Vertebrate Diversity study pack

The following web-book contains a series of information chapters broadly outlining the diversity of living vertebrates, with a few notes on their fossil relatives. Below is a collage of specimens from UCL's Grant Museum of Zoology illustrating the wide diversity covered in this web-book – from jawless vertebrates, sharks, and ray-finned fishes, to amphibians, reptiles, and mammals.

To **download** this resource as a single file, see the collection page: <https://open-education-repository.ucl.ac.uk/id/eprint/204>

Also see the related resource **Vertebrate Palaeontology and Evolution** study pack here: <https://open-education-repository.ucl.ac.uk/id/eprint/195>









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# Introduction

The first chapter considers the lampreys - a [clade](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_clade) of jawless vertebrates that are thought, based on analysis of their morphology, to be the group that first diverged from the remaining vertebrate [clades](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_clade).

Subsequent chapters follow a structure that roughly reflects the evolutionary relationships (or [phylogeny](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_phylogeny)) between the higher level vertebrate groups - for example, the turtles, lizards, tuatara, crocodiles, and birds are all reptiles and, as such, their chapters are clustered together. This structure need not imply any increase in complexity or morphological "progress" as one descends through the chapters - indeed, every [taxon](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_taxon) discussed in this web-book is [extant](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_extant), meaning that it has some members that are still living, and are therefore also evolving under the selection pressures of their current environment. Rather, the structure reflects the greater focus of this web-book on those four-limbed vertebrates (tetrapods) whose ancestors colonised the terrestrial world in the Devonian swamps of nearly 400 million years ago - in particular the hair-covered, milk-producing mammals.

While the structure of the web-book may not always act as an accurate representation of the evolutionary history of vertebrates, the phylogenetic tree below illustrates how all the major vertebrate [clades](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_clade) are thought to be related.



Adapted from Meyer & Zardoya (2003), this is a conservative estimate of vertebrate [phylogeny](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_phylogeny), reflecting the prevailing consensus between morphological and molecular data. Conflict between morphology and molecules is manifest at the unresolved nodes, or polytomies - those nodes that are formed when greater than two branches coalesce.

For example, the most popular view of morphologists is that lampreys represent the closest living relatives of the jawed vertebrates (Gnathostomata), together forming the Vertebrata. This hypothesis excludes hagfishes from the vertebrates on the basis that they do not possess some of the derived morphological features shared by lampreys and gnathostomes - in particular, they lack a vertebral column. Instead, hagfishes are placed as the sister group to the vertebrates, together forming the Craniata (or craniates) - animals possessing a skull, or cranium. This view of craniate evolution makes the living jawless vertebrates, or agnathans, a [paraphyletic](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#paraphyletic) group. This means that the jawless vertebrates do not form a natural (or [monophyletic](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_monophyletic)) grouping, as their most recent common ancestor is not unique to them - it is shared with the jawed vertebrates as well.

In contrast, molecular data tend to group the lampreys and hagfishes to the exclusion of the gnathostomes, making the living agnathans a [monophyletic](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_monophyletic) group termed Cyclostomi. Under the cyclostome hypothesis, it is presumed that the common ancestor of the cyclostomes and gnathostomes possessed a vertebral column, which was subsequently lost in the evolution of the hagfishes.

Despite the disparities between morphological and molecular data evident from the [cladogram](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossar_cladogram) above, the evolutionary history of the vertebrates is fairly well resolved, with many major traditionally identified groupings persisting through recent advances in methods for phylogenetic inference and the advent of molecular systematics. Consequently, this tree should be used as a working guide while exploring the [taxa](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_taxon) described within the web-book, providing an evolutionary context that highlights the shared ancestry of the different vertebrate lineages, as well as helping to trace some of the evolutionary innovations that gave rise to the many different forms - including the origin of jaws, ossification of the endochondral skeleton, evolution of terrestrially adapted limbs, and the amniotic egg.

