Overview of Lecture: Animal Diversity - Vertebrates
Read Text ch 34, A survey of human evolution.

Bullet Points:
- chordate clades and shared derived characters
- notochord, dorsal hollow nerve cord, pharyngeal slits, post-anal tail
- segmentation, shingles
- Urochordates: sea squirts
- Cephalochordates: amphioxus
- Hagfish
- Vertebrates

Gnathostomes
Chondrichthyes
Osteichthyes
Tetrapods
Amniotes
Reptiles' & Birds
Mammals
The notochord appears early in embryogeny and plays an important role in organizing

induction by **Sonic Hedgehog**! ‘morphogen’ {see ch 47}

In most adult chordates the notochord disappears … {remnants become spongy discs between vertebrae}

In some non-vertebrate chordates and fishes the notochord persists as a flexible rod that prevents collapse of the body during swimming.

above the notochord. ... ectoderm is induced to differentiate into the brain & spinal cord.

{HOX genes, incl. BF1, Otx & Hox3, induce anterior-posterior segments}
The embryonic fate of the clefts & slits varies depending on the taxonomic subgroup. In many of the non-vertebrate chordates, such as tunicates and cephalochordates, … elaborated as food straining devices.

In fish and juvenile amphibians, the pharyngeal arches develop into gills … organs of gas exchange between the water and blood. {in planktivorous fish ‘rakers’ are straining devices}

In adult amphibians and the amniote tetrapods (= “reptiles,” birds and mammals) the anteriormost cleft transforms {during ontogeny}
3. visceral (pharyngeal or gill) clefts & arches 

Jaw bones of fish evolved & develop from anterior arches.

Ear bones of mammals:
- Ear drum
- Middle ear
- Inner ear
- Stapes
- Incus (evolved from quadrates)
- Malleus (evolved from articular)

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Human Fetus at 40 days

Structures derived from Pharyngeal Arch Components (in humans):

<table>
<thead>
<tr>
<th>ARCH</th>
<th>NERVE</th>
<th>MUSCLES</th>
<th>SKELETAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Trigeminal (V)</td>
<td>Muscles of mastication</td>
<td>Maxilla &amp; mandible, Malleus &amp; Incus</td>
</tr>
<tr>
<td>Second</td>
<td>Facial (VII)</td>
<td>Muscles of facial expression</td>
<td>Upper part of hyoid bone, Stapes</td>
</tr>
<tr>
<td>Third</td>
<td>Glossopharyngeal (IX)</td>
<td>Stylopharyngeus</td>
<td>Lower part of hyoid bone</td>
</tr>
<tr>
<td>Fourth &amp; sixth</td>
<td>Vagus (X)</td>
<td>Muscles of speech &amp; swallowing</td>
<td>Cartilages of speech &amp; swallowing</td>
</tr>
</tbody>
</table>

Structures derived from Pharyngeal Pouches:

<table>
<thead>
<tr>
<th>POUCH NUMBER</th>
<th>DEFINITIVE STRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Middle ear cavity &amp; auditory tube</td>
</tr>
<tr>
<td>II</td>
<td>Palatine tonsil</td>
</tr>
<tr>
<td>III</td>
<td>Inferior parathyroid gland, Thymus</td>
</tr>
<tr>
<td>IV</td>
<td>Superior parathyroid gland, Ultimobranchial body</td>
</tr>
</tbody>
</table>

{+4. Muscular postanal tail}
**Segmentation** muscle somites & nerves

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**Causes of Herpes**

- Recurrence of Varicella from dormant state in the dorsal root ganglia
  - Cause is usually unknown
  - Linked to periods of stress, old age, immunosuppression
  - 10–20% of the infected population will manifest the virus
  - Rare in children

is a nerve infection caused by the chicken-pox virus. … results from reactivation of the chicken-pox virus that remained in your body since you had chicken pox—perhaps many years ago. 
{dorsal root nerve ganglia, organized in segments}
Nearly all are sessile as adults but they have free-swimming larvae. The larva swims until it attaches by its head to a surface and undergoes metamorphosis, during which it becomes sedentary & most of its chordate characteristics disappear.

Morphological traits of chordates are clear in the larval “tadpole” stage which shows Adults … with a mucous food trap in the pharyngeal floor that is homologous with the thyroid gland of vertebrates.

+ molecular phylogenies (later)
**Cephalochordata** are also known as **amphioxus** and **lancelets**. The group contains only about 20 species of sand-burrowing marine creatures.

