

Silurian and Devonian periods



Silurian and Devonian


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Paleozoic periods

- Paleozoic era
 - Cambrian 550-488 Ma
 - Ordovician 488-443 Ma
 - **Silurian 443-416 Ma**
 - **Devonian 416-359 Ma**
 - Carboniferous 359-299 Ma
 - Permian 299-245 Ma




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Ordovician survivors

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



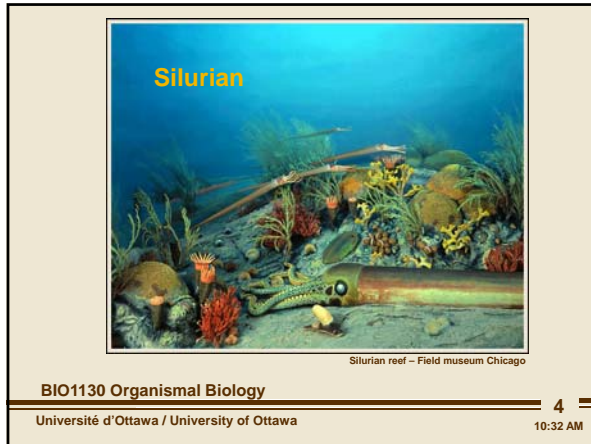
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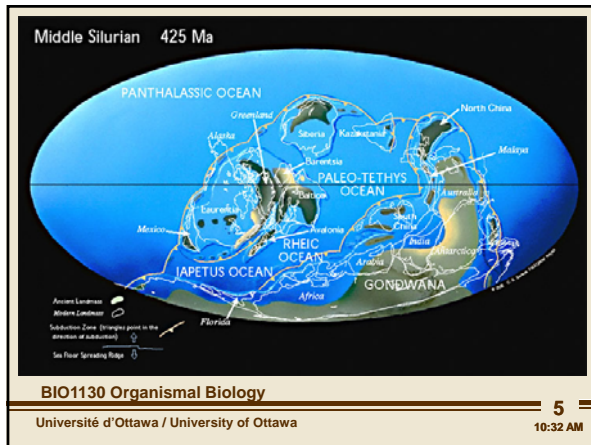
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end of cambrian and ordovician: everything was happening in the oceans and in the oceans we had the begining of the invertebrates and we had a tremendous number of them making their appreance. and we tried to account for it by a number of things like the begining of the apperance of calcium minerals that allows the begining of shells we accounted them by a newing (browing?) habitant that allowed a whole amount of organisms diverse. we also accounted for it for the fact the patternic genes that control all of animal development make their appreance at that point of time as well. but the primary producers are single cell organisms (the algea) and at the end of the ordovician there is the second largest extinsion on the face of the planet: continental land masses, drift toward the pole and because they are not on the equateor they are not warming the plante => we had ice start to beuild up in the pole as the planet starts to freeze => water level lowers => all that wonderful continental shelf with biodiversity was exploding in the camberian starts to disappear => the marine habitant becomes less prevelant => competition between invertebrates => only a few survive. 27% of the groups and 67% of the animal life in the oceans disappeared. the survivors until now are the main groups that we see today. they may not look like what we see today, for example our chaynoderms are still sitting on the bottom of the ocean with their arms facin up and they haven't flipped the other way and started moving. One of the major changes: Trilobites were arteropods and a lot of them disappeared at the end of ordovician and the remaining trilobites diversity, makes an opening for the other arteropods that are in the ocean to become larger in large like lobsters or fishes that we see today.

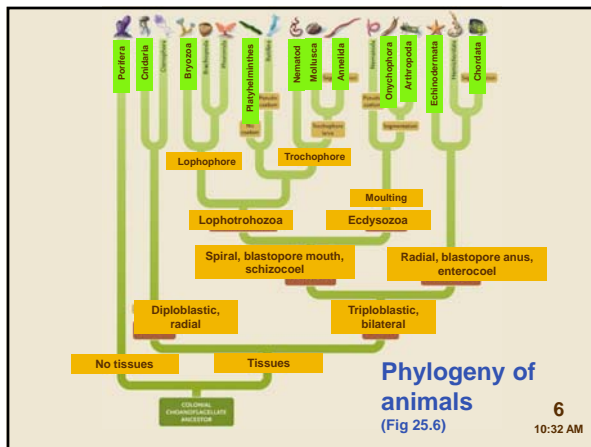
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what happens during silurian and devonian and specially silurian is that we start to see an animal fish like bone appearing as a vertebrate with a dorsal nerve cord with a vertebral protective bone around it and it is going to explode during the silurian in terms of a new type of life form. when we get to devonian, what we see is that the organisms start moving up to the land. so we get vertebrates in the ocean expanding during the silurian and when we get to devonian, we see that we have plants on the land and vertebrates start expanding on the land.

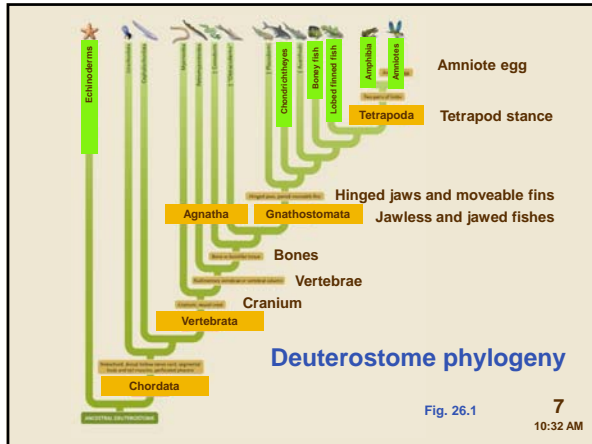


position of continents during the silurian: the major continent (Gondwana) is still in southern hemisphere and other continental masses are starting to drift together and they are going to form a super giant continent (Pangea) a little later on. but the consequence is that our continental shelves are back but they are very close to each other and so we end up with a very large ocean between all of the continents that is an ideal incubator for these new vertebrate fish types that are gonna make their appearance.

