). These are fused into one (the innominate bone). Innominate bones are evolutionary significant in that they allow birds to lay eggs. They meet at the acetabulum (the hip socket) and articulate with the femur, which is the first bone of the hind limb.

The upper leg consists of the femur. At the knee joint, the femur connects to the tibiotarsus (shin) and fibula (side of lower leg). The tarsometatarsus forms the upper part of the foot, digits make up the toes. The leg bones of birds are the heaviest, contributing to a low center of gravity. This aids in flight. A bird's skeleton comprises only about 5% of its total body weight

Birds feet are classificated as anisodactyl, zygodactyl, heterodactyl, syndactyl or pamprodactyl.

Muscular system



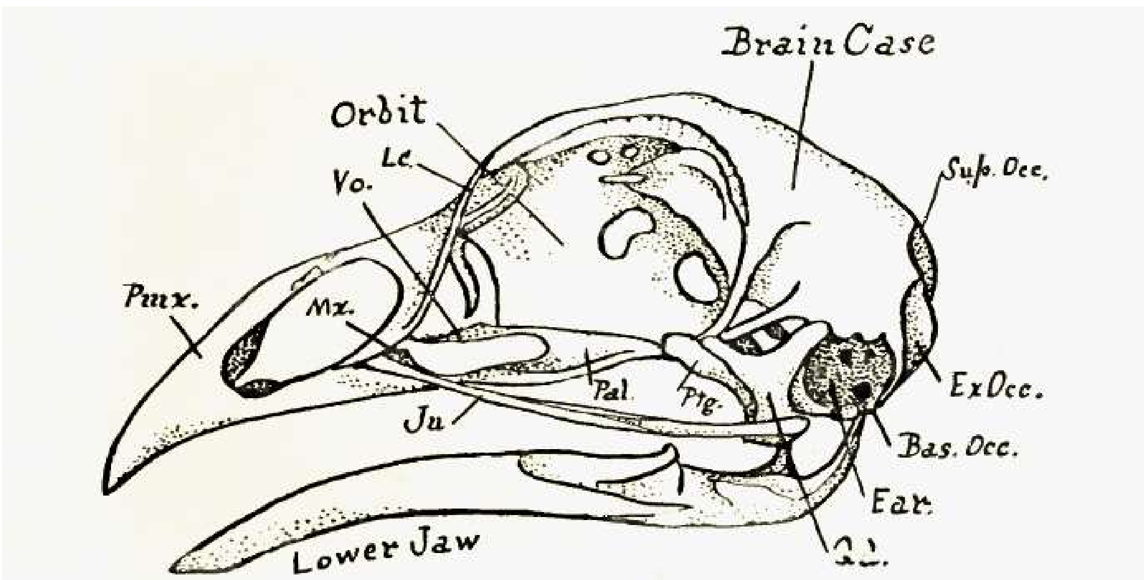
The supracoracoideus works using a pulley like system to lift the wing while the pectorals provide the powerful downstroke

Most birds have approximately 175 different muscles, mainly controlling the wings, skin, and legs. The largest muscles in the bird are the pectorals, or the breast muscles, which control the wings and make up about 15 - 25% of a flighted bird's body weight. They provide the powerful wing stroke essential for flight. The muscle ventral (underneath) to the pectorals is the supracoracoideus. It raises the wing between wingbeats. The supracoracoideus and the pectorals together make up about 25 – 35% of the bird's full body weight.

The skin muscles help a bird in its flight by adjusting the feathers, which are attached to the skin muscle and help the bird in its flight maneuvers.

There are only a few muscles in the trunk and the tail, but they are very strong and are essential for the bird. The pygostyle controls all the movement in the tail and controls the feathers in the tail. This gives the tail a larger surface area which helps keep the bird in the air.

Head



Skull of Fowl, showing orbit, brain-case, ear, lower jaw, premaxillary (*Pmx.*), maxillary (*Mx.*), vomer (*Vo.*), lacrymal (*Lc.*), jugal (*Ju.*), palatine (*Pal.*), pterygoid (*.Ptg*), quadrate (*Qd.*), and supra (*Sup. occ.*), ex (*Ex. occ.*), and basioccipital bones. (After Parker.)

Skull of a bird

Birds have acute eyesight - raptors have vision eight times sharper than humans - thanks to higher densities of photoreceptors in the retina (up to 1,000,000 per square mm in *Buteos*, compared to 200,000 for humans), a high number of optic nerves, a second set of eye muscles not found in other animals, and, in some cases, an indented fovea which magnifies the central part of the visual field. Many species, including hummingbirds and albatrosses, have two foveas in each eye. Many birds can detect polarised light. The eye occupies a considerable part of the skull and is surrounded by a sclerotic eye-ring, a ring of tiny bones that surround the eye. This character is also seen in the reptiles.

The bills of many waders have Herbst corpuscles which help them detect prey hidden under wet sand using minute pressure differences in the water. All extant birds can move the parts of the upper jaw relative to the brain case. However this is more prominent in some birds and can be readily detected in parrots.

Birds have a large brain to body mass ratio. This is reflected in the advanced and complex bird intelligence.

The region between the eye and bill on the side of a bird's head is called the lore. This region is sometimes featherless, and the skin may be tinted, as in many species of the cormorant family.

Reproduction

Fledgling

Although most male birds have no external sex organs, the male does have two testes which become hundreds of times larger during the breeding season to produce sperm. The testes in male birds are generally asymmetric with most birds having a larger left testis. Female birds in many families have only one the left ovary functional and connected to an oviduct although two ovaries are present in their embryonic stage. Although some birds may show two ovaries, the order Apterygiformes always retain both ovaries.

In the males of species without a phallus (see below), sperm is stored in the semenal glomera within the cloacal protuberance prior to copulation. During copulation, the female moves her tail to the side and the male either mounts the female from behind or in front (in the stitchbird), or moves very close to her. The cloacae then touch, so that the sperm can enter the female's reproductive tract. This can happen very fast, sometimes in less than half a second.

The sperm is stored in the female's sperm storage tubules for a week to more than a 100 days, depending on the species. Then, eggs will be fertilized individually as they leave the ovaries, before being laid by the female. The eggs continue their development outside the female body.

A juvenile Laughing Gull

Many waterfowl and some other birds, such as the ostrich and turkey, possess a phallus. The length is thought to be related to sperm competition. When not copulating, it is hidden within the proctodeum compartment within the cloaca, just inside the vent.

After the eggs hatch, parents provide varying degrees of care in terms of food and protection. Precocial birds can care for themselves independently within minutes of hatching; altricial hatchlings are helpless, blind, and naked, and require extended parental care. The chicks of many ground-nesting birds such as partridges and waders are often able to run virtually immediately after hatching; such birds are referred to as nidifugous. The young of hole-nesters, on the other hand, are often totally incapable of unassisted survival. The process whereby a chick acquires feathers until it can fly is called "fledging".

Some birds, such as pigeons, geese, and Red-crowned Cranes, remain with their mates for life and may produce offspring on a regular basis.

Scales

The scales of birds are composed of the same keratin as beaks, claws, and spurs. They are found mainly on the toes and metatarsus, but may be found further up on the ankle in some birds. Most bird scales do not overlap significantly, except in the cases of kingfishers and woodpeckers. The scales and scutes of birds are thought to be homologous to those of reptiles and mammals.

Bird embryos begin development with smooth skin. On the feet, the corneum, or outermost layer, of this skin may keratinize, thicken and form scales. These scales can be organized into;

1. Cancella – minute scales which are really just a thickening and hardening of the skin, crisscrossed with shallow grooves.
2. Reticula – small but distinct, separate, scales. Found on the lateral and medial surfaces (sides) of the chicken metatarsus. These are made up of alpha-keratin.
3. Scutella – scales that are not quite as large as scutes, such as those found on the caudal, or hind part, of the chicken metatarsus.
4. Scutes – the largest scales, usually on the anterior surface of the metatarsus and dorsal surface of the toes. These are made up of beta-keratin as in reptilian scales.

The rows of scutes on the anterior of the metatarsus can be called an acrometatarsium or acrotarsium.

Feathers can be intermixed with scales on some birds' feet. Feather follicles can lie between scales or even directly beneath them, in the deeper dermis layer of the skin. In this last case, feathers may emerge directly through scales, and be encircled at the plane of emergence entirely by the keratin of the scale.

Chapter- 2

Bird Vision

With forward facing eyes the Bald Eagle has a wide field of binocular vision.

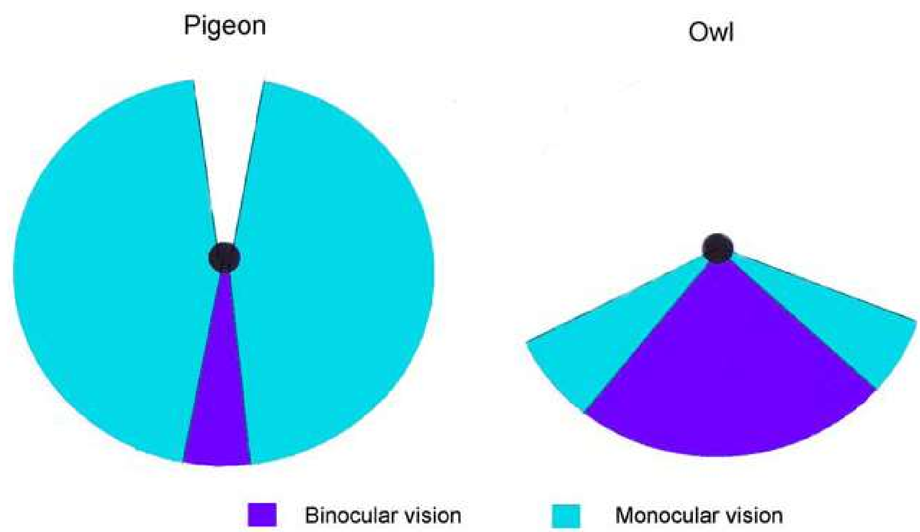
Vision is the most important sense for birds, since good eyesight is essential for safe flight, and this group has a number of adaptations which give visual acuity superior to that of other vertebrate groups; a pigeon has been described as "two eyes with wings". The avian eye resembles that of a reptile, with ciliary muscles that can change the shape of the lens rapidly and to a greater extent than in the mammals. Birds have the largest eyes relative to their size within the animal kingdom, and movement is consequently limited within the eye's bony socket. In addition to the two eyelids usually found in vertebrates, it is protected by a third transparent movable membrane. The eye's internal anatomy is similar to that of other vertebrates, but has a structure, the pecten oculi, unique to birds.

Birds, like fish, amphibians and reptiles, have four types of colour receptors in the eye. Most mammals have two types of receptors, although primates have three. This gives birds the ability to perceive not just the visible range but also the ultraviolet part of the spectrum, and other adaptations allow for the detection of polarised light or magnetic fields. Birds have proportionally more light receptors in the retina than mammals, and more nerve connections between the photoreceptors and the brain.

Some bird groups have specific modifications to their visual system linked to their way of life. Birds of prey have a very high density of receptors and other adaptations that maximise visual acuity. The placement of their eyes gives them good binocular vision enabling accurate judgement of distances. Nocturnal species have tubular eyes, low numbers of colour detectors, but a high density of rod cells which function well in poor light. Terns, gull and albatrosses are amongst the seabirds which have red or yellow oil drops in the colour receptors to improve distance vision especially in hazy conditions.

Extraocular anatomy

The eye of a bird most closely resembles that of the reptiles. Unlike the mammalian eye, it is not spherical, and the flatter shape enables more of its visual field to be in focus. A circle of bony plates, the sclerotic ring, surrounds the eye and hold it rigid, but an improvement over the reptilian eye, also found in mammals, is that the lens is pushed further forward, increasing the size of the image on the retina.



Fields of view for an owl and a pigeon

Most birds cannot move their eyes, although there are exceptions, such as the Great Cormorant. Birds with eyes on the sides of their heads have a wide visual field, useful for detecting predators, while those with eyes on the front of their heads, such as owls, have binocular vision and can estimate distances when hunting. The American Woodcock probably has the largest visual field of any bird, 360^{o} in the horizontal plane, and 180^{o} in the vertical plane.

The nictitating membrane of a Masked Lapwing

The eyelids of a bird are not used in blinking. Instead the eye is lubricated by the nictitating membrane, a third concealed eyelid that sweeps horizontally across the eye like a windscreen wiper. The nictitating membrane also covers the eye and acts as a contact lens in many aquatic birds when they are under water. When sleeping, the lower eyelid rises to cover the eye in most birds, with the exception of the horned owls where the upper eyelid is mobile.

The eye is also cleaned by tear secretions from the lachrymal gland and protected by an oily substance from the Harderian glands which coats the cornea and prevents dryness. The eye of a bird is larger compared to the size of the animal than for any other group of animals, although much of it is concealed in its skull. The Ostrich has the largest eye of any land vertebrate, with an axial length of 50 mm (2 in), twice that of the human eye.

Bird eye size is broadly related to body mass. A study of five orders (parrots, pigeons, petrels, raptors and owls) showed that eye mass is proportional to body mass, but as expected from their habits and visual ecology, raptors and owls have relatively large eyes for their body mass.

Behavioural studies show that many avian species focus on distant objects preferentially with their lateral and monocular field of vision, and birds will orient themselves sideways to maximise visual resolution. For a pigeon, resolution is twice as good with sideways monocular vision than forward binocular vision, whereas for humans the converse is true.

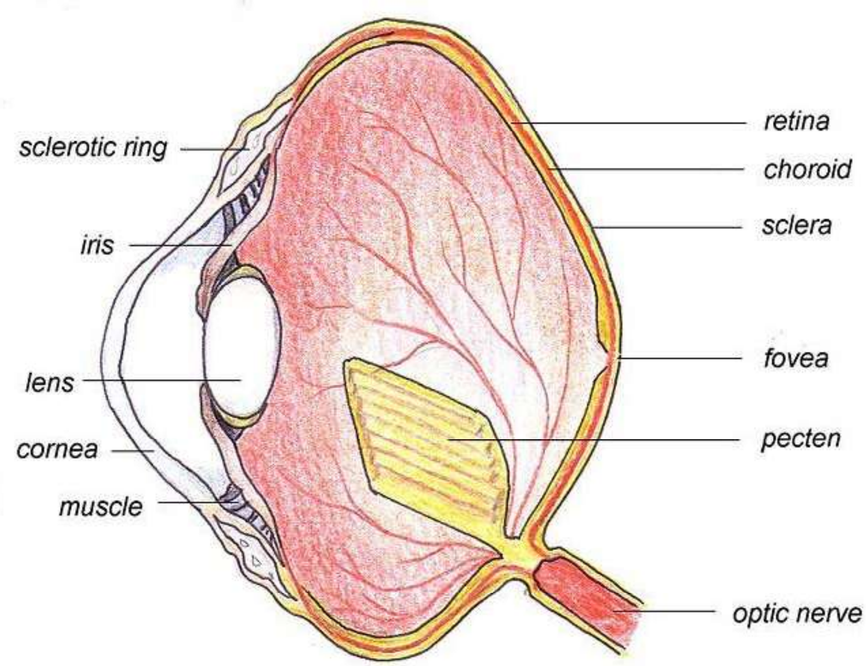
The European Robin has relatively large eyes, and starts to sing early in the morning.

The performance of the eye in low light levels depends on the distance between the lens and the retina, and small birds are effectively forced to be diurnal because their eyes are not large enough to give adequate night vision. Although many species migrate at night, they often collide with even brightly lit objects like lighthouses or oil platforms. Birds of prey are diurnal because, although their eyes are large, they are optimised to give maximum spatial resolution rather than light gathering, so they also do not function well in poor light. Many birds have an asymmetry in the eye's structure which enables them to keep the horizon and a significant part of the ground in focus simultaneously. The cost of this adaptation is that they have myopia in the lower part of their field of view.

Birds with relatively large eyes compared to their body mass, such as Common Redstarts and European Robins sing earlier at dawn than birds of the same size and smaller body mass. However, if birds have the same eye size but different body masses, the larger species sings later than the smaller. This may be because the smaller bird has to start the day earlier because of weight loss overnight.

Nocturnal birds have eyes optimised for visual sensitivity, with large corneas relative to the eye's length, whereas diurnal birds have longer eyes relative to the corneal diameter to give greater visual acuity. Information about the activities of extinct species can be deduced from measurements of the sclerotic ring and orbit depth. For the latter measurement to be made, the fossil must have retained its three-dimensional shape, so activity pattern cannot be determined with confidence from flattened specimens like *Archaeopteryx*, which has a complete sclerotic ring but no orbit depth measurement.

Anatomy of the eye



Anatomy of the avian eye

The main structures of the bird eye are similar to those of other vertebrates. The outer layer of the eye consists of the transparent cornea at the front, and two layers of sclera – a tough white collagen fibre layer which surrounds the rest of the eye and supports and protects the eye as a whole. The eye is divided internally by the lens into two main segments: the anterior segment and the posterior segment. The anterior chamber is filled with a watery fluid called the aqueous humour, and the posterior chamber contains the vitreous humour, a clear jelly-like substance.

The lens is a transparent convex or 'lens' shaped body with a harder outer layer and a softer inner layer. It focuses the light on the retina. The shape of the lens can be altered by ciliary muscles which are directly attached to lens capsule by means of the zonular fibres. In addition to these muscles, some birds also have a second set, Crampton's muscles, that can change the shape of the cornea, thus giving birds a greater range of accommodation than is possible for mammals. This accommodation can be rapid in some diving water birds such as in the mergansers. The iris is a coloured muscularly operated diaphragm in front of the lens which controls the amount of light entering the eye. At the centre of the iris is the pupil, the variable circular area through which the light passes into the eye.

Hummingbirds are amongst the many birds with two foveae

The retina is a relatively smooth curved multi-layered structure containing the photosensitive rod and cone cells with the associated neurons and blood vessels. The density of the photoreceptors is critical in determining the maximum attainable visual acuity. Humans have about 200,000 receptors per mm^2, but the House Sparrow has 400,000 and the Common Buzzard 1,000,000. The photoreceptors are not all individually connected to the optic nerve, and the ratio of nerve ganglia to receptors is important in determining resolution. This is very high for birds; the White Wagtail has 100,000 ganglion cells to 120,000 photoreceptors.

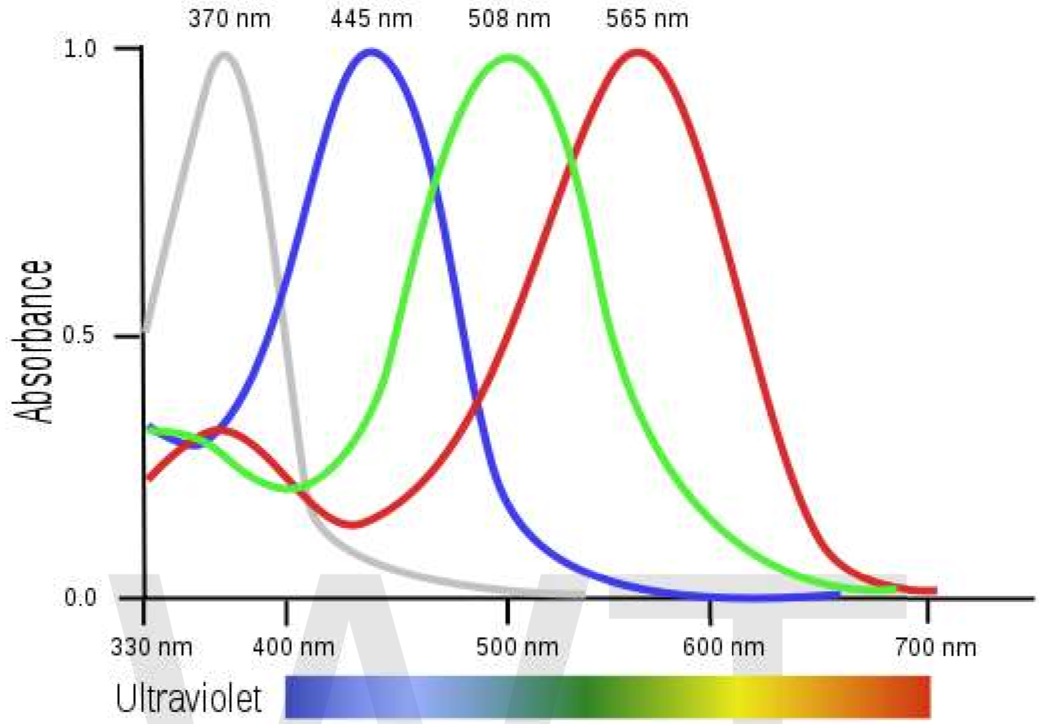
Rods are more sensitive to light, but give no colour information, whereas the less sensitive cones enable colour vision. In diurnal birds, 80% of the receptors may be cones (90% in some swifts) whereas nocturnal owls have almost all rods. As with other vertebrates except placental mammals, some of the cones may be double structures. These can amount to 50% of all cones in some species.

Towards the centre of the retina is the fovea which has a greater density of receptors and is the area of greatest forward visual acuity, i.e. sharpest, clearest detection of objects. In 54% of birds, including birds of prey, kingfishers, hummingbirds and swallows, there is second fovea for enhanced sideways viewing. The optic nerve is a bundle of nerve fibres which carry messages from the eye to the relevant parts of the brain and vice-versa. Like mammals, birds have a small blind spot without photoreceptors at the optic disc, under which the optic nerve and blood vessels join the eye.

The pecten is a poorly understood body consisting of folded tissue which projects from the retina. It is well supplied with blood vessels and appears to keep the retina supplied with nutrients, and may also shade the retina from dazzling light or aid in detecting moving objects.

The choroid is a layer situated behind the retina which contains many small arteries and veins. These provide arterial blood to the retina and drain venous blood. The choroid contains melanin, a pigment which gives the inner eye its dark colour, helping to prevent disruptive reflections.

Light perception



The four pigments in a bird's cones extend the range of colour vision into the ultraviolet.

There are two sorts of light receptors in a bird's eye, rods and cones. Rods, which contain the visual pigment rhodopsin are better for night vision because they are sensitive to small quantities of light. Cones detect specific colours (or wavelengths) of light, so they are more important to colour-oriented animals such as birds. Most birds are tetrachromatic, possessing ultraviolet (UV) sensitive cone cells in the eye as well as those for red, green and blue, but pigeons have an additional pigment and are therefore pentachromatic.

The four spectrally distinct cone pigments are derived from the protein opsin, linked to a small molecule called retinal, which is closely related to vitamin A. When the pigment absorbs light the retinal changes shape and alters the membrane potential of the cone cell affecting neurones in the ganglia layer of the retina. Each neurone in the ganglion layer may processes information from a number of photoreceptor cells, and may in turn trigger a nerve impulse to relay information along the optic nerve for further processing in specialised visual centres in the brain. The more intense a light, the more photons are absorbed by the visual pigments, the greater the excitation of each cone, and the brighter the light appears.

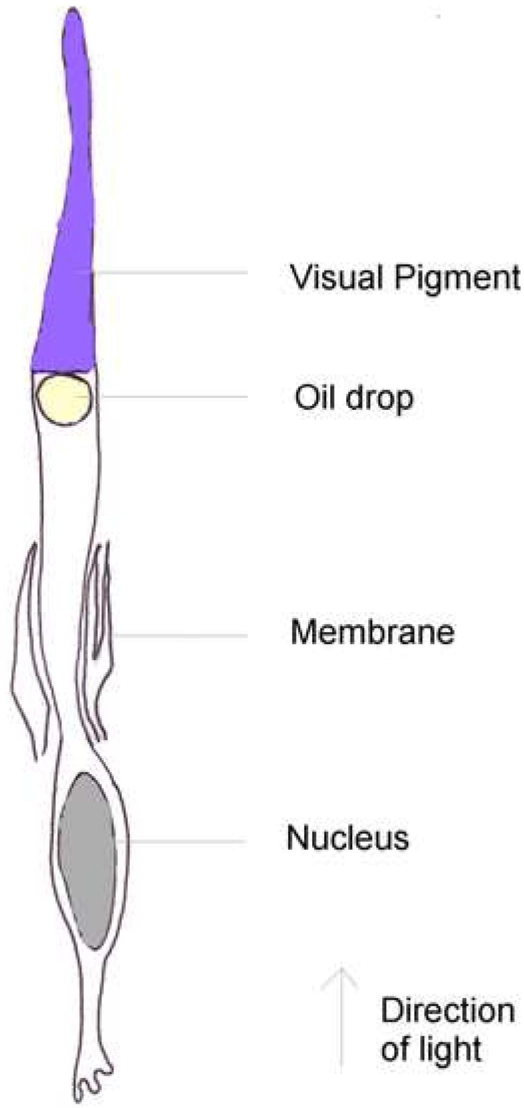


Diagram of a bird cone cell

By far the most abundant cone pigment in every bird species examined is the long-wavelength form of iodopsin, which absorbs at wavelengths near 570 nm. This is roughly the spectral region occupied by the red- and green-sensitive pigments in the primate retina, and this visual pigment dominates the colour sensitivity of birds. In penguins, this pigment appears to have shifted its absorption peak to 543 nm, presumably an adaptation to a blue aquatic environment.

The information conveyed by a single cone is limited: by itself, the cell cannot tell the brain which wavelength of light caused its excitation. A visual pigment may absorb two wavelengths equally, but even though their photons are of different energies, the cone cannot tell them apart, because they both cause the retinal to change shape and thus trigger the same impulse. For the brain to see colour, it must compare the responses of two or more classes of cones containing different visual pigments, so the four pigments in birds give increased discrimination.

Each cone of a bird or reptile contains a coloured oil droplet; these no longer exist in mammals. The droplets, which contain high concentrations of carotenoids, are placed so that light passes through before reaching the visual pigment. They act as filters, removing some wavelengths and narrowing the absorption spectra of the pigments. This reduces the response overlap between pigments and increases the number of colours that a bird can discern. Six types of cone oil droplets have been identified; five of these have carotenoid mixtures that absorb at different wavelengths and intensities, and the sixth type has no pigments.

The colours and distributions of retinal oil droplets vary considerably among species, and is more dependent on the ecological niche utilised (hunter, fisher, herbivore) than genetic relationships. As examples, diurnal hunters like the Barn Swallow and birds of prey have few coloured droplets, whereas the surface fishing Common Tern has a large number of red and yellow droplets in the dorsal retina. The evidence suggests that oil droplets respond to natural selection faster than the cone's visual pigments. Even within the range of wavelengths that are visible to humans, passerine birds can detect colour differences that humans do not register. This finer discrimination, together with the ability to see ultraviolet light, means that many species show sexual dichromatism that is visible to birds but not humans.

Migratory songbirds use the Earth's magnetic field, stars, the Sun, and polarised light patterns to determine their migratory direction. An American study showed that migratory Savannah Sparrows used polarised light from an area of sky near the horizon to recalibrate their magnetic navigation system at both sunrise and sunset. This suggested that skylight polarisation patterns are the primary calibration reference for all migratory songbirds. However, it appears that birds may be responding to secondary indicators of the angle of polarisation, and may not be actually capable of directly detecting polarisation direction in the absence of these cues.

Ultraviolet

The Common Kestrel can detect the ultraviolet trail of its vole prey.

Birds can perceive ultraviolet light, which is involved in courtship. Many birds show plumage patterns in ultraviolet that are invisible to the human eye; some birds whose sexes appear similar to the naked eye are distinguished by the presence of ultraviolet reflective patches on their feathers. Male Blue Tits have an ultraviolet reflective crown patch which is displayed in courtship by posturing and raising of their nape feathers. Male Blue Grosbeaks with the most, brightest and most UV-shifted blue in their plumage are larger, hold the most extensive territories with abundant prey, and feed their offspring more frequently than other males do.

The bill’s appearance is important in the interactions of the Blackbird. Although the UV component seems unimportant in interactions between territory-holding males, where the degree of orange is the main factor, the female responds more strongly to males with bills with good UV-reflectiveness.

A UV receptor may give an animal an advantage in foraging for food. The waxy surfaces of many fruits and berries reflect UV light that might advertise their presence. Common Kestrels are able to locate the trails of voles visually. These small rodents lay scent trails of urine and faeces that reflect UV light, making them visible to the kestrels, particularly in the spring before the scent marks are covered by vegetation.

Perception

Movement

A hunting Common Kestrel needs a steady visual image

Birds can resolve rapid movements better than humans, for whom flickering at a rate greater than 50 Hz appears as continuous movement. Humans cannot therefore distinguish individual flashes of a fluorescent light bulb oscillating at 60Hz, but Budgerigars and chickens have flicker thresholds of more than 100 Hz. A Cooper's Hawk can pursue agile prey through woodland and avoid branches and other objects at high speed; to humans such a chase would appear as a blur.

Birds can also detect slow moving objects. The movement of the sun and the constellations across the sky is imperceptible to humans, but detected by birds. The ability to detect these movements allows migrating birds to properly orient themselves.

To obtain steady images while flying or when perched on a swaying branch, birds hold the head as steady as possible with compensating reflexes. Maintaining a steady image is especially relevant for birds of prey.

Edges and shapes

When an object is partially blocked by another, humans unconsciously tend to make up for it and complete the shapes. It has however been demonstrated that pigeons do not complete occluded shapes. A study based on altering the grey level of a perch that was coloured differently from the background showed that budgerigars do not detect edges based on colours.

Magnetic fields

The perception of magnetic fields by migratory birds has been suggested to be light dependent. Birds move their head to detect the orientation of the magnetic field, and studies on the neural pathways have suggested that birds may be able to "see" the magnetic fields. The right eye of a migratory bird contains photoreceptive proteins called cryptochromes. Light excites these molecules to produce unpaired electrons that interact with the Earth's magnetic field, thus providing directional information.

