

Palaeozoic Periods

- Palaeozoic era
 - Cambrian 550-488 Ma
 - main event is multicellular animal life in the oceans
 - The oceans were populated by single celled algae
 - There is no multicellular plant life of any significant type or number in the oceans today
 - Whats unusual is that that period of time was one of the most diverse period of times in terms of animals and animal variation
 - its from a set of fossils called shales
 - Ordovician 488-443 Ma
 - Silurian 443-416 Ma
 - single celled plants start to form multicellular masses on the edge of the oceans
 - They will ultimately become the terrestrial plants of the living world
 - Devonian 416-359 Ma
 - the age of the plants
 - Plants are going to solve their reproductive and structural strategies to be able to function on land
 - The plants need to colonize the land to have any other animals on land
 - Anything thats going to come up on land has to have a food source there
 - So we have to wait a time before plants come up on land for other stuff to be able to move up
 - When the plants first move up on land and are able to solve their issues with standing up to compete for sunlight with the other tall plants
 - Their vascular tissues contain lignin, no other organisms around can break down; this causes all plants to tip over and fossilize
 - Carboniferous 359-299 Ma
 - fossil fuels on land
 - Only the fungi will be able to break them down
 - so much plant material that we get it as fossil fuels
 - also the time where animals get up on land
 - Permian 299-245 Ma

Late Cambrian 514 Ma

- pieces of continents that are drifting around
- They are going to collide into each other and do various things
- very important one: laurentia (continental mass) sitting on the equator
- Theres a huge continental shelf sitting around it
- There is a region where the continent dips into the water and gradually deepens and deepens before it tips off into the oceanic trenches
- Those continental shelves are very rich
- Because these areas are shallow, you get light penetration, nutrient supply
- They have the potential of being diverse
- Laurentia is not only sitting on the continental shelf, but its also on the equator

- This is a place where we have the best temperatures and the most light
- This Laurentian much more diverse in life
- This land mass is going to become North America
- On the eastern face of the Rocky Mountains has fossils way back in the Cambrian
- we now understand plate tectonics
- so now we know that there should be the same fossils from the ancient oceans in China
- and

Cambrian and Ordovician Periods

- The animals are weird and don't look like anything we have today

Burgess shales – Yoho National Park

- hundreds of fossilized invertebrate fossils
- something happened in the Cambrian and ever since that explosion, we've lost a lot of diversity
- extremely important to us: they show us ___
- we need to figure out what happened

The Cambrian explosion

- an article was posted in Time magazine after the 2 students noticed that the organisms in the Burgess shales were different animals
- there was a question that where did these animals come from

Burgess shales and its unusual invertebrates

- there are animals in these fossil beds that are not present on Earth today
- these invertebrate organisms look unusual
-
- ___ and they fossilized
- These fossils get uplifted in the Yoho National Park

Colonial choanocyte ancestor

- cell body with finger-like projections (microvilli) and there's a flagellum
- There's a constant stream of water that flows through the microvilli and up
- The spaces in-between the microvilli causes particles to get trapped in there and the cell starts phagocytosis and they get nourished
- Two or three of them get together into a colony
- 5 choanocytes working together can pump more water than a single choanocyte
- You get a better water flow and a better access to food
- There are still organisms that work this way called colonial choanocytes
 - They are thought to be a common ancestor
- Microvilli are identical around all organisms (that tells us that we are all descendants to an organism like this)
- This colony can't communicate with each other
- Sits at the base of the fungal
- We now know that animals and fungi are related through a common ancestor

Animal

- collagen: sticky substance not found in any other kingdoms
- Cells with different functions other than reproduction

- common ancestor of choanocytes

Animal architecture

- Tissues
 - nature of the cell-cell interactions
 - Tissues is a way that the cells communicate with each other
 - none diploblastic or triploblastic
 - blasty (
 - mesoderm is key in animal development because its used to make muscle
- Symmetry and cephalization
 - asymmetry, radial, and bilateral symmetry
 - radial: cut and get the same ; the organism moves all around in every direction
 - bilateral: cut only one way; organism moves in one direction and all of the sensory inputs are put at one end
- Embryology
 - protostome and deuterostome
- Body cavities
 - coelomate, pseudocoelomate, coelomate

Porifera

- sponges
- group that still have choanocytes today
- they arrange the choanocytes to pump water
- highly efficient organisms pumping large amounts of water through their bodies and feeding from it
- There is no cell to cell communication in sponges
- Its unusual because you have a multicellular organism that doesn't have tissues
- Totipotent cells: cells that can turn into any other cell
- This is an organism made up of entirely stem cells
- Asymmetric body plan

Colonial choanoflagellates

- sponge made up of different cells
- spongocoel: inner sponge cavity
- Pinacoderm: pinacocytes that stick together to make up the outer layer of the sponge
- Mesohyal: adhesive, gel matrix
- Spicules: give the sponge shape; skeleton
- These are the first animals that trapped and harvested the water in the ancient oceans

Sponge sex

- choanocytes become sperm
 - They use their flagellum to become sperm
- Archeocytes (sponge stem cells) from egg
 - fill up with nutrients to become an egg
 - archeocytes are like amoebocytes

Animal innovations (symplesiomorphies)

1. Gap junctions show the first cell to cell communication

2. True tissues with all components; you get an internal digestive epithelium with shows up for two cell layers

Junctions and tissues didn't come at the same time

Gap (septate) junctions (connexon)

- you have connexions that can open and close

-

Animal architecture: Tissues

- no tissues
- diploblastic germ layers
 - ectoderm and endoderm
- Triploblastic germ layers
- ectoderm, mesoderm, and endoderm

Gastrulation — digestive epithelium

- how does diploblasty occur
- blastulae
- The cell invaginate the ectoderm which creates a cellular lining inside
- Gastrulalic
- this inner lining creation makes a hole which now gives a mouth
- You now have the digestive epithelium
- Now that we have a mouth, we can look at the symmetry

Animal architecture: Symmetry and cephalization

- assymetric
- radial symmetry: symmetry in all different directions
 - animals get stuck in the radial form when they don't have a mesoderm
 - no mesoderm means no muscles
 - no muscles mean no movement
- bilateral symmetry and cephalization: can only get symmetry in one way

Cnidaria (autopormorphies)

- cnidocytes
- Polyp body plan
- Epitheliomusculature
- Cnidarian: With the exception of a few herbivorous coral species, cnidarians are carnivores that sting, entangle, or poison potential prey

Cnidocytes (cnidaria)

- a little cell that contains a_____
- the nematocyst
- it turns itself inside out
- it shoots out
- They needed to shoot out ___ to feel in those ?? arthropods
- This helped them penetrate the arthropod and immobilize it with poison to feed

Body wall — hydrostatic skeleton (cnidaria)

- formed from fluid filled closed cavities surrounded by body wall

- Dexterity: allows for movement
- this organism is able to move because we get the first skeleton in this animal
- role of skeleton
 - lengthen and strengthens a muscle
 - stretches the muscle
 - gives the form of the organism
- epithelial muscular cells:
 - myoneme: arranged in circular
 - ___: arranged in lateral directions
- The element used to compress is water part in the hydro static skeleton
- they have a mouth but no anus
 - called an incomplete digestive system
 - cnidaria is an animal trapped in the element at the gastric digestive evolution

Medusa and Polyp

- mesoglea: gelly like matrix between tissues
- muscles arranged in a circle are in the medusa
 - when they contract they bring the bell into the centre
 - when they relax the bell goes back to its original spot
 - this happens in the upper surface of the jellyfish
 - the water underneath gets shot out
 - you get a motion where the jellyfish rises, falls less, rises, falls less
- Cnidarians have a dimorphic life cycle; living first as a sedentary polyp and then as a motile, sexual medusa.
- polyp: stage in the life cycle where they are sessile

Jellyfish

- life cycles change over time
- we don't want to waste sperm and egg into the environment anymore
- gonozoid: specialized polyp for reproduction
- they create a female medusa and a male medusa
- those two met together, form a zygote
- planula moves in a directed motion across the substrate and one branch stopped and

Corals

- an animal
- maybe the sponges are older than what we thought

Coral reefs

- most biodiverse habitats in our oceans
- are prominent on the equator
- create microhabitats for the diversification of organism

Animal innovations (Symplesiomorphies)

1. Triploblastic modern musculature
2. Bilateral symmetry

When we talked about the cnidarians, there was no mention of radial symmetry. That is because another group on the bottom (echinodermata = starfish) that have radial symmetry.

