

450 mya

salmon, trout, bass...

## Vertebrates: Osteichthyes

### The Bony Fish

- ◆ Nearly all have a ossified (bony) endoskeleton with a hard matrix of **calcium phosphate** secreted by special cells called osteocytes
- ◆ **Body structure**
  - bony & cartilaginous skeleton
  - Paired fins with rays of cartilage or bone
  - jaws & paired appendages (fins)
  - Swim bladder to regulate buoyancy
  - **scales**
    - ◆ Skin glands secrete slimy mucus to further reduce drag in water

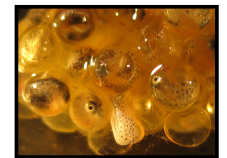
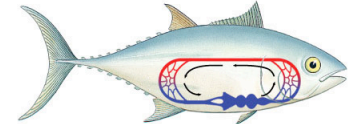
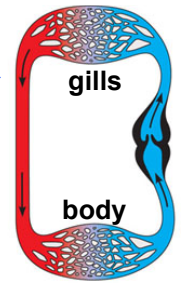


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## Vertebrates: Osteichthyes

### The Bony Fish

- ◆ **Body function**
  - **gills** with bony gill arches covered by **operculum** (protective bony flap) for gas exchange
  - two-chambered heart with **single loop** closed blood circulatory system
  - **ectotherms** (do not use metabolism to regulate internal body temperature)
- ◆ **Reproduction**
  - Most do **external fertilization**
  - **Oviparous**: external development in aquatic egg



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## Vertebrates: Osteichthyes

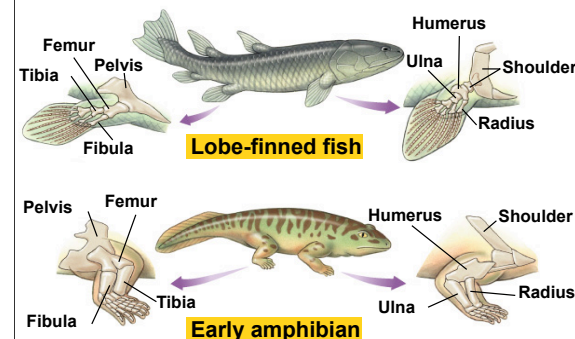
### Two types of Bony Fish

- ◆ **Ray-finned fish**
  - Fins supported by bony rays modified for maneuvering, defense etc..
- ◆ **Lobe-finned fish**
  - Rod-shaped bones surrounded by a thin layer of muscle in their pectoral and pelvic fins
  - ◆ May have evolved as an adaptation for swimming and 'walking' underwater across the floor in brackish waters



## Transition to Land

Evolution of **tetrapods**:  
Vertebrate gnathostomes with four limbs and "feet"



One lineage of **lobed-finned fish** became adapted to live on land and gave rise to all **tetrapods**

350 mya

## Vertebrates: Amphibian

frogs  
salamanders  
toads  
apoda

### Class Amphibia

("amphis" = both + "bios" = lives)

- The life stages of many frog species include first living in water & then land

#### Frogs

- Tadpole:** aquatic herbivore with gills, finned tail, lateral line system
- After metamorphosis becomes frog**
  - Develops legs, lungs, gills disappear, external eardrums, digestive system for carnivorous diet
- Amphibia:** Include all tetrapods that do not have amniotic eggs (an egg with adaptations to survive on dry land).
  - Spend part of their time on land, but most do not have the adaptations for an entirely terrestrial existence found in most other modern tetrapods (*the amniotes*).