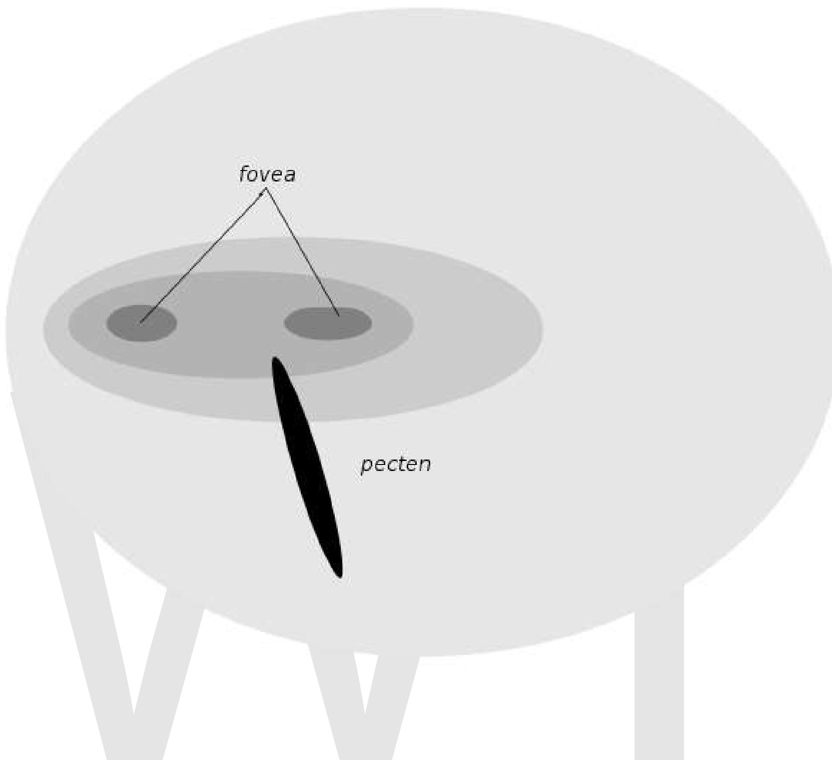
Variations across bird groups

Diurnal birds of prey

"Hawk-eyed" is a byword for visual acuity

The visual ability of birds of prey is legendary, and the keenness of their eyesight is due to a variety of factors. Raptors have large eyes for their size, 1.4 times greater than the average for birds of the same weight, and the eye is tube-shaped to produce a larger retinal image. The retina has a large number of receptors per square millimetre, which determines the degree of visual acuity. The more receptors an animal has, the higher its ability to distinguish individual objects at a distance, especially when, as in raptors, each receptor is typically attached to a single ganglion.

Many raptors have foveas with far more rods and cones than the human fovea (65,000/mm^2 in American Kestrel, 38,000 in humans) and this provides these birds with spectacular long distance vision. The fovea itself can also be lens-shaped, increasing the effective density of receptors further. This combination of factors gives *Buteo* buzzards distance vision 6 to 8 times better than humans.



Each retina of the Black-chested Buzzard-eagle has two fovea

The forward facing eyes of a bird of prey give binocular vision, which is assisted by a double fovea. The raptor's adaptations for optimum visual resolution (an American Kestrel can see a 2–mm insect from the top of an 18–m tree) has a disadvantage in that its vision is poor in low light level, and it must roost at night. Raptors may have to pursue mobile prey in the lower part of their visual field, and therefore do not have the lower field myopia adaptation demonstrated by many other birds. Scavenging birds like vultures do not need such sharp vision, so a condor has only a single fovea with about 35,000 receptors mm^2

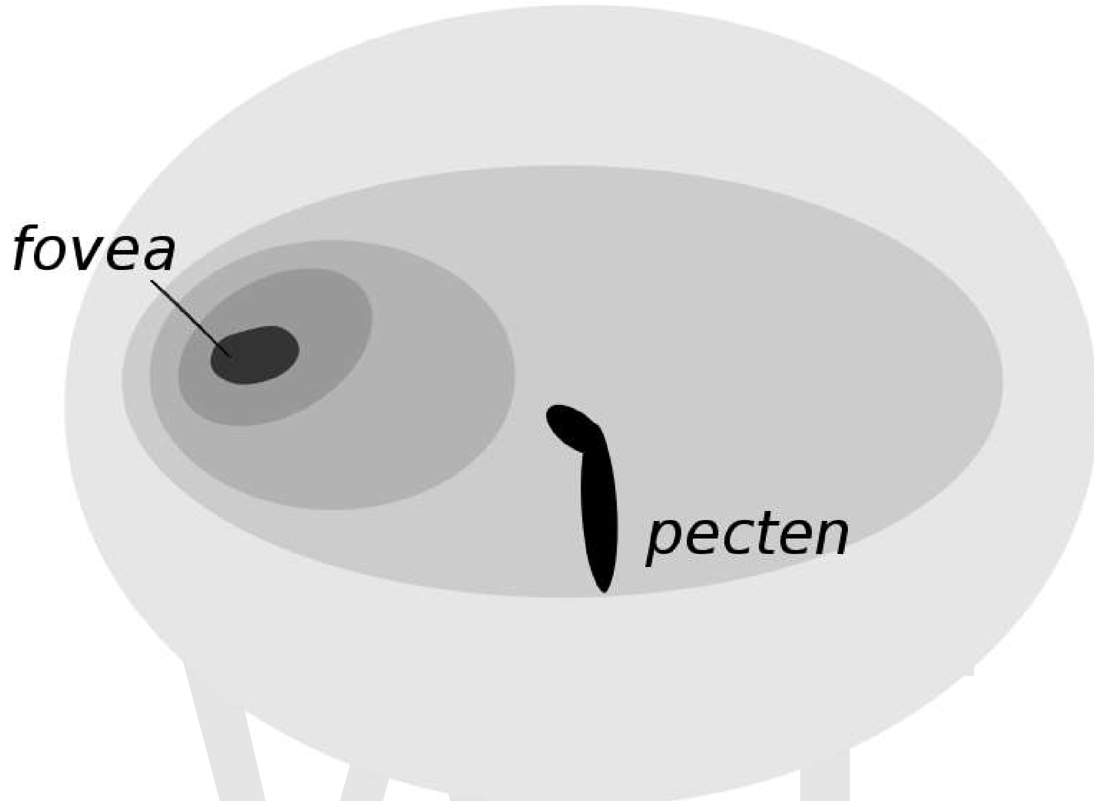
Raptors lack coloured oil drops in the cones, and probably have similar colour perception to humans, and lack the ability to detect polarised light. The generally brown, grey and white plumage of this group, and the absence of colour displays in courtship suggests that colour is relatively unimportant to these birds.

In most raptors a prominent eye ridge and its feathers extends above and in front of the eye. This "eyebrow" gives birds of prey their distinctive stare. The ridge physically protects the eye from wind, dust, and debris and shields it from excessive glare. The Osprey lacks this ridge, although the arrangement of the feathers above its eyes serves a similar function; it also possesses dark feathers in front of the eye which probably serve to reduce the glare from the water surface when the bird is hunting for its staple diet of fish.

Nocturnal birds

Eurasian Eagle-owl

Owls have very large eyes for their size, 2.2 times greater than the average for birds of the same weight, and positioned at the front of the head. The eyes have a field overlap of 50–70%, giving better binocular vision than for diurnal birds of prey (overlap 30–50%). The Tawny Owl's retina has about 56,000 light-sensitive rods per square millimetre (36 million per square inch); although earlier claims that it could see in the infrared part of the spectrum have been dismissed.



Each owl's retina has a single fovea

Adaptations to night vision include the large size of the eye, its tubular shape, large numbers of closely packed retinal rods, and an absence of cones, since colour vision is unnecessary at night. There are few coloured oil drops, which would reduce the light intensity, but the retina contains a reflective layer, the tapetum lucidum. This increases the amount of light each photosensitive cell receives, allowing the bird to see better in low light conditions. Owls normally have only one fovea, and that is poorly developed except in diurnal hunters like the Short-eared Owl.

Besides owls, bat hawks, frogmouths and nightjars also display good night vision. Some bird species nest deep in cave systems which are too dark for vision, and find their way to the nest with a simple form of echolocation. The Oilbird is the only nocturnal bird to echolocate, but several *Aerodramus* swiftlets also utilise this technique, with one species, Atiu Swiftlet, also using echolocation outside its caves.

Water birds

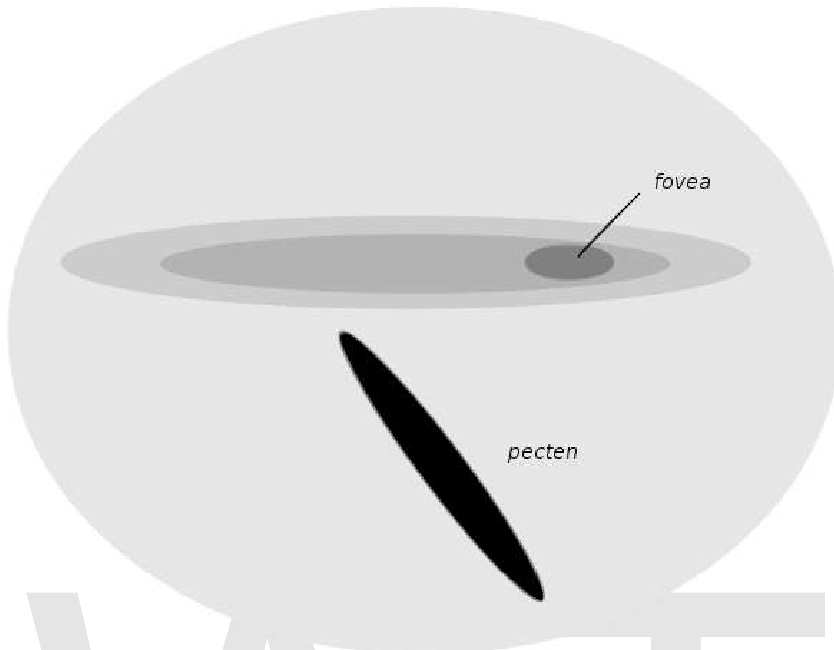
Terns have coloured oil droplets in the cones of the eye to improve distance vision

Seabirds such as terns and gulls that feed at the surface or plunge for food have red oil droplets in the cones of their retinas. This improves contrast and sharpens distance vision, especially in hazy conditions. Birds that have to look through an air/water interface have more deeply coloured carotenoid pigments in the oil drops than other species.

This helps them to locate shoals of fish, although it is uncertain whether they are sighting the phytoplankton on which the fish feed, or other feeding birds.

Birds that fish by stealth from above the water have to correct for refraction particularly when the fish are observed at an angle. Reef Herons and Little Egrets appear to be able to make the corrections needed when capturing fish and are more successful in catching fish when strikes are made at an acute angle and this higher success may be due to the inability of the fish to detect their predators.

Birds that pursue fish under water like auks and divers have far fewer red oil droplets, but they have special flexible lenses and use the nictitating membrane as an additional lens. This allows greater optical accommodation for good vision in air and water. Cormorants have a greater range of visual accommodation, at 50 dioptres, than any other bird, but the kingfishers are considered to have the best all-round (air and water) vision.



Each retina of the Manx Shearwater has one fovea and an elongated strip of high photoreceptor density

Tubenosed seabirds, which come ashore only to breed and spend most of their life wandering close to the surface of the oceans, have a long narrow area of visual sensitivity on the retina This region, the *area giganto cellularis*, has been found in the Manx Shearwater, Kerguelen Petrel, Great Shearwater, Broad-billed Prion and Common Diving-petrel. It is characterised by the presence of ganglion cells which are regularly arrayed and larger than those found in the rest of the retina, and morphologically appear similar to the cells of the retina in cats. The location and cellular morphology of this novel area suggests a function in the detection of items in a small binocular field projecting below and around the bill. It is not concerned primarily with high spatial resolution, but may assist in the detection of prey near the sea surface as a bird flies low over it.

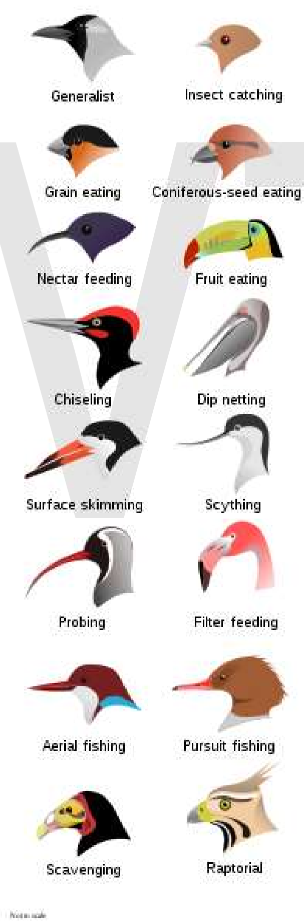
The Manx Shearwater, like many other seabirds, visits its breeding colonies at night to reduce the chances of attack by aerial predators. Two aspects of its optical structure suggest that the eye of this species is adapted to vision at night. In the shearwater's eyes the lens does most of the bending of light necessary to produce a focused image on the retina. The cornea, the outer covering of the eye, is relative flat and so of low refractive power. In a diurnal bird like the pigeon, the reverse is true; the cornea is highly curved and is the principal refractive component. The ration of refraction by the lens to that by the cornea is 1.6 for the shearwater and 0.4 for the pigeon; the figure for the shearwater is consistent with that for a range of different nocturnal bird and mammal.

The shorter focal length of shearwater eyes give them a smaller, but brighter, image than is the case for pigeons, so the latter has sharper daytime vision. Although the Manx Shearwater has adaptations for night vision, the effect is small, and it is likely that these birds also use smell and hearing to locate their nests.

It used to be thought that penguins were short-sighted on land. Although the cornea is flat and adapted to swimming underwater, the lens is very strong and can compensate for the reduced corneal focusing when out of water. Almost the opposite solution is used by the Hooded Merganser which can bulge part of the lens through the iris when submerged.

Chapter- 3

Beak



Comparison of bird beaks, displaying different shapes adapted to different feeding methods. Not to scale.

The **beak**, **bill** or **rostrum** is an external anatomical structure of birds which is used for eating and for grooming, manipulating objects, killing prey, probing for food, courtship and feeding young. The term beak is also used to refer to a similar mouthpart in some

Ornithischian dinosaurs, monotremes, cephalopods, cetaceans, pufferfishes, turtles, Anuran tadpoles and sirens.

Etymology

The terms 'beak' and 'bill' are interchangeable, although the former was formerly restricted to hooked beaks of birds of prey and parrots.

Anatomy

Beaks vary significantly in size and shape from species to species. The beak is composed of an upper jaw, called the maxilla, and a lower jaw, called the mandible. The jaw is made of bone, typically hollow or porous to reduce weight for flying. The outside surface of the beak is covered by a thin horny sheath of keratin called the **rhamphotheca**. Between the hard outer layer and the bone is a vascular layer containing blood vessels and nerve endings. The rhamphotheca can include **knob**, which is found above the beak of some swans, such as the Mute Swan, and some domesticated Chinese geese (*pictured*).

The beak has two holes called **nares** (nostrils) which connect to the hollow inner beak and thence to the respiratory system. The nares are usually at the base of the beak, near the dorsal surface. Kiwi are the only birds with nostrils at the end of their beak. In some birds, the nares are in a fleshy, often waxy structure at the base of the beak called the **cere** (from Latin *cera*, meaning wax). The cere is an indicator of the reproductive cycle of budgerigars.

Petrels and albatrosses have external horny sheaths called naricorns that protect the nares. These are separately placed on either side of the base of the upper mandible in albatrosses, but fused, with an internal septum, on the top of the base of the upper mandible in petrels. In the mallard, and perhaps in other ducks, there is no cere, and the nostrils are in the hard part of the beak, as a soft cere would be liable to injury when the duck dredges for food among submerged debris and stones.

On some birds, the tip of the beak is hard, dead tissue used for heavy-duty tasks such as cracking nuts or killing prey. On other birds, such as ducks, the tip of the bill is sensitive and contains nerves, for locating things by touch. The beak is worn down by use, so it grows continually throughout the bird's life. Some birds such as the Snow Goose have cutting serrations to their bills, these are known as *Tomia*.

Uses of beaks

As noted by Darwin in his observations on Galapagos Finches, birds' beaks have evolved to suit the ecological niche they fill: Raptors have decurved (downward curving) beaks for ripping up meat. Hummingbirds have long thin beaks for reaching nectar. The spoonbills' beaks allow them to filter-feed in shallow water. Unlike jaws with teeth, beaks are not used for chewing. Birds swallow their food whole, and it is broken up in the gizzard. Beaks are also very useful for scrabbling.

Billing

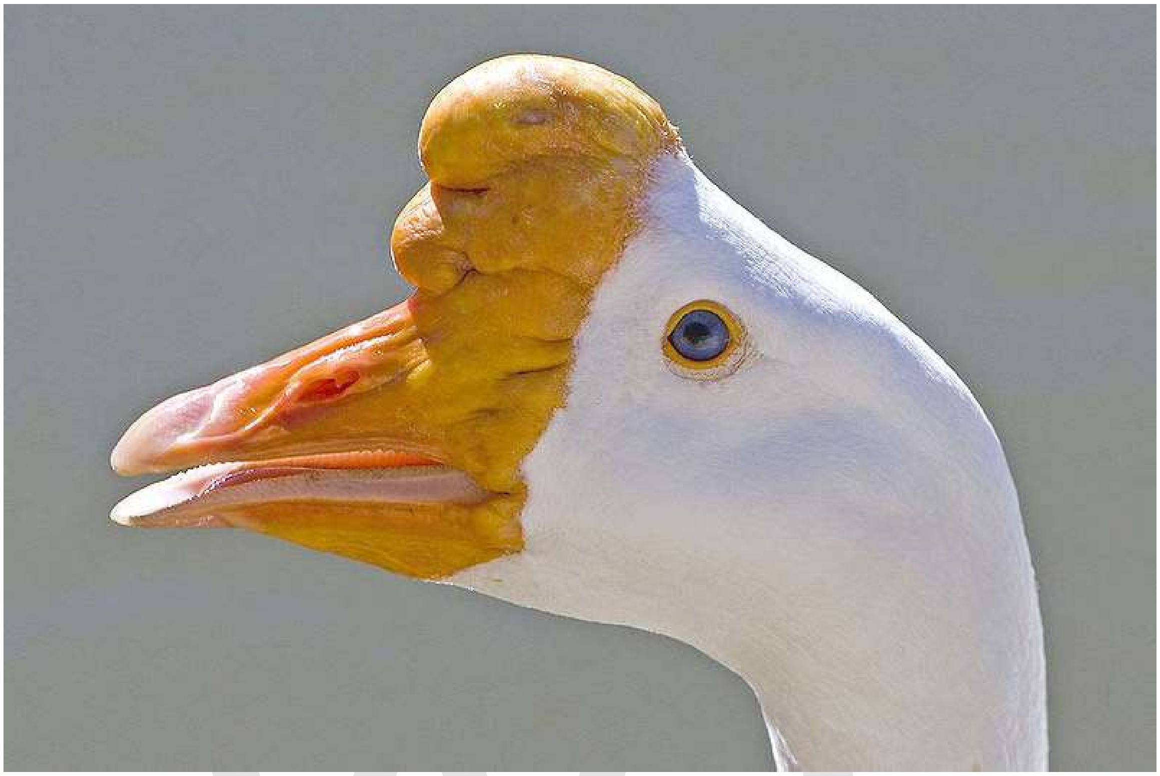
A fledgeling Common Starling shows the interior of its bill.

During courtship, mated pairs of a variety of bird species touch and clasp each other's bills. This is called **billing** and appears to strengthen the pair bond (Terres, 1980). Gannets raise their bills high and repeatedly clatter them (*pictured*); the male puffin nibbles at the female's beak; the male waxwing puts his bill in the female's mouth; and ravens hold each other's beaks in a prolonged "kiss".

Beak gallery

A variety of beaks

The bill of a scavenger—the Griffon Vulture.



The bill of a domesticated Chinese goose. The knob is highly exaggerated by farm selection.

Northern Gannets billing.

The bill of the Greater Flamingo.

The beak of a Brown Falcon.

The beak of an African Penguin.

The Kea uses its long curved beak to prey on animals as large as sheep.

The beak of a Catalina Macaw

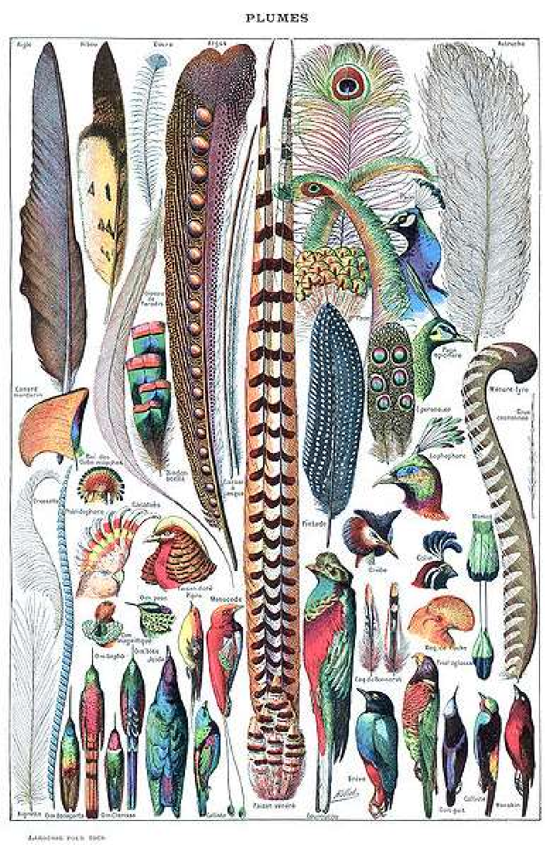
The beak of a malabar grey hornbill

The beak of a golden eagle

Dusky Moorhen, Gallinula tenebrosa

Chapter- 4

Feather

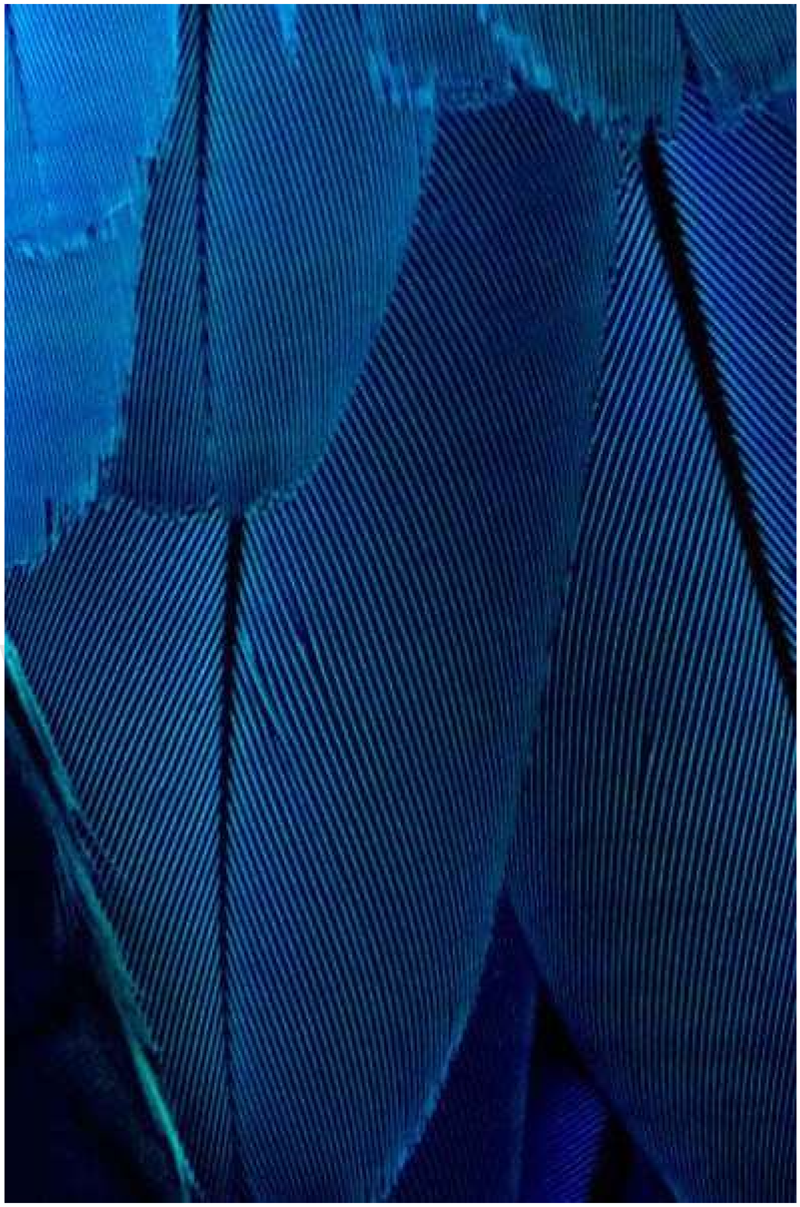


Feather variations

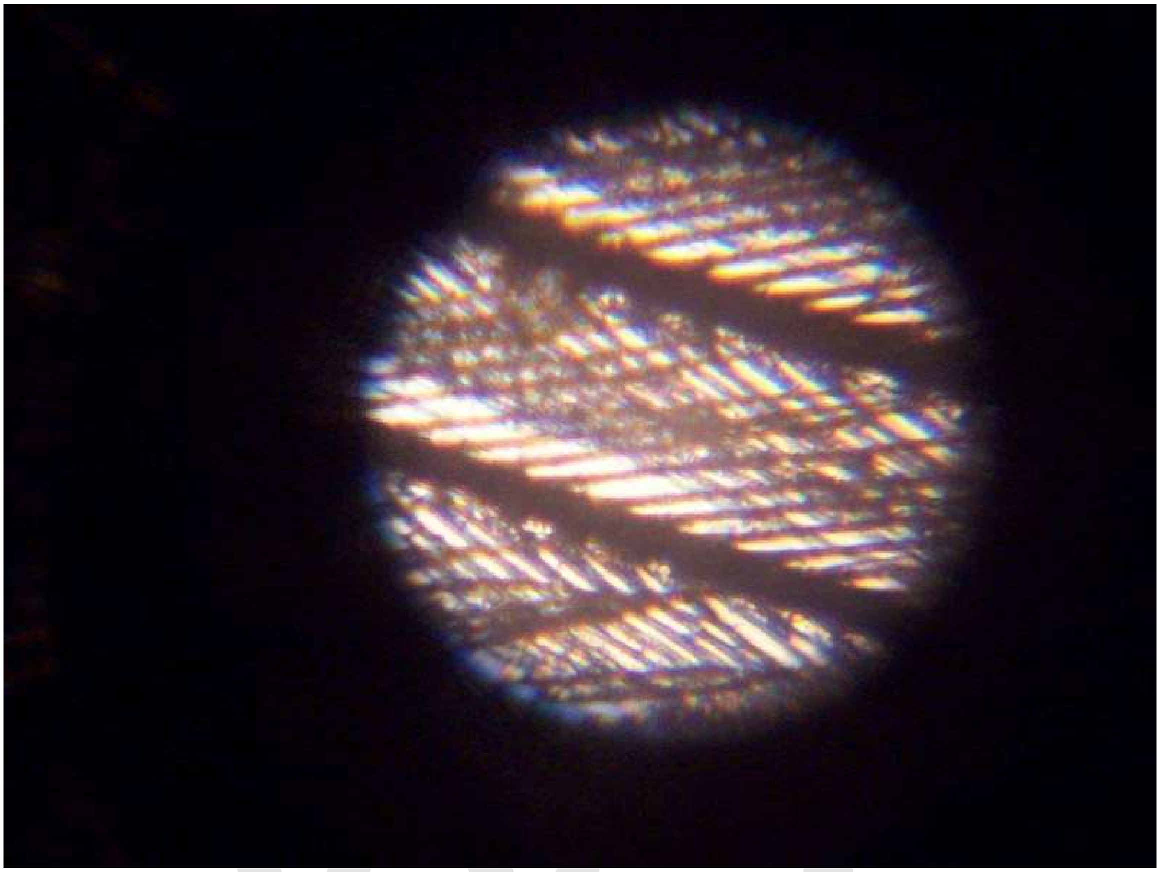
Feathers are one of the epidermal growths that form the distinctive outer covering, or plumage, on birds. They are considered the most complex integumentary structures found in vertebrates, and indeed a premier example of a complex evolutionary novelty. They are among the characteristics that distinguish the extant Aves from other living groups. Feathers have also been noticed in those Theropoda which have been termed feathered dinosaurs. Although feathers cover most parts of the body of birds, they arise only from certain well-defined tracts on the skin. They aid in flight, thermal insulation, waterproofing and coloration that helps in communication and protection.

Structure and characteristics

Parts of a feather:
1. Vane
2. Rachis
3. Barb
4. Afterfeather
5. Hollow shaft, calamus



Featherstructure of a Blue-and-yellow Macaw



Budgerigar feather, magnified, showing interlocking barbules

Feathers are among the most complex integumentary appendages found in vertebrates and are formed in tiny follicles in the epidermis, or outer skin layer, that produce keratin proteins. The β-keratins in feathers, beaks and claws — and the claws, scales and shells of reptiles — are composed of protein strands hydrogen-bonded into β-pleated sheets, which are then further twisted and crosslinked by disulfide bridges into structures even tougher than the α-keratins of mammalian hair, horns and hoof. The exact signals that induce the growth of feathers on the skin are not known but it has been found that the transcription factor cDermo-1 induces the growth of feathers on skin and scales on the leg.

