Phanerozoic Eon- *Paleozoic Era: Cambrian and Ordovician*

- there was a massive explosion in biodiversity
- essentially, all ancestors of organisms/animals we have today make their appearance during this era
- plants diversify and spread across the planet (they move onto land because there's food)
- 95-98% of life disappears during **permian extinction** (the biggest extinction of the planet) at the start of the paleozoic era

Setting the stage

- at the equator of the earth was **Laurentia** (the Paleozoic North America)
  - air currents created moist zones in the tropics that were rich for biodiversity, and there was maximum sun at the equator
  - had a **continental shell** which was a zone of water a few miles deep (which was quite shallow) and not too cold
  - animals make their first appearance at the top left shoreline of Laurentia
  - animals that died at that shoreline^ sunk into the water and became fossilized because of the lack of oxygen
  - we see that animal diversity occurred at the start of the Cambrian

- the **Burgess shales** in Yoho National Park represent where the first organisms were fossilized
  - fossils found in the shales are missing links of animals groups
  - the shales appeared on the cover of Times magazine for the discoveries it held within the fossils
  - it was often assumed that diversity increased over time, but the shales show that it decreased since the Cambrian
  - the shales were accidentally discovered in the 1920's-30's when a travelling family saw some rocks in the middle of the road and stopped to clear them (he took a rock home and cracked it open to find a fossil in there)
  - some of the fossils aren't rare, there have been hundreds of them from the same species found
  - some fossils have been fossilized so well, the shales were dissected and the digestive tract and other organs were analyzed

- **Snowball Earth** the hypothesis that the Earth's surface became entirely (or nearly entirely) frozen at least once during 650 million years ago
  - initially being a large land mass with no life, it was situated in the tropics where wet weather and rain occurred
  - being subjected to erosion led to calcium and silica being mixed into the ocean
  - the minerals began the carbon cycle (carbon being dissolved into the water to come to equilibrium with the air) and the earth started to cool down (CO_2 is a greenhouse gas)
  - methane was lost and the earth further cooled down
  - the combination of barren land and ice forming due to cold weather reflected even more heat off the earth (**domino effect**) and then the earth was covered in ice- *snowball earth*
  - BUT life still goes on under the water...
    - when snowball earth begins to melt, CO_2 starts to build up and heated air returns to earth
    - then there's an explosion in the diversity of life (**Cambrian explosion**)

- **Doushantuo fossils**
  - microscopic fossils of what look like embryos were found
  - the fossils date back approximately 590-565 Ma; that's app. 50 million years before the Cambrian even took place (app. 530 Ma)
  - it's possible that there were animals before snowball earth thawed
  - extra research: it's debated whether or not these are animals....some have contested that they're fossilized bacteria

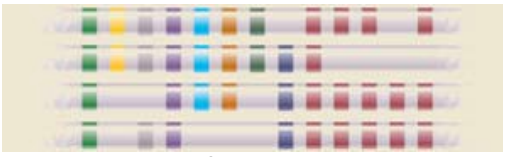
- **Ediacaran fossils**
  - in fossils, we can see tracks of organisms that dug through the sediment

- fossils of organisms with **fractile structure** (a branching structure which makes an organism grow)
- all the cells were identical since it was just predecessor cells cloning themselves to make animal grow
- if these organism with fractile structure are indeed multicellular, then multicellular life took place before the Cambrian explosion and snowball earth
- however, it's still undetermined whether they were developed before snowball earth or whether they developed during snowball earth but underwater
  - originally the bottom of the ocean was thick and covered with a bacterial and algueal mat that was impenetrable
  - later in the cambrian, the molluscs were the first to burrow into the substrate and tap into the organic material
  - worms them followed afterwards
  - the ability to burrow brought on advantages of getting food, being able to anchor, and protection

- **Homeotic genes**
  - these genes regulate the anterior and posterior axis of an organism
  - it ensures that during embryonic development, the organism properly develops the anterior and posterior ends

- **Hox genes**
  - these genes regulate the basic structure in the orientation of an organism
  - there are certain hox genes that are only anterior and others that are only posterior
    - this ensures proper organs are formed in proper locations of the body
  - when looking at hox genes of a fruitfly larva, there were a set of genes that were identical to that of a mouse

fruitfly hox genes



mouse hox genes

  - mutation of the hox genes will result in the organism growing/normal healthy structures, but at the wrong parts of the body (ex: the hox gene for antennae was cut from a fruitfly's central body and placed in the anterior
    - said fruitfly grew legs on it's head instead of antennae
  - some organisms have multiple copies of hox genes while some organisms lack what others have
    - jellyfish are missing a hox gene that's supposedly for bilateral symmetry
  - evolvement of homeotic genes was a major innovation because we could get a predictable pattern in the offspring from generation to generation
  - it was thought that homeotic genes made their first appearance in the cambrian and were expressed as different types of animals
    - somewhere in the beginning of the cambrian, we went from fractile animals to multicellular animals that had their appearance regulated by the homeotic and hox genes that is universal in all animals

  - **transcription factors** regulate gene expression by holding dna in a specific way for specific function
    - that's the secret to form an organism
    - since all cells have identical genetic information, how do cells know to be organ cells or skin cells or ??? kind of cells
      - it's all because of the transcription factors that specialize each cell

- it's clear that the animals of the ediacaran fossils had no homeotic genes or hox genes because they had a body pattern that was just repeating itself over and over

- reasons for Cambrian explosion:
  - snowball earth froze all potential so once conditions were right, diversity just took off
  - the regulation of pattern in organisms and fidelity of said patterns (hox genes)
  - the formation of armoured organisms led to predation and diversification of predators
  - however, the actual reason for the cambrian explosion is still a guess

Colonial forms

- **choanocytes** are collared cells with a flagellum found inside the internal chambers of sponge
- it is at the base of the phylogeny tree for animals and fungi
- choanocytes are an autapomorphy for animalia
  - other autapomorphies of animalia:
    - multicellular eukaryotes
    - ingestive heterotrophs
    - cells with different functions
    - collagen (holds cell together for now, but later it holds muscles and ligaments together)

Sponge

- sponge sit at the bottom of the evolutionary tree in a group called **porifera**
- it's unusual- they're multicellular, but none of their cells have a cell to cell communication mechanism
  - cells are stuck together with collagen glue
- at this point in evolution, there is no presence of tissues
  - instead, the choanocytes are arranged in a specific way in a sponge

- <u>sponge body</u>
  - the sponge body is arranged so it has a cavity in the middle of itself called a **spongocoel**
  - the **pinacoderm** lines the outer body of the sponge
    - similar to epithelium (but we can't call it epithelium because epithelium is a tissue and sponge don't have tissue)
  - the **choanoderm** lines the inner body of the sponge
    - it's a cell layer composed of choanocytes
    - flagella beat water from outside the spongocoel through pores of the wall and then up out of the **osculum** (opening at the top of the sponge)
    - as water is beat through the sponge, food particles are trapped in the microvilli that make up the collar of the choanocyte
    - only choanocytes feed (food is placed in a food vacuole to be dissolved in phagocytosis)
      - **amoeboid cells** act as the transport system and will carry the food vacuole to other cells that require nourishment
  - the **spicules** (needle-like structures) are between the layers of pinacoderm and choanoderm to provide skeletal support
    - when sponge are harvested, they're soaked in acid to dissolve the spicules (when we use a natural sponge, we're scrubbing a dead sponge on us)
  - despite not having a communication system between cells, we have a system of cells that
    - pump water
    - feed
    - act as outer surface
    - provide structure
    - transport
  - **totipotent cells** (unspecialized cell) can become gametes
    - when cells undergo meiosis, the sponge can choose to create gametes (either sperm or egg since sponge are hermaphrodites)
    - a sponge will release a cloud of sperm into the water to come into contact with another sponge