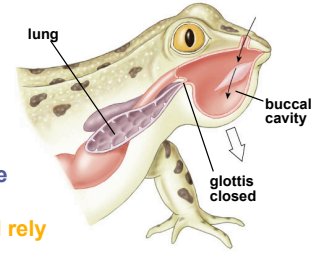


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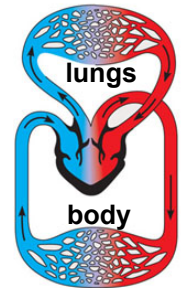
## Vertebrates: Amphibian

### Characteristics

- body structure**
  - legs (tetrapods)
  - Rely on moist skin for gas exchange (through diffusion)
    - Some lack lungs altogether and rely exclusively on "skin breathing"
- body function**
  - lungs** (work through positive pressure - air pushed into lungs from buccal cavity) & diffusion through skin for gas exchange
  - three-chambered heart:** arteries pump blood to body (system) and to lungs while veins from body and lungs bring blood back to heart
  - ectotherms** (do not use cell metabolism to maintain set body temperature - body temperature fluctuates with environment)



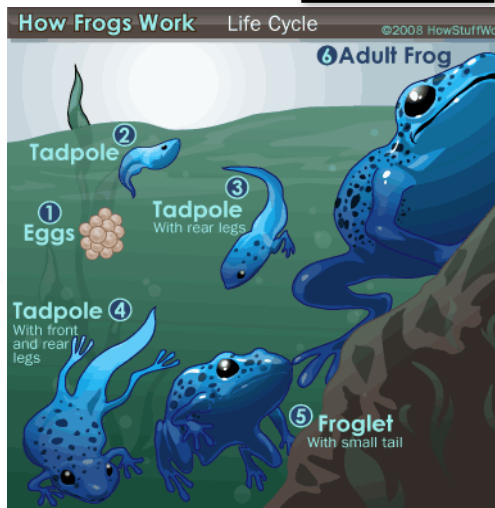
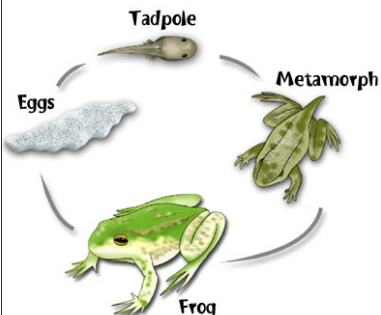
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## Vertebrates: Amphibian

### Reproduction

- external fertilization**
  - Lay eggs in water
    - Eggs dry up easily
- external development in aquatic egg
- metamorphosis** (tadpole to adult)

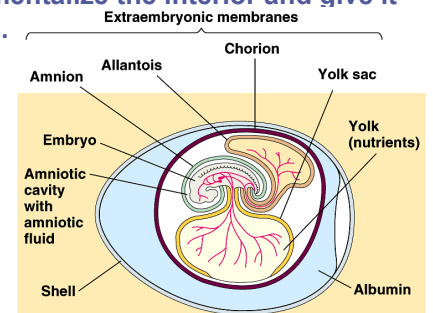


## The Amniotes - Adapted to Reproduce outside of water

- Amniotes are tetrapods with terrestrially adapted egg**
  - The egg contains four extra-embryonic (not part of embryo) membranes that compartmentalize the interior and give it several different functions.
    - Chorion
    - Allantois
    - Amnion
    - Yolk Sac



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Allowed embryo to develop on land, reducing the dependence of an aqueous environment for reproduction

- Include reptiles (including birds & mammals - reptile descendants)

## The Amniotes

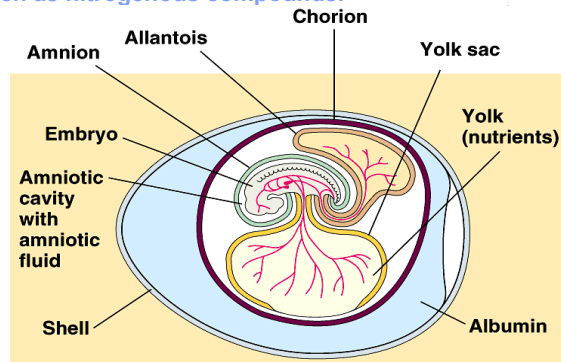


### Chorion

- Provides a special hard covering that is permeable to respiratory gases ( $O_2$  and  $CO_2$ ) while being impermeable to water vapor.

### Allantois

- A storage reservoir/disposal sac for metabolic waste products such as nitrogenous compounds.



