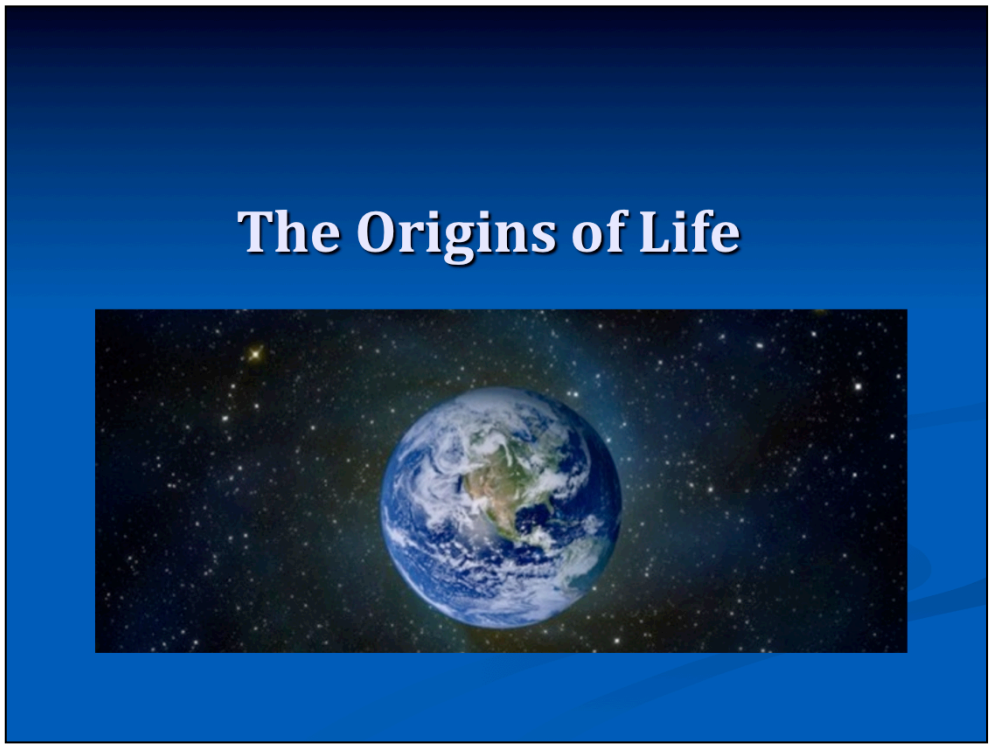
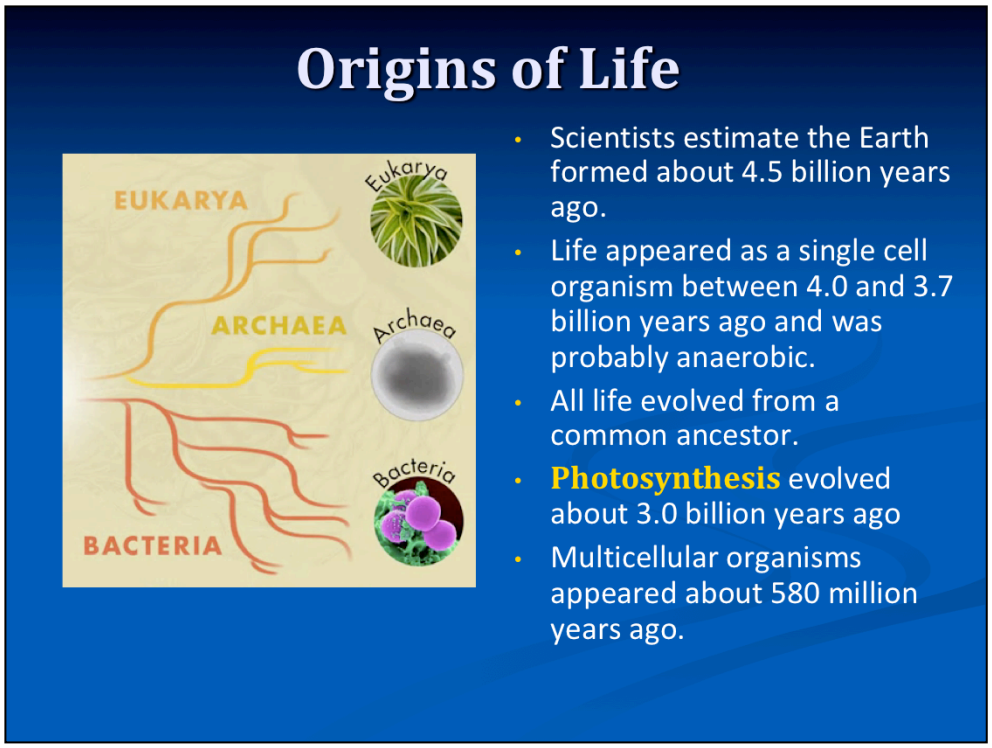


Evidence indicates that all living things descended from a single common ancestor through a branching of lineages. The important thing to remember is that life started as relatively simple cells in an aquatic environment and evolved into more intricately organized forms; existing traits were modified in response to an organisms changing environment.