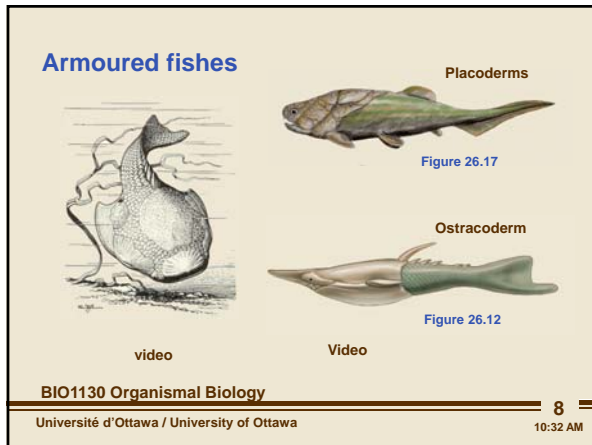


so what we end up is that all other groups that we have already looked at, having survivors that make it through, but the lineage that make the phylum chordata which includes the vertebrates is about to take off in terms of numbers.

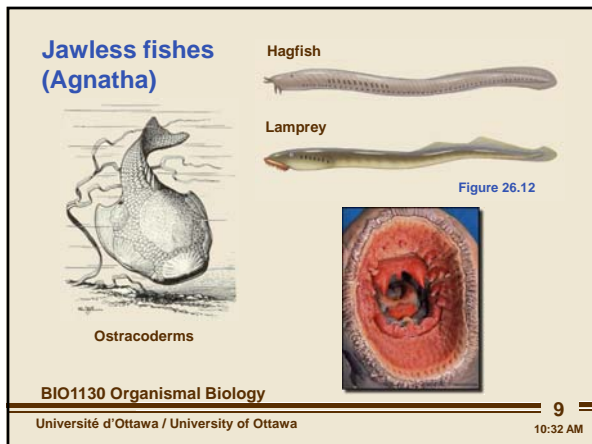
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and in that deuterostomes line, when we start to look at our evolutionary tree, the thing that we are gonna see, is the development of a brain case with bone to protect the brain (Skull), the vertabrate to protect the nerve cord, and vertabrates a part of a new swimming technique that the chordates have because hordates are all characterized by having attached tail and a tail is series of segmented bones that wave back and forward and what we gonna see is that how these early chordates don't have jaw (Agnatha) and will ultimately evolve a jaw (Gnathostomata)and we see that as we get into this lineage there are three types of fishes that we are gonna see cartilaginous fish + bony fish +lobbedfinned fishes



the fishes, at the beginning of this period : very small + have vertebrates + swim with the motion of tail + typically covered in great boney plates that they use as armor to protect against protetors + take advantage from the calcium minerals that they can participate from the ater. => called armour fish => two groups: Ostracodorm (absoloutly lack a jaw => swim around with their mouth open +. as they swim water pures into the mouth and moves along the openings on the side of the mouth cavity, and then the water pures out and while doing htis, the



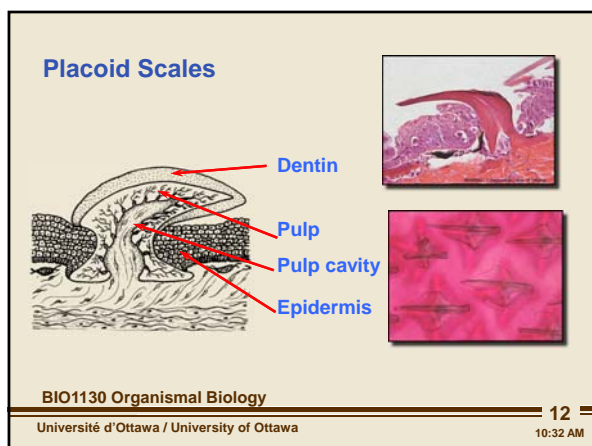
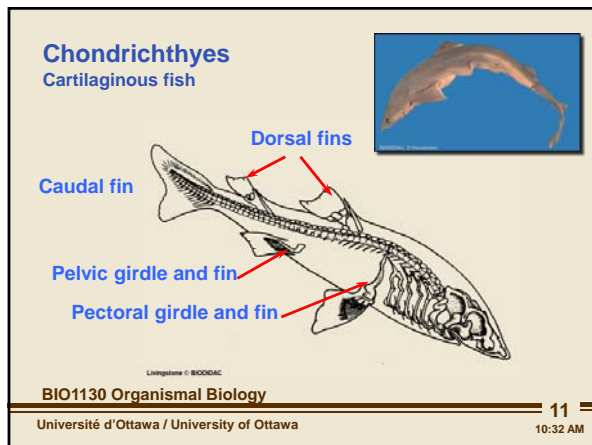
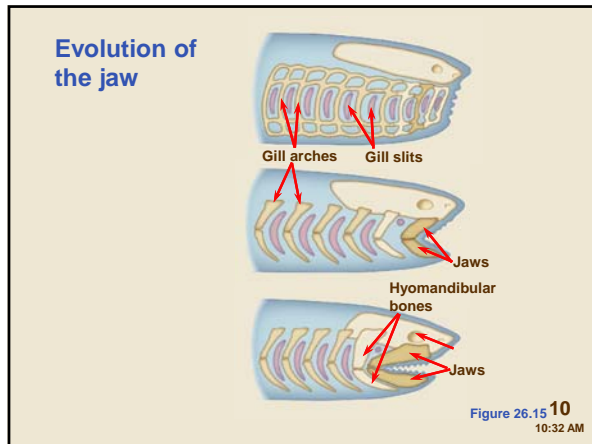
food gets trapped, and these openings, will ultimatels become the site for gass exchange and then ultimately the site for gills and respiration. almost all of them that we know are we know them by fossils but there are still 2 species of survivors: 1- lampery and 2- the hagfish