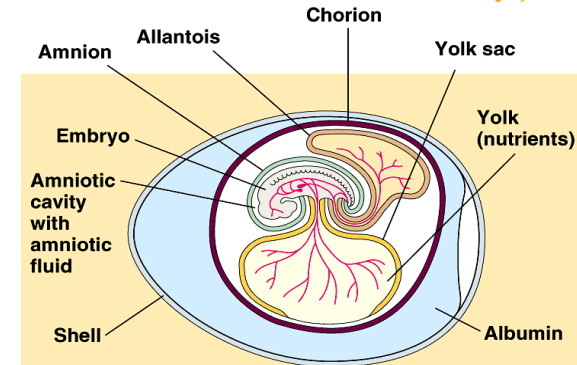
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## The Amniotes



### Yolk sac

- Contains food nutrients for the embryo, thus eliminating the need for a larval stage - food stored with embryo.
  - Extensively vascularized. Vessels carry nutrients to embryo.
- Other nutrients are stored in egg white, **albumin** (proteins that serve as reservoirs of amino acids for the embryo)



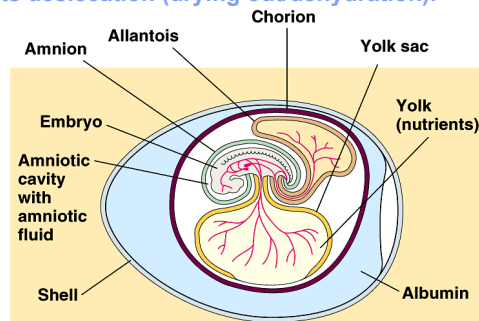
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## The Amniotes



### Amnion

- The **amniotic sac** - same as seen surrounding a developing human fetus, even if placental mammals like humans now engage in internal development instead of external development like reptiles and birds still do and thus have evolved not to lay the full amniotic egg anymore
- A fluid-filled sac that acts as a cushion for the embryo against mechanical shock
- Prevents desiccation (drying out/dehydration).



## The Amniotes

- Unlike in amphibians, amniotic eggs have a **shell** encasing the egg which prevents desiccation on dry land
  - Shell can be either hard from calcium carbonate (chicken egg) or leathery & flexible (turtle egg)
- Amniotes also have a **less permeable skin** and do **no skin breaking** (skin covered in oil or keratin scales to make a hydrophobic layer - adaptation so less water evaporates from body)
- Use **rib cage to ventilate lungs** instead of throat based ventilation

### Amphibian Egg



### Amniotic Egg



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320 mya

## Vertebrates: Reptiles

dinosaurs, turtles  
lizards, snakes  
alligators, crocodile

### Class Reptilia

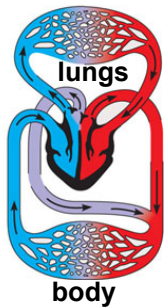
#### Characteristics

##### body structure

- First truly terrestrial animals
- dry skin covering in **scales** with protein **keratin** (like human nails and hair)
  - Protect animal from desiccation and abrasion (damage due to friction like against dirt/rocks)

##### body function

- lungs** for gas exchange
- thoracic breathing using **negative pressure**
  - Muscles pull open the thoracic cavity by pulling up on rib cage. The negative pressure draws air into lungs.
- three-chambered heart** with both pulmonary and systemic (body) circulation (partial septum, wall, formed in third chamber reduces some mixing of de-oxygenated and oxygenated blood)



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## Vertebrates: Reptiles

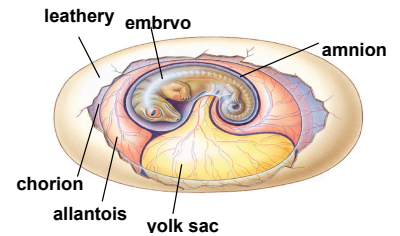
### body function

- ECTOTHERMIC** - do not use body's metabolism (sum of all chemical reactions) to control their body temperature
  - Use **behavioral adaptations** like seeking out sun or shade to control internal temperature
  - Allows reptile to survive on **less than 10% of the food energy required by comparably sized mammals** who break down high energy molecules to release energy not only for work but also to maintain body temperature

