# A Lecture With a Little Bit of Backbone Vertebrate History

### The Paleozoic Era

- scientists divide the earth's past into different time periods
  - large blocks of time are called eras
  - smaller blocks of time are called **periods**
- some periods are divided into epochs, which in turn can be divided into ages

### An evolutionary timeline.

- virtually all of the animals that survive at the present time originated in the sea at the beginning of the **Paleozoic era** 
  - the diversification of animal life began soon after the Cambrian period (545-490 M.Y.A.)
  - some Cambrian animals, such as trilobites, have no surviving close relatives
  - the first vertebrates evolved about 500 M.Y.A.

# Life in the Cambrian.

- while most of the animal phyla that evolved in the Cambrian remained marine, a few phyla, a few successfully invaded land
  - fungi and plants were the first terrestrial organisms, appearing over 500 M.Y.A.
  - arthropods were the first terrestrial animals, invading land about 410 M.Y.A.
  - vertebrates invaded the land during the Carboniferous period (360-280 M.Y.A.)
     amphibians were the first terrestrial vertebrates, preceding the reptiles, birds, and mammals
- mass extinctions are particularly sharp declines in species diversity
  - five mass extinctions have occurred during the history of life
    - the most drastic during the last ten million years of the **Permian period**, which marked the end of the Paleozoic era
      - an estimated 96% of all species of marine animals became extinct
    - the most well-studied occurred at the end of the **Cretaceous period** (65 M.Y.A.)
      - it was probably triggered by a large asteroid hitting the earth
      - dinosaurs went extinct at this time
- mass extinctions left vacant many ecological opportunities
  - these extinctions are always followed by rapid evolution among the relatively few species that survived
- we are currently experiencing a sixth mass extinction event
  - the number of species in the world is greater today than it has ever been

- but the number of species is declining at a rapid rate due to human activity
- some predict that as many as 25% of all species will become extinct in the near future

### The Mesozoic Era

- the **Mesozoic era** (248-65 M.Y.A.) was a time of intensive evolution of terrestrial plants and animals
  - dinosaurs and mammals appear at about the same time (i.e., 200 to 220 M.Y.A.),
    but the dinosaurs filled the evolutionary niche for large animals
  - for over 150 million years, dinosaurs dominate the surface of the earth
  - dinosaurs reached the height of their diversification and dominance during the Jurassic and Cretaceous periods

### An early reptile: the pelycosaur.

- the Mesozoic era has traditionally been divided into three periods:
  - Triassic
  - Jurassic
  - Cretaceous
- because of the major extinction that ended the Paleozoic era, only 4% of species survived into the Mesozoic

### **Dinosaurs.**

### Some dinosaurs were truly enormous.

- about 65 M.Y.A., at the end of the Cretaceous period, dinosaurs disappeared
  - this loss included flying reptiles (pterosaurs) and the great marine reptiles
  - mammals occupied the niches left open by the loss of the dinosaurs

### An extinct flying reptile.

### Extinction of the dinosaurs.

- many explanations have been advanced to explain the demise of the dinosaurs
  - the most widely accepted, proposed by Luis W. Alvarez, blames an asteroid impact
  - iridium is an element rare on earth but abundant in meteorites
  - a layer of iridium is abundant in many parts of the world in a layer of sediment that dates to the end of the Cretaceous period

### The Cenozoic Era

- the early **Cenozoic era** (65 M.Y.A. to present) was relatively warm compared to today's colder and drier climate
- the first half of the era was very warm with jungle-like forests at the poles
- a gradual cooling caused ice caps to form at the poles
  - the glaciation of Antarctica became fully established by about 13 M.Y.A.
- this was followed by a series of ice ages
  - the most recent ice age occurred less than 1 M.Y.A.
- many very large mammals evolved during the ice ages including:
  - mastodons, mammoths, saber-toothed tigers, and cave bears

#### **Fishes Dominate the Sea**

- a series of key evolutionary advances allowed vertebrates first to conquer the sea and then the land
- about half of all vertebrates are fishes
  - fishes provide the evolutionary base for the invasion by land by amphibians

#### Vertebrate family tree.

- all fishes have four important characteristics in common
  - gills
    - gills are used to extract dissolved oxygen from water
  - vertebral column
    - all fishes have an internal skeleton with a spine
  - single-loop blood circulation
    - blood is pumped in a single loop
    - the loop runs from the heart to the gills, then to the body, and returns to the heart

#### nutritional deficiencies

- fishes are unable to synthesize the aromatic amino acids and must consume them in their diet
- this trait has been inherited by all of their vertebrate descendants
- the first fishes were jawless and appeared in the sea about 500 M.Y.A.
  - **agnathans** are surviving jawless fishes found today
    - they include hagfish and lampreys