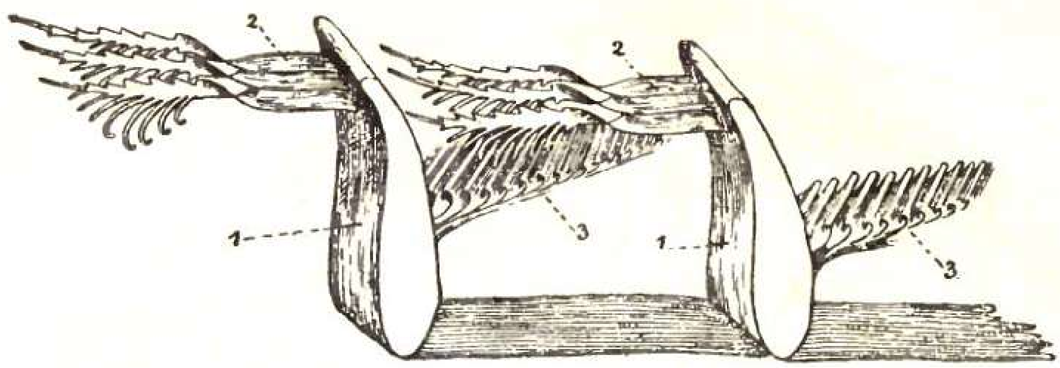


Diagram showing (1) section of barbs (*rami*) and (2, 3) interlocking barbules (*radii*). (After Pycraft.)

Feather microstructure showing interlocking barbules.

Classification

There are two basic types of feather: **vaned feathers** which cover the exterior of the body, and **down feathers** which are underneath the vaned feathers. The pennaceous feathers are vaned feathers. Also called **contour feathers**, pennaceous feathers arise from tracts and cover the whole body. A third rarer type of feathers, **filoplumes**, is hairlike and (if present in a bird) grows along the fluffy down feathers. In some passerines, filoplumes arise exposed beyond the contour feathers on the neck. The remiges, or flight feathers of the wing, and rectrices, the flight feathers of the tail are the most important feathers for flight. A typical vaned feather features a main shaft, called the rachis. Fused to the rachis are a series of branches, or barbs; the *barbs* themselves are also branched and form the *barbules*. These barbules have minute hooks called *barbicels* for cross-attachment. Down feathers are fluffy because they lack barbicels, so the barbules float free of each other, allowing the down to trap much air and provide excellent thermal insulation. At the base of the feather, the rachis expands to form the hollow tubular *calamus* (or quill) which inserts into a follicle in the skin. The basal part of the calamus is without vanes. This part is embedded within the skin follicle and has an opening at the base (proximal umbilicus) and a small opening on the side (distal umbilicus).

Hatchling birds of some species have a special kind of natal down (neossoptiles) and these are pushed out when the normal feathers (teleoptiles) emerge.

Flight feathers are stiffened so as to work against the air in the downstroke but yield in other directions. It is noted that the pattern of orientation of β-keratin fibers in the feathers of flying birds differs from that in flightless birds. The fibers are better aligned in the middle of the feather and less aligned towards the tips.

Functions

Feathers insulate birds from water and cold temperatures. They may also be plucked to line the nest and provide insulation to the eggs and young. The individual feathers in the wings and tail play important roles in controlling flight. Some species have a crest of feathers on their heads. Although feathers are light, a bird's plumage weighs two or three times more than its skeleton, since many bones are hollow and contain air sacs. Color patterns serve as camouflage against predators for birds in their habitats, and by predators looking for a meal. As with fish, the top and bottom colors may be different to provide camouflage during flight. Striking differences in feather patterns and colors are part of the sexual dimorphism of many bird species and are particularly important in selection of mating pairs. In some cases there are differences in the UV reflectivity of feathers across sexes even though no differences in color are noted in the visible range. The wing feathers of male Club-winged Manakins *Machaeropterus deliciosus* have special structures that are used to produce sounds by stridulation.

A contour feather from a Guinea fowl.

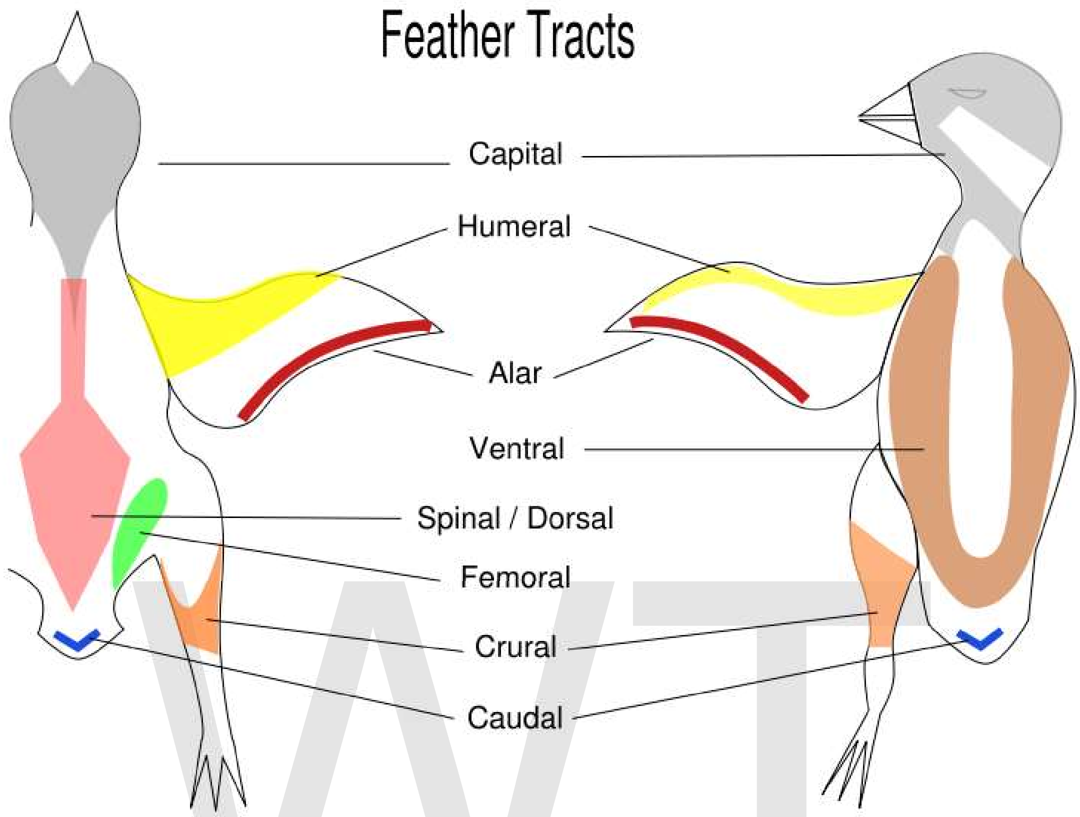
Some birds have a supply of powder down feathers which grow continuously, with small particles regularly breaking off from the ends of the barbules. These particles produce a powder that sifts through the feathers on the bird's body and acts as a waterproofing agent and a feather conditioner. Powder down has evolved independently in several taxa and can be found in down as well as pennaceous feathers. They may be scattered in plumage in the pigeons and parrots or in localized patches on the breast, belly or flanks as in herons and frogmouths. Herons use their bill to break the feathers and to spread them while cockatoos may use their head as a powder puff to apply the powder. Waterproofing can be lost by exposure to emulsifying agents due to human pollution. Feathers can become waterlogged and birds may sink. It is also very difficult to clean and rescue birds whose feathers have been fouled by oil spills. The feathers of cormorants soak up water and help in reducing buoyancy and thereby allowing the birds to swim submerged.

Rictal bristles of a White-cheeked Barbet

Bristles are stiff, tapering feathers with a large rachis but few barbs. **Rictal bristles** are bristles found around the eyes and bill. They may serve a similar purpose to eyelashes and vibrissae in mammals. It has been suggested that they may aid insectivorous birds in prey capture or that it may have sensory functions, however there is no clear evidence. In one study, Willow Flycatchers (*Empidonax traillii*) were found to catch insects equally well before and after removal of the rictal bristles.

Grebes are peculiar in their habit of ingesting their own feathers and also feeding them to their young. Observations on the diet and feather eating frequency suggest that ingesting feathers particularly down from their flanks aids in forming easily ejectable pellets along with their diet of fish.

Distribution



Feather tracts or pterylae and their naming

Contour feathers are not uniformly distributed on the skin of the bird except in some groups such as the Penguins, ratites and screamers. In most birds the feathers grow from specific tracts of skin called pterylae while there are regions which are free of feathers called apterylae. Filoplumes and down may arise from the apteriae, regions between the pterylae. The arrangement of these feather tracts, pterylosis or pterylography, varies across bird families and has been used in the past as a means for determining the evolutionary relationships of bird families.

Coloration

Colors resulting from different feather pigments **Left:** turacin (red) and turacoverdin (green, with some structural blue iridescence at lower end) on the wing of *Tauraco bannermani* **Right:** carotenoids (red) and melanins (dark) on belly/wings of *Ramphocelus bresilius*

The colors of feathers are produced by the presence of pigments, or by microscopic refractive structures, or by a combination of both.

Most feather pigments are melanins (brown and beige pheomelanins, black and grey eumelanins) and carotenoids (red, yellow, orange); other pigments occur only in certain taxa – the yellow to red psittacofulvins (found in some parrots) and the red turacin and green turacoverdin (porphyrin pigments found only in turacos). Structural coloration is involved in the production of blue colors, iridescence, most ultraviolet reflectance and in the enhancement of pigmentary colors; structural iridescence has been reported in fossil feathers dating back 40 million years. White feathers lack pigment and scatter light diffusely; albinism in birds is caused by defective pigment production, though structural coloration will not be affected (as can be seen e.g. in blue-and-white budgerigars).

A feather with no pigment

For example, the blues and bright greens of many parrots are produced by constructive interference of light reflecting from different layers of the structures in feathers, in the case of green plumage in addition to the yellow pigments; the specific feather structure involved is sometimes called the Dyck texture. Melanin is often involved in the absorption of some of the light; in combination with yellow pigment it produces dull olive-greens.

In some birds, the feather colors may be created or altered by uropygial gland secretions. The yellow bill colors of many hornbills are produced by preen gland secretions. Other differences that may only be visible in the ultraviolet region have been suggested but studies have failed to find evidence. Uropygial oil secretion may also have an inhibitory effect on feather bacteria.

A bird's feathers undergo wear and tear and are replaced periodically during its life through molting. New feathers, known as blood, or pin feathers (depending on the stage of growth) when developing, are formed through the same follicle from which the old ones were fledged. The presence of melanin in feathers increases their resistance to abrasion. One study notes that melanin based feathers were observed to degrade more quickly under bacterial action, even compared to unpigmented feathers from the same species, than those unpigmented or with carotenoid pigments. However, another study the same year compared the action of bacteria on pigmentations of two song sparrow species and observed that the darker pigmented feathers were more resistant and they cited other research also published in 2004 that stated increased melanin provided greater resistance. They observed that the greater resistance of the darker birds confirmed Gloger's rule. The evolution of coloration is based on sexual selection and it has been suggested that carotenoid-based pigments may have evolved since they are likely to be more honest signals of fitness because they are derived from special diets, or because carotenoids are also required for immune function.

Parasites

The feather surface is the home for some ectoparasites, notably feather lice (Phthiraptera) and feather mites. Feather lice typically live on a single host and can move only from parents to chicks or mating birds and occasionally by phoresy. This life history has resulted in most of the species being specific to the host and coevolving with the host, making them of interest in phylogenetic studies.

Feather holes are chewing traces of lice (most probably *Brueelia* spp. lice) on the wing and tail feathers. They were described on barn swallows, and because of easy countability, many evolutionary, ecological, and behavioral publications use them to quantify the intensity of infestation.

Interestingly, parasitic cuckoos which grow up in the nests of other species also have host specific feather lice and these seem to be transmitted only after they leave the host nest.

Birds maintain their feather condition by bathing in water, dust bathing and preening. A peculiar behavior of birds, anting, where ants are introduced into the plumage was suggested to help in reducing parasites but no supporting evidence has been found.

Evolution

Fossil feather of Archaeopteryx

The functional view on the evolution of feathers has traditionally focused on insulation, flight and display. Discoveries of non-flying Late Cretaceous feathered dinosaurs in China however suggest that flight could not have been the original primary function. There have been suggestions that feathers may have had their original function in thermoregulation, waterproofing or even as sinks for metabolic wastes such as sulphur. While feathers have been suggested as having evolved from reptilian scales, there are numerous objections, and more recent explanations have arisen from the paradigm of evolutionary developmental biology. Theories of the scale-based origins of feathers suggest that the planar scale structure was modified for their development into feathers by splitting to form the webbing; however, the developmental process involves a tubular structure arising from a follicle and the tube splitting longitudinally to form the webbing. The number of feathers per unit area of skin is higher in smaller birds than in larger birds, and this trend indicates their important role in thermal insulation, since smaller birds lose more heat due to the relatively larger surface area in proportion to their body weight. The coloration of feathers is believed to be primarily evolved in response to sexual selection. In many cases the physiological condition of the birds (especially males) is indicated by the quality of their feathers and this is used (by the females) in mate choice.

Feathered dinosaurs

Archaeopteryx lithographica (Berlin specimen)

Several non-avian dinosaurs had feathers on their limbs that would not have functioned for flight. One theory is that feathers originally evolved on dinosaurs as a result of insulation properties; those small dinosaurs that then grew longer feathers may have found them helpful in gliding leading to the evolution of proto-birds like *Archaeopteryx* and *Microraptor zhaoianus*. Dinosaurs that had feathers or protofeathers include *Pedopenna daohugouensis*, and *Dilong paradoxus*, a tyrannosauroid which is 60 to 70 million years older than *Tyrannosaurus rex*.

The majority of dinosaurs known to have had feathers or protofeathers are saurischians, however featherlike "filamentous integumentary structures" are also known from the ornithischians *Tianyulong* and *Psittacosaurus*. The exact nature of these structures is still under study.

Since the 1990s, dozens of feathered dinosaurs have been discovered in the clade Maniraptora, which includes the clade Avialae and the recent common ancestors of birds, Oviraptorosauria and Deinonychosauria. In 1998, the discovery of a feathered oviraptorosaurian, *Caudipteryx zoui*, challenged the notion that feathers were an exclusive structure of Avialae. Buried in the Yixian Formation in Liaoning, China, *C. zoui* lived during the Early Cretaceous Period. Present on the forelimbs and tails, their integumentary structure has been accepted as pennaceous vaned feathers based on the rachis and herringbone pattern of the barbs. In the clade Deinonychosauria, the continued divergence of feathers is also apparent in the families Troodontidae and Dromaeosauridae. Branched feathers with ranchis, barbs, and barbules were discovered in many members including *Sinornithosaurus millenii*, a dromaeosaurid found in the Yixian formation (124.6 MYA).

Previously, a temporal paradox existed in the evolution of feathers - theropods with highly derived bird-like characteristics occurred at a later time than *Archaeopteryx*, suggesting that the descendants of birds arose before the ancestor. However, this paradox was resolved in 2009 with the discovery of *Anchiornis huxleyi*, found in the Late Jurassic Tiaojishan Formation (160 MYA) in western Liaoning. By predating *Archaeopteryx*, *Anchornis* proves the existence of a modernly feathered theropod ancestor, providing insight into the dinosaur-bird transition. The specimen shows distribution of large pennaceous feathers on the forelimbs and tail, implying that pennaceous feathers spread to the rest of the body at a earlier stage in theropod evolution.

Chapter- 5

Arcopallium, Brood Patch and Comb (Anatomy)

Arcopallium

The **arcopallium** refers to regions of the avian brain which partially overlap regions homologous to the amygdala of mammals. These regions have formerly been referred to as **archistriatum**, and before this **epistriatum** or **amygdaloid complex**, and a recent change of nomenclature has divided the region into the **arcopallium** and **posterior pallial amygdala**. The new nomenclature, adopted in 2004, reflects a modern understanding that the avian brain is broadly similar to the mammalian brain, containing large regions homologous to the mammalian neocortex, claustrum, and pallial amygdala. The outdated nomenclature it replaced perceived the avian brain as consisting almost entirely of enlarged basal ganglia, to which more complex outer layers had been added during a progress toward mammalian intelligence.

Reassignments

Specific reassignments of terminology were made with consideration of retaining abbreviations, and include:

- Archistriatum: Arcopallium (A)
- Nucleus archistriatalis anterior: Anterior arcopallium (AA)
- Archistriatum, pars dorsalis: Dorsal arcopallium (AD)
- Upper part of Archistriatum, pars ventralis: Intermediate arcopallium (AI)
- Medial part of Archistriatum, pars ventralis: Medial arcopallium (AM)
- Robust nucleus of archistriatum in male songbirds: Robust nucleus of arcopallium (RA)
- Central nucleus of anterior archistriatum in parrots: Central nucleus of anterior arcopallium (AAC)
- Ventral part of Archistriatum, pars ventralis plus caudal part of Archistriatum: Posterior nucleus of the pallial amygdala (PoA)

- Nucleus taeniae: Nucleus taeniae of the amygdala (Tn/TnA)
- Region below paleostriatum primitivum posterior to anterior commissure: Subpallial amygdaloid area (PA/SpA)

Brood patch

Brood patch of Sand Martin

A **brood patch** is a patch of featherless skin that is visible on the underside of birds during the nesting season. This patch of skin is well supplied with blood vessels at the surface making it possible for the birds to transfer heat to their eggs when incubating. In most species the feathers in the region are shed automatically but ducks and geese may pluck the feathers and use them to line the nest. The feathers of the region regrow soon after the eggs hatch in the case of precocial birds but may be delayed in those birds having altricial young.

The positions of brood patches can vary with many having a single brood patch in the middle of the belly while some shorebirds have one patch on each side of the belly. Gulls and galliformes may have three brood patches. Pelicans, boobies and gannets do not develop brood patches, but instead cradle the eggs on their feet when incubating. Brood parasitic cuckoos do not develop brood patches. In species where both parents incubate, brood patches may develop in both sexes.

Comb (anatomy)

A rooster with a large red comb.

Anatomically, a **comb** is a fleshy growth, caruncle, or crest on the top of the head of gallinaceous birds, most notably turkeys, pheasants, and domestic chickens. Its alternative name **cockscomb** (spelling variations abound) is because combs are generally larger on males than on females (a male gallinaceous bird is called a cock).

Rooster cockscombs are red, but in other species the color may vary from light grey to deep blue or red; turkey cockscombs can vary in colour from bright red to blue.

In cookery

Cockscombs are used in cookery, often in combination with wattles or chicken kidneys.

Cockscombs were formerly used in French cuisine as garnishes. They were also used to prepare salpicons served in vol au vents, profiteroles, and so on; in that case, they were often combined with other luxury ingredients such as truffles, sweetbreads, or morels in a cream sauce.

In Italian cuisine, cockscombs are an important ingredient in the famous sauce called *Cibreo*, which also includes chicken livers, wattles, and unlaid eggs. It is used as a sauce for tagliatelle and in the molded potato-ricotta ring *Cimabella con cibreo*.

Cockscombs are prepared by parboiling and skinning, then cooking in court-bouillon. After preparation, they are greyish.

Other

Because of its bright color and distinctive shape, 'cockscomb' also describes various plants, including the florists' plant *Celosia cristata*, the meadow weed yellow rattle, sainfoin, wild poppy, lousewort, *Erythronium* and *Erythrina crista-galli*; the characteristic jester's cap; a shape of pasta (*creste di galli*); and so on.

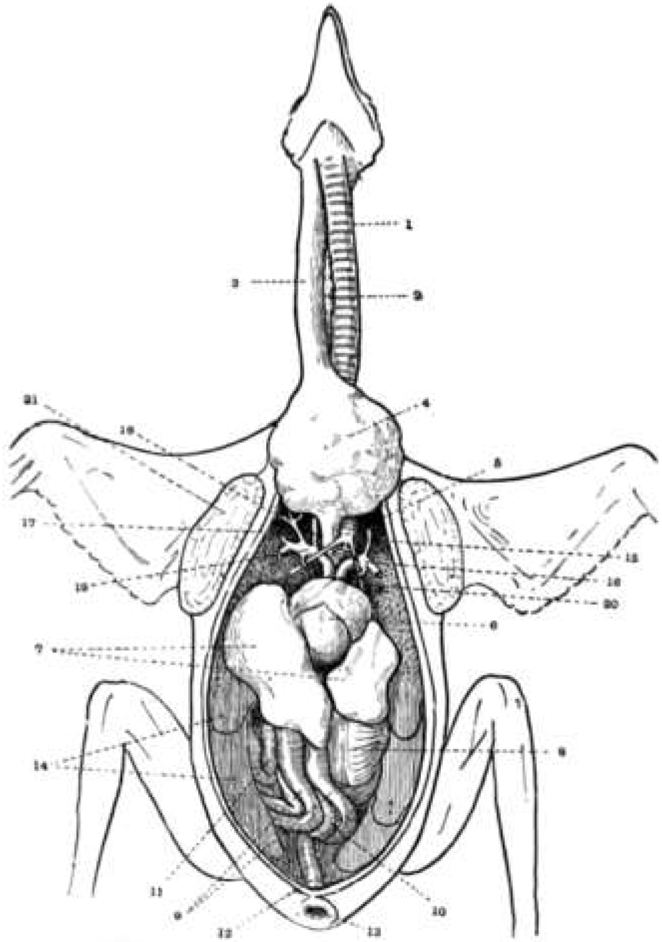
Chapter- 6

Crop (Anatomy), Culmen (Bird) and Furcula

Crop (anatomy)

A male Budgerigar with a full crop after feeding.

One Greater Flamingo-chick in Zoo Basel is fed on crop milk.



The chief Viscera of the Pigeon, *Columba livia*

1. Trachea. 2. Thymus gland. 3. Oesophagus. 4. Crop. 5. Syrinx. 6. Heart. 7. Liver. 8. Gizzard. 9. Duodenum. 10. Pancreas. 11. Small intestine. 12. Rectum. 13. Cloaca. 14. Air-sacs. 15. Left carotid. 16. Left subclavian. 17. Right carotid. 18. Brachial artery. 19. Right subclavian. 20. Muscles of syrinx. 21. Pectoralis major muscle cut across.

The crop (serial 4) prominently seen at the beginning of the alimentary canal.

A **crop** (or **croup**) is a thin-walled expanded portion of the alimentary tract used for the storage of food prior to digestion that is found in many animals, including gastropods, earthworms, leeches, insects, birds, and even some dinosaurs.

Bees

Cropping is used by bees to temporarily store nectar of flowers. When bees "suck" nectar, it is stored in their crop.

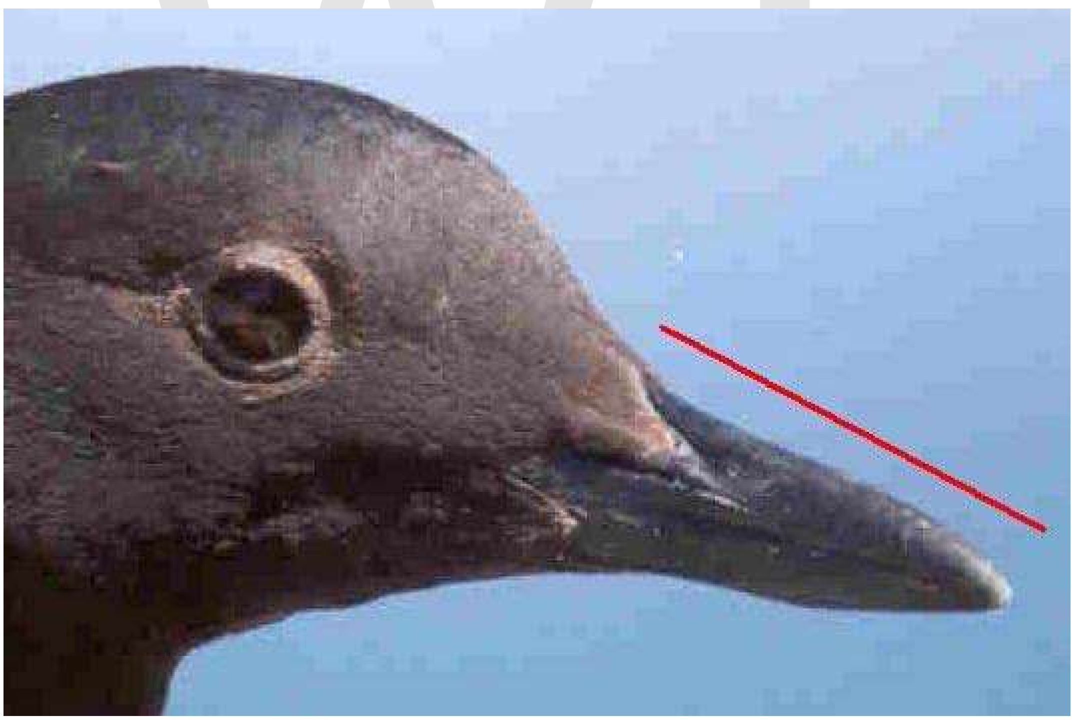
Birds

In a bird's digestive system, the crop is an expanded, muscular pouch near the gullet or throat. It is a part of the digestive tract, essentially an enlarged part of the esophagus. As with most other organisms that have a crop, the crop is used to temporarily store food. Not all birds have a crop. In adult doves and pigeons, the crop can produce crop milk to feed newly hatched birds.

Scavenging birds, such as vultures, will gorge themselves when prey is abundant, causing their crop to bulge. They subsequently sit, sleepy or half torpid, to digest their food.

Most raptors have one; like falcons, hawks, eagles and vultures (as stated above) but owls do not.

Culmen (bird)

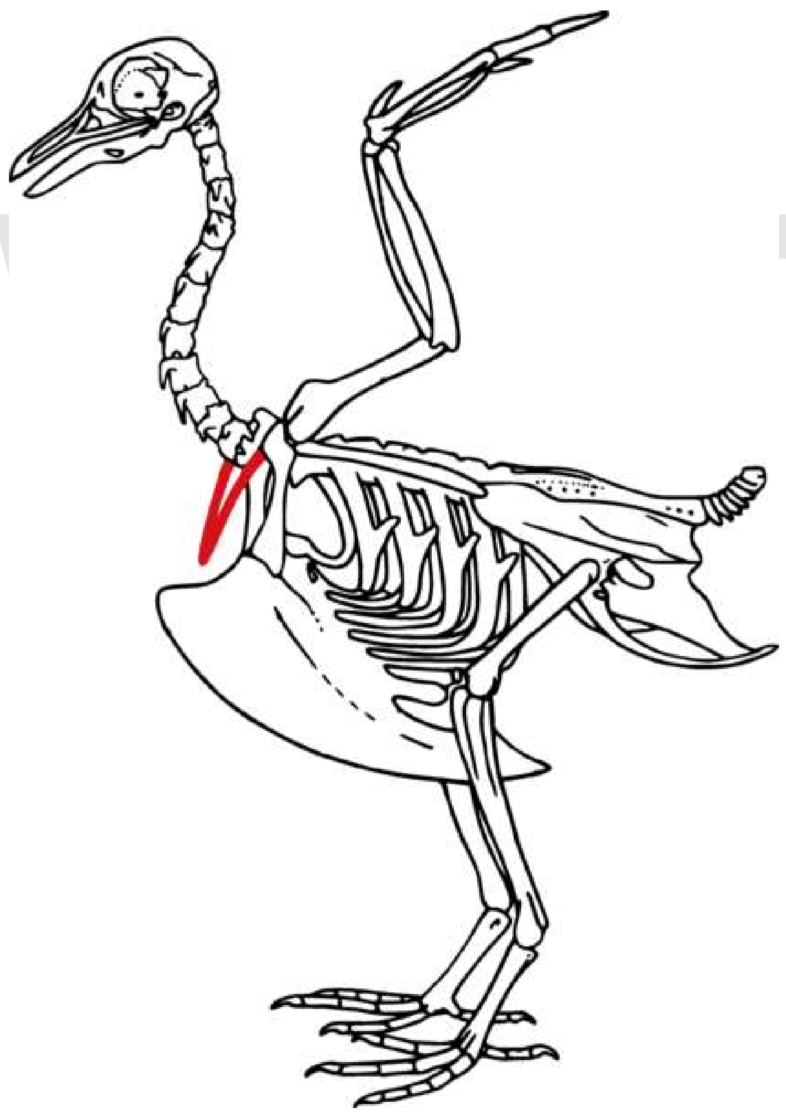


Pigeon Guillemot showing length of Culmen

The **culmen** or **culmen ridge** is a part of a bird's bill. It is the external ridge along the outer part of the centre of the upper mandible, formed where the two halves of the mandible join.

The shape of the culmen can be a useful identification feature. For example, the shape of the culmen differs markedly between the Common Guillemot (evenly, shallowly curved) and the Brünnich's Guillemot, which has a more abrupt angle to its culmen. The same can apply to the colour or patterning — White-billed Diver has a completely pale culmen, whereas on the similar Great Northern Diver this area is dark.

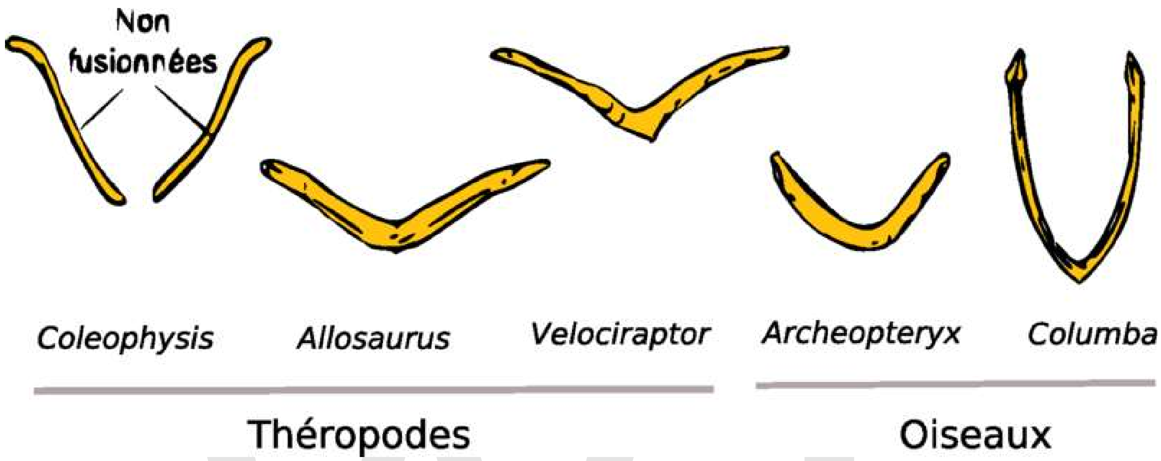
Furcula



This stylised bird skeleton highlights the furcula

The **furcula** is a forked bone found in birds and thecodonts, formed by the fusion of the two clavicles. In birds, its function is the strengthening of the thoracic skeleton to withstand the rigors of flight.