        - the sperm accumulates on the microvilli of a new sponge and is put into a vacuole to be passed to an amoebocyte that will become an egg so a zygote is formed
        - if there's any remaining unused sperm, it is consumed as food
    - keep in mind: the sponge has NO MOUTH and it doesn't even have a digestive tract
    - sponge aren't even symmetrical; they're just a piece of tissue that's folded up on itself

Symmetry

- the oral opening of an organism determines it's symmetry
- **radial symmetry** is when we have oral opening that we can draw a line through (as well as the rest of the body) and we get multiple identical halves (like cutting a circle)
    - ie jellyfish
- **bilateral symmetry** is when the oral opening can only be cut 1 way to get symmetrical halves
    - ie human
- **asymetry** is when the oral opening can't have 2 symmetrical halves no matter which way it's cut
    - ie sponge

Animal symplesiomorphies

- they're called symplesiomorphies because we don't have a taxanomic name for the group that inherits these traits
- **gap (septate) junctions** allow for direct cell to cell communication by connecting the cytoplasms to allow molecule, ion and electrical impulse sharing
    - on top of the gap junctions are **connexon** which regulate the communication between cells by opening and closing
- **tissues**
    - the first group of organisms are **diploblastic** germ layer
        - only have **endoderm** (the innermost layer of cells in the embryo) and **ectoderm** (the outermost layer of cells in embryo)
    - **triploblastic** germ layers appear afterwards with a **mesoderm** (made up of muscles)
    - ectoderm is the **epithelium** (body covering) and **nerve cells** (in the nervous system)
    - endoderm is the material that lines the gut
    - to be diploblastic is to have tissue that covers the guts and interior and exterior, but they have no muscles
    - **gastrulation** is formation of the **gastrula** (hollow cup shaped structure with 3 layers of cell) when **blastula** (the hollow ball of developing animal embryos)
        - gastrulation occurs when the blastula gets punched on one side until it hits the other side (essentially, that part of the epithelium was once on the outside and then it got punched and folded up so it was on the inside
        - now we have an inner epithelial layer which is the **endoderm** and it becomes the linign of the digestive tract
        - the **blastopore** is the name of the new cavity inside the gastrula

Cnidaria

- **cnidaria** are invertebrate animal (ie jellyfish, hydra, coral) that have stringing structures in the mouth called **cnidocytes**
    - **cnidocytes** are “stinging cells”
    - it contains an organelle called **nematocyst** which allows the cnidocyte to develop under pressure and act as a coiled spring
    - if the cnidocyte is touched or attacked, it inverts it's charge and stings the prey at the speed of 2m/s
    - there's usually a poison on the tip of the cnidocyte to immobilize prey
        - that's why box jellyfish are deadly, even after ingestion
        - the cnidocytes are like a taser; it sens out a jolt of shock and then reels in the prey

- **cnidaria** have a **polyp body plan** which is 2 cell layers surrounding a cavity with a tree of tentacles surrounding the mouth (the body was formed through gastrulation where the oral opening of cnidaria is like the blastopore)

    - cnadiaria catch prey by waving it's tentacles at the mouth, catch prey, and then put the prey into it's body cavity
    - the **gastrodermis** is the first cell layer
        - **the nutritive cells** in the gastrodermis absorb food via phagocytosis
        - **gland cells** dump enzymes into the gastrovascular cavity to break down food particles/prey which is then absorbed by phagocytosis
    - the **epidermis** is the cell layer that covers the entire organism
        - epidermis is made up of cnidocytes for protection, and **nerve tissue** made by ectoderm
    - **epithelial muscular cells**
        - **circular** muscular cells at the base of the the cnidaria run in circles between the gastrodermis and epidermis
        - **longitudinal** muscular cells run up and down the organism (these are muscular strands inside the epithelial cell)
        - thanks to these muscular cells, we have our first type of skeleton- the **hydrostatic ekeleton** because the antagonistic muscles are working against water
            - the purpose of the skeleton is to stretch contracted muscles
            - when myosin motors crawl down actin filament, it has no way to get to it's original location (the only thing that brings it back is the stretching of antagonistic muscle)
            - bone structure eventually leads to shape and morphology...but for now it's sole role is to stretch and contract muscle

- jellyfish are have a **medusa** body form
    - it's a flipped polyp that underwent a shape change to be more umbrella like with a hydrostatic skeleton
    - the umbrella is made up of circular epithelial muscle cells that is made of water
    - when the umbrella contracts, it folds on itself which squeezes water out of it and it rises and when the umbrella relaxes, water comes back in and it sinks
    - the secret is that the water going in the umbrella has to go in slower than the water going out (if it travelled at the same speed, the jellyfish would just move up and down with no net movement)

- jellyfish life cycle
    - mature jellyfish release large amount of sperm and egg into the environment
    - zygote is formed and it undergoes a series of mitotic divisions to become a **planula larva**
    - larva sits on substrate and moves around
    - the larva becomes a **gastrula** (remember the hollowed out cup shape)
    - the gastrula anchors itself to a rock
    - branching occurs where multiple polyps form from 1
    - all the polyps share 1 digestive tract- food is collected by the **gastrozooid**
    - there's a **gonozooid** which possesses gonads to become an adult male/female jellyfish to reproduce

- another organism that is composed of polyps are coral; they're a series of interconnected polyps
    - their polyps extract calcium from the water to make cup like structures which act as a shield for them to hide in when predators come around
    - coral reefs can build up habitats to become the biggest diversity of marine organisms
    - coral and algae have a symbiotic relationship; algae produce sugar and coral produce warm sunny water and protection
    - but global warming is breaking this symbiosis because algae are dying
    - the death of 1/3 of coral reefs will occur called **coral bleaching**

Mesoderm

- the **mesoderm** is the cell layer between the endoderm and ectoderm which forms muscles for being able to move in the environment
- it's sufficiently complex to have direct fine tune movement
- there are 2 ways that mesoderm is formed:

    - at the lip of the blastopore (between the endoderm and ectoderm), mesoderm cells start to proliferate and that entire gap is filled with a block of mesoderm
- parts of the primitive gut all of a sudden begin to periforate and level off to form mesoderm

Coelom

- the **coelom** is the body cavity found
- the coelom is formed in 2 ways:
    - for **protosomes** (organisms that had their blastopore become a mouth first), the coelom was formed by **schizocoely** (when the mesoderm develops a crack in it, and the crack becomes the coelom)
    - for **deuterostomes** (organisms that had their blastopore become the anus), the coelom was formed by **enterocoley** (where 2 bubbles of mesoderm expand and fill the space between the endoderm and ectoderm to become the coelom)
- why have a coelom?
    - When organisms want to digest food, they can do so without having to move since the mesoderm holds it in place
    - organisms that need room in the body for ovaries have a separate compartment from digestive tract
- **acoelomates**: organisms with no coelom they just have a solid block of mesoderm (ie. Flat worm)
- **pseudocoelomates**: organisms with mesoderm only associated with outer body wall (the organism has to move in order to propel food down the digestive tract)
- **coelomates**: organisms with a true coelom entirely lined with mesoderm (there's mesoterian a connective tissue that holds the gut in place to the mesoderm)
- coelomates are primitive
    - acoelomates derived after because the coelom wasn't needed by flatworms (got rid of it)
    - pseudocoelom is scattered all over the evolutionary tree
        - it arose a number of time in history
        - pseudocoeloms derived because an organism underwent miniaturization
            - some organisms have a strategy to simplify instead of becoming more complex
            - some organisms that are as complex as large organisms are the size of amoeba