Animal architecture — Embryology: Cleavage

- At the 4 cell stage (when a zygote has divided) between that, you get a division
- The cells on top do a little bit of a twist and put their rounded edges on top
- when you go for a 4-8 stage, you get a spiral cleavage on top because its in a spiral
- some organisms have radial symmetry

Animal architecture — Embryology gastrulation

- Where is the mouth of an organism?
- you have a gastrulation that gives us an invagination with results in endoderm
- To get a digestive tract with two openings, the other side forms a spore and that spore makes a hole on the other end
- You now have a linear processing of the food
- Whereas cnidarians only had a mouth and no anus. they spit out what they could't digest
- If a blastopore becomes a mouth, they are called protostomes. Proto= first, stome= mouth
- The ones where the mouth is the second opening is a deuterostome. deuterostome=second

Animal architecture — Embryology: coelom formation

- coel = cavity
- schizo = split
- another way is that mesoderm cells from the endodermic cells form the gut by singling the cells of the ectoderm to become mesoderm
- It gets bigger and bigger until it completely fills the mesodermal space
- you have little blurb of tissue that pockets on the side, it then splits from the gut
- Mesodermal space = enterocoel
- Mesoderm = schizocoel

Protostomes vs Deuterostomes

- Protostomes
 - Blastopore mouth
 - Spiral cleavage
 - Schizocoely
- Deuterostomes
 - Blastopore anus
 - Radial cleavage
 - Enterocoely

Animal architecture — Body cavities

- Acoelomate: the organisms with a solid block of mesoderm, no cavity, or fluid filled space
- Pseudocoelomate
- Coelomate

When mesoderm forms, it forms simultaneously with a body cavity
So the coelomate would be a plesiomorphy

Animal architecture — Body cavities: Acoelomate

- solid mass of mesoderm

- Only cavity seen is the digestive tract

Animal architecture — Body cavities: Pseudoelomate

- mesoderm is associated with the ectoderm
- But there's no mesoderm associated with the endoderm (gut)
- Which means that there are no muscles lining the gut
- so to move food down the digestive tract, you need to use the muscles of your whole body
- Body movement responsible for propelling food through the gut

Animal architecture — Body cavities: Coelomate

- mesoderm associated with the gut

Protostomia

- Blastopore is mouth
- There are 3 protostome lineages

Three main protostome groups

- Ecdysozoa: cytoskeleton
 - the animals that mold
 - discard the exoskeleton and grow a new one
 - builds a cuticle, an outer layer of organic material that functions as an exoskeleton
- Lophotrochozoa
 - Lophophore or: tentacular feeding structure with cilia all around that pump the water to feed
 - Trochophore: larval stage, as it swims the cilia band propels to bring food in
 - IT'S A LOPHOPHORE OR A TROCHOPHORE, NOBODY HAD BOTH BUT THEY HAD ONE OR THE OTHER
- Platyzoa
 - gets its name from the flat worms
 - the group has lost their coelom and are primarily acoelomate

Ecdysozoa

- Moulded protein cuticle
 - No surface cilia (no cilia on epidermal surface)
 - Every other animal has cilia
 - they can be broken into 2 different groups based on the proteins used
1. Collagenous cuticle
 - group that uses collagen
 2. Epitheliomuscular pharynx
 - Group that uses chitin

Symplesiomorphies

1. Collagenous cuticle without microvilli. Longitudinal but no circular muscles
2. Epitheliomuscular pharynx

Nematoda

- Pseudocoelomate body cavity
- only musculature are longitudinal muscles along the outside
- They don't have great compression

- The muscle contracts on one side
- Cuticle is elastic, they wiggle using muscle contractions
- they aren't aquatic, they are found in soils
- They have this whip-like movement to move around the soil

Ascaris body wall detail

- Pseudocoelomate body cavity
- No peripheral nervous system
- Strategy in being miniature
- They are the only animals to have amoebic sperm
- Body wall = muscles constantly contracting and putting pressure on the fluid inside

Epitheliomuscular pharynx

- Creates a dual valve system
- Clamps the valve adjacent to the gut and the valve to the mouth

Triradiate Pharynx

- epithelial musculature
- Divide into three (tricuspid valve) in the heart
- Instead of epithelium
- One cell layer to control opening and closing of the pharynx
- Efficient to open and close a circular valve

Panarthropoda

- instead of strengthening the cuticle with collagen, we strengthen it with chitin
- Chitin is one of the biggest carbohydrates
- Food manipulated by limbs before they swallow it
- They preprocess the food which makes it more efficient to digest; smaller pieces = greater surface area
- Only other group to do this — jaws, others swallow whole

Onychophora

- very unique way of feeding
- Oral papillae with slime glands
- Body wall musculature continuous sheet
- Unarticulated limbs
 - hydrostatic skeleton to move body and limbs
- Little worm like structure
- Repeated segmentation
- Jaws inside the mouth used to tear and shred food before they swallow
- Hydrostatic skeleton that can be bent and claw to grab living fossils
- Hasn't changed its appearance, evolved very early; only found on southern extremes of two continents

Arthropoda

- Articulated exoskeleton of plates
- muscles arranged in bands
- Compound eye

- Largest phylum of organisms
- Crustacea live in marine environments; largest is the terrestrial
- Cuticle now becomes plates and bend adjacent to each other
- Articulations are the joints between the plates
- Solid chitin plates
- Name from articulations associated with the leg
- No longer rely on hydrostatic skeleton for movement
- New visual system — the compound eye

Arthropods: Trilobites

- disappeared completely slowly over time
- Hard-shelled, segmented creatures

Arthropoda: Crustacea

- Segmentally arranged
- Appendages during the length of the body are all the same
- Some appendages take on specialized roles
 - claw defences
 - Legs for walking
 - swimming legs
- Take appendages and turn them into different structures

Filter feeding

- Success from how similar all the appendages being the same during the length of the body
- Constantly moving — metachromal wave movement
- Unidirectional flow of water from the front into the box and then when the box closes, the water is squeezed out
- This allows the organism to propel forward
- They were the first swimmer and the first to effectively trap algae
- First to develop their limbs to move, feed, and swim at the same time

Three main protostome Groups

- Ecdysozoa
- Lophotrochozoa
 - Lophophore or Trochophore
- Platyzoa

Spiralia (autopomorphy)

- Spiral cleavage (the development of the embryo)
- autopomorphy/ innovation at this point of time is spiral cleavage
- This is the traits that sits for protostomes and notostomes
- When we get cell cleavage, it occurs in a number of different ways
- you don't always get a perfect 4 cells on top of the spiral cleavage
- protostome characteristic doesn't include spiral cleavage
- The spiralia is a taxonomic group that have a spiral cleavage

Lophotrochozoa

- Either precedes of a U shaped gut and lophophore or

- Trochophore larval stage
- This group is defined by having one or another thing, not both

Lophophorates

- Lophophore
 - book definition: A unique double ring of hollow ciliated tentacles that surround the oral opening in a number of animal phyla
- U-shaped gut
- Group of animals that have returned to recessive state
- Sessile: attach itself to a substrate
- They live in a protective casing
- Body type disadvantage: sitting on the posterior end of the body, sitting in poop
- The digestive tract its u shaped, will bend backwards to a place close to the mouth

Briozoans

- they are colonial
- one of the great reef holders of the cambrian oceans
- important in the diversification in ancient oceans

Bryozoa

(Lophophorates)

- A little organism sitting inside its casing
- Has little tentacles sticking out
- The set of tentacles is called a lophophore
- they use the tentacles to feed
- Their advantage is that they have a body cavity
- The tentacles are hollow and can be controlled by the organism
- The surface of the tentacles are covered in cilia
- The cilia trap the food particles
- The cilia also create a water current. They pump water in the water column
- they live in colonies and each colony are connected to each other and share nutrients within the colony
- They are another one of the weird body plants that makes its appearance in the Cambrian and is still here today
- use radial cleavage

Trochozoa (autapomorphy)

- Presence of the trochophore larval stage
- Trochophore google definition: having a roughly spherical body, a band of cilia, and a spinning motion.

