Overview of Lecture: Animal Diversity - Vertebrates (plus some other Chordates that lack vertebrae)
see the schedule for reading and watching assignments

• chordate clades and shared derived characters
• notochord, dorsal hollow nerve cord, pharyngeal slits, post-anal tail
• your gill arch and cleft homologues (your inner fish)
• segmentation, shingles
• Urochordates: sea squirts
• Cephalochordates: amphioxus
• neural crest
• Hagfish – have a head
• Vertebrates
  Gnathostomes – jaws
  Osteichthyes – boney fish
  Tetrapods – 4 legs
  Amniotes – land egg
  ‘Reptiles' & Birds
  Mammals
Learning Goals:

1. Be able to name and describe the four fundamental physical features of chordates. Explain how it could be that we are chordates but lack a notochord. Do human embryos ever have a notochord? If yes, what role does it play in development (if any) and what happens to it? Do human embryos or adults have gill arches and clefts? If yes, what happens to them over ontogeny (development)? Do humans ever have muscular postanal tails? Explain.

2. Be able to explain what the disease shingles is and use the symptoms of shingles in humans to illustrate the segmental nature of the human body.

3. Be able to describe the basic features of the amniotic “land” egg. Are amphibians amniotes? How does that explain why amphibians need to lay their eggs in water, or at least very wet places? Are humans amniotes?

4. Be able to name three distinctive physical features of mammals (not including our distinctive teeth). Describe the strange role that a “domesticated” endogenous retrovirus seems to play in the evolution and function of placental mammals.
Watch: Bozeman Science: Animals

Vertebrates

- Lancelet
- Lamprey
- Cartilage fish
- Bony fish
- Lobe-finned fish
- Amphibians
- Reptiles
- Mammals

- Head
- Jaws
- Lungs or lung derivatives
- Lobed-fins
- 4 Legs
- Amniotic egg
- Milk
The big 4 shared derived traits of the chordates

1. Notochord
2. Dorsal hollow nerve cord
3. Pharyngeal slits
4. Post-anal tail

Watch: Chordates - CrashCourse
The notochord appears early in embryogeny and plays an important role in organizing the embryonic development of nearby structures. Induction by Sonic Hedgehog protein ‘morphogen’ {see ch 47}

In some non-vertebrate chordates and fishes the notochord persists as a flexible rod that prevents collapse of the body during swimming. In most adult chordates the notochord disappears … {remnants part of spongy discs between vertebrae}
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)
Jaw bones of jawed vertebrates evolved from anterior arches.

http://phylogeny.arizona.edu/tree/eukaryotes/animals/chordata/chordata.html

3. Visceral (pharyngeal or gill) clefts & arches

Muscular postanal tail – lost in most humans.

3. Visceral (pharyngeal or gill) clefts & arches

Ear bones of mammals evolved from posterior jaw bones... sort of, loosely.

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**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>Malleus &amp; incus</td>
</tr>
<tr>
<td>Second</td>
<td>Facial (VII)</td>
<td>Muscles of facial expression</td>
<td></td>
</tr>
<tr>
<td>Third</td>
<td>Glossopharyngeal (IX)</td>
<td>Stylopharyngeus</td>
<td>Upper 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</td>
</tr>
<tr>
<td>IV</td>
<td>Thymus</td>
</tr>
<tr>
<td></td>
<td>Brachial body</td>
</tr>
</tbody>
</table>
Segmentation muscle somites & nerves; regulated by HOX gene complexes

Shingles (Herpes varicella-zoster) is a nerve infection that results from reactivation of the chicken-pox virus that remained in your body since you had chicken pox—perhaps many years ago.

Causes of Herpes Zoster/Shingles

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

the CDC isn't recommending the shingles vaccine until you reach age 60
The strictly marine **Urochordata** or Tunicata are commonly known as **tunicates**, sea squirts, and salps. There are roughly 1,600 species of urochordates; most are small solitary animals but some are colonial organisms.

Nearly all are **sessile as adults** but they have **free-swimming larvae**. The larva swims until it settles, 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:

- **1. notochord**
- **2. dorsal hollow nerve cord**
- **3. pharyngeal slits and arches**
- **4. post-anal muscular tail**

**Duterostomes**

**Bilateria**
Cephalochordata are also known as **amphioxus** and **lancelets**. … only about 20 species of sand-burrowing marine creatures.