lampery spends most of its life as a protitor. a parasite of other fish. use its mouth to attaches to a large fish. use its suction with all these teeth around the mouth to hold on and uses its tounge with its great horny teeth on it can

grind away the tissue of its parasite host and the lamprey drinks what comes out of that wound. Lamprey life cycle consists of eggs that are laid in fresh water streams and to lay the eggs, male lampreys swim from the ocean which they spend most of their life. they swim up rivers until they reach the gravel beds and when they get to the gravel beds, they move the gravel around, the females lay their eggs and the males fertilize the eggs and the male and female die. then the little egg hatches into a larva that spend around 4 years in the rivers and as it reaches the critical size, it will migrate out of the stream to the small river, to the big river out into the ocean where they will live for another 15-20 years until it matures and when it wants to mate, again it will swim back and lay its egg at exactly the same place as it was born 20-30 years later. there has been a major ecological disaster in 1960's and 1970's. they could not originally get up the st. laurent river but they could and as they destroyed the barriers that prevented them from getting to the great lake system. and niagara falls was the principle barrier and killed all the fishes as they exploded into population of fishes of the great lake. they became problematic because they changed their life cycle and instead of returning to the ocean, the great lakes water system was such a large water.

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One of the great things that happens in vertebrates: the development of jaw. a weird gene duplication appears in the animal world. between agnatha and the ones that gonna have jaws, there was a complete duplication of genome in the chordinate lineage. it allows the group to experiment with different morphologies and different forms. how it works? don't know but we know it exists. means when you have 2 sets of genes you have one backup gene and you can use one set to do other things without the risk of being detramentally effected because you already have the backup. swhat happens is that cartilage structures that were in agnatha that were holding opening the mouth so water comes in and out, developed an inner layer of muscle, and it was an interesting inovation because it mens that if the muscle in the inside og that cartilage contracted => cartilage bends. and if you do this on both sides => you are changing the shape of the cavity of the mouth => you are contracting the size of the mouth cavity and then spring it back to the large size => if while you are doing this mechanism, you direct the flow of water into the mouth and you pump it out of the slips on the sides => now you can irrigate your gills without swimming around. => you can now pump water in and eat. => now they can stop. over time this relaxing became much more pronounced => that hinged developd in the cartilage => the very first cartilage in the front flexes on it self and it closes. => these become the jaws. the cartilage which is behind also does the same thing and assists with the articulation of the jaw => hyomandibular bones. these groups are organisms are reffered as Gnathostomes. => they are the first animals that



can capture food big enough to put into the mouth and close the mouth before it goes away and to assist with that on the surface of the jaw, develop small little teeth and the teeth acts as rippers and hold on the food when you try to swallow it. first they could only trap small things, but as we progressed like in the shark, the jaw became strong enough that now you could actually hold on the things that are bigger than your self. the teeth never become good enough to chip the food to pieces and that would never happen until much later on.

those fish like organisms fall into 3 categories:

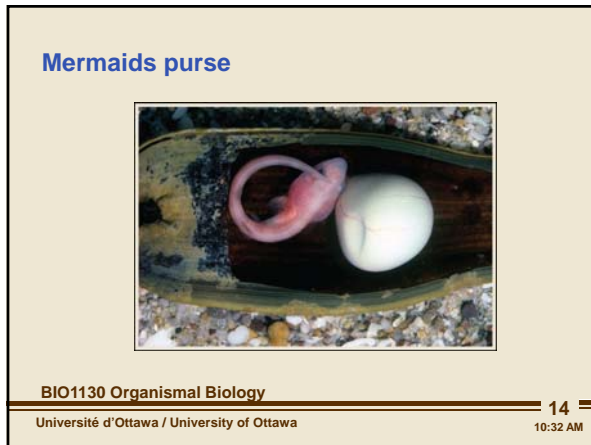
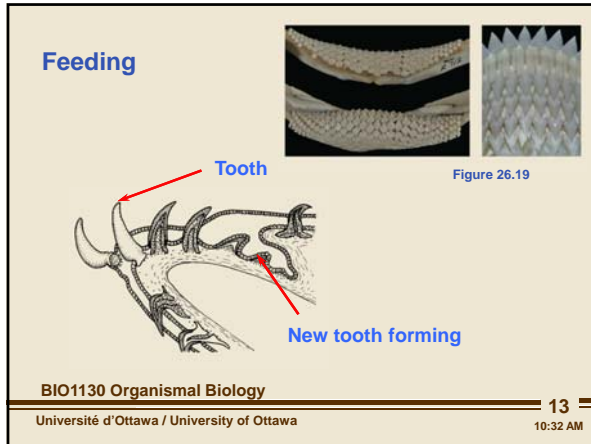
1- Sharks (Chondrichthyes fish). all of the fish architectures, carry this traditional chordate characteristic of the tail that in going to move back and forth so the fish can swim, and when we get into gnathostomes, in addition to the jaw, we also get paired fins. we get a back set of pelvic fins, a front set of pectoral fin that are paired because there are one on each side; and these contain bones that are articulating with the body and that articulation with the body isn't very pronounced with the sharks and they don't move that much. and those two sets of fins, combined with the dorsal fin create the ideal positioning for the fins to move in a 3D environment by positioning in x,y and z axis.

we have a problem while swimming in the ocean.

