Subphylum Vertebrata

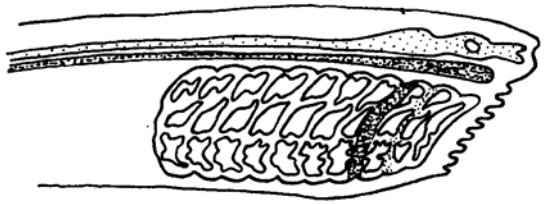
Superclass Agnatha (jawless vertebrates)

- **Class Myxini**
- **Class Cephalaspidomorphi**

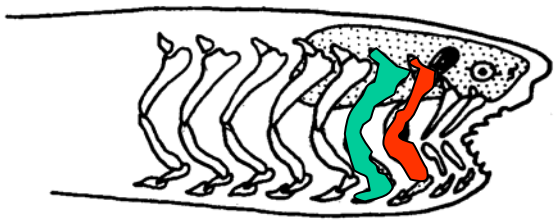
Superclass Gnathostomata (jawed vertebrates)

- **Class Chondrichthyes**
- **Class Osteichthyes**
- **Class Amphibia**
- **Class Reptilia**
- **Class Aves**
- **Class Mammalia**

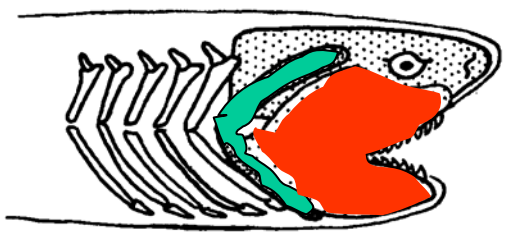
The Evolution of Jaws



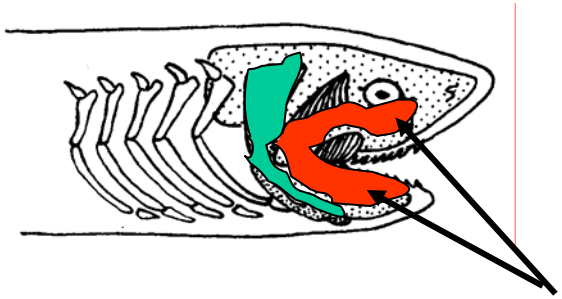
No jaws, no bony gill arches.



No jaws, bony gill arches.



Anterior gill arches lost, gill arches 3 and 4 form jaws.



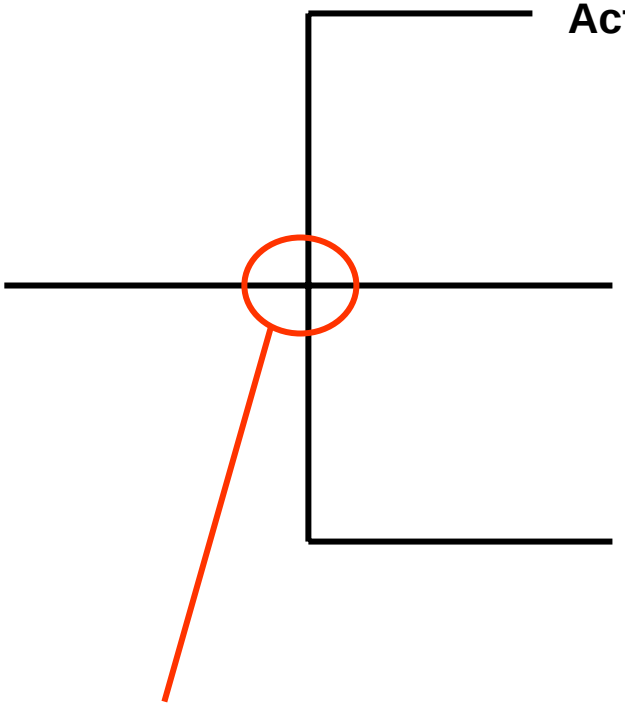
Gnathostome condition.

Class Osteichthyes

the “bony” fish

Class Osteichthyes

Actually 3 classes:

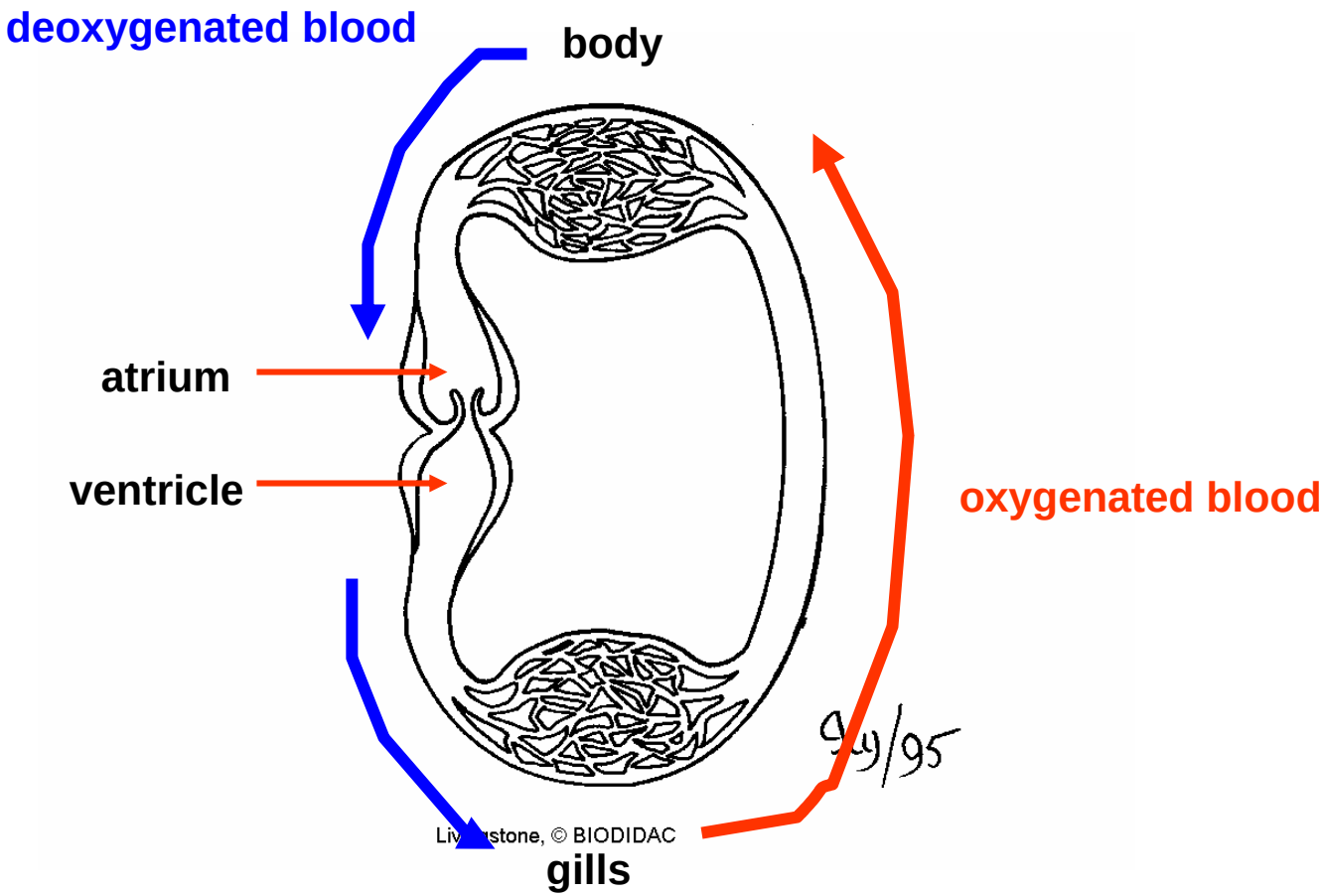


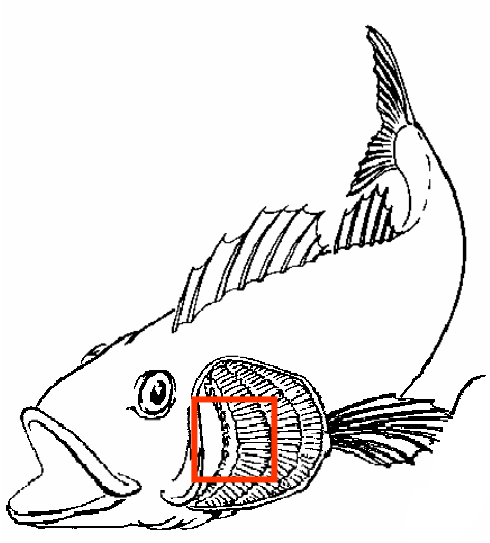
These three classes diverged 400 million years ago and probably evolved in freshwater

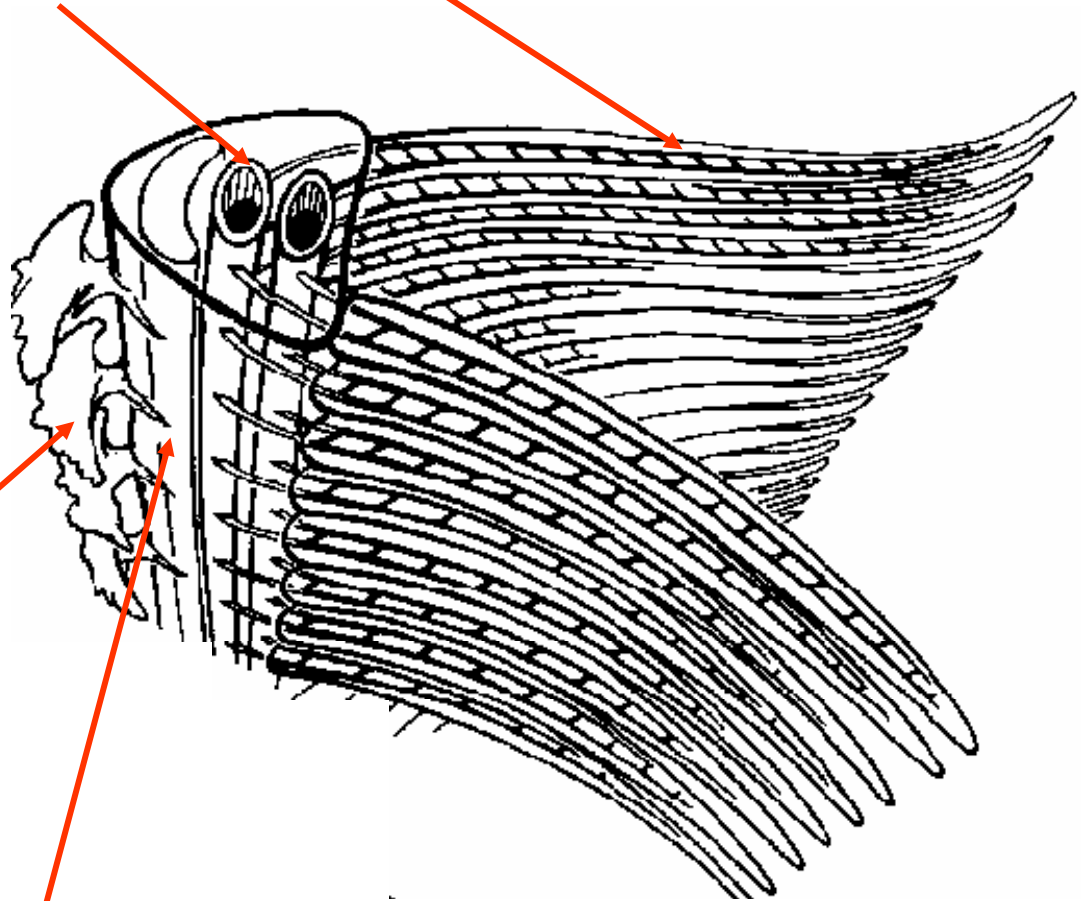
Ray-finned fish: 99 % of extant fish

Lobe-finned fish: 1 genus

Lungfish: 3 genera


deoxygenated blood
body
atrium
ventricle
oxygenated blood
gills
© BIODIDAC



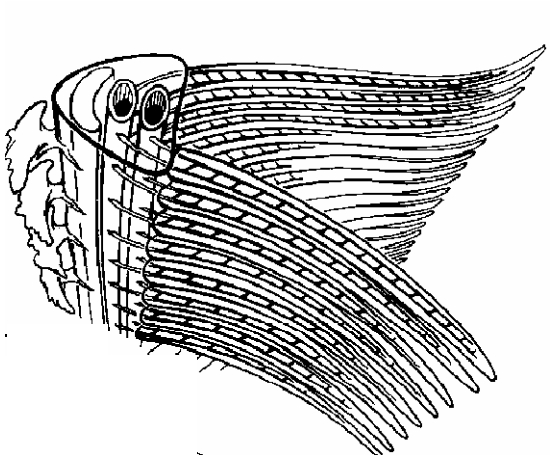


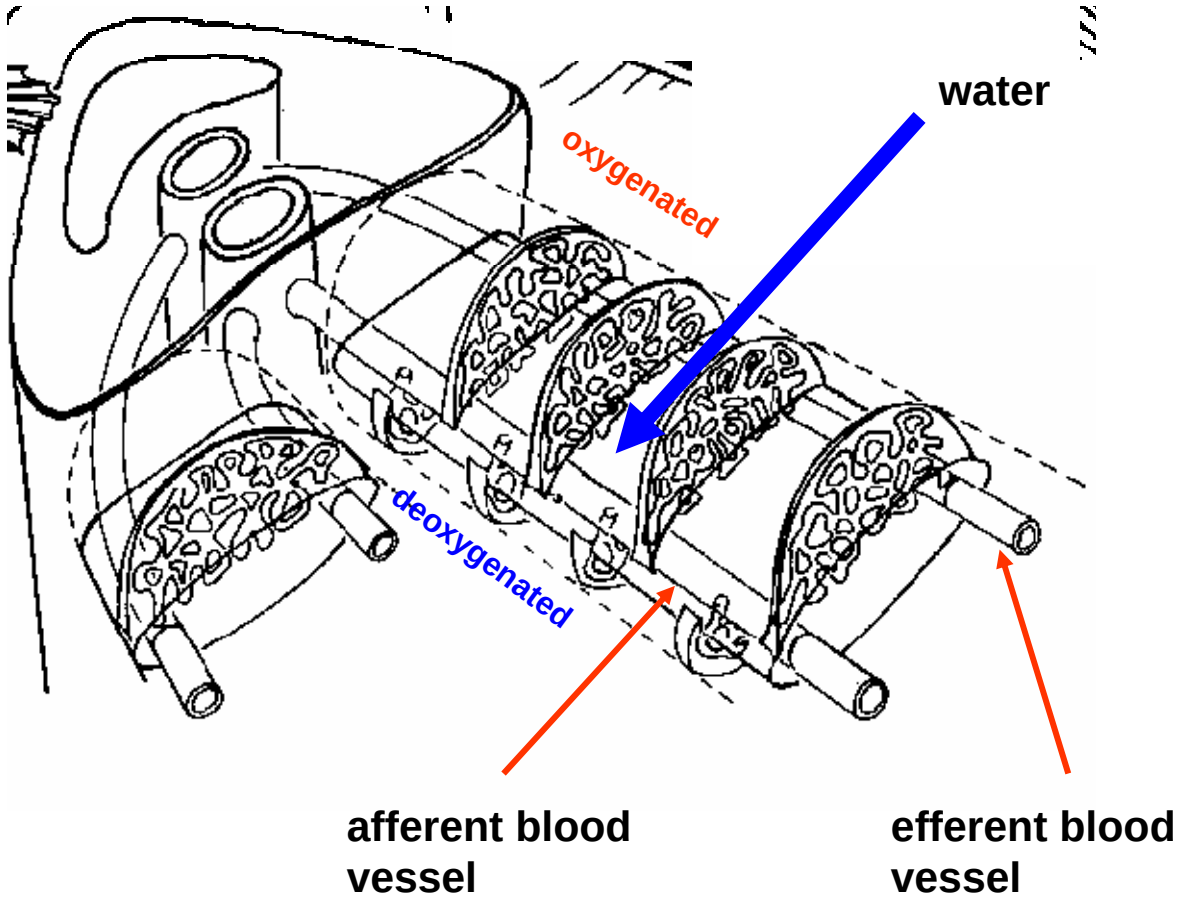
blood vessels

gill filament

gill raker

gill arch




water
oxygenated
deoxygenated
afferent blood vessel
efferent blood vessel

Vertebrates began to invade land 400 million years ago

Differences between the aquatic and environment:

1. Oxygen content (oxygen is 20 times more abundant in air than water)
2. Density (air is less dense than water)
3. Temperature (fluctuates more on land)
4. Habitat diversity (more on land)

During the Devonian, vertebrates evolved 2 traits that would allow them to colonize land:

The Devonian (400 million years ago)

- The freshwater environment was unstable
- All of the freshwater fish that survived this period had a lung that was derived from the pharynx.
- Vertebrate limbs also evolved during the Devonian

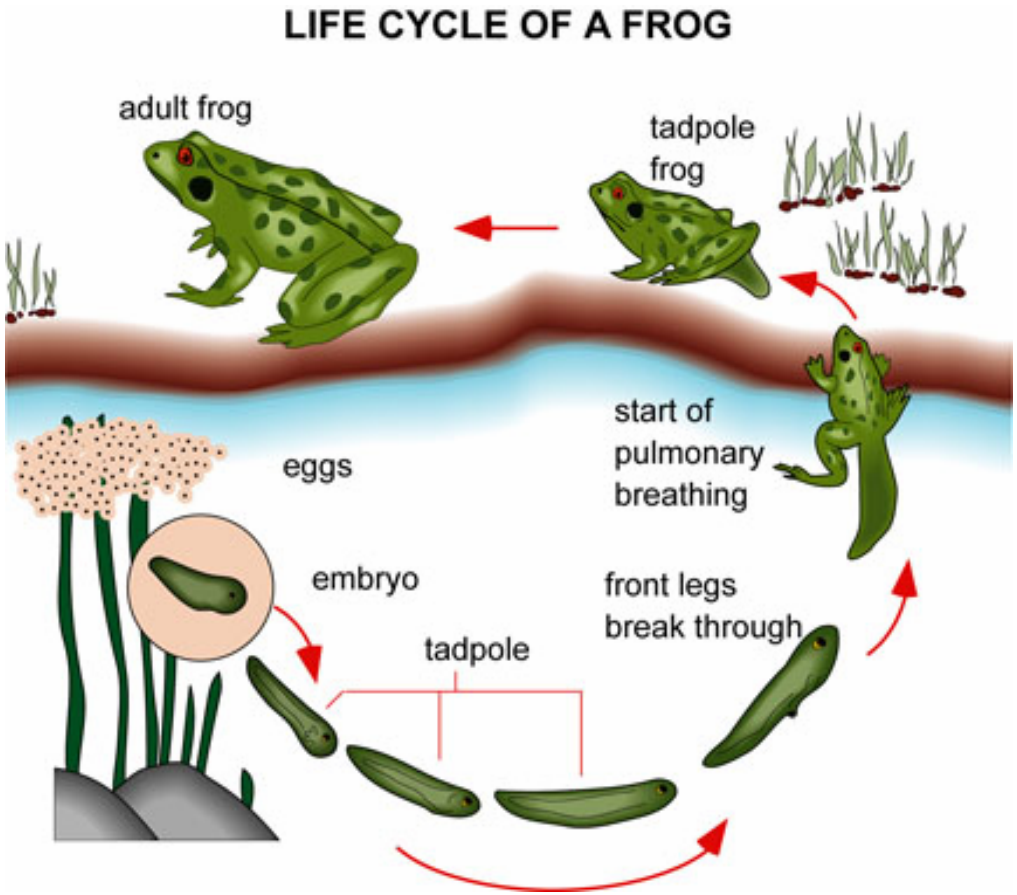
Class Amphibia

frogs, toads, and salamanders

Class Amphibia

- 4200 species
- mostly bony skeleton
- 4 limbs (tetrapods)
- smooth, moist, glandular skin
- three chambered heart
- gills, lungs, and/or skin respiration
- ectothermic (body temperature matches the temperature of the environment)

The lifecycle of most amphibians mirrors the evolutionary transition from an aquatic to a terrestrial existence.

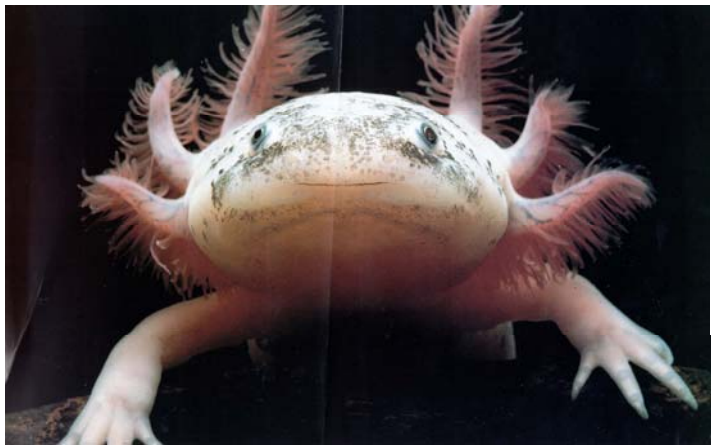


Caecilians:

- 160 species
- Limbless, burrowing, mostly blind

Salamanders:

- 360 species
- Tailed amphibians
- Limbs at about right angle to the body.



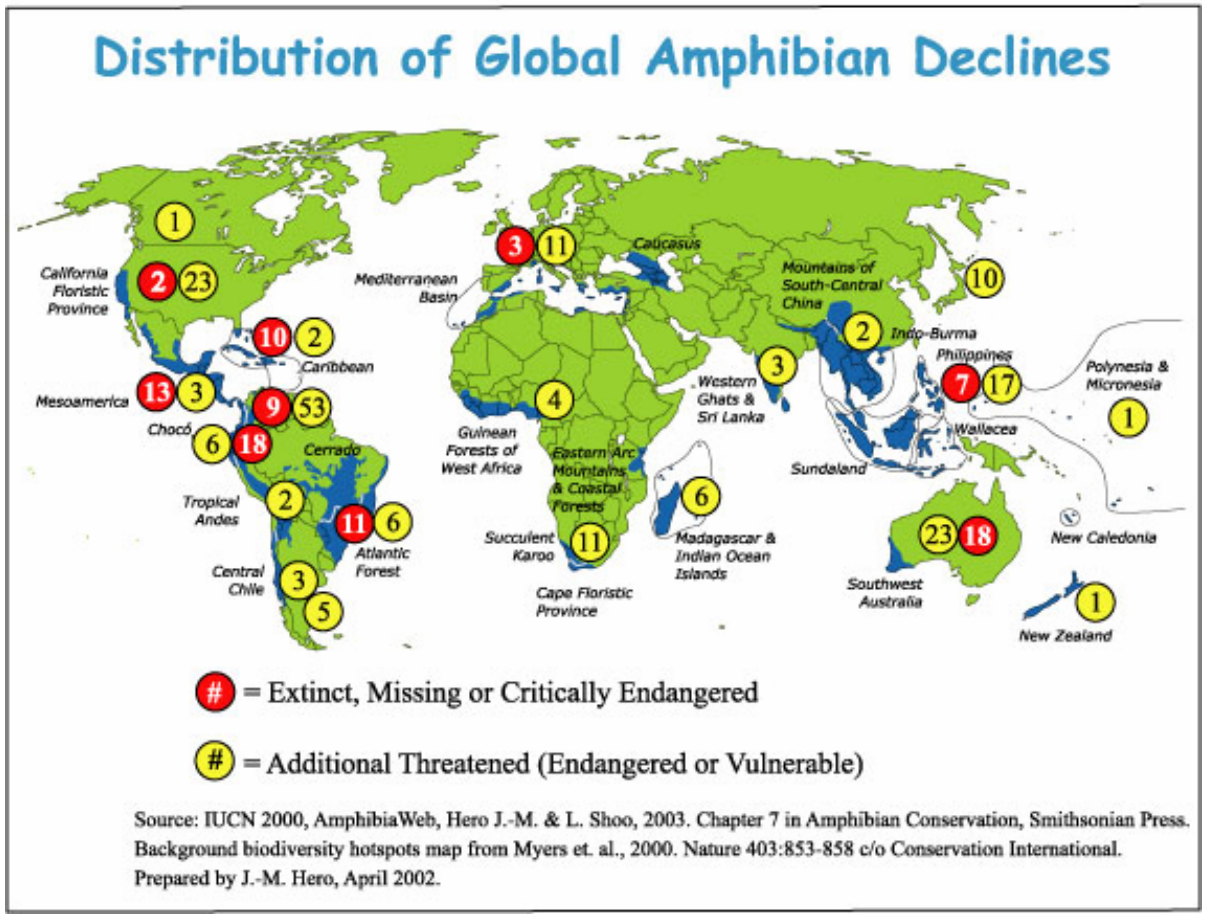
Paedomorphosis: the evolutionary retention of juvenile characteristics in reproductively mature individuals.

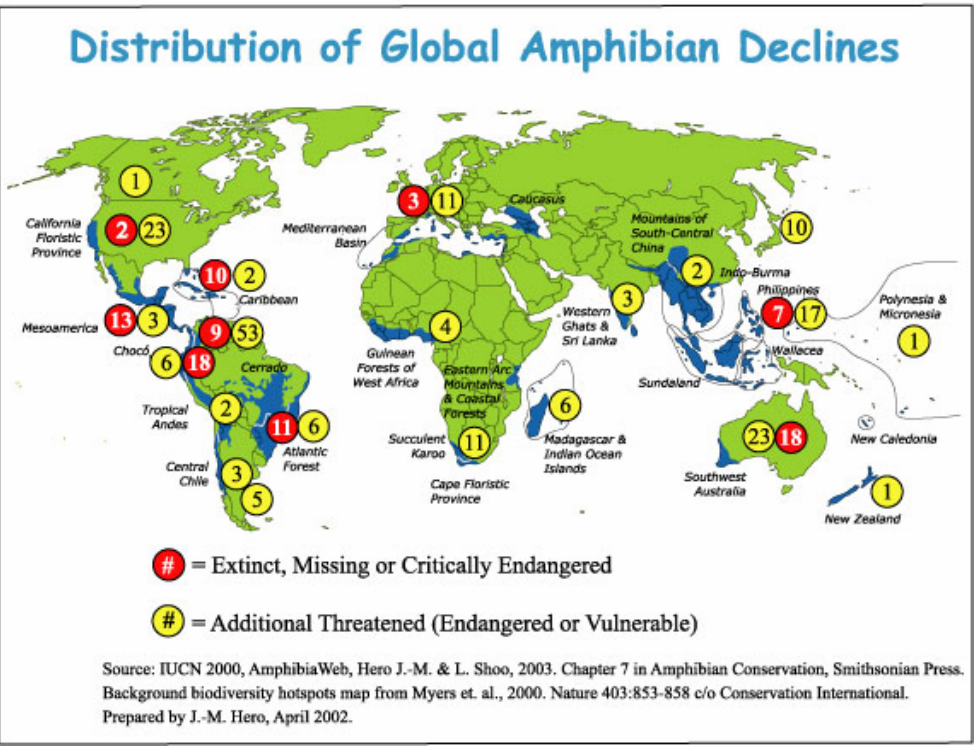
Paedomoprphosis can be obligate or facultative.

Anurans (frogs and toads):

- 3500 species
- Head and trunk fused, no tail
- Powerful hind limbs.

Amphibian populations are declining globally





Possible causes of this decline are :

1. Habitat destruction.
2. Introduced species.
3. UV light
4. Overexploitation.
5. Climate change.
6. Contaminants
7. Diseases and parasites.
8. Synergism.

Possible causes of the amphibian decline: Habitat loss

1. Habitat destruction: complete elimination of suitable habitat.

2. Habitat alteration: changes in habitat that alter ecosystem function.

3. Habitat fragementation: results in isolated populations.

Possible causes of the amphibian decline: Introduced species

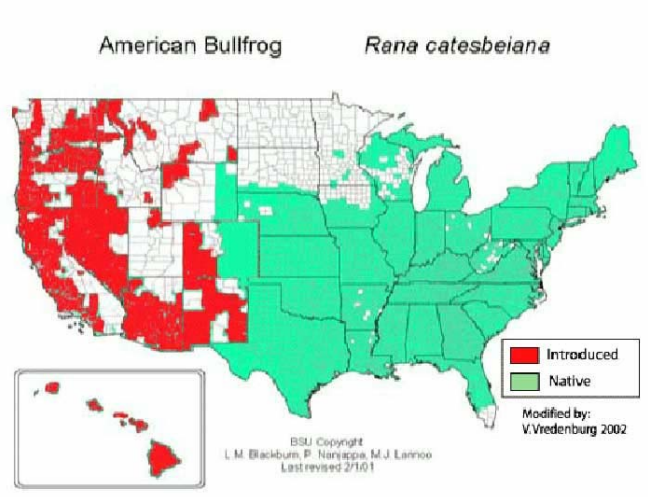
Rana mucosa

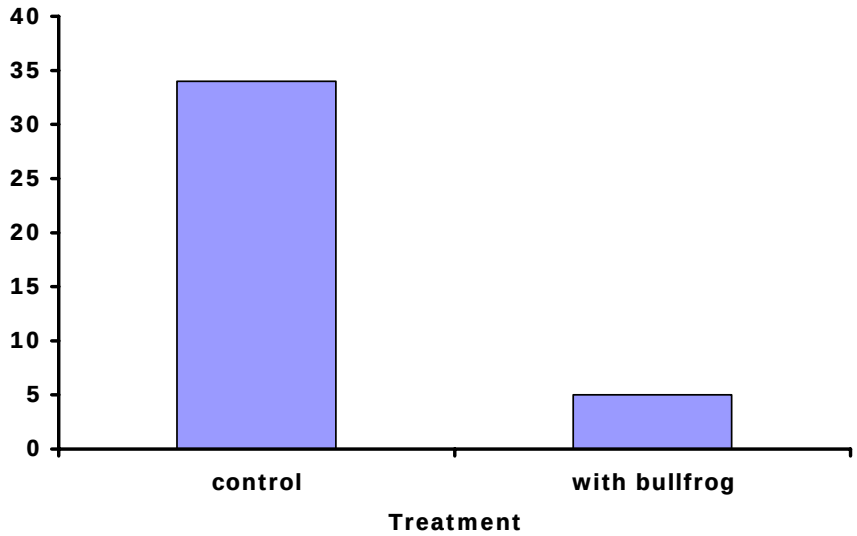
- Once the most common vertebrate in lakes in the Sierra Nevada
- Until the mid 1800's, 99 % of lakes in the Sierra Nevada were fishless