Protostomes

- this group had their blastopore become a mouth first
    - **ecdysozoa** are organisms that have an external skeleton and are required to molt (ie. Insects, crustaceans)
        - **ecdysis** is the process of molting
    - **lophotrochozoa** have 2 subcategories
        - **lophophores** are organisms that have a fan of ciliated tentacles surrounding the mouth
        - **trochophores** are organisms with larva that have a band of cilia around their circular body
        - **platyzoa** are organisms that lost their coelom and there is no coelomic space in their endoderm (they're typically flattened- ie flatworms)

Nematoda

- typically of the **worm** family
- nematodes don't have muscle lining the gut; just epithelium
- all organs are suspended in the cavity (upon dissection, all the organs just spill out of the body cavity)
- **Ascaris** is a genus of parasitic nematodes
    - ascaris are organisms that underwent **miniaturization** (they reverted to simplicity instead of becoming more complex)
    - they simplified their nerve system by having cytoplasmic arms directly receive nerve core signal action potential (instead of having nerve cells transmit action potential from nerve core to muscle)
    - they only possess longitudinal muscles on a fluid filled cavity (their body)
        - with no partition, the worm's entire body will bend even if muscles are contracted on only 1 side
        - this body plan's induced sinusoidal movement is excellent for moving through substrate and weaving through very small cracks (ie. Host tissue, grains of sand, etc)
        - in order to maintain a tough cuticle, their muscles are constantly contracted
            - the problem with constantly contracted muscles is that food can't stay in their body (imagine

trying to keep toothpaste in a tube that's always being squeezed)
- to compensate for the lack of muscles in the digestive tract, they have an **epitheliomuscular pharynx**
  - it's pharynx has 2 rings of epithelial muscles that open alternatively so food stays down
  - the **triradiate pharynx** opening is divided into 3 sections (2 is not enough, 4 is too much)
  - the pharynx is another example of miniaturization because instead of having epithelial and muscle cells in the pharynx,the 2 kinds of cells are combined

Onychophora

- also known as the **velvet worm**
- it's a segmented caterpillar like organism that has a series of legs down it's body's length for movement
- the antennae feel around for food
- claws to grip the substrate
- 2 jaws in the mouth with muscles to accommodate for chewing
- it drenches its prey with a sticky glue substance to prevent it from escaping
- velvet worms are living fossils
  - in the Burgess Shales, there were fossils of them, except they were marine (crawling on the ocean floor instead of the floor of the forest)
  - upon coming into land, their body was modified

Panarthropoda

- are organisms with a chitin-reinforced cuticle
- instead of passively ingesting food, these animals are able to manipulate their food with limbs
- appendages to manipulate food range from jaws, mandibles, claws, etc
- being able to manipulate food allows for more efficiency when digesting

Arthropoda

- **arthropods** are organisms with plates of exoskeleton, and muscles arranged in bands
- arthropod limbs are tubular sections with joints and linear hinges between them to create structure of appendages
- the hinges between plates of exoskeleton are made of the same cuticle as that of the velvet worm

- **trilobites** were abundant arthropods of the cambrian...however, they didn't survive the mass extinctions
- their exoskeleton was segmented

Arthropoda- ecdysozoa

- **crustacea** are another group of arthropoda including lobsters, crayfish, crab, shrimp
- they've taken over the role of abundancy for the trilobites
- instead of all segments being identical, they develop into **tagma** (segments having specialized functions)
  - antenna to detect food
  - mouthpart to manipulate food
  - walking legs for locomotion
  - **cheliped** (pincer-like structure on lobsters and crabs) for defense
  - **swimmerets** (tiny swimming legs under the tail of the arthropod) for swimming or to make water currents to incubate eggs (female)

- **filter feeding** is done in crustaceans by small appendages near the mouth
- these little limbs compose of flaps (1 on either side of the articulate point)
- flaps open on a power stroke and close on a recovery stroke (doing the metachronal wave produces a smooth gliding motion)
- on the inside is another pair of flaps which are perforated and little hairs on them create a mesh
  - these flaps act like nets to filter food particles from water

    - during the recovery stroke, the food particles are pushed towards the mouth
- with filter feeding, not only does the organism have locomotion, but it gets food at the same time

Arthropoda- lophotrochozoa

- **lophotrochozoa** have interesting feeding mechanisms
- the **lophophores** (a ring of ciliated tentacles used for feeding)
- these mechanisms allow them to become **sessile** (immobile)

- **lophophorates** are sessile animals with a u-shaped gut (unlike cnidarian which have incomplete guts...lophophorates have an anus)
- to avoid a bad mess when it craps (since it's sessile), they have a modified gut so that the anus is outside the lophophore keep their surrounding water purified

Ex: **Bryzoans**

- are moss-like aquatic organisms
- they're sessile and fleshy
- to protect themselves (and their lophophore), they can extract calcium from water to form a defensive armor
- to feed, they spread the lophophores out of their calcium casing and cilia on the surface create a water current to trap food particles which will then pass them down to the mouth
    - it's another type of filter feeding structure

- **trochozoa** are **trochophores** that have a ciliated band around the middle of it's body during the larva stage
    - the beating of cilia traps food and puts it in the larva's mouth
    - cilia also propels animal through the water
    - once development is finished, it settles on the ground to turn itself into a **mollusc**

Ex: **Molluscs**

- are unsegmented vertebrates with a calcareous shell
- traits of a mollusc:
    - stomach and digestive gland: to digest food
    - **radula**: feeding structure
        - the mollusc has a tongue with a surface that's a layer of epithelium that secretes a rough surface of barbed hooks
        - the radula is capable of scraping food/organic particles that are stuck to rocks and substrate
        - the tongue is like sandpaper and the mollusc eats the dust that gets scraped off
    - food: for locomotion
        - the foot is firmly suctioned to the substrate so that the mollusc can move around
        - an opening in the food by the shell allows it to breathe while hiding under it's armour as well as stick it's tongue out to lick the floor too
    - gill: at the back of the mantle for breathing
    - **mantle**: a layer of epithelium that secretes the shell out of the water's calcium
- the mollusc traits are so efficient that this makes them the second most abundant animal life form (arthropods being the first)

- the mollusc body plan can be modified for many different functions:
    - **gastropods**: snails
        - to escape predators, they have a shell on the back of their foot that acts as a door to seal themselves in the shell
        - the door allows snails to stay on land (and even live in deserts)
        - in harsh conditions, or when against predators, they remain dormant in the shell for months on end
        - of all the mollusc groups, this is the only one found in terrestrial environment

- **cephalopods** are the active predatory molluscs such as octopus or squid
  - they enlarged the size of their body by elongating the upper body to have a cone shaped mantle
  - the elongation causes head to become closer to the foot/posterior end
    - cephalopod = head-foot organism
  - the foot modified itself into tentacles that surround the mouth to be used for trapping prey instead of for creeping and locomotion
  - to swim, water is pumped into the mantle cavity and then shot out like a funnel to create a jet propulsion
  - as organisms got bigger and bigger, the shells began to wrap into spirals

