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.

# Rhynchocephalians

**Rhynchocephalia - tuatara**

|  |
| --- |
| Vertebrata; Gnathostomata; Osteichthyes; Sarcopterygii; Tetrapoda; Amniota; Sauropsida;Reptilia; [Diapsida](#_diapsid); Sauria; Lepidosauromorpha; Lepidosauria; **Rhynchocephalia** |

The **Rhynchocephalia** is the sister group to the **Squamata** (lizards and their relatives), united in the [monophyletic](#_monophyletic) [clade](#_Clade) **Lepidosauria** by the following [synapomorphies](#_synapomorphy):

* Derived skin structure with **shedding** mechanisms. Epidermis is periodically lost and replaced in a cyclic switch between the production of α-keratin and β-keratin.
* An opening, or window, in the pelvis called the **thyroid fenestra**.
* Paired male **hemipenes** - intromittent organs used to deliver sperm to the female during copulation. They are held hidden within eversible pouches in a transverse [cloacal](#_cloaca) slit. Note this is well defined in squamates but only rudimentary in male tuatara (the only [extant](#_extant) rhynchocephalian).
* The possession of fracture planes within tail [vertebrae](#_vertebrae), allowing **caudal autotomy** - the ability to self-amputate the tail. This is used as a defensive escape mechanism.
* Extra centres of ossification in the epiphyses of the limb bones.
* Knee joint in which the fibula fits into a lateral recess on the femur. This is unique within tetrapods.
* Sexual segment of the kidney.
* Specialised foot and ankle structure, including:
	+ Fused astralago-calcaneun and enlarged fourth distal tarsal - combined, these two features produce a specialised mesotarsal joint that aids in movement over rough terrain.
	+ Hooked fifth metatarsal - this acts in a manner analagous to a rudimentary mammalian heel.

Lepidosauria is defined as encompassing the last common ancestor of Rhynchocephalia and Squamata, plus all its descendants. **Lepidosauromorpha** contains lepidosaurs and stem-lepidosaurs known from fossils (e.g.Kuehneosaurus). If only [extant](#_extant) [taxa](#_taxon) are considered then Lepidosauria is the sister group to the Archosauria (crocodilians, dinosaurs, birds, and possibly turtles). Lepidosauromorpha and Archosauromorpha (Archosaurs plus now extinct stem-Archosaurs) are sometimes together referred to as **Sauria**. A larger more inclusive grouping, [Diapsida](#_diapsid), contains Lepidosauromorpha and Archosauromorpha along with various fossil [taxa](#_taxon) (such as Petrolacosaurus and plesiosaurs). [Diapsida](#_diapsid) is in turn nested within **Sauropsida** (equal to a [monophyletic](#_monophyletic) definition of **Reptilia** as used by some authors) which contains additional fossil [taxa](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_taxon) such as procolophonids and captorhinids.

## Diversity and Lower Taxonomy

The Rhynchocephalia is now represented by just a single [extant](#_extant) genus, Sphenodon, comprising two species, S. punctatus and S. guntheri (the status of which is questioned). In its nativeNew Zealand, Sphenodon is known as the tuatara - derived from a Māori term meaning "peaks on the back".

This apparently minimal diversity has led many authors to suggest that the Rhynchocephalia is a conservative and relatively unchanged group with uniform morphology; however, there are a number of fossil [taxa](#_taxon) known that demonstrate variation in body shape, skull structure and tooth morphology.

Distribution and Habitat

Although globally distributed in the Mesozoic, the living representatives of the Rhynchocephalia (Sphenodon) are now restricted to the terrestrial habitat of New Zealand's offshore islands.

* Sphenodon punctatus (Northern + Cook Strait tuatara) - present on 33 islands.
* Sphenodon guntheri (Brothers Island tuatara) - present on only three islands.

## Conservation Status (IUCN)

* Sphenodon punctatus (Northern + Cook Strait tuatara) - Least Concern (LC) - not updated since 1996
* Sphenodon guntheri (Brothers Island tuatara) - Vulnerable (Vu) - not updated since 1996

## Uniting features ([**synapomorphies**](#_synapomorphy)) of the Rhychocephalia

* Enlarged palatine tooth row - allowing the application of three-point bending to food items. This is a unique feature amongst [amniote](#_amniote)s.
* Acrodont dentition - teeth fused to the crest of the jaw bone, with no sockets. These teeth are not usually replaced and tend to be added to the back of the jaw bone as it grows.
* Posterior extension of the [dentary](#_Dentary).