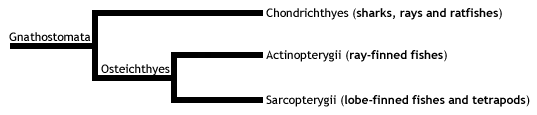
# Ray-finned Fishes

**Actinopterygii - ray-finned fishes**

|  |
| --- |
| Vertebrata; Gnathostomata; Osteichthyes; **Actinopterygii** |

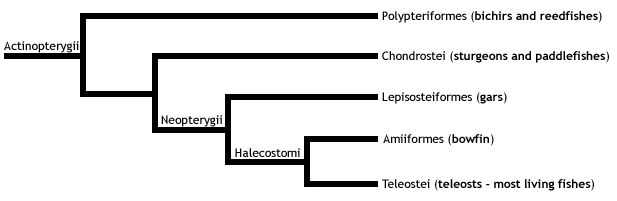
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| [Show Lateral view of Black Labeo (Carp) in spirit Image](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/rayfinned_fishes.html)  Lateral view of Black Labeo (Carp) in spirit | [Show Carp skeleton Image](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/rayfinned_fishes.html)  Carp skeleton | [Show Carp skeleton Image](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/rayfinned_fishes.html)  Carp skeleton | [Show Fish swim bladder in spirit Image](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/rayfinned_fishes.html)  Fish swim bladder in spirit |

The **actinopterygians**, or ray-finned fish, are one of the two major [clade](#_Clade)s of bony fish (**Osteichthyes**), the other being the lobe-finned fish, or **Sarcopterygians**. The **Chondrichthyes** (cartilaginous fish) are the [extant](#_extant) **sister** [clade](#_Clade) of the Osteichthyes. Below is a [cladogram](#_cladogram) to show these relationships:



## Diversity and Lower Taxonomy

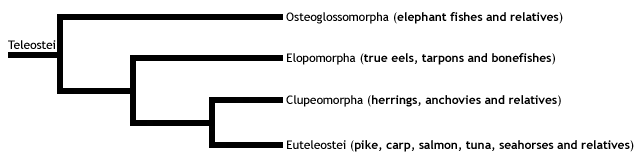
* The subclass Actinopterygii comprises some 27,000 species of ray-finned bony fishes, making it the largest **radiation** of any vertebrate group. As a result, covering the whole group in detail would be extremely complex and, more importantly, hugely baffling! Therefore, the information below aims to highlight the key groups of ray-finned fish in an evolutionary context, explaining how each [clade](#_Clade) is divided and related.
* Actinopterygians can be divided into two distinct groups: [basal](#_Basal) actinopterygians and neopterygians (most [[extant](#_extant)](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_extant) fishes). The [basal](#_Basal) actinopterygians comprise two closely related small [taxa](#_taxon), the more primitive Polypteriformes (containing a single family of bichirs), and the Chondrostei (containing two families, the sturgeons and the paddlefishes). The following [cladogram](#_cladogram) illustrates these relationships:



* Living neopterygians can then be split into three groups (see [cladogram](#_cladogram) above), the first two of which are considered primitive neopterygians:

1. The gars, forming a single family in the order Lepisosteiformes. These are medium- to large-sized (ranging from 1 - 4 metres long) predatory fishes with elongate bodies and jaws, long needle-like teeth, and thick armoured scales.
2. The bowfin, Amia calva, the single living species forming the Order Amiiformes. The bowfin ranges in length from 0.5 - 1 metre, and is characterised by its long dorsal fin extending across most of the length of the body.
3. The teleosts, the largest radiation of vertebrate life, exhibiting huge diversity in more than 20,000 species of ray-finned fishes across 40 orders.

* The [clade](#_Clade) Teleostei contains four main subgroups, shown in the [cladogram](#_cladogram) below. The highly derived Euteleostei is the largest of the teleosts groups, with around 17,000 species in 375 families. This group shows tremendous diversity, and includes both the largest (the ocean sunfish, reaching up to 3.6 m in length) and the smallest (Paedocypris, a genus of the carp family with females as small as 7.9 mm) [[extant](#_extant)](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_extant) bony fish species.



