Phanerozoic Eon-Paleozoic Era Nov. 2015
*Explosion of Multicellular Life

1 Intro
- By the end of Proterozoic, we are going to see the multicellular life arise.
- Broken down into 3 Eras:
  - Paleozoic Era
    - Cambrian 550-448 Ma
    - Ordovician 488-416 Ma
    - Silurian and Devonian-Single cell plants start to form multicellular plants in the edges of the oceans. The devonian is called the Ages of Plants. This is when they start to move up on land.
    - Carboniferous: so many plant materials. Time animals start to move up on land and use food.
    - Permian
- Cambrian Explosion
  - One of the most diverse period of time in terms of animal variation

4-5
- Continental shells
  - Very rich area. Shallow that allows life processes to occur
  - Have continental shell sitting on the equator where there's the best temp. and diverse life
- Cambrian and Ordovician Periods
  - Their appearance looks weird.
  - The way they were preserved was different where they went to an area deep into the ocean where their was no oxygen and that's where they fossilized.
  - Burgess shales-Yoho National park
    - Area to find these fossils.
    - Challenge is to figure out what happened.
- Ever since the Cambrian explosion we've lost diversity in organisms
- Fossils: In Siberia, there should be the same fossils from that ancient ocean.

Cambrian and Ordovician
- Incredible array of organisms that weren't thought to fossilized did fossilize.
- Why did the population weird looking organisms all arise at once.

9 Burgess Shales
- Choanocyte
  - Consists of a cell body with microvilli and a flagellum
  - Constant stream of water going through the sieve(microvilli).
  - Water being beng through microvilli and take in nutrients by phagocytosis.
  - They exist today in clusters or mats.
  - Five choanocytes working together will get a better water flow, more food particles to take in and increases fitness

	➢ Ancestors to all animals ➢ Tells us that we are all descendant from a cell that looks something like this.
10 Animalia Cladogram Autapomorphies ➢ Multicellular eukaryotes ➢ Ingestive Heterotrophs ➢ Cells with different functions ○ Other than reproduction ○ Cells stick together. ➢ Choanocytes ○ Sits at the bottom of fungal ○ Common Ancestor ➢ Collagen ○ Common in all animals collagen. A sticky substance that stick cells together. ➢ First group we see in animalia is the porifera	12 ➢ Tissues ○ Cells communicating w/ each other in some way ○ One group that doesn't and some will have diploblastic or triploblastic ○ Three embryonic layers: ectoderm, endoderm and mesoderm-Used to make muscle ➢ Symmetry ○ Asymmetry ○ Radial ■ Cut in more than one way ex: Jellyfish ○ Bilateral Symmetry ■ Able to cut in one direction ■ Usually an organism that moves ➢ Embryology ○ Protostome and deuterostome ➢ Body Cavities ○ Coelomate, pseudocoelomate, acoelomate
13 Porifera- Sponges ➢ Use of choanocytes in an aquiferous system ○ Organisms that have choanocytes today ➢ When you look at cells in sponge, they don't have cell-to-cell communication ➢ Cells are independent ➢ NO tissues ➢ Totipotent Cells-Any cell in the body can turn anyone of the cells. They can all turn into each other if needed. ➢ An organism made up entirely stem cells. ➢ Asymmetric body plan	14 Colonial choanoflagellates ➢ Choanocytes lines up inner surface of cavity ○ Spongocoel pushes out water through the osculum ○ Choanoderm- a derm made of choanocytes ○ Pinacoderm- cells that stick together to make an outer surface made of pinacocytes ○ *Mesohyal- forms an adhesive ○ Gives food to an amoebas ○ amoebocytes- able to differentiate into different cells functions ○ Spicules- made of protein