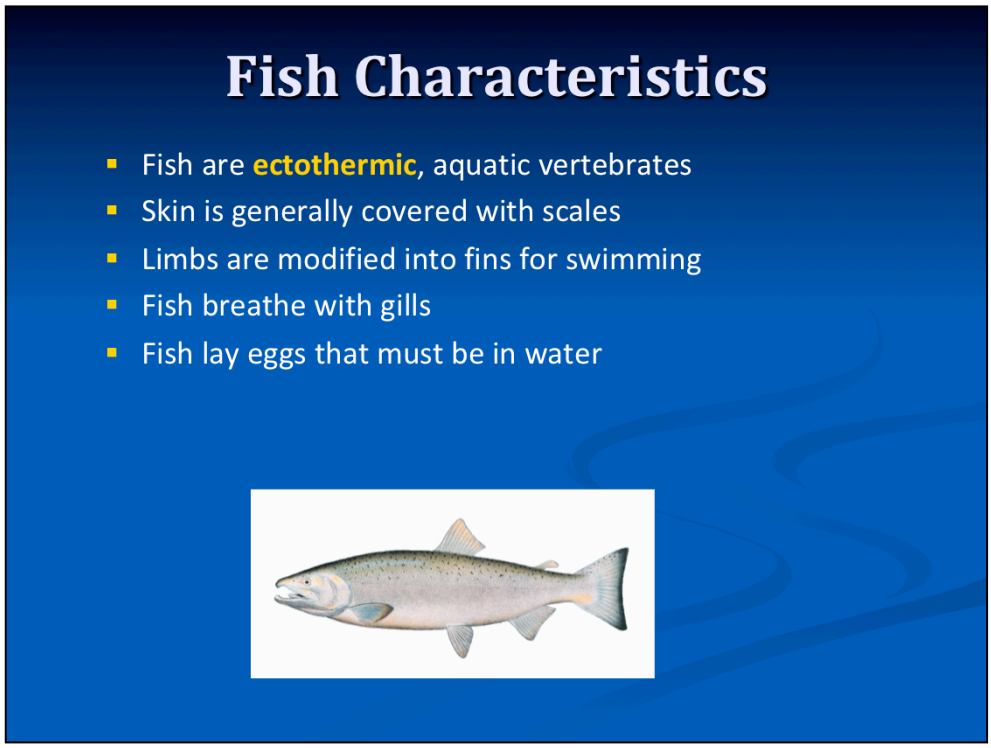


The earth formed about 4.5 billion years ago; there was no water and the atmosphere was noxious. The planet began to cool and water formed the oceans. These warm, salty seas created more stable conditions for life to evolve. How life originated and how the first cell came into being are matters of speculation; between 4.0 and 3.7 billion years ago, cell walls formed and life appeared. Since then, all life has evolved from this common ancestor.

It was not until approximately 3.0 billion years ago that **photosynthesis** evolved and oxygen was released into the water and eventually accumulated in the atmosphere. Aerobic respiration, which takes place in the presence of oxygen, evolved after oxygen was added to the Earth's atmosphere.

Life remained mostly small and microscopic until about 580 million years ago, when complex multicellular life formed. Life was bound to water for the first 3 billion years; these animals were invertebrates. **Invertebrates** are any animal lacking a backbone, including all species not classified as vertebrates. Most animals today are invertebrates such as corals, insects, worms, jellyfish, starfish, and snails. The first shells appearing in the fossil records denote the start of the invertebrate group **arthropods**, which includes arachnids, insects, millipedes, centipedes and crustaceans. Due to lack of a supportive system, a majority of invertebrates are small.

The Sculpture Learning Plaza has examples of single-celled, aquatic organisms including amoeba, vorticella and stentor and plaques of many more. There are also many invertebrates including: a leafcutter ant, a vallela, horseshoe crab, nautilus, vampire squid, giant clam, giraffe weevil, scorpion, centipede, tardigrade, and a coconut crab. Early plants are also represented among the sculptures by a magnolia and orchid.



Fish were the first group of animals to develop a backbone. The jawless fish were the first **vertebrates** to appear about 500 million years ago. Vertebrates are characterized by a bony or cartilaginous skeleton and a well-developed brain and nervous system. These internal skeletons provided a framework for the body, grew as the body grew, allowed for muscle attachment and provided flexibility in movement. **Note:** In addition to fish, vertebrates also include amphibians, reptiles, birds, and mammals.

Fish as a whole have spread into every available kind of aquatic environment, however, each species has tolerance for only a limited range of environmental conditions. For fish, being **ectothermic** means that their body temperature varies directly with water temperature. Some large fish, such as tuna and sharks generate and conserve enough heat above the surrounding water but they do not maintain a specific body temperature.

Fish are generally covered with scales, which provide protection against injury and infection. Their limbs are modified into fins for swimming. The gills allow the fish to absorb oxygen from the water. Fish lay eggs in the water; these eggs do not have a shell and would dry out in the air.

