Vertebrate Palaeontology and Evolution study pack

This resource is designed to familiarise you with the structure, diversity and evolutionary history of vertebrates through analysing images of specimens held at UCL’s [Grant Museum of Zoology](http://www.ucl.ac.uk/museums/zoology). It contains seven chapters: an introduction to vertebrate diversity, Fishes, the fish-tetrapod transition, Amphibians and Amniotes, Lepidosaurs and Chelonians, Archosaurs, and Birds and flight. All images have accompanying text, including information about the specimen plus hints about what to look for and the questions to consider when analysing the images. Please note that this resource does not look at mammals in detail – instead, this fascinating group are given a more thorough treatment in another Object Based Learning for Higher Education (OBL4HE) resource entitled ‘Vertebrate Diversity’ and the Virtual Educational Resource for the Biosciences (VERB) resource ‘Eutherians’.

* Verb Diversity: <https://open-education-repository.ucl.ac.uk/id/eprint/204>
* Eutherians (VERB): <https://open-education-repository.ucl.ac.uk/id/eprint/210>

Scalebars are provided throughout (except for models). Please note that there are two different scale bars used, one with 1cm divisions and one with 0.5cm divisions.

Multiple images of specimens are provided to try to illustrate the various anatomical features. However, please note that the limitations of photography (especially for specimens in cases or bottles) means that some distortion may occur or parts may be concealed or generally hard to determine.

To **download** this resource in its entirety, see the resource's collection page: <https://open-education-repository.ucl.ac.uk/195/>

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# Chapter 4: Amphibians & Amniotes

This chapter allows you to take a second look at some of the early tetrapods (temnospondyls, baphetids, nectrideans etc.), and introduces you to the modern amphibians and some amniotes. The chapter includes some extant material, especially frogs, salamanders and turtles.

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## 4.1 Loxomma



*Loxomma* is a member of a group of early tetrapods called loxommatids. Loxommatids (also called baphetids) appear in the Early Carboniferous, but were most common during the later part of this period. This group is known from a few skulls and mandibles, but virtually nothing is known about their postcranial skeletons. Baphetids can be recognised by the possession of one clear derived character state: the [orbit](http://www.ucl.ac.uk/museums-static/obl4he/vertebratepalaeo/glossary.html#zoomoodle_glossary_orbit) (eye socket) is extended forward, giving this opening a ‘keyhole’ shape.

What animal does this skull remind you of – and what do you think *Loxomma* ate?





## 4.2 Amphibamus grandiceps

These two casts are of the anterior portions of two individuals. *Amphibamus* is a dissorophoid temnospondyl from the mid-Permian of North America. It is an interesting and important animal because dissorophoids have been suggested as potential ancestors of the frogs or perhaps all lissamphibians.



Note the structure of the skull, especially its large openings for the eyes etc. Compare one of these casts with one or more of the frog and salamander skeletons.

## 4.3 Dissorophus multicinctus



This is the skull of a dissorophoid temnospondyl. Dissorophoids may have given rise to the ancestors of frogs, or perhaps all lissamphibians.

Note the presence of large palatal vacuities. Identify the other major openings in the skull (what is the most posterioropening on the side of the skull, immediately behind the eye?).





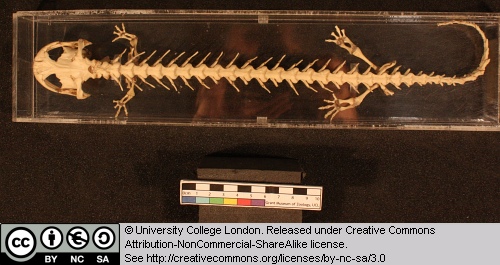
## 4.4 Palaeobatrachus goldfussi

This is a cast of a complete fossil frog.



Note the presence of: the open and lightly built skull, the short trunk region (how many [vertebrae](#_vertebrae) can you count), the urostyle, the absence of ribs, the specialised [ilium](#_ilium), and the long back legs.

## 4.5 Cryptobranchus [The giant salamander]



This is the skeleton of an [extant](#_extant) salamander. Note the following features: the open structure of the skull, the elongate body and relative shortness of the hind limbs, the long tail.