	mesh. This gives sponge its shape ➢ Diversified in huge numbers ➢ Around for millions of years
15 Sponge Sex ➢ Choanocytes become sperm ➢ Archeocytes same as amoebocytes form an egg ➢ Sperm gets trapped into the microvilli which is recognized by the sponges as their own ➢ Gametic isolation was one of the key events for animals ➢ Original form of reproduction in animals was to just spread their	16 Platyhelminthes ➢ Gap(septate) junctions-loss of choanocyte ○ have cell to cell communication ○ An organism that has an external and internal epithelium that is two cell layer(diploblastic) ➢ True tissues with all components
17 gap(septate) junctions ➢ Can open and close	18 Tissues ➢ No tissues ➢ Diploblastic Gastrulation ➢ Blastula- a hollow ball of cell ➢ A cellular lining is formed and this lining is called a gastrula. The centre is specialized and becomes a mouth. This creates a digestive epithelium.
21 Symmetry and cephalization ➢ Bilateral ○ Centralized their nervous system	22 Cnidaria-Jellyfish ➢ Cnidocytes ○ Used to collect their food ○ Stinging cells ○ Only found in this group ○ Contains a discharge, this contains barbs and poison to immobilize prey ○ Shoots out strong force because they feed on very first organisms. This needs to be done in order to pierce through their body. ➢ Predatory Group ➢ Polyp Body plan ○ Don't have muscle so they move very uniquely ○ A U-shaped with tentacles surrounding it ○ Two cell layer:outer layer-epidermis and gastrodermis-a stomach lining ○ First organism to have a

	skeleton ■ Original Role of a skeleton was to lengthen muscle ○ Myoneme- a strand of muscle arranged in a circle around the central cavity. ➢ UNIQUE:Epithelial Musculature ○ myoneme that is arranged longitudinally ○ When muscles contract the jellyfish turns into a balloon shape and then it contracts it goes back to its original shape ➢ Only organism that uses epithelial muscle ➢ It has a mouth but has no anus. Referred to as incomplete digestive system. ➢ Polyp is an ancestral form
25 Cnidaria ➢ Mesoglea- matrix between tissues. An incompressible gel matrix. ➢ HYdrostatic skeleton ○ Jellyfish dependant on it	26 Jellyfish Reproduction ➢ A sessile organism ➢ Gonozoid- will produce little medusa and will release sperm and egg. If it becomes fertilized it become a zygote then become a planula larvae
27-29 Corals ➢ Cambrian is 550 million years ago. BUT the corals were 650 million years ago?!!? ➢ All coral reefs of the worlds are built by miniature polyps ➢ Most biodiverse habitats in the world ➢ Create microhabitats to maintain biodiversity for organisms ➢ Some were even embedded in mountaintops. ➢ Major modifiers of the ocean ➢ Most of our corals today have co-evolved with algals, Have a symbiotic relationship with algae and coral. Need each other the survive ➢ Coral bleaching- Corals losing algal symbiont due to temperature rising. ➢ Major builders of the planet.	30. Animal ➢ Tissues→ Triploblastic ○ Presence of mesoderm and arrival of musculature ○ Animal Architecture Symmetry ➢ Asymmetry ex:Porifera ➢ Radial ex.Cnidarians ➢ Bilateral symmetry Embryology ➢ Protostome ➢ Deuterostome Body Cavity ➢ Coelomate ➢ pseudocoelomate ➢ acoelomate

31-32 Embryology

- Cleavage
  - When the shift occurs it looks like they do a spiral to sit on top of each other. Spiral Cleavage
  - Radial Cleavage
- Gastrulation
- Where is the mouth of the organism
  - These cells invaginated
  - When these cells create an opposite side they have a linear digestive tract. A digestive tract with two openings
  - Have now a linear processing of the food
  - Blastopore becomes the mouth
  - Protostome- the first opening becomes the mouth
  - Deuterostome- the second opening becomes the mouth
    - blastopore becomes the anus
- Coelom formation
  - Mesoderm cells starts to make a solid mass of tissue and proliferate
  - You end up with a mesodermal filling up the space b/w ecto and endoderm.
  - 2nd type- Mesoderm proliferate to make a pocket.
  - Enterocoel- a cavity formed from gut tissue

34 Protostomes vs. deuterostomes

- Can divide them into two lineages: protostomes and deuterostomes
- Deuterostomes

35 Body Cavities

- When mesoderms forms it forms simultaneously with a body cavity
- Pseudocoelomate- have a body cavity but have a partial mesoderm

36 Body Cavities

- Acoelomate
- Coelomate
  - Has a mesoderm on the outside and inside
- Pseudocoelomate
  - the gut has no mesoderm associated with digestive tract