Other types of fish besides the jawless fish include the bony fish (i.e. carp, tuna) and the cartilaginous fish (i.e. sharks, rays). We will not be going into detail of these classes of vertebrates as they are not part of the primary exhibits of the zoo.

The Zoo does have some carp in the Exploration Zone that like to hide under the bridge. The Sculpture Learning Plaza has examples of fish including the freshwater eel, hammerhead shark, piranha, mudskipper and a coelacanth.

Plants were the first multicellular organisms to invade land. Sunlight was a limiting factor in the ocean and plants began spreading out on the surface to get more sunlight. With the invasion of plants onto the landscape, the available oxygen in the environment rose, making it possible for aerobic organisms to exist on land.

The evolutionary transition from water to land occurred over millions of years. In transitioning to land, an organism had to withstand the effects of gravity, had to be able to breath air, had to minimize water loss and be able to regulate its temperature and also to adjust its senses so they are suited for air instead of water.

The first animals to live on land were arthropods, probably ancient centipedes and scorpions. Land was an unoccupied habitat; oxygen was accumulating in the atmosphere and there was now a potential food source available. The arthropods of the ocean were great candidates to come onto the land because they already had an exoskeleton, a hard shell to help maintain water balance.

The first limbed vertebrates evolved from the lobe-finned fish about 360 million years ago. They probably only occasionally ventured onto land at first, coming from freshwater bodies of water. They crawled out of the shallows and swallowed gulps of air with primitive lungs, found less competition for food on land and were able to avoid large predatory fish.

Once **tetrapods** or four-legged vertebrates developed digits on their limbs, they were able to adapt more to walking on land than paddling in the water. The insects had already invaded land, which provided a food source for vertebrates to exploit as they moved onto dry land.

The *Ichthyostega,* that you see above, was a transitional fossil between fish and tetrapods, combining a fish-like tail and gills with an amphibian skull and limbs.

Amphibian Characteristics

- Amphibians are **ectothermic** vertebrates
- Their skin lacks scales, hair, and feathers, and is either smooth (like a frog) or rough (like a toad). They are dependent upon moisture and subject to desiccation; their skin must remain moist to aid in breathing
- Undergo **metamorphosis**; amphibians lay eggs in water, which hatch into an intermediate life form, tadpole or larva, that usually breathes with gills, and change into the adult form that breathes air and can live outside water

Tiger Salamander

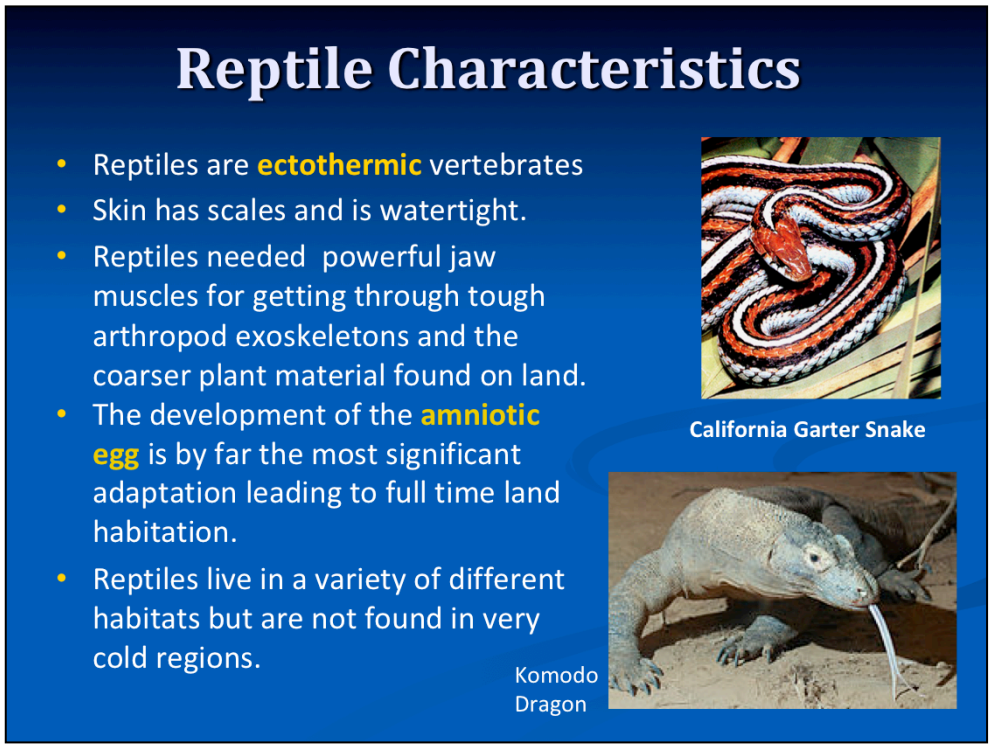
Amphibians first appeared in the fossil record about 350 million years ago, evolving from a tetrapod ancestor. They were the first vertebrates to live on land; they followed the food source of plants and insects. The transition from aquatic to terrestrial living is indicated in the Class Amphibia.

