Course Name: I Think Biology

Professor Name: Dr.Jayanti Ray Mukherjee

And

Dr.Prachi Gupta

Department Name: Biology

Institute Name: Azim Premji University

Week:4

Lecture:19

W4L19_Our Favourite Cells - Part 2

Hi, my name is Jayanti Mukherjee, and as a part of I think biology NPTEL course, today I am going to talk about my favorite cell. Let's get started. Do you recognize this picture? I am sure many of you do. So what are these? These are something called stoma or stomata. You have heard of it. I am sorry the picture quality is not that good but one of my students took it with her cell phone actually and that is the reason the quality is a bit poor. But I am a plant ecologist. I look at stomata characteristics and behavior and that is the foremost reason why my favorite cells are stomata.

So what are stomata? These are generally very microscopic pores as you all know enclosed by a pair of guard cells that flanks a stomatal aperture that are you know that bows down or bows out when water fills in these guard cells. So we all know that right? But I am coming to that. They are found in the epidermal layers of the leaves and stems and also help the plant to breathe. So stomata have multiple functions. We will go to that one by one.

Let's take a look at where are they found. These are the basic structures of stomata, and this is how they look when they are turgid and flaccid. The first thing is when the stomata pores are closed as you can see water runs out while when the stomata pores are open the guard cells are very turgid and that's how it is possible to keep the pores open. So stomata are found in most land plants. Almost all of them. But the functions kept changing and that is what we are going to talk about today and how it becomes very interesting to study stomata.

So in lower dicots or eudicots as you know they are found mostly predominantly on the lower surface whereas in monocots they are found on both surfaces. And as you know dicots and eudicots what I mean are reticulate venation and broadleaf where monocots are parallel venation and more thin needle-type leaves which you have been studying since you are in school. So there is no confusion there. So, there are two broader shapes of stomata. This one is called the let me put the pointer out. These are the kidney-shaped stomata and these are the dumbbell-shaped stomata. So kidney-shaped stomata are found on the dicots and eudicots whereas the monocots have dumbbell-shaped stomata. So where and when this evolution took place and why that is what is very interesting also to know. One of my undergraduate students and I wrote this resonance article on stomata. Feel free to go and look it up and these figures are all from that article.

So stomata have shaped the evolutionary pathway of plants. Now why do I say that? So as you can see these are the variations in structures of stomata and we will go one by one but look at what I have written here. Variation in structure and alignment of stomata pore complex has been linked to the increase in efficiency of light capture and photosynthesis. So let us take a look at what are these.

So first is the anomocytic stomata.You can see these. So you can see that there are what is the difference between this and all the others on this list. These don t have something which is the yellow things, the yellow subsidiary cells. Those are called subsidiary cells. So these are the first initial types of stomata that evolved. Then slowly they started becoming a little bit more complex. Two subsidiary cells which was horizontally placed, then vertically placed, then divided into four subsidiary cells and then of course we have this graminoid complex or the monocot dumbbell-shaped stomata which are two very large subsidiary cells, flanking the guard cells and the stomata pores. In some of the families also you see there are many more subsidiary cells, even two layers of subsidiary cells which has evolved. So these having subsidiary cells, the shape of the guard cell and the whole stomatal complex had made it over the evolutionary period more and more efficient in performing their role. Now what are those roles?

Here is what I mean. So did stomata evolve for photosynthesis? Let me ask you this question. Think about it. Were they always good at signaling this light and carbon dioxide? As in dicots and monocots just as we looked? Actually No. So initially when stomata evolved, early mosses were the first land plants that you will see. Before that, they were all grouped into Protista algae from where these mosses evolved are called Protista. So early mosses had something like these on their sporangium where the spores were found. So stomata on those sporangium had a sole purpose and can you guess what the purpose would be? Was it a gas exchange? No. It was even though there could have been gas exchange, the most important function of stomata at that time was desiccation, to help in desiccation and the dehiscence of the spores for spore desorption. So when the sporangium is ready, the stomata will take, open up, and dry up fully, the sporangium will be dried and it will burst and release the spores. So that was the initial function when it came.

But of course, as you know once land plants started coming to land more and becoming independent, coming off the land surface going to high as up as 100 meters, stomata became the most important cell that the plant would have. As you all know the main functions were light capturing, light signaling, and also hormone sensing. So these were light capturing and then there is another thing we will come to that again. But stomata became very very highly efficient in light capturing, better stomata regulation, and increase in photosynthetic efficiency. This became of course over the initial time, not in one day.