Protostomia- Autapomorphy

- Blastopore is more

40 Ecdysozoa

- Have a suit of armour that animals

➢ Platyhelminthes ex, of an acoelomates	live inside. ➢ Ecdysozoa ○ Their shell has a fixed size. A process called moulting or ecdysis occurs when they must shed their old shell because they're growing. ➢ Platyzoa ➢ Lophotrochozoa ○ They were unusually different from each other that they weren't thought to share a common ancestor. ○ However, they have similar molecular makeup ○ lophophore or trochophore it's never both. ○ A taxonomic name was created whether they have one thing or the other..
Ecdysozoa ➢ Has no cilia on surface ➢ every single animal group has a cilia ➢ Moulted protein cuticle ➢	Symplesiomorphies ➢ Get rid of the circular muscles, they only have longitudinal muscles ➢ Nematoda ○ Have a unique epithelial muscular pharynx ○
45-46 Nematoda Pseudocoelomate ➢ ex: Nematodes ➢ Have an outer rigid, elastic cuticle ➢ They're usually found in soils. They feed on bacteria and single celled organisms. ➢ HUge diversity of these out there that weren't catalogued. Could probably even outnumber arthropods. ➢ Has specialized in miniaturization. They've minimized themselves and still be able to function. Probably why the circular muscles are missing.	47 Ascaris body wall detail ➢ No peripheral NS ➢ Only animals that have amoebic sperm ➢ Body wall
48 Epitheliomuscular pharynx ➢ Has a dual valve system. So food doesn't come out when it opens its mouth 49 Triradiate Pharynx	50 Panarthropoda- Autapomorphies ➢ Cuticle with chitin ○ Instead of collagen we have a chitin which is a polysaccharide. Has a

➢ Has three components ➢ Found throughout the animal world ex: tricuspid of the heart ➢ They have brought back an ancient trait which is a one cell layer in the pharynx.	acetylglucosamine chain ○ ex: arthropoda ○ They have segments and each segment has a limb. Some limbs are used to manipulate food before eating it. They preprocess the food ○ They shred it into pieces to make it easier to digest ○ Vertebrates preprocess their food using their jaw
Onychophora- Velvet worms ➢ Have a soft like body worm characteristics but have a chitin. ➢ This outer "shell" is thin enough that they can move with ➢ Unarticulated limbs ➢ Oral papillae with slime glands	52-53 ➢ Has jaws inside the mouth that tear apart foods before eating it. ➢ Hydrostatic skeleton ➢ Living fossils- hasn't change appearance even way back then. Very old organism but still alive till now ➢ During pangea- they were already there
54 Arthropoda ➢ The largest phylum of organisms ➢ articulated exoskeleton of plates ○ Cuticles turn into plates ○ Gets its name from their articulation of its leg ➢ Muscles are arranged in bands ○ Muscles move across articulating joint ➢ Compound eye ○ New visual system	55 Trilobites ➢ Disappeared over time. 56 Crustacea ➢ They take the appendages on every single of the body.. ➢ Have extensive tagmatization ○ Have legs specialized for walking, have a claw etc. ➢ Very efficient way to move and trap food at the same time. Up til now they're still doing this.
57 Filter feeding ➢ When it swims it uses appendages to get a flow of water down in the middle through the "box" ➢ The water coming in through the middle the food particles are getting trapped. ➢ First animals to use their limbs to move, swim and feed at the same time	58 Crustacea ➢ A group that can swim find the productivity and feed
59 3 main protostome groups ➢	60 Spiralia(autapomorphy) ➢ Spiral Cleavage ○ Trait that sits in the holy

	triplet of protostomes and deuterostomes. ○ When we get cell cleavage in the ecdysozoa, not perfect cells that can be placed on top of each other ○ Molecular work showed that spiral cleavage is not the base ○ protostome characteristic does not include spiral cleavage ○ Moved its position in the tree
61 Lophotrochozoa ➢ problematic with data however, they are closely related ➢ Morphology not a good way to classify ➢ Don't have lophophore or trochophore at the same time. It's one or the other	62 Lophophorates ➢ sessile organism ➢ Lophophore ○ Has distinct disadvantage, sitting on posterior end of the body. ➢ Has a U shaped gut ○ anus located near mouth
63 Bryozoans ➢ Great reef builders of the ocean ➢ Corals and bryozoans:Two important components of diversification of the ancient oceans ➢ Use radial cleavage and enterocoelic pouching.	64 Bryozoa ➢ Has ciliated tentacles ○ able to control tentacles ○ Cillia trapping food particles and pass them on all the way to its mouth ○ Cillia also creates water current and filter feds and capture food. ➢ Advantage that they have is that they have a body cavity ➢ U shaped gut ○ No danger of contaminating food that's coming out of anus ➢ Colonial: able to share nutrients w/ each other ➢ Weird body plans that still here today,existed way back then and able to survive till now
65 Trochozoa(autapomorphy) ➢ Have a trochophore larval stage ➢ Has distinct morphology ➢ undergo morphogenesis ○ able to become one of 4 phyla organisms	66 Trochophore larva