Amphibians are **ectothermic** animals who spend part of their time on land and part in the water. Despite their adaptations to terrestrial life, they still require cool, moist environments for their jelly-like eggs and their adult gas-permeable skin. Their skin must remain moist to aid in breathing. This permeable skin makes amphibians particularly vulnerable to environmental disturbances, from chemical pollution to the thinning ozone layer and global climate change.

Amphibian means to lead a "double life". Amphibians are the only land vertebrate that go through a change in the larval, or tadpole, state into adult. This is known as **metamorphosis**. The tadpole lives in a niche that is different from the adult's, resulting in less competition within the species; metamorphosis reduces competition between the tadpole and adult and allows for specialization for feeding and reproduction.

In time, amphibians moved out of the water to take advantage of the burgeoning amount of prey on land. What kept them tied to the water was the need to lay their eggs there and most still had a water-bound larval form. Amphibians were the only vertebrate life forms on land for about 60 million years. They became rare and diminutive as better-adapted reptiles began to take over the land.

The living representatives of the Class Amphibia include frogs, toads, newts, salamanders and limbless caecilians. The Tropical Building has a variety of amphibians including some poison dart frogs, smoky jungle frogs and red-eyed tree frogs. The Sculpture Learning Plaza has several amphibians including horned marsupial frog, goliath frog, caecilian, and a hellbender.



Reptiles first arose from amphibians in the swamps present during the late Carboniferous period. The word "reptile" comes from Latin, meaning “to crawl”. Reptiles have claws on their toes to help navigate the terrain (except legless species, such as legless lizards and snakes).

Like amphibians and fish, reptiles are **ectothermic** vertebrates. Being on land, however, they developed water-tight skin for water conservation and overlapping scales to protect them from the harsher terrestrial environment with its sand and rocks. Ribs are found on most reptilian vertebrae to protect their internal organs.

One of the main differences between reptiles and amphibians is seen in the jaws, as reptiles developed a greater biting strength than their amphibian ancestors. As feeding shifted from an aquatic environment to a terrestrial one, animals needed more powerful jaw muscles for getting through tough arthropod exoskeletons and the coarser plant material. The early diversification of amniotes produced holes in the side of the skull behind the eyes, providing space for the large muscles needed for feeding. These holes allowed for the attachment of larger, stronger jaw muscles resulting in more powerful and faster bites.

Reptiles walk with what’s called a “sprawled” gait, which is akin to doing a pushup. Their legs stick out to the sides of the body so their center of gravity stays low and stable making it difficult for them to tip over, and also keeping their softer and more vulnerable bellies protected. In walking or running, they twist first to one side and then to the other. It is difficult to move and breathe at the same time, so they are restricted to short bursts of movement and are thus ambush predators.

The development of the **amniotic egg** saw the rise of the Class Reptilia and was the most significant adaptation leading to full time land habitation. Reptiles inhabit every continent with the exception of Antarctica. They can be found in tropical forests, deserts, oceans, rivers, and lakes. They are not seen in very cold regions as they rely on external sources of heat to regulate their body temperature.

Reptiles are represented by lizards, snakes, turtles, tortoises, alligators, crocodiles and the tuatara.

The Zoo has red-eared slider turtles in the children’s zoo and a desert, leopard and radiated tortoise in the ARC and a Komodo dragon. The Tropical Building has a green anaconda, emerald tree boa, amazon tree boa, and a red-tailed boa, plumed basilisk and other reptiles. The Sculpture Learning Plaza has a leatherback sea turtle, tuatara, Galapagos marine iguana, panther chameleon, rattlesnake, Burmese python and a salt water crocodile.

Amniotic Egg

- Animals were no longer restricted to having to be near water to lay eggs
- The amniotic egg has a semipermeable shell that keeps the embryo inside an internal membrane from drying out
- The swimming larval stage as the bridge to the land form was no longer needed
- The yolk inside the egg could feed the embryo until hatching into something that could start on land
- Reptile eggs have leathery shell.

Reptiles, birds and mammals are all referred to as amniotes; embryos develop in a protective environment of the amniotic egg. This is an adaptation found in terrestrial life forms.

With the amniotic egg, animals were no longer restricted to having to be near water to lay eggs. The shell is semipermeable and keeps the embryo inside an internal membrane from drying out but still allows the exchange of gases. Metamorphosis was no longer needed as the bridge to a land form. The yolk inside the egg fed the embryo until hatching. With the leathery shell on the egg, fertilization by the male needed to be internal, prior to the shell being formed.