* The Euteleostei comprises three groups:

1. Order Esociformes - a small group containing pikes and mudminnows.
2. Division Ostariophysi - a large group including carps, catfishes, minnows, piranhas, and relatives. These 6,500 species form approximately 80 percent of all living freshwater fish species.
3. Division Neognathi - contains two groups, the Order Salmoniformes (salmon, trout and smelts), and theSubdivision Neoteleostei. The neoteleosts are divided into four groups: three [basal](#_Basal) groups containing many deep-sea fishes (including the bioluminous lanternfishes), and a single group of highly advanced fishes - the acanthomorphs, or spiny-rayed teleosts (acanth is Ancient Greek for thorn). Spiny teleosts then fall into two groups, the Paracanthopterygii (1200 species of cods, haddocks and anglerfishes) and the Acanthopterygii, a huge [clade](#_Clade) containing around 12,000 [[extant](#_extant)](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_extant) species, which dominate the vast majority of the world's open ocean and shallow marine environments. Within this [clade](#_Clade) is theAtherinomorpha (guppies, killifishes and relatives), and the Percomorpha - by far the most diverse group of fish, containing over one-third of all ray-finned fish species, and exhibiting a fascinating array of body forms - including perches, seahorses, flatfishes, pufferfishes, and tunas

## Distribution and Habitat

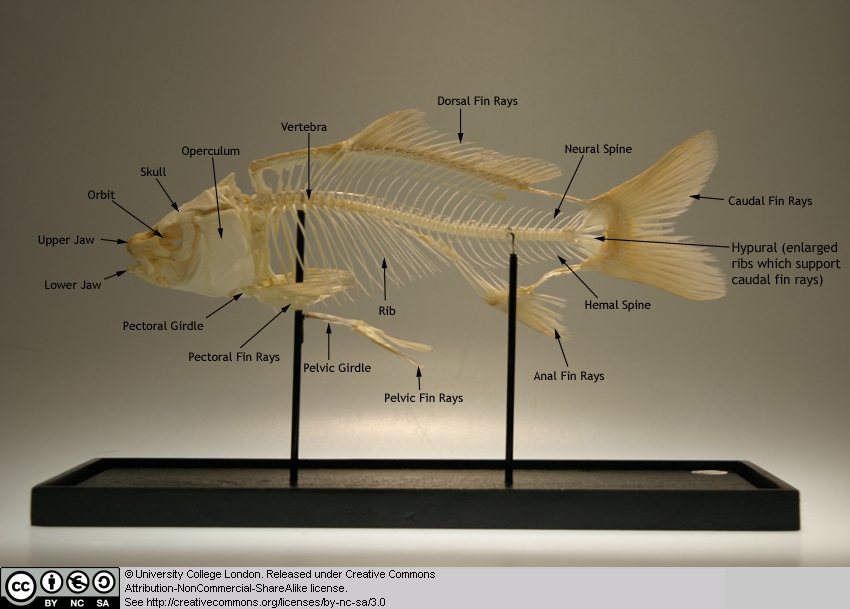
As one would expect from their massive diversity, there are certain species of ray-finned fishes present in waters worldwide. However, some [clades](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_clade) are much smaller than others, and consequently have much narrower distributions. It would be a huge task to highlight the distribution of all actinopterygian species, or even families, and so the following is a list of the geographical distributions and aquatic environments of the evolutionarily key groups outlined above:

* Polypteriformes (bichirs and reedfishes) - Africa; freshwater.
* Chondrostei (sturgeons and paddlefish) - Northern Hemisphere; coastal and freshwater.
* Lepisosteiformes (gars) - North and Central America and Cuba; fresh and brackish water.
* Amiiformes (bowfin) - North America; freshwater.
* Osteoglossomorpha (elephant fishes and relatives) - Worldwide; mostly tropical freshwater.
* Elopomorpha (true eels and relatives) - Worldwide; mostly marine.
* Clupeomorpha (herrings, anchovies, and relatives) - Worldwide; mostly marine.
* Esociformes (pikes and mudminnows) - North America, Western Europe and Northern Eurasia; freshwater.
* Ostariophysi (carps, catfishes, piranhas, and relatives) - Worldwide; mostly freshwater.
* Salmoniformes (slamons, trouts, and relatives) - Temperate Northern and Southern hemisphere; freshwater.
* Paracanthopterygii (cods, haddocks, and anglerfishes) - Northern hemisphere; marine and freshwater.
* Atherinomorpha (guppies, killifishes, and relatives) - Worldwide; surface-dwelling; freshwater and marine.
* Percomorpha (perches, seahorses, tunas, and relatives) - Worldwide; mostly marine.