- jawed fishes appeared around 410 M.Y.A.
  - jaws evolved from the frontmost of a series of cartilages that reinforced the tissue between gill slits
- the earliest jawed fishes were heavily armored but have been replaced, for the last 250 million years, by sharks or bony fishes
- sharks replaced the heavy body armor with a flexible skeleton made of cartilage
  - this made possible fast and maneuverable swimming
- sharks, along with skates and rays, belong to the class Chondrichthyes
  - there are 750 species in this class today
  - while some are filter feeders, most sharks are predators and have a mouth armed with rows of sharp teeth
  - shark eggs are fertilized internally
    - about 40% of the chrondrichthyans lay fertilized eggs
    - the remainder give birth to live young

# Chondrichthyes.

- bony fishes have a heavier internal skeleton made of bone
  - but they achieve maneuverability through the aid of a swim bladder, a gas-filled sac that allow fish to regulate their buoyant density
  - the swim bladder allows a bony fish to remain suspended at any depth in the water without expending effort
    - sharks gain buoyancy from oil production in their livers, but they must still actively move to counteract their denser-than-water bodies

# Diagram of a swim bladder.

- bony fishes comprise the class **Osteichthyes** 
  - some bony fishes are lobe-finned (subclass **Sarcopterygii**)
    - this group includes the ancestors of the first tetrapods (four-legged animals)
  - other bony fishes are ray-finned (subclass Actinopterygii)
    - this group includes the vast majority of today's fishes
- bony fishes are the most successful of all fishes, indeed of all vertebrates
  - there are nearly 30K species of bony fishes

# **Major Classes of Fishes**

• bony fishes have many adaptations that have helped make them such evolutionary successes

### Iateral line system

- a special sensory system that enables fish to detect changes in water pressure
- operculum
  - a bony covering on top of the opening of the gills
  - this allows for the fish to ventilate the gills while remaining stationary

### Amphibians Invade the Land

- the amphibians include frogs, salamanders, caecilians
  - they are the first terrestrial vertebrates and evolved from the lobe-finned fishes

### **Orders of Amphibians**

- amphibians have five key characteristics that allowed them to invade land successfully
  - legs
  - Iungs
  - cutaneous respiration
  - pulmonary veins
  - partially divided heart
- approximately 4850 species exist today in the class Amphibia
- most of today's amphibians must reproduce in water and live the early part of their lives there

### **Reptiles Conquer the Land**

- all living reptiles share the following fundamental characteristics
  - amniotic egg
    - this innovation is a watertight environment that offers the embryo protection against drying out
  - dry skin
    - reptiles are covered by scales or armor in order to prevent drying out
  - thoracic breathing
    - reptiles increase their lung capacity by expanding their chest cavity when breathing in air

### A key adaptation of reptiles: watertight eggs.

• today some 7000 species of reptiles belong to the class Reptilia

- reptiles improved on the evolutionary innovations of amphibians to terrestrial life
  - reptilian legs were arranged to support better body weight and to facilitate more efficient locomotion
  - lungs and heart became more efficient in reptiles than in amphibians

### **Orders of Reptiles**

### **Birds Master the Air**

- birds evolved from bipedal dinosaurs about 150 M.Y.A.
  - they only became common after the pterosaurs became extinct
  - many scientists consider birds to be feathered dinosaurs, given their similarity in so many respects to dinosaurs
- modern birds lack teeth and have only vestigial tails
- they retain many reptilian characteristics
  - birds lay amniotic eggs (but with hard shells)
  - birds have reptilian scales on their feet and lower legs
- birds are different than reptiles in that they have
  - feathers
    - these are derived from reptilian scales but adapted for flight
  - flight skeleton
    - The bones of birds are thin and hollow, reducing weight while providing enhanced points for flight muscle attachment

### A key adaptation of birds: feathers.

- birds are **endothermic** 
  - their high body temperatures enhance metabolism, satisfying the large energy requirements of flight
- the oldest bird of which there is a clear fossil is *Archaeopteryx*
- there are about 8600 species of birds in the class **Aves** today

# **Major Order of Birds**

### Mammals Adapt to Colder Times

- mammals evolved about 220 M.Y.A. and belong to the class Mammalia
  - members of this class share three key characteristics
    - mammary glands
    - hair
    - middle ear

- the first mammals evolved from therapsids
- they were small shrew-like creatures
- they lived inconspicuously in an age dominated by dinosaurs
- the direct descendant of the therapsids were the members of the subclass Protheria
  - protherians laid shelled eggs
  - today they are represented by the **monotremes** 
    - this group includes the duckbill platypus and the spiny anteater (echidna)
- the other major mammalian group is the subclass Theria
  - there are two major living therian groups
    - the marsupials
    - the placental mammals

# **Major Orders of Therian Mammals**

- modern mammals have a number of characteristics that make them successful
  - **endothermy** allows for mammals to be active at any time of day or night and to colonize harsh environments
  - placenta is an adaptation for nourishing developing young that will be born live
  - teeth type varies in mammals, allowing specialization to eating habits
  - hooves and horns help with locomotion in running mammals

### The placenta.

- today's mammals include
  - monotremes
  - marsupials
  - placental mammals