The following theropods have been found to have furculae: dromaeosaurids (including a new North American species of Velociraptor), Oviraptorids, Tyrannosaurids, Troodontids, Coelophysids and Allosauroids.



Evolution of the furcula

Chapter- 7

Anatomical Terms of Location

Standard anatomical terms of location are employed in science which deal with the anatomy of animals to avoid ambiguities which might otherwise arise. They are not language-specific, and thus require no translation. They are universal terms that may be readily understood by zoologists who speak any language.

Unfortunately, while these terms are standardized within specific fields of biology, they can differ dramatically from one discipline to another. Differences in terminology remain a problem that, to some extent, still separates the fields of zoological anatomy (sometimes called zootomy) and human (medical) anatomy (sometimes called androtomy).

The Craniata (vertebrates) share a substantial heritage of common structure, allowing much of the same terminology to be used for all of them. It is necessary for this terminology to be based on the anatomy of the animal in a standard way to avoid ambiguities such as might occur if a word such as "top" were used, which might designate the head of a human but the left or right side of a flounder. Most animals, furthermore, are capable of moving relative to their environment. So while "up" might refer to the direction of a standing human's head, the same term ("up") might be thought to point the direction to the belly for a supine human (at least, a sufficiently stout one). It is also necessary to employ some specific anatomical knowledge in order to apply the terminology unambiguously: *E.g.* while the ears would be *superior* to (above) the shoulders in a human, this fails when describing the armadillo, where the shoulders are above the ears. Thus in veterinary terminology, the ears would be *cranial* to (*i.e.* "towards the head from") the shoulders in the armadillo, the dog, the kangaroo, or any other vertebrate, including the human. Similarly, while the belly is considered *anterior* to (in front of) the back in humans, this terminology fails for the flounder, the armadillo and the dog (although it could work for the kangaroo). In veterinary terms, the belly would be *ventral* ("towards the abdomen") in all vertebrates. In human anatomy, as will be explained below, all naming is based on positions relative to the body in a standing (standard anatomical) position with arms at the side and palms facing forwards (thumbs out). While the universal vertebrate terminology used in veterinary medicine would work in human medicine, the human terms are thought to be too well established to change.

For invertebrates, locational terminology becomes more complicated, as many species are not bilaterally symmetrical. In these species, terminology depends on the type of symmetry present (if any).

Thus, standardized anatomical (and zootomical) terms of location have been developed, usually based on Latin words, to enable all biological and medical scientists to precisely delineate and communicate information about animal (including human) bodies and their component organs.

Standard anatomical position

Because animals can change orientation with respect to their environment, and because any appendages (arms, legs, tentacles, *etc.*) can change position with respect to the main body, it is important that any positional descriptive terms refer to the organism when it is in its **standard anatomical position**.

Thus, and very importantly, *all descriptions are with respect to the organism in its standard anatomical position*, even when the organism in question has appendages in another position. For example, see Fig. 9, where the tentacles are curved, and therefore not in anatomical position. However, a straight position is assumed when describing the proximo-distal axis. This helps avoid confusion in terminology when referring to the same organism in different postures.

Medical (human) anatomy

Unlike the situation in zootomy, standard anatomical position is rigidly defined for human anatomy. As with other vertebrates, the human body is standing erect and at rest. Unlike the situation in other vertebrates, the limbs are placed in positions reminiscent of the supine position imposed on cadavers during autopsy. Therefore, the body has its feet together (or slightly separated), and its arms are rotated outward so that the palms are forward, and the thumbs are pointed away from the body (forearms supine). As well, the arms are usually moved slightly out from the body, so that the hands do not touch the sides. The positions of the limbs (and the arms in particular) have important implications for directional terms in those appendages. The penis in males is also erect in the anatomical position, hence the dorsal surface of the penis is actually anterior in the flaccid state.

Skull

In humans, the anatomical position of the skull has been agreed by international convention to be the Frankfurt plane, a position in which the lower margins of the orbits, the orbitales, and the upper margins of the ear canals, the poria, all lie in the same horizontal plane. This is a good approximation to the position in which the skull would be if the subject were standing upright and facing forward normally.

Directional terms

Ultimately, the bodies we are most familiar with are vertebrate bodies similar to our own. All vertebrates (including humans) have the same basic body plan (or bauplan)—they are bilaterally symmetrical. That is, they have mirror-image left and right halves if divided down the centre. For these reasons, the basic directional terms can be considered to be those used in vertebrates. By extension, the same terms are used for many other (invertebrate) organisms as well.

Vertebrate directional terms

To begin, distinct, polar-opposite ends of the organism are chosen. By definition, each pair of opposite points defines an **axis**. In a bilaterally-symmetrical organism, there are 6 polar opposite points, giving three axes that intersect at right angles—the x, y, and z axes familiar from three-dimensional geometry.

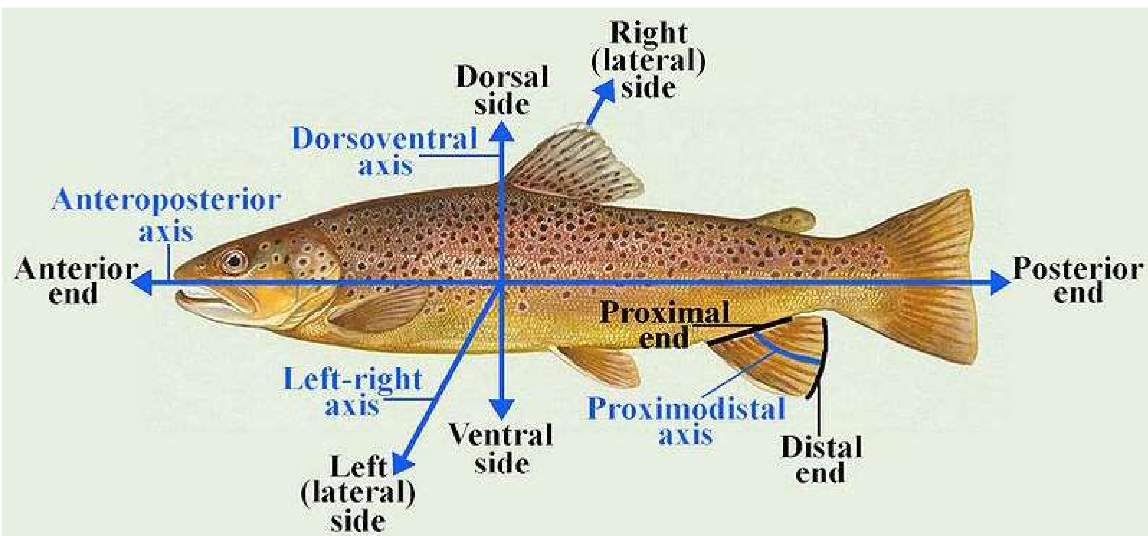


Figure 2: Anatomical directions and defined axes in a vertebrate

Anterior and posterior

The most obvious end-points are the "nose" and "tail" (see Fig. 2). Anatomically, the nose is referred to as the **anterior end** (Latin *ante*; before). In organisms like vertebrates, that have distinct heads, the anterior end is sometimes referred to as the **rostral end** (Latin *rostrum*; beak), the **cranial end** (Greek *kranion*; skull), or the **cephalic end** (Greek *kephalē*; head). For reasons of broader applicability, especially in organisms without distinct heads (many invertebrates), "anterior" is usually preferred.

The polar opposite to the anterior end is the **posterior end** (Latin *post*; after). Another term for posterior is **caudal** (Latin *caudum*; tail, though in humans this refers to the feet i.e. inferior rather than posterior)—a term which strictly applies only to vertebrates, and therefore less preferred, except in veterinary medicine where these terms are standard.

By drawing a line connecting these two points, we define the **anteroposterior axis** (sometimes written antero-posterior). Caudal and Posterior (back end) are often used interchangeably. In veterinary medicine, caudo-cranial is preferred between head and tail, and rostro-caudal between nose and neck. Less-used synonyms would be rostrocaudal or cephalocaudal axes (see Table 1). For brevity, the term anteroposterior is often abbreviated to read **AP** (or A-P) **axis**. As well as defining the anteroposterior axis, the terms "anterior" and "posterior" also define **relative positions** along the axis. Thus, in the fish in Fig. 2, the gill openings are *posterior* relative *to* the eyes, but *anterior to* the tail.

Table 1: Defined Axes in Vertebrate Zoology

Directional term	Defined Axis	Synonyms	Axis runs...
Anterior Posterior	Anteroposterior	Rostrocaudal[1], Craniocaudal[1], Cephalocaudal[2]	...from head end to opposite end of body or tail.
Dorsal Ventral	Dorsoventral	—	...from spinal column (back) to belly (front).
Left (lateral) Right (lateral)	Left-right	Dextro-sinister[2], Sinistro-dexter[2]	...from left to right sides of body.
Medial Left or right (lateral)	Mediolateral[3]	—	...from centre of organism to one or other side.
Proximal Distal	Proximodistal	—	...from tip of an appendage (distal) to where it joins the body (proximal).

Notes:
(1) Fairly common usage.
(2) Uncommon usage.
(3) Equivalent to one-half of the left-right axis.
(The terms "intermediate", "ipsilateral", "contralateral", "superficial" and "deep", while indicating directions, are relative terms and thus do not properly define fixed anatomical axes. Also, while the "rostrocaudal" and anteroposterior directionality are equivalent in a significant portion of the human body, they are different directions in other parts of the body.)

Dorsal and ventral

The next most obvious end-points are the back and belly. These are termed the **dorsal end** (Latin *dorsum*; back) and the **ventral end** (Latin *venter*; abdomen), respectively. By connecting the outermost points the **dorsoventral axis** is formed (sometimes hyphenated: **dorso-ventral**). This is commonly abbreviated to **DV** (or D-V) **axis**. The DV axis, by definition, is perpendicular (at right angles to) the AP axis at all times (see below).

As with anteroposterior, the terms "dorsal" and "ventral" are also used to describe relative positions along the dorsoventral axis. Thus, the pectoral fins are *dorsal to* the anal fin, but *ventral to* the dorsal fin in Fig. 2. (Note that these fins are not aligned anteroposteriorly, either—the dorsal fin being posterior to the pectoral, and anterior to the anal fins, respectively.)

Left and right (lateral), and medial

The last axis, by geometric definition, must be at right angles to both the AP and DV axes. Obviously, the **left side** and **right side** of the organism are the outermost points between the two "sides" of the organism. When connected, these points form the **left-right axis** (commonly abbreviated to **LR** (or L-R) **axis**. In Latin, this is called the **dextro-sinistral** (or, more uncommonly, the **sinistro-dextral**) **axis**, from ***dexter*** (right) and ***sinister*** (left). **It is important to note that the "left" and "right" sides are the sides of *the organism*, and not those of *the observer*.**

"Left-right" is typically used in English and some other languages.

As with the other directions, the terms can be used as relative terms, to describe locations along the left-right axis. Thus, in Fig. 2 the dorsal fin is *right of* the left pectoral fin, but is *left of* the right eye. However, as left and right sides are mirror images, usage like this tends to be somewhat confusing, as structures are duplicated on both sides (*i.e.* above there is both a right eye and a left eye, forcing one to specify which is used as a reference).

To counter this clumsiness of usage, the directional term **lateral** (Latin *lateralis*; "to the side") is used as a modifier for both sides, yielding the **left lateral** and **right lateral** sides. As an opposite to lateral, the term **median** (Latin *medius*; "middle") is used to define a point in the centre of the organism (where the left-right axis intersects the midsagittal plane), and the term **medial** means "towards the median plane". Thus, rather than "left-right" axis and its inherent clumsiness of usage, the term **mediolateral** (also sometimes hyphenated **medio-lateral**) **axis** is frequently used. Sometimes this is abbreviated to **ML** (or M-L) **axis**. Properly, the ML axis is a half axis; practically, its usage is less clumsy and less linguistically biased than "left-right". The terms may still be used relatively to describe locations along the LR axis. Thus, in Fig. 2 the gills are *medial to* the operculum, but *lateral to* the heart.

The usage "mediolateral" is strictly used to describe relative position along the left-right axis, to avoid confusion with the terms "superficial" and "deep".

Sources of confusion

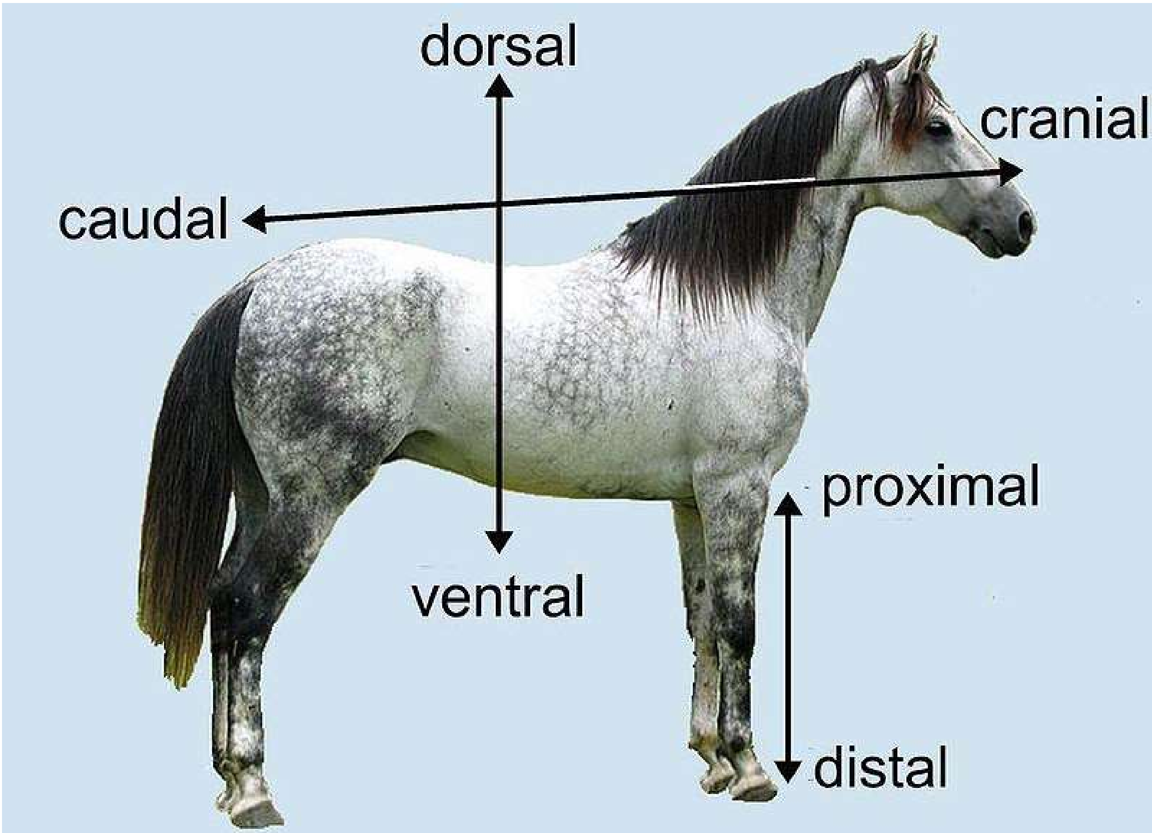


Figure 3: Directional axes in the tetrapod vertebrate *Equus caballus* (a horse). The axis between cranial and caudal is the Cr-Cd axis, and between the dorsal and ventral is the D-V axis. (Left-right axis not shown; image shows the right side of the organism.)

Together, the AP, DV and LR (or ML) axes allow for precise three-dimensional descriptions of location within any bilaterally-symmetrical organism, whether vertebrate or invertebrate. In practice, the terms can cause some confusion when, unlike the fish shown in Fig. 2, the organism in question is not strictly linear in form, which includes most tetrapods (see Figs. 3 and 4). For example, the AP axis in Fig. 3 does not appear to be at right angles to the DV axis. Rather, it is a depiction of the approximate average AP axis, when all body segments are included.

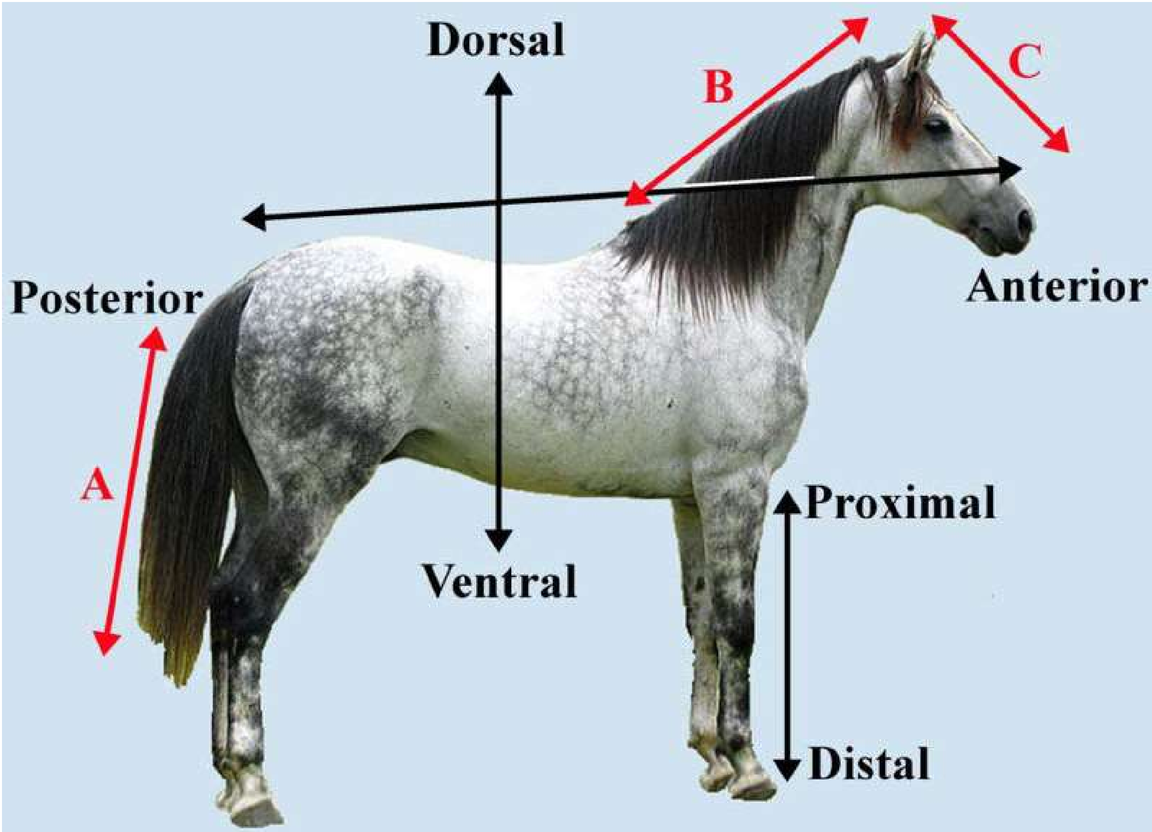
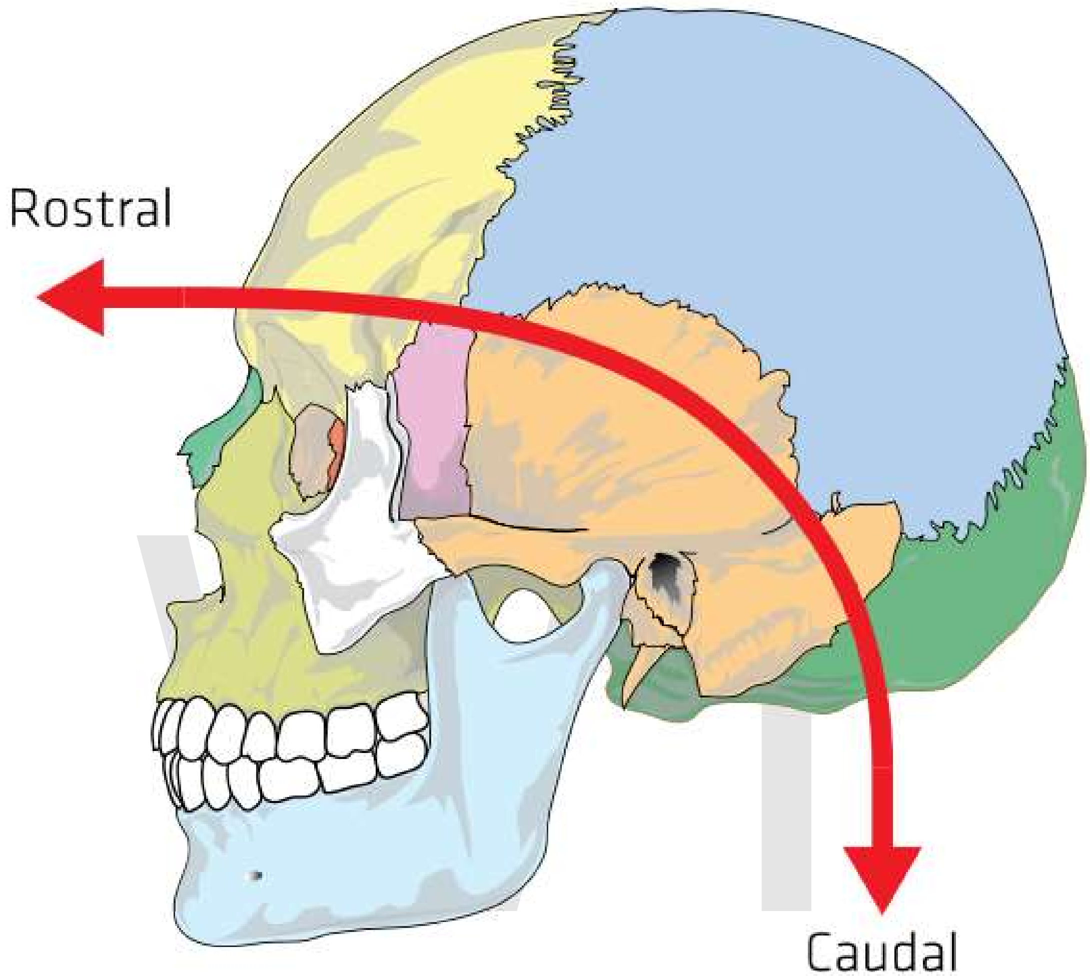


Figure 4: Different directional AP axes in three body segments of a horse). Axis (A) (in red) shows the AP axis of the tail, (B) shows the AP axis of the neck, and (C) shows the AP axis of the head.

When considering *any one segment*, the dorsoventral axis is perpendicular to the AP axis. Thus, in Fig. 4, the DV axis of the tail would run from the "back" of the tail (posterior end of the trunk), to the "underside" of the tail (near the legs)—nearly parallel to the AP axis of the main body.

As a general rule of thumb, if the body is included in consideration, the AP axis of the main body would be used, as would the DV and ML axes perpendicular to it. However, if considering *only* one segment, the AP axis would shift to reflect the axes shown in Fig. 4, with the DV and ML axes shifting correspondingly. Alternatively, to avoid confusion, AP, DV and ML terms are used *strictly* in relation to the main body, and the terms proximal and distal are used for body segments such as the head, neck and tail.

To avoid this confusion, in veterinary medicine, the terms anterior, posterior, superior, and inferior are generally avoided except for certain structures within the head. By using the terms cranial, caudal, dorsal and ventral, all tetrapod organisms (including bipeds) can be described uniformly.



Rostral and Caudal shown on a human skull

In humans, the directions "rostral" and "caudal" often become confused with anterior and posterior, or superior and inferior. The difference between the two is most easily visualized when looking at the head, as can be seen in the image to the right. From the most caudal of positions in the nervous system (of a person) to a nearby, rostral area, it is equally accurate to say the area in question is rostral as to say it is superior. However, in the frontal lobes of the telencephalon, to say an area is rostral to a nearby area is equivalent to saying it is anterior (or ventral). Those two lines lie on planes perpendicular to one another! This occurs, as becomes clear in the diagram, due to the intuitive yet curious curving "C" shape of rostrocaudal directionality when discussing the human brain.

Proximal and distal

The term **proximal** (Latin *proximus*; nearest; aka. "proxil") describes where the appendage joins the body, and the term **distal** (Latin *distare*; to stand away from) is used for the point furthest from the point of attachment to the body. Since appendages often move independently of (and therefore change position with respect to) the main body, these separate directional terms are used when describing them.

As noted above, the standard AP, DV and ML directional axes, can cause some confusion when describing parts of the body that can change position (move) relative to the main body. This is particularly true when considering **appendages**. "Appendages" would include vertebrate fins (see Fig. 2) and limbs (see Figs. 3 and 4), but properly apply to any structure that extends (and can at least potentially move separately) from the main body. Thus, "appendage" would also include such structures as external ears (pinnae) and hair (in mammals), feathers (in birds) and scales (fish, reptiles and birds). As well, varieties of tentacles or other projections from the body in invertebrates and the male in many vertebrates and some invertebrates, would be included.

By connecting the two points, the **proximodistal** (sometimes hyphenated to **proximo-distal**) **axis** is created. (The abbreviation **AB axis** is occasionally, but not commonly, used.) As before, the terms "proximal" and "distal" can be used as relative terms to indicate where structures lie along the proximodistal axis. Thus, the "elbow" is proximal to the hoof, but distal to the "shoulder" in Figs. 3 and 4.

Choosing terms for the other two axes perpendicular to the proximodistal axis could be variable, as they would also depend on the position of the limb. For that reason, when considering any organism, the other two axes are considered to be relative to the appendage **when in standard anatomical position**. This is roughly defined for all organisms, as in the normal position when at rest and not moving. For tetrapod vertebrates, this includes the caveat that they are standing erect and not lying down. Thus, the fish in Fig. 2, and the horse in Figs. 3 and 4 are in standard anatomical position. (Special considerations with respect to limb position are applied in human anatomy).

Other directional terms

In addition to the three primary axes (AP, DV and the ML half-axis) and the proximodistal axis of appendages, several directional terms can be used in bilaterally symmetrical animals. These terms are **strictly relative**, and as such *do not and cannot be used to define fixed axes*. These terms include:

- **Ipsilateral** (Latin *ipse*; self/same): on the same side as another structure. Thus, the left arm is **ipsilateral to** the left leg.
- **Contralateral** (Latin *contra*; against): on the opposite from another structure. Thus, the left arm is **contralateral to** the right arm, or the right leg.

- **Superficial** (Latin *superfacies; at the surface or face*): near the outer surface of the organism. Thus, skin is **superficial to** the muscle layer. The opposite is "deep", or "visceral".
- **Deep**: further away from the surface of the organism. Thus, the muscular layer is **deep to** the skin, but superficial to the intestines. This is one of the few terms where the English vernacular is prevalent. The proper anglicised Latin term would be **profound** (Latin *profundus*; due to depth), but this word has other meanings in English. In other languages, the equivalent term is usually similar to "profound" (*e.g. profond*, meaning deep, in French).
- **Intermediate** (Latin *intermedius*; *inter*, between and *medius*, middle): between two other structures. Thus, the navel is **intermediate to** (or **intermediate between**) the left arm and the contralateral (right) leg.
- **Visceral** (Latin *viscus*; *internal organs*, *flesh*): associated with organs within the body's cavities. The stomach is a viscus within the abdominal cavity, and is covered with a lining called the visceral peritoneum.
- **Parietal** (Latin *paries* "wall"): pertaining to the wall of a body cavity. The parietal peritoneum is the lining on the inside of the abdominal cavity. (Parietal can also refer specifically to the parietal bone of the skull or associated structures.)
- **Axial** (Latin *axis* from Greek *axōn* "axle"): Towards the central axis of the organism or an extremity.
- **Abaxial** : away from the central axis of the organism or extremity
- **Rostral** (Latin - rostr(um), *beak* or *nose*): situated toward the oral or nasal region, or in the case of the brain, towards the tip of the frontal lobes.
- **Caudal** (Latin - caud(a), *tail*): of, at, or near the tail or the posterior end of the body. In the human case, towards the bottom of the feet (also the "tail" of the spinal cord, and body).

Invertebrate directional terms

The large variety of body shapes present in invertebrates presents a difficult problem when attempting to apply standard directional terms. Depending on the organism, some terms are taken by analogy from the vertebrate terms, and appropriate novel terms are applied, as necessary. In all cases, the usage of terms is dependent on the bauplan of the organism.

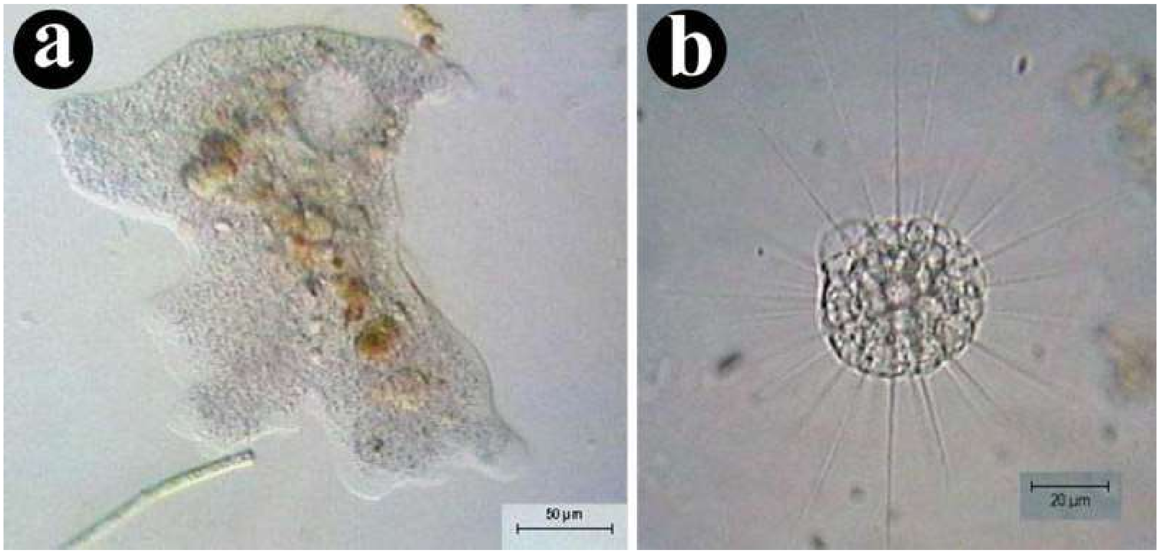


Figure 5: Asymmetrical and spherical body shapes. (a) An organism with an asymmetrical bauplan (*Amoeba proteus*—an amoeba). (b) An organism with a spherical bauplan (*Actinophrys sol*—a heliozoan.