## Fossil [**taxa**](#_taxon) and rhynchocephalian [**phylogeny**](#_phylogeny)

Thought to have originated in the Early Triassic (~250-240 mya), rhychocephalians achieved global distribution in the Early Mesozoic, and were a major part of faunal assemblages for a large proportion of this era. In addition to the phylogenetically [basal](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_basal)-most [taxa](#_taxon), such asGephryosaurus, there are 5 distinct, apparently [monophyletic](#_monophyletic) lineages of derived rhynchocephalians: the clevosaurs, pleurosaurs, sapheosaurs, sphenodontines, and eilenodontines. These groups - whose phylogenetic interrelationships are uncertain - are all extinct, except the sphenodontines, which include the [extant](#_extant) Sphenodon. The phylogenetic tree below illustrates rhynchocephalian interrelationships based on Jones (Journal of Morphology, 2008):



"[**Basal**](#_Basal)[**taxa**](http://www.ucl.ac.uk/museums-static/obl4he/vertebratediversity/glossary.html#zoomoodle_glossary_taxon)" - known from the Triassic through to the Early Jurassic, this is a [paraphyletic](#_Paraphyletic) assemblage, consisting of [taxa](#_taxon) that originated early in the rhyncocephalian lineage - includingGephryosaurus, Diphydontosaurus, and Planocephalosaurus. The "[basal](#_Basal) [taxa](#_taxon)" possess many relatively simple maxillary and [dentary](#_Dentary) teeth, with a conical form suitable for piercing small, invertebrate prey. The dentition perhaps demonstrates transition from an ancestral state, as they are **pleuro-acrodont** (in the ancestral **pleurodont** condition, teeth are set into the inner sides of the jaw bones). All other rhychocephalians have a fully acrodont dentition, and some of the more derived forms discussed below show a trend towards fewer, stouter teeth, that are more resilient to loading and bending forces, thus suitable for seizing larger prey. The shape of the jaw joint indicates that some sliding movement of the lower jaw could occur during food processing.

Clevosaurs - a group of carnivorous ryhnchocephalians known from the Mid Triassic to the Early Jurassic. Clevosaurs possess a highly specialised dentition, with a blade-like morphology that were used in conjunction with a precise vertical (**orthal**) cutting action like that of a pair of scissors. With this dentition and a skull size of 20-40+ mm, they were able to seize large invertebrates and probably even some small vertebrates.

Pleurosaurs - one of the two groups of aquatic rhynchocephalians - the other being the sapheosaurs. This aquatic habit is thought to have evolved independently in the two lineages. The pleurosaurs, known from the Early Mid to the Late Jurassic, possess a flattened, elongate skull (60-80mm), trunk and tail specialised for their aquatic mode of life, and have a dentition similar to that of the clevosaurs.

Sapheosaurs- the second group of aquatic rhynchocephalians - known only from around the Jurassic-Cretaceous boundary (~206 mya). The sapheosaur fossil record is poorly known and little is known about their specialisations. The dentition has been described as blade-like and may resemble that of the clevosaurs or pleurosaurs.

Sphenodontines- known from the Early Jurassic onwards, this is the group that includes the [extant](#_extant) genus, Sphenodon. The sphenodontines possess only a single enlarged palatine tooth row, running parallel to the maxillary teeth. Each maxillary and palatine tooth bears a posterior flange. The teeth on the [dentary](#_Dentary) are conical with an anteriorly placed apex. Following wear they bear two small anterior flanges or “shoulders”. When the jaws close the lower jaw slides forward (protraction) to allow a shearing action analogous to that of a steak knife. This is termed a **propalinal**, or more specifically **prooral**, jaw action. This allows members of this group to process tougher, more complex prey, such as arthropods and small vertebrates but in a different way to clevosaurs and pleurosaurs.

Eilenodontines - a group of highly specialised rhynchocephalians, that may form the sister group to the sphenodontines. Known from the Late Jurassic to the Mid Late Cretaceous, the eilenodontines were the largest group of rhynchocephalians, with skull sizes reaching between 80-150mm and robust jaws. The dentition of the eilenodontines is in many ways like that of the sphenodontines - they have similar maxillary teeth, have a single enlarged palatal tooth row parallel to the maxillary teeth, and utilise some kind of **propalinal** jaw action. However, the [dentary](#_Dentary) teeth are wider, with a thickened layer of [enamel](#_Enamel). When worn (which they usually are) each tooth possesses a flat wear facet bounded by sharp [enamel](#_Enamel) edges. These resemble the teeth of mammalian herbivores and are therefore considered suitable for processing plant material, and thus indicate an herbivorous diet for the group.

## References

Jones, MEH. 2008. Skull shape and feeding strategy in *Sphenodon* and other Rhynchocephalia ([Diapsida](#_diapsid): Lepidosauria). Journal of Morphology **269**: 945-966.

Evans, SE. 2003. At the feet of the dinosaurs: the early history and radiation of lizards. Biological Reviews **78**: 513-551.

# [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