Age of the Dinosaurs

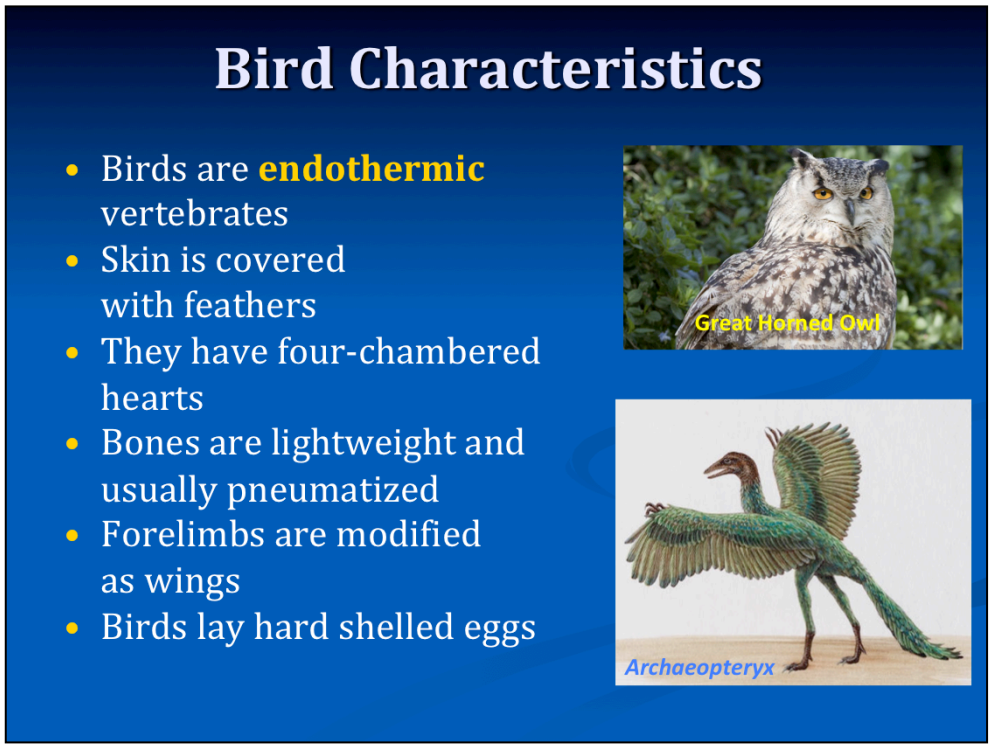
- Mesozoic Era was the "Age of Dinosaurs"
- Dinosaurs walked, with limbs erect, on their toes in a stance that put hips directly in line with limbs
- Dinosaurs gave rise to modern birds; birds are the only living descendants of the dinosaurs
- Mass extinction at end of Mesozoic Era resulted in the "Rise of Mammals"

At the end of the Paleozoic Era, when reptiles were beginning to radiate across the lands, there was the largest mass extinction event ever in the history of earth. Over 90% of marine life and 70% of land species went extinct. This opened up new niches for species such as the dinosaur to radiate into. The Mesozoic Era became the "Age of Dinosaurs".

Dinosaur means "terrible lizard". They were different from the reptiles in that they had an erect stance; an erect stance positions the limb bones directly under the body. This allows the limb bones to passively support the body's weight without muscles having to strain. This was in contrast to the reptile's sprawling stance who held its legs out to either side of its body. For example holding yourself in a push up position requires a lot of effort just to keep yourself in that position. However, if you straighten out your arms and hold them directly underneath you in an upright manner, it becomes much easier. Creatures with an erect stance use less energy to move around and using less energy can be a big evolutionary advantage. **Note:** mammals and birds have an erect stance like the dinosaurs.

There was another mass extinction at the end of the Mesozoic Era, 65 million years ago. It is now widely agreed that an object, 10 kilometers across, struck just off the coast of the Yucatan peninsula in southeastern Mexico. After the collision, dust and ash filled the atmosphere, blocking sunlight and disrupting the food chain by killing off photosynthesizing organisms and in turn the herbivorous dinosaurs and finally the carnivores that preyed on them. Modern birds are derived from a bipedal dinosaur group, the theropods and are the only living descendants of the dinosaurs.

The only creatures that endured were those that could subsist on insects and worms. All dinosaurs except birds went extinct at this time. This mass extinction event allowed for the sudden expansion of mammals, speciating to fill ecological niches left vacant by the dinosaurs. This process is known as **adaptive radiation**. The Cenozoic Era became the "Age of Mammals".



Birds belong to a specialized branch of the dinosaur family tree; all non-avian dinosaurs went extinct at the end of the Cretaceous period. The first true bird, ***Archaeopteryx,*** evolved during the late Jurassic Period. *Archaeopteryx* possessed characteristics of both birds and reptiles and was viewed as the perfect example of an intermediate species that bridged the gap between two major classes of vertebrate groups. It still retained many reptilian features such as claws on the front of the wings, sharp teeth, and a long bony tail but this specimen possessed the most important avian characteristic, feathers. *Archaeopteryx* probably walked and fluttered around more than high flying as its tail would not allow much lift, but its feathers were asymmetrical, which are needed for flight and had pneumatized bones like modern birds.

Since *Archaeopteryx*, newly discovered fossils showed that birds were not the only animals to develop feathers; several dinosaur groups had feathered species as well. These early feathers were likely used for sexual display or thermal regulation. Reduced tail bones and distinctive feet are what set birds apart from dinosaurs.