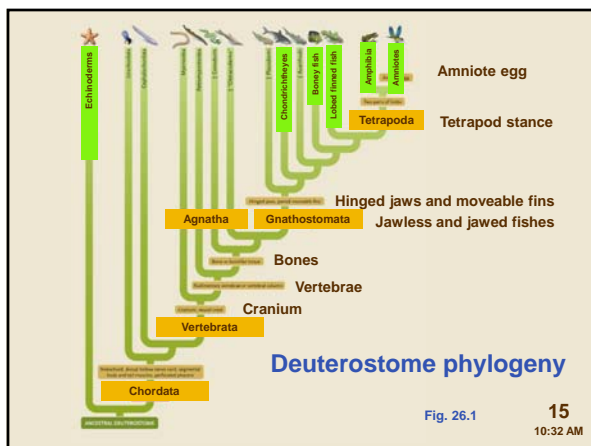
we discarded the weight of the armoured plate and if you have a smooth skin and you try to swim inside water, what happens is that as water flows through the surface, there is an adhesion to the water and it is pulled towards the surface => the movement of water constantly slows you down as it slides over your body => shark and the other fishes that are going to come => scales over their body => in shark they are unique because they are produced by the skin, underneath and they are made by dentin and a pulpy core and they project backwards all through the surface of the shark. => how it helps? when body flows over the body, it creates microtubulence => there is a buffer of water that is lightly mixing and the laminar flow is not happening against these surface of the fish that is swimming. => enhances locomotion. so they have dealt with the viscosity of the water.

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not all the sharks eat meat and some eat algae and they eat everything! but the important thing is that their teeth are in highly modified scale. same style but bigger they are used to lock down so they can grasp it and by swimming, the torque of their movement rip the body apart and they float in the water and then the shark comes back and swallow them and because their teeth may rip out, they constantly replace their teeth. if aquatic vertebrates stop swimming they sink (more dense than water) => they want to spend no energy and not to sink => sharks do it by producing large amounts of oil and their cells and their body cavities and their cells and tissues are filled with shark oil and because oil will float, they can float instead of sinking.



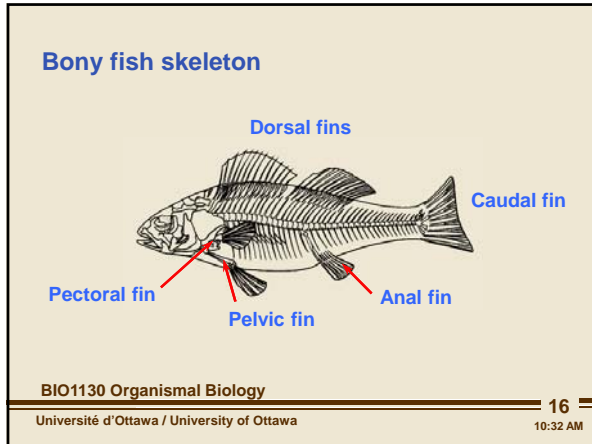
sharks do something completely different in their reproduction strategy: the strategy in invertebrates was to produce lots of eggs and fertilize them and try to produce lots of youngs. shark's strategy: very few youngs in the life time but giving all the nutrients that the new youngs need to them which takes a lot of effort by female and then placing the young in a special protective case (the mermaid's purse) and they place the mermaid's case in crack or a protective location and inside it the very rich egg provides enough nutrients to the egg to become a miniature adult so we have to larva shark (like in the fishes) and it will feed and enlarge => that is our problem with the shark population around the world, they are getting close to extinction because of the shark fin soup problem. the reason that it is a problem is that a female shark produces around only 20 sharks during his life. and when you kill an immature female or female for her fins, you have made it hard for the population to replace itself.



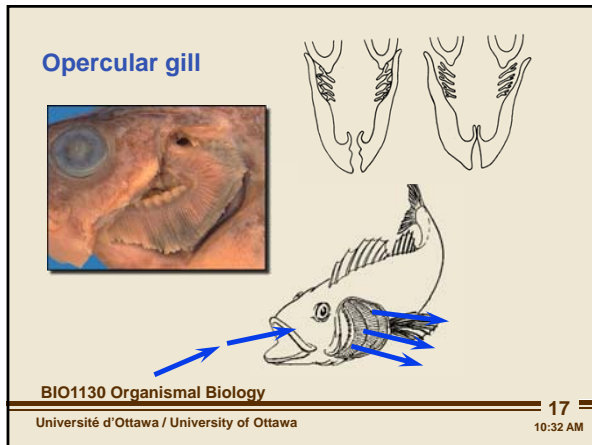
next the bony fish is going to come.

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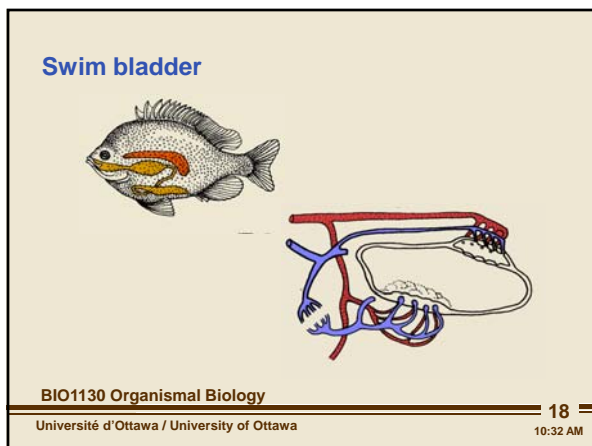
bony fish perfects a number of things that the sharks still have problem with. sharks don't move very well (because all of their locomotion is coming from the tail and a minimum steering from the fins) they are called bony fish because their fins are supported by needle size bones. in these fishes, the pectoral fin and the pelvic fin will become much more mobile and be able to articulate against the edge of the body which makes them to do delicate maneuvering and they can maneuver using pectoral and pelvic fins instead of the tail. the chondrichthyes sihes used tail which worked for them because in them (in ancesstors), the pumping mechanism was lost when they got their jaws were



made and in order to breath, they have to swim with their mouth open. the bony fish will find the solution to this because we gonna see they will pump the water but now they can stay in one location. they solved this by having:



by having the opercular gill. like the shark, the water has to pass the gill surface to irrarate it. but they have developed a tissue that they can swing out and swing in => and when it swing out it will pull water out of the mouth. if you close it and open the mouth, you can put water in. => so they open the mouth, fill it with water, close it and then the gill swings out and pulls the water out of the mouth. +. they can sit now and hide.



to counter the issue of sinking, they have swim bladder => filled with gas => hooked in by capalirries to the circulatory system. if they swim in the lower heights, the pressure of the water above, squeezes the bag of air shrink and get smaller ao if you learn to figure out the amount of air to increase you to a certain level, you will stop sinking. but as you go deeper, you need more air and as you rise, you need less air. if you don't want to float up or sink to the bottom. => the

amount of air in it can be balanced by the depth, they change the amount of the oxygen in the bladder by adjusting by the oxygen that goes to the blood through out the gills. (so they use their circulary system to change the oxygen in the bag).

we don't have anything speciall about the feeding and fishes feed on everything and there is no specialization on it. but we have specialization in locomotion by solving the problem of sinking and respiration.