## 4.6 Amphiuma neaus

This specimen is partially obscured by the lables of the container.



This is the skeleton of a highly aquatic extant salamander. What features suggest its adaption for life in water?



## 4.7 Ichthyophis



This is a preserved specimen of an [extant](#_extant) caecilian. Note the following features: the complete absence of limbs, the elongate body that seems to be composed of numerous segments, the small head (can you see eyes? Can you detect a small tentacle-like structure in front of where the eyes should be?).



## 4.8 Diadectes sp.

This is the cast of a skull of a very close relative of the [amniotes](#_amniote). Diadectomorphs lived during the Late Carboniferous and Permian.



Make sure you can identify the main openings in the skull. Notice that there are no openings in the temporal region (the area immediately behind the eye). Compare this temporal area with its equivalent in one of the true [amniote](#_amniote)s, such as *Dimetrodon* [seen in Chapter 1] or the procolophonids).







## 4.9 Labidosaurus sp.



This is the skull of an early [amniote](#_amniote) from the Late Permian of North America. *Labidosaurus* is a captorhinid, a group of small to medium sized [amniote](#_amniote)s that probably fed on invertebrates and other small vertebrates.





Note that there are no openings in the temporal region (the area immediately behind the eye on the side of the skull). Can you detect the transverse flange of the pterygoid which is characteristic of [amniote](#_amniote)s (look at the palate of the animal and see if you can detect paired downwardly projecting ridges at the back end of the palate).

## 4.10 Procolophon sp.



This is a cast of the skull, lower jaw and shoulder girdle of a procolophonid. This group includes fairly small [amniote](#_amniote)s from the Permian and Triassic. Procolophonids and pareiasaurs (see *Bradysaurus* and *Scutosaurus*) are thought to be closely related to each other according to several recent [cladistic](#_cladistic) analyses. Together with a few other groups of early [amniote](#_amniote)s procolophonids and pareiasaurs are regarded as members of a [clade](#_Clade) called the parareptiles. Turtles may have evolved from parareptile ancestors: some authors have suggested the procolophonids, others have proposed the pareiasaurs (but these hypotheses remain controversial).

Procolophonids can be recognised by several features in the skull. Note: the skull is subtriangular in dorsal view, and is somewhat dorsoventrally flattened, the [orbit](#_Orbit) is emarginated along its back edge (what might this feature have been for?), in some forms there are various spikes of bone on the head (see *Hypsognathus*): what function might these have served?

## 4.11 Hypsognathus fenneri

This is the cast of the skull and lower jaw of a procolophonid.



Procolophonids are members of a parareptile [clade](#_Clade) of [amniote](#_amniote)s which also includes the pareiasaurs and possibly turtles. Note the dorsoventrally flattened, subtriangular head, which possesses little bumps and spikes on its surface. These features, combined with the emargination of the posterior margin of the [orbit](#_Orbit), are highly characteristic of the procolophonids. (See also Procolophon).





Can you identify the transverse flange of the pterygoid that tells you this animal is probably an [amniote](#_amniote)?



## 4.12 Other taxa

In this chapter we also revisit *Diplocaulus* and *Seymouria* from [Chapter 3](https://open-education-repository.ucl.ac.uk/id/eprint/197) and the toad and *Dimetrodon* from [Chapter 1](https://open-education-repository.ucl.ac.uk/id/eprint/194).

# [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.

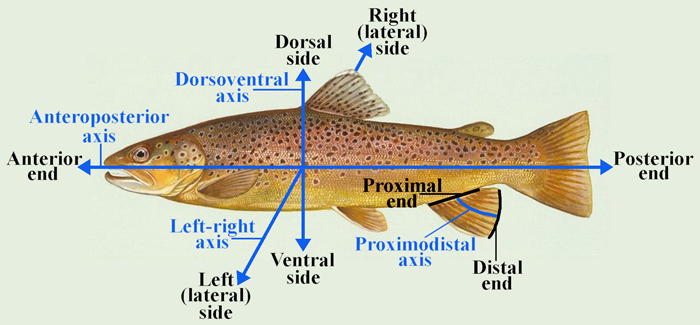
Lumbar vertebrae: Generally larger, with small ribs not attached to the sternum, which support the posterior musculature.

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