And sensing ABA. ABA is, I am sure you already know, it's called abscisic acid, it is a plant hormone and it is called also the plant stress hormone. Whenever a plant gets stressed, this is the first thing that is secreted and roots start secreting abscisic acid. When it first senses it is drought, ABA is transported to the leaves, and stomata immediately pick up the signal and close. So here is drought there, on the ground we don't want to lose any water, let it shut down. So they are very good in hormonal signaling as well as carbohydrate and light signaling, most importantly light signaling.

But there are some evolutionary trade-offs or constraints that happen. What is that trade-off? One biggest trade-offs is that if you compare stomata or plants with humans, it is like if you open your mouth to breathe air or breathe, then you lose blood or you lose something very precious. That's what happened with stomata. So, when it was opening for photosynthesis, taking carbon dioxide in, it was also losing water. So now, this trade-off had to be balanced very much to survive in an environment because when the stomata lose too much water, the cell functions will stop. So, the cell cannot carry on, it will get desiccated very fast. So stomata have, regulation has to be very efficient to pick up the recipe. That is giving rise to this carbon gain and water loss, thus giving rise to a multi-layer complexity in understanding this physiology and in the earlier stomata. And there were plants tackled over the evolutionary time, you would be very surprised to know that they tackled this problem with one very small thing which is the size density trade-off. There are other things too, but I am just going to talk about this.

So, initially, when a plant evolved, you know, they had this kidney-shaped stomata and the stomata in lower dicots were quite big. So, what does this mean? If the stomata are big and they have to open up, so the minimum amount of water loss through those bigger pores is much higher. So, what happened was, they were, even if they were open, even if they had fewer stomata at that period, the water loss was much more. Then what happened during the early Cretaceous, and late Cretaceous was the plants underwent some genetic changes and one of those genetic changes was their genome started duplicating and also genome, genome sorry, it downsized. So, these two genetic changes happened over the era.

And what happened due to this was cell size and mechanics in the cell changed. Stomata size reduced. So, in contrast to this kind of big stomata, you see stomata size now became very-very smaller and this is one pattern of stomata and this was found in and where you could small-small-small many stomata whereas larger only a few stomata. So, this is called the side density trait. Now, why I am saying plants adjust? You will be very surprised to see because as I said if there are bigger pores, the minimum amount of water loss through these pores is more.

So, this kind of pattern generally came to see in more vector decline whereas these other smaller stomata whereas newer stomata are generally found scientists are even now working on these things and finding that they are more associated with drier climates and why. Also, stomata can behave in a very patchy manner. So, it's not necessarily all the stomata at one point will be open. There could be a few closed, there could be a few open. It depends on where the light falls. Specks of light can initiate the opening of stomata and plants and the stomata on other parts of the leaf, same leaf would remain closed to conserve water.

Right? So, this way, this size density trait also helped plants to adjust and generate more variation to adapt to very climatic changes. So, it's called patchy stomata behavior. So, now let's sum up. Crucial function-wise, stomata, as you see, are one of the most important cells on the plant and perform the most important job for us as well as the planting. It is photosynthesis, carbon sequestration, and as well as transpiration which are eventually also responsible for pooling our climate.

Right? So, pooling our environment, pooling our climate, more recent research is showing that stomata have many, many, many more functions than just photosynthesis and transpiration. They are involved also in certain types of herbivory, certain types of pest control, and all those other functions. But the coolest are these two and that is the reason why stomata are my favorite cells. Thank you for listening. I hope you enjoy this video.

Hello, my name is Prachi and today I'll be talking about my favorite cell. So, before I talk about my favorite cell, I would like to start with the images of these two cells. These are the cells you might be familiar with from your textbooks, maybe from school or college. So, look at these images. Can you guess which one is a plant cell and which one is an animal cell? I'm pretty sure looking at these images, you would be able to recognize it as a plant cell or an animal cell.

As you can see in this image on the right-hand side, the chloroplast is present, there is a central vacuole and there is a cell wall. These all are the characteristics of a plant cell and on the left-hand side, you have an animal cell that does not have all these characteristics. So, these are the cell pictures that we usually come across in our textbooks. But do all cells have a similar structure? Do all cells have these same cell organelles? Look at this image. This image has three different cell types in it, but I want you to focus on the cells that I have marked here in black arrows. Maybe you can pause your video for a moment and take a moment to look at this image. Can you guess, if is it a plant cell or is it an animal cell? Maybe not. These cells look nothing like the cells that we saw in the previous slide. So, which cells are these? Let me tell you, these are the cells that are found in plants and they are known as vessel elements and these are my favorite cells. And I will tell you more about my favorite cells.

