Deuterostome Animals

A major lineage of animals that share a pattern of embryological development, including radial cleavage, formation of the anus before the mouth, and the formation of the coelom by pinching off layers of the mesoderm from the gut. Includes Echinodermata, Chordates, and Hemichordata
Who are the Deuterostomines?

• When humpbacked whale, a starfish, sea urchin, or human is just beginning to grow, the gut starts developing from the posterior (anus) to the anterior (mouth).

• Most of the deuterostomines belong to one of two groups that include the majority of its members -- the **echinoderms** (the spiny skinned starfish, sea urchins, and their relatives) and the **chordates** (which include fish and other vertebrates).
Bilateria

- Deuterostomes belong to a larger group within the kingdom Animalia called the **Bilateria**, because they are bilaterally symmetrical with a left and a right side to their bodies.
- What about star fish? Are they bilaterally symmetric??
- Obviously this is not true for adult echinoderms like starfish.
- The answer lies in the development of the embryo. If you were to watch an embryonic starfish develop, you would see that it begins life bilaterally, but switches to radial symmetry as it matures.
- It is theorized that this was a reversion to radial symmetry
Echinoderm Larvae
Why study deuterostomes?

• The obvious reason... WE ARE DEUTEROSTOMES!!!!
• They are essential primary and secondary consumers in marine and terrestrial ecosystems
• They make up the largest, most advanced, and highest evolved animals in existence
• They are used in medicines and pharmaceuticals
Echinoderms hydrostatic skeleton

- Water vascular systems- a series of continuous fluid filled tubes and chambers within an Echinoderm
  - One tube is open to the exterior, where it meets the body wall
    - Allows sea water to flow into and out of the system
- Fluid moves via cilia that line the tubes and chambers
- This powers the elongated, fluid filled, tube feet system used by the Echinoderms
- The “podia” are the sections that extend outside the body
  - As these are filled they suction and then are able to release by pumping the water out
- This (hydrostatic skeleton) allows for locomotion
- Also used in feeding...
Chordata

• Defined by 4 morphological traits:
  – Pharyngeal gill slits: openings into the throat
  – Notochord: Stiff, flexible rod that runs the length of the body
  – Dorsal hollow nerve chord: A bundle of nerve cells that run the length of the body
  – Muscular tail: Which extends past the anus
Hemichordata

- Hemichordata is not classified as members of Chordata because they lack all but one of these three morphological traits.
  - They have **NO** tail
  - They have **NO** notochord
  - They have **NO** dorsal hollow nerve chord
  - They **DO** have pharyngeal gill slits which they use for gas exchange and feeding

- They are commonly called acorn worms
- They are sessile suspension feeders that live in the ocean
Hemichordata “acorn worms”
Back to Chordata

• Three major lineages of Chordates
  – **Urochordata**
    • Tunicates or sea squirts: Small suspension feeders that attach to hard surfaces in the oceans as adults
  – **Cephalochordata**
    • Lancelets or amphioxus: Small, mobile suspension feeders that look like little fish
  – **Vertebrata**
    • Sharks, bony fish, reptiles, amphibians, and mammals: You should know what these are...
What Rocks Will Tell Us

• Echinoderms and vertebrates are present in the burgess shale deposits during the Cambrian explosion, 544-515 mya.
  – Vertebrates showed streamline, fishlike bodies with a distinct head, reinforced gills, and a cartilage notochord
  – They also had exoskeletons made of cartilage
  – As this lineage diversified, several key innovations arose:
Key innovations found in Dwayne Johnson:

• Fossils found in the Ordovician period (480 mya) are the first to show bones. Bone is a tissue consisting of cells and blood vessels encased in a matrix made primarily of calcium phosphate ($\text{Ca}_3\text{P}_4$), with a small amount of calcium carbonate ($\text{CaCO}_3$).

• When bone first evolved, it was found predominantly in the exoskeleton.

• It seemed bones' initial development was predominantly for predatory protection.
Bones for protection???

Have we ever seen organisms with bones for protection???
Jaws were next...
Jaws were next...