Trout

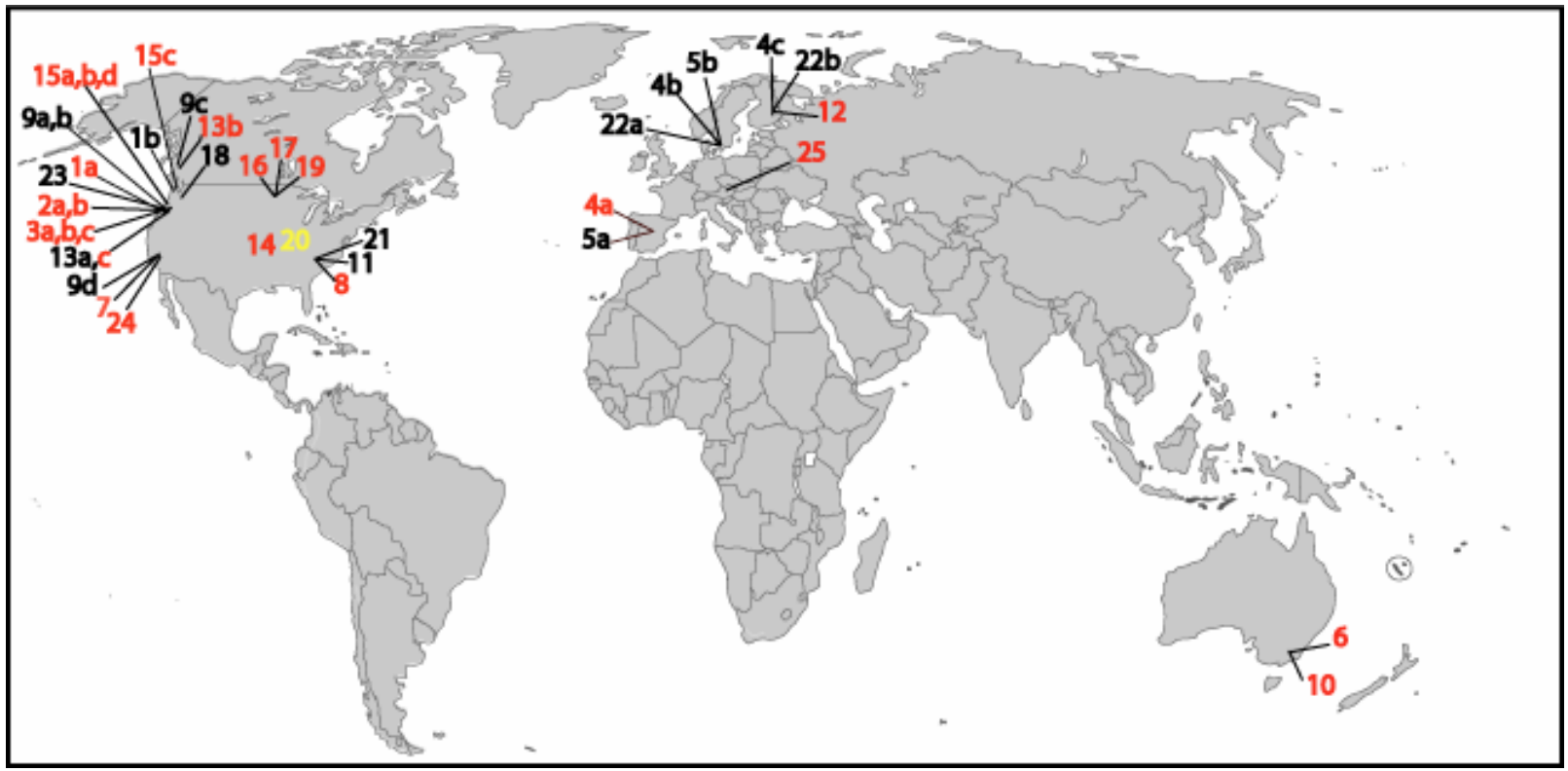
- Trout were introduced to streams in the Sierra
- Now >80 % of all lakes in the Sierra Nevada have fish
- *Rana mucosa* is now endangered.

Possible causes of the amphibian decline: Introduced species





Possible causes of the amphibian decline: Increased UV B radiation



Negative effect of UV on survival

No effect

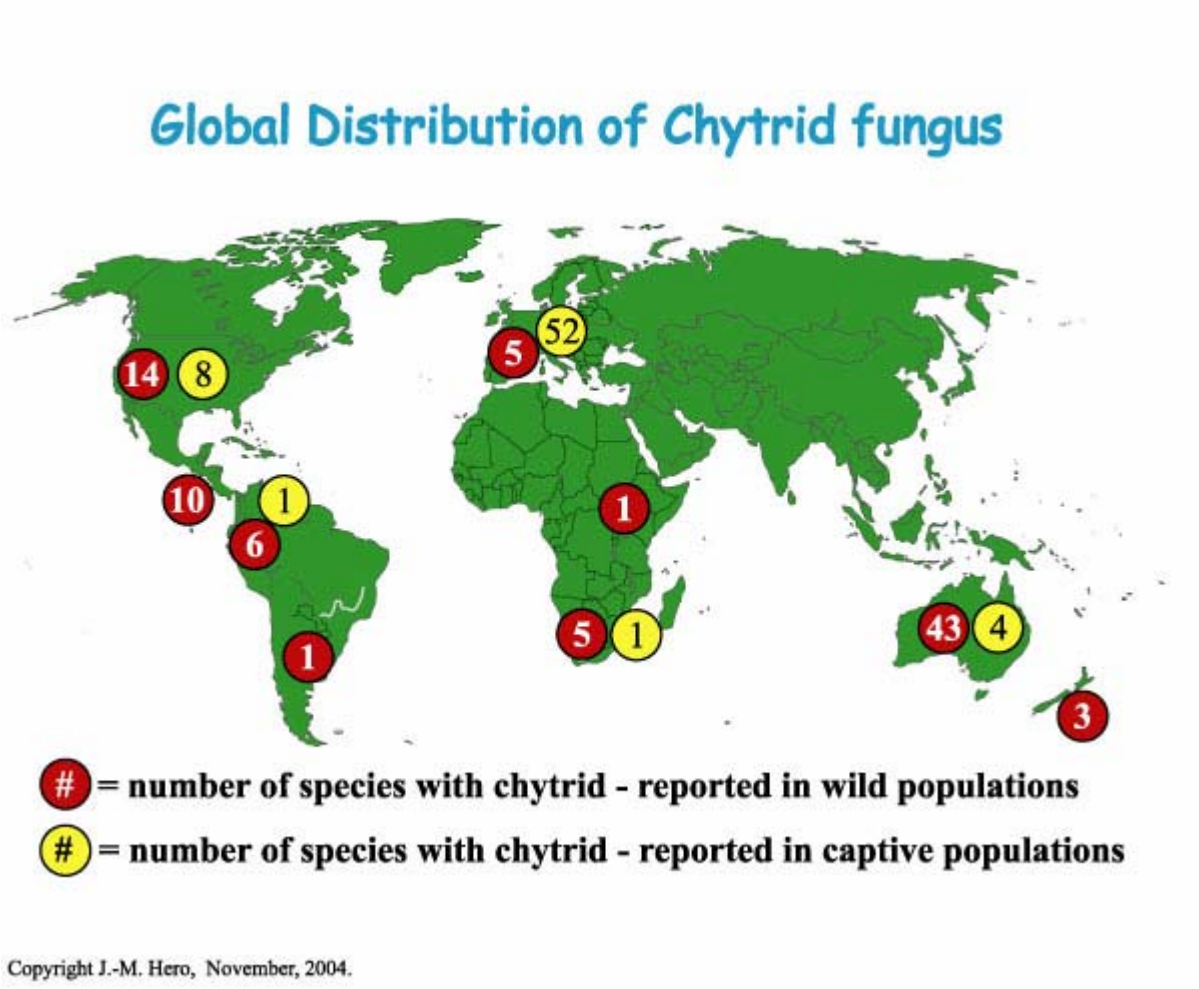
Positive effect

Possible causes of the amphibian decline:
Contaminants

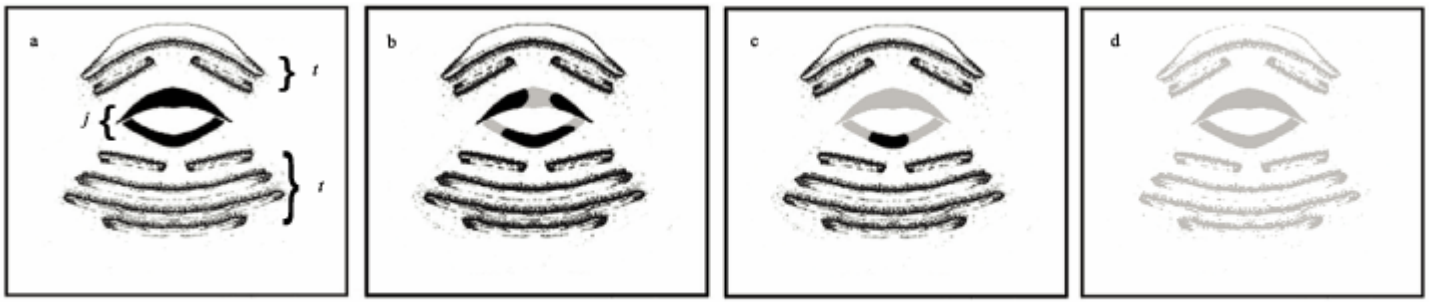
Contaminant / effect on animal:

1. Atrazine / demasculinization and hermaphroditisim
2. Heavy metals / decreased hatching success
3. Nitrogen pollution / changes in feeding behavior, deformities

Possible causes of the amphibian decline: Parasites and diseases



Possible causes of the amphibian decline: Parasites and diseases



Infected with *Batrachochytrium dendrobatidis*

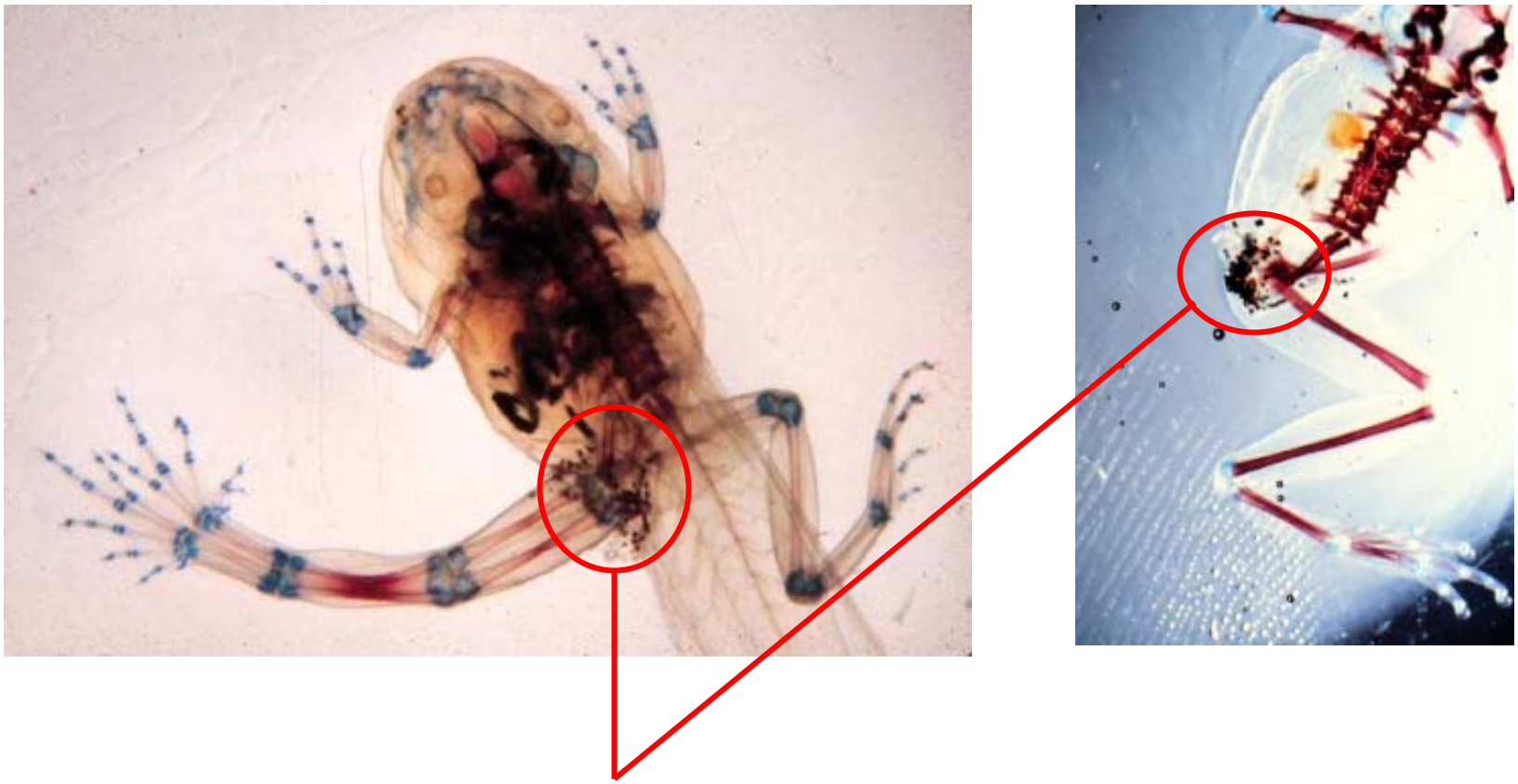
- Chytrid fungus causes the depigmentation of tadpole mouthparts, and leads to post metamorphic death
- It is not known whether the the chytrid fungus is spreading geographically or whether it has always been present

Possible causes of the amphibian decline: Parasites and diseases

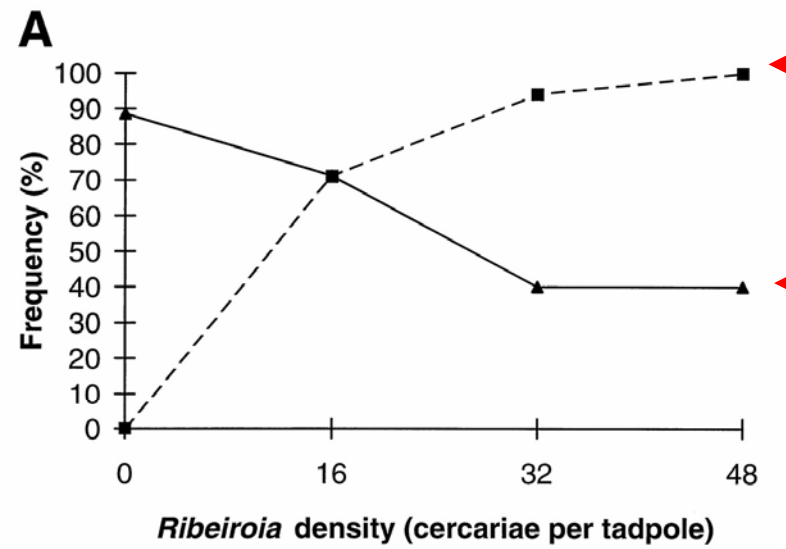
Limb deformities in amphibians have been recorded since the 1950's.