Asymmetrical and spherical organisms

In organisms with a changeable shape, such as amoeboid organisms (Fig. 5a), directional terms are meaningless, since the shape of the organism is changeable, and no fixed axes are present. Similarly, in organisms that are spherical in shape (Fig. 5b), there is nothing to distinguish one line through the centre of the organism from another. An infinite number of triads of mutually perpendicular axes could be defined, but any such choice of axes would be functionally and practically indistinguishable from all others, and therefore would be useless. In such organisms, only the terms *superficial* and *deep* hold any descriptive meaning.

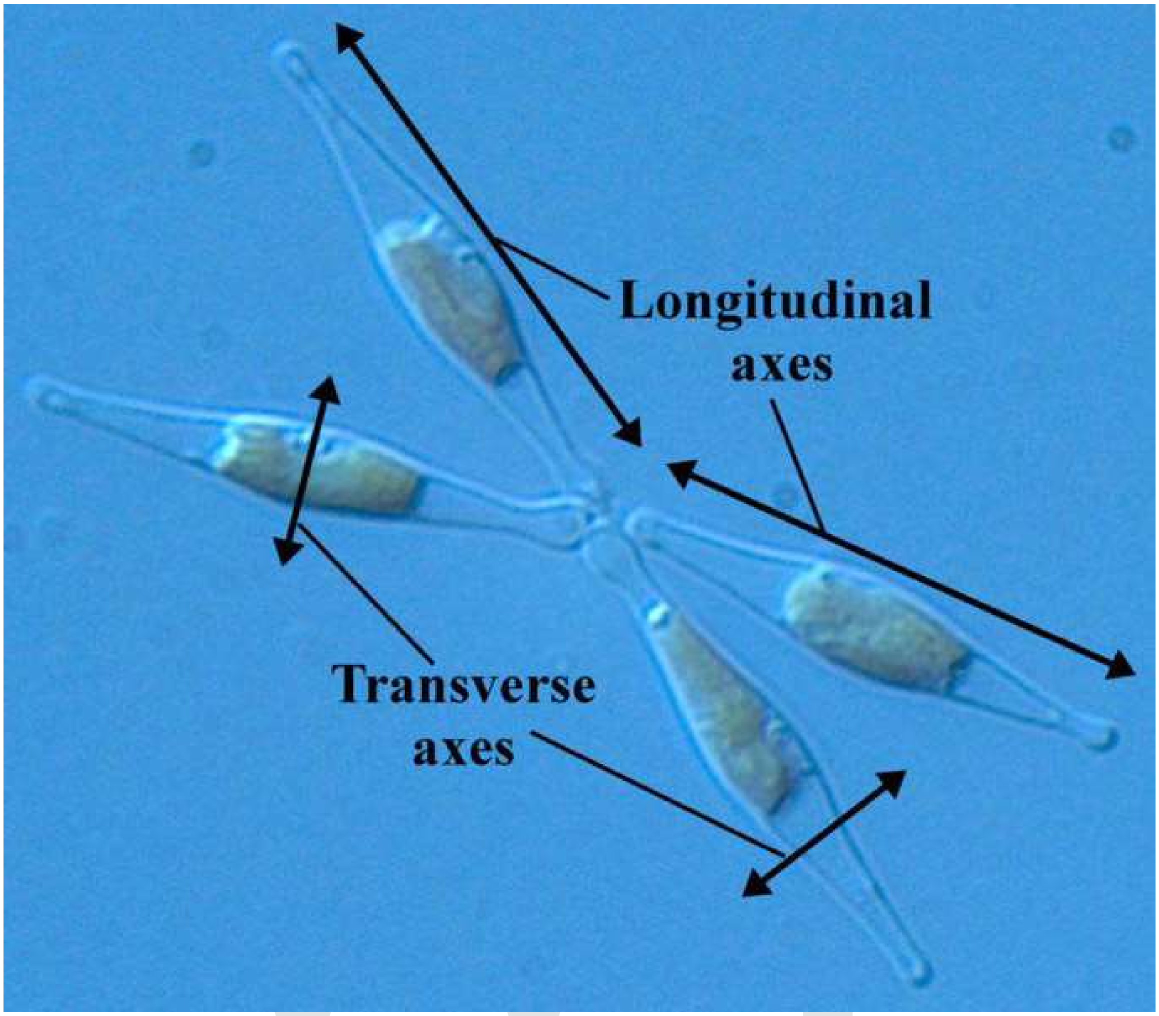


Figure 6: Four individuals of *Phaeodactylum tricornutum*, a diatom with a fixed elongated shape.

Elongated organisms

In organisms that maintain a constant shape and have one dimension longer than the other, at least two directional terms can be used. The **long** or **longitudinal axis** is defined by points at the opposite ends of the organism. Similarly, a perpendicular **transverse axis** can be defined by points on opposite sides of the organism. There is typically no basis for the definition of a third axis. Usually such organisms, like that pictured in Fig. 6, are planktonic (free-swimming) protists, and are nearly always viewed on microscope slides, where they appear essentially two-dimensional. In some cases a third axis can be defined, particularly where a non-terminal cytostome or other unique structure is present.

Elongated organisms with distinctive ends

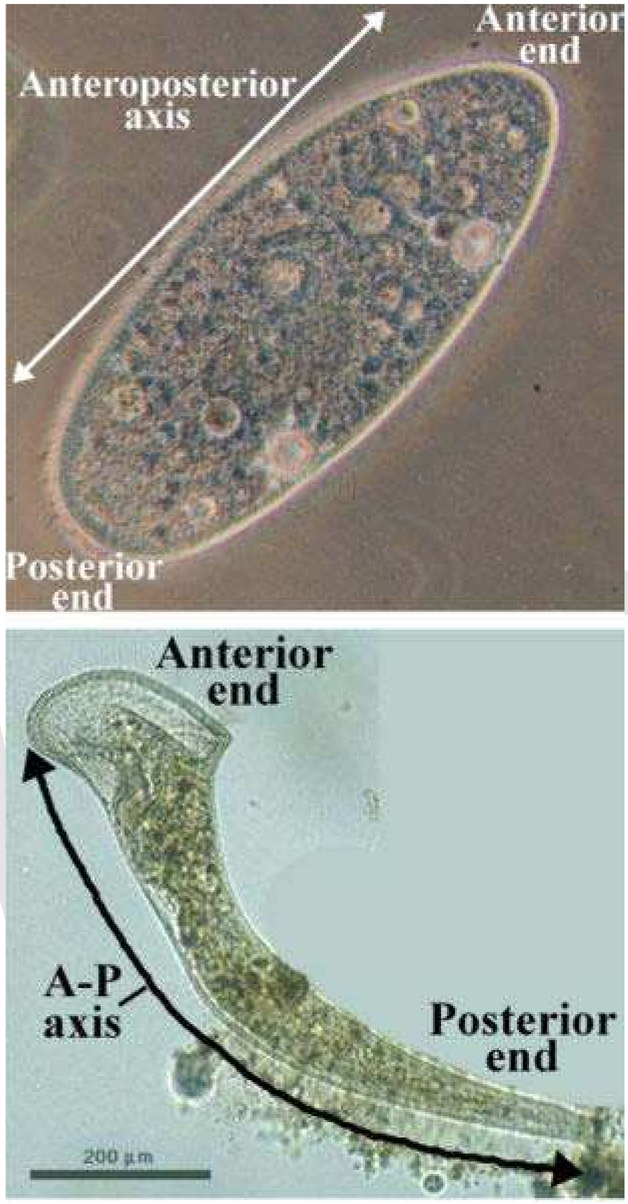


Figure 7: Organisms where the ends of the long axis are distinct. (*Paramecium caudatum*, above, and *Stentor roeseli*, below.)

Some elongated protists have distinctive ends of the body. In such organisms, the end with a mouth (or equivalent structure, such as the cytostome in *Paramecium* or *Stentor*), or the end that usually points in the direction of the organism's locomotion (such as the end with the flagellum in *Euglena*), is normally designated as the **anterior end**. The opposite end then becomes the **posterior end**, and by connecting them, an **anteroposterior axis** is formed. Properly, this terminology would only apply to an organism that is always planktonic (not normally attached to a surface, as in Fig. 7 top), although the term can also be applied to one that is sessile (normally attached to a surface, as in Fig. 7, bottom, and Fig. 8).

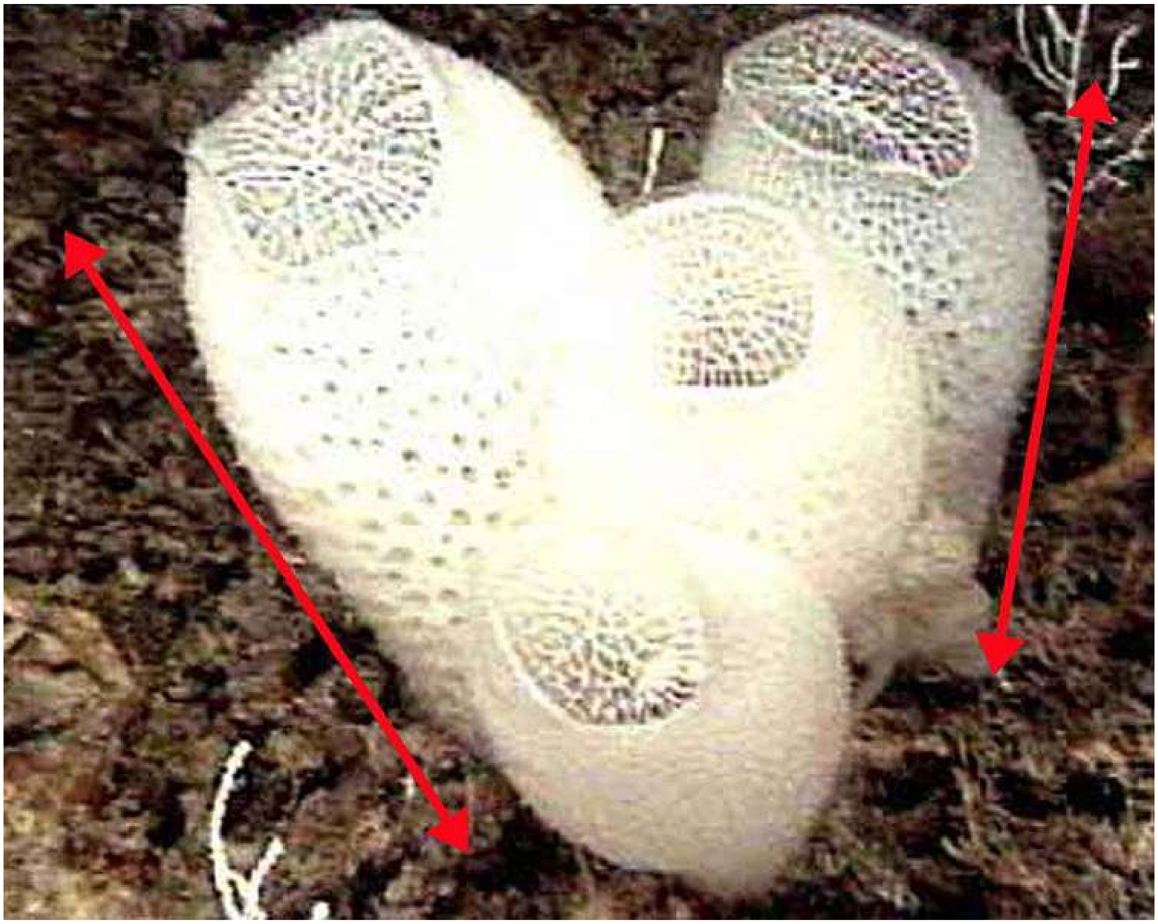


Figure 8: A cluster of *Euplectella aspergillum* sponges (Venus flower baskets), showing the apical-basal axes.

Organisms that are attached to a substrate, such as sponges (Fig. 8), or some animal-like protists also have distinctive ends. The part of the organism attached to the substrate is usually referred to as the **basal end** (Latin *basis*; support or foundation), whereas the end furthest from the attachment is referred to as the **apical end** (Latin *apex*; peak, tip). Thus, by joining the two ends, an **apical-basal** (or **basal-apical**) **axis** is formed (see Fig. 8). **Transverse axes** may be defined indifferently in any direction perpendicular to this axis, as there is no symmetry present.

Radially-symmetrical organisms

Radially symmetrical organisms include those in the group Radiata—primarily jellyfish, sea anemones and corals and the comb jellies. Adult echinoderms (sea stars (starfish), sea urchins, and sea cucumbers and others) are also included, since they are pentaradial (*i.e.* they have fivefold discrete rotational symmetry). Echinoderm larvae are *not* included, since they are bilaterally symmetrical.

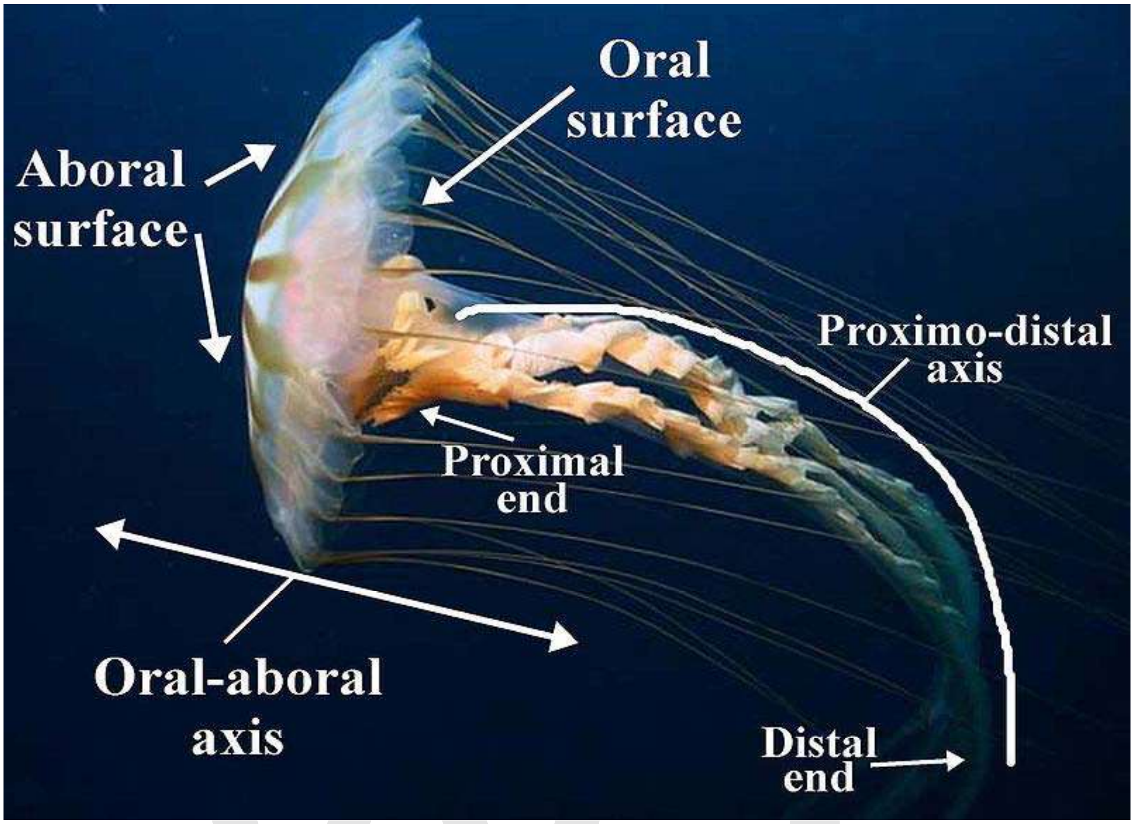


Figure 9: *Chrysoara spp.* (a jellyfish), showing the oral-aboral, and proximodistal axes. (Note that the appendages are not in standard anatomical position, so that the axis is curved.)

Unlike spherical and asymmetrical organisms, radially-symmetrical animals always have one distinctive axis.

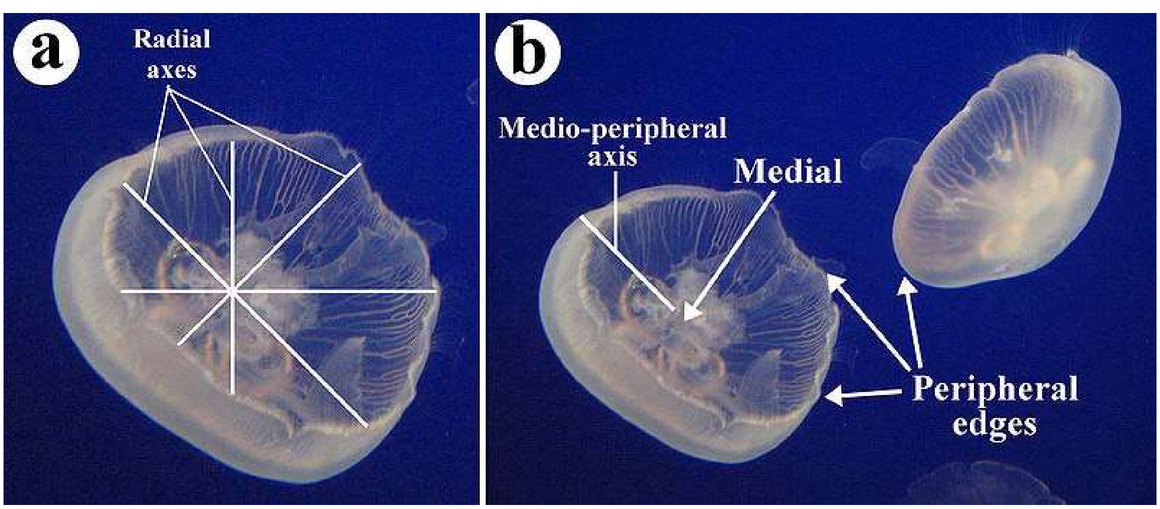


Figure 10: *Aurelia aurita*, another species of jellyfish, showing multiple radial and medio-peripheral axes.

Cnidarians have an incomplete digestive system, meaning that one end of the organism has a mouth, and the opposite end has no opening from the gut (coelenteron). For this reason, the end of the organism with the mouth is referred to as the **oral end** (Latin *oris*; mouth), and the opposite surface is the **aboral end** (Latin *ab-*; prefix meaning "away from"). Thus, by joining the polar opposite oral and aboral ends, an **oral-aboral axis** is formed (Fig. 9).

As with vertebrates, appendages that move independently of the body (tentacles in cnidarians and comb jellies), have a definite **proximodistal axis** (Fig. 8). Unlike vertebrates, cnidarians (jellyfish, sea anemones, corals) have no other distinctive axes, and multiple **radial axes** are possible (Fig. 10).

It is noteworthy that some "biradially-symmetrical" comb jellies have distinct "**tentacular**" and "**pharyngeal**" axes, and are thus anatomically equivalent to bilaterally-symmetrical animals. As well, adult echinoderms (starfish, sea urchins, sea cucumbers) are *pentaradial*, and have only five symmetrical radial axes (unlike the multiple axes in cnidarians).

Lateral, **dorsal**, and **ventral** have no meaning in such organisms, and all can be replaced by the generic term **peripheral** (Latin *peri-*; around; see Table 2). **Medial** can be used, but in the case of radiates indicates the central *point* of these organisms, rather than a central *axis* (as in vertebrates). Thus, as there are many possible radial axes, there are multiple **medio-peripheral** (half-) **axes** (Fig. 10).

Table 2: Comparison of Directional Terms used in Radially-Symmetrical[1] and Bilaterally-Symmetrical Animals

Bilateral Bauplans		Radial Bauplans	
Direction	**Synonyms**	**Direction**	**Synonyms**
Anterior	Rostral, Cranial, Cephalic[2]	Oral	Apical[3]
Posterior	Caudal[2]	Aboral	Basal[3]
Dorsal	—	Peripheral[4,5]	—
Ventral	—	Peripheral[4,5]	—
Left (lateral)	Sinister	Peripheral[4,5]	—
Right (lateral)	Dexter	Peripheral[4,5]	—
Medial	—	*Same*[6]	—
Proximal	—	*Same*	—
Distal	—	*Same*	—

Notes:
(1) Includes both Radiates and adult Echinoderms.
(2) Rarely used.
(3) Only in organisms attached to a substrate.
(4) Vertebrate equivalents are meaningless in radial animals.
(5) Roughly equivalent to "superficial".
(6) Roughly equivalent to "deep".

Arachnids

Two specialized terms are sometimes used for describing views of arachnid legs and pedipalps. **Prolateral** refers to the surface of a leg which is closest to the anterior end of an arachnid's body. **Retrolateral** refers to the surface of a leg which is closest to the posterior end of an arachnid's body.

Medical (human) directional terms

As humans are bilaterally-symmetrical organisms, anatomical directions in humans can usually be correctly described using the same terms as those for vertebrates and other members of the taxonomic group Bilateria. However, for historical and other reasons, standard human directional terminology has several differences from that used for other bilaterally-symmetrical organisms.

Why zootomy and androtomy terms differ

The terms of zootomy and androtomy came into usage at a time when all scientific communication took place in Latin. In their original Latin forms the respective meanings of "anterior" and "posterior" are *in front of* (or *before*) and *behind* (or *after*), those of "dorsal" and "ventral" are *towards the spine* and *towards the belly*, and those of "superior" and "inferior" are *above* and *below*. From these meanings it can be seen that in the most general terms the anterior/posterior axis is oriented to the direction of forward motion, the dorsal/ventral axis is oriented to the anatomy of the vertebrate torso, and the superior/inferior axis is oriented to gravity.

For almost all vertebrates, including almost all bipeds, these axes all provide a consistent reference for anatomical positions across species—with the inferior/superior axis being roughly the same as the dorsal/ventral axis, and therefore redundant. Humans, however, have the rare property of having a torso oriented perpendicular to their direction of forward motion—while their head orientation remains consistent with other vertebrates on this axis. This makes the dorsal/ventral axis on humans redundant with the anterior/posterior axis, and the inferior/superior axis necessary. Because of this difference with humans, the anterior/posterior and inferior/superior axes are inconsistent between humans and other vertebrates in torso anatomy but consistent in head anatomy. As all three of these axes are used in the naming of anatomical structures, and most human anatomical structures are shared by other animals, these differences can lead to considerable confusion. For example, in the naming of brain structures, the non-human context of the dorsal/ventral axis was used. Therefore, in human anatomy, "dorsal" can refer to two different (perpendicular) directions—the posterior direction in the context of the torso, and the superior direction in the context of the brain. Ironically, the "dorsal" direction in the human brain, besides being perpendicular to the "dorsal" direction in the human torso, is actually the *opposite* direction of what might be inferred from the literal Latin meaning of "toward the spine".

While it would be possible to introduce a system of axes that is completely consistent between humans and other vertebrates by having two separate pairs of axes, one used exclusively for the head (e.g. anterior/posterior and inferior/superior) and the other exclusively for the torso (e.g. dorsal/ventral and caudal("toward the tail")/rostral("toward the beak")), doing so would require the renaming very many anatomical structures.

For a quick comparison of equivalent terminology used in vertebrate and human anatomy, see Table 3 (below).

Table 3: Equivalent directional terms used in vertebrate zoology and human anatomy

Vertebrate zootomy		Human torso		Human head	
Direction	**Synonyms**	**Direction**	**Synonyms**	**Direction**	**Synonyms**
Anterior	Rostral, Cranial, Cephalic[1]	Superior	*Same*[1], Up	Anterior	Front
Posterior	Caudal	Inferior	Caudal[1], Down	Posterior	Back
Dorsal	—	Posterior	Dorsal, Back	Superior	Dorsal, Up
Ventral	—	Anterior	Ventral, Front	Inferior	Ventral, Down
lateral	Away from the middle	*Same*	—	*Same*	—
Left (lateral)	Sinister[1]	*Same*	—	*Same*	—
Right (lateral)	Dexter[1]	*Same*	—	*Same*	—
Medial	Middle	*Same*	—	*Same*	—
Proximal	Away from extremity	*Same*	—	*Same*	—
Distal	Towards extremity	*Same*	—	*Same*	—
Intermediate[2]	—	*Same*	—	*Same*	—
Ipsilateral[2]	Same side	*Same*	—	*Same*	—
Contralateral[2]	Opposite side	*Same*	—	*Same*	—
Superficial[2]	—	*Same*	—	*Same*	—
Deep[2]	—	*Same*	—	*Same*	—

Notes:
(1) Rarely used.
(2) Strictly relative term, used with other locational descriptors.

Superior and inferior

As with other vertebrates, two of the most obvious extremes are the "top" and the "bottom" of the organism. In standard anatomical position, these correspond to the head and feet, respectively in humans. The head end is referred to as the **superior end** (Latin *superior*: "above"), while the feet are referred to as the **inferior end** (Latin *inferior*: "below"). Thus, the axis formed by joining the two is the **superior-inferior axis**.

As with other vertebrate terminology, there are synonymous terms for superior and inferior (Table 3). The terms **cranial** and **cephalic** are often encountered. "Cranial", as a reference to the skull, is fairly commonly used, whereas "cephalic" is uncommonly used. The term "rostral" is rarely used in human anatomy, referring more to the front of the face than the superior aspect of the organism. This term is more applicable in organisms with longer heads, such as equids. Similarly, the term **caudal** is occasionally used in human anatomy, and the **cranio-caudal axis** is occasionally encountered. Generally, this usage would only be used with respect to the head and main body (trunk), and not when considering the limbs.

As with vertebrate directional terms, superior and inferior can be used in a relative sense in humans, but can not be uniformly applied to other organisms with varying normal anatomical positions. For example, the shoulders are *superior to* the navel, but *inferior to* the eyes in humans. In any tetrapod, the shoulders are *cranial to* the belly, but *caudal to* the eyes.

Anterior and posterior

In human anatomical usage, **anterior** refers to the "front" of the individual, and is *synonymous with **ventral***, other than in the head. Similarly, **posterior**, refers to the "back" of the subject, and is *synonymous with **dorsal***, other than in the head (see Table 3). The terms "dorsal" and "ventral" are used in human anatomy, but infrequently when referring to the body as a whole. The **anteroposterior axis** is preferred usage for describing the axis connecting the front and the back in humans.

"Anterior" and "posterior" can also be used as relative terms. Thus, the eyes are *posterior to* the nose, but *anterior to* the back of the head in humans. However, in the horse, for example, the eyes are *caudal to* the nose, and rostral to the back of the head.

Left and right (lateral), and medial

Left and right **lateral** are used in the same sense as they are in other vertebrates, as is **medial**. The **left-right axis** is rarely used in medicine; instead, the **mediolateral axis** is used almost exclusively.

Appendages

As in other vertebrates, the terms "**proximal**" and "**distal**" are used to describe the point of attachment to, and part of an appendage furthest away from, the body, respectively. However, other terms are used for direction in the appendages, given the unique position of the limbs (in standard anatomical position) in humans.

Relative directions

Also, in common usage, the segments of the digestive system closest to the mouth are termed **proximal**, as opposed to those closest to the anus, which are termed **distal**. The terms *oral* "of the mouth" and *aboral* "away from the mouth" are also used.

Relative directions in the limbs

Specialized terms are used to describe location on appendages, parts that have a point of attachment to the main trunk of the body. Structures that are close to the point of attachment of the body are **proximal** or **central**, while ones more distant from the attachment point are **distal** or **peripheral**. For example, the hands are at the distal end of the arms, while the shoulders are at the proximal ends. These terms can also be used relatively to organs, for example the proximal end of the urethra is attached to the bladder.

In the limbs of most animals, the terms **cranial** and **caudal** are used in the regions proximal to the carpus (the wrist, in the forelimb) and the tarsus (the ankle in the hindlimb). Objects and surfaces closer to or facing towards the head are *cranial*; those facing away or farther from the head are *caudal*.

Distal to the carpal joint, the term **dorsal** replaces **cranial** and **palmar** replaces **caudal**. Similarly, distal to the tarsal joint the term **dorsal** replaces **cranial** and **plantar** replaces **caudal**. For example, the top of a dog's paw is its *dorsal* surface; the underside, either the *palmar* (on the forelimb) or the *plantar* (on the hindlimb) surface.

The sides of the forearm are named after its bones: Structures closer to the radius are **radial**, structures closer to the ulna are **ulnar**, and structures relating to both bones are referred to as **radioulnar**. Similarly, in the lower leg, structures near the tibia (shinbone) are **tibial** and structures near the fibula are **fibular** (or **peroneal**).

Volar (sometimes used as a synonym for "palmar") refers to the underside, for both the palm and the sole (*plantar*), as in **volar pads** on the underside of hands, fingers, feet and toes.

The terms valgus and varus are used to refer to angulation of the distal part of a limb at a joint. For example, at the elbow joint, in the anatomical position, the forearm and the upper arm do not lie in a straight line, but the forearm is angulated laterally with respect to the upper arm by about 5–10°. The forearm is said to be "in valgus". Angulation at a joint may be normal (as in the elbow) or abnormal.

General usage

Three basic reference planes are used in zoological anatomy.