- **ammonites** extinct cephalopods that had coiled shells
  - they were very abundant during existence
  - similar to octopus and squid but they had a shell for protection
  - they were agile swimmers and hunters
  - used colour to communicate and camouflage themselves
  - when fish were starting to dominate the ammonites, the ammonites evolved to lose their hard shell in order to become more agile and swim better than the fish
  - as a result, that guaranteed their evolutionary success in evolution

- **bivalves** molluscs with their body enclosed within a hinged shell such as clams and mussels
  - bivalves evolved the mollusc body to become sessile animals
  - it bent the mollusc shell around the sides to form a hinged shell
  - this filter feeder burrows itself deep into the substrate to protect itself
    - an opening in the shell allows it to feed even while hiding in the shell
    - water is moved by cilia on the gills and trapped food particles are passed to the mouth
    - some of these siphons to feed are 3 feet long

- end result: the mollusc body proves to be an adaptive body plan to accommodate different life styles

Ex: **<u>Annelida (marine worm)</u>**

- annelids have segmentation like the velvet worm, but take it to the extreme
  - the segments have longitudinal tissue, mesoderm and circular muscle
  - segments are somite (they're identical unlike the lobster with different-looking segments) with **setae** (hair/bristle-like structures)
- motion in the annelids
  - muscle contraction changes shape of the segments to act like a hydrostatic skeleton
    - the longitudinal muscles contract and worm increases in diameter (but gets shorter)
    - setae stick out and anchor themselves into the ground
    - circular muscles contract and make setae go back in (lengthens the worm as well)
    - process is repeated in an accordion pattern to move forward
  - this unique form of locomotion allows it to burrow deep into the substrate by ramming substrate into it's mouth as it moves forward
    - this is the secret of the worm because no other organism has thought of eating into the ground for organic material
    - as they burrow into the ground, food passes through their digestive tract and they crap out what they don't use

- **platyzoa** are organisms that have lost the coelom and they are acoelomates or pseudocoeloms; they also don't have a circulatory system or **metanephridia** (excretory organs)

Ex: **<u>Platyhelminthes</u>**

- they have longitudinal and latitudinal muscles (use longitudinal muscles to change shape)
- **dorsal ventral muscles** are for retaining the flattened body shape
- possess glands that produce a cement glue to stick to the substrate if predators try to peel them off
- for protection, they feed on cnidaria
  - they integrate the unfired cnidocytes into their own body and use the cnidocytes as a defence

mechanism
- their mouth is on their underside so they can pick up food on the substrate as they move along and continue to feed while resting flat against surface
- **hermaphrodism** (possessing both male and female reproductive systems) is common among organisms that aren't very mobile
  - it's better to produce 1 offspring per worm instead of 1 offspring per 2 worms
  - to prevent self fertilization, flatworm will exchange their sperm with another flatworm
    - the worms will deposit sperm in each other's **seminal receptacle** (the part of the flatworm that receives sperm)
    - only after separation, an egg will be produced and then the sperm will fertilize it

- life cycle of a (example: liver) **fluke** (parasitic flatworm)
  - fluke parasites always have a snail as an intermediate host (indicates that their relationship is an ancient one)
  - fluke is in the liver of infected
  - fluke egg is passed down to the digestive tract and then into fecal waste
  - eggs are washed down by rain/water runoff into lakes, rivers and streams
  - the snail ingests fecal matter and fluke eggs begin to hatch
  - undergoes morphological changes to become **sporocysts** (initial stage of development) and then into **redia** (a larva)
  - it grows into **cercaria** (the swimming form of the fluke) and it swims to infect a another intermediate vertebrate host (ex: fish)
  - It burrows deep into the muscle and waits for fish to be consumed
  - if the fish isn't cooked properly, the cercaria hatches in the consumer's digestive tract
- parasites can be very specific of the hosts; flukes will always have snails as an intermediate host

Ex: **<u>Swimmer's itch</u>**
- when rashes develop on the legs of humans after going into lakes/water
- this parasite is specific in ducks
- SI is caused by cercaria
  - cercaria try to break through our skin but fails because it's adapted to break through duck skin
  - as a result, an itch occurs

Deuterostomes
- these animals had their blastopore become the anus

Ex: **<u>Echinodermata (starfish)</u>**
- echinodermata are invertebrate marine animals with radial symmetry
- autapomorphies of starfish:
  - pentaramous symmetry
  - water vascular system
    - fluid system used for locomotion
    - little **ampulla** (suction plungers on the underside of starfish legs) are hydrostatic skeletons
    - when the ampulla is contracted, it changes shape the foot shape and makes the starfish move in a certain direction
    - the ampulla allow starfish to be **stars of death**...it gives them enough anchor on the substrate to run around searching for clams
    - when a starfish finds a clam, the ampulla suction onto its shell and pries the 2 halves apart like a book
      - thanks to mutable connective tissue, it rigidifies arms to keep clam pried open and them proceeds to vomit digestive enzymes on the clam to enjoy a clam slurpee
  - mutable connective tissue
    - their internal skeleton that secretes calcarious plates can articulate with each other through connective tissue
    - the connective tissue is connected to the nervous system (instead of collagen like other

animals) so based on nerve signals, the calcarious plates can be fluid and flexible or lock together to become really hard and rigid
        - this could be an advantage if trying to hide from predators (the fluid tissue allows starfish to hide inside a crack and then it rigidifies itself in the crack to lock itself in place)
    - the larval stage of echinoderms are bilaterally symmetrical, but the larva decides to adopt radial symmetry
    - the first echinoderms were sessile
        - their arms that surrounded the mouth were extended upwards to catch food
        - the arms would form a basket to catch the food and bring it to the mouth
        - the success for starfish was that it caught food before it hit the substrate where other organisms were waiting to catch it too
        - but ultimately it decided to flip over and put it's feet on the substrate to be able to move around

Phanerozoic Eon- *Paleozoic Era: Silurian and Devonian*

- the end ordovician was the first of 5 **mass extinctions** (where there's a loss of 50% or more of existing phylum diversity)
    - this was the second biggest extinction of all 5
    - the world entered an intense ice age
        - it's believed the cause was due to **Gondwana** (a supercontinent like Laurentia) developing large ice sheets
        - the ice sheets caused a drop in sea levels and greenhouse gases

- at the end of the ordivician, lots of the “weird” organisms don't make it
    - the survivors are the organisms that we recognize today
        - cnidaria – corals
        - molluscs- shelled cephalopods, bivalves, gastropods
        - worms
        - echinoderms
        - bryozoa
        - arthropods – trilobites, marine forms (crustacea)

The Silurian

- this time of the phanerozoic occurs when supercontinents Gondwana and Laurentia come together to form Pangea
    - between these 2 continents is a huge marine shelf (a rich breeding ground for biodiversity)
    - a new organism makes it's appearance with a set of new traits associated to chordates
        - the new organism swims through water and undulates it's **tail** (by definition is a structure that extends behind the anal opening)
        - the tail wags back and forth to create a propulsive force to move organism
        - as the organism swims in water with an open mouth, slits and openings behind the mouth open for water to go out
        - there's a mucus layer at the bottom of pharynx to trap food
        - development of gills and respiration

Armoured Fish

- fish didn't always have scales
- originally they had armour that protected themselves
- **placoderms** were armoured fish that had the front part of the body encased in broad flat bony plates
- **ostracoderms** were jawless armoured fish