Since the early 1990s, there has been an apparent increase in the number of frogs found with limb deformities.

Possible causes of the amphibian decline: Parasites and diseases

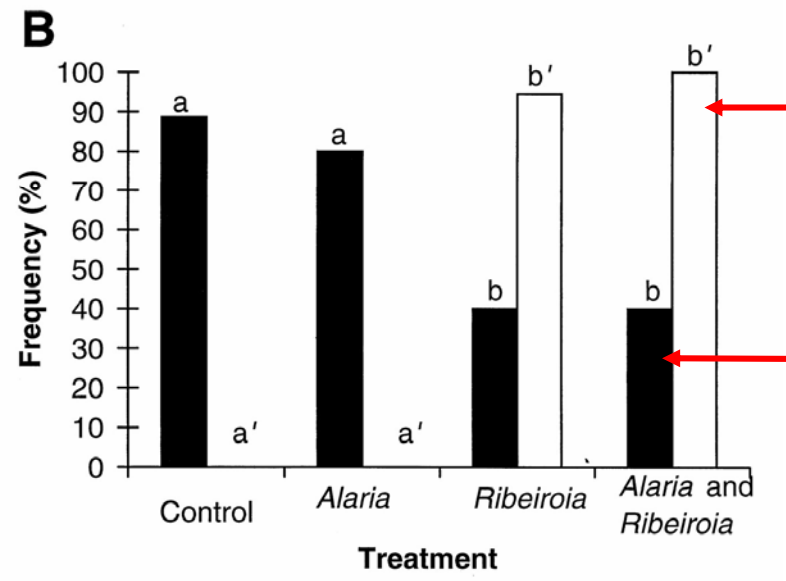


Cysts formed by the trematode, *Ribeiroia*



Deformities

Survival

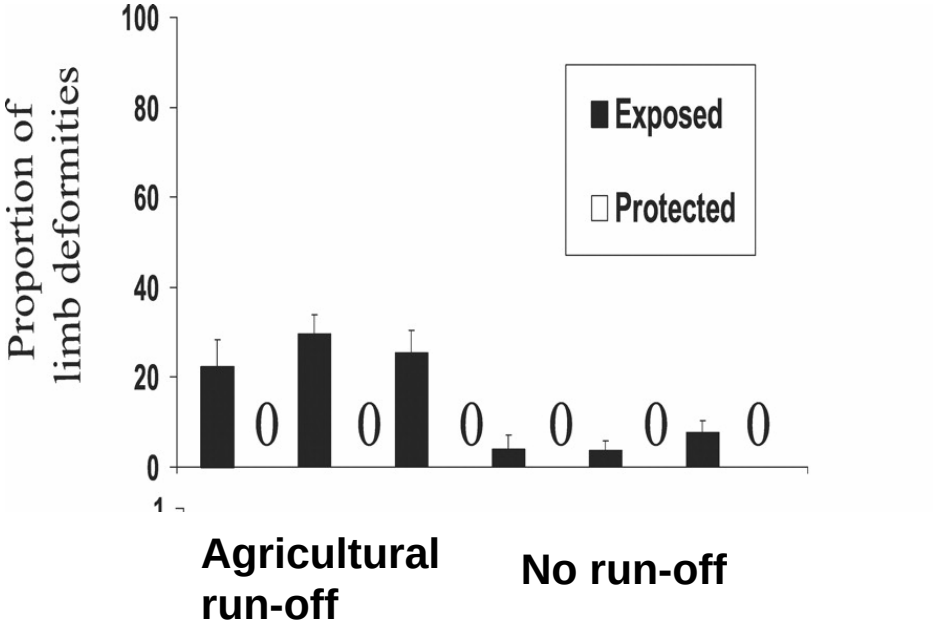


Deformities

Survival

Johnson, et al. 1999

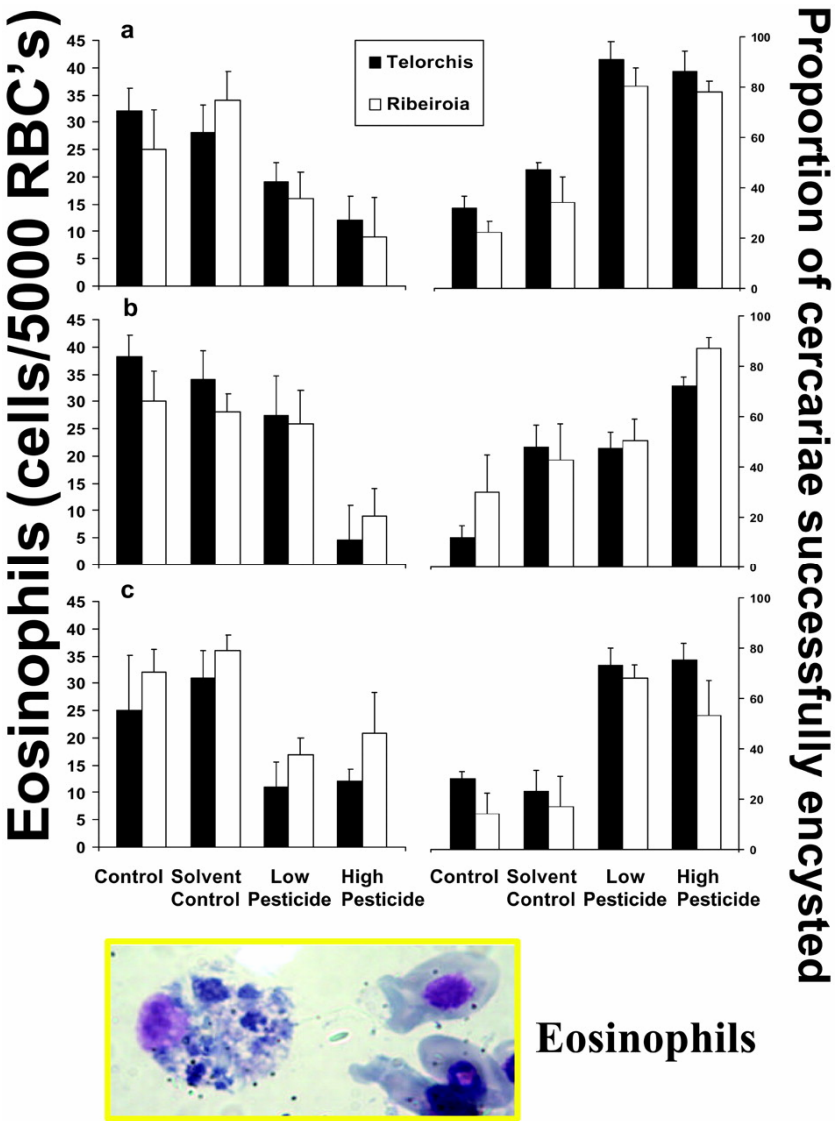
Possible causes of the amphibian decline: Synergism



Deformities are more common near agricultural run-off.

From Kiesecker 2002

Possible causes of the amphibian decline: Synergism



Pesticides affect a frog's immune response to the parasite.

From Kiesecker 2002

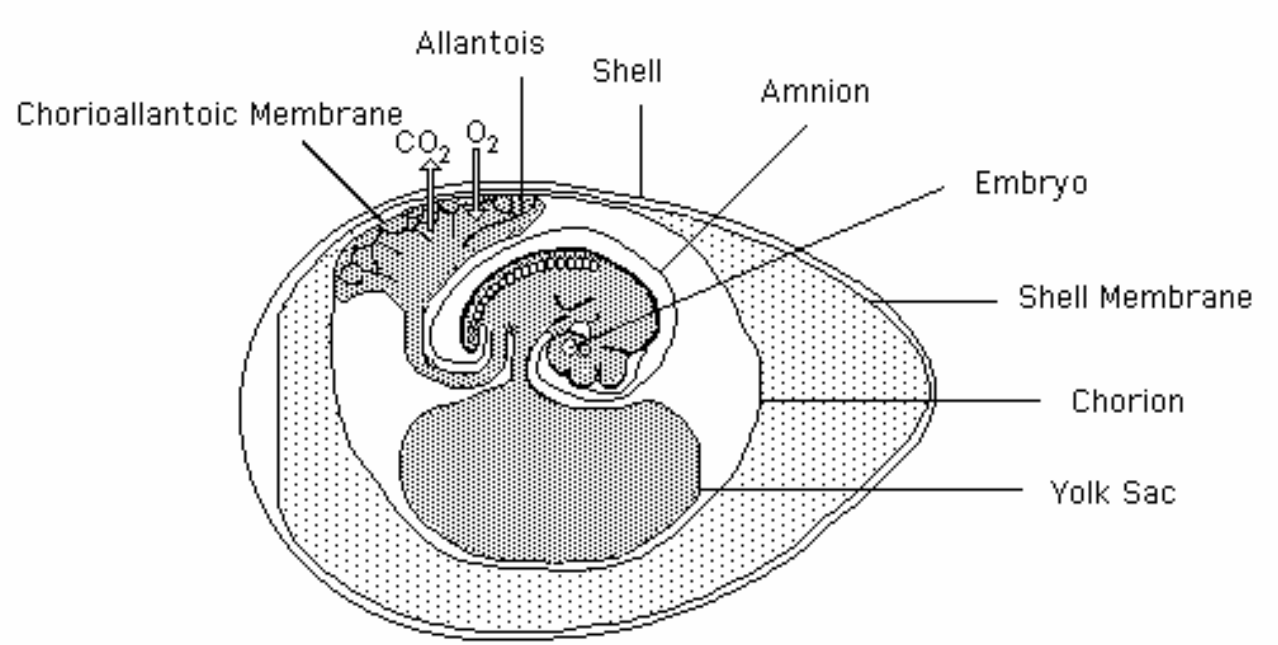
Subphylum Vertebrata

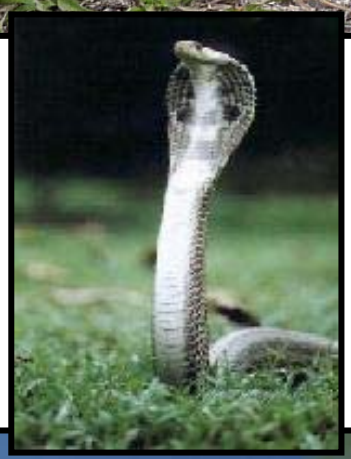
- Class Agnatha
- Class Chondrichthyes
- Class Osteichthyes
- Class Amphibia
- ★ Class Reptilia
- ★ Class Aves
- ★ Class Mammalia

★ Amniotes

The Amniotic Egg

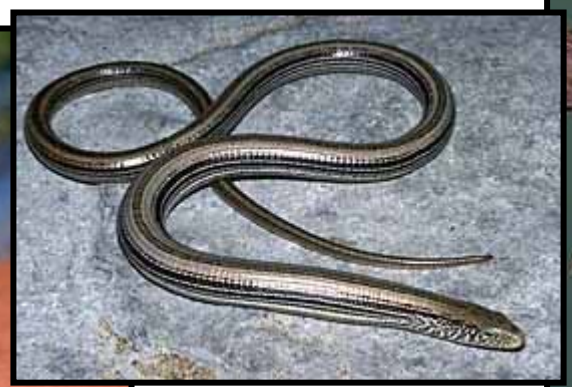
- amniotic eggs are shelled and contain a fluid-filled sac (the amnion) that surrounds the embryo
- the evolution of the amniotic egg allowed the amniotes to reproduce away from water





Class Reptilia

lizards, snakes, turtles, alligators, and crocodiles

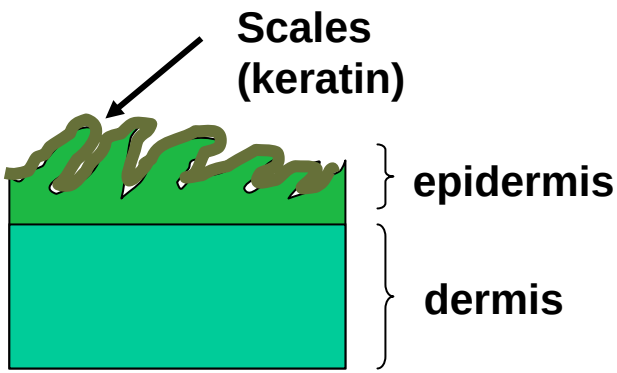


Class Reptilia

- 7000 species
- mostly bony skeleton
- 4 limbs (tetrapods)
- body covered by horny, epidermal scales
- few glands
- three chambered heart (except for crocodilians)
- respiration exclusively by lungs
- amniotic egg
- ectothermic

Class Reptilia

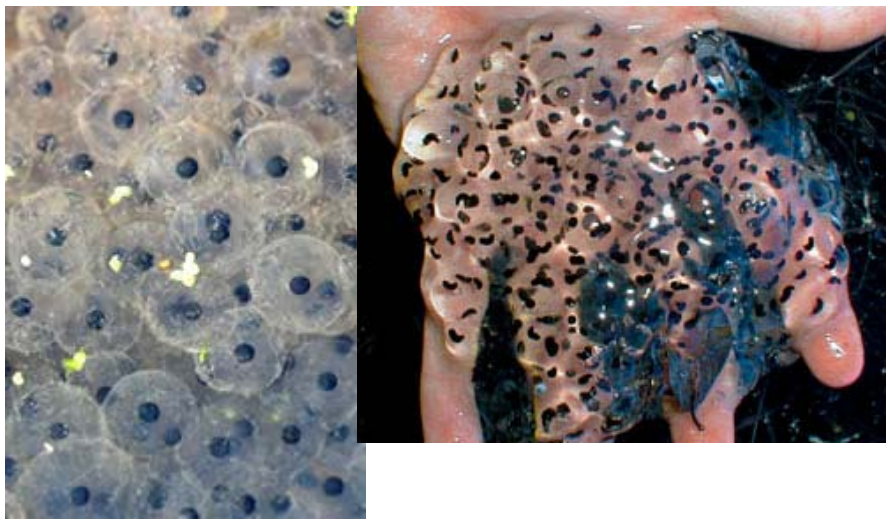
Major differences between Reptiles and Amphibians:
1. The skin: reptiles have a thin epidermis covered in scales. Amphibians do not have scales and do not molt.



