….and finally….

The Phylum Chordata

A tremendous amount of variation exists within this phylum, but..

All chordates possess, at some point during their life cycle (even if it is only during embryonic development) 4 main features
  – The Chordate “Big 4”
Taxonomy of Chordates

- Kingdom Animalia
  - Phylum Chordata
    - Urochordata – the tunicates
    - Cephalochordata – the lancelets
    - Craniates – includes the vertebrates
Cephalochordata
(cephalos = head + chord)

- Commonly known as lancelets (Branchiostoma)
- Marine filter feeders
- Small size – 2 – 5cm
- Adults possess all of the “Big 4”
- Found in all warm seas of the world; concentrated in localized populations (as many as 5,000/meter²)
Notice: Big 4; segmentation, esp. chevron-shaped, segmented muscles; cephalization

Urochordata
(uro = tail + chord)

- Commonly known as tunicates or sea squirts
- Marine
- Planktonic filter feeders
- Larvae exhibit “big 4”
- Adults only retain one of the “Big 4” as they change (metamorphosis); the pharyngeal slits – used in filter feeding
- No cephalization in adults
Craniates

- Cranium – endoskeletal elements which surround the brain
- Pronounced cephalization
- Neural crest present during embryonic development
- Heart with at least two chambers
- Kidneys as organ for metabolic waste removal and osmoregulation
- Red blood cells with hemoglobin
- Most spp. Dioecious
Myxini – the hagfish

The hagfish – marine bottom scavenger
Skeleton made of cartilage
Retain notochord through adulthood
Lack jaws and vertebrae
Pharyngeal cleft elements modified for gas exchange
- gills
Very flexible
Poor swimmer – no paired fins
Produce slime as a mechanism to prevent predation
hagfish knot
hagfish slime youtube clip
The Vertebrates

Craniates with vertebrae
skeletal elements surrounding the notochord and spinal cord
More extensive cranium/skull

Petromyzontida– the lampreys

Parasites as adults
Larvae – live in freshwater streams/ resemble lancelets
Adults migrate to large lakes or seas to reproduce
Gnathostomes
Evolution of vertebrate jaws and paired fins

• Placoderms (extinct group of fish) are thought to be the first jawed vertebrates; this occurred during the Devonian period (360-400 million years ago)

• Jaws and paired fins were major evolutionary breakthroughs in vertebrate history
  – Jaws allow for the use of untapped food resources – prior to jaws, vertebrates had to be detritivores or filter feeders
  – Paired fins increased maneuverability in the water
  – Lateral line system – for sensory perception
  – Vertebrates could now become active predators

  Dunkleosteus – early gnathostome

– Pharyngeal slit elements evolved into jaws and the remaining pharyngeal skeletal elements could now become adapted to support more advanced gills for respiration
– In addition a true cranium formed protecting the brain
Chondrichthyes

(*chondro* = cartilage + *ichthyes* = fish)

- Sharks, skates and rays
- Approx 750 extant spp.
- Endoskeleton of cartilage
- Well developed jaws with teeth (modified scales-placoid scales)
- Paired fins (pectoral and pelvic)
- Caudal fin (tail) with cartilage endoskeleton present in upper lobe (heterocercal tail)

A finely adapted killing machine: Sharks
- Fusiform body shape – torpedo; reduce drag
- Laminar flow of water across body; placoid scales; reduce drag
- Large eyes
- Lateral line
- Ampullae of Lorinzini
- Highly mobile – pectoral, pelvic dorsal, anal and caudal fins
Reproduction in sharks

• All spp. are dioecious
• Internal fertilization
  – Oviparous – lay eggs that hatch outside mother’s body
  – Ovoviviparous – retain fertilized eggs inside oviduct of female; young nourished by yolk and emerge as live young
  – Viviparous – rudimentary placental attachment; young nourished by mother’s body and emerge as live young
• Cloaca – common chamber/ opening to the outside where reproductive, digestive and excretory systems merge

Osteichthyes

*osteo = bone + ichthyes = fish*

• Vertebrates with a bony endoskeleton
• Ossified bone of calcium phosphate
• Historically, this term was used just for bony fish.
• However, this group currently contains:
  – Bony fish groups and tetrapods (amphibians, reptiles and mammals)
Ray-finned fishes
(Actinopterygii)