Trochophore larva

- has a distinct morphology
- has a central ciliated band
- The little trochophore will undergoes
- As it beats, it propels water to swim and collects food
- Book definition: This free-swimming ciliated larval stage is found in a number of animal phyla including the Mollusca and Annelida. The larvae has a unique circle of preoral cilia around the

middle of the body. Trochophores are often considered an ancestral characteristic of protostomes

Animal innovations (symplesiomorphies)

1. Trochophore
2. Schizocoel (they don't define a protostome b/c they aren't at the base of the tree)
3. Dorsal heart and pericardial cavity

Mollusca

- Radula
- Dorsal mantle
- Calcareous spicules or shells
- Ventral ciliated muscular foot
- They have a food source that no other animal is feeding on
- Mantle layer of tissue
- Secrete mineral salts
- Create shells or spicules
- Distinct body plan — ventral muscular foot — two parts organ system on top of the locomotion

Molluscs (Trochozoa)

- the diversity of the group is huge
- the fossil record is phenomenal
- The fossil shows that certain groups (annienites) have completely disappeared
- adaptive radiation:
- this group includes things like snail, slugs, octopus

Mollusc traits

- They have a ventral muscular foot that propels the mollusc from under its shell
- The mantle under creates a shell
- This is the first animal that can hide between a shell and it's predator
- When the snail goes to hide, there's a little opening for a mantle cavity that allows the circulation of water
- The mantle cavity has a gill that is covered with cilia with is important for creating a water current
- The mollusc can breathe and digest and feed all while hiding in the shell

Mollusc radula

- very unique feeding structure
- on the surface of the tongue is hardened teeth
- The teeth can slide back and forth on the surface
- The teeth grind on the surface of rocks, scrape it off, tearing little bits and eating it
- They succeed so well that this is the second most abundant phylum

Snails (Gastropods)

- have a shell that they have coiled up
- They compacted their body into a spiral
- they pull themselves into the shell when they sense danger

- They also have another little shell on the back to close the opening up
- The shell is so good that they can come up on land
- These animals are hermaphrodites (male and female sex)

Advantage of hermaphrodite mating:

both organism has a fertilized egg

This is good for a slow moving organism that has a rare time to bump into another organism
So when you do bump into another one, you make sure that you guys can make offsprings to assure your generation will pass down

- The seminal receptacle is a place where the organism will store the sperm from the other organism
- Then after, you will bring down an egg to the stored sperm
- The terrestrial snail has a very distinct mating
- They both have a dart that try to ram it into the other snail
- The snail that is penetrated the deepest with a dart, will retain the dart in the body wall
- This will change the behaviour of the snail to have more of a female role of a mating pair than the other

Squids and octopods (Cephalopods)

- the muscular foot has now become tentacles that shoot out, grab food and place it back in the mouth
- They are a very agile group
- There's a huge fossil record of these organisms called AMMONITES

Ammonites

- thousands and thousands of fossils packed together
- There were a lot of these predators in the cambrian oceans
- When they died, they all dropped to the bottom of the ocean and fossilized
- ammonite is a fossil inside the fossilized shell (pearls)
- What happens is the when the fresh fish take over, these predators cant compete and they lose their shells
- One of the big predatory forms are squids and arthropods in the bottom of the oceans

Clams (Bivalves)

- take the shell, fold it in half and live inside
- Use the cilia inside the gill for water current to bring in water and feed
- They filter feed
- These organisms don't have a radula
- It borrows itself into the substrate (shell), pumps water and takes in food particles from the water
- It has a little ability to move
- It uses a foot that it sticks out to push itself
- A clam has two large muscles

So after this we have 3 different types of organisms that have different variations of a shell, foot etc.

Annelida

(autapomorphies)

- Metamerism of mesodermal structures
- Four bundles of setae (hairs)

Annelida: marine worms

- earthworm shows the original way of feeding

Annelida: Metamerization

- when the longitudinal muscles are stretched, the setae comes back
- when the longitudinal muscles contract, the setae anchors down to the ground

- They swallow the soil and wait for it to go out the other end, this helps them to move around in the soil
- They are not only moving, but they can also extract the organic material in the soil
- They are the first organisms that burrow
- earth worm shows us the very first way that organisms fed and moved around
- They are the third most prevalent groups

Annelida: Marine Worms

-

Platyzoa

- Loss of coelom
- Acoelomate or pseudocoelom
- Loss of metanephridia and circulatory system

This is the group that lost the coelom. They were a huge problem in zoology because they were placed in the bottom of the phylogenetic tree. But that's not the case, it's supposed to be higher up.

Loss of a coelom is an acoelomate.

Metanephridia is what filter the coelomic fluid

Platyhelminthes

- Incomplete gut
- They have no anus
- Complex reproductive system associated with hermaphroditism
- This is the only phylum that is exclusively hermaphroditic
- yes we had some hermaphrodites in molluscs but the whole phylum isn't, just the molluscs

Body cavities — Acoelomate

- these aren't going to be solid animals
- we can use longitudinal muscles and circular muscles to change the shape of the organism
- but the ventral muscles keeps them flattened
- the cilia on the ventral surface for movement
- the gland helps them stick tightly to the surface that they are on
- 2 types of motion, ciliary motion and muscle motion
- with cilia movement, you get a nice gliding around
- the muscle movement, shows movement like an accordion
- but these movements don't give us a clue why these organisms got rid of the coelomate

Flat worms (platyhelminthes)

- the mouth is found on the ventral side
- This is unusual because your mouth is on the bottom and not the front of the worm
- not only did they have an incomplete digestive tract, they also don't have any evolutionary advance of the mouth
- the animal glues itself to the surface, and then uses the mid ventral surface to secrete enzymes and feed on the substrate
- they are stuck really hard on the surface, their flat shape is advantageous as the predators cannot pluck them out. its almost impossible
- now the digestive tract is not a blump but flat all around the body of the worm
- by becoming completely flattened, there was no need for a ceolom
- Flat worms figured out how to eat the cnidarians and not get stung by the cnidocytes
- They completely cover themselves in the cnidocytes and use it as an armour against predators
- This is a highly specialized organism

- Slide 85 is the reproductive system of the flat worm
- The seminal vesicle is a storing place for the sperm
- in the seminal receptacle,
- The ovary will produce the egg, it will pass by the yolk glands to give nutrients

Take out slide 86 & 87

Life Cycle

- Flat worms invaded the fluid filled body cavities of other evolving organisms
- 2 forms of flat worm parasites: flukes and tapeworms
- Flat worms use their characteristic of flatness and being able to stick onto things to become parasites
- When they go into another organism, they stick on the wall of the organ, and as they are completely flat, they don't obstruct the circulation of the normal organ
- So they don't obstruct the function of the organ that they are in

- A miracidium becomes a sporocyst
- largo amplification:
- the next stage is the redia
- the radia under largo amplification
- then they become the cecaria
- the cecaria is released from the gastropod into the outside
- it will then look for another live host
- It can go into the fish for example
- if the fish becomes food for a human in a raw form, it can turn into an adult

- flukes arised in the cambrian
- But there were no vertebrates at that time
- so the flukes figured out a way to invade a gastropod
- they then invaded fish
- and then another 400 years later, this organism found out how to invade the vertebrates

Deuterostomia

- Blastopore becomes the anus
- in this group we have the echinoderms

Echinodermata

- Pentamerous symmetry
- Water vascular system
- mutable connective tissue
- don't confuse the water vascular system with a sponge (aquiferous system)
- These animals have an endoskeleton
- starfish can change their body shape to being very flexible to being very rigid
- They have a nervous control over their connective tissue
- Went back to being radially symmetric

Starfish and relatives

- larval stages bilaterally symmetric
- Discarded the advantage to become radially symmetric

- Sessile, radial arms along the ribs of arms
- Unique tube feet that push food
- The mouth is in the upward direction
- Sitting on stalks can make it rigid
- Orient it into the water current will give it constant food into the set of arms
- It will catch organic fallen matter before it hits the bottom
- That's the reason for its success
- It ultimately flips itself the other way
- Starfish is the upside down version of this ancestor

Water vascular system

- Each tube foot are separated by a valve
- This can act as an independent hydrostatic skeleton
- Clamp suction cup, levelling animal and then detaching — nervous system makes them move in unison
- Predators and carnivores (they eat clams and polyps)
- Their invert stomach secretes enzymes to feed

An explanation for the Cambrian explosion

- Snowball earth
- Burrowing
- Shelled arms race
- Developmental — hox genes
- short period of time for branching

Late Proterozoic 650 Ma

- Most of the continental land masses were exposed at the equator
- Before life on land we just had rocks
- Rocks didn't have a heat absorbent surface
- The heat was being absorbed by the oceans
- Rocks reflected the sun energy which helped in cooling the planet

- Huge amounts of precipitation on raw rock running into the ocean
- We also had rock erosions — minerals washing into the oceans which caused an influx of cations in the oceans
- CO₂ being removed and therefore cools the planet
- Oxygen reacts with methane in the atmosphere and destroys the methane
- This replaces the warming greenhouse gas to CO₂ and this also causes cooling
- Freezes at extremes — reflect light — keeps calling planet
- Soon cant go back and the earth keeps freezing and cant stop
- Slush ball earth doesn't all freeze
- Causes a loss in the diversity of the multicellular life
- As soon as ice disappears, there is an explosion

Early animal evolution

- Edicara fossils
- First found in australia

Doushantuo fossils

- Less than 0.1 mm
- Early stage embryos — cell to cell communication
- Embryos of multicellular life
- 590 million years ago
- Life of some form that turns into multicellular life
- They don't know how they fossilized
- They look like embryos so there mustve been life before the cambrian explosion

