Chordates $\rightarrow$ Vertebrates

From basal Deuterostomes
Outline

• Origins of Deuterostomes & Chordates
• Characteristics of Deuterostomes & Chordates
• Themes in Chordate evolution?
• Vertebrate adaptations?
• How are Vertebrates related?
• Who are the contemporary Vertebrates?
Deuterostome ancestors & characters

What kind of traits are these?
Figure 33-7 Biological Science, 2/e
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Synapomorphies of Chordata

1. Pharyngeal gill pouches
   • Modified in adults of terrestrial lineages; become gills in aquatic lineages

2. Notochord (gelatinous; cartilaginous)
   • Organizes body
   • Forms somites: blocks of tissue that produce limbs, segmented skeletal muscle, ribs

3. Dorsal, hollow, nerve chord

4. Muscular, post-anal tail
Chordate precursors

- Echinoderms
  - Sea stars; brittle stars
- Hemichordates
  - Acorn worms

Echino Hemi Uro Cephalo Verts

Hemichordata (acorn worms; a phylum closely related to chordates)

Adult
Water flow
Pharyngeal gill slits
Overhead drawing: Generalized chordate features
Themes in evolution of Chordates

• Increasing cephalization
• Gaining teeth, jaws, and diversifying them.
• Vertebrate structures from invertebrate bodies
  - **Skeletons** (endo), cephalization of DHNC, limbs
• **Morphological innovations** that allowed invasion of land
Fossils mark some major innovations

- Bony exoskeleton
- Jaws and teeth
- Limbs capable of moving on land
- Amniotic egg

First vertebrates: Cambrian
First cartilaginous fishes: Ordovician
First fish with extensive bone: Silurian
First bony fish with jaws: Devonian
First tetrapods: Carboniferous (Mississippian)
First amniotes: Permian

542 mya to 251 mya
Major innovations

• From Cartilage
  - Scattered, unorganized cells surrounded by proteins & polysaccharides; **Avascular**
  - Stiff, flexible

• To Bone (~ 480 Mya) **Exoskeleton 1st**
  - *Organized* cells surrounded by proteins & calcium crystals; **Vascularized**
  - Rigid; stiff in compression, relatively flexible under tension
Major innovations

• From **Pharyngeal gill slits**
  - For acquiring $O_2$ & some filter feeding
  - One gill arch becomes modified ->

• **To Jaws (~ 430 Mya)**
  - Now we can bite! Goodbye suspension feeding
  - Eat big stuff
    • Not just floating rice grains
  - Eat attached stuff
Pharyngeal gill slits -> Jaws

- **Vertebrates**
  - Gill arch evolved into **jaws**
  - Same shape and movement
  - Jaws & arches (and **not** neighboring structures) derive from **neural crest cells**
  - Attached muscles originate from same population of embryonic cells
  - Ray-finned fishes modified arches further
Major innovations

• From **Fins**
  - Great for propulsion or steering in water

• To **4 limbs (~ 375 Mya)**
  - Tetrapods
  - Allowed access to terrestrial environments
Locomotion

• Evidence for transition from Fish
  - Lungfish
  - Structural evidence
    • Many fossil intermediates
  - Molecular genetic evidence
    • In both limbs & fins, the same patterning genes are active at same time.
Major innovations

- From unbound gelatinous egg
  - Fine if bathed in water
- To Amniotic egg (~ 355 Mya) Amniotes
  - Watertight shell (or case) enclosing food supply, water supply & waste repository
  - Provides freedom from aquatic environments
  - Now you can live anywhere, because egg (membrane or shell) resists desiccation
Amniotic egg

- Early Tetrapods = Amphibian-like eggs
- Contemporary Amniotes have encased, membrane-bound eggs
  - Watertight
  - Albumen layer: water supply
  - Amnion: cushions embryo
  - Yolk sac: nutrients
  - Allantois: waste container
  - Chorion: SA for gas exchange
Major innovations

- From smooth, moist epithelia
  - Good for exchanging H₂O and O₂ and waste in water
- To hard, **keratinized** epithelia
  - Necessary for preventing desiccation
Clicker Q

What challenges did Vertebrates face in moving from an aquatic to a terrestrial environment?