Agnatha

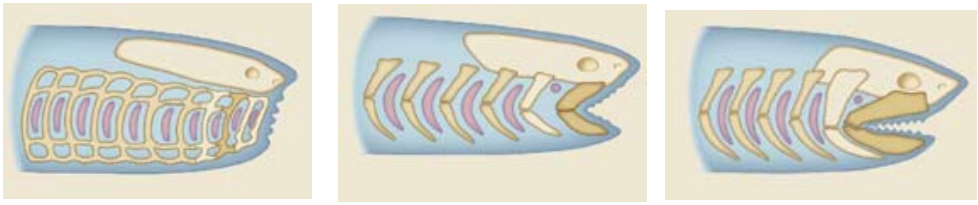
- is a class of jawless fish in the chordata phylum
- the lamprey is the only remaining descendant of the agnathan fish
  - however, lamprey are parasitic
  - it latches onto host with it's sharp teeth which will constantly burrow and dig at host flesh so that it drains and pusses bodily fluids that the lamprey feeds upon
  - originally lampreys were just in the oceans and not in the great lakes
  - due to manmade waterways, lamprey have slipped through dams into our great lakes
  - they collapsed the fish (ie trout) population ever since
  - **lampricide** (a poison engineered to kill lamprey larva) has been introduced to the great lakes in attempt to eradicate the lampreys

Gnathostome Ancestor

- **gnathostome** (jawed vertebrate)
- the development of jaws allowed to eat more efficiently
- the gnathostome ancestor also developed a set of fins on each side of the body
  - without fins, an organism has to undulate their entire body (and head)
  - the fins allow movement while keeping head still
    - the fins create stability and wagging tail provides propulsion

Evolution of the jaw

- the ancestor started off with openings on the sides of the body and **gill arches** (pieces of cartilage) held the gill slits open
- in the development of the gill arch, the 2 pieces of cartilages form a supporting structure (like a door frame)
- the 2 pieces of cartilage extend from the ventral fin to the dorsal fin and it creates a rod that holds the mouth open
  - a sort of hinge is created where the 2 pieces of bone/cartilage separate
  - water can be sucked in when hinges open to open mouth
  - water is spit out through gill openings when hinges close



- gnathostomes have many duplications of hox genes
  - the advantage to having multiple copies is that if there's a mutation, there's a “back up” copy that will be expressed instead
  - the numerous copies allow for experimentation with body shape and form
- gnathostomes arose once, and then all other organisms coming after it have jaws

Chondrichthyes

- **chondrichthyes** are **cartilagenous** fish (ie shark)
  - their axial skeleton runs down the length of it's body
  - they have **paired fins** with a skeleton within them, but the fin bones are NOT connected to the axial skeleton
    - they're connected to the muscle tissue of the body
    - the fins aren't flexible...in order to stop, the organisms makes broad lefts and rights (it deviates direction until it's stationary)
  - they have a **heterocercal tail** (a tail that is bigger at the top and smaller at the bottom)
    - the specific shape allows for specific movement so it doesn't drive itself into the ground

- their **placoid scales** (are tough scales that cover the skin of the cartilaginous fish)
  - the scales are made of a calcium precipitate that consists of a dentin outer layer, enamel coating and a pulp
  - essentially, placoid scales are built like teeth
- the teeth are larger placoid scales
  - the teeth grab hold of the prey so it doesn't get away
  - shark don't have ability to tear prey apart so once it catches prey, it swims violently in hopes that the teeth sink deeper into the prey to kill it
  - the teeth are NOT embedded in bone like human teeth- instead they're anchored into the skin
    - this makes it easy to remove the teeth
    - no worries; they have rows and rows of teeth which constantly grow back
- they reproduce with a **mermaid's purse** (the rigid, horned casing that holds the egg for certain cartilaginous fish)
  - certain cartilaginous fish have a contrary reproduction method when compared to the standard (usually with hopes of having offspring survive, fish will lay hundreds or thousands of eggs so at least 1 of the eggs will mature into adult- sharks however only produce 1 or 2 young per year)
  - sharks do direct sperm transfer to fertilize the egg
    - the mother shark has provided the egg with yolk and food which she puts into a mermaid's purse then hides the purse in a crack/safe place
    - the baby spends 9-12 months in the purse
    - once all nutrients have been eaten and the baby has matured, it opens the purse
    - what exits the purse is not a baby- but a tiny predator ready to hunt for it's survival
  - however, some shark give live birth

- shark fin soup has declined shark population by millions all over the world
  - sharks are hunted only for fins while the remainder of the shark is discarded
  - this is so detrimental for the population because shark only produce 1-2 young a year...not hundreds like other fish
  - by killing all adult shark for fins, there won't be future generations
  - the shark population is on the verge of collapse

Actinopterygii

- **actinopterygii** are ray finned fish that constitute a class (or subclass) of **bony fish**
  - the bony fish skeleton have little bones in the fin that are attached to the axial skeleton (a contrast from sharks whose fins aren't attached to the axial skeleton)
    - being attached to the skeleton (and not muscle), these fins can move independently from the body
    - the fish sits still while the fins and tail move to tread water (just like sculling)
    - the tail fins are ideal for rapid motion (rapid swimmers like tuna are all tail and no fin and stationary fish are all fin and no tail)

  - the bone of the jaw are unhinged from each other so fish can suction their food into their mouth
    - the extra bones in the jaw allow fish to shove/throw it's jaw forward, suction and then catch prey
    - the prey don't detect any current from the jaw's throwing motion because the fish suctions water into it's mouth as it throws it's jaw out to cancel any net forward vibration that the prey would feel

  - the **swim bladder** (a gas filled sac in bony fish) help it regulate buoyancy
    - think of a balloon in water: the deeper you go, the smaller the balloon gets but bring it to the surface and it will expand and get bigger
    - applying the same concept to the swim bladder:
      - to stay afloat at the bottom of the water, the swim bladder takes oxygen from blood to make the sac bigger which results in increased buoyancy
      - to sink to the bottom of the water, the swim bladder removes oxygen from the sac and puts it into the blood to make the sac smaller to decrease buoyancy

    - the **opercular gill** had an **operculum** (flap of tissue that covers the gill)
        - the fish would open mouth, intake water while expanding buccal cavity, close mouth and contract buccal cavity while swinging the operculum to the side
        - this repetition gives a unidirectional flow of water to go in and out of the fish
    - bony fish are the most numerically diverse of all vertebrate groups

Lobe finned fish

- the tetrapod stance evolved from the **lobe finned fish**
    - instead of having bony needles in the fins, they have bones and muscles that will support the fins
- in the devonium, the world is a warm place
    - freshwater environments (containing fish) will dry out
    - lobe finned fish have a lung for oxygen
    - they use their lobe finned fins to push on the substrate to stick their head out of the water to get a gulp of fresh air
    - some of them even leave their water (ie a pond) and walk across land to find a new pond that hasn't been touched by other fish yet
- this is the start of land vertebrates