Class Reptilia

Major differences between Reptiles and Amphibians:

2. The amniotic egg:



Amphibian eggs are not shelled, and need to be kept moist

Reptile eggs are shelled, and can withstand desiccation

Class Reptilia

Major differences between Reptiles and Amphibians:
3. Jaws: The jaw bones and muscles of reptiles are more developed than the jaws of amphibians (larger and longer)

Amphibian jaws can close quickly but apply little force

Reptile jaws can close powerfully and apply great force

Class Reptilia

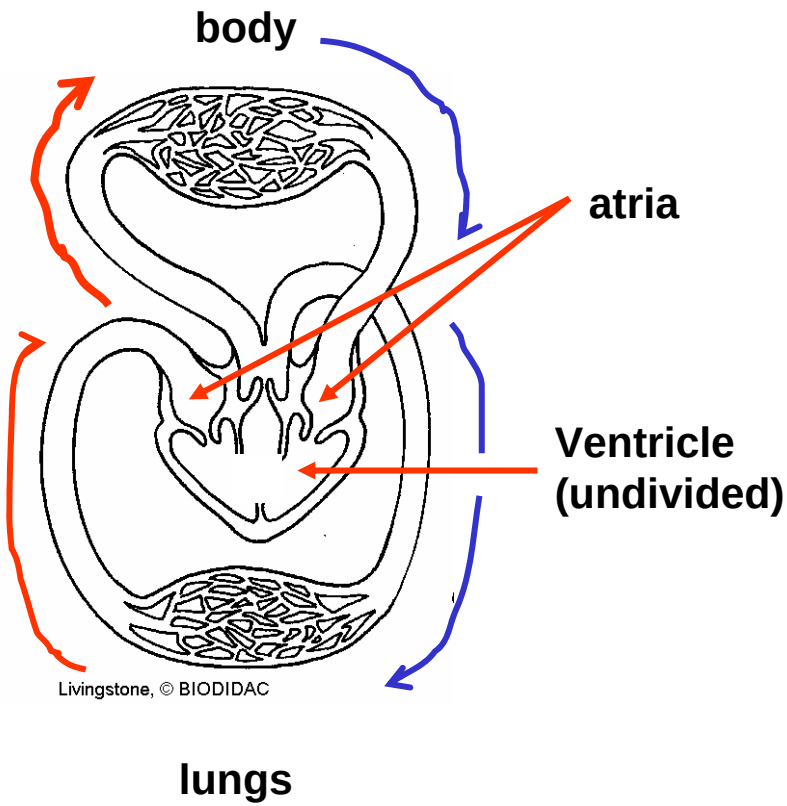
Major differences between Reptiles and Amphibians:

4. Reptiles have a copulatory organ, amphibians do not:

Fertilization is external in most Amphibians, and eggs are not shelled

Fertilization is internal in reptiles and they lay shelled eggs or give live birth

Amphibian circulatory system



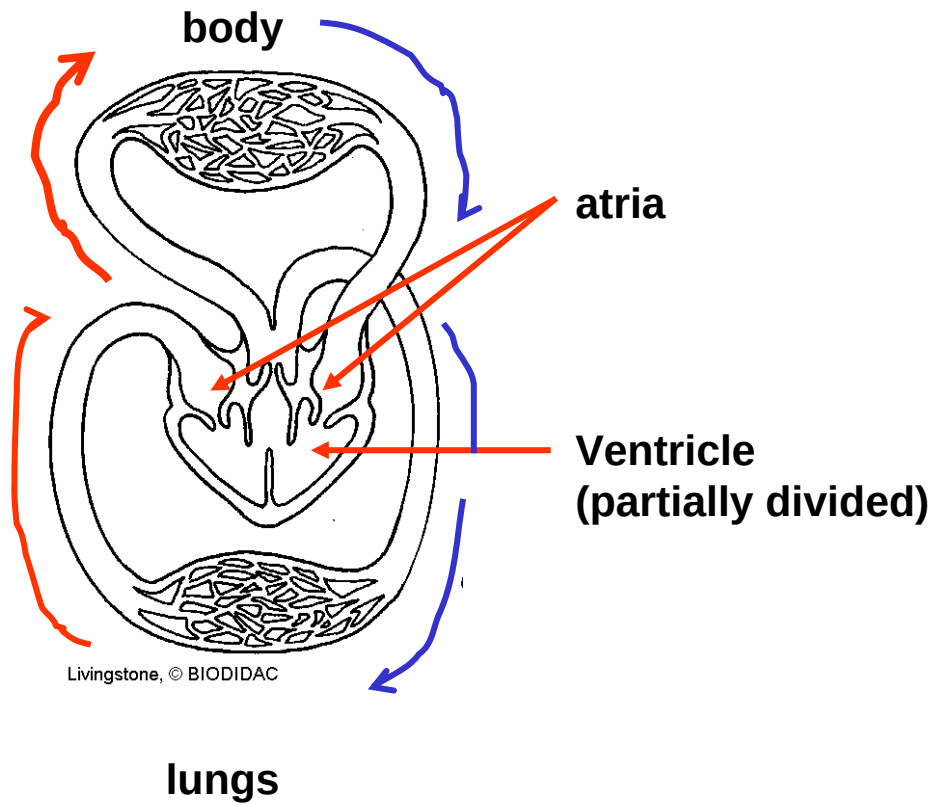
Amphibian rely on lungs/ gills/ and the skin for respiration. Amphibians force air into the lungs gulping with the mouth.

Class Reptilia

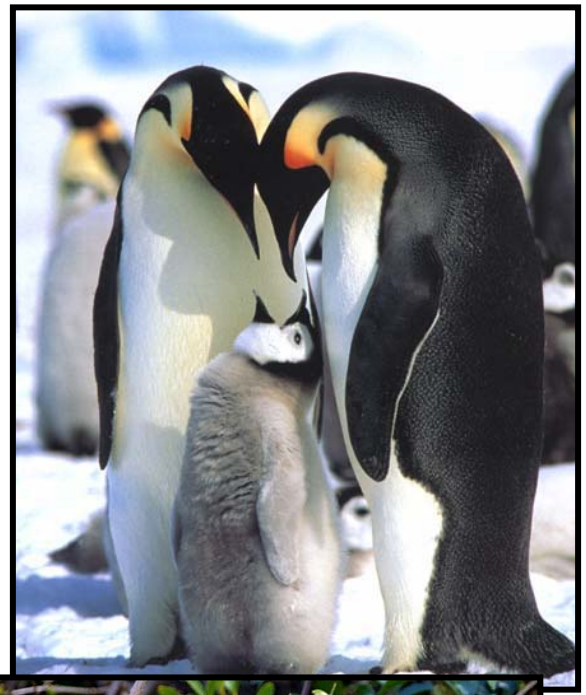
Major differences between Reptiles and Amphibians:

5. The circulatory and respiratory systems:

Reptile circulatory system

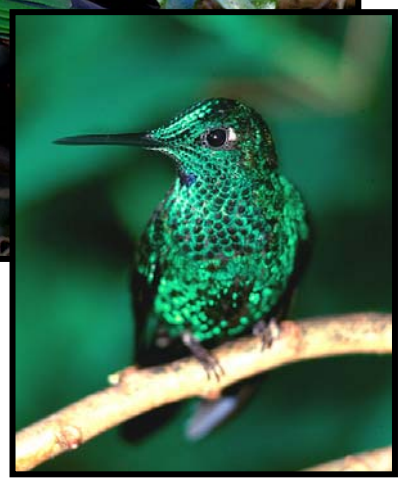


Reptiles rely on lungs for respiration, there is no gas exchange through the skin. Reptiles also suck air into the lungs by enlarging the thoracic cavity.



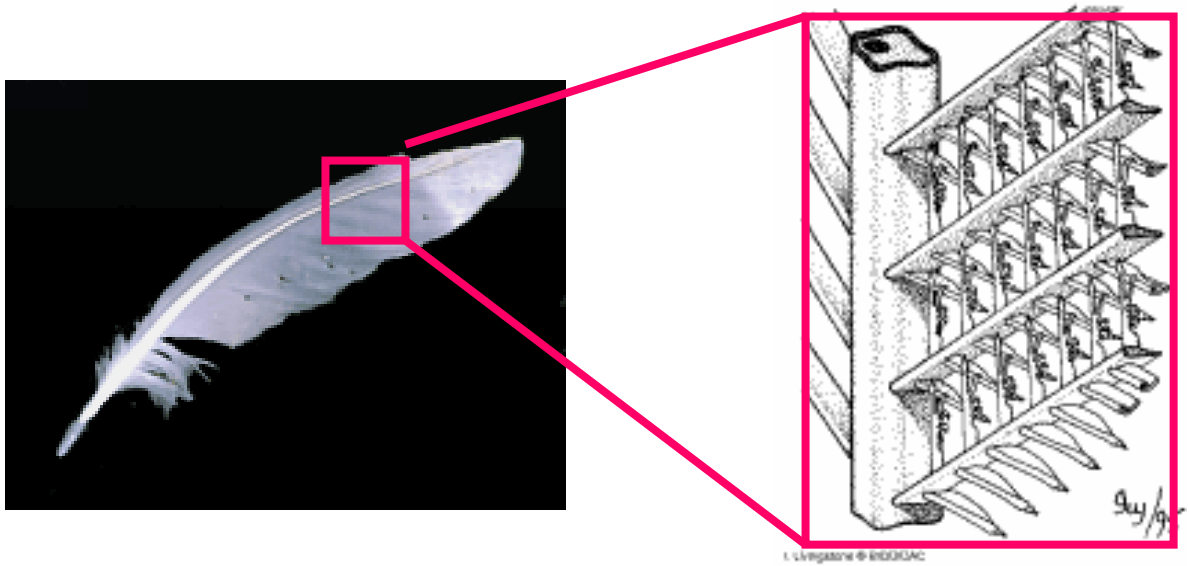
Class Aves

birds



Class Aves

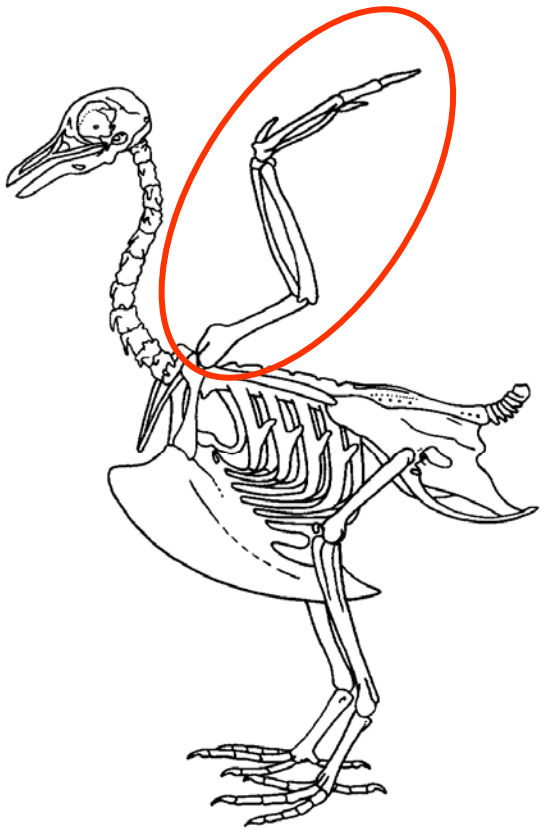
- 10, 000 species
- mostly bony skeleton with air cavities in the bones
- 4 limbs with forelimbs modified into wings
- four chambered heart
- amniotic egg
- in most species, the female only has the left ovary
- scales on legs and feathers which are modified scales

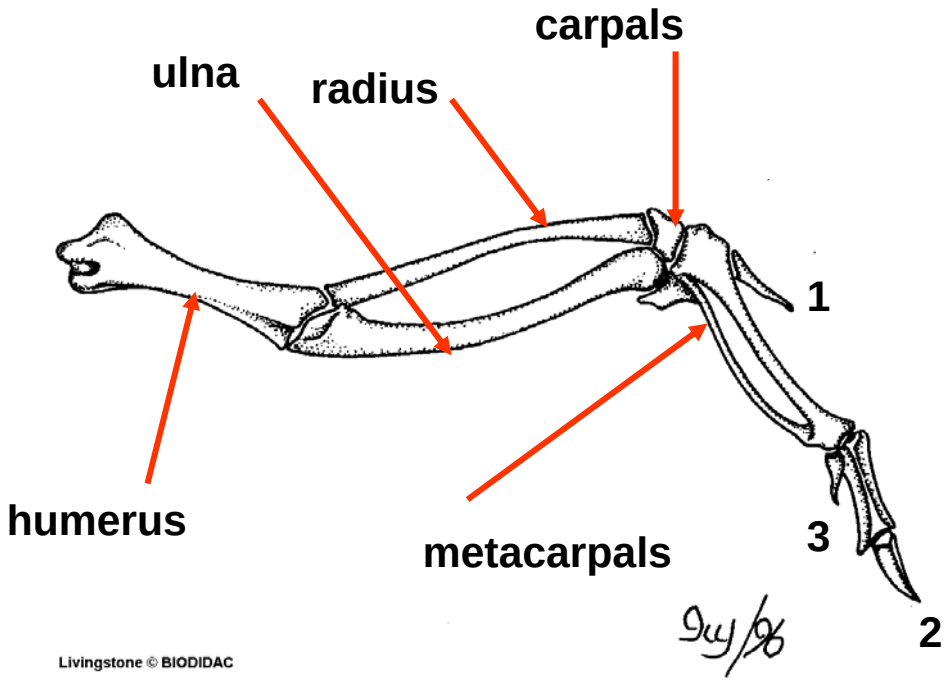


Class Aves

Adaptations for flight:

1. Wings



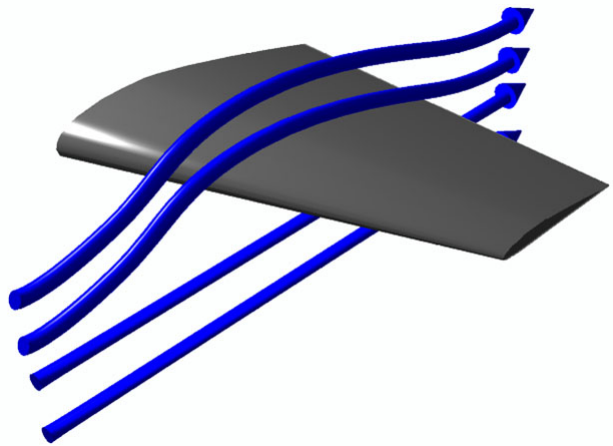


Class Aves

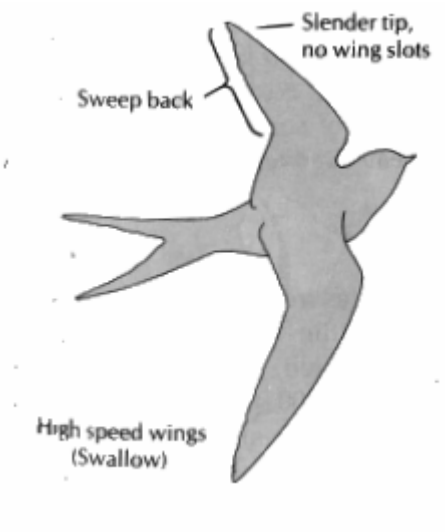
Adaptations for flight:

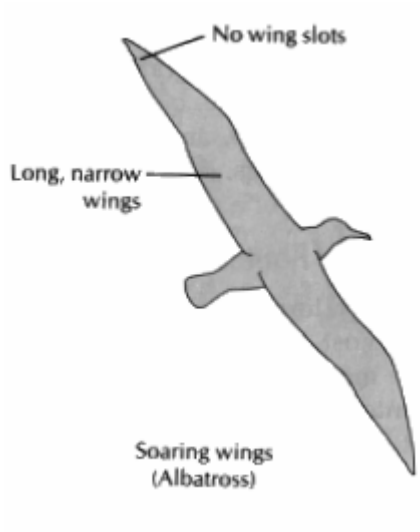
1. Wings

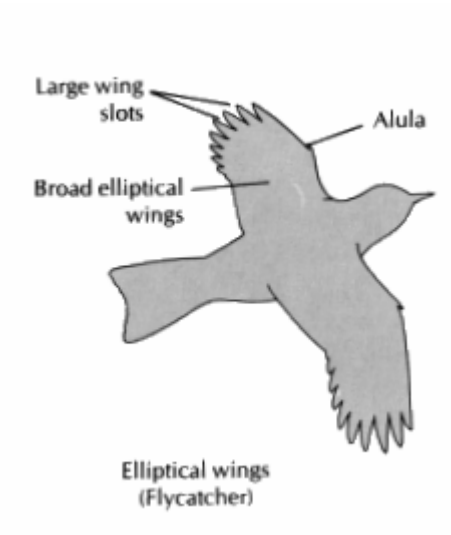
fast moving air, low pressure

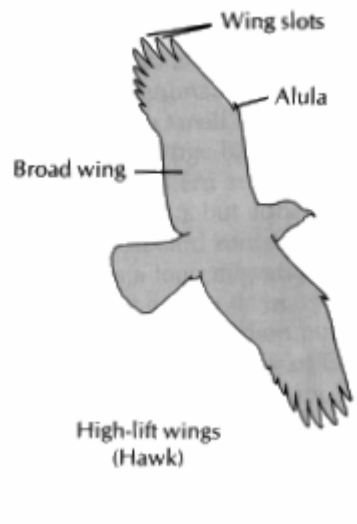


slow moving air, high pressure





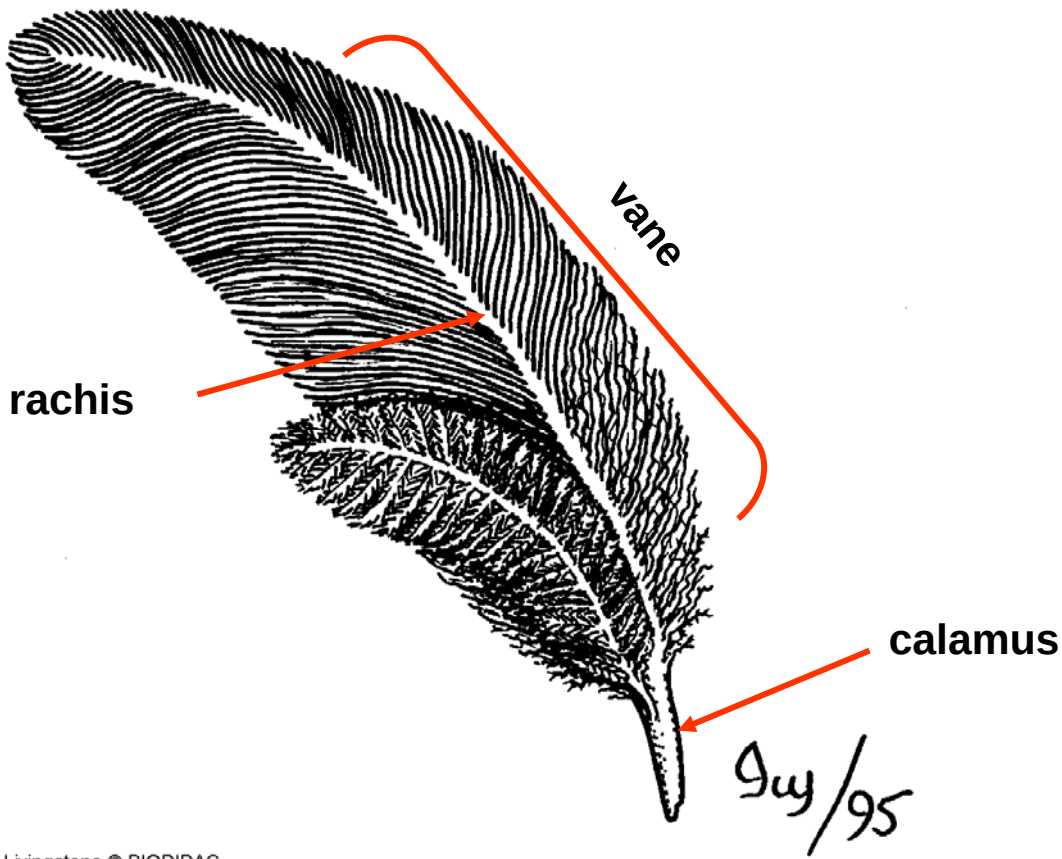




Class Aves

Adaptations for flight:

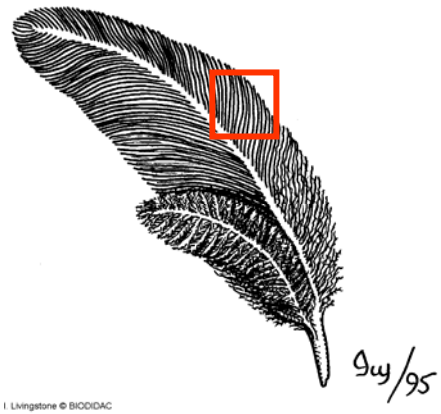
2. Feathers

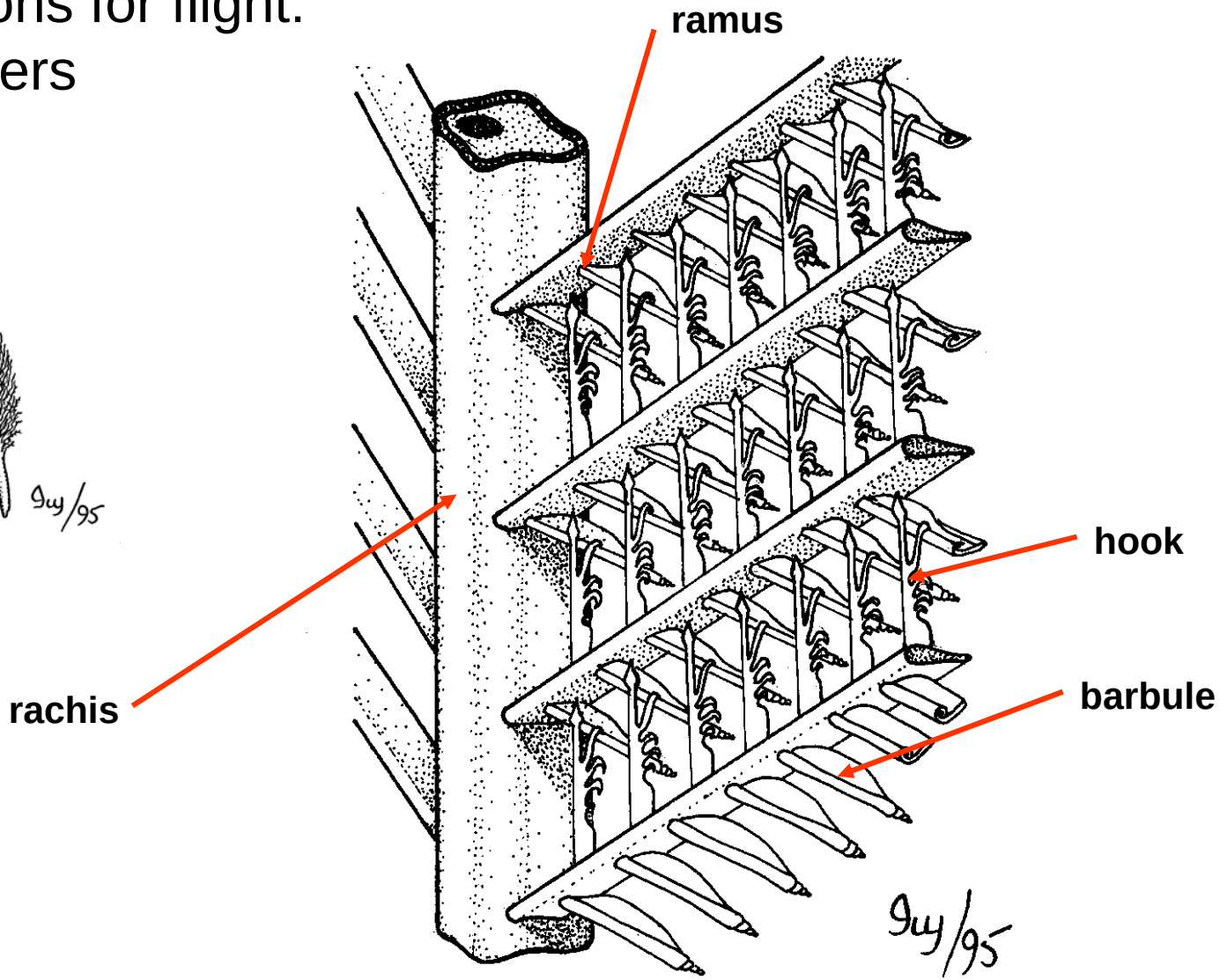


Class Aves

Adaptations for flight:

2. Feathers

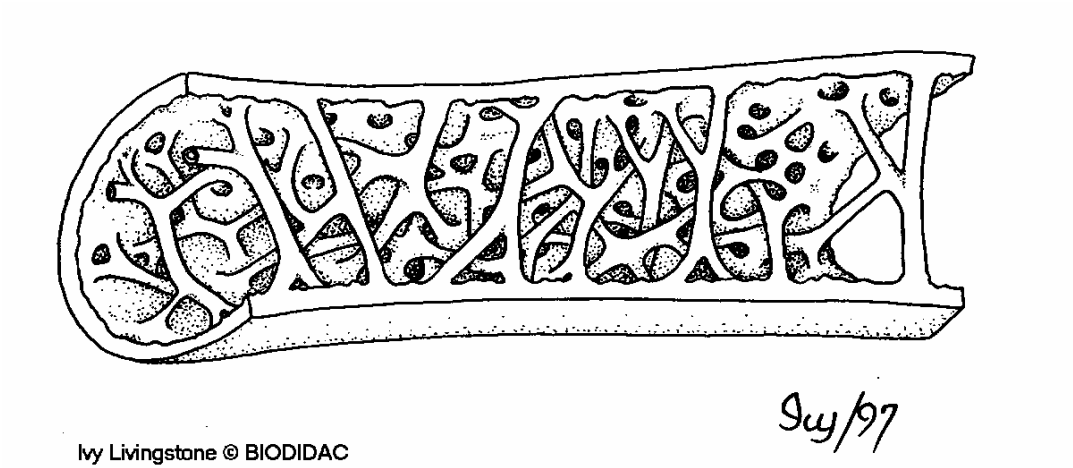




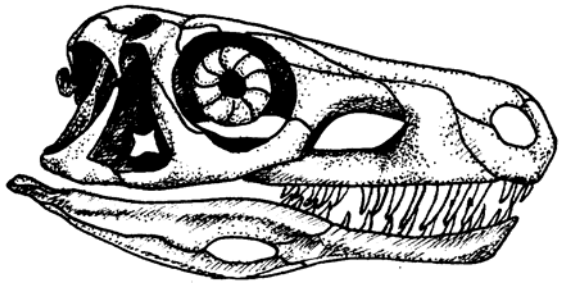
Class Aves

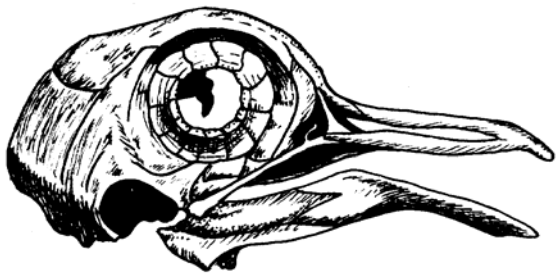
Adaptations for flight:

3. A light and sturdy skeleton

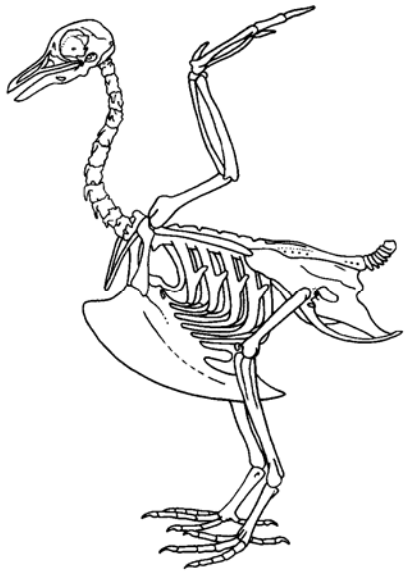


the avian skeleton is made of pneumatized bone, which is strong and light.





The avian skull is extremely light and is fused.

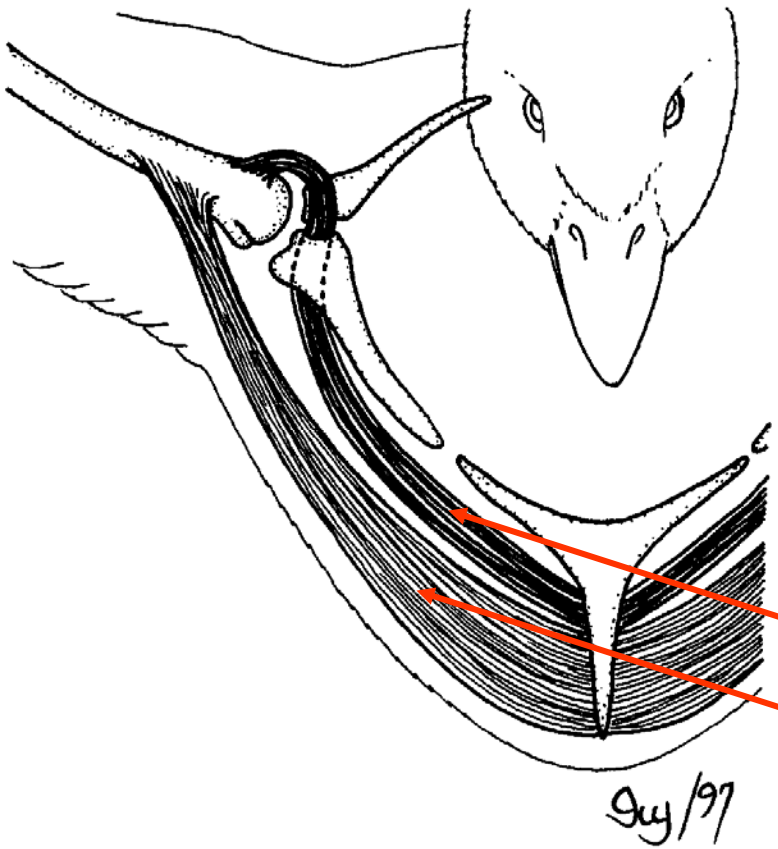


Most vertebrae are fused, and most birds have a keeled sternum to which the flight muscles attach.

Class Aves

Adaptations for flight:

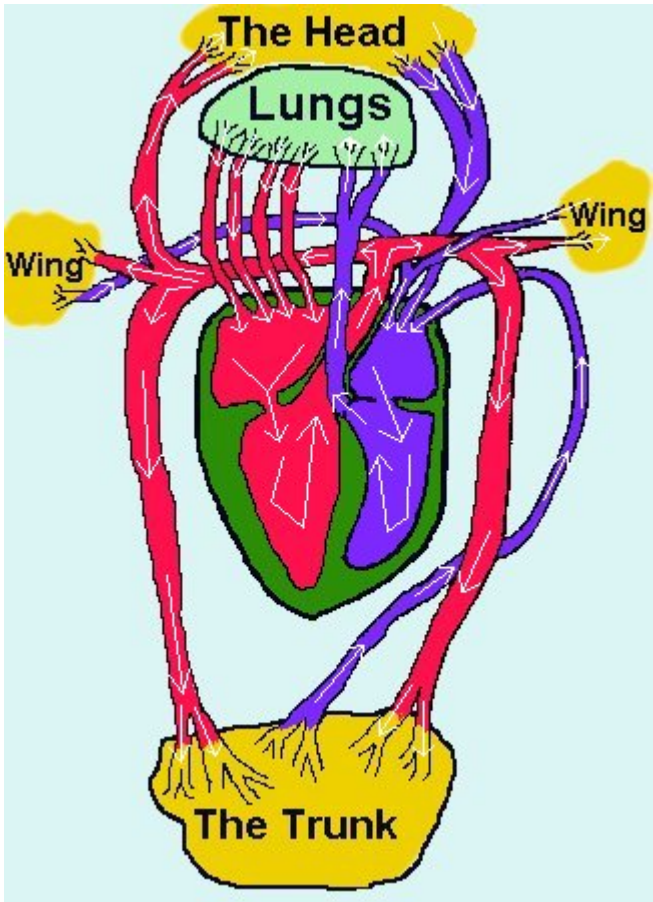
4. Flight muscles:



The muscles that move the wings (the pectoralis and the supracoracoideus) are hypertrohpied.