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(sung to the tune of "It's a Long Way to Tipperary")

**chorus:**

*It's a long way from amphioxus*

*It's a long way from amphioxus*
*To the meanest human cuss.*

*It's good-bye, fins and gill slits,*
*Hello, lungs and hair!*

*It's a long, long way from amphioxus,*
*But we all came from there!*

---

What is wrong w/ this song? (aside from the obvious!)

---

might have selected for retention of ‘svelte’ juvenile morphology
Amphioxus and tunicates as evolutionary model systems • Review article

... all extant chordates, at some stage in their life have:

Vertebrates have acquired several specific characters.

(not present in Urochordates or Cephalochordates)

The most important ‘invention’ of vertebrates ...

a new head with a full array of sensory organs
derived mainly from neural crest ...

which enabled vertebrates
to shift to an active predatory lifestyle.

is referred to as the fourth germ layer ...

These cells migrate extensively to yield:

dorsal root ganglia,
sympathetic chain ganglia,
the four pre-aortic ganglia ...

sensory ganglia of the fifth, seventh, ninth and tenth
dentin-producing cells of the teeth, melanocytes,
smooth muscle of great arteries ...
cornea, lens, and ciliary muscle of the eye ...
a head - consisting of a brain at the anterior end of the dorsal nerve cord, eyes and other sensory organs, and a skull - opened up a completely new way of feeding for chordates: active predation

Class Myxini: Hagfishes
~30 species of hagfishes, all marine. mainly bottom-dwelling scavengers. The skeleton is entirely cartilage: - cartilaginous cranium (skull)

{“degenerate” sister group to vertebrates}

Hagfish embryology with reference to the evolution of the neural crest.
K.G. Ota et al. 2007 Nature 446, 672-675
... hagfish neural crest is specified by molecular mechanisms that are general to vertebrates.
Vertebrates are craniates that have a backbone

Class Cephalaspidomorphi:
There are about 35 species of lampreys
marine & freshwater

The notochord of lampreys persists as the main axial skeleton in the adult, as it does in hagfishes.
Lampreys also have pairs of cartilaginous projections partially enclosing the nerve cord.

{which pass for vertebrae}

Hagfishes and lampreys
During the late Silurian & early Devonian period, **gnathostomes** largely replaced the agnathans.

The common ancestors of all gnathostomes

The lateral line system, a row of sensors sensitive to vibrations ... runs the length of each side of the body in aquatic gnathostomes

Single-loop circulation - OK for low metab. rate ectotherms

Fishes & vert. descendants cannot synthesize ‘essential’ aromatic Amino Acids (ch 41)
Sharks and their relatives, are called **cartilaginous fishes** because they have relatively flexible endoskeletons made of cartilage rather than bone. In most species, parts of the skeleton are strengthened by mineralized granules, and the teeth are bony. The **cartilaginous skeleton of these fishes is a derived characteristic, not a primitive one**; the ancestors of Chondrichthyes had bony skeletons, They have a **lateral line** (pressure sensor) but **no operculum** (boney gill cover, helps pump water); & **no swim bladder** to maintain neutral buoyancy. Unlike most bony fish, sharks have **internal fertilization**.

The Shark Research Institute (SRI) is engaged in a worldwide study to locate, tag and document the behavior of whale sharks, Rhincodon typus, the largest fish in the sea.
The **bony fishes** (**Osteichthyes**) evolved in fresh water

**Bony fishes** have a lateral line system – like **Chondrichthyes**
... can breathe while stationary by drawing water through the gills
by movement of the **operculum**
... the transfer of gases between the blood & **swim bladder**
helps control the buoyancy of the fish ...
... are the most numerous vertebrates (≈ 30,000 species).

<table>
<thead>
<tr>
<th>Table 34.1 Major Classes of Fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
</tr>
<tr>
<td>Actinopterygii</td>
</tr>
<tr>
<td>Sarcopterygii</td>
</tr>
</tbody>
</table>

Nearly all the families of fishes familiar to us

**class Actinopterygii**:

**Lobe-finned fishes** (**Sarcopterygii**) have muscular pectoral and pelvic fins
supported by extensions of the bony skeleton
- the **coelacanth** (**Latimeria**)

{+ **Dipnoi lungfishes**}
Zoology: Record-breaking fish
Zoologists have unveiled
the smallest free-living vertebrate ever found.
Mature females of the fish Paedocypris progenetica (pictured right),
which lives in highly acidic blackwater peat swamps in southeast Asia,
average just 7.9 millimetres in length.
Described by Ralf Britz, of London's Natural History Museum, and his colleagues,
the miniature species has a larva-like appearance,
with a skull that does not form properly, leaving it with a hole in the top.
But the specimens' gonadal development shows them to be mature adults
- and males possess a unique specialized structure near their genitals
thought to be used for clasping the female during mating.
Tetrapods are: {lost in apoda, snakes, legless lizards; some whales lose hind legs}

The bones of the pelvic girdle are fused to the backbone, permitting forces generated by the hind legs to be transferred to the body.