## Features

* The skeleton of the paired fins is formed from many small bones, called **fin rays**, in a fan-like arrangement, which are supported at the bases of the fins by parallel rows of bones called **radials**. All living actinopterygians except bichirs and reedfishes (Order Polypteryformes) also have branching rays in unpaired fins.
* Modified the ancestral fish character of a breathing lung into a **swim bladder** to aid and adjust **buoyancy**. Although it is easy to assume that lungs are an adaptation unique to terrestrial vertebrates (**tetrapods**), it is likely that lungs evolved in early armoured fishes called **placoderms** in the seas of the **Silurian** and **Devonian** around 415 million years ago, and are therefore a shared ancestral character of all bony fishes, including their tetrapod descendents. The swim bladder is a smooth-walled (i.e., non-**alveolar**) modified lung that is virtually impermeable to gas. Therefore, gas can be gulped - or indeed transferred from the bloodstream in many more derived teleosts - into the swimbladder of ray-finned fishes to reduce the overall density of the body, and afford **neutral buoyancy**. This allows fish to remain stationary in the water column, and thus waste less energy. As the pressure of the water column on the body changes with depth, actinopterygians must regulate the volume of air in their swim bladders to remain neutrally buoyant. Some ray-finned fishes, such as the gars of North and Central America and Cuba, are **secondary** air-breathers, who have evolved an alveolar lung to survive in their low-oxygen environment.
* Single dorsal fin. Some fishes, such as salmons and catfishes, have an additional fin positioned just posterior of the dorsal fin, called the adipose fin, which is small, soft and fleshy.
* Ancestrally, ray-finned fishes were covered in tough rhomboidal **ganoid scales**, formed of a thick layer of **spongy bone**, covered with [**dentine**](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_dentine), followed by **ganoine** (a substance derived from [enamel](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_enamel) - the material that covers human teeth). However, the more derived fish groups have modified the structure of their scales to increase flexibility and reduce weight, in order to improve locomotory efficiency - allowing individuals to become more advanced predators, as well as more evasive prey. Living species within the teleost [clade](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_clade) have reduced scales that are circular, flexible, thin, and overlapping **craniocaudally - cycloid** scales. One group, the spiny-rayed teleosts (Order Acanthomorpha), have further modified their scales to a form termed **ctenoid** (cten is Ancient Greek for comb), which bear comb-like spines on the posterior edge.
* While many [basal](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_basal) actinopterygians possess a primitive **heterocercal** tail - one in which the fin lobes are different in length (asymmetrical) - there is increasing symmetry towards the teleost group, with teleosts themselves possessing a **homocercal** tail, which is completely symmetrical in appearance (the images clearly show this in a species of carp).
* The jaws of ray-finned fish have undergone many modifications through their evolution. Early forms had simple snapping jaws with weak jaw-closing muscles, which were used to grab prey. The neopterygians then lost the connection between the cheek bones and the posterior of the upper jaw (**maxilla**). This caused the maxilla to be rotated forwards and to the side when the jaws were opened, increasing the volume of the **oral cavity** to create a suction effect, drawing prey items into the mouth. Further skeletal jaw modifications, alongside flaps of skin around the maxilla then allowed teleosts to have a highly protruding tube-like mouth, whose fully circular opening produced a stronger and highly directional suction force into the oral cavity, which also retained prey on jaw closure. These adaptations to increase suction were crucial in the evolution of ray-finned fishes as active predators, as lunging towards prey items in water actually acts to push them away by forcing a flow of water towards them.

## Labelled image of a typical ray-finned fish skeleton



[**Chondrichthyes**](#_Chondrichthyes)

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# [Glossary](http://www.ucl.ac.uk/museums-static/obl4he/vertebratepalaeo/glossary.html)

## A

### akinetic

In anatomy, this refers to a low level of flexibility in a structure due to a lack of moveable joints.

### amniote

Those vertebrates with an amniotic egg. The [extant](#_extant) [clades](#_Clade) are Testudines (turtles), [Diapsida](#_diapsid) (lepidosaurians, crocodilians, and birds), and [Synapsida](#_synapsid) (mammals).

### anapsid

Skull possessing **no** **temporal fenestrae** (NB. an- = without).  
  