Most major characteristics of birds can be directly related to their adaptations for flight. Birds are **endothermic** vertebrates and were able to regulate their own body temperatures through metabolic processes. Feathers help maintain a constant body temperature and are important in the ability to fly. More than any other trait, the ability to maintain a constant, high body temperature has allowed birds and mammals to be active and to live in all possible habitats and at all seasons. Endothermy required an increase in food intake to be able to generate enough heat to maintain a constant internal body temperature. Bird skin is covered with feathers.

Birds have four-chambered hearts, which allows the oxygenated blood to remain separate from the deoxygenated blood and is more efficient. Their hearts tend to be larger relative to body size than mammals in order to meet the high metabolic demands of flight. Their bones are lightweight and usually pneumatized with criss-crossing struts for structural strength. Forelimbs are modified as wings and birds lay hard-shelled eggs that need to be fertilized internally by the male.

Birds also have an efficient unidirectional respiratory system. Unidirectional flow means that air moving through bird lungs is largely 'fresh' air & has a higher oxygen content. In contrast, air flow is 'bidirectional' in mammals, moving back and forth into and out of the lungs. As a result, air coming into a mammal's lungs is mixed with 'old' air (air that has been in the lungs for a while) & this 'mixed air' has less oxygen. So, in bird lungs, more oxygen is available to diffuse into the blood.

There are many types of birds throughout the Zoo. The Sculpture Learning Plaza has a California condor, a horned puffin, a hoatzin, and a kiwi.

Mammal ancestors were mammal-like reptiles that were around the same time as dinosaurs. The earliest identifiable mammals were tiny, shrew-like mammals and emerged during the late Triassic period about 200 million years ago. Early mammals were probably nocturnal in order to avoid competition with the dominant carnivorous dinosaurs during this time period. They were probably mostly **insectivorous** and lived in the trees. Early mammal superior sense of smell and hearing, backed up by a larger brain, facilitated entry into nocturnal niches with less exposure to dinosaur predation. The nocturnal lifestyle may have contributed greatly to the development of mammalian traits such as endothermy and hair. Being **endothermic** allowed mammals to be less vulnerable to fluctuations in external temperature and with the aid of hair, they are able in inhabit cooler environments.

The Mesozoic era is considered the "Age of the Dinosaurs". When the dinosaurs died off 65.5 million years ago and the Cenozoic Era, the "Age of the Mammals", began mammals were able to radiate into all the niches that were left vacant by the dinosaurs and marine reptiles. In general, mammals had bigger brains with better senses, more diverse modes of locomotion and were more adapted to eat a variety of food and inhabit more types of habitats than the reptiles.

In the evolution of mammals, the limbs shift to a new position below the body, allowing mammals to become larger and move faster. An erect stance allowed the limb bones to passively support the body's weight without muscles having to strain. Mammals were relatively faster and could travel longer distances than the reptiles.

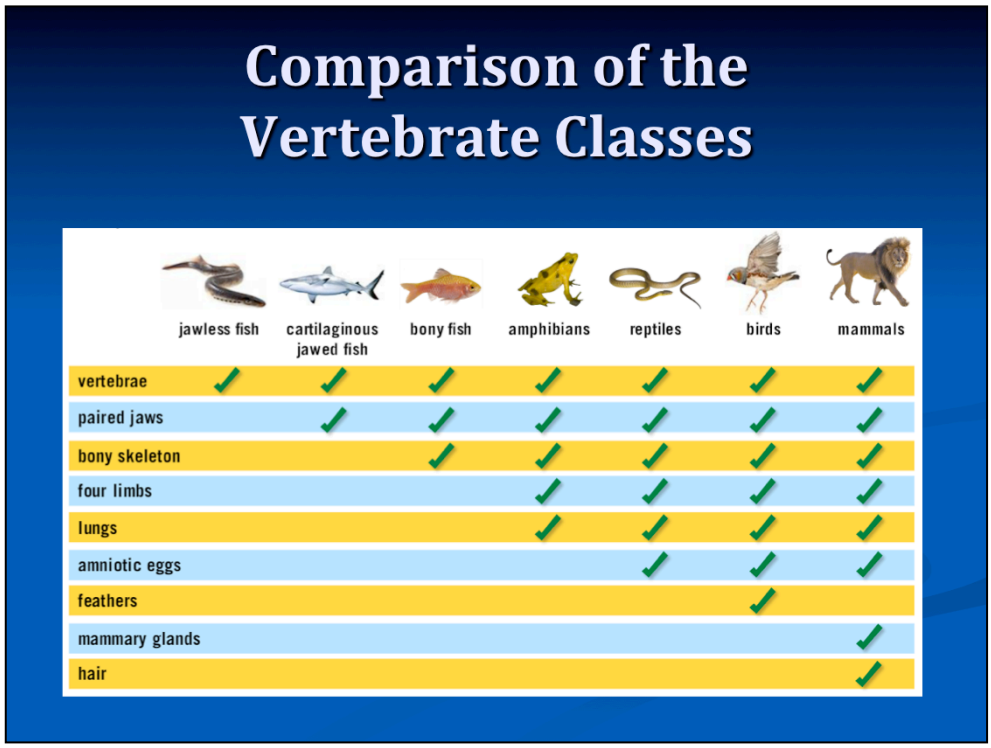
Mammal relatives had a single hole behind each orbit, which provided attachment sites for strong jaw muscles. Combined this with fused lower jaws, mammal jaws were stronger and capable of new coarser foods. Part of the successful strategy was the differentiated teeth (**heterodonts**) that allowed them to adapt to a variety of diets and environments. Fish, amphibians and most reptiles were **homodonts** and their teeth were all similar.