- Birds are reptiles too, however they are **ENDOTHERMIC**

### reproduction

- internal fertilization
- external development in **amniotic egg**
  - Some snakes and lizards are viviparous too...
    - Extra-embryonic layers form a kind of placenta that enables the embryo to obtain nutrients from its mother directly



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150 mya

## Vertebrates: Birds

finches, hawk  
ostrich, turkey

### Class Aves

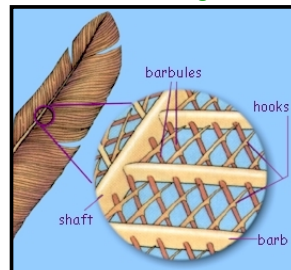
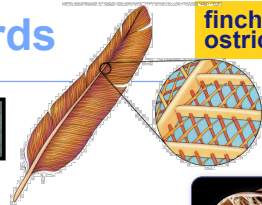
#### Characteristics

##### body structure

- Anatomy modified for flight**
  - Feathers & wings** contribute to **aerodynamics**
  - Weight saving modifications** make flying more efficient:
    - Thin, hollow or honeycomb bones and flight skeleton keep bird light weight
    - Lack urinary bladder - no storage of urine to save on weight
    - Feathers are strong but light weight
    - Most females have only 1 ovary
    - Toothless

##### body function

- Excellent eye sight and fine muscle control
- Larger brains proportionally than non-bird reptiles and amphibians
- Complex behavior especially during mating seasons & courtship rituals



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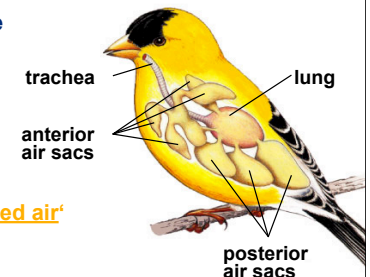
150 mya

## Vertebrates: Birds

finches, hawk  
ostrich, turkey

### Very efficient lungs & air sacs

- Birds do not have a diaphragm like mammals
- Air is moved in and out of the respiratory system through pressure changes in the air sacs.
  - Gas exchange happens in the lung not in the air sacs
- The air sacs permit a **unidirectional flow** of air through the lungs.
  - Air moving through bird lungs is largely **'fresh' air** & has a **higher oxygen content**.
    - more oxygen is available to diffuse into the blood
  - Air flow is **'bidirectional'** in mammals, moving back & forth into & out of the lungs.
    - Air coming into a mammal's lungs mixed with 'old' air (air that has in the lungs for a while) & this **'mixed air'** has **less oxygen**.



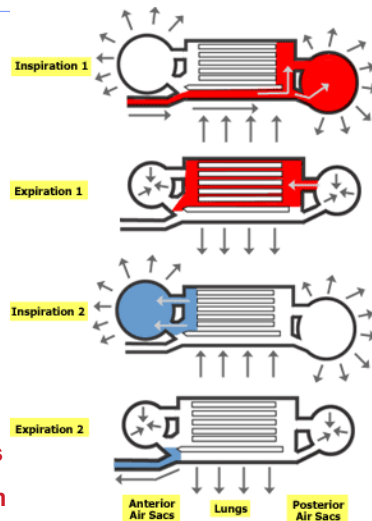
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## Bird's Respiratory Systems

1. Muscles pull sternum (chest bone) outward. **Negative pressure in the air sacs** causes air to enter.
2. **Expiration is not passive.** Muscles contract, increase pressure on air sacs, & **push the air out.**
3. **Bird lungs do not expand or contract** like the lungs of mammals.
4. In mammals the exchange of O<sub>2</sub> & CO<sub>2</sub> occurs in microscopic sacs in the lungs (**alveoli**). In the avian lung, the gas exchange occurs in the walls of microscopic tubules, called '**air capillaries**.'
5. Two cycles of breathing & exhaling is required to move a volume of air through the whole respiratory system