- The first vertebrate with jaws showed up in the fossil record about 430 million years ago
  - This allowed vertebrates to bite, so they were not limited to only suspension feeding (as they were before this evolutionary step forward)
  - Soon after, jaw bones with teeth began to appear
  - This adaptation allowed for a spectacular and rapid radiation of jawed fishes in both marine and freshwater habitats
What could have caused this?
Terrestrial Life

• Next came the evolutionary trip to a whole new world...
  – The transition to land

• The first limbed animals capable of living on land are dated to about 357 mya.
  – The organisms seemed to have modified fins that could be used as legs
  – They were the first tetrapods (four legged animals)
  – It would still be awhile until terrestrial reproduction was mastered (These tetrapods were amphibian-like)
Cryptobranchus alleganiensis

Hellbender
What came first the chicken or...

• The next huge step in evolution was the development of the **amniotic egg**
  – Includes the lineage **Amniota** and includes all vertebrates excluding amphibians

• The **amniotic egg** is an egg that has a watertight shell or case enclosing a membrane-bound food & water supply and a waste repository.
  – This allowed vertebrates to finally leave the waters edge
Deuterostome Model Organisms

• Deuterostomes, like protostomes, have members that have been great helps to understanding science.

• The major echinoderm of study has been the sea urchin (Class Echinoidea)
  – Sea urchins have been spectacular models of developmental biology
Echinoidea

- Sea urchin development is very easy to view under a common light microscope
  - It was noticed as early as the 1800s
- This was the first organism that allowed for the viewing of sperm cell fertilization of the ovum
- They have had their genomes completely sequenced
- Homology has been found between Sea Urchin and vertebrate immune genes
  - Sea urchins code for at least 222 Toll-like receptor (TLR) genes and over 200 genes related to the Nod-like-receptor (NLR) family found in vertebrates
TLRs

• **Toll-like receptors (TLRs)** are a class of single membrane-spanning, non-catalytic receptors that recognize structurally conserved molecules derived from microorganisms once they have breached physical barriers such as the skin or intestinal tract, and activate immune cell responses.

• They are believed to play a key role in the innate immune response.
  – Quick immune response, the non-lasting response
NLRs

• The Nod-like receptor (NLR) gene family codes for various proteins that serve as pattern recognition receptors (PRRs) which sense microbial products in the cytoplasm of cells
  – PRRs are produced by your immune system with the goal of recognizing foreign material, especially those linked to cell stress
  – These evolved prior to the evolution of the auto immune system
Deuterostome Model Organisms

• The model “ray-finned fish” for science advancement is the Zebrafish (*Danio rerio*)
  – *D. rerio* are a common and useful model organisms for studies of vertebrate development and gene function
  – One of the few fish to ever attempt space travel
  – Have very fast development, progressing from egg to larvae in under three days
  – Embryos are large, robust, and transparent
  – Development occurs externally to the mother, which allows for experimental manipulation and observation.
  – They also have remarkable and unknown rates of regeneration
The most famous model organism in all of science is the tetrapod deuterostome, the **lab mouse** (*Mus minimus*)

*Mus minimus* has been used as a model organism because of its relative similarity (both in irritability and genomics) to humans

- Generally, humans and mice will react to similar stimuli in a similar way

They have had their genomes mapped

Is considered the second most successful mammalian species, behind only humans

Is small, breeds rapidly, and matures in a relatively short time for a mammal

Average life span is 2.5 years in a lab... in the wild, it is 4 months
The most ancient group of vertebrates (lampreys & hagfish) lack jaws entirely
  – These are deposit feeders or ectoparasites

The theory is that the morphology of gill arches (curved regions of tissue between the gills) changed through natural selection
  – This is called the gill arch hypothesis
Gill Arch Hypothesis (pg758)

• 3 lines of evidence, drawn from comparative anatomy & embryology, support the gill-arch hypothesis:
  – 1. Both gill arches and jaws consist of flattened bars of bony or cartilaginous tissue that hinge and bend forward
  – 2. Both are derived in the embryo from specialized cells called neural crest cells
  – 3. The muscles that move jaws & gill arches are derived from the same embryonic cells
Fig. 4. Embryonic Homo with early gill arch structures.
So this is how it may have happened...
Moving and Breathing???