Ediacaran Fossils

- these fossils tell us that it didn't necessarily happen in the cambrian
- Multicellular structures well before the cambrian

Cambrian Burrowers

- Advantages
 - Feeding
 - Anchorage
 - Protection
- In the cambrian, we have the first burrowers
- as soon as the burrowers come by, the huge fossilized form changes
- now you have animals that have protection against predators
- What we end up with is the burrowing animals and shell animals

An explanation for the Cambrian explosion

- Snowball earth
- Burrowing
- Shelled arms race
- Developmental genes

Homeotic genes

- How do you take cells that all contain the same genetic program, and turn them on to make specific structures

- Answer: homeotic genes
- Some genes already contain a message
- Others are turned on within the embryo
- When the embryo starts development and starts dividing, the mRNA makes a protein called the transcription factor
- The transcription factor takes DNA, folds it and aligns them to get a different protein
- There is a posterior and an anterior that makes different proteins
- A cell sitting at the anterior, receives a load of the green factor
- The posterior gets a load of the red
- The middle gets a load of the black
- so depending of where the cell is placed, they will get different mixes of transcription factors

Hox Genes

- You have a set of homeotic genes (hox genes) sitting in the embryo
- You have a universal common in the sequence of these genes across animals
- somewhere around the cambrian or just before, the genetics that control pattern made its first appearance
- The very first experiments in pattern and predicted pattern makes it appearance only once
- then the pattern gets perfected
- How genes are the most ancient genes out there
- we also have a pattern of genes in plants

Mass extinctions

- almost 1/3 of all of the different taxa disappeared
- Most of them are the burga shales
- Then life will start over

Silurian and Devonian —

Ordovician survivors

- Cnidaria — corals
- Molluscs
 - Shelled cephalopods
 - Bivalves
 - Gastropods
- Worms
- Echinoderms
- Bryozoa
- Arthropods
 - Trilobites (some)
 - Marine forms (Crustacea)

Middle Silurian

The age of fishes and of plants, we are going to see green things move up on land

- Pangea comes around this time
- a huge ocean of continental block was a great incubator for all animal forms

Animal innovations (symplesiomorphies)

- We are the chordates
- In the last 5-6 yrs, we've identified the ancestor of the group chordata in the burge shells
- Why it made this group successful
 1. Pharyngeal gill slits
 2. Endostyle (important in feeding), notochord, Post-anal tail and tadpole swimming

Pharyngeal gill slits

- an ancestor swimming with an open mouth
- The water comes into the mouth and across the pharyngeal slits
- Water moves in and out and the slits are supplied with blood
- The endostyle produces a mucus net and cilia stretches to the top, at the top, it takes that mucus net. balls it all up and into the digestive system
- The mucus net is porous and on the inner surface, it traps food
- The food is the algae that sits at the base
- An animal uses its locomotion and at the same time takes in food.
- Another group that moves and feeds simultaneously is the crustacea

Notochord

- It's a cartilagenous rod
- The nature of the notochord is to take that rod but you can't compress it; it will not shrink
- But if you trap a few of them, you may be able to make it bend
- There are muscles along the side segmentally arranged

Segmentation

- When the muscles contract on one side, it bends
- This structure helps with motion
- You get a sort of tadpole
- The organism adds more segments past the anus of the organism
- This is called post-anal segmentation (which is a tail)
- You have this little organism with a wonderful way to swim
- This organism sits at the base of the chordate ancestry

- This organism, cephalochordate

Cephalochordate

- this organism likes to live in borrows
- It uses cilia in its cavity to pump water into their mouth cavity
- This organism has all of the things associated with chordates

Where do the characteristics associated with vertebrates come from?

Vertebrata

-
- Axial skeleton (bony structure) with vertebrae

Vertebrate phylogeny

- Vertebrates have vertebrae and a brain case
- The agnatha do not have a jaw, they still have that open circular mouth

Jawless fishes (Agnatha)

- armoured with large plates of bone
- Almost all of armoured plated fish disappeared or replaced
- Two survivors: hagfish and lamprey
- Lamprey: long eel like body, tail with fins, pharyngeal openings on side, adapted itself to host, clamps down on one side of fish, uses keratinized teeth to claw and dig away the tissues of the host
- Open wound on host is where they get nutrients
- The problem for lampreys is that little nostril on top for water movement through the body
- Lifecycle: adult lamprey moves into creeks onto sandy gravel
- They lay eggs and those eggs hatch as larvae and grow and mature into young adults back into the oceans
- They return to creeks in which they were born

Pteromyzontida

- Lamprey: take an open mouth and are able to be parasites

Jawless Fishes (Agnatha)

- These organisms armoured themselves with a bony surface
- At the end of the Ordovician, most of these fish disappeared or were replaced
- There are 2 survivors, the hagfish and the lamprey
- The lamprey has a long eel like body, long tail with fins, pharyngeal openings on the sides, its an ectoparasite (living on the outer surface of the prey) it clamps down on the side of the fish and uses the keratin (teeth) on the outside
- It uses its teeth on the inside and damage the tissue of the host, spray anticoagulant and wait for the blood, pus and everything to be taken in as food
- They have a nostril on top for water
- Life cycle:

Gnathostomata

- Every organism that has a jaw
- Genome duplication
- Jaw
- Paired fins
 - the fins stabilize the main body
 - This allows the tail to propel the body easier
 - The fins allow the main body to not tip, twist, or turn — it's stable

Evolution of the Jaw

- over time the muscles around the pharynx compress and spring back
- We are increasing and decreasing the volume of the pharyngeal cavity
- Two front arches that become hinged to the point where they can close and now trap food
- you can now fill the mouth with water, close the mouth, push the pharynx and squeeze water into the digestive tract
- You don't have to rely on filter feeding
- two bones fuse together to make the jaw
- Over time, the jaw develops teeth

Genome duplication homeotic hox genes

- only case of entire genome duplication that occurs in an animal

- The hot genes of the lamprey is only one
- When you look at the gnathostomes, the entire genome duplicated twice
- The genes that are controlling pattern have quadrupled
- This meant that you had a set of genes that you could experiment with while the other set could function correctly
- There is a huge diversity in the small group
- We sense that its from the duplication
- The ray fin fishes have undergone one more round of duplication

Chondrichthyes were sharks and fish

- Cartilaginous skeleton
- Placoid scales
- Heterocercal tail (unusual tail shape)
- Unique jaw bone

Chondrichthyes

- Everything is made of cartilage
- the fins are held into place by the musculature of the body
- They can't move with the fins (fins aren't agile or articulated)
- The tail is bigger on top than on the bottom (heterocercal tail)
- When they swim, they generate downward pressure that is deflected by fins in the front
- This propels and its the shark while swimming
- they are constantly combating gravity
- Cartilage is a lot less dense than bone
- Their bodies are lighter than they would be if they were made of bone
- This minimizes the sinking
- They have a very large liver that produces oil
- Every single tail movement is turned to swimming movement and not battling gravity

Placoid Scales

- Surface of shark
- Scale-like embedded in layer under the epidermis
- Laminar flow— want to prevent it
- Scales on surface — to create vortices and to slide through with less resistance
- Exact composition as teeth
- The teeth are large scales: not anchored into the body other than in skin

Feeding

- the teeth are not anchored into the body other than into the epidermis
- If they get torn off, they will always get a new tooth
- Their jaw is a holding mechanism to hold onto a prey
- It clamps down with a jaw
- It rolls and flaps around and hopes pieces will break off so it can eat the pieces
- They have uge muscles to close the jaw but weak ones to open it

Mermaids purse

- sharks produce very few young
- The shark female produces only one egg per reproductive cycle

- Once the egg is fertilized, they will cover it with an impenetrable leathery case (mermaids purse)
- They will then go hide it
- They will then go do it again next year
- The time spent in the purse is 6-7 months
- The downfall in the shark is the finning industry
- the industry will cut off the fin and make shark fin soup
- As a result, some species are extinct and some are on the verge of extinction
- A female shark may only give birth to 5 new shark in her lifetime

Vertebrate phylogeny

- We are going to replace the skeleton with a bony skeleton
- Teeth are going to be embedded in the jaw so we don't have the same problem as sharks
- We are going to see a swim bladder or a lung
- Actinopterygii = rays
- Sacropterygii = lobed fins

Actinopterygill

- Fins supported with bony rays
- Swim bladder
- Modification of the jaw for suction feeding

Sacropterygii

- Fins supported by muscles and bones that extend into the fin

Bony fish skeleton

- We don't have fins imbedded in the body wall
- These fish can manipulate their fins
- Fish don't have to always swim
- They will not sink even though it's not moving
- This means it will spend less energy in terms of movement
- The animal is able to hover or slightly move orientation
- The fins allow for this to happen
- The maneuver fins are almost all fin because they allow agility in terms of movement