[Amniotes](#_amniote) with this skull condition form a [paraphyletic](#_Paraphyletic) group including the Parareptilia (turtles and their extinct relatives), the extinct common ancestor of all [amniotes](#_amniote), and [basal](#_Basal)eureptiles (the extinct precursors of [diapsids](#_diapsid)).  
  
Note that the Testudines (turtles and relatives) have modified the anapsid condition through a reduction (emargination) of the posterior region of the skull.

### Apatite

Calcium phosphate: the crystalline component of bone.

### apomorphy

A derived or specialised character.

### Appendicular skeleton

The endoskeletal element of the fins or limbs of a vertebrate, and their associated girdles (pectoral or pelvic).

### Axial skeleton

All parts of the vertebrate endoskeleton except the limbs or fins and their associated girdles. That is, the cranium, visceral skeleton, notochord, [vertebrae](#_vertebrae), and ribs.

## B

### Basal

Of, relating to, located at, or forming a base.

### Bicuspid

A tooth bearing two [cusps](#_Cusp).

## C

### Calcified cartilage

[Cartilage](#_Cartilage) strengthened with a scattering of [apatite](#_Apatite) crystals (calcium phosphate), as seen in Chondrichthians.

### Cartilage

A tough, elastic, fibrous connective tissue composed of collagen fibres. Used as skeletal tissue in vertebrates, it is non-mineralised and is often the developmental precursor of bone.

### Clade

A phylogenetic lineage comprising a common ancestor and all its descendant species.  
  
Note that the difference between a [taxon](#_taxon) and a clade is that a clade must include all descendant species from a common ancestor, whereas a [taxon](#_taxon) need not.

### cladistic

Relating to the branching sequences of [phylogeny](#_phylogeny).

### cladogram

A branching tree-like diagram representing the phylogenetic relationships (evolutionary history) of a lineage.

### cloaca

The common opening for the reproductive, urinary, and digestive tracts, seen in all vertebrates except therian mammals (marsupials and placental mammals).

The term comes from the Latin for sewer.

### Cursorial

Adapted for running.

### Cusp

The biting point of a tooth.

## D

### Dentary

The anterior bone of the lower jaw which bears the teeth. It forms the whole of the lower jaw in mammals.

### Dentine

A bone-like substance, lacking cell bodies and consisting mainly of calcium phosphate ([apatite](#_Apatite)) in a fibrous matrix.

### Dermal bone

A type of bone forming within the dermis - the deep layer of vertebrate skin cells below the surface layer, the epidermis.

### diapsid

Skull possessing both an **upper and a lower** **temporal fenestra** (NB. di- = two).   
  
[Amniotes](#_amniote) with this skull condition form the [monophyletic](#_monophyletic) [clade](#_Clade) **Diapsida**, which includes the lepidosaurs (lizards, snakes, and tuatara), archosaurs (crocodilians, dinosaurs, and birds), and their other extinct relatives.   
  
Note that some diapsids, such as lizards, have lost the temporal bar separating the fenestrae to form one large window. Others, such as the Aves (birds), have merged both fenestrae with the [orbit](#_Orbit).

## E

### Enamel

The crystalline material covering the crown of a tooth, or certain scales.

### Endopterygota

A [clade](#_Clade) of insects charachterised by their undergoing complete metamorphosis (i.e. [holometabolous](#_Holometabolous)).  
  
See Insect Diversity WebBook for the [clades](#_Clade) within (from Neuroptera down).

### Epidermal

Pertaining to, or originating from, the epidermis - the surface layer of skin cells in vertebrates

### euryapsid

Skull possessing an **upper** [**temporal fenestra**](#_temporal_fenestra) **only**.  
  
However, animals with this skull condition do not represent an important [amniote](#_amniote) lineage, as they are likely to be a [polyphyletic](#_polyphyletic) group, originating a least twice within the [Diapsida](#_diapsid). [Euryapsids](#_euryapsid) include the plesiosaurs and ichthyosaurs - Mesozoic marine reptiles.

### extant

Not extinct.

## F

### fossorial

Specialised for burrowing.

### furcula

The fused clavicle bones of a bird, also known as the wishbone.

## H

### Hemimetabolous

Refers to a type of insect development that is categorised by three distinct, progressive life stages: egg, nymph, imago (adult). Changes are gradual, with no pupal stage.  
  