• The next major accomplishment to consider is moving and breathing
• We have already discussed the water vascular system and tube feet of the Echinoderms, now lets focus on the tetrapods
• Most tetrapods live on land and use their limbs to move and are able to breathe with lungs... What collective selective pressures could have driven this evolution???
  – How did all of this happen?
Consider the lungfish

• Lungfish are a species of fish that inhabit shallow, low oxygen pools.
• In order to move in these pools, their fins evolved a very foot-like morphology, in which they use to walk along the pools bottom & along muddy flats from pool to pool
• To supplement the poor oxygen intake by their gills, they evolved lungs, allowing them to gain oxygen from the air
• They also survive droughts by burying themselves in mud
Lungfish (Class: Sarcoptrygii 
Supclass: Dipnoi)
Fin to Limbs

• These theory is even further supported by the observation of homologies between the zebrafish fin and the upper parts of the mouse leg & foot

• This, and the observation of fin morphology changes within ancient fish and amphibians has solidified the accountability of this theory
The Evolution of Bird Flight

- Xing Xu (2003) released a publication on the fossilized dinosaur called *Microraptor gui* which had feathers on both legs and wings
- According to skeletal relationships, almost unquestionably related to ancient birds
- Fossil evidence supports feather evolution started with simple projections from the skin and ended with the complex structures we see today.
  - It is unsure if the initial purpose of feathers was for courtship, other types of displays, or insulation
  - It is believed to have evolved with tree dwelling “glider” organisms who lived in the canopies
  - Once feathered dinosaurs took to the air, an amazing amount of adaptive radiation occurred creating the remarkable diversity of birds
Microrapter gui
Archaeopteryx
Amniotic Egg

- In addition to having a shell that is largely watertight, the amniotic egg contains a membrane-bound supply of water in a protein rich solution called **albumen**
- The embryo is enveloped in a protective inner membrane known as the **amnion**
- The **yolk sac** is a membrane pouch that contains nutrients for the growing embryo
- The **allantois** is the waste retaining membrane
- The middle membrane which allows gas exchange is called the **chorion**
Diagram of a developing embryo showing:
- Yolk sac
- Allantois
- Carbon dioxide
- Oxygen
- Air space
- Albumin
- Chorion
- Eggshell
- Embryo
- Amnion
From Amniote to Placentals

• The next major innovation in reproduction eliminated the need to be oviparous (egg laying)
• These new viviparous species give nourishment and birth to young by means of an innovation called a placenta
  – The **placenta** is an organ rich in blood vessels, that facilitates a flow of oxygen and nutrients from mother to developing offspring during gestation
    • **Gestation** is the period of embryonic development before birth
Opossum (Pouch)

Mammal (Eutherian)

www.bible.ca

Vertebrates, Kenneth V. Kardong, 1998 p 186, 184
The Joys of Parenting

• The term **parental care** encompasses any action by a parent that might improve the ability of the offspring to survive
  – Includes supplying food, keeping young warm and dry, and protection from danger
  – This is more extreme in some organisms than others
• This is most common in bird and mammal species but is found in insects, reptiles, and amphibians
• The evolution of parental care is linked to the remarkable success of mammals
Milk Production in Mammals

- Female mammals are the only group of organisms who produce nutrient rich milk for offspring by means of lactation.
Poison Dart Frog Parenting

• Father poison dart frogs deposit eggs in small pools; upon hatching, the tadpoles are given a piggyback ride to a safe pool
Crocodilian Parenting

- Mother crocodiles listen for the call of their newly hatched offspring, gently dig them up, and escort them to the river. Then generally defend them for up to two years.
Song Bird Parents

- Song bird parents equally care for offspring until they are ready to fully care for themselves (90% fatality rate in song birds if one parent is killed)
Archerfish

The archerfish is a perch-like ray-finned fish that leaps from the water to lay its eggs safely on overhanging leaves and grasses, and then squirts them every few minutes to keep them wet and breathing.
Dad Gives Birth??