Now, to begin with, you might have heard of the terms xylem and phloem tissue. You might know that the xylem helps in the conduction of water and minerals in plants and the phloem helps in the conduction of food in plants. So, pay attention that I am saying the word tissue here, which means this tissue is made up of different types of cells. So, let's talk about xylem tissue now. It is made up of four different types of cells, xylem parenchyma, xylem fibres, tracheids, and xylem vessels.

These xylem vessels are made up of different vessel elements, different cells joined together. These are the main conducting parts of the xylem. These vessel elements, these vessels, they help in the conduction of water and minerals in the plant. So, let's learn more about these vessel elements.

So, just think about it for a moment. Here on the right-hand side, I have a picture of one single cell, one single vessel element. How small is this? These vessel elements, join together and they help in the conduction of water in the small trees and even in the larger trees that we see around us. So, this image I have taken under a microscope and this is the cell that helps in the conduction of water in plants, in huge plants that we see around us. These are, as I told you, these are the water-conducting cells and they are present in angiosperms only, which means they are present only in flowering plants. They are absent in pteridophytes and gymnosperms. Some advanced gymnosperms may have vessels.

Now, the average diameter of a vessel element is usually 15 to 250 micrometers. Just pay attention, I am using the word micrometer and you may remember from your numbers and scales class in biology, that we talked about it in the second week, you learned about different units of measurement in biology and micrometer, how small is that? So, these vessel elements, have such small diameters, it is in micrometers and they help in the conduction of water in plants. Another intriguing thing about them is that they are dead cells. They do not have any cell organelles. It just has a cell wall around it, which makes it rigid and very long-lasting.

It is the lignin in the xylem vessels which hold up the trees. So, it has lignified cell walls. Now, as I told you, this is a vessel element. So, as you can see in this image on the right-hand side, there is a presence of a perforation plate at the end of a single vessel element. So, multiple vessel elements, join end to end to form a single vessel.

So, as you can see on the left-hand side, there is an image of a vessel. So, as you see there, VE represents vessel elements. So, one vessel element is represented here with white dashed lines. So, this is a single vessel element that joins with another vessel element at the endpoint. So, multiple vessel elements are joined together to form a vessel, a water-conducting tube.

These vessels are long tubular elements that run in a vertical direction from the soil to the crumb. This single vessel that we are talking about, is made up of different vessel elements, and different cells, they can have as few as two vessel elements or they can even have hundreds or even thousands of vessel elements. So, now what do you think? Now, I have told you that a single cell is known as a vessel element. They join end to end to form a vessel and the vessel helps in the conduction of water from the root of the tree to the stem of the tree to the leaves of the tree.

Okay. So, what do you think? Is there a single vessel running from the base of the tree to the very top of the tree? Is it a single vessel that is conducting water from the base to the topmost part? The answer is it's like a network or a mesh of vessels that help in the conduction of water. So, now I want you to look at the image on the left-hand side. So, as you can see here, they have shown different vessels, and different vessels are joined side by side as well. As you can see, there is one vessel that is in light blue. So, as you can see, the pink dashed line is there. So, this is one vessel, then there is the next vessel and then there is the next vessel. So, there are three vessel elements joined to form this vessel. Okay. But it ends here. It's not going to the very top. It ends here. But now it is connected to another vessel from the sideways which is a dark blue vessel.

Now, this vessel has two vessel elements as you can see. One is here and one is here. So, this light blue vessel is conducting water in the vertical direction from below to top and then it is transferring the water laterally and in the sideways direction to this dark blue vessel. And this dark blue vessel is further transferring the water to the red-colored vessel here. Then it transfers water to green colored vessel. So, it's not like one vessel running from the base of the tree to the very topmost of the tree. There is a network. Vessels end at a certain point and then another vessel takes up the job. So, there is a network sort of structure that runs throughout the trunk of the tree. Okay. So, this is just a representative diagram and the colors here are just to show you an arrangement of different vessel elements within the tree.

Okay. The second image shows you the cross-section. So, if you cut a plant in a transverse direction then you will be able to see different pores-like structures which are pores in a cross section. But we are mainly focusing on the vessels here running in the vertical direction. Okay. Moving to next. Now, in this image, how are these vessels conducting water laterally? How are they transferring water to the next vessel that they come in contact with? So, these vessels on their walls have something called inter-vessel pits. Okay. So, they transfer water from one vessel to another vessel through these pits. This here on the right-hand side is a schematic diagram. Here you can see these are different vessels and circular structures, the small circular structures that you see here are inter-vessel pits. As you can see the water is moving from this vessel in the upward direction and then it moves to the sideward direction through the inter-vessel pit.

