

Vertebrate Diversity Lecture Guide

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*Number in outline corresponds to slide number the PowerPoint presentation.

1. Phylum Chordata

2. Key Features of Chordates

- a. If you recall the phylogeny of the major animal phyla presented in the last module, the chordates are one of two groups classified as deuterostomes. Aside from this commonality, there are 4 key characteristics that identify the phylum Chordata.
 - 1) The first is what is known as a notochord. This is a flexible rod that in most chordates is only present during embryonic development. As the skeleton develops, the notochord becomes part of the vertebral column.
 - 2) The second requirement of a chordate is the presence of a hollow nerve cord that runs the length of the torso. In vertebrates this nerve cord becomes modified during embryonic development to become the brain and spinal cord.
 - 3) Third is the presence of pharyngeal gill slits. For some chordates, these slits serve as gills for the purpose of breathing, in others, such as humans, these slits are the embryonic precursors to components of the jaw.
 - 4) And finally, the presence of a post-anal tail marks a chordate.

3. Chordate Features Usually Lost

- a. If you are somewhat puzzled by these characteristics, it is most likely because most vertebrates that may come to your mind don't display most of these traits. This is because the majority of vertebrates, humans included only have these characteristics as an embryo.
- b. This picture of a human fetus demonstrates 2 of these traits: the post-anal tail and the gill slits. You can also see the beginnings of the vertebral column along the dorsal side, which is derived from both the nerve cord and the notochord.

4. Chordate Phylogeny

- a. There are several ways to organize chordates, grouping them into clades, based on certain characteristics. You can group the lancelets and tunicates into a group of invertebrate chordates. These two phyla are the most ancestral groups in the phylum. These two groups are also the only animals in this group that do not have a brain encased by bone or cartilage.
- b. The rest of the phyla are known as craniates. Within the craniate's clade, all but a group commonly known as hagfishes are vertebrates.
- c. You can subdivide this group even further by classifying vertebrates as tetrapods, or animals that have or have an ancestor that have four limbs.

5. Trends in Vertebrate Evolution

- a. With our focus being on the vertebrate clade, let's begin our exploration of the major groups of animals in this phylum. As we explore the animal kingdom, keep a look out for a few trends that will emerge as we move through the different clades. As we move through time, we are going to see a shift from the presence of a notochord in the adult form to the presence of a vertebral column.
- b. We will see the expansion and development of the nerve cord into the head to form the most complex brain in the animal kingdom. And we will see the evolution of limbs that evolved from the paired fins of fishes, the development of a jaw, that arose from the support structures of the gill and the development of lungs, believed to have evolved from an organ found in bony fishes that help regulate buoyancy in that group.

6. Fishes

- a. Fishes include a wide variety of forms and functions. Most do share a few common traits however. Fishes are cold blooded and breathe using gills, a feature necessary for pulling oxygen out of the water. The complexity of the chordates can be examined by looking at the complexity of the organ systems. The most ancestral chordates have the most ancestral organs, such as a 2 chambered heart, and sensory organs geared towards an underwater existence.

7. Jawless Fishes

- a. The one invertebrate chordate worthy of mention is the group known as hagfishes. These animals are the least derived of the chordates and are different from the animals that come next because they are the only craniates that the notochord persists into adulthood, and are therefore considered an invertebrate.
- b. Lampreys, like the hagfishes, lack a jaw, and instead have a large sucker structure for a mouth. Unlike the hagfishes however, lampreys do have a spinal cord and are the first true vertebrates. Most lampreys are parasitic, attaching themselves to larger fish and sucks blood and fluid out of the host body.

8. Jawed Fishes

- a. The phylum Chondrichthyes, AKA the cartilaginous fishes, consists entirely of marine predators, and have specialized sensory organs geared towards detecting movement and vibration in the water, as well as a keen sense of smell.
- b. Ray finned fish and lobe finned fish, collectively known as Osteichthyes, AKA bony fish, are defined by their bony skeleton. Most of the fish that you are probably most familiar with are considered ray finned fishes. Most bony fishes have a unique organ, known as a swim bladder. The swim bladder is a gas filled organ that helps the animal remain buoyant and move up and down in the water column by regulating the amount of gas in the organ.

9. Adaptations to life on land

- a. As we leave the fishes behind, we now are faced with some major challenges, because we are preparing, evolutionarily speaking, to move onto land. Some of the adaptations that arose in the animal kingdom to help combat these challenges, the same challenges that plants faced are very similar in function to the adaptations seen in plants.
- b. Animals must develop a denser, sturdier skeleton to combat the effects of gravity, analogous to the development of lignin in plants. Animals began to develop a much more complex circulatory system to help deal with the dry conditions of land, as well as the ability to pull oxygen from air instead of water, much like the development of vascular tissue in plants.
- c. One thing that plants did not have to deal with is the ability to move on dry land, and the ability to hear, see, and smell on land. Sensory organs found in the fishes are all geared towards sensing their surroundings while being surrounded by water. Light and sound act much differently in water versus air, so animal sensory organs must make a shift to facilitate these differences.