Bony fin rays

- The fins are all supported by the bony rays
- This is an autapomorphy for this group of animals

Suction feeding

- Unique way of feeding
- They have a lateral line (line of cell that runs down the length of the body)
- It picks up vibrational information coming through the water
- This means that an animal is moving in water
- These are low level vibrations; the fish have developed the ability to detect these low vibrations
- They hinged the jaw in a very unusual way
- It allows them to open the jaw very rapidly and very wide

- You now have a mechanism of capturing a prey long before they know you're there
- This is a brand new feeding mechanism and it's part of the success in these fish
- There are no teeth on the jaw
- The back of mouth has a set of teeth
- The front sucks in food and the back chews

Swim bladder

- The swim bladder is a bag of air located in the dorsal surface of the body wall
- Its a closed bag
- When the fish dives in the water, it releases oxygen from the blood into the bag
- As the fish rises into the water, it takes out the gas in the bag
- It is now capable of hovering and be neutroboyant in the water

Opercular gill

- The ability of breathing while being still
- Opercular gill: bony plate outside the fish
- When the fish breathes, it snaps the gills which blocks any water going into the ocean water
- It then opens its mouth and fills it with water in the cavity
- It then closes the mouth and pushes water out across the gills
- It can now pump water without moving its body
- predators: seahorse
- This group has gone through one more round of genomic duplication
- They have increased their biodiversity

Evolution of the tetrapod stance

- Fresh water fishes
- Fresh water environment aren't very stable; they warm up
- These fishes can stick their mouth out of the water and breathe air
- They have now muscles and support that allows them to go up at the surface of the water
- This is the beginning of the muscles to come up on land
- They involve into tetrapods

Plantae

- Important addition on land in the environment

Plantae (autapormorphies)

- Cellulase rossette: people would call this verdate
- Phragmoplast Cell division
- Plasmodesmata
- Alternation of generations: people would call this plantae

Cellulose and cellulose synthase

- Cellulose synthesis
- the cellulase gene is bacterial origin, so referring to cellulose isn't just a plant thing
- Cellulose is a series of glucose molecules
- Individual cellulose molecules can interact together through hydrogen bonding
- The more you have, they can form a microfibril
- These microfibrils put together to make a fibril

Cellulose and cellulose synthetase

- Unique way how cellulose is made by plants
- going to take glucose molecules available in the plasm
- sticks them together and turns it into a strand to be produced outside of the cell
- It's in a group of six to produce a cellulose molecules
- They then assemble to another set of six to make a cellulose fibril: rosette
- You get 36 cellulose molecules in a rosette and every plant has one
- This rosette is what makes a plant a plant
- There are thousands of them on the surface of a plant
- Those are attached to molecular motors
- The motors are attached to microtubules
- This allows cellulose to move across
- As the cell grows, it lays it down in consecutive layers
- This makes a very strong cell wall all controlled by microtubules

Primary cell wall

- You have more than just cellulose in the cell wall

Phragmoplastic cell division

- brand new way to carry out cell division
- when the cell divides, there is no cell to cell communication b/c the cell wall is between it
- Plants are able to divide with the help of microtubules
- When the signal comes to divide, all the microtubules band around the cell
- Then the microtubules disorient into microtubules to pull apart the chromosomes
- This is all happening without a centriole
- The spindles are not being governed by a centriole; we don't know what is
- they pick up vesicles
- These vesicles form a ring that gets larger and larger
- This vesicle becomes the cell plate
- It will then fuse to the outer cell wall
- The microtubules reorganize themselves to lay down the cell wall

Plasmodesmata

- The openings or holes in the interconnecting cell plates
- they have cytoplasm and endoplasmic reticular space in between the holes of the vesicles
- We have cytoplasmic and endoplasmic connectivity
- This allows cell to cell communication
- This transport; diffusion; is called a symplastic pathway (through cytoplasm)
- apoplectic transport: through cell wall

Alternation of generations in land plants

- the spores will land on the ground somewhere and become
- zygotes will come together to become a sporophyte
- when they move up on land, the spore stage has to become protected to become a sporophyte
- That's why these two are separated into 2 different parts

Sorting out plant parts on a gametophyte (n)

- Gametophyte

- Have gametangia producing gametes
 - antheridia — a sperm; plant has gone through mitotic stages to form sperm
 - archegonia — egg; gametophyte tissue that will form placental tissue to make an egg. This egg is well nourished by the placental cells
- Formed from a zygote

Sorting out plant part on a sporophyte (n)

- Sporophyte (spore plant) $2n$
 - Have sporangia producing spores
 - Form a zygote (fusion of sperm and egg)
- There is no zygote released, the sperm will come to the egg inside

Transitions to land (plants)

- Water conservation
 - across exchange surfaces
 - across body wall in general
- Protect the gametes against drying out
- Support system (gravity)
 - once we are out of water, we have no support from water buoyancy
 - plants need to lift themselves off the substrate to reach the sun

Liverwort

- Earliest and simple plants
- Masses of photosynthetic cells called a thallus
- Its a structure with no vascular tissue
- apoplectic transport is important for the movement of water
- 2 structures: umbrella-like structure (egg) & flat-like structure

Pores and rhizoid

- The tissue is divided into 2 layers: the photosynthetic layer and the storage layer
- rhizoid: kind of like roots without any vascular tissues; rely on transport from above
- This is why these plants don't get particularly big
- they have air pores that allow CO_2 to come in for photosynthesis
- This space under the epidermis is dangerous in terms of water loss
- So the liverwort live in moist places

Archegonia & antheridia

- archegonia has chains waiting to receive sperm
- The dots on the antheridia are sperm ready to be released

Liverwort life cycle

- How does sperm swim to the eggs? With rainfall
- When it rains, rain droplets hit the surface of an antheridia and they splash up
- When they splash up, they will hit the archegonia waiting ahead
- This is called splash fertilization
- The chances of splash fertilization and hitting the neighbour is minimal
- So, they self-fertilize
- The sperm is going to fertilize the archegonia to form a sporophyte

- the sporophyte matures and pops out

Gemma cups (asexual)

- Inside the gemma cups are little tissues that allow to splash up
- Second way for fertilization

Plant phylogeny

What happens next is we close the pore

Which will allow little water to leave

meristem: cells that can differentiate into very different structures, they are called determinate because they will differentiate into one structure

Stomatophyta:

1. stomata, determinate meristem

Transition to land — water conservation

- Stomate: set of guard cells that open and close based on CO₂
- Guard cells
 - there are 2 of them and when the cellulose cell wall is laid down, its laid down in such way that the now of the outer surface cannot change and the inner surface can (it's stretchy)
- We now have a way of regulating the opening

Meristem

Meristem is a primordial cell, a cell that is going to differentiate into a cell

This meristem is base tissue

It can piece off to another cell, this is b/c of indeterminate meristems

- Determinate
 - cells that will differentiate into specialized cell
- Indeterminate
 - cells that will differentiate into anything but can also turn into more indeterminate stems
 - Its a self propagating tissue
 - it can generate new meristems itself

Mosses

- we've now added the stomata so we now have better water regulation occurring
- we've now got this determinate meristem
- but we still have the problem of the spores

Moss anatomy

- Female gametophyte is being spertilized
- The spores still remain on the gametophyte
- We getter a better water casement in this group
- We still have a plant with another plant going out of it
- The diploid zygote undergoes cell division and creates this stock that pushes up into the air that gives us the sporophyte
- By pushing the structure into the air, the spores are distant to the plant and up in the air so the spores will go farther away with the wind

Moss life cycle

- The sperm will still have to swim to the egg
- We still have splash fertilization
- We still haven't solved the swimming issue
- But the good thing that happens is that the spore cells sit at the top of the capsule
- All of those little spores are in the water proof capsule
- When the time comes, the capsule will rupture and the spores will leave into the wind current
- The spores themselves are haploid
- It will land and grow to a protonema
- It will go into a gametophyte that is either a male or female
- The good thing here is that the spores in the capsule will launch out
- The gametophyte stage is pushed further apart away from the parent plant
- We still have some sort of self-fertilization though so it is not completely gone
- But the spore distribution gives us a better chance to have two distinct different sexes

Early Devonian

- Plates are beginning to fuse
- Which will begin to form the pangea
- Populating the land with plants that are successful

Devonian terrestrial environment

- The plants on earth do not have seeds
- We are finally going to get vascular tissue to make the plant grown and hold itself up
- In the Devonian, we will move to the indeterminate meristem

Tracheophyta

1. Indeterminate meristem
2. Lignified secondary cell wall, trachea cells, and sieve elements long-lived sporophyte
 - We move to indeterminate meristem
 - Sporophyte stage is beginning to dominate
 - Sphagnum mosses: sets the stage for tracheal and vascular tissue, secreted into the cell matrix phenolic compounds
 - Bacteria: protect cell wall from being broken down, why it was used as medicine to promote wound healing

The early mosses secreted into the cell wall cellulose.