Plants

- plants share similar characteristics to animals

- **cellulose and cellulose synthase**
    - cellulose is a polysaccharide consisting of chains of glucose monomers
    - cellulose cell walls are not exclusive to plants....certain bacteria produce cellulose as well
    - along the glucose chain, every other glucose is upside down from it's neighbours
        - the arrangement of the glucose molecules in the chain allow for a tighter packing of **glucans** (chain of glucose monomers) and **hydrogen bonding** between the hydroxyl and oxygen molecules of the glucan
    - cellulose is produced from a wheel of 6 **rosettes** (a bundle of 6 **cellulose synthase molecules**)
        - each cellulose synthase molecule creates 1 glucan strand
        - the rosette's hexagonal configuration explains why plant microfibrils are composed of 36 glucan strands (6 synthase molecules on each of the 6 petals of the rosette)
        - each rosette has 3 different synthase enzymes, and if any one of them is missing, the structure disintegrates
        - the rosette is self assembling- when all 3 synthase molecules are present, they come together inside the endomembrane system before inserting itself into the plasma membrane
    - the orientation of cellulose microfibrils in the cell wall are laid down by microtubules to match the requirements of the plant
        - microfibrils all laid in the same direction provide flexibility to the plant (for growing baby plants)
        - microfibrils laid in different directions provide rigidity (for grown plants that need strong structure)
    - the 36 cellulase molecules are common to every single plant

- **Phragmoplastic cell division**
    - plants don't have centrioles for cell division like animal cells
    - plants can't do cytokenesis because then there would be a cell wall separating the 2 cells and a criteria for multicellularity is for cell-cell communication
    - to compensate for lack of centrioles, microtubules assume another responsibility
        - microtubules surround the plant cell will form a band around the middle of the cell (to hold onto the nucleus)
        - the microtubules rotate to orient the nucleus on it's side
        - microtubules become the traditional spindle fibers
        - molecular motors grab the chromosomes and pull them to opposite poles of the wall
        - molecular motors travel and take vesicles filled with cellulose and material to build a cell wall to the centre

        - at the centre where the 2 microtubules don't meet, the vesicles tupture and release the cell wall material where a **cell plate** (the beginning of a cell wall) begin to form
            - the cell plate keeps getting bigger and bigger until a cell wall is formed

- **plasmodesmeta**
    - are perforations on cell walls between daughter cells that allow for cytoplasmic connections between plant cells and for cell to cell communication
    - there are thousands of pores that allow cell to cell communication, but they can open and close to regulate communication between the 2 cells

Alternation of generation in land plants

- a plant produces spores by meiosis
- sporophytes produce spores and gametophytes produce gametes
- spores create haploid organisms
- spores become gametes to release sperm and egg
- zygote forms after fertilization
- now we have a multicellular diploid

Sorting out plant parts

- **gametophytes** are plants that produce gametes
    - it's a haploid plant that produces gametes in specialized cells (that specialized cells that make gametes)
    - **antheridia** (the male sex organ of the plant) is the structure that makes sperm
        - inside the antheridia are cells called **sperm mother cells** that will undergo meiosis to become the male gamete (sperm)
    - **archegonia** (the female sex organ of the plant) is the structure that makes the egg
        - there's only 1 egg in the archegonia
        - the gametophyte supplies nutrients to the archegonia for egg development at the **placenta** (the region of nutrient exchange)
    - ultimately, the goal is to get the sperm to the egg

- **sporophytes** are plants that produce spores
    - the egg stays attached to the zygote and the sperm will come to the egg
    - the zygote undergoes cell division to create tissue that's interactive to the plant it's attached to and produce haploid spores
    - these spores are released by the wind to land on the ground and them germinate

Transition to land

- water conservation
    - it can get dry on land, so knowing how to conserve water is important
    - protect gametes from drying out
    - support system
        - with no buoyancy force from earth, the plants need to rigidify to defy gravity

Liverworts

- are one of the most primitive plants
- they live mostly in moist environments
- their habitat has minimal desiccation
- liverworts don't have leaves, they have **thallas** (which are structures the liverwort uses to engage in photosynthesis on one side and then absorb nutrients/moisture on the other side

- the upper surface is covered with a waxy **cuticle** that waterproofs the plant
    - however, the wax makes it unbreathable for the plant
    - to allow gas exchange, the plant opens it's pores

        - but liverwort can't open/close their pores which is why they always live in moist environments
    - **rhizoids** are finger like extensions of the plant that are under the soil
        - they absorb water using the ability to wick it upwards with cellulose

- life cycle of liverwort:
    - shaped like an umbrella with splash cups
        - the goal of the splash cup to for rain to land on it and then little droplets that splash off of the cup will splash upwards onto the archegonia
        - **gemma cups** are cups for asexual reproduction
    - some liverworts just absorb rain water and when the pressure is high enough, sperm is shot into the air
    - LIFE CYCLE OF LIVERWORT???

Plant accommodations

- to prevent loss of water, plants have **guard cells** on the surface of their leaves
    - they can change their shape according to the moisture gradient in the cells surrounding the guard cells
        - on hot days, the plant loses water and the cells around the guard cells deflate to keep any moisture left in the plant and not lose it to the environment
        - on cooler days, the higher water pressure of guard cells cause swelling, and less moisture is lost from the plant
    - the **meristem** is the point of growth of a plant
        - **determinate meristem** is a meristem that will grow to a fixed length and then stop
        - **indeterminate meristem** is a meristem that continues to grow and then branches
            - when we look at a tree with many branches, that's the indeterminate meristem
        - meristem is at the tip of the plant and potential meristem is along the length of the plant
        - essentially, the meristem is like “plant stem cells”- it isn't specialized and can turn into anything (an embryo that's turning into a different plant)
        - each growing point on the plant has genetic variation
            - in a tree with hundreds/thousands of meristem tips, none are identical
                - increases chances of survival for the tree if there are selective pressures because if one part dies, there's still another part of the tree that might be able to withstand the pressure

Moss

- moss have characteristics of determinant meristem
- there was an archegonia at the bottom of the moss that contained an egg
    - the egg was fertilized to produce a zygote
    - the zygote underwent mitotic division to form a meristem
    - the meristem pushed up and grow a stem that rises out of the plant with a **capsule** (a structure that holds spores that will be released into the wind)
        - when spores land on the ground, they produce a leafy gametophyte that is capable of completing the life cycle
- there is no vascular tissue in moss
- the rhizoids absorb water from the environment and soil
- when moss dry out, it enters a dormant state- but once water is poured on it, it immediately comes back to life
- cellulose can be degraded/broken down by bacteria so moss will embed **phenolic groups** in it's tissue which are antibacterial

- life cycle of moss:
    - start with a capsule that releases spores
    - the spores grow a **protonema** (a thread-like chain of cells) which grow end on end and allow clumps, lumps and groups to grow from it
        - it's a complex cell structure instead of a linearly simple one

        - the protonema grows to be either male or female
            - the male has a splash cup to produce sperm
            - the female has an archegonia that will produce an egg
        - water-transported sperm lands on the archegonia and travels to egg to fertilize it
        - the fertilized zygote undergoes mitotic division to create multicellular diploid sporophytes
        - gametophyte produces the sporophyte (the stem) and the capsule at the tip releases spores
- the end devonian marks another extinction
    - loss of coral reef
    - green matter of the planet is washed into the streams and oxygen is used to decompose it (decreased oxygen in water afterwards)
    - on land, the extinction doesn't have much of an effect- plants are simple and very robust