Adaptations for flight:

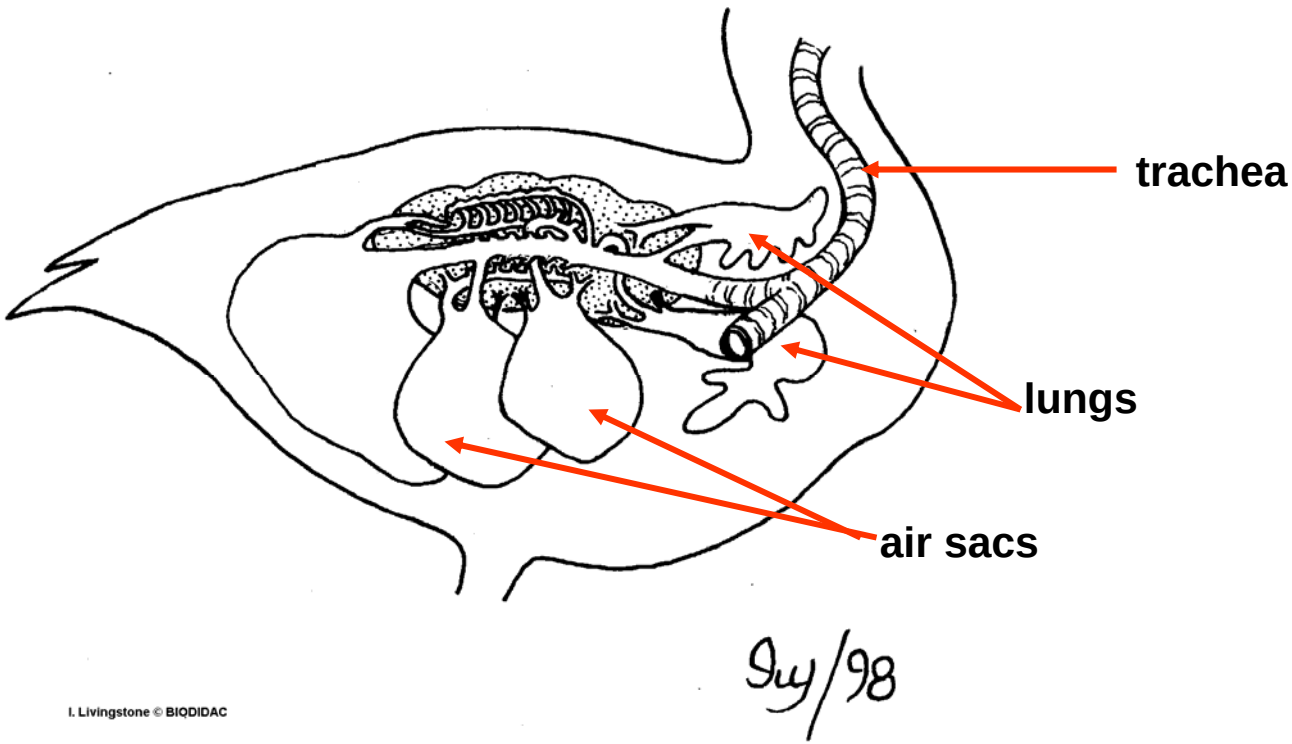
5. Efficient circulatory and respiratory systems.

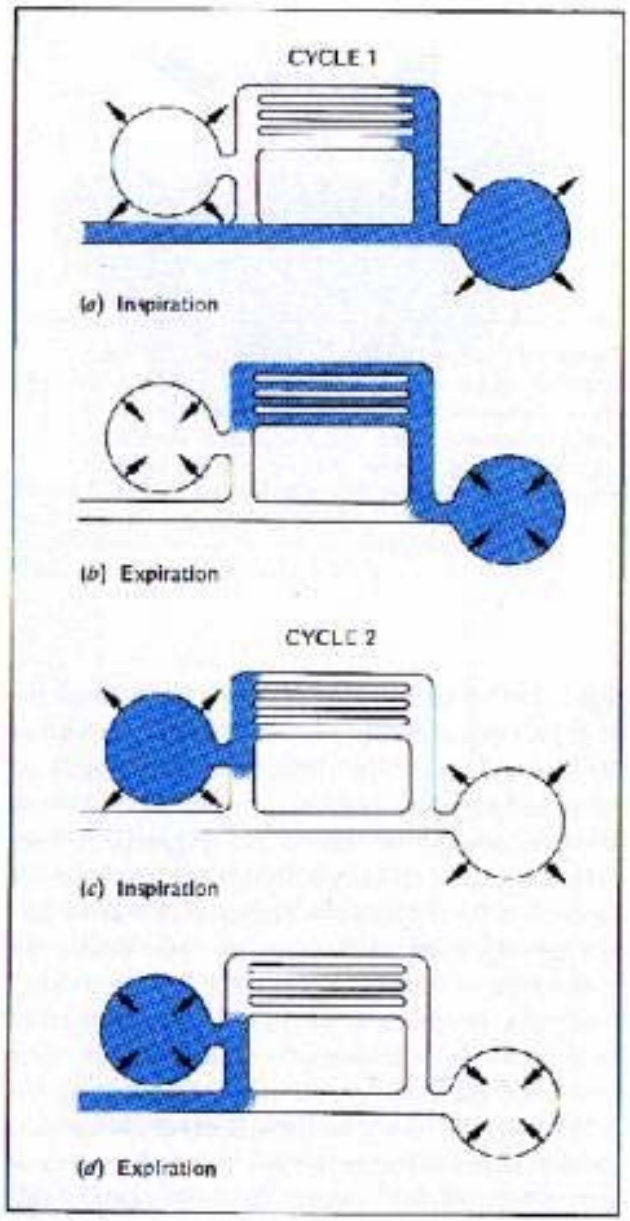


The heart has 4 chambers, so oxygenated and deoxygenated blood do not mix.

Class Aves

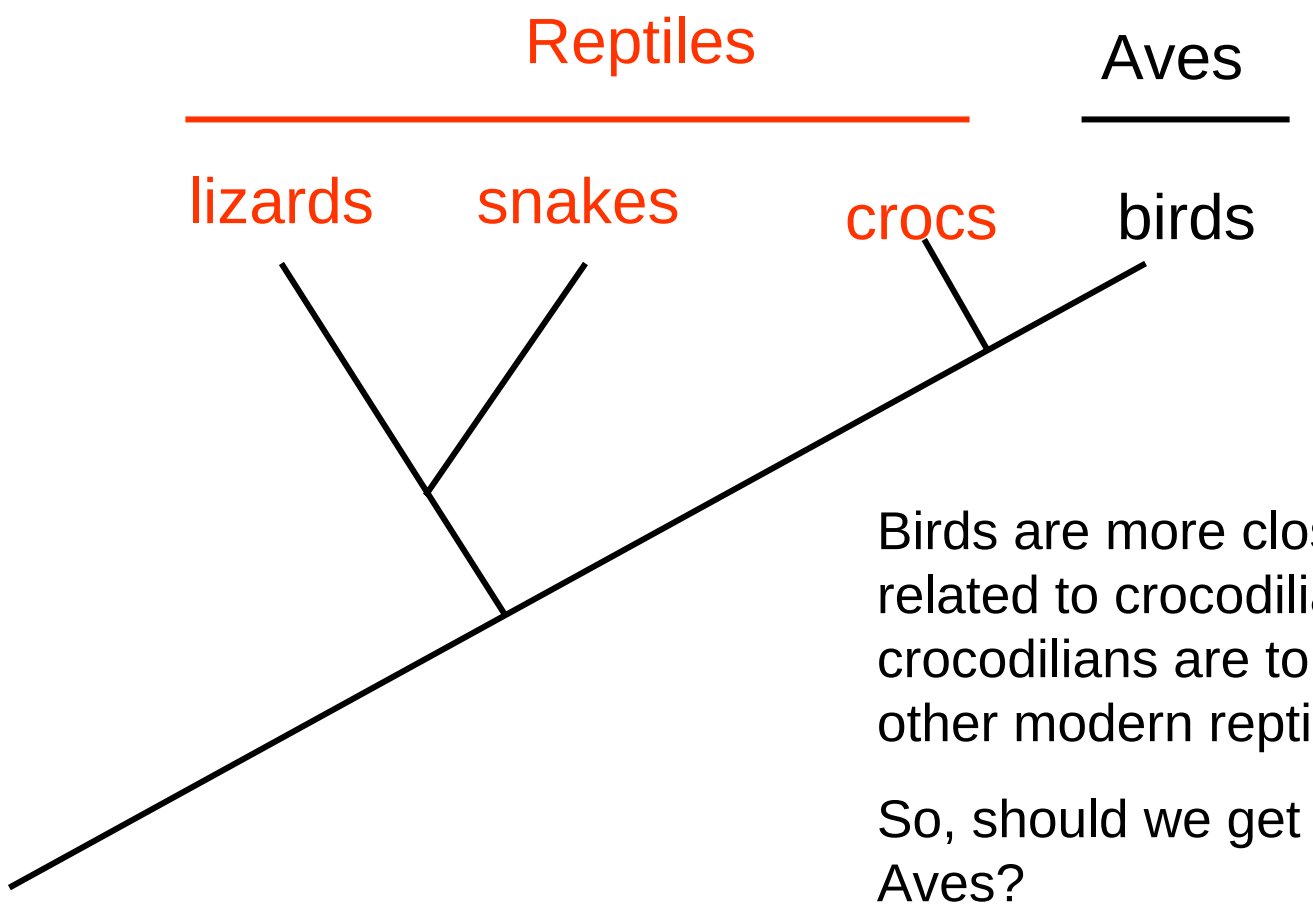
- endothermic (body temperature is regulated metabolically)
- flow-through respiratory system





Flow-through respiratory system: air only flows through the lungs once.

What is the phylogenetic position of Class Aves?



Birds are more closely related to crocodilians than crocodilians are to any other modern reptile.

So, should we get rid of Aves?

The relationship between taxonomy and systematics

- **Theories of taxonomy: what principles do we use to recognize and rank taxonomic groups ?**

1. **Traditional evolutionary taxonomy**
    - Taxa recognized based on common descent and amount of adaptive evolution
2. **Phylogenetic systematics (aka cladistics)**
    - Taxa recognized based on common descent

Theories of Taxonomy

1. **Traditional evolutionary taxonomy**

2. **Phylogenetic systematics (aka cladistics)**

These two theories differ in the way they view the relationship between phylogeny and taxonomy

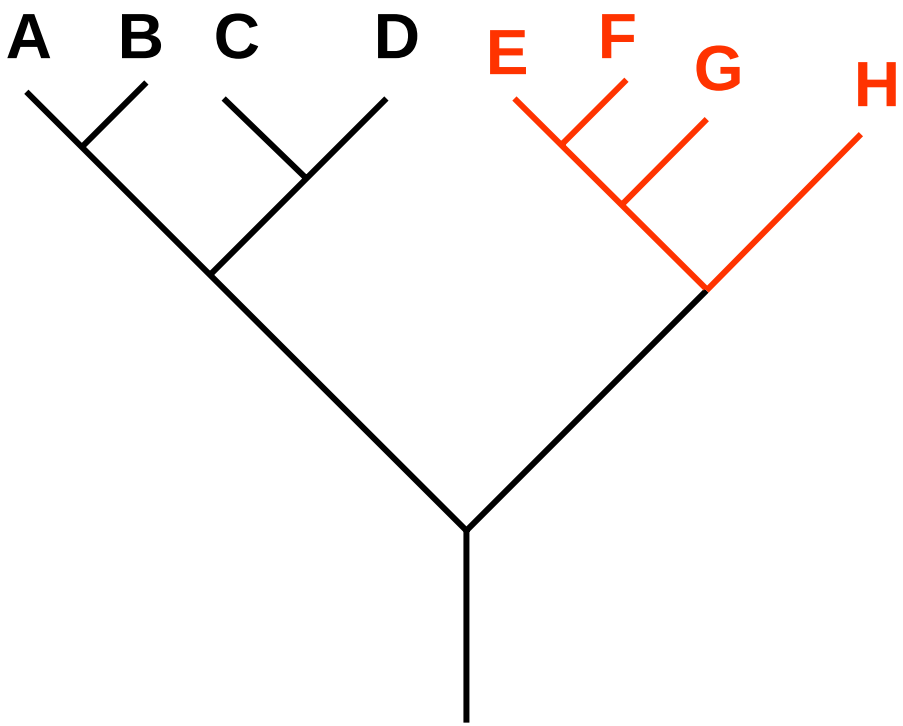
The relationship between a taxonomic group and a phylogeny can take one of three forms:

1. Monophyly

2. Paraphyly

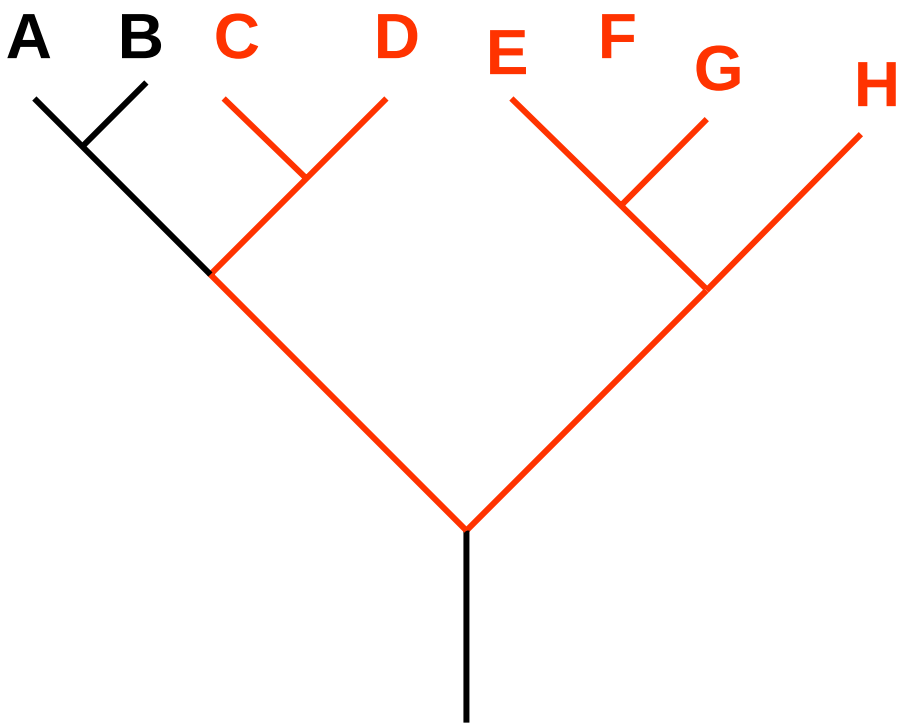
3. Polyphyly

Monophyly: a group of taxa that contains the most recent common ancestor off all members of the group and its descendents