67 1.Trochophore 2.Schizocoel 3. Dorsal heart and pericardial cavity ➢	68 Mollusca ➢ They create b/w them two huge innovations in animal design ➢ Has unique feeding structure:Radula ○ Feeding on feed nobody is feeding on ○ ➢ Dorsal Mantle ○ release mineral salts to make shell ➢ Calcareous spicules or shells ○ ➢ Ventral ciliated muscular foot ○ consists of a locomotory system ○ Organ system sits on top of the locomotory structure
69 Mollusca ➢ Has phenomenal fossil records ○ Certain groups have disappeared ➢ Has simple architecture that share one common origin ➢ Adaptive radiation	70 Mollusc Traits ➢ Ventral muscular foot ➢ Mantle ○ has set of muscle that run through the foot ○ 1st animal to be able to hide within the shell that its building. ➢ Gill covered in cilia ○ cilia creates water current ○ When it hides there's a hole at the back where it can breath ○ Can feed, digest and breathe even when it's hiding under its shell
71 Mollusc Radula ➢ Surface of the tongue is a set of feet. Then slide it back and forth to grind surface to scrape of organic materials and tearing it into bits and then swallow it. ➢ No animal in Cambrian was able to do this. Able to extract food from surfaces of rocks ➢ 2nd most abundant in the world	72 Snails (Gastropods) ➢ Have a shell that coiled up ○ Took their body and compacted their body inside it ➢ Hermaphrodite: contain both male and female sex organs ○ Every mating event ends up with two fertilized organisms ○ Double progeny produced ○ Have assurance that the sperm and egg can never meet up with each other ○ Sperm transfer comes first then fertilization ○ Seminal receptacle- a place

	where the sperm is stored and after egg is matured, it sends it down to where sperm is. ○ Terrestrial snail have a very distinct mating ritual: Has a dart where they ram it into the other snail. ■ The snail penetrated deepest is going to have the dart. ○ Ensure the likelihood of fertilization
73 Squids and Octopods (Cephalopods) ➢ Also have a huge fossil record ➢ Elongated the viscera and body. Became more conical shaped ➢ Animal is tucked within inside the shell.The muscular foot became tentacles that shoot out and grab food to put in mouth	74 Ammonites ➢ One of the big predators in the Cambrian oceans ➢ Inside has a pearly layer. ➢ At the end of the permian, there will be a massive extinction. ○ The fish species that are evolving they're wiped out. ○ The freshwater fish species become the predators and the ammonites cannot compete with it.
75 Clams(Bivalves) ➢ Use cilia on its gill, that creates water currents to get food ➢ Has no radula but buries itself to get food ➢ Very little ability to move but has a foot that can stick out to move ➢	77 Annelida(autapomorphies) ➢ develop segmentation ➢ Metameres created by the mesoderm ➢ Has four bundles of setae
79 Metamerization ➢ Metamere is its own hydrostatic skeleton ➢ Setae anchors the worm in place ➢ Don't crawl across the surface but burrow into the substrate. Try and push material away to get through or swallow it and out the other it.(first burrowers) ○ While they're swallowing the soils they extract the nutrients needed.	80 Marine Worms ➢ Eat a substrate no one was feeding on ➢ 3rd most prevalent group
81 Platyzoa ➢ Loss coelom → many coelomic	82 Platyhelminthes(autapomorphy) ➢ Incomplete gut-No anus present