Through evolution, two bones of the reptilian jaw, over time, migrated to the inner ear in the mammal, creating the three inner ear bones, which transmit sounds more efficiently and allow more acute hearing.

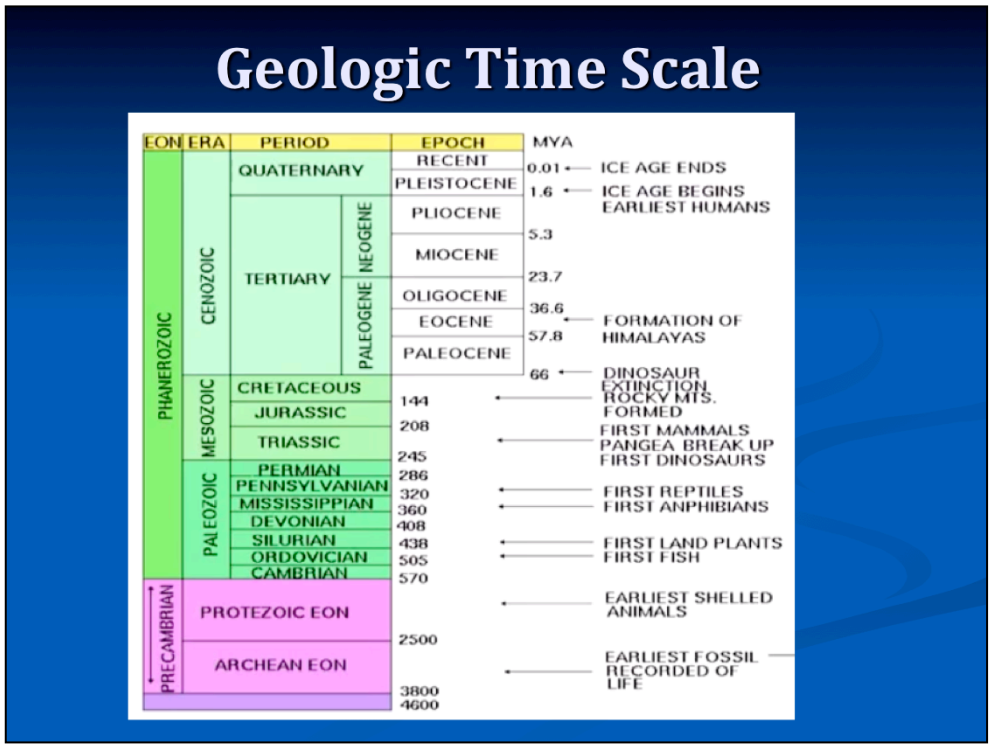
Mammary glands contributed to the success of mammals providing nutritional as well as antimicrobial properties of milk. The extended period of contact between mothers and their young provided the opportunity for more learning. This is especially important in the "higher primates".

The three divergent lines of mammals based on their reproductive strategy all evolved during the Cretaceous period. We will discuss the differences in reproductive strategies of **monotremes**, **marsupials** and **placental mammals** when we talk about the Class Mammalia in a later unit.