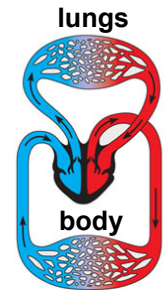
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## Bird's Respiratory Systems

- ♦ **body function**
  - **four-chambered heart**
    - ♦ Efficient systemic and pulmonary blood pumping
  - **Endotherms**
    - ♦ Use their own metabolic processes to regulate temperature
    - ♦ Keeps bodies at optimal temperature for their enzymes to function at the fastest rates no matter the external environmental temperature
- ♦ **reproduction**
  - **internal fertilization**
  - **external development in amniotic egg**

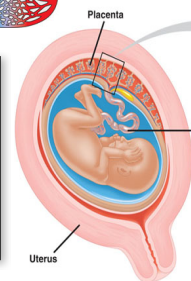
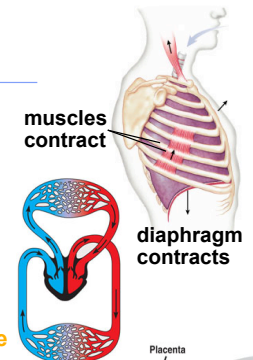
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## Vertebrates: Mammals

- ♦ **body function**
  - Lungs with diaphragm to help ventilate lungs
    - ♦ Breathing occurs by **negative pressure**
    - ♦ Exhalation is passive
  - **four-chambered heart**
    - ♦ Efficient nutrient and gas delivery and waste disposal
  - **Endotherms**
    - ♦ High metabolic rates since respiration used to store energy on ATP for work but also to release energy to maintain body temperature
- ♦ **reproduction**
  - **internal fertilization**
  - **internal development in uterus**
    - ♦ **nourishment through placenta**
  - birth live young
  - often considerable **parental care**
  - **mammary glands make milk** for offspring's nourishment
    - ♦ Provides balanced diet rich in fats, sugars, proteins, minerals and vitamins

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220 mya / 65 mya

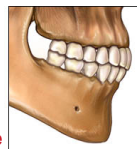
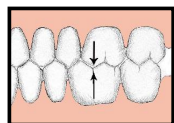
## Vertebrates: Mammals

- Mammals are amniotes known as **synapsids**
  - ♦ Early non-mammalian synapsids **lacked hair**, had **big gaits**, **laid eggs**, and had a single **temporal fenestra**, hole behind the eye socket on the sides of the skull
  - By early Cretaceous, 3 lineages of mammals emerged.

mice, ferret  
elephants, bats  
whales, humans

### Characteristics

- ♦ **body structure**
  - Hair (*lost in whales*)
  - Fat layer under skin to retain heat in body since bodies are kept at constant body temperature
  - specialized occlusion teeth
    - ♦ Incisors and canine teeth for shearing
    - ♦ Premolars and molars for crushing and grinding
    - Contrastingly, reptile teeth are generally uniform in size & shape



## Mammalian Subgroups

### ♦ monotremes

- egg-laying mammals
  - ♦ Embryonic development occurs outside of mother
- have hair and produce milk
- lack placenta & true nipples
  - ♦ duckbilled platypus, echidna



### ♦ marsupials

- pouched mammals
  - ♦ Offspring completes embryonic development while feeding from nipples in pouch
- short-lived placenta
  - ♦ koala, kangaroo, opossum



### ♦ eutherians (placental mammals)

- true placenta
  - ♦ Structure through which nutrient & waste diffuse into and out of the embryo from the mother's blood
- Complete embryonic development in uterus
  - ♦ shrews, bats, whales, humans



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## Vertebrate quick check...

- Which vertebrates lay eggs with shells?
- Which vertebrates are covered with scales?
- What adaptations do birds have for flying?
- What kind of symmetry do all vertebrates have?
- Which vertebrates are ectothermic and which are endothermic?
- Why must amphibians live near water?
- What reproductive adaptations made mammals very successful?
- What characteristics distinguish the 3 subgroups of mammals?

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That's  
the buzz!  
Any  
Questions?

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2007-2008