functions have disappeared ○ When mesoderm made its appearance, the coelom was also occurring at the same time. ➢ acoelomate or pseudocoelomate ➢ loss of metanephridia and circulatory system	➢ Triploblastic ➢ A group that decided to develop a strategy to get smaller and less complex. ➢ Surface to volume ratio advantageous for them ➢ Complex reproductive system associated with hermaphroditism ○ only hermaphrodite that shows up….
83 Acoelomate ➢ use longitudinal and circular muscle to change the shape of an organism ➢ has a set of cilia on ventral surface to allow them to swim and move ➢ Two various distinct locomotion:gliding across the surface ○ contracting the circular muscles to move ○	84 Flatworms ➢ Mouth located on ventral side in the midbody ➢ Put in the bottom of the evolutionary tree because of their incomplete gut and location of the mouth. ➢ Very first flatworms: has a group o digestive cells in the mid ventral surface where they could consume food. Now it becomes a sac that run throughout the body and able to absorb nutrients through diffusion. ➢ Figured out how to eat a cnidarian polyp without getting stung by the cnidocytes. ➢ They take the cnidocytes and take them in and use it as a defence mechanism. ➢ Highly specialized organism that shouldn't be placed at the bottom
85 Reproductive system ➢ Seminal vesicle- storage area for sperm prior to mating ➢ inserted directed to the seminal receptacle ➢ After they finish mating the male repro. will shut down and the female egg will be released. ➢ Ignore slide 86 and 87	88 Life cycle ➢ Invade fluid filled cavities of other organisms ➢ Parasitic in two forms flukes and tapeworms ○ Flukes flattened leaf like organisms ○ Tapeworms ○ ex:urinary bladder,liver ducts, lungs ➢ Able to stick their body to the wall of the organ tissue, don't obstruct the flow of fluids because of their flat body
89 Deuterostomia (autapomorphies) ➢ Blastopore becomes the anus ➢	89 Echinodermata (autapo.) ➢ Pentaramous symmetry ○ Goes back to radial

	symmetry why? ➢ Mutable connective tissue ○ Have an endoskeleton. Surrounded by epidermal layer ○ Connective tissue controlled by their NS. ○ Starfish can change it body from flexible to very rigid.
91 starfish and Relatives ➢ Diploblastic radially organism involved into triploblastic radially organism ➢ Larval stage was radially symmetric organisms but undergo morphological stage and becomes radially symmetric	92 ➢ has unique two feet ➢ Has a U shaped gut that were sitting on stalks ○ can make their arms rigid ➢ Flipps itself the other way and now their mouths are facing down ex:Starfish
93 Water Vascular system ➢ each tube foot are separated by a valve. ○ All works by itself. ➢ tube feed all work in a coordinated manner ➢ Major prey: clams ○ Spreads the clam open a little bit and sticks it stomach inside out out and releases digestives enzymes to break down the clam ➢ EVERTED stomach	94 An explanation for the Cambrian explosion ➢ Snowball earth ○ ➢ Burrowing ➢ Branching pattern seemed to happen all at once ○ Happens very quickly within a few hundred million years
95 Late Proterozoic 650 Ma ➢ Snowball earth ○ A phenomenon, a period of time that were exposed… ○ Important:before there were any life on land. JUST RW ROCK. Not a very heat absorbent surface ○ Raw rock reflects the sun's energy and we get cooling of the planet ○ SOmething that will never happen again:Huge amounts of precipitations on raw rock that runs to the oceans and we get minerals into the ocean	96 Early animal evolution ➢ Cryogenian where everything was frozen ➢ Doushantuo fossils

○ When the oxygen makes it appearance it reacts with methane. Replace methane to CO2 and losing CO2 ➢ slushball earth ○ a band of open ice pack that doesn't freeze entirely ➢ We get a complete stopping in increase of biodiversity ➢ Everything stopped become the earth is covered in ice. Everything gets put on hold ➢ Due to the volcanic occurrence greenhouse gases will make its appearance ➢	
97 Doushantuo Fossils ➢ Very tiny about 0.1mm ➢ Early stage of embryos. Embryos of multicellular life. ➢ this implies that there was multicellular life before cambrian explosion ➢ Embryos were very delicate and raises a question how they fossilized	98 Ediacaran Fossils ➢ All look like multicellular organisms millions of years before cambrian ➢ There was something else going on ➢ 580-542 Ma ➢
99 Cambrian Burrowers ➢ we find there is no burrowing deep into the surface ➢ Impermeable algal mat ➢ Advantages ○ Feeding ○ Anchorage ○ Protection ➢	100 Shelled Arms Race
101 Homeotic genes ➢ If every has the same genetic program how do you turn them on/off.. ➢ Transcription factor- take DNA and fold it and send it down	102-103 Homeotic Genes - HOX GENES ➢ After the programming has occurred and can move it to another area….. ➢ Found in all animals except they're in different concentrations ➢ Universal in animal living world ➢ Somewhere in the Cambrian is that the genetics that control pattern made its first appearance ➢ Patterning genes perfected to make different kinds of organisms

104 Mass Extinctions ➢ Occurs at the end of Ordovician ➢ ⅓ of the organisms disappear ➢ 2nd largest mass extinct ➢ Life will start over at the end of the mass extinction	*Nothing is on land yet.Plant first then there will be animals coming up on land