The bony fish: ~30,000 spp.
• Ossified endoskeleton of bone (calcium phosphate)
• Skin covered with scales
• Epidermal glands secrete protective mucus (also reduces drag)
• Paired fins (pelvic and pectoral) and unpaired fins all supported with spiny rays
• Operculum – bony flap covers and protects gills; aids in ventilation
• Swim bladder
• Most have homocercal caudal fin
Bony fish and tetrapods: the move onto land

• Two extant groups of bony fish have evolutionary ties to the move onto land by vertebrates
  – The lobe-finned fish (Sarcopterygii) –
    • Coelacanth
    • Lungfish

Due to the ease of fossilization in the shallow aquatic environs of the Devonian, scientists have a fairly good fossil record for tracing the lineage of tetrapods.
The tetrapods

- Terrestrial vertebrates
- Pelvic and pectoral girdles
- Cervical vertebrae allow side to side and up and down
- Adaptations for terrestrial life
  - Dehydration?
  - Reproduction?
  - Gas exchange?
    - Lungs (swim bladder) for gas exchange
    - Ribs which could expand to aid ventilation
    - This required a modification to the closed circulatory system
Amphibia

(\textit{amphi} = dual + \textit{bio} = life)

- 4,800 spp.
- Earliest amphibians known from the Carboniferous (approx. 350 mya)
- Smooth glandular skin; dehydration
- No keratinized structures (claws, nails)
- Bone endoskeleton
- 3 chambered heart
- Ectotherms
  - Frogs
  - Salamanders
  - Caecilians
• External fertilization
• Metamorphic life cycle
• Non-shelled, anamniotic egg
Amniotes – a simple set of membranes

![Diagram of extraembryonic membranes]

![Diagram showing the evolutionary relationships of various groups, including amphibians, reptiles, birds, mammals, and tetrapods]
Reptiles
(literally, *to creep*)

- Keratinized epidermal scales
  - Feathers in birds
- Fewer epidermal glands
- Better lungs
- Bony endoskeleton
- Teeth (homodont dentition)
- 3 chambered heart with partial I.V. septum
  - (4 chambers in birds)
- Shelled amniotic egg
- Ectotherms
  - (except birds are endothermic)
Extant reptile groups

- Turtles
- Lizards & Snakes (Squamates)
- Crocodilians
- Birds
Origin of Birds

• Theropod dinosaurs (?)

Aves

(avis=bird)

• 8,600 spp.
• Adapted for volant lifestyle
  – Keratinized feathers
  – Hollow bones
  – Keeled sternum
  – Reduction in number of bones
  – Reduction in organs (one ovary and no urinary bladder)
  – No teeth – food manipulation with modified beak
  – Keen vision
  – Large brain; esp. motor areas
  – High metabolism
  – 4 chambered heart
  – Parabronchi lungs
Mechanics of flight

(a) Wing

(b) Bone structure

(c) Feather structure

Anterior air sacs

Posterior air sacs

Lungs

Airflow

Air tubes (parabronchi) in lung

1 mm

1 First inhalation
2 First exhalation
3 Second inhalation
4 Second exhalation
Wing is an airfoil:
Bernoulli’s Principle: air passing on dorsal side of wing travels faster than air passing on ventral side; creates high pressure on ventral face and creates “LIFT”

Mammalia
(mammary glands)

• 4,500 extant spp.
• Epidermal hair (keratin)
• Mammary glands produce milk
• 4 chambered heart
• Diaphragm for ventilation of lungs
• High metabolic rate
• Heterodont dentition
• RBC’s enucleate
• Ossicles (auditory bones)
• Complex CNS with highly developed brain
Origin of mammals

- Therapsid reptiles
  - Dentary-squamosal jaw articulation
  - Articular-quadratoquadrate articulation becomes malleus and incus

Three groups of mammals

1. Monotremes
   - spiny anteater or echidna and duck-billed platypus
   - Lay shelled egg
   - Found in Australia and New Guinea
2. Marsupials
- very short gestation period; little placental formation
  - Red kangaroo – 33 days
- Embryos complete development in marsupium (pouch)
- Found in Australia and North and South America (opossums)

3. Eutheria
  True Placental Mammals
  Young complete development in uterus joined to mother with a well developed placenta
  Cosmopolitan distribution
Why are monotremes and most marsupials found only in Australia?

Competition –
Continental Drift -

Placing humans in the “tree of life”