- The male sea horse collects the fertilized eggs from the mother and guards them until they hatch... when at that time he releases the young as if giving birth to them
The best parents ever???

- The emperor penguins make a grueling and dangerous yearly trip to safely hatch and care for their young. WATCH MARCH OF THE PENGUINS if you don’t believe me!
Great parents
Remarkable Diversity
Echinodermata

- Echinoderm (Echino=spiny; derm=skin) were named for the external spikes evident in most species

- They consist of the classes:
  - Asteroidea (Sea stars)
  - Echinoidea (Sea urchins & sand dollars)
Chordata

- Remember that the chordates are named because of a centralized dorsal nerve chord that all members utilize.

- Also recall there are three sub-groups of Chordata:
  - 1. The Urochordata
    - Tunicates and sea squirts
  - 2. Cephalochordates
    - Lancelets
  - 3. Vertebrata
    - Animals containing a... cranium.
    - The only thing that ALL members of vertebrata contain is bony, cartilaginous, or fibrous case that encloses the brain.
    - Most members do have contain bony or cartilaginous vertebrae, but they don’t all.
    - (They were once called Craniata)
Myxinoidea (Hagfish)

• Belong to a group called the jawless fishes or Agnathans
• Many of the members of this group are known only by the fossils they left behind
• All members are aquatic
• They lack any sort of vertebral column
• Are scavengers and predators mostly feeding on the dead carcasses of organisms (deposit feeding)
• Some Hagfish are thought to feed on polychaetas and buried prey in the slime on the ocean floor
• Virtually nothing is known of hagfish reproduction
Petromyzontoidea (Lampreys)

• Generally are ectoparasites, attaching to the side of a fish and using the spines in their mouths they cut a hole and feed on the blood
• Have small pieces of cartilage along the length of their dorsal hollow nerve cord
• Can swim or inch themselves upstream grasping with their mouths moving like an inch worm
• Have no paired fins that aid in movement
• Are anadromous meaning they spend their adult lives in lakes and oceans but swim upstream to breed (only breed once)
Chondrichthyes (Cartilaginous Fish)

- The sharks, skates, and rays are believed to be an ancient group of organisms with many unchanged sense the days of the dinosaurs
- Most are marine, though a few live in freshwater (and a few marine species as well)
- Have jaws and paired fins
- A few species are suspension feeders, feeding on plankton, but most are predators
- Skates and Rays are ambush predators
- Sharks are active hunters and **top predators**
- Skates are oviparous; Rays are Viviparous; Sharks can be viviparous, ovoviviparous, and oviparous (viviparous sharks have a placenta-like organ that nourish the young)
Skate
Actinopterygii (Ray-Finned Fish)

• The ray finned fish get their name from the formation of the long ray shaped bones within their fins
• They all contain a remarkable organ called a swim bladder
  – This allows them to float even despite having a body that is denser than water (w/o moving)
• They are largely the most successful vertebrate species in terms of numbers (24k sp)
  – The Teleostei are the lineage (order) containing 20k sp including tuna, trout, cod, goldfish, etc.
• Reproduction is mostly external (spawning) egg laying (oviparous) but some are live-bearing (viviparous)
Actinistia (Coelacanths)

• Grouped with lungfish as lobe-finned fish
• Common and diverse in the fossil record in the Devonian period
  – Only about eight species live today
• Instead of rayed bones supporting their fins, their fins are fleshy lobes
  – This represents an important link between ray-finned fish and tetrapods
• Coelacanths live in deep marine habitats (as deep as 150-700m below the surface
• They are predators that eat predominantly fish
• Swim by moving pelvic fins similar to the way tetrapods walk
• Internal sexual reproduction with all members being ovoviviparous
Dipnoi (Lungfish)