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Evolution of the tetrapod stance

Figure 26.23
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Figure 26.24
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Transitions to land (plants)

- **Water conservation**
 - Across exchange surfaces
 - Across body wall in general
- **Protect the gametes against drying out**
- **Support system (gravity)**

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Phylogeny of plants

Figure 24.9
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the third group is lobbed fin fishes. what distinguishes them is that their fins are supported internally by thick bones that are in them and that thick bones is enough to allow them to burrow into the sand and sediments, dig things up. another things in addition to their lobbed fins, they have lungs (not swim bladder). they take oxygen accross their gills like other fishes but they can take their head out of water, take a gulp of air and fill their lungs. this is important because it is fresh water nad in devonian, as plants move upto the land one of the things that gonna happen is that the earth is gonna alternate from fairly wet to fairley dry periods. and for the fishes that are living in the fresh water lakes and rivers, as the water warms up, they become poor in quality by losing their oxygen which is not good fish => they are able to reach out of the water though. but not only that, because of the bones in the fins, the fins are strong enough to move their limbs to move accross land to maybe find another better aquatic enviroment and pound of fresh water. and they are going to be the fish ancesor of everything that is going to come up on land. so in this period of time that we are going from suilirian to devonian, we see boney fish (which are the major groups of fishes in the oceans today), we see the cartilaginous fish and we have the ancesor of the amphibians when we move this group up on land.

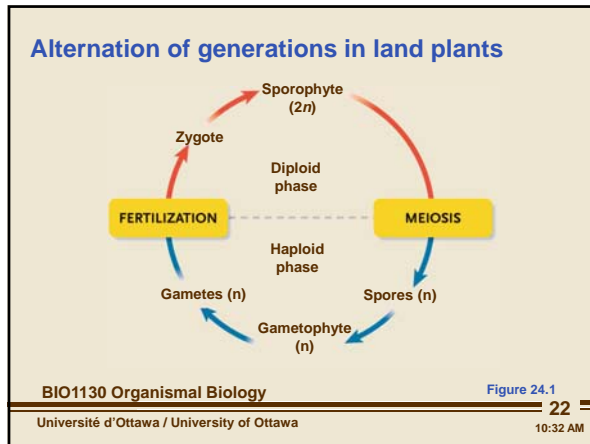
when they are moving to the land, one of the issues that we should deal with is the loss of water. gas exchange surfaces are going to lose water beause gasses will only dissolve in liquid to be absorb so the gas exchange areas are always wet. the body if doesn;t have a water proof surface on it, will be a site for losing water as well. so for both the animals and the plants, when they move up to the land we are going to watch out on the top of the other ellements that we are looking for. we are going

to look for other solutions. the other problem with living on land, is to get the sperm and the egg together, sperm have to swim and they swim through water. in aquatic environment it was easy. but in land, you need some mechanism to protect the sperm either a close system where you can have an aquatic environment for the sperm to swim or you need to package it in some way to get it to the egg and both the animals and the plants are going to face with that. and finally, on the land, the gravity has a bigger impact on organisms in compare with water because tissue has the same near density as water so if I throw you to the ocean and don't you take a breath, you will slowly sink to the bottom of the ocean, but from a building you through fast => so everything on land, needs to have a support system to hold it up (skeletal elements) and it is the same for the plants because plants are going to move up to the land and they are going to face a real dichotomy in their life; they have to have a system to be able to absorb minerals from the soils which they are in and they have a second system to trap the CO₂ and photosynthesis which has to be in the air. and if you are going to be a larger plant, you are gonna need a mechanism to connect those two things together. (vascular system of the plants)

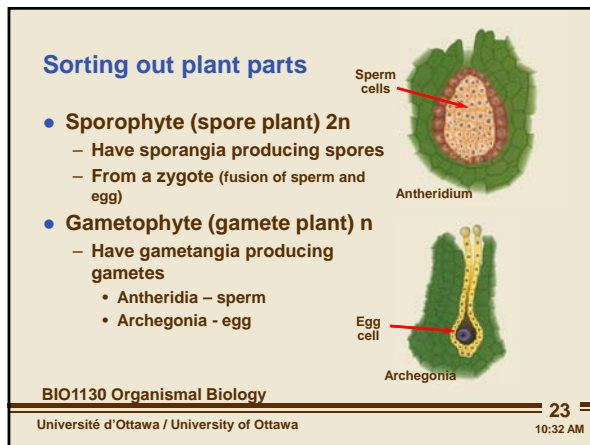
if you look at the cladogram of the plants, they are gonna be changes on how do we get the gas into the leaves or photosynthetic tissue. in our early plants there will be no control and the gas exchange surface will be freely accessible and then ultimately we are going to put valves in that regulate the movement of air so that photosynthetic surfaces only available for the gasses when it is doing photosynthesis (Stomata). to be able to stand up and top be able to support the size and the height of the plants as they become taller, they are going to create a secondary cell wall ultimately made out of "lignin". and this lignin is gonna create very effective "vascular tissue" for making material flow from one end to the plant to the other. so lignin makes its first appearance by supporting plant cells and later will become vascular tissue. and we will solve the problem of sperm swimming to the egg when we generate the very first "Seeds". do many of the strategies that are the key elements of the animal evolution are also in plants where we went from diploblasty to triploblasty and ..., what plants are gonna do is to first solve the problem of gas exchange and then body surface so it is not losing water. then it is going to create a support structure so the plant cells don't collapse under the effect of gravity then it is going to create a vascular system to be able to move later on within the plant and then we are gonna solve the problem that the sperm had to swim to the seeds to be able to do that.