Some hemimetabolous insects include grasshoppers, cicadas, cockroaches, termites, earwigs, and dragonflies.  
  
Also termed incomplete metamorphosis.

### Holometabolous

Refers to a type of insect development that is categorised by four distinct, progressive life stages: embryo, larva, pupa, imago (adult).  
  
Seen exlusively in the [Endopterygota](#_Endopterygota), which includes beetles, butterflies, wasps, bees, ants, and others.  
  
Also termed complete metamorphosis.

### Horny

Consisting of horn - a tough material composed mainly of keratin.

## I

### ilium

In tetrapods, the dorsal section of the pelvis, which articulates with one or more sacral [vertebrae](#_vertebrae).

## K

### Kinetic

In anatomy, referring to a high level of flexibility afforded by numerous moveable joints.

## L

### Lymph heart

Muscular dilation in a lymph vessel, which pumps lymph (fluid containing white blood cells called lymphocytes important in immune response) around the body of some lungfishes, amphibians and reptiles.

## M

### Metacone

In mammals, the metacone is the distobuccal (rear-most and cheek side) cusp of an upper molar tooth.

### monophyletic

Having a single evolutionary origin. A [taxon](#_taxon) is monophyletic if it contains all the descendants of a common ancestor.

For example, mammals are a monophyletic group, as all species descended from the first known mammal are considered mammals.

See [paraphyletic](#_Paraphyletic) and [polyphyletic](#_polyphyletic) for alternative terms.

### Myrmecophagy

Feeding behaviour categorised by an exclusive (or near exclusive) diet of ants ant termites.

## O

### Orbit

The bony socket of the eye.

### Osteosclerosis

An increase in the density of bone.

## P

### Pachyostosis

A thickening of the bone, often associated with a reduction in the volume of marrow tissue contained within.

### Paracone

In mammals, the paracone is the mesiobuccal (front-most and cheek side) [cusp](#_Cusp) of an upper molar tooth.

### Paraphyletic

A [taxon](#_taxon) including a common ancestor and some but not all of its descendants.   
  
For example, the class Reptilia is paraphyletic, as it does not include birds, who are considered a separate class: Aves. However, birds evolved from theropod dinosaurs, and are therefore reptiles themselves. Similarly, all tetrapods are, evolutionarily speaking, lobe-finned fish.  
  
Importantly, reptiles can be made [monophyletic](#_monophyletic) through the addition of birds to the [taxon](#_taxon).  
  
See [monophyletic](#_monophyletic) and [polyphyletic](#_polyphyletic) for alternative terms.

### Pectoral girdle

In vertebrates, the skeletal structure that provides support for the fore limbs or fins.

### Pelvic girdle

In vertebrates, the skeletal structure that provides support for the hind limbs or fins, which also fuses with the sacral [vertebrae](#_vertebrae).

### phylogeny

The evolutionary history of organismal lineages as they develop through time.

### plesiomorphy

An ancestral character.

### polyphyletic

Referring to a group that does not contain the common ancestor of all the [taxa](#_taxon) within. Therefore, this is not a true taxonomic group, but is often a term used to categorise organisms with a similar ecology, such as insectivorious mammals, or marine mammals.  
  
It is also used when the evolutionary origin of a group, such as snakes, is unsure, and characteristic species within may have originated separately.

### Protocone

In mammals, the protocone is the mesiolingual [cusp](#_Cusp) of an upper molar tooth.

### Pulp cavity

The space within a tooth, or a [dentine](#_Dentine) scale, occupied by blood vessels and nerves.

## S

### symplesiomorphy

A character that is shared between groups but was inherited from an ancestor prior to the last common ancestor.  
  
These are characters that - at the level at which they are referred to as sym[plesiomorphies](#_plesiomorphy) - are not used to form [cladistic](#_cladistic) groupings, or [clades](#_Clade).

### synapomorphy

A derived or specialised character that is shared between two or more groups, and was inherited from the common ancestor in which it originated.  
  
These are the characters that morphological systematists use to support the existence of particular [clades](#_Clade), forming the basis of the field of [**cladistic**](#_cladistic)**s**.

### synapsid

Skull possessing a **lower** [**temporal fenestra**](#_temporal_fenestra) **only**.   
  