(http://phylogeny.arizona.edu/tree/eukaryotes/animals/chordata/chordata.html)

(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!*

See: Evolutionary crossroads in developmental biology: amphioxus
S Bertrand & H Escriva 2011

(http://www3.pgh.net/~newcomer/amphioxus.htm)

What is wrong w/ this song? (aside from the obvious!)
Amphioxus and tunicates as evolutionary model systems • Review article

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

Vertebrates have acquired several characters. 
{not present in Urochordates or Cephalochordates}
The most important ‘invention’ of vertebrates ... 
a new head [cranium] with a full array of sensory organs 
derived mainly from neural crest ...
which enabled vertebrates
to shift to an active predatory lifestyle.

The neural crest,

the four pre-aortic ganglia ...
the adrenal medulla,
neural, releases epinephrine, norepinephrine
sensory ganglia of the fifth, seventh, ninth and tenth cranial nerves, muscle, bone, and cartilage in the face, 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
Vertebrates are craniates that have a skeletal backbone \[\text{not the notochord}\].

Lampreys lack bony jaws and paired appendages.
The common ancestors of all gnathostomes had an additional duplication of Hox genes that regulate development of segments anterior to posterior.

**Tetrapods** are craniate, vertebrate gnathostomes that have four legs & feet. *{lost in snakes; 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. *{useful for hopping/walking}*

*Amphibians lack the amniotic ‘land’ egg.*
The game-changing amniotic egg - April Tucker

Oxygen (O₂)

Carbon Dioxide (CO₂)

Shell

Chorion

Allantois

Amnion

https://www.youtube.com/watch?v=Qq0kMEWzdHg
The amniotic (land) egg has a unique set of membranes: amnion, chorion, and allantois.

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

**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.

**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.

**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”).

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**Placental mammals**

- Embryo
- Umbilical cord
- Placenta
- Chorion
- Yolk sac
- Uterus
- Amnion
Syncytin is a captive retroviral envelope protein involved in human placental morphogenesis.
S Mi et al. NATURE | VOL 403 | 17 FEBRUARY 2000
https://www.nature.com/nature/journal/v403/n6771/pdf/403785a0.pdf?origin=ppub

Many mammalian viruses have acquired genes from their hosts during their evolution.
Here we describe the opposite situation, **where a viral gene has been sequestered
to serve an important function in the physiology of a mammalian host.**

This gene, encoding a protein that we have called syncytin, is the envelope gene
of a recently identified human endogenous defective retrovirus, HERV-W2.
We find that the major sites of syncytin expression are placental syncytiotrophoblasts,
multinucleated cells that originate from fetal trophoblasts. …

Our data indicate that syncytin may mediate placental [function] in vivo,
and thus may be important in human placental morphogenesis.

[See: http://blogs.discovermagazine.com/loom/2012/02/14/mammals-made-by-viruses/#.Wd5p7a2ZOky ]

**Retroviruses and the Placenta**
David Haig Current Biology Volume 22, Issue 15, 7 August 2012
… the placenta became a site where retroviral genes were ‘domesticated’
to serve adaptive functions in the host,

**The Viruses That Made Us Human**
http://www.pbs.org/wgbh/nova/next/evolution/endogenous-retroviruses/
Early mammals used the spare viral parts left in the junk drawers of the genome
to use a viral gene to help create the placenta.
Syncytin is produced as a precursor to the formation of the cellular layer that allows for the fusion of the placenta and uterus. But what makes syncytin even more incredible is that it didn’t arise from a mammalian gene: syncytin arose from a virus.

So what originally started as a viral gene designed to produce proteins that would fuse the host’s cells together, thereby allowing the virus to spread with greater ease, now serves to connect mother and child.

Quite simply, syncytin is critical and without it, human life could never form.

Another syncytin gene, called syncytin 2, serves to suppress the mother’s immune system to prevent her body from attacking and rejecting her baby’s tissues as it would a foreign body.
Modern “Reptiles” are paraphyletic. There is an incredibly rich and diverse array of fossil reptiles.

The phylogeny of turtles is still unresolved.

... exhibits a fascinating combination of reptilian and mammalian characters.

All **mammals** share three characteristics not found in other animals: **3 middle ear bones; hair; and the production of milk** by modified sweat glands called **mammary glands.**

+ specialized **teeth**