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we want to see how plants have solved a set of issues that are going to be solved by the animals that come on land. and they started with the things that they all can do. and one of the things that all of them have, is this alternation of generation and this alternation of generation is going to dominate what they are going to be able to do. in alternation of generation you gonna have two plant like structures. one is going to be sporophyte and one is going to be a gametophyte. sporophyte is the one that is going to be diploid, it is going to undergo meiosis, and the mitotic products are gonna be spores that will get to the ground and grow to some kind of other plant like

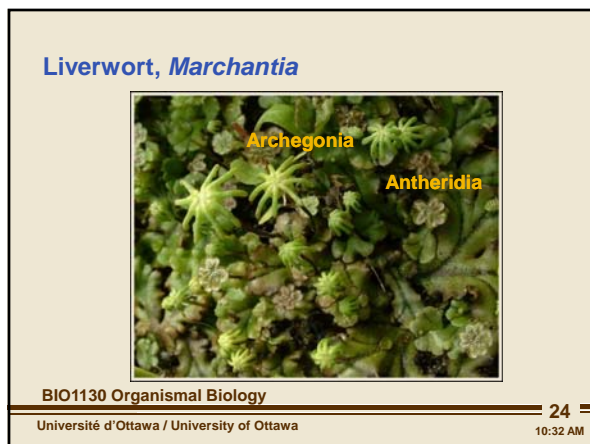


structure called gametophyte, and all the cells in that are haploid so we won't need miosis again and we just need to get some of those cells and turn them to gametes, have them fertilize to a zygote, return to the 2n state, the zygote state and then grows to some plant like structure. and this is important because the shift between these two is one of the major problems that plants have to solve.



the cells that are producing spores, because on our sporophyte

we have photosyntetic cells that are capturing light, we gonna have some cells that gonna be responsible for the life cycle, just as we have gonades as in animals there are gonna be some cells responsible for continuing the life cycle and in sporophyte, what it has is a set of cells that make spores (sporangia) and in gametophyte, the cells that are makin gametes are called gametangia. because there is no sexuality associated with spores, there is all we should know about sporangia. But gametangia



comes in two types: Antheridia (makes sperm) and Archegonia (makes egg). one spore makes a plant that has

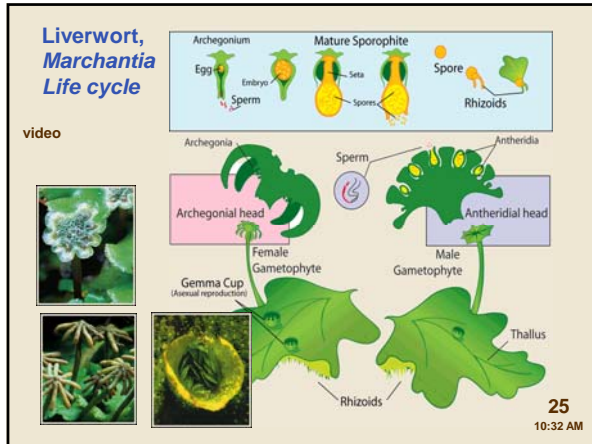
both of these things. and this is because plants are going to allow self-fertilization and this appears at the beginning of the appearance of the plants.

Algae started to work together and cooperate and we ended up getting cells that communicate with each other because we are heading to multi-cellularity. but they were just masses of green tissue. the difference was that these masses of green tissue could produce specialized reproduction organs.

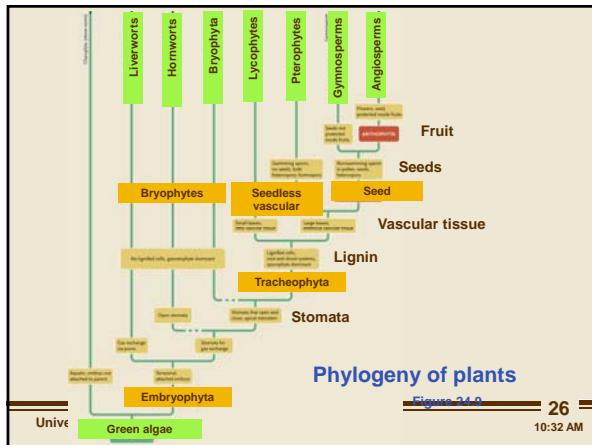
* we call the mass of tissues (just a mass): Thallus. there 2 structures coming off the thallus. One looks like a giant big umbrella which is Archegonia and some disk shape structures which are Antheridia. and they can be on a same plant.

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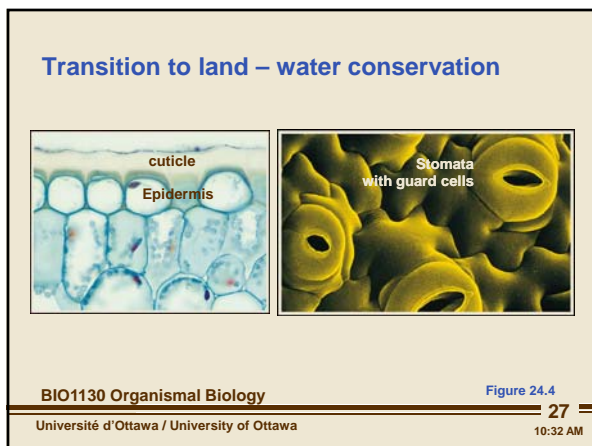
All of the eggs that are produced are on the under side of the Archegonia. and sperms are produced on the Antheridia facing up. now how to get the sperm from antheridia to archegonia? rain drops on the antheridia and splash and the sperm get in through and they hit the under side of the archegonia and sit there. => called splash fertilization. fertilized egg is now diploid and it will grow and divide and produces a small sporophyte that hangs from underneath still attached to the original archegonia on top and the spores will be released on the wind which fall on the ground and falls on the ground and makes a new one and the life cycle completes itself. and they have



another trick that they have these cups and divide up these plants to little disks and if water falls on it, the disk will flow in the water and land some where else and make a new marchantia. but they still depend on water.