- We have already mentioned the lungfishes ability to breathe via lungs and its ability to walk on its fleshy fins
- They are also lobe finned fish (Like Actinistia)
- Lungfish live in shallow, freshwater ponds mainly but have been seen in larger lakes
- Burrow into mud and enter into a quiescent state if pool dries up
- They are omnivorous meaning they eat algae and plants as well as animals
- External fertilization with all lungfish with all members being oviparous
  - Offspring resemble baby salamanders
Amphibia (Amphibians)

- All 4,800 sp. of frogs, toads, salamanders, and caecilians make up the three clades in the class Amphibia
- Literally translated their name means “both sides living” referring to the aquatic/terrestrial lifestyles of this group
  - All offspring are aquatic while most adults are terrestrial
- Adults are carnivores
- Most amphibians have four well developed and specialized limbs (Caecilians are the exception)
  - Caecilians lack limbs and eyes, terrestrial forms burrow
- Most frogs and salamanders are oviparous; Caecilians are mostly viviparous
  - Frog external reproduction utilizes amplexis
Monotremata (Platypus and Echidnas)

- The most ancient lineage of mammals still alive today
  - Found only in Australia and New Zealand
- They are oviparous mammals (the only egg laying mammals) and have low metabolic rates
- They have a leathery bill or beak
- They are predators that feed on small insects, mollusks, larvae, and small animals
- Platypuses swim with the aid of their webbed feet and Echidnas walk four legs
- Platypuses lay their eggs in burrows, while Echidnas keep their eggs in a pouch on their stomachs
Marsupiala (Marsupials)

• Found in the Americas and Australia, these organisms were thought to be numerous in ancient times.
• Females have a placenta, but offspring are born underdeveloped and must crawl from the opening of the reproductive tract to the nipple (often within a pouch).
• Shows multiple forms of convergent evolution to non-marsupial organisms.
• Offspring spend more time feeding externally at a nipple than nurtured by a placenta.
Eutheria (Placental mammals)

• The placental mammals most species rich and morphologically diverse mammals
• Have diverse tooth types and digestive tracts for their specialized life cycles (Herb, omn, and pred.)
• Movement varies from the finned dolphins and whales to the bipedal human.
• Internal fertilization and development
  – Long gestation with a placenta forming from both maternal and fetal material
  – All feed milk by lactation
Testudinia (Turtles & Tortoises)

• All turtles, terapins, and tortoises have a shell made of bony plates that fuse to the vertebrate and ribs.
  – No... despite popular belief turtles can not leave their shells... that is a HERMIT CRAB that does that

• They are either herbivores or carnivores
  – Carnivores are generally ambush predators

• All are oviparous and lay eggs in a nest or burrow (No other parental care)

• Chromosomes do not normally determine sex of offspring, they are almost entirely TDSD
  – Temperature Determined Sex Determination
  – Males from high temp; females from low temp
Lepidosauria (Lizards and Snakes)

- Often times lizards and snakes are collectively termed “Squamates”.
- All snakes are limbless but not all lizards have legs (Legless lizard is not a snake)
- Boas and Pythons have vestigial hip and leg bones, leading to the hypothesis that snakes evolved FROM lizards
- Snakes have multiple members that are venomous; Lizards have only one venomous sp called the Gila monster
- Six groups of lizards and one group of snake can asexually reproduce via mitosis instead of meiosis
Crocodilia (Crocodiles and Alligators)

- Only 21 sp are known all living in aquatic or semi-aquatic ecosystems
- They have eyes and nostrils at the top of their heads, allowing them to sit at the top of the water with all but nostrils and eyes submerged
- They are all carnivore predators w/ prey subdued by drowning
- Generally slow on land compared to aquatic speeds
- Extensive parental care from eggs through maturity
- Very intelligent predator
Aves (Birds)

• Descended from a unique type of dinosaur that evolved feathers
  – Likely for insulation or courtship originally
• They have a reduced number of hollow bones that allow for a lower body weight
• They are endothermic
  – This has allowed many researchers to believe dinosaurs were also endothermic
• 9,700sp occupy almost every habitat known to man, including some species that live on the open ocean for much of their lives
• Instead of teeth, birds have a beak
• Birds are oviparous with extensive parental care
The Hominin Radiation