The sphagnum mosses started to secrete phenolic compounds into the cellulose walls to protect themselves. The phenolics will prevent bacteria growth and promote healing

Lignin

- Hydrophobic (because of the phenolic rings)
 - the water will not react with the cell wall
 - we end up with a tube that if we have water on the bottom, the water will try to get away from the hydrophobic wall and so it will start pulling up the water towards the top to escape
 - This is the beginnings of vascularity of plants
 - there is now a rigidity in the cell
- Indigestible (it cannot be broken down)
- Bacterial and fungal lignases (they will finally figure out how to break lignin down)
- Toxic to bacteria (prevents things from breaking down the cellulose wall)
- When you get cellulose wall with lignin in it, it can't be decomposed, so it ends up fossilizing

- There is a biomass that is accumulating with nothing to be able to break it down
- So there is a huge amount of plants that fossilized and it doesn't go away until the bacteria come in

Evolution of plant vascular tissue

- a complete line of lignin in the cell wall
- Lignin starts off as simple rings
- Gives the plant vascular its rigidity
- Become solid surface with small pits or openings in it

Tracheids

- Referred to as second cell wall
- Line end to end of length of plant
- what is unusual about them is that they have to die
- When they die, the cytoplasm disappears from the cell
- There is now the hydrophobic material
- When you have bundles of them, they will form the xylem

Sieve tube elements

- A cell
- They come in pairs and they are alive
- They also stay alive
- There is a cytoplasmic connection between the two cells
- There are also companion cells beside them

Vascular flow

- The companion cells moves glucose in and out
- It will either take out the glucose or bring it to another cell
- The sugar concentration of the sieve element goes up
- Increasing sugar draws water into the sieve element from the tracheid cell
- Turgor pressure: the buildup of the pressure of the water but the cell cannot swell
- At the other end of the sieve element (phloem) theres another companion cell that takes out the sugar from the phloem fluid.
- The bottom is called the sink
- Taking sugar, pushing it into the sieve element, causing a pull of a water into the tube,
- All being assisted by the xylem and the companion cells
- The sieve elements are not structural, their goal is to bring the sugar into the cel

Evolutionary trend in plant life cycles

- There is a slow and gradual shift in the life cycle of the plant
- We are minimizing the time in the gametophyte stage

Mass extinctions

- End devonian: for the first time, there is a organic material from the nonvascular plants when they die to flood into the oceans that has never been there before. That material promotes bacterial growth and the oxygen levels drop in the oceans. There is so much plant mass accumulating that it is producing a lot of CO₂ level in the oceans, this then changes the CO₂ balance on the planet. This decreases the greenhouse effect and there is a cooling of the planet. The reef disappear at this point in time

- The change in the temperatures in the oceans (temperatures drop) kills off all of the reefs at this point of time, this also has an effect

Carboniferous and Permian

- The carboniferous gets its name b/c this is when the vascular plants are going to take off
- The plants are going to be really huge
- They will lay down all the carbon and coal deposits that we use as fossil fuels today
- It will end with the Permian
- The permian is the biggest mass extinction that occurred on the planet

Early Carboniferous 356 Ma

- Very moist, wet and damp time on earth
- The continents are starting to get together
- They are starting to be in the position of pangea
- This is going to allow the sort of global diversification on the planet that will get pulled apart later on
- And so we end up with the beginnings of one large continental or block thats all attached to each other

Carboniferous terrestrial environment

- A carboniferous is a place that if you walked in a carboniferous forest, you wouldn't recognize it at all
- The big trees that are 35-40 feet tall are represented today by what are very small sort of relic species in the forests
-

Carboniferous coral forests

- Club mosses
- Giant horse tails
- Tree ferns

Plant phylogeny

1. True leaves, chloroplast DNA inversion
 - We actually develop true leaves
 - We get photosynthetic tissue that has transport and vascular tissue in it
 - We are now taking the photosynthetic surfaces and not relying on symplastic transport by cytoplasm to move things around
 - We now have tracheal and sieve tubes all the way into these photosynthetic structures that are all over the surfaces of the plant
 - There is a really weird inverted repeat in the monilophyta, gymnosperms, and angiosperms
 - There is a whole string of DNA that has inverted and repeated in the chloroplast DNA
 - Every single plant in these three groups, (these are going to be the ferns, the conifers, the flowering plants) has that inverted piece of DNA in the chloroplasts
 - So we know they are all related b/c of that invertedness

Ferns

- Do a number of things that start resolve issues in terms of the dispersion of the spores
- The top of the ferns is the sporophyte

Fern life-cycle

- The leptosporangia are firing the spores into the air
- The spores land on the ground
- They germinate
- You get a little plant
- It proliferates like crazy
- And then you get this little heart shaped type of structure with roots on one side and on it are going to be both antheridium and archegonium
- Water is going to hit this mature gametophyte and that's going to allow the sperm to disperse and then try to get into an archegonium
- If we've dispersed our spores, chances are the little one that's next to you may be from a different plant
- when the rain comes, the splash-fertilization may form a zygote from two different ferns
- The zygote will undergo divisions and that will become the sporophyte
- The sporophyte will grow up and out of the gametophyte

Leptosporangia

- fern frond
- little brown spots underneath where we are going to produce the spores
- very specialized structures in terms of how they are formed b/c these are not simple spore sacks that are going to release the spores and hope for the best
- The little brown spots underneath the leaves are specialized for the production of the spores
- These brown spots are called leptosporangia
- These leptosporangia have the ability to launch the spores out
- These are named leptosporangia because they have a launching structure that surrounds the spores that are being produced inside
- The cells that make up the leptosporangia has an extremely thick cell wall
- The thick cell wall is attached to a thin cell wall
- When it becomes time for the spores to be released, the water volume on the inside (between the thick and thin cell walls) decreases
- When water is removed, the volume inside decreases and causes the thin cell wall to bulge in
- As it starts to bulge in, it causes the structure of the kernel of the fern to straighten out
- It has all the spores sitting there but it will get to a point where the cells rupture because they can't put up with all the tension
- Then the cell wall breaks, the elasticity returns to normal and the spores get shot
- This ensures that the spores disperse away from the parent plant
- When the gametophyte forms away from the parent, maybe there is going to be a gametophyte from a completely different fern beside it and it could get fertilized from that other gametophyte
- you still have splash fertilization but at least it's not going to be from the same fern

Gametophyte and germinating sporophyte

- You have an indeterminate meristem that goes down and produces a root
- You now have an indeterminate meristem that goes up to produce a leaf
- These allow some photosynthetic surfaces to make their appearance in history
- The gametophyte is short lived, it will ultimately die

- We are now able to enhance dispersion of the spores in the hopes that when gametophytes are produced, they are not all surrounded by gametophytes from the same plants
- gives us genetic mixing

Plant phylogeny

1. Seeds

- The seed is the solution to the fertilization from a completely different organism

Spores vs Seeds

- homosporous: male and female are in one place
 - spores are going to produce both gametophyte sexes
 - you cannot tell the difference between the male and female
- Heterosporous
 - starts to appear
 - instead of a spore producing male and female (antheridia and archegonia)
 - You get spores that produce male gametophyte, and spores producing female gametophyte
 - the males are smaller and females larger
 - females are larger because they will make the nourishment for the egg
- The female megaspore will be put inside a structure and it's going to stay on the plant
- There is now a female gametophyte growing on the sporophyte plant but somewhere else on that plant we are going to produce the male spores
- Those male spores are going to be dispersed
- We are going to hope the male spore lands on the female gametophyte
- That dispersing spore is going to undergo a differentiation to become pollen
- The pollen grain is actually the male gametophyte
- When we pollenate, we are moving male gametophytes (not the spores anymore) through the air for fertilization

Conifers (Gymnosperms)

- first ones to do this ^^

Cones (Strobila)

- The bottom of the tree has male cones that have microspores
- We get male pollen from the bottom of the tree
- The top of the tree has female
- The pinecone are often close because they are fertilized and have a seed in there
- They will ultimately open to release the seed
- The pollen will be released to the wind
- It is highly unlikely that the wind will bring the pollen from the bottom to the top of the tree
- So the wind will bring the pollen to other trees around
- This helps prevent self-fertilization

Conifer life cycle

- We have microspores inside the male cone
- You have to remember that this is a sporophyte (2n)
- Inside there is the spore mother cell (the first cell that will undergo meiosis)
- Meiosis will produce 4 meiotic products
- Those meiotic products will undergo hundred-thousands of mitotic divisions to produce more