27: the holes in the epidermis that lets the CO2 through to the cells never closes => their gas exchange surface is exposed to air at all times. => if the air was dry, they would dry out and die. what will come next => we gonna put two special cells around



that opening and only when we are doing photosynthesis and we need CO2, we will open the valve so now we have a regulatory system to prevent the gas exchange surface from dry. then at the same time, a non-living layer of waxes appear on the surface which water proofs the surface although they are not leaf yet because there is no vascular tissue.

26: when we look at our evolutionary sequence, we see that this is one of the major opening. you can't see it from the back of stomata (developed for gas exchange with an opening and closing mechanism) there are Liverworts with no gas exchange and anybody which is coming next will have opening, closing stomata

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The first group that we are gonna look at them and they have

as Mosses. they still don't have vascular tissue and a root

system to pick up liquid and nutrients (they rely on the water that they trap with the leafy tissue) but they have stomata and they can open and close them. they are covered in a waxy tissue and they can resist water loss.

But the life cycle is a little bit different. Because what happens is that that lets starts with spore: sporophyte has released spores and spores have landed on the ground and they become a plant like structure that still have no vascular tissue but it can

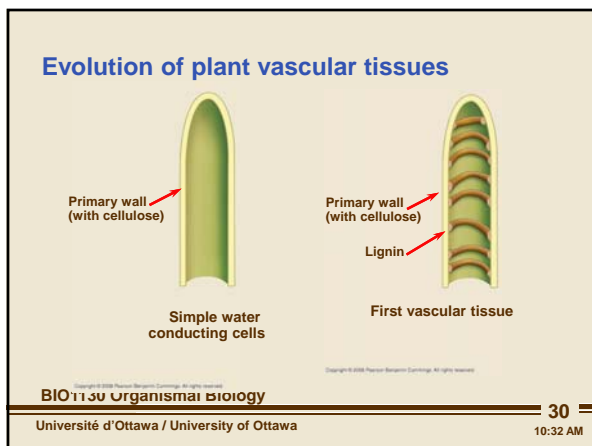
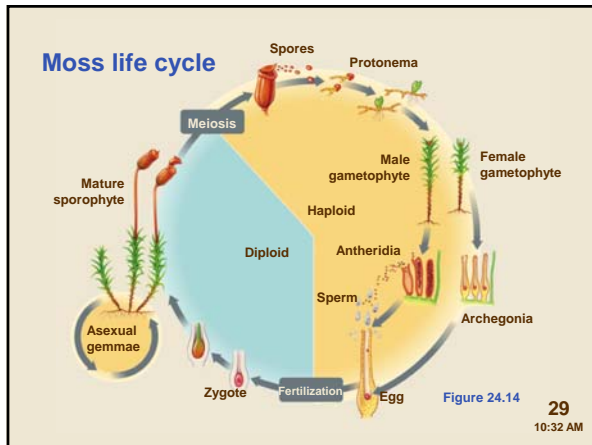
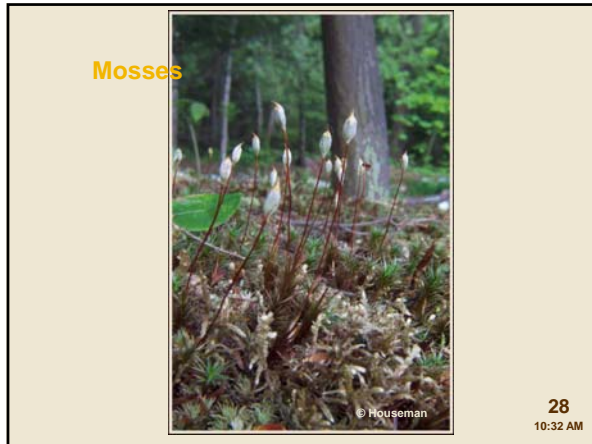
still hold and support itself up. and at the top of these plant like structure, will either be an Antheridia or an Archegonia and the faith is determined if it is going to be male or female. so

these structures will release the sperms into the air, they will find an archegonia to land on with an egg inside and the sperm on in the water that has splashed around (it is still all splashing) and then fertelize the egg and the egg becomes diploid and then it devides and grow and it is the thing which

is gonna make sporophyte. the things weird about moses is that the gametophyte underneath, supports the sporophyte on the top and we see that gametophyte and sporophyte start to appear on the same structure. and that is one of the key events,

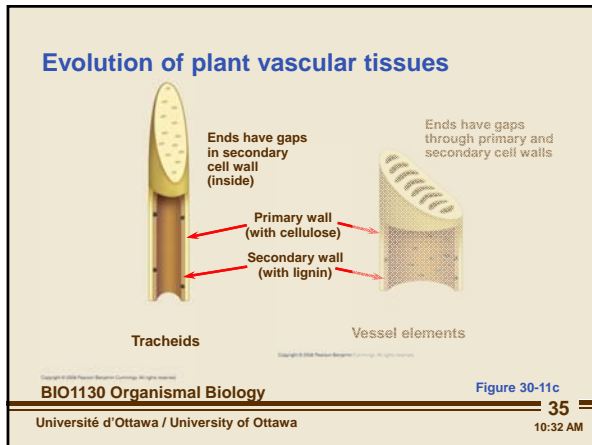
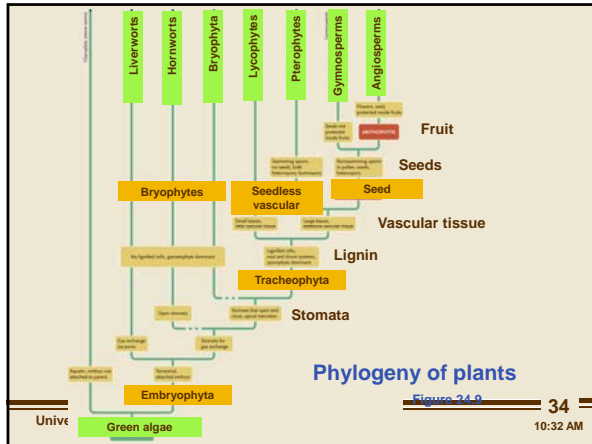
because one of the things that have happened is that plant cells, instead of just having cellulose holding them up, now have started to use this new compound called lingnin to reinforce by spirals of this material inside the plant cells. so one plant cell adjacent to another plant cells adjacent to another plant cell,