Amphibians lack

... on the origin and phylogeny of living amphibians
Scientists have stumbled across the first example of a photosynthetic organism living inside a vertebrate's cells. The discovery is a surprise because the adaptive immune systems of vertebrates generally destroy foreign biological material. In this case, however, a symbiotic alga seems to be surviving unchallenged — and might be giving its host a solar-powered metabolic boost. The embryos of the spotted salamander (A. maculatum) have long been known to enjoy a mutualistic relationship with the single-celled alga O. amblystomatis. The salamanders' viridescent eggs are coloured by algae living in the jelly-like material that surrounds the embryo. The embryos produce nitrogen-rich waste that is useful to the algae, which, in turn, supply the developing embryos with extra oxygen. The algae clearly benefit their salamander hosts: Lynda Goff ... showed 30 years ago that salamander embryos lacking algae in their surrounding jelly are slower to hatch. One ... most curious discoveries suggests that the algae may be a maternal gift. [Kearney] found the same algae in the oviducts of adult female spotted salamanders, where the embryo-encompassing jelly sacs first form.
Amphibians wiped out before they are discovered

Fungal disease drives the loss of 30 species in Panama.

Janet Fang

A Panamanian park has lost around 40% of its amphibian species in the past decade, with some dying out before biologists had even learned of their existence, according to research published today in the Proceedings of the National Academies of Science USA. Combining genetics with nearly ten years of field surveys, biologists discovered 11 new species, only to find that five of them are already extinct in the area.

"We're losing things before we find them," says Andrew Crawford, an evolutionary geneticist at the University of the Andes in Bogotá, Colombia.

The Panamanian golden frog (Atelopus zeteki) is...
The **amniotic (land) egg**

**Extraembryonic membranes**

- **Allantois.** The allantois is a disposal sac for certain metabolic wastes produced by the embryo. The membrane of the allantois also functions with the chorion as a respiratory organ.

- **Chorion.** The chorion and the membrane of the allantois exchange gases between the embryo and the air. Oxygen and carbon dioxide diffuse freely across the shell.

- **Yolk sac.** The yolk sac contains the yolk, a stockpile of nutrients. Blood vessels in the yolk sac membrane transport nutrients from the yolk into the embryo. Other nutrients are stored in the albumen (“egg white”).

**Amnion.** The amnion protects the embryo in a fluid-filled cavity that cushions against mechanical shock.

**Placental mammals** have suppressed the egg shell & yolk sac, and elaborated the amniotic membranes to enable nutrients and wastes to pass between mother and embryo. The **chorion & allantois** fuse,
There is an incredibly rich and diverse array of fossil reptiles.

Modern "Reptiles" are paraphyletic.

Phylogeny of turtles is still unresolved.

Almost every part of a bird’s anatomy is modified to enhance flight. The bones are honeycombed – strong but light. The skeleton of a frigate bird has a wingspan of more than 2 m but weighs only about 113 g (4 oz) {≈ a Quarterpounder!}


Birds have the smallest genomes of all amniotes *{less non-coding “junk”}* ... may have been favoured by the demands of flight ... reducing metabolic costs. ... bats possess smaller genomes than do mammalian sister groups. ... there is a well-known positive relationship between cell size and genome size ... it is possible to approximate osteocyte (bone-cell) size from fossilized bones ... the small genomes ... evolved in the saurischian dinosaur lineage ...
Marsupial mammals bear their young much earlier than placential mammals and then nurture them in a maternal pouch. They split from the placential line more than 100 million years ago, and the evolutionary relationships among the Australasian (left) and South American (right) species have been debated. Nilsson et al. have performed genome-wide scans for retroposition integrations in the opossum and kangaroo genomes. A subset of the resulting loci was validated in 20 species from the seven marsupial orders, yielding 53 phylogenetically informative retroposition markers that root modern marsupials and demonstrate a clear separation between the South American and Australasian denizens. Furthermore, they support the view that the marsupial fauna of Australia was populated by a single Gondwanan migration event originating from what is today South America.

Genome analysis of the platypus reveals unique signatures of evolution Warren et al. 2008 Nature 453, 175-183. ... exhibits a fascinating combination of reptilian and mammalian characters.

Human breasts are more than mammary glands. They have been shaped by sexual selection – (possibly as a signal of youth & health)

All mammals share three characteristics not found in other animals:

- by modified sweat glands called mammary glands.

http://animaldiversity.ummz.umich.edu/chordata/mammalia.html