1. Resisting desiccation
2. Exchanging gases in a new media (air vs. water)
3. Moving through an environment dominated by gravity
4. All of the above
Vertebrate diversity
Vertebrate Diversity

- Feeding
  - Jaws
- Locomotion
  - Tetrapod limb
- Reproduction
  - Amniotic egg
Feeding

- Echinoderms
  - Suspension feeding
  - Deposit feeding
  - Harvesting

- Basal Vertebrates - jawless
  - Deposit feeding
  - Ectoparasites
Locomotion

• Aquatic Vertebrates
  - Fins & lateral undulation

• Lungfish
  - Limb-like fins: short distance excursions
  - Lungs: additional $O_2$
  - Burrow in mud: survive droughts

• Tetrapods
  - Fully functional limbs
Reproduction

1. Amniotic egg
2. Placenta
3. Parental care
Placenta

- Placenta “replaces” yolk sac & allantois
  - Highly vascularized for nutrient & gas exchange
- Probably represents a trade-off
  - Invest lots in few offspring
  - Invest little in many offspring
Parental care

- Widespread in vertebrates
  - Any energy output that increases survival of offspring
- Highly developed & consistent in birds & mammals
  - Feeding; warming; protecting
  - Lactation: offspring totally dependent on mother for nutrition
  - Placentation & Lactation represent highest energy provisioning & output of any animal
“Agnathans”

- 110 species
- **Hagfish**
  - Scavengers and predators
  - Carcass and buried prey
- **Lampreys**
  - Ectoparasites
  - Attach, rasp, drink
Chondricthyes

- 840 species
- Cartilagenous skeletons
- Mostly marine
- **Feeding**: Mostly predators

**Sharks**
- **Movement**: Lateral undulation
- **Active** predators

**Skates, Rays**
- **Locomotion**: pectoral fin flapping
- **Feeding**: *Sit & wait.*
  - Electrocute/stun prey
Actinopterygii

- Ray-finned fishes
- 24,000 species
- Huge diversity
  - Feeding
  - Locomotion
  - Reproduction
Sarcopterygii

- 8 species
- **Actinista** (coelocanth)
  - Omnivorous; fish & plant matter
- **Dipnoi** (Lungfish)
- Limbs made of distinguishable bones & muscle
- Lungs in Dipnoi
- **Movement**: Lateral undulation
- **Repro**: Oviparous
Amphibia

- 4800 species
- **Frogs & toads; Salamanders; Caecilians**
- **Feeding:**
  - Carnivorous adults
  - Mostly sit & wait
- **Movement:**
  - Lateral undulation; hopping; burrowing
- **Repro:**
  - Oviparous
  - External fert. (F&T)
  - Internal fert. (Sallys, Caecilians)
Mammalia

- **Monotremes (3)**
  - Oviparous; nutritious sweat

- **Marsupials (275)**
  - Viviparous; prolonged lactation

- **Placentals (4300)**
  - Viviparous; prolonged gestation

- **Movement:**
  - Swim, walk, glide, fly, brachiate, burrow, hop

- **Feeding:**
  - Carnivores, herbivores, omnivores
Testudinia

- 271 species
- **Feeding:**
  - Herbivores; carnivores
- **Reproduction:**
  - Oviparous; Temp-dependent sex determination; no care
- **Movement:**
  - Swim; walk; burrow
- **Turtles**
  - Marine & freshwater
- **Tortoises**
  - Terrestrial
Archosauria

- **Repro**: Oviparous; extensive parental care
- **Crocodiles, alligators, caimans**
  - 21 species
  - **Locomotion**: Walk, gallop, lateral undulation
  - **Feeding**: predators
- **Birds**
  - 9700 species
  - **Locomotion**: Fly, run, swim
  - **Feeding**: omnivores, herbivores (nectar, seeds), predators
Lepidosauria

- Tuataras, Squamata ("lizards" & snakes)
- 6800 species
- Many limb reductions
- Feeding:
  - Predators
    - sit & wait & active
    - Constriction, venom injection, twist & shear
  - Herbivores
- Movement: Lateral undulation
- Repro: oviparous, ovoviviparous; some parthenogenesis in whiptails