they have help up by lignin and they diffuse things between their



common cytoplasm. so that mose is able to move fluids through it simple diffusion between cells and the cells won't collapse and when the water is lost they just stay rigid. And moses in dry enviroments just lose their color a bit and become just some crispy and as water get back to the plant, it rehydrates the plant and it will come back to life. as we get into devunian we see vascular tissue appearing => they become large

Silurian and Devonian periods



The innovation that comes after the mosses: the innovation of vascular tissue. (a mechanism to connect a photosynthetic surface to an absorptive surface). as an organism plant is going to collect its energy from sun and it needs to have a huge surface volume to capture sun's energy and that surface volume must be exposed above everything else, so it can make contact with the sun. so you have this surface that is involved in energy trapping. (autotrophs capturing sun's energy that must rise away from the ground.) but at the same time, plants gonna require minerals and nutrients to be able to grow and those are going to be associated with the soils and the moisture in the

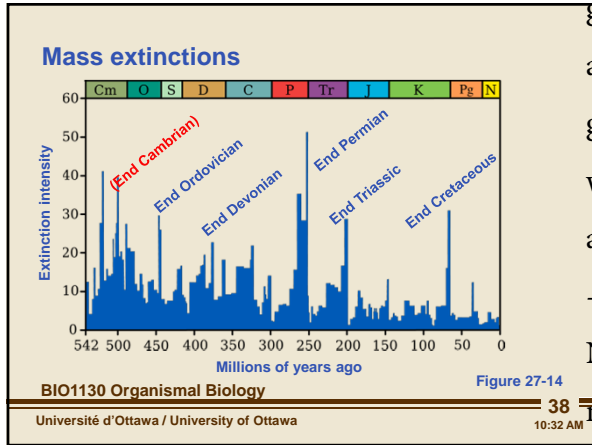
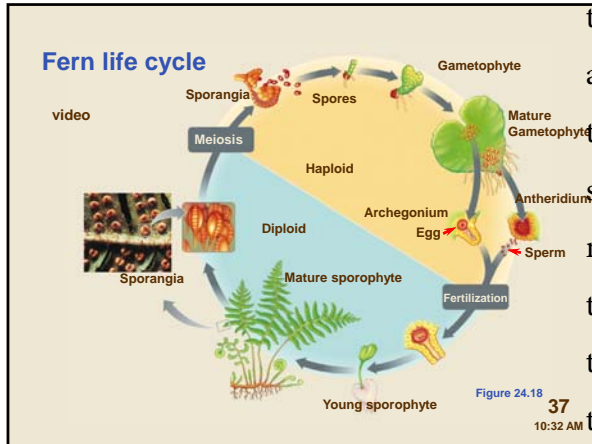
soils in which they are anchored so you have got this dichotomy in plants which you got this high energy surface area and you got a second major surface area that is gonna be involved in absorbing material that are in the soils and they have to be connected in some way with each other => vascular tissue

This vascular tissue is again a modification of lignin and we gonna look at lignin in detail in the next topic. but basically

what happens is that when one of this plant cells that is going to be involved in transport grows, instead of a lignin forming rings to support it, it actually produces a secondary cell wall. and when these cells die, the lignin stays in place and when the cells die in vascular tissue, they are connected end to end and the plant cells deteriorates from inside and become hollow tubes and the best way to compare them is large capillary drinking straws that grow as the plants grow.

this lignified plant tissue, becomes a major innovation and one of the first groups that are gonna use it, are the ferns.

Silurian and Devonian periods



we are going to see in the life cycle that the gametophyte and the sporophyte are starting to become fairly co-independent organism. we saw in mosses and we see it again in the ferns. the large green structures that we see are the sporophytes. and if you take a fern and look underneath it, you will see brown little dots and these are the sporangia. no they are held on the surface of the sporophyte and they start to associate. when they make spores and it goes by wind and fall in the ground, it will start mitotic division of the tissues and we will also start getting roots that are going to absorb nutrient. what will happen is that near the base, we see archogonia forming and at the tip, we gonna see the antheridia. what happens in that antheridia will make sperms and they will get hit by water, migrate and re-fertilize the eggs that are there. sometimes the sperm may fertilize the adjacent gametophyte plant. and from the zygote, it is going to raise stem and a very first fern from and then it will keep dividing until we get a full fern.

we are still relying on water to move the sperm between archegonia and archegonia.

Now we are at the end of the devonian and we get the second mass extinction of the face of the plant. 2 major reasons: huge

amount of plants which have started to make appearance on and in the terrestrial environment is sucking large amounts of CO₂ out of through the atmosphere. and as we remove CO₂, we are removing the greenhouse warming gasses => the planet will cool and to makes things worse, these plants are now collapsing and dying and nutrients which were trapped in the plants will turn into soils and we gonna get soils for the first time in the terrestrial environment and soil will also get into the river system and so we dump a lot of organic material into the oceans for the first time => bacterial growth => oceans lose their oxygen carrying capacity => animals start to suffer because of the low levels of oxygen => and it is cold so we get icebergs being made, continental shelves get deteriorated again. and what doesn't get affected at the end of the devonian, are plants.