- They will be packaged up as the pollen grain that will be taken up by the wind
- The top of the tree has the female cones
- Inside them is a megaspore
- This is the diploid cell that is going to undergo meiosis
- When it undergoes meiosis it's going to discard 3 of the 4 products
- That one cell will undergo modifications and sit and wait for the arrival of the pollen grain
- When the pollen grain arrives, it will land on the opening and the nuclear material of the pollen grain to fertilize the egg will be transferred

Gymnosperm pollen

- The microspore mother cell undergoes meiosis to produce 4 products
- Those products undergo thousands of mitotic divisions to produce more copies
- And then they undergo 2 cell divisions to finally form the pollen grain
- The pollen grain is produced by the cells of which 2 are the most important:
- There is the tube cell and the generative cell
- The other two cells (prothallial & wings) are primarily involved in making and shaping the pollen grain
- And so the gymnosperm pollen is made of 4 cells
- The generative cell is going to make the nuclear material to combine with the egg nucleus
- The shape and wings enhances the movement of the pollen grain in the wind
- The pollen is a large grain

Gymnosperm seed formation

- The pollen falls in the female surface opening
 - As soon as it falls in, the thing (the scales) will close up
 - The pollen grain will then germinate
 - The tube cell will make (mine) a passage way to the egg
 - Meanwhile, the megaspore has undergone a it's 4 cell divisions of which 3 have disappeared and its now sitting waiting for the pollen to come
 - The tube cell burrows its way down
 - The generative cell follows in behind and makes its way down to get fertilization
 - It takes 1 year and a half in a pine tree for this to happen
 - Then the zygote that's been fertilized is going to undergo cell division to become a female gametophyte
 - the cell enlarges to become a female gametophyte
 - And ultimately there is going to be an archegonia that will fertilize the egg
- (The archegonia is found on the female gametophyte. Here we are heterosporous. So you find the archegonia only on the female gametophyte and the antheridium only on the male gametophyte. In the pine life cycle here, the antheridium becomes the mitotic events that create the pollen. The archegonium will be where we get the one egg sitting and waiting for the pollen to arrive)
- The gametophyte is being internalized, receives the sperm and then nourishes it as we develop

Gymnosperm seeds

- You've got the embryo that has just been produced from the diploid cell when we got our fertilization

- This embryo is going to be the new sporophyte
- the female gametophyte is still there feeding the seed with rich nutrients
- So you end up with our embryo surrounded by the remains of the female gametophyte which are rich in nutrients to supply it
- The female gametophyte was imbedded in the parent plant
- So what you've got is casing from the parent plant surrounding the whole thing
- A seed is actually 3 generations
 - inside the new sporophyte (embryo)
 - A reserve of supplies from the generation before it (gametophyte)
 - The parent that built that gametophyte is protecting it with a shell
- The shell is highly waterproof and can be released into the environment and when it finds the right conditions, the baby sporophyte inside can germinate out
- We really never see the whole gametophyte stage b/c its locked inside the plant
- The male gametophyte is also locked inside the pollen grain
- All female cones prepare for the arrival of a pollen but not always is there fertilization
- There is also a huge amount of pollen being produced that never makes it to the plant (The fix for that is when we get to the flowering plant)

Fungi

- Lignified plant material is building up but there is nobody to break it down. The bacteria and the fungi develop a way to break down lignin, use it as a resource and get at the cellulose
- The fungi is more able to do this
- Fungi are absorptive heterotrophs
- The fungi have strands of filaments that are arranged end to end of single cells

Unique fungal terms

- Septa, hypha and mycelia
- Hypha: single strand of cells
- Mycelia: when the strands are wound around each other
- Each of the cell is able to absorb the nutrients from the environment around it

- Septa. The fungi develop septal walls in between their cells. This happens later in the fungi organism. The question was how do you get different types of cells when they are all connected together? Well the septal walls solved this problem. Instead of just simple mycelia, you get complex structures.

- you have a cell, (fungi are haploid)
- When these cells divide, all of a sudden there is a second nucleus and the cell just keeps getting bigger
- After a certain time one of those cells have a strand with a whole bunch of nuclei
- Those nuclei represent what happened in the cell's divisions
- But cell walls and plasma membranes never developed in between
- You basically have a growing cell with nothing inside except the nuclei
- The only evidence that the cell has undergone cell division is because of the increased number of nuclei
- These nuclei add on at the growing tip of the cell
- There's no barriers as a consequence of the cell division so this allows cell to cell communication

- One of the secrets to the fungi is that they can use cytoplasmic transport down the length of all those fibres and they can distribute the nutrients to everybody down the whole length of the fungus
- It does create a problem for mitotic division
- There is no distinction of where one cell ends and where one begins
- So the fungi do a completely different type of cell division

Division:

- The chromosomes line up in the middle
 - What we have is a microtubule organizing region at each pole of the cell
 - Pole-spindle bodies: there are the microtubules set on the inside of the cell and those on the outside of the cell
 - The microtubules inside pull the chromosomes to the opposite ends
 - Then the nuclear envelope evaginates to form two nuclei
 - The microtubules on the outside drag the nucleus to its appropriate end
 - As the hypha extends, the nuclei extends behind it and they are all evenly spaced to be able to provide the nuclear material along the whole length of the strand
 - The fungi are also absorbing the nutrients on their body surface and pass it along the cytoplasm to be able to supply everything that's there
-
- The problem with fungi is when they mate
 - Two different fungi meet up; Type A and Type B
 - When they meet up, they fuse their cell membranes and put septal walls in-between their nuclei
 - There is now 2 nuclei in that cell (where they fuse)
 - The cell will undergo cell division and produce two new cells with two nuclei
 - So we end up with a situation where in the mating sequence, there is a fusion of two cells (plasmogamy)
 - We put the wall in-between and then we get a cell with two nuclei (dikaryotic cell)
 - When it does come the time for the cell to reproduce sexually, those nuclei will fuse (karyogamy) at a later time, form a diploid nucleus that will immediately undergo meiosis to produce haploid
 - The part where the haploid nucleus immediately get together to form a zygote in the plants and animals is delayed in the fungi

More Fungal Terms

- Plasmogamy
 - dikaryote cell
 - Two cells fuse together
- Karyogamy
 - Diploid cell
 - When we fuse the two nuclei
 - this doesn't happen in plants and animals
- Meiosis
 - Haploid cells

Typical fungal life cycle

- Spore producing cells (haploid cells) are being released from the fungus
- The spores will undergo growth through mitosis into the mycelium interconnected cells
- Some fungal colonies are one individual that can be over a mile in diameter

- When the time comes, two different strands combine and then we get the two cells that combine together that has the two nuclei
- We refer to this part as “n+n” because the two nuclei haven't fused together yet
- This can continue to grow
- So now you can have a fungus that has both types of mycelia (dikaryotic and monokaryotic)
- Ultimately when the signal is right, one of those diploid dikaryotic cells will allow the nuclei to fuse to form a zygote
- It will then undergo one mitotic division to produce 4 spores
- The spores will then be released to grow back into mycelium

Basidiomycota life cycle

- In the soils, are the monokaryotic and dikaryotic mycelia that are absorbing the nutrients from all of the plant material that they are breaking down
- They are transporting all of the nutrients between them
- underground, dikaryotic mycelia will form bundles (complex structures)
- When it becomes time, all of the other mycelia will absorb water and transport it down the mycelia into the dikaryotic mycelia
- And a mushroom will come up from under the ground
- The structure will be underground already in a deflated state and after water, the structure will pump up
- That is why you could get mushrooms form overnight

- In the gills, you have a dykariotic cells that will undergo meiosis to make 4 products attached to that stock

Basidiospore's

- Underneath the umbrella of a mushroom, there is a stock (basidium) with 4 spores (basidiospores)
- You can get millions of combinations of the zygote and the egg in the gills
- Each spore is going to be genetically different from the other one
- The mushroom is shooting out huge amount of variation that is not possible in plants and animals
- That is what makes them their massive diversification

Fungal mutualism

- something about fungi that is really important in terms of the colonization of the terrestrial environment
- a plant grown in the presence of fungi does better than the one in the absence of fungi
- There is been a long history of plants and fungi forming mutualistic association
- When the fungi secrete the enzymes to digest the material around them, they also do acid digestions
- They create acidic environments
- This solubilizes minerals that are in the rocks and substrates
- This causes the plants to use those minerals as nutrients
- At the same time, the plant is leaking out some of its glucose to the fungus to be able to provide it with a carbohydrate reserve

Types of fungal mutualism

Ectomycoorhizal fungi (EMF)

- When we look at plant roots, we can see some form of fungal association
- One of them is where the fungal cells wrap themselves around the surface of the root
- This is referred to as ectomycorrhizal
- ectomycorrhizal: fungal filaments on the outside
- you have a lot of little tubules of the fungi that are increasing the surface area of the plants