Okay. Then it's going on the top and then you can see these connections. Right. So, through these connections between different vessels, water can move laterally through these inter-vessel pits. So, this mesh-like structure is all connected through these inter-vessel pits.

Okay. So, vessels conduct water in plants in the vertical direction from the base to the top of the tree and they also conduct water in the lateral direction. So, now as I told you these vessels do not have any cell organelles. They are dead cells. But was that always the case? Were they differentiated like that? No. When these vessels are formed in a plant, they are formed from vascular cambium which are meristematic cells.

When they start forming vessels, the immature vessel elements do have cell organelles, they do have a nucleus, they do have mitochondria, Golgi apparatus, endoplasmic reticulum, and cytoplasm. But over time as they mature, they become dead. All the cell organelles disappear and there is a secondary wall thickening. So, I want you to think about it for a moment.

The vessels help in the conduction of water. Right. As we talked about they do not have any cell organelles. So, you can understand their structure. They have these are tube-like structures with very rigid cell walls which do not have any cell organelles. So, just think for a moment about how their shape is reflecting their function.

In the previous session in your introduction to cells by Dr. Divya Uma, you already learned how the shape of a cell reflects its function. Now, I want you to think for a moment about how the shape of this vessel element reflects its function. So, since there are no cell organelles, there is no obstruction in the conduction of water. So, how does the shape reflect the function of this vessel element?

Now, we have talked about these vessel elements, their shape, and their structure. Do they have the same type of shape or the same type of structure in all the plants? No. Even one cell type differs so much in different plant species. So, different plant species may have different shapes of vessels. As we talked about their perforation plate which is present at the end side of this vessel element, even they can be of different types. We talked about inter-vessel pits, and how their arrangement can be different in different plant species.

We are talking about just one cell type and even one cell type differs so much more in different plant species. Even this one cell type shows lots of variation, in its shape, size, its structure. Another interesting fact about these vessel elements is that the vessel elements, they are usually wider in the plants that are growing in warmer climates and they are usually narrow in the plants that are growing in colder climates. Try and relate it to something like when there is like hot summer day, we get very thirsty and we need more water. Trees also need more water in hot and warm environments, right? So, plants that are growing in warmer environments, do have wider vessels to have more water conduction.

Another interesting thing about these vessel elements is, that you might have heard of annual growth rings which help in knowing the age of a tree. So, in deciduous trees, usually found in temperate regions, they have ring porous wood. So, in these types of trees, in deciduous trees, you will find two types of vessels that are formed within a year in one growth season. One will be earlywood vessels and the other one will be latewood vessels. So, these earlywood vessels, are distinctly larger than those which are found in latewood.

This ring porosity is considered an adaptation to seasonal climates. The big vessels of earlywood, help in enhanced sap conduction, and enhanced water conduction during the beginning of the growth season. Just take a moment to think about what you learned about vessels and how cool are these vessel elements. So, these vessel elements, are dead cells. They have a very different structure than what you are used to seeing in your textbooks. These small tiny vessels, help in the conduction of water in the large trees that we see around us.

Even different plant species have different types of shapes, sizes, and structures and even in the same tree, you can find different types of vessels. As you can see in this picture right here, you can have two different sizes of vessels within the same tree, right? Usually in deciduous trees, these two different sizes of vessels are distinctly different. To summarize, in the previous lecture, you learned about three favorite cells from three different instructors. You learned about *Toxoplasma gondii*, Diatoms, and *Myxotricha paradoxa.*

And in this lecture, you learned about stomata and vessel elements. So, what is the difference between these two lectures? Just take a moment and think. In the previous lectures, all the cell types we talked about were unicellular organisms, single cells which is in itself an organism. And in today's lecture, we talked about two different types of cells which are cell types found in plants, right? So, take a moment and appreciate the cells that make up our living world. We say that the cell is the fundamental unit of life and this fundamental unit of life, it differs so much, it has so much variation and how amazing is that? So, you should remember that the cell types are much more than what we usually see in our textbooks. They have so much variation in their shape, size, their function and I would like you to go and search for your favorite cell.

With this, we'll end today's lecture I hope you enjoyed learning about all of our favorite cells and I hope you can appreciate how many different cell types are out there. Thank you. See you in the next lecture.