- A **sagittal plane**, being a plane parallel to the sagittal suture, divides the body into sinister and dexter (left and right) portions.
    - The **midsagittal** or **median** plane is in the mid line; i.e. it would pass through mid line structures such as the navel or spine, and all other sagittal planes (also referred to as **parasagittal planes**) are parallel to it. Median can also refer to the midsagittal plane of other structures, such as a digit.
- A **coronal** or **frontal** plane divides the body into dorsal and ventral (back and front, or posterior and anterior) portions.
- A **transverse plane**, also known as an *axial plane* or *cross-section*, divides the body into cranial and caudal (head and tail) portions.

For post-embryonic humans a coronal plane is vertical and a transverse plane is horizontal, but for embryos and quadrupeds a coronal plane is horizontal and a transverse plane is vertical.

When describing anatomical motion, these planes describe the axis along which an action is performed. So by moving through the transverse plane, movement travels from head to toe. For example, if a person jumped directly up and then down, their body would be moving through the transverse plane in the coronal and sagittal planes.

Some of these terms come from Latin. *Sagittal* means "like an arrow", a reference to the position of the spine which naturally divides the body into right and left equal halves, the exact meaning of the term "midsagittal", or to the shape of the sagittal suture, which defines the sagittal plane and is shaped like an arrow.

A *longitudinal plane* is any plane perpendicular to the transverse plane. The coronal plane and the sagittal plane are examples of longitudinal planes.

Usage in human anatomy

Sometimes the orientation of certain planes needs to be distinguished, for instance in medical imaging techniques such as sonography, CT scans, MRI scans, or PET scans. One imagines a human in the anatomical position, and an X-Y-Z coordinate system with the Z-axis going from front to back, the X-axis going from left to right, and the Y-axis going from up to down. The Z-axis axis is always forward (Tait-Bryan angles) and the right-hand rule applies.

- A **transverse** (also known as **axial** or **horizontal**) plane is an X-Z plane, parallel to the ground, which (in humans) separates the superior from the inferior, or put another way, the head from the feet.
- A **coronal** (also known as **frontal**) plane is a Y-X plane, perpendicular to the ground, which (in humans) separates the anterior from the posterior, the front from the back, the ventral from the dorsal.
- A **sagittal** (also known as **lateral**) plane is an Y-Z plane, perpendicular to the ground, which separates left from right. The midsagittal plane is the specific sagittal plane that is exactly in the middle of the body.

The axes and the sagittal plane are the same for bipeds and quadrupeds, but the orientation of the coronal and transverse planes switch. The axes on particular pieces of equipment may or may not correspond to axes of the body, especially since the body and the equipment may be in different relative orientations.

Occasionally, in medicine, abdominal organs may be described with reference to the **trans-pyloric plane** which is a transverse plane passing through the pylorus.

Anatomical planes in animal brains

In discussing the neuroanatomy of animals, particularly rodents used in neuroscience research, a simplistic convention has been to name the sections of the brain according to the homologous human sections. Hence, what is technically a *transverse* (orthogonal) section with respect to the body length axis of a rat (dividing anterior from posterior) may often be referred to in rat neuroanatomical coordinates as a *coronal* section, and likewise a *coronal* section with respect to the body (i.e. dividing ventral from dorsal) in a rat brain is referred to as *transverse*. This preserves the comparison with the human brain, whose length axis in rough approximation is rotated with respect to the body axis by **90 degrees** in the ventral direction. It implies that the planes of the brain are not necessarily the same as those of the body.

Actually, the situation is more complex, since comparative embryology shows that the length axis of the neural tube (the primordium of the brain) has three internal bending points, namely two ventral bendings at the cervical and cephalic flexures (cervical flexure roughly between the medulla oblongata and the spinal cord, and cephalic flexure between the diencephalon and the midbrain), and a dorsal (pontine or rhombic) flexure at the midst of the hindbrain, behind the cerebellum. The latter flexure mainly appears in mammals and sauropsids (reptiles and birds), whereas the other two, and principally the cephalic flexure, appear in all vertebrates (the sum of the cervical and cephalic ventral flexures is the cause of the 90 degree angle mentioned above in humans between body axis and brain axis). This more realistic concept of the longitudinal structure of vertebrate brains implies that any section plane, except the sagittal plane, will intersect variably different parts of the same brain as the section series proceeds across it (relativity of actual sections with regard to topological morphological status in the ideal unbent neural tube). Any precise description of a brain section plane therefore has to make reference to the anteroposterior part of the brain to which the description refers (e.g., transverse to the midbrain, or horizontal to the diencephalon). A necessary note of caution is that modern embryologic orthodoxy indicates that the brain's true length axis finishes rostrally somewhere in the hypothalamus where basal and alar zones interconnect from left to right across the median line; therefore, the axis does not enter the telencephalic area, although various authors, both recent and classic, have assumed a telencephalic end of

the axis. The causal argument for this lies in the end of the axial mesoderm -mainly the notochord, but also the prechordal plate- under the hypothalamus. Early inductive effects of the axial mesoderm upon the overlying neural ectoderm is the mechanism that establishes the length dimension upon the brain primordium, jointly with establishing what is ventral in the brain (close to the axial mesoderm) in contrast with what is dorsal (distant from the axial mesoderm). Apart of the lack of a causal argument for introducing the axis in the telencephalon, there is the obvious difficulty that there is a pair of telencephalic vesicles, so that a bifid axis is actually implied in these outdated versions.

Chapter- 8

Barbel (Anatomy) and Carapace

Barbel (anatomy)

This koi carp has two pairs of barbels, the second pair being quite small.

This Asian arowana has large, protruding barbels

A **barbel** on a fish is a slender, whiskerlike tactile organ near the mouth. Fish that have barbels include the catfish, the carp, the goatfish, sturgeon, the zebrafish (*Danio rerio*) and some species of shark. They house the taste buds of such fish and are used to search for food in murky water.

Barbels are often erroneously referred to as *barbs*, which are found in bird feathers for flight.

Barbels may be located in a variety of places. Maxillary barbels refer to barbels on either side of the mouth. Barbels may also be nasal, or extended from the nostrils. Also, barbels are often mandibular or mental, or located on the chin.

Barbel are frequently featured in the fishing magazine *Angler's Mail* as well as many other fishing publications.

Carapace

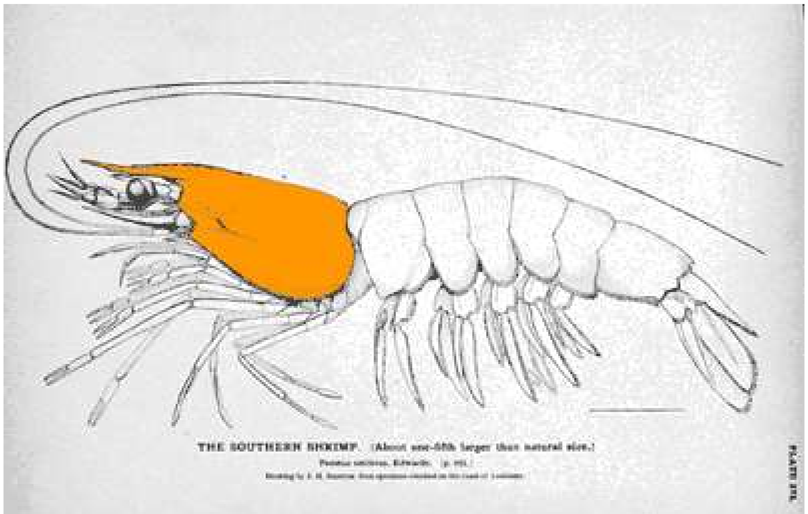
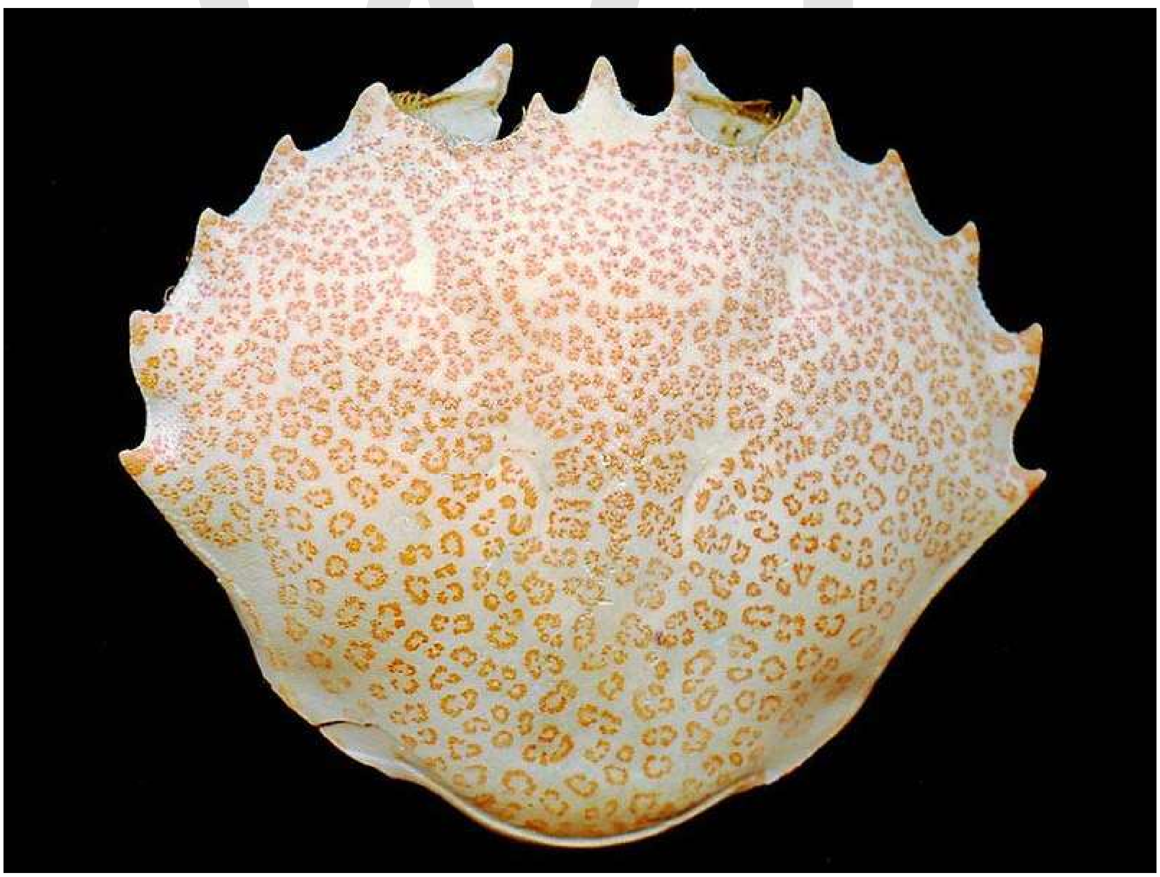


Diagram of a prawn, with the carapace highlighted in orange



The molted carapace of a lady crab from Long Beach, New York

A molted carapace of *Cancer irroratus* from Long Beach, New York

A **carapace** is a dorsal (upper) section of the exoskeleton or shell in a number of animal groups, including arthropods such as crustaceans and arachnids as well as vertebrates such as turtles and tortoises. In turtles and tortoises, the underside is called the plastron.

Crustaceans

In crustaceans, the carapace is a part of the exoskeleton that covers the cephalothorax. It is particularly well developed in lobsters and crabs.

The carapace functions as a protective cover over the cephalothorax. Where it projects forward beyond the eyes, this projection is called a rostrum. The carapace is calcified to varying degrees in different crustaceans.

Zooplankton within the phylum Crustacea also have a carapace. These include Cladocera, Copepods, Ostracods, and Isopods, however Isopods only have a developed "cephalic shield" carapace covering the head.

Arachnida

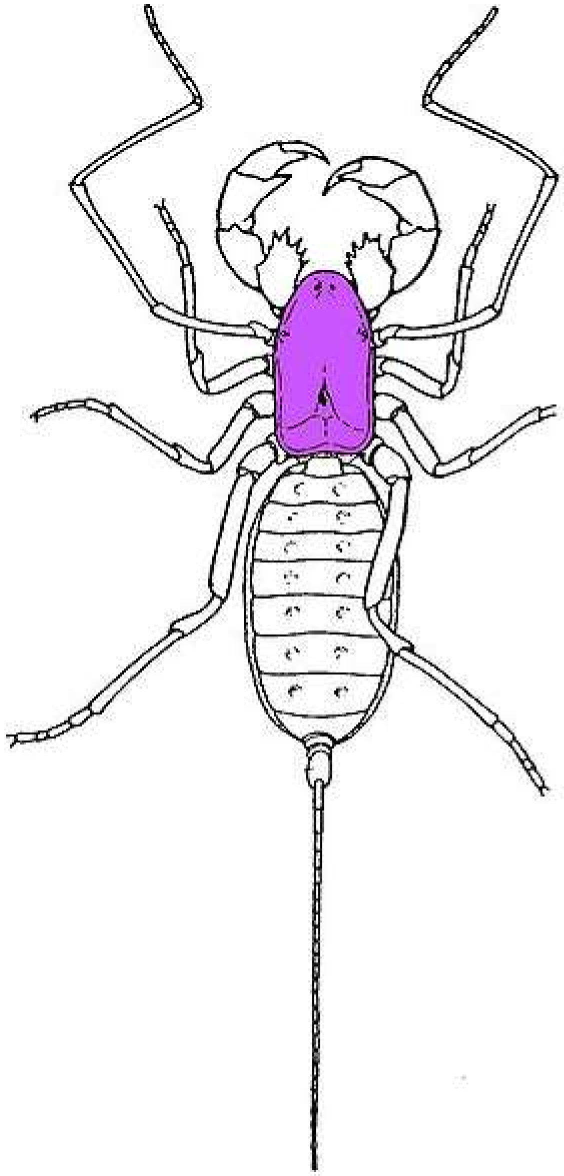


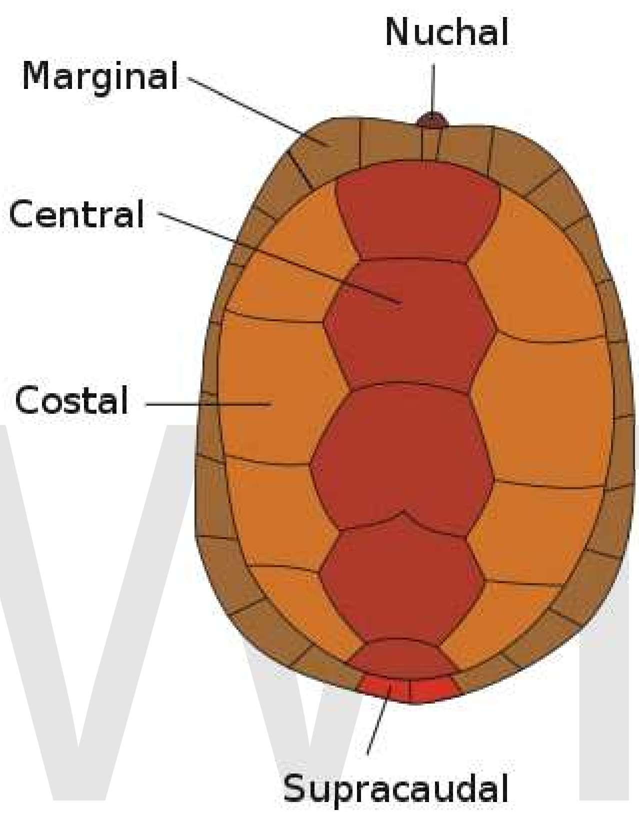
Diagram of an arachnid, with the carapace highlighted in purple

In arachnids, the carapace is formed by the fusion of prosomal tergites into a single plate which carries the eyes, ocularium, ozopores (a pair of openings of the scent gland of Opiliones) and diverse phaneres.

In a few orders, such as Solifugae and Schizomida the carapace may be subdivided. In Opiliones some authors prefer to use the term carapace interchangeably with the term cephalothorax, which is incorrect usage, because carapace refers only to the dorsal part of the exoskeleton of the cephalothorax.

An alternative term for the carapace of arachnids and their relatives, which avoids confusion with crustaceans, is **prosomal dorsal shield**.

Turtles and tortoises



The scutes of a turtle's carapace

The **carapace** is the dorsal, convex part of the shell structure of a turtle, consisting primarily of the animal's broad ribcage. The spine and ribs are fused to bony plates beneath the skin which interlock to form a hard shell. Exterior to the skin the shell is covered by scutes, which are horny plates made of keratin that protect the shell from scrapes and bruises.

Turtles can survive surprisingly severe injuries to the carapace, and even deep cracks or missing portions can fill in with bone and heal. The softshell turtles, pig-nose turtle and leatherback sea turtle lack scutes and the bony carapace is covered only by skin.

The carapaces of many species of turtles are brightly colored and patterned and allow individuals to identify others of their species at a distance. The scutes of the carapace grow outward in concentric circles similar to the growth rings on a tree as the turtle or tortoise grows. These rings typically correspond to one year of growth and can be used to estimate the age of an individual. The plastron makes up the lower half of a turtle's shell.

Chapter- 9

Exoskeleton

The discarded exoskeleton of a dragonfly nymph

An **exoskeleton** is an external skeleton that supports and protects an animal's body, in contrast to the internal skeleton (endoskeleton) of, for example, a human. In popular usage, some of the larger kinds of exoskeletons are known as "**shells**". Some examples of exoskeleton animals include insects such as grasshoppers and cockroaches, and crustaceans such as crabs and lobsters. The shells of the various groups of shelled mollusks, including those of snails, clams, tusk shells, chitons and nautilus are also exoskeletons.

Mineralized exoskeletons first appeared in the fossil record about 550 million years ago, and their evolution is considered by some to have played a role in the subsequent Cambrian explosion of animals.

Some animals, such as the tortoise, have both an endoskeleton and an exoskeleton.

Role of the exoskeleton

Exoskeletons contain rigid and resistant components that fulfil a set of functional roles including protection, excretion, sensing, support, feeding and acting as a barrier against desiccation in terrestrial organisms. Exoskeletons have a role in defence from pests and predators, support, and in providing an attachment framework for musculature.

Exoskeletons contain chitin and when calcium carbonate is added, the exoskeleton grows in strength and hardness.

Diversity

Many taxa produce exoskeletons, which are composed of a range of materials. Bone, cartilage, or dentine is used in the Ostracoderm fish and turtles. Chitin forms the exoskeleton in arthropods including insects, arachnids such as spiders, crustaceans such as crabs and lobsters, and in some fungi and bacteria. Calcium carbonates constitute the shells of molluscs, brachiopods, and some tube-building polychaete worms. Silica forms the exoskeleton in the microscopic diatoms and radiolaria.

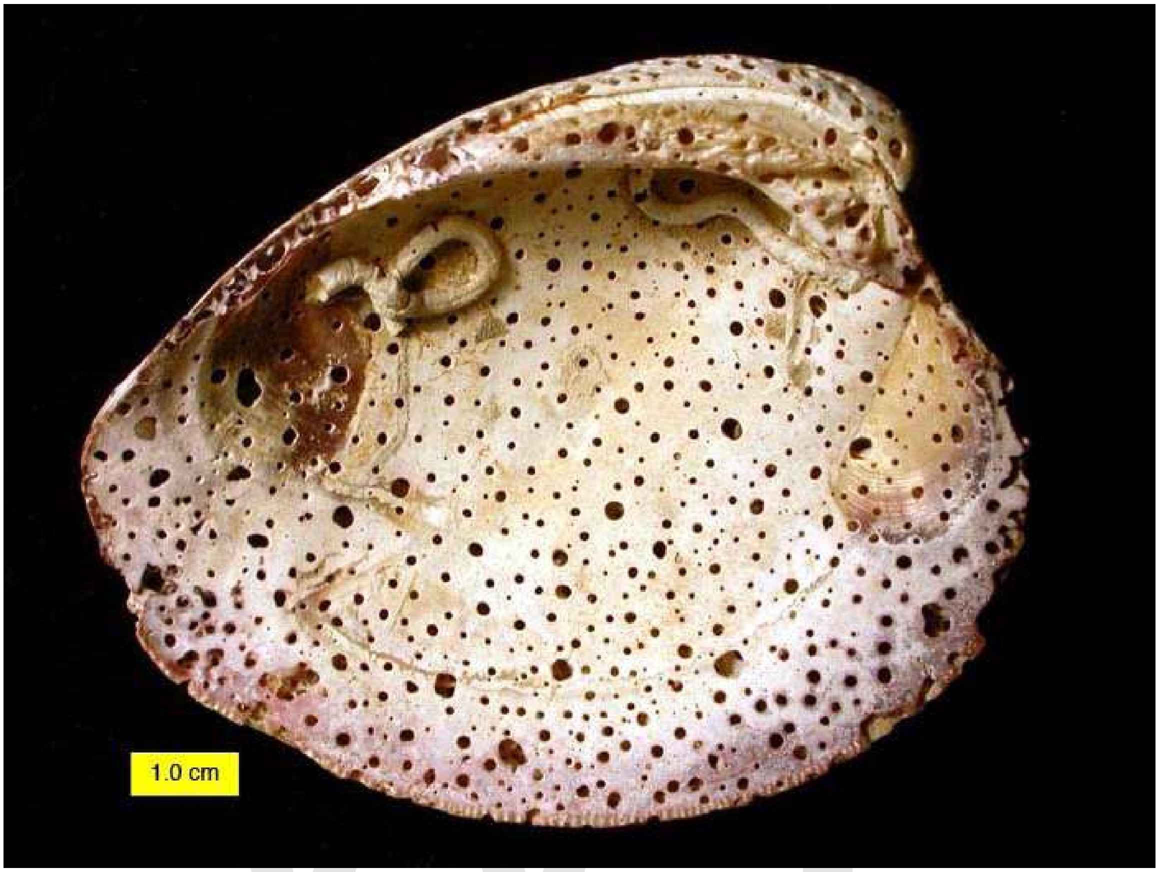
Some organisms, such as some foraminifera, agglutinate exoskeletons by sticking grains of sand and shell to their exterior. Contrary to a common misconception, echinoderms do not possess an exoskeleton, as their test is always contained within a layer of living tissue.

Exoskeletons have evolved independently many times; 18 lineages evolved calcified exoskeletons alone. Further, other lineages have produced tough outer coatings analogous to an exoskeleton, such as some mammals – (constructed from bone in the armadillo, and hair in the pangolin) – and reptiles (turtle and Ankylosaur armor are constructed of bone; crocodiles have bony scutes and horny scales).

Growth in an exoskeleton

Since exoskeletons are rigid, they present some limits to growth. Some organisms grow by adding new material to the aperture of their shell, but many must moult their shell when they outgrow it, producing a replacement.

Palaeontological significance



Borings in exoskeletons can provide evidence of animal behavior. In this case, boring sponges attacked this hard clam shell after the death of the clam, producing the trace fossil *Entobia*.

Exoskeletons, as hard parts of organisms, are greatly useful in assisting preservation of organisms, whose soft parts usually rot before they can be fossilized. Mineralized exoskeletons can be preserved "as is", as shell fragments, for example. The possession of an exoskeleton also permits a couple of other routes to fossilization. For instance, the tough layer can resist compaction, allowing a mold of the organism to be formed underneath the skeleton, which may later decay. Alternatively, exceptional preservation may result in chitin being mineralized, as in the Burgess Shale, or transformed to the resistant polymer keratin, which can resist decay and be recovered.

However our dependence on fossilized skeletons also significantly limits our understanding of evolution. Only the parts of organisms that were already mineralized are usually preserved, such as the shells of mollusks. It helps that exoskeletons often contain "muscle scars", marks where muscles have been attached to the exoskeleton, which may allow the reconstruction of much of an organism's internal parts from its exoskeleton alone. The most significant limitation is that, although there are 30-plus phyla of living animals, two-thirds of these phyla have never been found as fossils, because most animal species are soft-bodied and decay before they can become fossilized.

Mineralized skeletons first appear in the fossil record shortly before the base of the Cambrian period, 550 million years ago. The evolution of a mineralized exoskeleton is seen by some as a possible driving force of the Cambrian explosion of animal life, resulting in a diversification of predatory and defensive tactics. However, some Precambrian (Ediacaran) organisms produced tough outer shells, while others, such as *Cloudina*, had a calcified exoskeleton. Some *Cloudina* shells even show evidence of predation, in the form of borings.

Evolution

On the whole, the fossil record only contains mineralised exoskeletons, since these are by far the most durable. Since most lineages with exoskeletons are thought to have started out with a non-mineralised exoskeleton which they later mineralised, this makes it difficult to comment on the very early evolution of each lineage's exoskeleton. We do know that in a very short course of time just before the Cambrian period exoskeletons made of various materials – silica, calcium phosphate, calcite, aragonite, and even glued-together mineral flakes – sprang up in a range of different environments. Most lineages adopted the form of calcium carbonate which was stable in the ocean at the time they first mineralissd, and did not change from this mineral morph - even when it became the less favorable.

Some Precambrian (Ediacaran) organisms produced tough but non-mineralized outer shells, while others, such as *Cloudina*, had a calcified exoskeleton, but mineralized skeletons did not become common until the beginning of the Cambrian period, with the rise of the "small shelly fauna". Just after the base of the Cambrian, these miniature fossils become diverse and abundant – this abruptness may be an illusion, since the chemical conditions which preserved the small shellies appeared at the same time. Most other shell forming organisms appear during the Cambrian period, with the Bryozoans being the only calcifying phylum to appear later, in the Ordovician. The sudden appearance of shells has been linked to a change in ocean chemistry which made the calcium compounds of which the shells are constructed stable enough to be precipitated into a shell. However this is unlikely to be a sufficient cause, as the main construction cost of shells is in creating the proteins and polysaccharides required for the shell's composite structure, not in the precipitation of the mineral components. Skeletonisation also appeared at almost exactly the same time that animals started burrowing to avoid predation, and one of the earliest exoskeletons was made of glued-together mineral flakes, suggesting that skeletonisation was likewise a response to increased pressure from predators.

Ocean chemistry may also control which mineral shells are constructed of. Calcium carbonate has two forms, the stable calcite, and the metastable aragonite, which is stable within a reasonable range of chemical environments but rapidly becomes unstable outside this range. When the oceans contain a relatively high proportion of magnesium compared to calcium, aragonite is more stable, but as the magnesium concentration drops, it becomes less stable, hence harder to incorporate into an exoskeleton, as it will tend to dissolve.

With the exception of the mollusks, whose shells often comprise both forms, most lineages use just one form of the mineral. The form used appears to reflect the seawater chemistry – thus which form was more easily precipitated – at the time that the lineage first evolved a calcified skeleton, and does not change thereafter. However, the relative abundance of calcite- and aragonite-using lineages does not reflect subsequent seawater chemistry – the magnesium/calcium ratio of the oceans appears to have a negligible impact on organisms' success, which is instead controlled mainly by how well they recover from mass extinctions. A recently-discovered modern gastropod that lives near deep-sea hydrothermal vents illustrates the influence of both ancient and modern local chemical environments: its shell is made of aragonite, which is found in some of the earliest fossil mollusks; but it also has armor plates on the sides of its foot, and these are mineralized with the iron sulfides pyrite and greigite, which had never previously been found in any metazoan but whose ingredients are emitted in large quantities by the vents.

Artificial "exoskeletons"

Humans have long used armor as an artificial exoskeleton for protection, especially in combat. Exoskeletal machines (also called powered exoskeletons) are also starting to be used for medical and industrial purposes, while powered human exoskeletons are a feature of science fiction writing, but are currently moving into prototype stage.

Orthoses are a limited, medical form of exoskeleton. An orthosis (plural *orthoses*) is a device which attaches to a limb, or the torso, to support the function or correct the shape of that limb or the spine. Orthotics is the field dealing with orthoses, their use, and their manufacture. An orthotist is a person who designs and fits orthoses. A prosthesis (plural *prostheses*) is a device that substitutes for a missing part of a limb. If the prosthesis is a hollow shell and self-carrying, it is exoskeletal. If internal tubes are used in the device and the cover (cosmesis) to create the outside shape is made of a soft, non-carrying material, it is endoskeletal. Prosthetics is the field that deals with prostheses, use, and their manufacture. A prosthetist is a person who designs and fits prostheses.

Parenthetically, the exoskeleton has been used as an architectural model.

Perhaps the first animals to use a naturally-occurring "artificial exoskeleton" were the hermit crabs, the majority of which are obliged constantly to "wear" an empty gastropod shell, in order to protect their soft abdomens.

Chapter- 10

Cat Anatomy

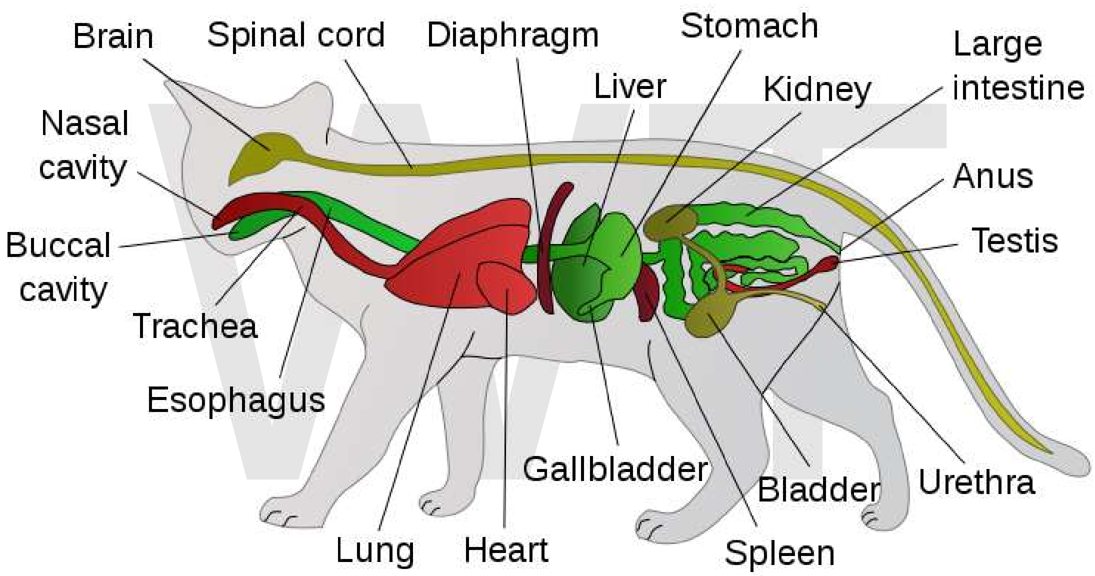


Diagram of the general anatomy of a male cat

General characteristics

Mouth

Cats have highly specialized teeth for the killing of prey and the tearing of meat. The *premolar* and *first molar* together compose the *carnassial pair* on each side of the mouth, which efficiently functions to shear meat like a pair of scissors. While this is present in canids, it is highly developed in felines. The cat's tongue has sharp spines, or *papillae*, useful for retaining and ripping flesh from a carcass. These papillae are small backward-facing hooks that contain keratin which also assist in their grooming.