10. Amphibians

- a. The amphibians represent an evolutionary path that begins to cut ties with an entirely aquatic existence, but they are still tied to water for at least part of their life cycle. Most amphibians require water to breed. Amphibians rely on external fertilization, with females laying their eggs in a body of water, where the males release their sperm to fertilize the eggs.

- b. Many amphibians spend the first part of their lives as aquatic larvae. Most adults however, have four limbs, adapted to live most of their adulthood on dry land. This feature means we have entered into the most derived clade within in the phylum Chordata, the tetrapods. Other features of the amphibian phylum include a moist, thin skin that is allows gas exchange to occur directly through their skin. One feature that sets them apart from the fishes is the presence of a three chambered heart that allows for a more efficient circulating of the blood. A highly efficient circulatory system is essential to the terrestrial lifestyle of many adult amphibians.

11. Reptiles

- a. The next group of vertebrates, who represent the next phase in evolutionary progress, are the reptiles. This group of animals was the first vertebrates to cut ties completely with an aquatic habitat. They were able to do this, not only because to the 3 chambered heart that first appeared in the amphibians, but also because of the development of a tough scaly skin that resists water loss, a shift to internal fertilization, and the development of an amniotic egg.
- b. The amniotic egg is truly an amazing feat, allowing complete development of the offspring before hatching. What this means is that most reptiles hatch out of an egg in an adult form, there is no metamorphosis stage present in this group.
- c. Representative animals in this group include crocodiles, turtles, snakes and lizards. Each of these groups evolved with special identifying traits that allowed them to move into an otherwise unoccupied niche. Turtle for example have a protective shell that protects adults from predation, snakes lost their limbs to take advantage of subterranean habitats, and lizards have specialized scales that allow them to thrive in many climates, including hot desert habitats with little water. Crocodiles are believed to be the closest living relatives to birds.

12. Evolution of Birds

- a. Birds first appeared about 150 million years ago in the fossil record. As mentioned before, it is believed that birds evolved from dinosaurs. A fossil that provides evidence for this was found in 1861 and sold to the Natural History Museum in London. The archaeopteryx is the very first “missing link” fossil ever discovered. This animal displayed characteristics of both birds and dinosaurs, demonstrating an intermediate form between two closely related species linked through evolution.
- b. At the time of its discovery the lack of intermediate forms of organisms was one of the biggest arguments against Charles Darwin’ theory of evolution. The discovery of this fossil was a huge turning point for the scientific community in embracing Darwin’s controversial theory.
- c. Fun fact to share at parties: The curator of the Natural History Museum at the time of archaeopteryx’s purchase was a man by the name of Richard Owen. He was a devotedly religious man, and harbored a deep seeded hatred of Darwin and his heretical ideas. So in the end, Owen was responsible for purchasing and describing the first piece of solid evidence to support his greatest enemy’s theory. And I find that terrible ironic!

13. Birds

- a. So birds. Just like reptiles, birds produce amniotic eggs, lending even more evidence to their evolutionary ties. Birds have several adaptations that allowed them to breach a habitat thus far in evolutionary time only been dominated by a few select animals.

- b. In this group we see a shift from scaly body coverings of the reptiles to a highly specialized scale: the feather. The capacity of flight is one of the most energetically expensive lifestyles seen in animals, and therefore there are several features that birds evolved to allow them to fly. Birds have hollow bones and reduced organ size to minimize their body weight to facilitate flying.
- c. Birds are also the first warm blooded animals to arise. Being warm blooded allowed birds to have extremely efficient metabolism, maximizing their ability to power their muscles used in flight. Being warm blooded however, means that birds have a much higher energy and oxygen demand, which means that birds require an extremely effective respiratory system. And birds in fact do have the most efficient respiratory system in the animal kingdom, being able to absorb oxygen out of the air both on inhalation AND exhalation. The rest of animals that rely on lungs for gas exchange can only absorb on the inhale, and release carbon dioxide on the exhale.
- d. The various species of birds found in the phylum Aves have any number of special adaptations that allow a diverse number of lifestyles in this phylum. Feet and beak structures for example cater to a variety of feeding strategies, everything from predatory birds to seed eaters and swimmers.

14. Mammals

- a. And now on to the pinnacle animal evolution! The mammal! Mammals have evolved to fill nearly every niche and live in every habitat found on earth, which is why they are often considered the pinnacle of evolution. Some of the defining features of mammals include being endothermic, covered with fur or hair for insulation, mammary glands used to nourish their young, giving birth to live young (with a couple of noted exceptions) and highly developed nervous systems and brains, more so than any other group of animals. There are three main groups of mammals: the Monotremes, the marsupials, and the placental mammals.
 - 1) Monotremes are the noted exception to giving birth to live young. These animals actually lay eggs. There are only 3 extant animals in this group, the platypus, and 2 species of anteater.
 - 2) The marsupials are characterized by raising their young in pouches through most of their fetal development. These animals do have a placenta and a uterus, but the embryos spend a very short amount of time in utero before being born and migrating into the pouch. Nearly all marsupials are found in Australia, only one species is found in North America, the opossum.
 - 3) Placental mammals, known scientifically and eutherians, have similar reproductive methods to their marsupial cousins, but gestation is typically much longer in eutherians, spending a much longer period of time developing in the womb.