Arbuscular mycorrhizal fungi (AMF)

- The fungal filaments penetrate inside some of the plant cells
- They elaborate into these great big surface areas to be able to supply the cells with minerals
- In turn, the plant is providing glucose to the fungus

Fungi –Lichens

- A group of fungi
- Highly specialized organisms
- They can withstand all kinds of adverse conditions
- They can dry completely out: you can take them and crush them to a powder
- They are made of 2 organisms, cyanobacteria (original creators of photosynthesis) and photobionts
- The fungi wind their mycelia and hypha around bacterial cells and form clusters
- These clusters are referred to as photobionts
- The fungus is taking minerals from the soil
- They pass the minerals to the cyanobacterium
- The cyanobacterium are using the minerals to make glucose
- The fungi placed the photobionts up on the surface where the sunlight is
- The photobionts are supplying glucose too
- There is now a mutualism between the fungi and a bacterial cell
- Tells us that fungi have an important interface with photosynthetic organisms

Arthropoda

- Articulated exoskeleton of plates
- Muscles arranged in bands
- Compound eye
- The arthropods came up on land when the spore forming plants became dominant
- This became a food source for the arthropods
- They are the first to tap into this really rich resource that's there

Insect external anatomy (Tagmatization)

- There is one ancestral insect to all of the forms that come up on land
- Tagmatization: took appendages on segments, fused them together to have one specific function
- We have three tagma
- The first tagma is the head:
 - its made from 6 tagma
 - On the head there are sensory antennas and feeding appendages
 - The head is a tagma that's being specialized for sensory input and feeding
- 2nd tagma Thorax:
 - composed of 3 segments
 - strictly used for locomotion and movement

- if you open it up, you will see just muscle (digestive tract)
- Its a block of muscle to assist the legs
- 3rd tagma Abdomen:
 - where all the functions of life occur
 - the big plates of the abdomen allows them to expand in length and diameter
 - When the insect takes in a large meal, it can expand its expanded admonen
 - The female is able to allow an expanded abdomen for the egg
- All insects have a head, thorax, and abdomen
- They all have the same morphological tagma but they each modify the appendages

Compound eye

- Unique visual system
- The eye is composed of a whole set of photoreceptors
- Each one of those circles are photoreceptors
- They consist of a lens that collects light from part of the photoreceptor's visual field
- The light is bent and refracted so what you end up is a blurring of everything
- the signal is sent down the retinular cell
- Retinular cell (sensitive cell): composed of 3 different light ray frequencies
- The light is going to be recorded in terms of what levels of light are there (in terms of the three intensities) and the cells respond accordingly
- The insect doesn't see red, it sees ultraviolet as it's 3rd receptor

Mosaic model

- The insect sees a pixelated screen (we are putting together dots of light)
- As we add more and more resolution, it gets better
- You can see more and more

Insect movement: Flight and wing holding mechanism

- Ancestral insects didn't fly
- It came along later
- Flying and folding back the wings after allows them to walk around
- Flight was a big thing because it allows the insects to disperse, move around to different environments
- This allowed them to change areas to a better environment for feeding
- An example would be the monarch butterfly
- When predators make an appearance, the insects can fly out to escape

Cuticle — Exoskeleton

- When things come up on land, we also have to waterproof the body
- The insects have a very unique way of doing that
- Cuticle is divided into 2 components
 - One is the pro cuticle: where we have the protein and the chitin reinforcing rods
 - Epicuticle: outer layer layered with wax to waterproof the whole body of the insect; extra layer on top of the pro cuticle
- Epicuticle is such an effective waterproofing agent that you can buy it (shellac)
- The insect sucks out plant sap on a tree and spins a rigid foam on the outside to live underneath that foam, this is the epicuticle
- Shellac is liquified insect epicuticle

Insect reproduction

- We still need to waterproof sperm transfer
- In internal fertilization, some groups will pass the sperm directly into the female
- But more frequently they produce a spermatophore (sperm package)
- Spermatophore: you put the sperm in a waterproof container so that when you do pass it to the female, there is no chance that the sperm will dry out
- The female waterproofs her egg by putting a shell around it; there is only one opening to the egg, to be able to fertilize it
- This morphology is so successful, it dominated

Tetrapod

- Tetrapod stance with appendicular skeleton of fore- and hind-limb
- They are descendants of the low finned fish limbs when they came up on land

Amphibia

- Buccal force breathing
- Skin is primary respiratory organ

Amphibians

- Amphibians are a hugely diverse group of which the vast majority have disappeared
- The reptiles will displace the amphibians as the dominant tetrapods on the planet when they come along
- The model of the very first amphibian looks nothing like a salamander or frog we see today

Buccal force respiration

- Breathing is how we recognize the group
- Because amphibians, reptiles, and mammals have slightly different ways in which they breathe
- All amphibians have different breathing styles
- The frog pushes air into their lungs
- Frogs have lungs inherited from the lungfish
- The ancestor frog gulps air 3 or 4 times and pushes it into the lungs
- This inflates the lungs
- To expel the air, its body wall (the musculature) squeezes it out

Amphibian skin

- The most important thing is the amphibian skin as their main respiratory structure
- Frogs and amphibians (the earliest ones) needed to keep their skin moist
- To keep it moist they had a whole set of glands that produced liquids that oozed over the surface if they were not in water
- They cant dry out when they come up to land or else they would suffocate
- They lose their protective scales and coverings that were in the fish ancestors
- Amphibians have poison glands for predators
- Some of the most toxic chemicals out there are from amphibians

Amphibian food

- They adapted to a food source as they are on land
- The insects were already dominant in the atmosphere as they came up on land
- What the ancestor was trying is to be able to catch these insects

- To catch them, they use their tongue
- They shoot out their tongue and are able to stick/grab an insect and pull it back in
- This feeding became dominant and so they changed their body to accommodate this way of feeding (redesigned bone structure associated with the jaw)
- They hinged the tongue at the front instead of the back
- This allows them to use the whole length of the tongue in terms of hunting
- This group figures out how to feed on the dominant animals that were there
- This group is the next group on land

Amphibian locomotion

- The amphibians only partially solved the problem with gravity
- When they have to start walking, they have to push themselves up
- The limbs of the amphibians are on the sides so they have to push themselves up and try to move at the same time with their limbs
- The lateral motion of swimming in ancestors in the fish is still there in the first amphibians
- This problem gets fixed in reptiles where they get their limbs on the bottom of their bodies

Amphibian life cycle

- All amphibians need to go back to water to lay their eggs and for their young to develop

Mass extinctions

- The end of the permian is the largest mass extinction to occur on the planet
- Over 90% of all of the organisms in the oceans are gone
- What will be left are some survivors that will diversify

Types of extinction

- Background extinction
- Mass extinctions
- The life span of most species lasts about 10 million years
- There's a gradual change on the planet — background extinction
- In a mass extinction, more than 50% of the genera are gone afterwards
- We are now officially in the middle of the 6th mass extinction on the planet

Causes of mass extinctions

- Asteroid impacts: at the end of the cenozoic (doesn't actually happen)
- Elevated Carbon dioxide
 - Flood basalts: probably one of the main culprits
 - Volcanoes: volcanoes would erupt, spew greenhouse gases and change the temperature of the planet and cause mass extinctions (they now know that there's no way)
 - Gas hydrates
- Marine anoxia
 - two causes:
 - a large amount of organic amount in the oceans
 - an elevated amount of gases warms the planet, warms the oceans, and decreases the oxygen levels in the oceans
- Sea level changes

Flood basalts

- When the continents are drifting apart, the crust of the earth gets very thin and there can be an upwelling amount of magma underneath that comes poring onto the surface
- Flood basalts are geological features around the earth
- Fields of magma that have solidified are 100s to 1000s of square miles
- They form high mountains
- A lot of magma poring out of the earth at one specific time

Gas hydrates

- Sitting at the bottom of the oceans there is a group called the methanogens
- In the deepest parts of the oceans, when they produce methane, it doesn't come out as gas b/c of the pressure of the water
- Instead, it crystallizes out as a solid crystal of methane interlaced as frozen water
- That is what's called a gas hydrate
- The gas hydrates have been building up
- If you can go down there and get it, you will get naturally compressed liquified gas
- If the oceans warm up or if the water levels drop, the pressure on gas hydrates decreases causes them to release the liquified methane
- If they release the methane in huge quantities, that's even more greenhouse gases being put on the planet

- The permian was such a dramatic extinction b/c it had the perfect storm:
- huge release of flood basalts, warming temperature, the depth of oceans changing, things dying and increasing the inorganic materials in the oceans

Surviving mass extinctions

- Plants: they were reproducing by spores and spores were blown around everywhere
- Insects: mostly survived in the permian
- Small size and global distribution
- Generalist life style (specialized organisms disappeared)