As facilitated by their oral structures, cats use a variety of vocalizations for communication, including meowing, purring, hissing, growling, squeaking, chirping, clicking, and grunting. Their types of body language: position of ears and tail, relaxation of whole body, kneading of paws, all are indicators of mood.

Ears

Thirty-two individual muscles in each ear allow for a manner of directional hearing; a cat can move each ear independently of the other. Because of this mobility, a cat can move its body in one direction and point its ears in another direction. Most cats have straight ears pointing upward. Unlike dogs, flap-eared breeds are extremely rare (*Scottish Folds* are one such exceptional mutation). When angry or frightened, a cat will lay back its ears to accompany the growling or hissing sounds it makes. Cats also turn their ears back when they are playing or to listen to a sound coming from behind them. The angle of cats' ears is an important clue to their mood.

Legs

Cats, like dogs, are digitigrades. They walk directly on their toes, with the bones of their feet making up the lower part of the visible leg. Cats are capable of walking very precisely because like all felines, they directly register; that is, they place each hind paw (almost) directly in the print of the corresponding forepaw, minimizing noise and visible tracks. This also provides sure footing for their hind paws when they navigate rough terrain. The two back legs make the cat able to leap far distances and fall from high places without getting hurt.

Claws

Close-up of a cat's claw.

Like nearly all members of the family Felidae, cats have retractable claws. In their normal, relaxed position, the claws are sheathed with the skin and fur around the toe pads. This keeps the claws sharp by preventing wear from contact with the ground and allows the silent stalking of prey. The claws on the forefeet are typically sharper than those on the hind feet. Cats can voluntarily extend their claws on one or more paws. They may extend their claws in hunting or self-defense, climbing, "kneading", or for extra traction on soft surfaces (bedspreads, thick rugs, skin, etc.). It is also possible to make a cooperative cat extend its claws by carefully pressing both the top and bottom of the paw. The curved claws may become entangled in carpet or thick fabric, which may cause injury if the cat is unable to free itself.

Most cats have five claws on their front paws, and four or five on their rear paws. Because of an ancient mutation, however, domestic and feral cats are prone to polydactylyism, (particularly in the east coast of Canada and northeast coast of the United States) and may have six or seven toes. The fifth front claw (the *dewclaw*) is proximal to the other claws. There is a protrusion which appears to be a sixth "finger". This special feature of the front paws, on the inside of the wrists, is the carpal pad, also found on the paws of big cats and dogs. It has no function in normal walking, but is thought to be an anti-skidding device used while jumping.

Temperature and heart rate

Two cats curled up together.

The normal body temperature of a cat is between 38 and 39 °C (101 and 102.2 °F). A cat is considered *febrile* (hyperthermic) if it has a temperature of 39.5 °C (103 °F) or greater, or *hypothermic* if less than 37.5 °C (100 °F). For comparison, humans have a normal temperature of approximately 36.8 °C (98.6 °F). A domestic cat's normal heart rate ranges from 140 to 220 beats per minute, and is largely dependent on how excited the cat is. For a cat at rest, the average heart rate usually is between 150 and 180 bpm, about twice that of a human (average 80 bpm).

Skin

Cats possess rather loose skin; this allows them to turn and confront a predator or another cat in a fight, even when it has a grip on them. This is also an advantage for veterinary purposes, as it simplifies injections. In fact, the lives of cats with kidney failure can sometimes be extended for years by the regular injection of large volumes of fluid subcutaneously, which serves as an alternative to dialysis.

The particularly loose skin at the back of the neck is known as the *scruff*, and is the area by which a mother cat grips her kittens to carry them. As a result, cats tend to become quiet and passive when gripped there. This behavior also extends into adulthood, when a male will grab the female by the scruff to immobilize her while he mounts, and to prevent her from running away as the mating process takes place.

This technique can be useful when attempting to treat or move an uncooperative cat. However, since an adult cat is heavier than a kitten, a pet cat should never be carried by the scruff, but should instead have its weight supported at the rump and hind legs, and at the chest and front paws. Often (much like a small child), a cat will lie with its head and front paws over a person's shoulder, and its back legs and rump supported under the person's arm.

Skeleton

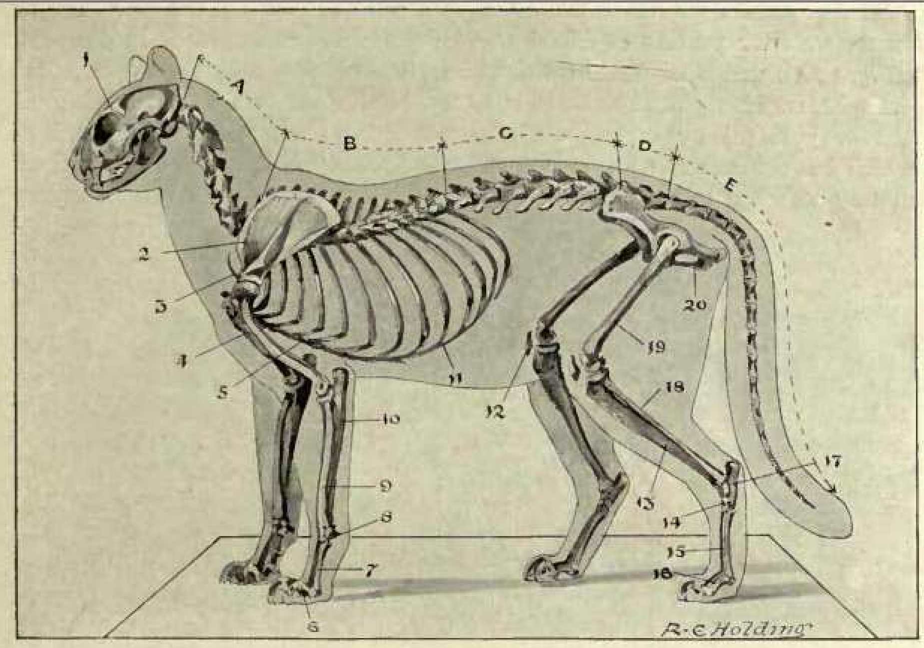


FIG. VIII.—SKELETON OF A CAT.

A. CERVICAL OR NECK BONES (7 in number). *B.* DORSAL OR THORACIC BONES (13 in number, each bearing a rib). *C.* LUMBAR BONES (7 in number). *D.* SACRAL BONES (3 in number). *E.* CAUDAL OR TAIL BONES (19 to 21 in number).

1.—Cranium, or Skull.
2.—Scapula, or Shoulder-blade.
3.—Clavicle, or Collar-bone.
4.—Humerus.
5.—Sternum, or Breast-bone.
6.—Phalanges of the Toes.
7.—Metacarpal Bones.
8.—Carpal or Wrist-bones.
9.—Radius.
10.—Ulna.
11.—Costal cartilages, uniting ends of Ribs to Sternum.
12.—Patella, or Knee-cap.
13.—Tibia.
14.—Tarsal Bones.
15.—Metatarsal Bones.
16.—Phalanges of Hind Toes.
17.—Heel-bone, or "Calcis."
18.—Fibula.
19.—Femur, or Thigh-bone.
20.—Pelvis, or Hip-bone.

Cats have 7 cervical vertebrae like almost all mammals, 13 thoracic vertebrae (humans have 12), 7 lumbar vertebrae (humans have 5), 3 sacral vertebrae (humans have 5 because of their bipedal posture), and, except for Manx cats, 22 or 23 caudal vertebrae (humans have 3 to 5, fused into an internal coccyx). The extra lumbar and thoracic vertebrae account for the cat's enhanced spinal mobility and flexibility, compared to humans. The caudal vertebrae form the *tail*, used by the cat as a counterbalance to the body during quick movements. Cats also have free-floating clavicle bones, which allows them to pass their body through any space into which they can fit their heads.

Muscles

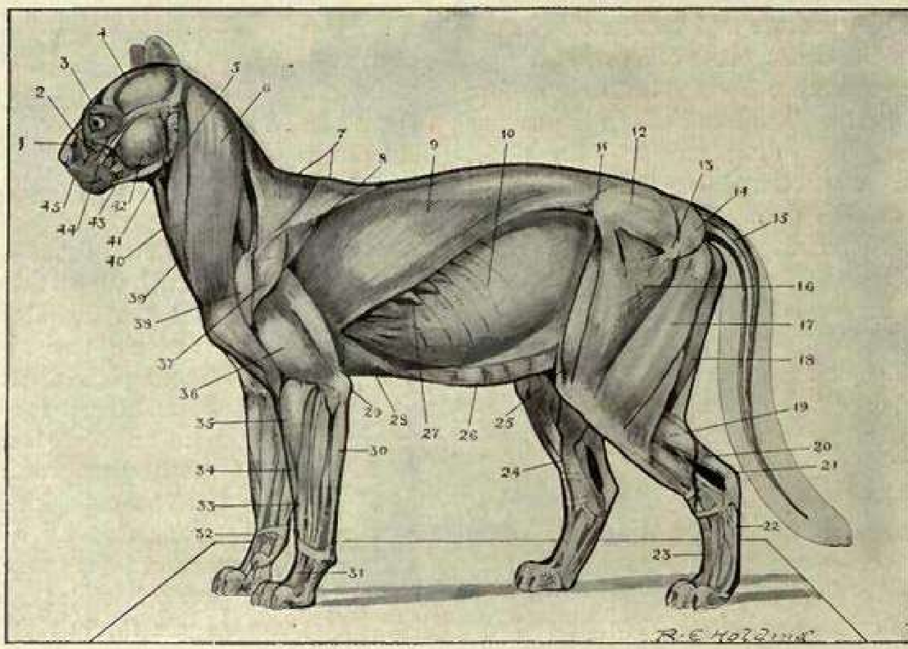


FIG. VII.—SUPERFICIAL MUSCLES OF A CAT.

1.—Maxillaris.
2.—Caninus, or Nasalis.
3.—Orbicularis.
4.—Temporalis.
5.—Mastoideus.
6.—Cephalo-humeral.
7.—Posterior and anterior portions of Trapezius.
8.—Infraspinatus.
9.—Latissimus dorsi.
10.—Great Oblique.
11.—Prominence of Hip-bone.
12.—Gluteus medius.
13.—Prominence of Thigh-bone, or Femur.
14.—Gluteus maximus.
15.—Muscles concerned in the movements of the Tail.
16.—Fascia lata covering deeper muscles.
17.—Biceps femoralis.
18.—Semi-tendinosus.
19.—Gastrocnemius.
20.—External Saphenous Vein.
21.—Point of Heel, or Os Calcis.
22.—Plantar or Flexor Tendons of Sole of Foot.
23.—Extensor Tendons of Toes.
24.—Internal or Inner Saphenous.
25.—Sartorius.
26.—Rectus abdominis.
27.—Serratus magnus.
28.—Pectoralis major.
29.—Elbow, or Olecranon Process of Ulna.
30.—Flexor carpi ulnaris.
31.—Superficial Extensors of Toes.
32.—Annular or Wrist Ligament.
33.—Extensor communis digitorum.
34.—Flexor carpi radialis.
35.—Extensor carpi radialis.
36.—Triceps.
37.—Scapular deltoid.
38.—Acromion deltoid.
39.—Mastoideus.
40.—Sterno-hyoid.
41.—Parotid Gland.
42.—Masseter Muscle.
43.—External Maxillary Vein.
44.—Zigomaticus.
45.—Zigomaticus labialis.

Abdominal

External Abdominal Oblique

This muscle's origin is the lumbodorsal fascia and ribs.

- Insertion: pubis and linea alba (via aponeurosis)
- Action: compresses abdominal contents; laterally flexes and rotates vertebral column

Internal Abdominal Oblique

This muscle's origin is the lumbodorsal fascia and pelvis.

- Insertion: linea alba (via aponeurosis)

- Action: compresses abdominal contents; laterally flexes and rotates vertebral column

Transversus Abdominis

This muscle is the innermost abdominal muscle.

- Origin: second sheet of the lumbodorsal fascia and the pelvic girdle
- Insertion: linea alba
- Action: compressor of the abdomen

Rectus Abdominis

To see this muscle, first remove the extensive aponeurosis situated on the ventral surface of the cat. Its fibers are extremely longitudinal, on each side of the linea alba. It is also traversed by the inscriptiones tendinae, or what others called *myosepta*.

Deltoid

The **deltoid muscles** lie just lateral to the trapezius muscles, originating from several fibers spanning the clavicle and scapula, converging to insert at the humerus. Anatomically, there are only two deltoids in the cat, the *acromiodeltoid* and the *spinodeltoid*. However, to conform to human anatomy standards, the clavobrachialis is now also considered a deltoid and is commonly referred to as the *clavodeltoid*.

Acromiodeltoid

The acromiodeltoid is the shortest of the deltoid muscles. It lies lateral to (to the side of) the clavodeltoid, and in a more husky cat it may only be seen by lifting or reflecting the clavodeltoid. It originates at the acromion process and inserts at the deltoid ridge. When contracted, it raises and rotates the humerus outward.

Spinodeltoid

A stout and short muscle lying posterior to the acromiodeltoid. It lies along the lower border of the scapula, and it passes through the upper arm, across the upper end of muscles of the upper arm. It originates at the spine of the scapula and inserts at the deltoid ridge. Its action is to raise and rotate the humerus outward.

Head

Masseter

The **Masseter** is a great, powerful, and very thick muscle covered by a tough, shining fascia lying ventral to the zygomatic arch, which is its origin. It inserts into the posterior half of the lateral surface of the mandible. Its action is the elevation of the mandible (closing of the jaw).

Temporalis

The **temporalis** is a great mass of mandibular muscle, and is also covered by a tough and shiny fascia. It lies dorsal to the zygomatic arch and fills the temporal fossa of the skull. It arises from the side of the skull and inserts into the coronoid process of the mandible. It too, elevates the jaw.

Integumental

The two main integumentary muscles of a cat are the *platysma* and the *cutaneous maximus*. The *cutaneous maximus* covers the dorsal region of the cat and allows it to shake its skin. The *platysma* covers the neck and allows the cat to stretch the skin over the pectoralis major and deltoid muscles.

Neck and back

Rhomboideus

The Rhomboideus is a thick, large muscle below the Trapezius muscles. It extends from the vertebral border of the scapula to the mid-dorsal line.

- Origin: neural spines of the first four thoracic vertebrae
- Insertion: vertebral border of the scapula
- Action: draws the scapula to the dorsal

Rhomboideus Capitis

The Rhomboideus capitis is the most cranial of the deeper muscles. It is underneath the Clavotrapezius.

- Origin: superior nuchal line
- Insertion: scapula

Splenius

The Splenius is the most superficial of all the deep muscles. It is a thin, broad sheet of muscle underneath the Clavotrapezius and deflecting it. It is crossed also by the Rhomboideus capitis. Its origin is the mid-dorsal line of the neck and fascia. The insertion is the superior nuchal line and atlas. It raises or turns the head.

Serratus Ventralis

The Serratus Ventralis is exposed by cutting the wing-like Latissimus Dorsi. The said muscle is covered entirely by adipose tissue. The origin is from the first nine or ten ribs and from part of the cervical vertebrae. The insertion is the vertebral border of the scapula. It draws scapula forward, backward, and against the body.

Serratus Dorsalis

The Serratus Dorsalis is medial to both the scapula and the Serratus Ventralis.

- Origin: apoeurosis following the length of the mid-dorsal line
- Insertion: dorsal portion of the last ribs
- Action: draws ribs cranial

Intercostals

The Intercostals are a set of muscles sandwiched between the ribs. They interconnect ribs, and are therefore the primary respiratory skeletal muscles. They are divided into the *external* and the *internal subscapularis*. The origin and insertion are in the ribs. The intercostals pull the ribs backwards or forwards.

Caudofemoralis

The Caudofemoralis is a muscle found in the pelvic limb and is unique to the felids (cats). The Caudofemoralis acts to flex the tail laterally to its respective side when the pelvic limb is bearing weight. When the pelvic limb is lifted off the ground, contraction of the Caudofemoralis causes the limb to abduct and the shank to extend by extending the hip joint.

Pectoral

Pectoantebrachialis

Pectoantebrachialis muscle is just one-half inch wide, and is the most superficial in the pectoral muscles.

- Origin: manubrium of the sternum
- Insertion: in a flat tendon on the fascia of the proximal end of the ulna
- Action: draws the arm towards the chest

Pectoralis Major

The pectoralis major, also called *pectoralis superficialis*, is a broad triangular portion of the pectoralis muscle which is immediately below the pectoantebrachialis. It is actually smaller than the pectoralis minor muscle.

- Origin: sternum and median ventral raphe
- Insertion: humerus
- Action: draws the arm towards the chest

Pectoralis Minor

The pectoralis minor muscle is larger than the Pectoralis major. However, most of its anterior border is covered by the pectoralis major.

- Origin: ribs 3-5
- Insertion: coracoid process of scapula
- Action: tipping of the scapula, elevation of ribs 3-5

Xiphihumeralis

The most posterior, flat, thin, and long strip of pectoral muscle is the Xiphihumeralis. It is a band of parallel fibers that is found felines but not in humans. Its origin is the Xiphoid Process of the sternum. The insertion is the humerus.

Trapezius

In the cat there are three thin flat muscles that cover the back, and to a lesser extent, the neck. They pull the scapula toward the mid-dorsal line, anteriorly, and posteriorly.

Clavotrapezius

The most anterior of the trapezius muscles, it is also the largest. Its fibers run obliquely to the ventral surface.

- Origin: superior nuchal line and median dorsal line
- Insertion: clavicle
- Action: draws the clavicle dorsal and towards the head

Acromiotrapezius

Acromiotrapezius is the middle trapezius muscle. It covers the dorsal and lateral surfaces of the scapula.

- Origin: neural spines of the cervical vertebrae

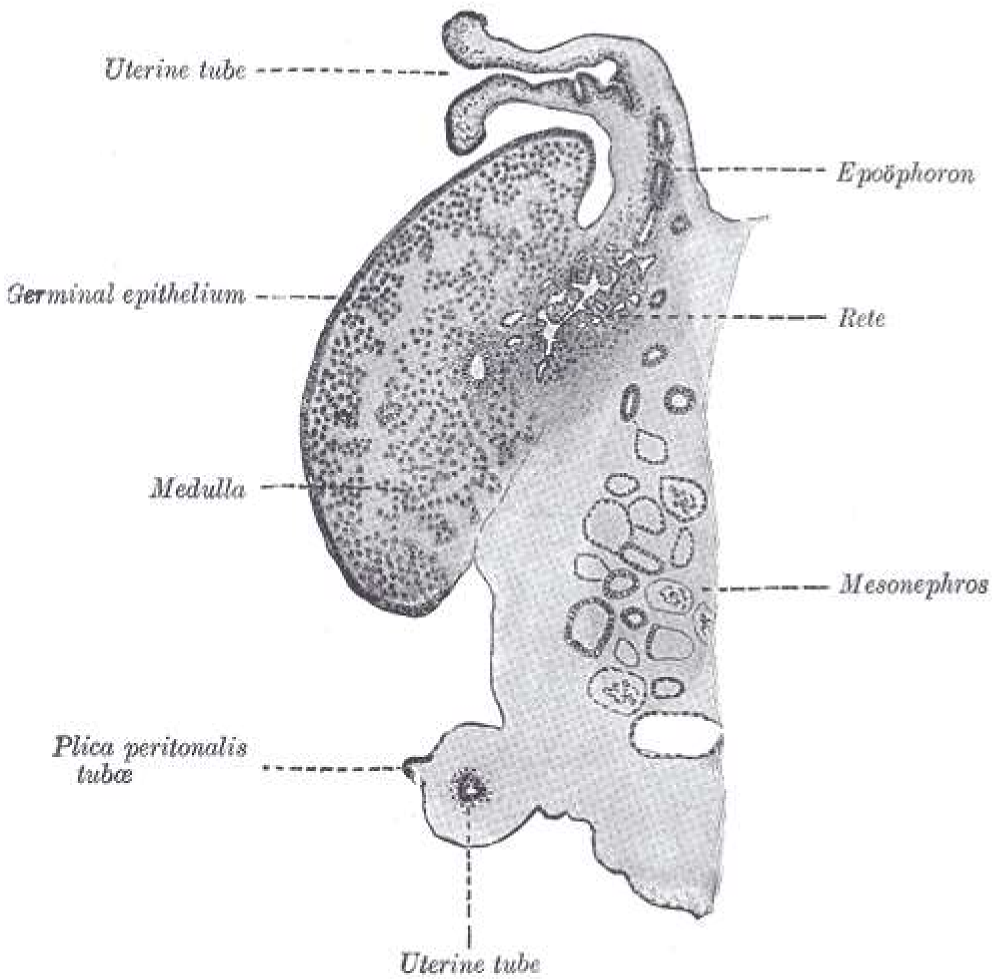
- Insertion: in the metacromion process and fascia of clavotrapezius
- Action: draws the scapula to the dorsal, and holds the two scapula together

Spinotrapezius

Spinotrapezius, also called *thoracic trapezius*, is the most posterior of the three. It is triangular shaped. Posterior to the acromiotrapezius and overlaps latissimus dorsi on the front.

- Origin: neural spines of the thoracic vertebrae
- Insertion: scapular fascia
- Action: draws the scapula to the dorsal and caudal regions

Genitalia



Longitudinal plane section of ovary of cat embryo of 9.4 cm. long. Seen is the cat version of uterine tube, epoophoron, germinal epithelium, rete, Medulla of ovary, mesonephros, plica peritonalis tubae

Female genitalia

In the female cat, the genitalia include:

- Two gonads
- Uterus
- Vagina
- Genital passages
- Teats

Together with the vulva, the vagina of cat is involved in mating and provides a channel for newborns during *parturition*, or birth. The vagina is long and wide. Genital passages are the oviducts of the cat. They are short, narrow, and not very sinuous.

Chapter- 11

Horn (Anatomy)

A goat with spiral horns

A **horn** is a pointed projection of the skin on the head of various animals, consisting of a covering of horn (keratin and other proteins) surrounding a core of living bone. True horns are found mainly among the ruminant artiodactyls, in the families Antilocapridae (pronghorn) and Bovidae (cattle, goats, antelope etc.). One pair of horns is usual, but two pairs occur in a few wild species and in a few domesticated breeds of sheep. Partial or deformed horns in livestock are called *scurs*.

Horns usually have a curved or spiral shape, often with ridges or fluting. In many species only males have horns. Horns start to grow soon after birth, and continue to grow throughout the life of the animal (except in pronghorns, which shed the outer layer annually, but retain the bony core). Similar growths on other parts of the body are not usually called horns, but spurs, claws or hoofs, depending on the part of the body on which they occur.

Other hornlike growths

The term "horn" is also popularly applied to other hard and pointed features attached to the head of animals in various other families:

- Giraffidae: Giraffes have one or more pairs of bony bumps on their heads, called ossicones. These are covered with furred skin.
- Cervidae: Most deer have antlers, which are not true horns. When fully developed, antlers are dead bone without a horn or skin covering; they are borne only by adults (usually males) and are shed and regrown each year.
- Rhinocerotidae: The "horns" of rhinoceroses are made of keratin and grow continuously, but do not have a bone core.
- Ceratopsidae: The "horns" of the *Triceratops* were extensions of its skull bones although debate exists over whether they had a keratin covering.
- Horned lizards (*Phrynosoma*): These lizards have horns on their heads which have a hard keratin covering over a bony core, like mammalian horns.
- Insects: Some insects (such as rhinoceros beetles) have horn-like structures on the head or thorax (or both). These are pointed outgrowths of the hard chitinous exoskeleton. Some (such as stag beetles) have greatly enlarged jaws, also made of chitin.
- Canidae: Golden jackals are known to occasionally develop a horny growth on the skull, which is associated with magical powers in south-eastern Asia.

Many mammal species in various families have tusks, which often serve the same functions as horns, but are in fact oversize teeth. These include the Moschidae (Musk deer, which are ruminants), Suidae (Wild Boars), Proboscidea (Elephants), Monodontidae (Narwhals) and Odobenidae (Walruses).

A Hebridean sheep with one horn on one side and two on the other.

Polled animals or *pollards* are those of normally-horned (mainly domesticated) species whose horns have been removed, or which have not grown. In some cases such animals have small horny growths in the skin where their horns would be – these are known as *scurs*.

On humans

Cutaneous horns are the only examples of horns growing on people. They are believed to be caused by exposure to radiation. They are most often benign growths and can be removed by a razor.

Cases of people with *naturally* growing horns have been historically described, sometimes propagated to mythical status. And there are several cases of photographic evidence to prove the phenomenon with modern science. There are human cadaveric specimens that show outgrowings, but these are instead classified as osteomas or other excrescences. Theoretically, there may be children born with horns which are corrected with early surgical intervention. The phenomenon of humans with horns has been observed in countries lacking such advanced medicine. There are even people living now, several in China, with cases of cutaneous horns, most common in the elderly.

Some people, notably The Enigma, have horn implants; that is, they have implanted silicone beneath the skin as a form of body modification.

Animal uses of horns

Both male and female African buffaloes bear horns

Animals have a variety of uses for horns and antlers, including defending themselves from predators and fighting members of their own species for territory, dominance or mating priority. Horns are usually present only in males but in some species, females too may possess horns. It has been theorized by researchers that taller species living in the open are more visible from longer distances and more likely to benefit from horns to defend themselves against predators. Female bovids that are not hidden from predators due to their large size or open Savannah like habitat are more likely to bear horns than small or camouflaged species.

In addition, horns may be used to root in the soil or strip bark from trees. In animal courtship many use horns in displays. For example, the male blue wildebeest reams the bark and branches of trees to impress the female and lure her into his territory. Some animals with true horns use them for cooling. The blood vessels in the bony core allow the horns to function as a radiator.

Human uses of horns

Water buffalo horn used as a hammer with cleaver to cut fish in southeast China.

- Horned animals are sometimes hunted so their mounted head or horns can be displayed as a hunting trophy or as decorative objects. This practice can be considered controversial, especially as some animals are threatened or endangered due to reduced populations partially from pressures of such hunting.

- Some cultures use bovid horns as musical instruments, for example the shofar. These have evolved into brass instruments in which, unlike the trumpet, the bore gradually increases in width through most of its length — that is to say, it is conical rather than cylindrical. These are called horns, though now made of metal.

- Drinking horns are bovid horns removed from the bone core, cleaned and polished and used as drinking vessels. It has been suggested that the shape of a natural horn was also the model for the rhyton, a horn-shaped drinking vessel.

- Powder horns were originally bovid horns fitted with lids and carrying straps, used to carry gunpowder. Powder flasks of any material may be referred to as powder horns.

- Antelope horns are used in traditional Chinese medicine.

- Horns consist of keratin, and the term "horn" is used to refer to this material, sometimes including similarly solid keratin from other parts of animals, such as hoofs. Horn may be used as a material in tools, furniture and decoration, among other uses. In these applications, horn is valued for its hardness, and it has given rise to the expression *hard as horn*. Horn is somewhat thermoplastic and (like tortoiseshell) was formerly used for many purposes where plastic would now be used. Horn may be used to make glue.

- Horn bows are bows made from a combination of horn, sinew and usually wood. These materials allow more energy to be stored in a short bow than wood alone.

- Ivory comes from the teeth of animals, not horns.

- "Horn" buttons are usually made from deer antlers, not true horn.

Chapter- 12

Metamorphosis

A dragonfly in its final moult, undergoing metamorphosis from its nymph form to an adult.

Metamorphosis is a biological process by which an animal physically develops after birth or hatching, involving a conspicuous and relatively abrupt change in the animal's body structure through cell growth and differentiation. Some insects, amphibians, molluscs, crustaceans, Cnidarians, echinoderms and tunicates undergo metamorphosis, which is usually accompanied by a change of habitat or behavior.