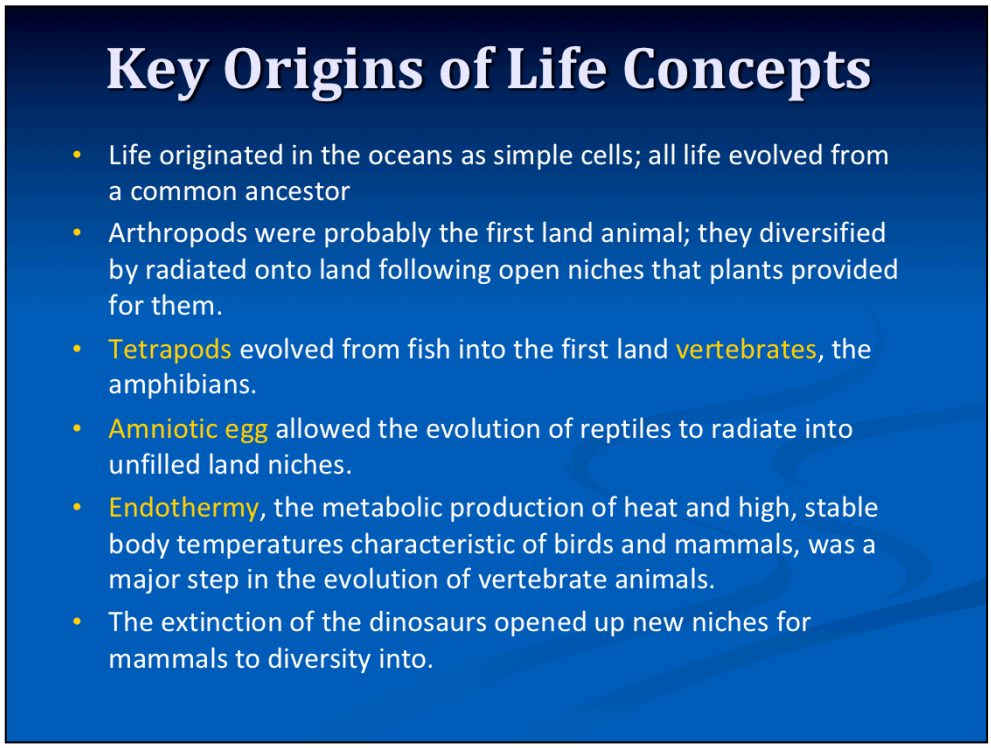
There are many types of mammals throughout the Zoo. The Sculpture Learning Plaza has a duck-billed platypus, aye-aye, arctic hare, Ethiopian wolf, Indian flying fox, pangolin, star-nosed mole, Tasmanian devil and a gray whale.



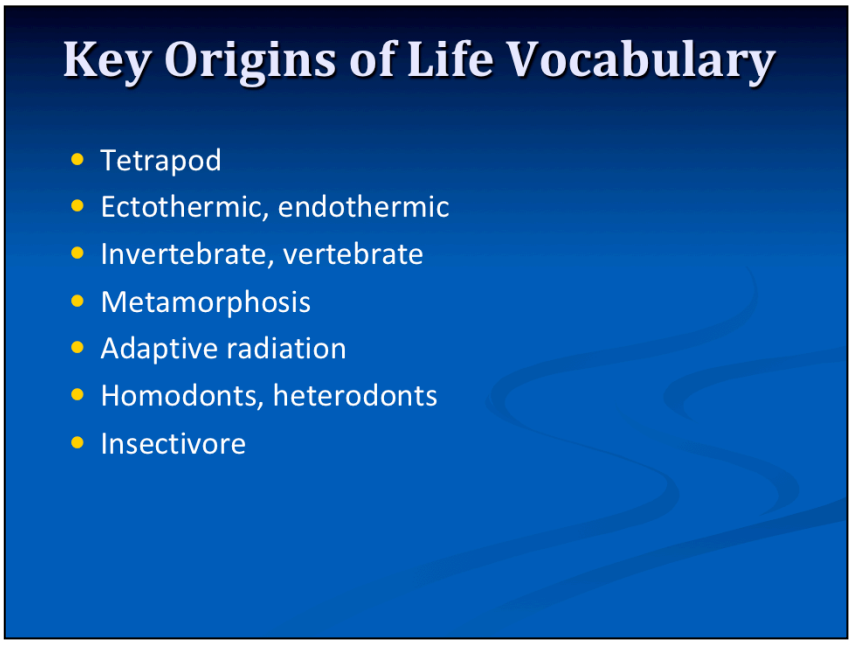
This is just a review of the various Class of Vertebrates and their general characteristics.



The geologic time scale is used to describe the timing and relationships between events that have occurred throughout Earth's history. It is a good tool for understanding the history of Earth and the evolution of life. The relative timeline of when things occur may help in your understanding of the characteristics of an animal. While the dates are estimates based on scientific evidence, it is interesting to consider timescale of when the earth first formed, life began and the relatively new event of life on land and the earliest humans.



Corresponds to pages 4-7 in Zoology Study Guide of the Docents Notebook.



Definitions:

Adaptive radiation: process in which organisms diversify rapidly into a multitude of new forms, particularly when a change in the environment makes new resources available, creates new challenges and opens environmental niches**.**

Ectothermic: any animal whose regulation of body temperature depends on external sources, such as sunlight or a heated rock surface.

Endothermic: any animal dependent on or capable of the internal generation of heat. The animal is able to maintain a relatively constant internal temperature, irrespective of the temperature of the surroundings.

Homodonts: animals which have similar types of teeth.

Heterodonts: animals which have different kinds of teeth; for example, most mammal teeth are differentiated into incisors, canines and molars.

Insectivore: having a diet consisting of insects.

Invertebrate: any animal lacking a backbone, including all species not classified as vertebrates. Most animals are invertebrates; corals, insects, worms, jellyfish, starfish, and snails are invertebrates.

Metamorphosis: a major change in the form or structure of some animals or insects that happens as the animal or insect becomes an adult.

Tetrapod: a four-legged vertebrate; this group includes amphibians, reptiles and mammals.

Vertebrate: an animal characterized by a bony or cartilaginous skeleton and a well-developed brain: the group contains fishes, amphibians, reptiles, birds, and mammals.