[Amniotes](#_amniote) with this skull condition form the [monophyletic](#_monophyletic) [clade](#_Clade) **Synapsida**, which includes the mammals and their extinct ancestors, the non-mammalian reptile-like synapsids.  
  
Note that in the Mammalia, the lower temporal fenestra has merged with the [orbit](#_Orbit).

## T

### taxon

A group of organisms sharing a common ancestry.  
  
Note that the difference between a taxon and a [clade](#_Clade) is that a [clade](#_Clade) must include all descendant species from a common ancestor, whereas a taxon need not.  
  
Pl. taxa.

### temporal fenestra

An opening in the temporal region of the skull seen in [amniotes](#_amniote), providing a flat edge for the attachment of strong lower jaw closing muscles to the skull.  
  
[Amniotes](#_amniote) show **four skull types**, based on the position and number of these temporal fenestrae, two of which define two major lineages of the [amniotes](#_amniote). The skull types and associated groups are as follows:  
  
1) [**Synapsid**](#_synapsid) - Skull possessing a **lower temporal fenestra only**. [Amniotes](#_amniote) with this skull condition form the [monophyletic](#_monophyletic) [clade](#_Clade) [**Synapsida**](#_synapsid), which includes the mammals and their extinct ancestors, the mammal-like reptiles. Note that in the Mammalia, the lower temporal fenestra has merged with the [orbit](#_Orbit).  
  
2) [**Diapsid**](#_diapsid) - Skull possessing both an **upper and a lower** **temporal fenestra** (NB. di- = two). [Amniotes](#_amniote) with this skull condition form the [monophyletic](#_monophyletic) [clade](#_Clade) [**Diapsida**](#_diapsid), which includes the lepidosaurs (lizards, snakes, and tuatara), archosaurs (crocodilians, dinosaurs, and birds), and their other extinct relatives. Note that some groups within the [Diapsida](#_diapsid), such as lizards, have lost the temporal bar separating the fenestrae to form one large window. Others, such as the Aves (birds), have merged both fenestrae with the [orbit](#_Orbit).  
  
3) [**Anapsid**](#_anapsid) - Skull possessing **no** **temporal fenestrae** (NB. an- = without). [Amniotes](#_amniote) with this skull condition form a [paraphyletic](#_Paraphyletic) group including the Parareptilia (turtles and their extinct relatives), the extinct common ancestor of all [amniotes](#_amniote), and [basal](#_Basal) eureptiles (the extinct precursors of [diapsids](#_diapsid)). Note that the Testudines (turtles and relatives) have modified the [anapsid](#_anapsid) condition through a reduction (emargination) of the posteriorregion of the skull.  
  
4) [**Euryapsid**](#_euryapsid) - Skull possessing an **upper temporal fenestra only**. However, animals with this skull condition do not represent an important[amniote](#_amniote) lineage, as they are likely to be a [polyphyletic](#_polyphyletic) group, originating a least twice within the [Diapsida](#_diapsid). [Euryapsids](#_euryapsid) include the plesiosaurs and ichthyosaurs - Mesozoic marine reptiles.

## V

### vertebrae

From anterior to posterior:

Cervical vertebrae: Facilitate the mobility of the head. The first two, the **atlas** and the **axis** are highly specialised, the former articulating with the occipital region of the skull.

Thoracic vertebrae: Articulate with the ribs that fuse with the sternum.

Lumbar vertebrae: Generally larger, with small ribs not attached to the sternum, which support the posterior musculature.

Sacral vertebrae: Fused to the [pelvic girdle](#_Pelvic_girdle), allowing the transfer of force from the [appendicular skeleton](#_Appendicular_skeleton) (limbs) during locomotion.

Caudal vertebrae: Small and less specialised, forming the tail.

### Vertebrate anatomical directions and axes

The image below illustrates the terms used for anatomical directions and axes in vertebrates.



### Vestigial

Occurring as a structure that, once functional (whether during development or in earlier evolutionary forms), is **now reduced** or **degenerate**. An example is the vestigial [pelvic girdle](#_Pelvic_girdle) seen in many snakes, including the boas and pythons, which bears no function.

## Z

### Zygapophysis

Articular process of a vertebra that articulates with the corresponding process of an adjacent vertebra.  
  
Plural = zygapophyses