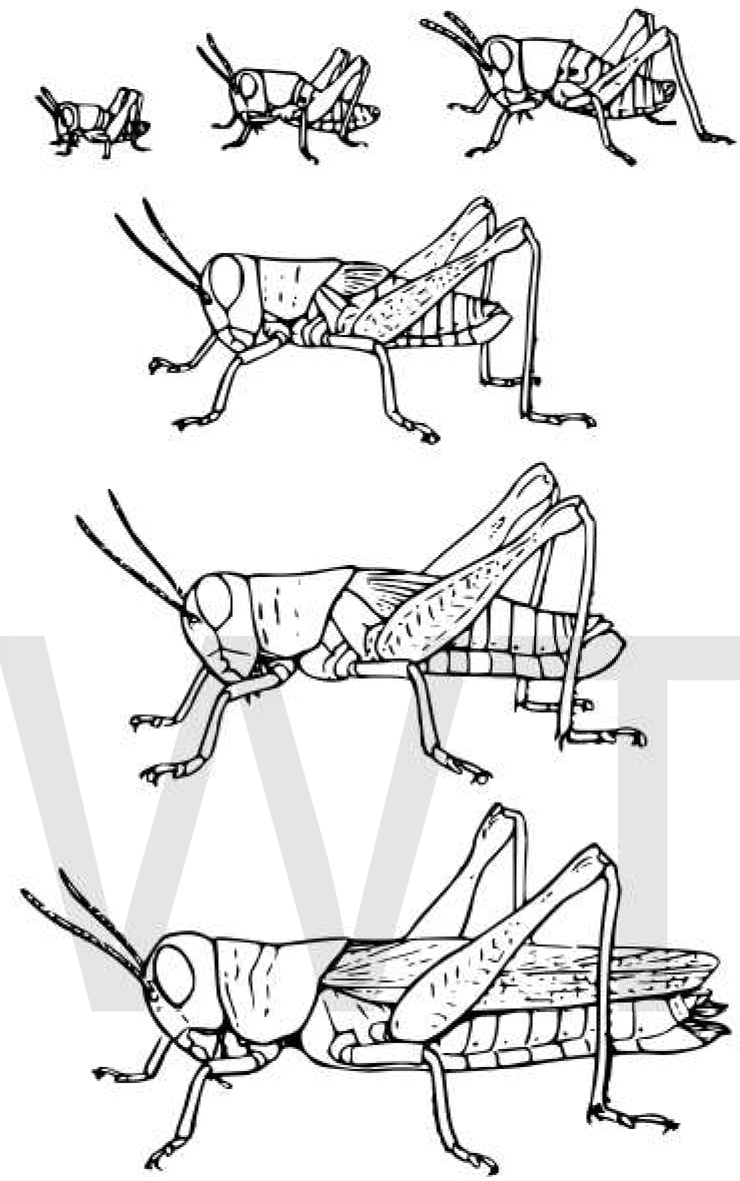
Scientific usage of the term is exclusive, and is not applied to general aspects of cell growth, including rapid growth spurts. References to "metamorphosis" in mammals are imprecise and only colloquial, but historically idealist ideas of transformation and monadology, as in Goethe's *Metamorphosis of Plants*, influenced the development of ideas of evolution.

Etymology

The word "metamorphosis" derives from Greek *μεταμόρφωσις*, "transformation, transforming", from *μετα-* (*meta-*), "change" + *μορφή* (*morphe*) "form".

Insect metamorphosis

All insects in the Pterygota undergo a marked change in form, or metamorphosis, from immature to adult. These insects either have hemimetabolous development, and undergo an incomplete or partial metamorphosis, or holometabolous development, which undergo a complete metamorphosis, including a pupal or resting stage between the larval and adult forms.



Incomplete metamorphosis in the grasshopper with different instar nymphs

In hemimetabolous insects, immature stages are called nymphs. Development proceeds in repeated stages of growth and ecdysis (moulting); these stages are called instars. The juvenile forms closely resemble adults, but are smaller and lack adult features such as wings and genitalia. This process is also known as "partial" or "incomplete" metamorphosis. The differences between nymphs in different instars are small, often just differences in body proportions and the number of segments, although external wing buds will form in later instars.

In holometabolous insects, immature stages are called larvae, and differ markedly from the adults. Insects which undergo holometabolism pass through a larval stage, then enter an inactive state called pupa, or chrysalis, and finally emerge as adults. This process is called "complete" metamorphosis. Whilst inside the pupa, the insect will excrete digestive juices, to destroy much of the larva's body, leaving a few cells intact. Some of the remaining cells will begin the growth of the adult, using the nutrients from the broken down larva. This process of cell death is called histolysis, and cell regrowth histogenesis.

According to latest researches, adult Manduca sexta is able to retain the behaviour learned as a caterpillar.

Many observations have indicated that programmed cell death plays a considerable role during physiological processes of multicellular organisms, particularly during embryogenesis and metamorphosis.

Pieris rapae larva

Pieris rapae pupa

Pieris rapae pupa, ready to hatch.

A *Pieris rapae* adult

Hormonal control

Insect growth and metamorphosis are controlled by hormones synthesized by endocrine glands near the front of the body.

Neurosecretory cells in an insect's brain secrete a hormone, the prothoracicotropic hormone (PTTH) that activates prothoracic glands, which secrete a second hormone, usually Ecdysone (a ecdysteroid), that induces ecdysis.

PTTH also stimulates the corpora allata, a retrocerebral organ, to produce juvenile hormone (JH), which prevents the development of adult characteristics during ecdysis. In holometabolous insects, molts between larval instars have a high level of JH, the moult to the pupal stage has a low level of JH, and the final, or imaginal, molt has no JH present at all.

Amphibian metamorphosis

Just before metamorphosis, only 24 hours are needed to reach the stage in the next picture

Almost functional common frog with some remains of the gill sac and a not fully developed jaw

In typical amphibian development, eggs are laid in water and larvae are adapted to an aquatic lifestyle. Frogs, toads, and newts all hatch from the egg as larvae with external gills. Afterwards, newt larvae start a predatory lifestyle, while tadpoles mostly scrape food off surfaces with their horny tooth ridges.

Metamorphosis in amphibians is regulated by thyroxin concentration in the blood, which stimulates metamorphosis, and prolactin, which counteracts its effect. Specific events are dependent on threshold values for different tissues. Because most embryonic development is outside the parental body, development is subject to many adaptations due to specific ecological circumstances. For this reason tadpoles can have horny ridges for teeth, whiskers, and fins. They also make use of the lateral line organ. After metamorphosis, these organs become redundant and will be resorbed by controlled cell death, called apoptosis. The amount of adaptation to specific ecological circumstances is remarkable, with many discoveries still being made.

Frogs and toads

With frogs and toads, the external gills of the newly hatched tadpole are covered with a gill sac after a few days, and lungs are quickly formed. Front legs are formed under the gill sac, and hindlegs are visible a few days later. Following that there is usually a longer stage during which the tadpole lives off a vegetarian diet. Tadpoles use a relatively long, spiral‐shaped gut to digest that diet.

Rapid changes in the body can then be observed as the lifestyle of the frog changes completely. The spiral‐shaped mouth with horny tooth ridges is resorbed together with the spiral gut. The animal develops a big jaw, and its gills disappear along with its gill sac. Eyes and legs grow quickly, a tongue is formed, and all this is accompanied by associated changes in the neural networks (development of stereoscopic vision, loss of the lateral line system, etc.) All this can happen in about a day, so it is truly a metamorphosis. It isn't until a few days later that the tail is reabsorbed, due to the higher thyroxin concentrations required for tail resorption.

Newts

The large external gills of the crested newt

In newts, there is no true metamorphosis because newt larvae already feed as predators and continue doing so as adults. Newts' gills are never covered by a gill sac and will be resorbed only just before the animal leaves the water. Just as in tadpoles, their lungs are functional early, but newts don't make as much use of them as tadpoles do. Newts often have an aquatic phase in spring and summer, and a land phase in winter. For adaptation to a water phase, prolactin is the required hormone, and for adaptation to the land phase, thyroxin. External gills do not return in subsequent aquatic phases because these are completely absorbed upon leaving the water for the first time.

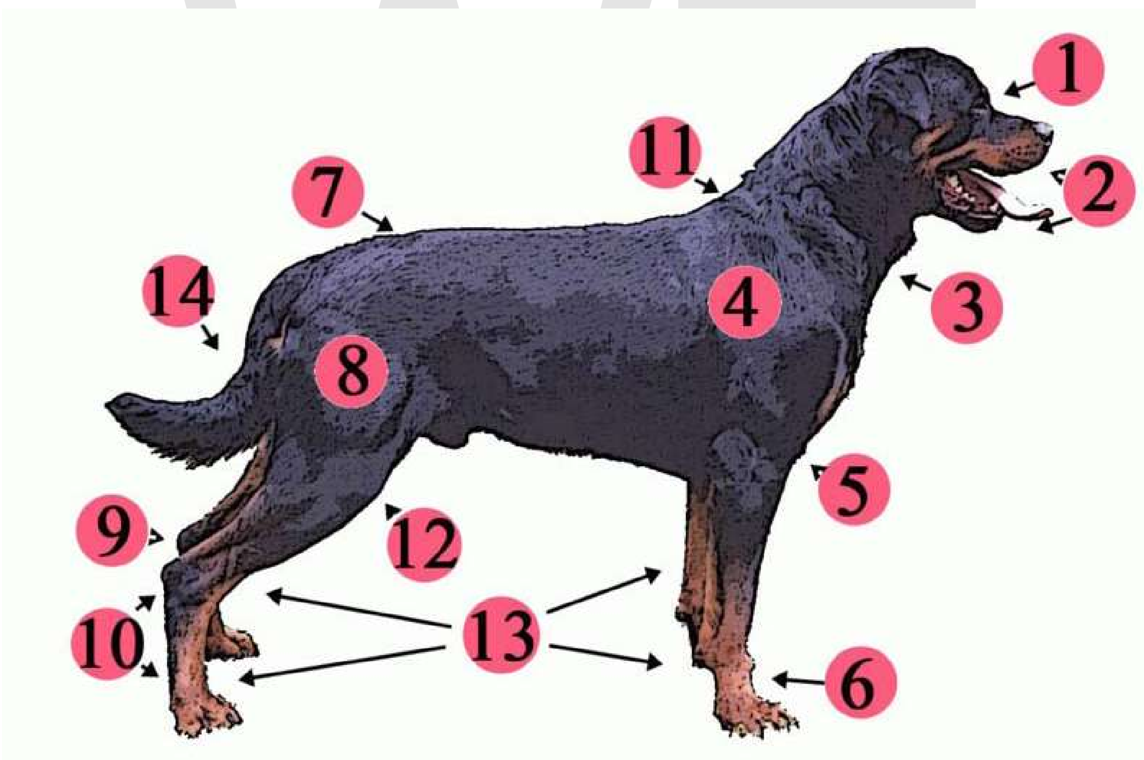
Metamorphosis in fish and invertebrate aquatic animals

Little known is that also fish, i.e. bony fish, undergo metamorphosis. Fish metamorphosis is typically under strong control by thyroid hormone. Examples include the agnatha, salmon, and lamprey, which must change from a freshwater to saltwater lifestyle (diadromous). Additionally, the flatfish begins its life bilaterally symmetrical, and one eye must move to join the other side of the fish in its adult form. The European eel has a number of metamorphoses, from the larval stage to the leptocephalus stage, then a quick outspoken metamorphosis from leptocephalus to glass eel at the edge of the continental shelf (8 days for Japanese eel), two months at the border of fresh and salt water the glass eel undergoes a quick metamorphosis into elver, which then has a long stage of growth followed by a more gradual metamorphosis to the migrating phase. In the pre-adult fresh water stage it also has phenotypic plasticity because fish eating eels develop very wide mandibles, making the head look blunt. Leptocephali are very common and a common phase for all Elopomorpha (Tarpon- and eellike fishes). Most bony fishes undergo metamorphosis after absorption of the yolk sac because after that phase they need to be able to feed for themselves.

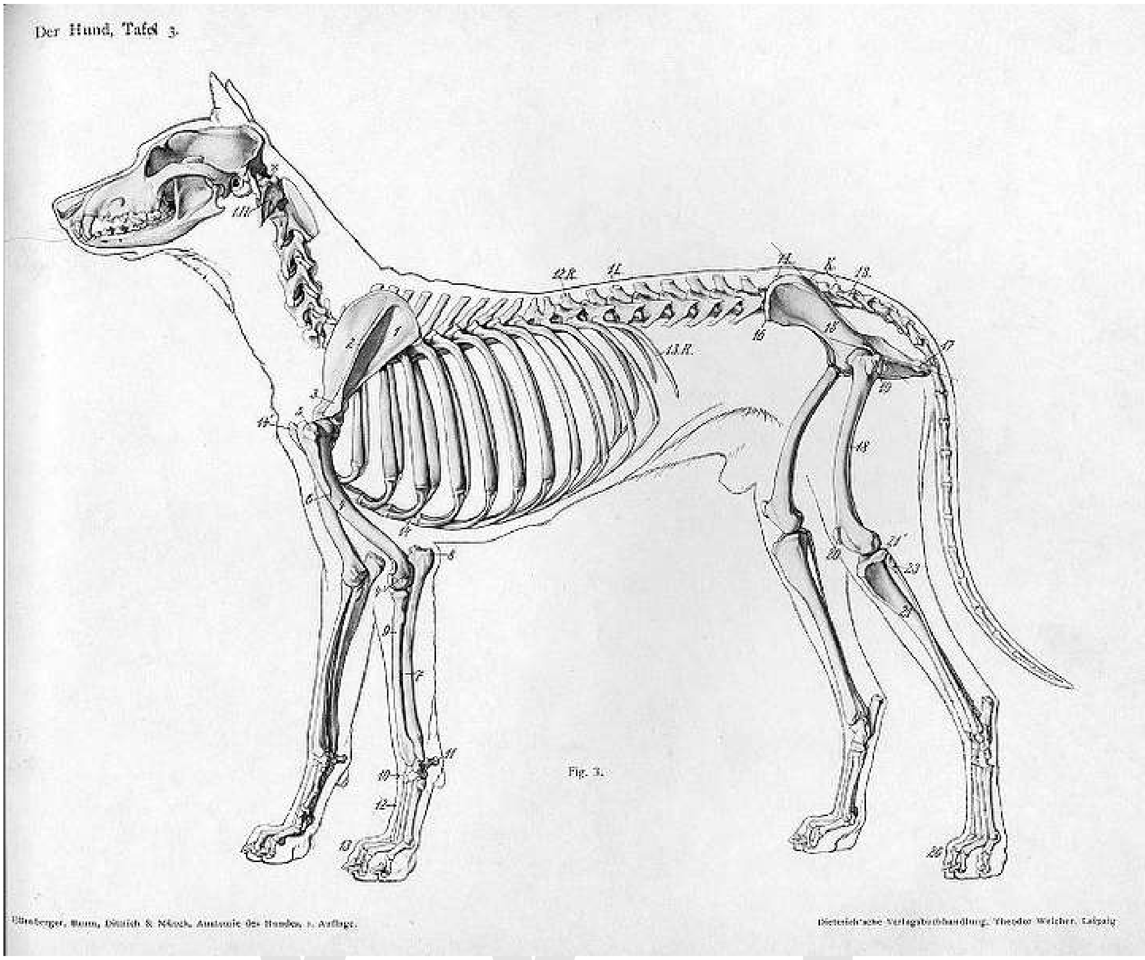
Chapter- 13

Dog Anatomy

Dog anatomy includes the same internal structures that are in humans. Details of structures vary tremendously from breed to breed, more than in any other animal species, wild or domesticated, as dogs vary from the tiny Chihuahua to the giant Irish Wolfhound.



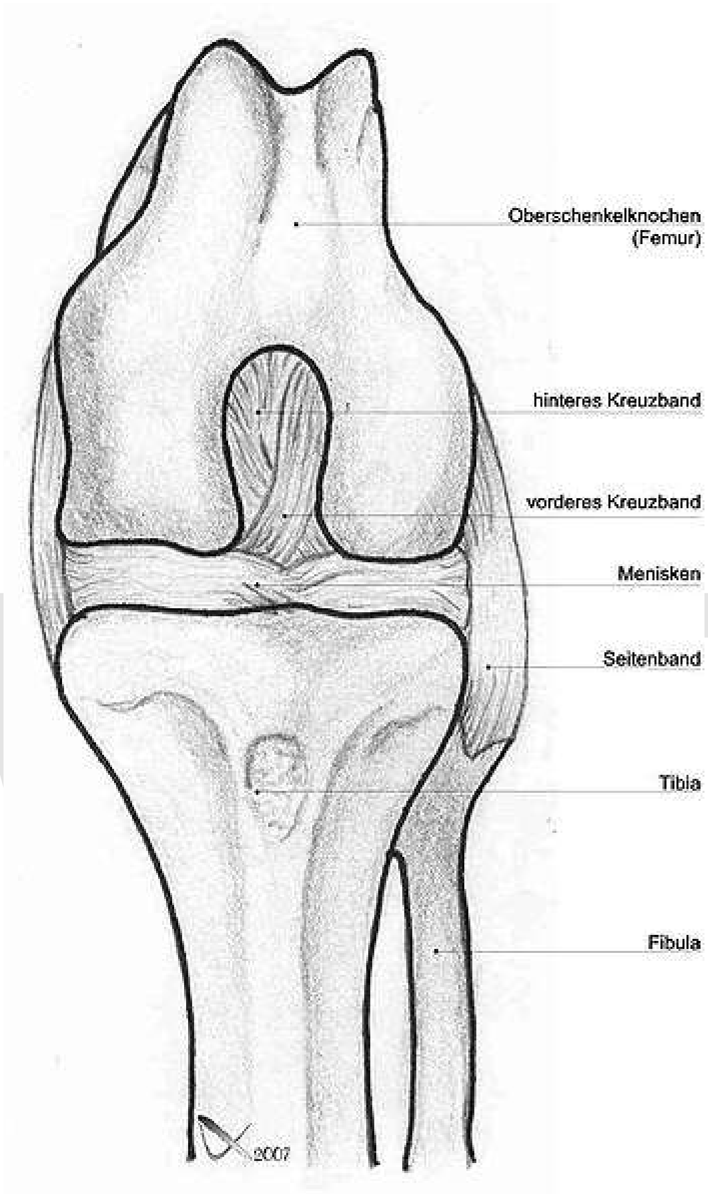
Croup 8.Leg (thigh and hip) 9.Hock 10.Hind feet 11.Withers 12.Stifle 13.Paws 14.Tail



Skeleton of a domestic dog

Skull of a dog

Physical characteristics



Dog knee

Like most predatory mammals, the dog has powerful muscles, a cardiovascular system that supports both sprinting and endurance, and teeth for catching, holding, and tearing.

The dog's ancestral skeleton provided the ability to run and leap. Their legs are designed to propel them forward rapidly, leaping as necessary, to chase and overcome prey. Consequently, they have small, tight feet, walking on their toes; their rear legs are fairly rigid and sturdy; the front legs are loose and flexible, with only muscle attaching them to the torso.

Although selective breeding has changed the appearance of many breeds, all dogs retain the basic ingredients from their distant ancestors. Dogs have disconnected shoulder bones (lacking the collar bone of the human skeleton) that allow a greater stride length for running and leaping. They walk on four toes, front and back, and have vestigial dewclaws (dog thumbs) on their front legs and sometimes on their rear legs.When a dog has extra dewclaws in addition to the usual one on each front leg, the dog is said to be "double dewclawed".

There is some debate about whether a dewclaw helps dogs to gain traction when they run because, in some dogs, the dewclaw makes contact when they are running and the nail on the dewclaw often wears down in the same way that the nails on their other toes do, from contact with the ground. However, in many dogs the dewclaws never make contact with the ground; in this case, the dewclaw's nail never wears away, and it is then often trimmed to keep it to a safe length.

The dewclaws are not dead appendages. They can be used to lightly grip bones and other items that dogs hold with the paws. However, in some dogs these claws may not appear to be connected to the leg at all except by a flap of skin; in such dogs the claws do not have a use for gripping as the claw can easily fold or turn.

There is also some debate as to whether dewclaws should be surgically removed. The argument for removal states that dewclaws are a weak digit, barely attached to the leg, so that they can rip partway off or easily catch on something and break, which can be extremely painful and prone to infection. Others say the pain of removing a dewclaw is far greater than any other risk. For this reason, removal of dewclaws is illegal in many countries. There is, perhaps, an exception for hunting dogs, who can sometimes tear the dewclaw while running in overgrown vegetation. If a dewclaw is to be removed, this should be done when the dog is a puppy, sometimes as young as 3 days old, though it can also be performed on older dogs if necessary (though the surgery may be more difficult then). The surgery is fairly straight-forward and may even be done with only local anesthetics if the digit is not well connected to the leg. Unfortunately many dogs can't resist licking at their sore paws following the surgery, so owners need to remain vigilant.

In addition, for those dogs whose dewclaws make contact with the ground when they run, it is possible that removing them could be a disadvantage for a dog's speed in running and changing of direction, particularly in performance dog sports such as dog agility.

The dog's ancestor was about the size of a Dingo, and its skeleton took about 10 months to mature. Today's toy breeds have skeletons that mature in only a few months, while giant breeds such as the Mastiffs take 16 to 18 months for the skeleton to mature. Dwarfism has affected the proportions of some breeds' skeletons, as in the Basset Hound.

Knowledge of basic anatomy also helps when competing in dog shows or contests.

Size

Researchers have identified a particular piece of genetic material that is common to every small-dog breed and, in turn, is probably responsible for making them tiny. The study, published in 2007, found a regulatory sequence (not a gene) next to the gene IGF1; together the gene and regulatory sequence together are known as a haplotype that "is a major contributor to body size in all small dogs." Medium and large size dogs do not usually have the regulatory sequence, although the small-size sequence was found in the Rottweiler breed. The study included 3,241 dogs from 143 breeds. The researchers concluded the genetic instructions to make dogs small must be at least 12,000 years old, and it is not found in wolves. Another study has shown that lap dogs (small dogs) are among the oldest dog types.

Modern dog breeds show more variation in size, appearance, and behavior than any other domestic animal. Within the range of extremes, dogs generally share attributes with their wild ancestors, the wolves. Dogs are predators and scavengers, possessing sharp teeth and strong jaws for attacking, holding, and tearing their food. Although selective breeding has changed the appearance of many breeds, all dogs retain basic traits from their distant ancestors. Like many other predatory mammals, the dog has powerful muscles, fused wristbones, a cardiovascular system that supports both sprinting and endurance, and teeth for catching and tearing.

Sight

A Greyhound, one of many breeds of sighthound

Like most mammals, dogs are dichromats and have color vision equivalent to red-green color blindness in humans. Different breeds of dogs have different eye shapes and dimensions, and they also have different retina configurations. Dogs with long noses have a "*visual streak*" which runs across the width of the retina and gives them a very wide field of excellent vision, while those with short noses have an "*area centralis*" — a central patch with up to three times the density of nerve endings as the *visual streak* — giving them detailed sight much more like a human's.

Some breeds, particularly the sighthounds, have a field of vision up to 270° (compared to 180° for humans), although broad-headed breeds with short noses have a much narrower field of vision, as low as 180°.

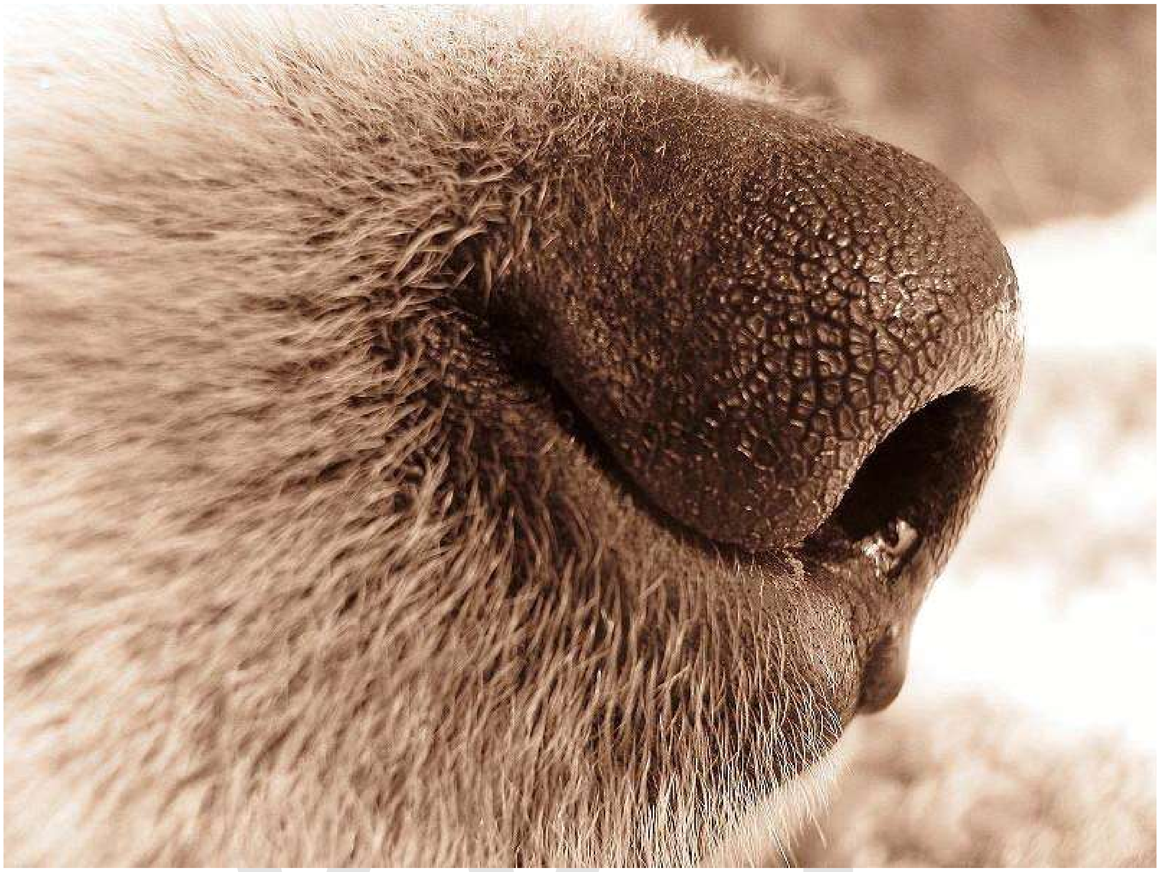
Hearing

According to hypertextbook.com, the frequency range of dog hearing is approximately 40 Hz to 60,000 Hz. Dogs detect sounds as low as the 16 to 20 Hz frequency range (compared to 20 to 70 Hz for humans) and above 45 kHz (compared to 13 to 20 kHz for humans), and in addition have a degree of ear mobility that helps them to rapidly pinpoint the exact location of a sound. Eighteen or more muscles can tilt, rotate and raise or lower a dog's ear. Additionally, a dog can identify a sound's location much faster than a human can, as well as hear sounds up to four times the distance that humans are able to. Those with more natural ear shapes, like those of wild canids like the fox, generally hear better than those with the floppier ears of many domesticated species.

Smell

Scent hounds, especially the Bloodhound, are bred for their keen sense of smell.

Dogs have nearly 220 million smell-sensitive cells over an area about the size of a pocket handkerchief (compared to 5 million over an area the size of a postage stamp for humans). According to nhm.org, dogs can sense odours at concentrations nearly 100 million times lower than humans can. According to Dummies.com, the percentage of the dog's brain that is devoted to analyzing smells is actually 40 times larger than that of a human. Some dog breeds have been selectively bred for excellence in detecting scents, even compared to their canine brethren.



The highly sensitive nose of a dog.

Coat

Domestic dogs often display the remnants of counter-shading, a common natural camouflage pattern. The general theory of countershading is that an animal that is lit from above will appear lighter on its upper half and darker on its lower half where it will usually be in its own shade. This is a pattern that predators can learn to watch for. A countershaded animal will have dark coloring on its upper surfaces and light coloring below. This reduces the general visibility of the animal. One reminder of this pattern is that many breeds will have the occasional "blaze", stripe, or "star" of white fur on their chest or undersides.

Dogs diverged from a now-extinct Asian wolf between 12,000 and 15,000 years ago, according to recent DNA studies. In that time, the long nose and heavy grey-colored double coat of the wolf has changed into the wide variety of dog shapes and coats and colors seen today. The change was due at first to genetic changes that occurred as the original dogs learned to tolerate the presence of humans, as shown in the research on foxes by Dmitri Belyaev in his Farm-Fox Experiment. The research found that a genetic change to tameness brought along other unexpected changes as well; one notable change was in the coats, changed from a typical fox coat to a spotted coat resembling a dog's coat. As ancient dogs learned to live near humans and became less like wolves, their appearance changed as well, long before any selective breeding was done by people.

A Stanford University School of Medicine study published in Science in October, 2007 found the genetics that explain coat colors in other mammals such as in horse coats and in cat coats, did not apply to dogs. The project took samples from 38 different breeds to find the gene (a beta defensin gene) responsible for dog coat color. One version produces yellow dogs, and a mutation produces black. All dog coat colors are modifications of black or yellow. For example, the white in white miniature schnauzers is a cream color, not albinism (a genotype of e/e at MC1R.)

Modern dog breeds exhibit a diverse array of fur coats, including dogs without fur, such as the Mexican Hairless Dog. Dog coats vary in texture, color, and markings, and a specialized vocabulary has evolved to describe each characteristic.

Tail

There are many different shapes for dog tails: straight, straight up, sickle, curled, cork-screw. In some breeds, the tail is traditionally docked to avoid injuries (especially for hunting dogs). It can happen that some puppies are born with a short tail or no tail in some breeds.

Puppy characteristics

This probably 15 weeks old German shepherd mongrel already shows an upward erection trend of the ears, with varying grades of erection during the day

Puppies often have characteristics that do not last beyond early puppyhood. Eye color often changes from blue to its adult color as the puppy matures. The coat color may change: Kerry Blue Terrier puppies have black coats at birth and change to blue with maturity, and Dalmatians are white and gain their spots with age. The ear shape will also often change, especially with erect-eared breeds such as the German Shepherd Dog which have soft ears at birth, but the cartilage strengthens with age. Labrador Retrievers and other swimming dogs, start of with a very fluffy puppy coat, and over time the water proof layer grows. Puppies that are going to grow into larger dogs, often will have over sized paws to begin with, and then the rest of them grow to fit.

Temperature regulation

It is a common misconception that dogs do not sweat. They do sweat, mainly through the footpads, but only a small fraction of a dog's excess heat is lost this way. Primarily, dogs regulate their body temperature through panting. Panting moves cooling air over the moist surfaces of the tongue and lungs, rejecting heat to the atmosphere.

Dogs possess a rete mirabile, a complex of intermingled small arteries and veins, in the carotid sinus at the base of their neck. This acts to thermally isolate the head, containing the brain, the most temperature-sensitive organ, from the body, containing the muscles, where most of the heat is generated. The result is that dogs can sustain intense physical exertion over a prolonged time in a hot environment, compared to animals which lack this apparatus; thus, a dog chasing a jackrabbit through the desert may not be able to outrun the rabbit, but it can continue the chase until the rabbit slows due to overheating.