Devonian terrestrial environment - *Tracheophytes*

- plants continue branching and get taller and taller
- the **lignified secondary cell wall** help create structure for the plant
    - lignin is a complex organic polymer that's deposited int he cell wall of plants to make them “woody”
    - the lignin is extremely rich in phenolic groups which allows it to be hydrophobic, indigestible, resistant against bacteria and slightly toxic to ward off predators
    - first, the lignin would make rings around the cell wall, but after some time, it spiralled and then coats the entire interior of the cell wall- becoming the secondary cell wall
    - no biological organism can break down lignin
    - it's the second most abundant carbon based substance in the world (right after cellulose)
    - lignified plants didn't go into composition cycle- they became fossilized and turn into coal

- there needs to be a plumbing system in the plant to keep the meristem and lignified cell wall connected to each other
    - the primary cell wall was pure cellulose
    - tracheophytes develop **tracheids** (a water conducting cell that moves nutrients/minerals through the plant)
        - when the cells mature, they die and empty (become hollow)
        - adjacent tracheary cells are connected to each other through plasmodesmata
        - this long hollow tube runs along the length of the plant from root to leaves
            - when water evaporates from leaves, water travels from the roots, up the tubes to the leaves through a method called **transpiration** (the loss of water at the leaf surface creates a suction that pulls water up through the tubes)

- there's also **sieve tubes** which help with the transport of sugars throughout the plant
    - sieve tubes are alive and not lignified
    - the cytoplasm of the cells are connected by a sieve plate
    - sieve tubes need a **companion cell** to help transport sugars throughout the plant from sieve cells
    - the secret of the transport system is for sugars to travel from a source of high concentration down to a source of low concentration
        - the photosynthetic source rich in sugars is the leaf
        - the high concentration of sugar diffuses into the companion cell
        - since sugar level is high in sieve tubes (and sieve tubes are right beside xylem tubes that carry water), the concentration gradient makes water from the xylem flow into the sieve tube
        - the rigidity of sieve tube doesn't allow for shape change to accommodate increased water volume
        - all that water pressure pushes sugar water up or down the plant
            - the sugar water is transported to part of the plant that need sugar most
            - it's normally placed in the **sink** which is where sugars need to be stores in the plant
            - usually the roots (it is the roots during the winter season)

- originally, the sporophyte stage was temporary, but now it will be the most prolonged stage of the life cycle

Devonian terrestrial environment – *Carboniferous*

- **monilophytes** (ferns) have vascular tissue but no seeds
- life cycle of a fern
  - under the leaves of fern are **sorri** (brown spots that hold **sporangia** where spores are created)
  - spores are catapulted into the environment in **leptosporangia**
    - when water evaporates from the leptosporangia, the pressure gives it ability to shoot seeds for dispersal
  - the spore germinates to form a short lived baby gametophyte
  - gametophyte has an archegonia and antheridia
  - the egg is fertilized and grows to be a new fern and that completes the fern life cycle

- **conifer gymnosperms** are trees that have needle-like leaves and the seeds are unprotected by fruits or ovaries
  - originally, there were male/female gametophytes and sperm had to be transported to the egg
  - now, the male gamete will be transferred via pollen
  - the seed is a reserve of nutrients for development
    - there are male and female **cones** (the reproductive structure of the conifer tree containing pollen [male] or seeds [female])
    - in the spring, male cones produce huge amounts of pollen that the wind blows to female cones
      - the pollen contains **generative cells** which contain nuclear material to fertilize egg and contains **tube cells** which help transport male gametes to ovule

  - life cycle of conifer

  - seed formation
    - male gamete lands on top of ovule and germinates to make pollen tube that carries male nucleus to ovule
    - zygote is formed when male gamete reaches the egg
    - formed zygote returns to diploid stage
    - egg forms a sporophyte
      - now we have a sporophyte surrounded by the tissue of original female gametophyte (archegonia) with provided nourishment, then surrounded in another layer of the original plant's casing which provides a protective seed coat
    - unlike ferns that throw out sperm and egg and hope for fertilization, gymnosperms create a protected seed that will have a nutritive reserve to live off of until the plant can do photosynthesis
    - however, this method of reproduction has it's disadvantages
      - huge amounts of pollen have to be produced
      - tree relies on wind to carry pollen
      - overproduction of pollen can be wasteful
      - it's wasted effort of the archegonia if not every seed is fertilized
      - the time for a pollen grain to land in the female part could take lots of time(ie 2-3 years)

Fungi

- fungi are **heterotrophs** that live within their food
- they're composed of a series of cells arranged end to end with a **septa** (a division) in between
  - the septa is not primitive; it's a new innovation
  - the early fungi had a nucleus that would just sit there inside a cell that would slowly enlarge
  - the genetic material would duplicate to make a second nucleus
  - if we look at a **hypha** (a branching filament that makes up the fungi), we'll see that it's filled with many nuclei all lined up with no septa or cell walls (ie a huge cytoplasm with many nuclei lined up one after another)
  - fungi cells divide differently from normal cells
    - the nucleus divides and we have 2 haploid nuclei (not diploid nuclei)
    - while usual cell division will divide sister chromatids outside of the nucleus, fungi will divide

genetic information inside the nucleus
    - when fungi mate, they fuse cytoplasm in a process called **plasmogamy** and then develop a septa wall between 2 specific nuclei at the tip of the “cell”
        - the 2 nuclei of the fungi fuse to form a zygote in a process called **karyogamy**
        - the zygote undergoes meiosis to return to the haploid stage
        - after mating, the cell is n+n instead because they're not intact

- **basidiomycota** (mushroom) life cycle
    - when rain comes down, the network of underground micelia absorbs the water
    - since the fungi is made of chitin (and the walls don't expand with water absorption), the water travels up and down the tubes to make the bulb of the mushroom expand and come out of the ground
        - this can happen very quickly (1 day grass is clear, the next day it's filled with mushrooms)
    - the underside of the mushroom has gills
        - on the tip of each gill is 1 cell with both nuclei that will fuse and undergo karyogamy, meiosis 1 and 2 and then package the haploid nuclei in a spore like structure
        - each spore on the tip of the gill has recombinant dna (from the crossing over and sharing of genetic material of 2 different nuclei)
            - each spore has different genetic information from it's neighbouring spore
            - they're NOT clones, but they're every possible combination of recombinant dna
            - this is the advantage that fungi have: they create every possible combination they can on the umbrella of the mushroom to be released into the ground to fertilize
            - (whereas humans, we have billions and infinite possible combinations of genetic material, but we only use 1 of the combinations at a time with only 1 baby at a time)

- plants and fungi have a symbiotic relationship
    - an **ectomycorrhiza** is the relationship that happens between fungi and plant's roots
        - fungi extracts minerals from rock and soil to give to plant
        - in return, plants give fungi sugars
        - it's believed that this is what allowed plants to move onto land
        - over 95% of plants have an ectomycorrhiza with fungi

    - **arbuscular mycorrhiza** is the relationship between fungi and plant where the fungi penetrate plant cells

    - **lichen** have **photobiotonts** (cells/organisms that perform photosynthesis) inside them
        - could be photosynthetic bacteria or green algae)
        - the lichen gives photobiotants a home while they give sugars to the fungi

Arthropoda

- whoever comes on land first has the most potential to dominate it, and this is the insects
- insects have the same body layout
    - **tagmatization** (where each section of the body has specific function/purpose)
    - **head** is composed of 6 segments – function: food acquisition
    - **thorax** is composed of 3 segments – function: for wings, locomotion and movement
    - **abdomen –** function: to accommodate basic function system
        - the abdomen has an accordion structure so that it can expand/shrink depending on what the insect needs (ie hold eggs)