• There have been few things more debated about then the evolution of mankind

• Religions and science have clashed and will continue to clash over the creation story, but what you must remember is the difference between faith and science
  – Do not ever let anyone change your beliefs... but always remember that knowledge of something will only strengthen your views.
The Hominin Radiation

• The lineage called primates consists of two main groups:
  – Prosimians- (before monkeys) which are lemurs, tarsiers, pottos, and lorises of Madagascar, Africa, and South Asia
  – Anthropoids- (Human-like) all other monkeys

• The radiation of Hominin is listed on the phlogeny graph on page 773 in your book
Human Lineage

- The lineage where science places the humans and great apes is called **Hominid**
- It currently links chimpanzees and bonobos as humans closest living ancestor or relative
- Most of the ape groups either “knuckle-walk” or “fist walk” using legs as primary locomotion and hands as continuous support
- Humans are the only Hominid to walk using only their hind legs (called Bipedal locomotion)
  - Bipedal locomotion is the shared trait that distinguishes the group called Hominin
Hominin

• Though the fossil record of hominin evolution is not nearly as complete as researchers would like, but currently we have found 14sp (15 with the “Ardi” fossil find)
• Fossils show first Hominin signs about 6-7mya
• New Hominin fossils are found every year, but many of them are controversial as far as where they should be grouped
• They are generally organized into four groups:
“Ardi”
4 Groups of Hominin

- *Australopithecus* – (small apes) slender built ape-like organisms that were bipedal
- *Paranthropus* – (Beside-humans) these bipedal robust ape-like organisms had broad skulls with a sagittal crest (flange of bone at the top of the skull). Called *nutcracker men* because of the hypothesis that their large jaws were used to crush shelled seeds
- *Early Homo* – in the same genus as humans, these narrow faced, small jawed organisms had large brain cases. Likely used tools.
- *Recent Homo* – date from 1.2 mya-present, had large brain cases, flattened faces, and small jaws. Were accomplished tool makers and painters (includes Neanderthals and Cro-magnons)
Australopithecus
Paranthropus
This is the face that's changing a thousand minds. It could be the face of the first human to leave Africa. And it's not what anyone expected.
Recent Homo
Assimilation Hypothesis

• Some scientists believe that *H. sapiens* is derived from an ancient mixture of the traits of *H. neanderthalis* and *H. erectus* who were found extensively throughout Europe and Asia.

• They believe that this interbreeding eventually led to the extinction of the other Homo species.

• This combined with the hypothesis that *H. sapiens* appeared to be warring with and maybe even hunting the lesser evolved Hominins.
Assimilation Hypothesis

• This hypothesis (despite having exceptional points) has recently come under fire when researchers questioned *H. sapien* DNA extracts

• If the assimilation hypothesis is correct, *H. sapiens* should contain similar gene sequences (base-pair sequences) as those found in *H. erectus* and *H. Neanderthalis*

• However, after a 379-base-pair section of the Neanderthal mitochondrial genome was sequenced, it was EXTREMELY different from *H. sapiens.*

• Currently it as not been possible to sample DNA from the fossils of *H. erectus*
Out-of-Africa Hypothesis

• This hypothesis contends that *H. sapiens* evolved independently of European and Asian *Homo* species.
  – Meaning NO interbreeding

• This hypothesis states that *H. sapiens* evolved its distinct traits in Africa, then dispersed throughout the world

• All fossil evidence supports the idea that *H. sapiens* was found almost exclusively in Africa; then without any known reason, they were found across the continents
Creation Hypothesis

• Many religions do not put a lot of stock in the evolution of mankind (In fact, many religions argue with the idea that evolution exists)

• Though these hypotheses differ greatly from religion to religion many of them ignore or disregard the fossil finding of early Hominin species

• Regardless, it is important to remember that no scientific explanation is one hundred percent backed by natural reasoning, just as the faith based explanations lack natural reasoning

• Remember, find your own answers... faith, science, learn about everything... then choose your hypothesis!