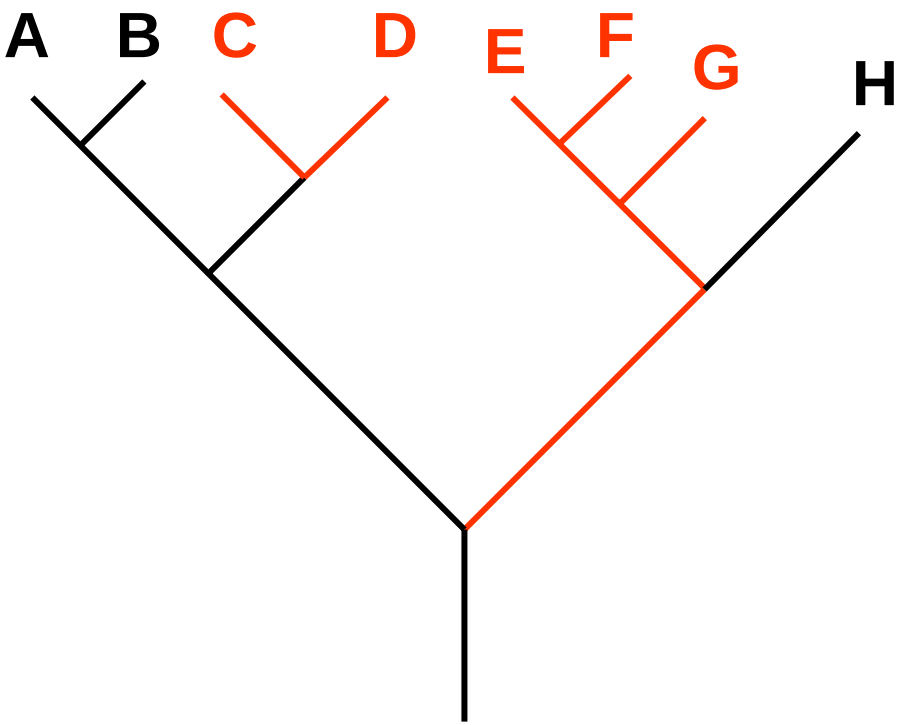
E, F, G, H represent a monophyletic group

Paraphyly: a group of taxa that contains the most recent common ancestor off all members of the group and some, but not all of its descendents



C, D, E, F, G, H represent a paraphyletic group

Polyphyly: a group of taxa that does not include the most recent common ancestor of all of the group members



C, D, E, F, G, represent a polyphyletic group

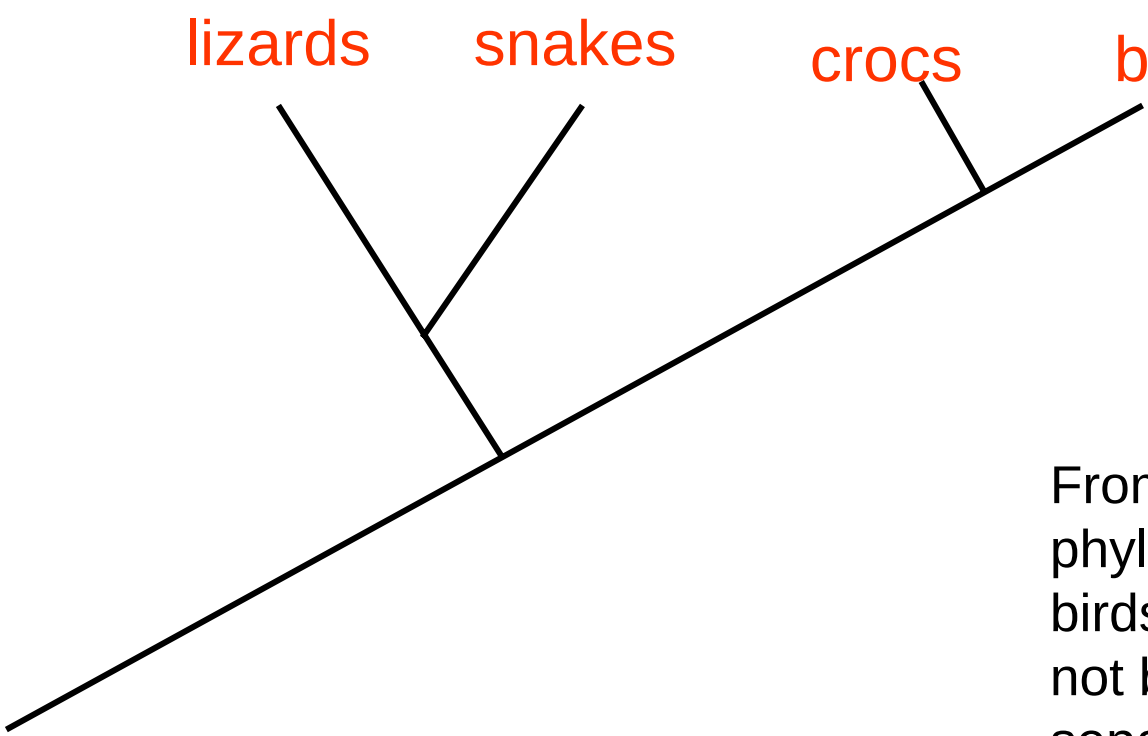
Classification and Phylogeny of Animals

1. **Traditional evolutionary taxonomy: monophyly or paraphyly**

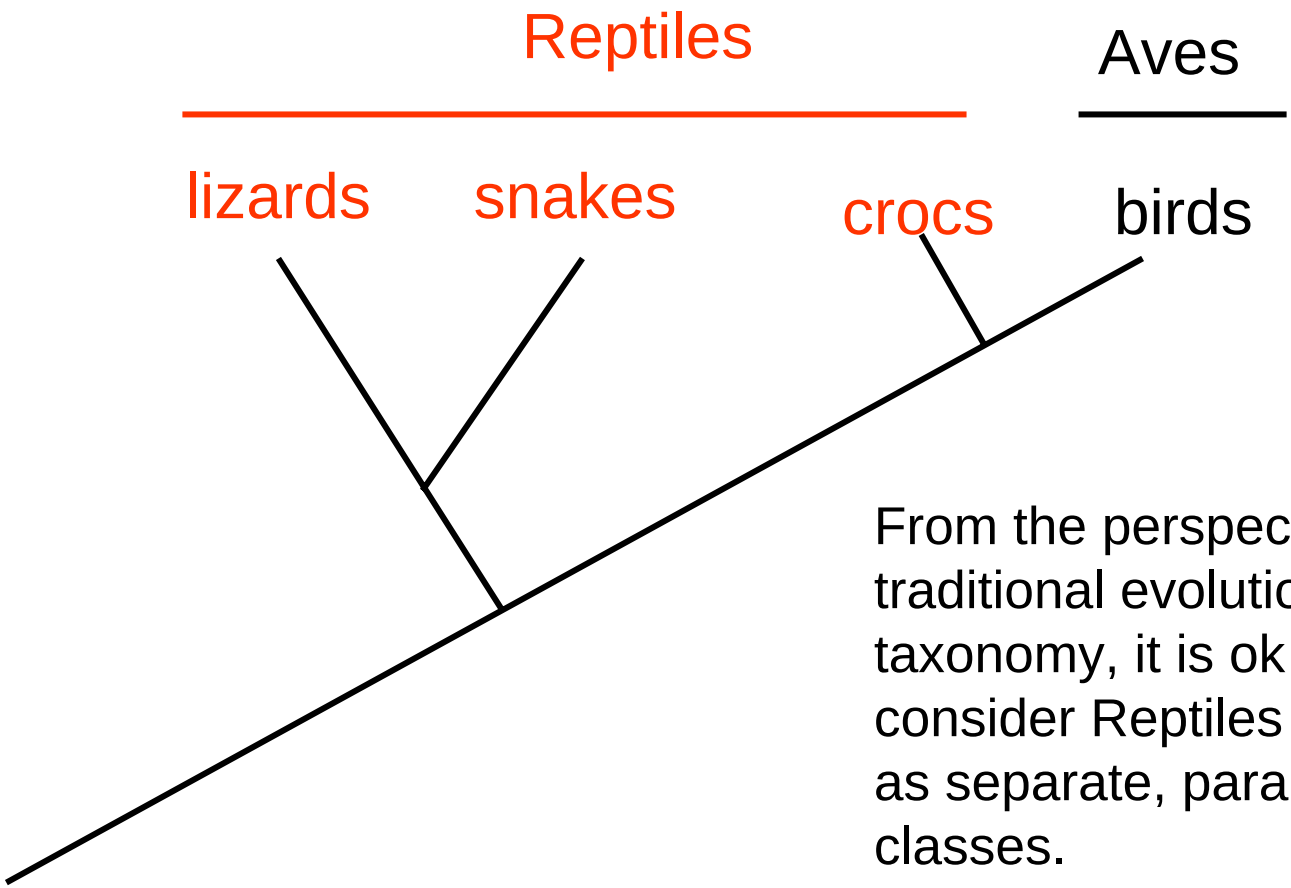
2. **Phylogenetic systematics (aka cladistics): only monophyly**

Currently, taxonomy is mixture of both these perespectives.

Reptiles: monophyletic



From the perspective of phylogenetic systematics, birds and reptiles should not be divided into separate classes



From the perspective of traditional evolutionary taxonomy, it is ok to consider Reptiles and Aves as separate, paraphyletic classes.

Class Mammalia

the mammals

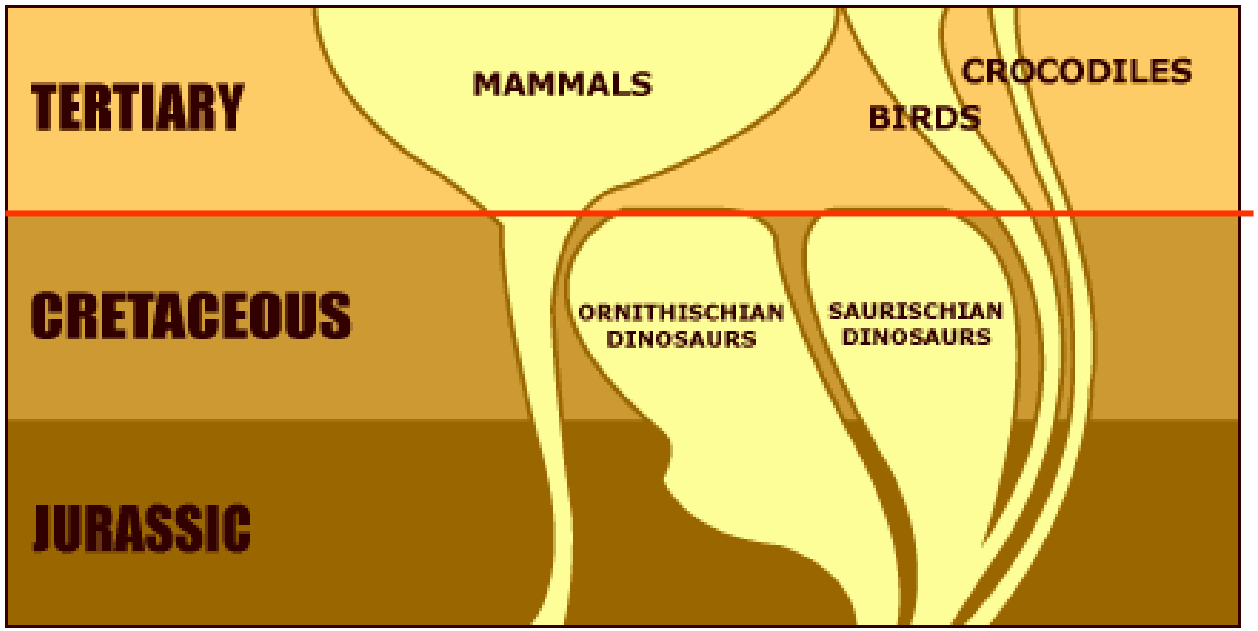
Class Mammalia

- mostly bony skeleton
- 4 limbs (tetrapods)
- body covered by hair (can be modified into quills)
- many glands (e.g. mammary, sweat, scent…)
- four chambered heart
- respiration exclusively by lungs
- embryos develop in uterus or amniotic egg
- young are nourished with milk
- endothermic

Class Mammalia

Unique mammalian characteristics:

1. Hair
2. 4 chambered heart with a functional left aortic heart.
3. Red blood cells lack nuclei
4. Mammary glands
5. Diaphragm

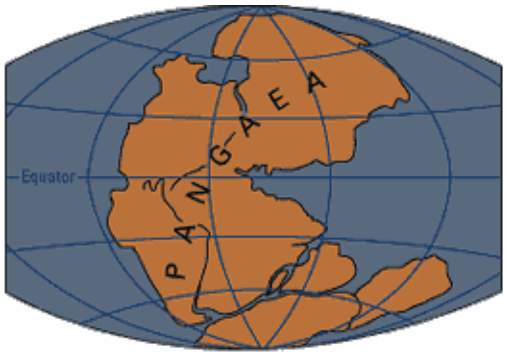


KT extinction

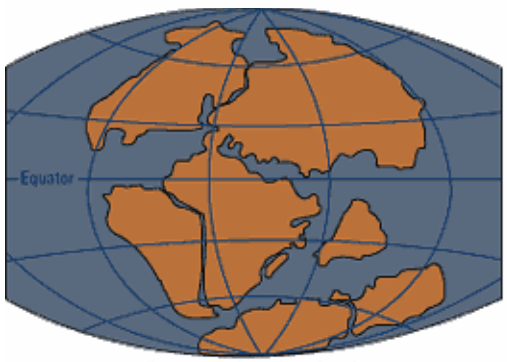
Most of the novel mammalian characteristics had evolved 150 million years before the KT extinction. Why did the mammals only radiate after the mass extinction?

Why did the mammals only radiate after the mass extinction?

1. The extinction of the mesozoic reptiles opened up a lot of niches
2. The break up of Pangea allowed for different lineages to diversify in genetic isolation.

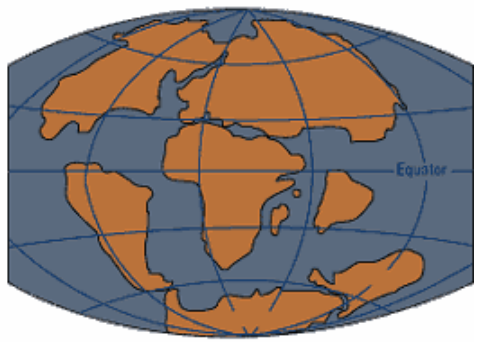


Permian Period
225 million years ago



Jurassic Period
135 million years ago

Triassic Period
200 million years ago



Cretaceous Period
65 million years ago

Class Mammalia

3 groups of mammals:

- **monotremes (echidna and platypus)**
  →oviparous

- **marsupials**
  →Viviparous, altricial young that complete development in a pouch outside the uterus

- **eutherians**
  → viviparous, young complete development in the uterus