- the first insects didn't have wings for flight
    - they came up on land and were feeding on spores
    - with land predators such as scorpions, insects developed wings to escape
        - wings also allow them to own the terrestrial environment because insects can fly around and disperse
    - insects needed to waterproof themselves

        - change the cuticle
        - cuticle is usually embedded with protein (collagen or chitin)
        - they put an epicuticle on top of the original cuticle
        - the **epicuticle** produces a lot of wax to waterproof the wings
            - there's even an insect that makes so much shellac, it's used for furniture
    - insects also waterproof their gametes
        - sperm is packed in **spermatophores** and then transferred to the female for storage
        - females put a casing around the egg before it gets fertilized
        - there's a hole/small opening in the casing that the sperm has to go down before it can meet the egg

- the tetrapod (descendant of lobe finned fish) makes it's appearance
- since the environment is moist, many of the techniques to conserve water are halted because it's not needed
- **amphibia** don't solve terrestrial issues (they have lungs) but in reality, their respiratory structure is their skin
    - they exchange gas with skin even though they have lungs
    - to breathe, they do **buccal force respiration** (forced respiration with mouth)
        - they swallow air and push it into their lungs)
        - other animals don't force breathing like frogs do because they have lungs and diaphragms
- since gas exchange is done with the skin, it's important that it's always moist
    - instead of scales as a defence mechanism, they secrete poisons from their skin so that predators don't eat them

- amphibian food
    - as amphibians came out of the water, they feed on the insects
    - since insects were fast, they used what they had – a long tongue hinged at the front

Phanerozoic Eon- Mesozoic *Era*

Triassic

- is a major period of time in movement of the continents
- they fuse in the middle of the earth
- when they pull apart, another mass extinction takes place: *End Triassic*
    - End Triassic has more impact on the ocean environment
    - plants are cleared out so that reptile form is the dominant form

Jurassic

- continents continue to shift into position of where they are today

- the **amnio egg** appears
    - it's an egg where there's a protective case around the embryo that contains nutrients for the embryo
    - composition of the amniote egg
        - embryo: baby sits inside the egg
        - shell: the hard casing that protects the egg
        - yolk sac: the sac of nutrients that the embryo will survive on
        - chorion: outermost membrane that surrounds an embryo (helps with development of placenta)
        - amnion: innermost membrane that surrounds an embryo
        - allantois: the sac that contains metabolic waste so food resource isn't poisoned
        - albumen: provides water for the embryo

- reptiles develop **keratinized skin**
  - the protein embedded in epidermal cells die and stick together outside the body
  - it creates a waterproof skin for the reptile
  - it elaborates into scales
  - keratin is almost in toenails, feathers

- the powerful **jaw** appears as well
  - while some organisms eat the prey whole, it's more effective to be able to tear apart the prey
    - tearing prey apart allows for more to be eaten
    - it's difficult (impossible) to swallow a whole chicken, but once cut up, it can be easily eaten
  - crocodile are **homodont** (their teeth are all the same shape and appearance)
  - with the use of the jaw, the predator can puncture the lung of prey, crush it, etc then take its time eating it

  - the muscles that drive the jaw are inserted in the skull (inside brain case)
    - when jaw opened and closed, it would impact/shaken the brain with each bite
    - instead, the muscle is now inserted through a hole outside of the skull
      - reptiles have 2 holes for muscle insertion
      - mammals only have 1 hole

    - **anapsids** (reptiles that lack the temporal opening of the skull)
      - the turtle fuses it's bone structure and shell to create an armour
      - it modified it's jaw so it doesn't have the huge crushing teeth, yet the jaw is still powerful

    - **diapsids** (reptiles that have 2 temporal openings in the skull)
      - dinosaurs, pterosaurs, snakes, crocodiles, lizards
      - diapsids can be divided into 3 groups based on body structure
        - **saurischian** dinosaurs: longneck herbivores, small carnivorous
          - pubis bone is perpendicular to ischium
        - **ornithiscian** dinosaurs: horned, duck-billed, hooded (primarily herbivores)
          - pubis and ischium are parallel to each other
        - **pserosaur** dinosaurs: bird dinosaurs

      - **synapsid** (ancestor to mammals)
        - being small, it's competitors were small dinosaurs
        - they knew how to keep cool at night (warm blooded)
        - glandular skin (communicate by smell)
        - specialized teeth to chew food

- massive change in plants
  - gymnosperms come along and wipe out diversity of pollen producing plants
  - **angiosperms** (plants with flowers and produces seeds in a carpel [female reproductive organ- ovary, stigma, style]) come along and wipe out diversity of gymnosperms
    - gymnosperms now only grow in cold environments
  - flower is a huge innovation
    - female part of the flower: carpel, ovary, style
    - male part of flower: stamen, anther
    - angiosperm life cycle
    - angiosperms use animals for pollen dispersal
      - this is much more effective than gymnosperms because they don't overproduce pollen and waste energy
      - they also produce “bait” (incentive) for animals to help with pollen transfer- they offer fruit, nectar, etc
      - having animals help with pollen dispersal guarantees fertilization

        - methods of seed dispersal
            - wind (by having seeds in an airborne casing), water, animals (burrs)

- A METERIOTE HITS MEXICO AND WORLD GOES TO HELL
    - but that's not true
    - the dinosaurs were so successful towards the end (before crustaceous) that they were globally modifying their environment
        - they were eating all the plants
        - top predators were eating all the herbivores (based on fossil records, the number of predators was stable but the number of prey was diminishing more and more)
        - essentially, the food chain was collapsing as herbivores were dying off (as a consequence, the top predators were then dying out as well)
        - the meteorite took a situation that was already deteriorating and then finished off the group that was most susceptible

Phanerozoic Eon- Cenozoic *Era*

Birds

- flying warm blooded dinosaurs
- birds created large feathers (insulated that allowed them to be active at night)
    - originally, the limbs with feathers were used to catch insects
        - feathers weren't used for flight, but as a net to catch food
        - but eventually one bird decides to flap it's wings up and down instead of left and right and discovers flight (called the **ground up theory of avian flight**)
        - the counter-theory to the ground up theory of avian flight is the **tree down theory of avian flight** (where the ancestor bird fell off a tree and opened it's wings to fly with the mouth open to eat insects on the way down)
    - bird morphology is relative to it's ability to fly
        - lighter skeleton
        - wings placed on top of animal instead of on bottom for power drive
        - bones are porous
        - no teeth in jaw
        - jaw is made of keratin (lighter structure)
    - parental care is strong with birds
        - a lot of care in nurturing young

Mammals

- skin
    - produces insulated hair
    - sebaceous gland keeps hair moist to not be brittle
    - eccrine gland creates sweat to help cool down
- jaw
    - teeth for different function (**heterodont** where teeth have a specific shape for different function)
    - can cut, grind, and manipulate food with teeth before ingestion to make digestion most efficient
    - set of baby teeth and adult teeth
- reproduction
    - first mammals laid eggs (**oviparous**)
        - when platypus lays eggs, the young hatch and then she holds them against her
        - skin secretions will nourish her young
    - **viviparous** mammals internalize the embryo (not in egg anymore)
        - in marsupials, when the embryo grows, the mother's immune system attacks it- thinking it's a parasite and tries to expel it

        - the embryo comes out at an immature stage, and then goes into the **marsupium** (pouch that protects eggs) to continue growing
    - **eutherian** mammals have a placenta
        - the embryo can stay inside mother for a period of time
        - a lot of investment in care for young