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W4L17_Introduction to Cells

Hello everybody, my name is Divya. I am a Biology Faculty at Azim Premji University. Today we are going to be looking at cells. So cells are really important and we are going to be looking at various aspects of cells. Why are they important? Why are they kind of small in size and how big can they get? Is there some kind of limitation on how big they can get? And what are the various functions that the cell does? And how do things move from one part of the cell to another part of the cell? So we will also learn about various cell organelles inside the cell. But before going into these nitty-gritty details, I want to take a minute to tell you about a story.

This is a real incident. So there was a 25-year-old girl who was very, very athletic. She was running regularly. She was very active. She participated in a lot of stuff and she was very energetic. Then when she turned 25, she realized that she was suddenly becoming very tired. She could not even in fact walk a few meters. She would feel very tired even if she walked a few meters. So then she went to a doctor and later she found out that she had some kind of mitochondrial disease.

So this kind of illustrates that even small organelles such as mitochondria are extremely important for large-scale effects and large-scale functions. This kind of shows why cells are really important. So several diseases are defects of various cellular organelles. Of course, we won't go into that, but that kind of illustrates why cells are really important because cells are the building blocks of all organisms. So all of us, all living beings are composed of one or more cells.

They can be unicellular where there is a single cell performing all the activities or it can be multicellular organisms where multiple cells get together to form an organism. So cell is the unit, the basic unit of all living things and it is nice to see that the cell kind of compartmentalizes life from the external surroundings. So whatever happens in the external surroundings, it does not affect the cell immediately. Of course, there are various adaptations that the cell would have had to kind of live in its external environment. Cells also exist from pre-existing, arise from pre-existing cells. That means that one cell will give rise to another cell through reproduction. So these are known as these are certain basic facts of cell theory. And cell was discovered in the 1600s by Hooke when he was looking at a cork. So this is a plant material under a microscope and he saw very, very structured blocks and he called them cells, and from there onwards the journey of finding out what the subcellular components and other things started. So let us look at how big these cells are.

So cells are microscopic, most cells are microscopic. So say, for example, a plant or an animal cell if you look at it, those are around 10 microns big. Bacterial cells are even smaller which is around 1 micron large whereas frog eggs are slightly bigger or even human eggs in comparison to your regular plant or animal cells. This is a nice representation because it kind of puts things in perspective. So we are about 1 meter. So if you take an average height of a human being that is in meters a ship would be 100 fold, so around 100 meters long. So when compared to that cells are, really, really tiny. So this is a relative size chart based on a logarithmic scale. So now we know that cells are rather small, but what is the reason? Why cannot cells grow bigger than that? Why cannot cells be as big as this room or as big as a house for example? There are certain limitations. So think about that.

So a cell I told you earlier that it kind of, is a contained unit, right? It separates whatever is happening inside from the external world, but there are a lot of things going in and out of a cell. So there are molecules entering cells and then their products are created and that has to be put out of the cell, right? So there is a lot of metabolism happening in the cell. There is movement of particles in and out of cells. So all those things are limited by the surface area of the cell membrane. So there are only so much, so many particles that can enter because the surface area is of one size or a certain range.

But if say for example, to kind of increase the surface area, certain cells, certain specialized cells can have very, very convoluted or very ridged surfaces. So This increases surface area thereby allowing larger amounts of molecules or particles to enter in and out of the cells. So those are some of the adaptations that some of the cells undergo to increase the surface area. But basically, cells are limited by surface area. One more reason is we kind of think about cells as two-dimensional structures because that is how textbooks depict them, right? We kind of draw them like these round and we put in certain organelles inside it. But cells in reality are three-dimensional, right? It has volume. It is not just one flat thing. It is a three-dimensional object. So the volume of a cell, if you think about a cell as a sphere, volume increases much more rapidly. The volume of a sphere is much more than the surface area.

So as the cell grows, the volume increases much more rapidly than its area. So that also limits the cell size. It cannot grow really big. So that limits the cell size. But certain cells are long. For example, the nerve cells of a giraffe are one cell, and that can be long. So in comparison, I have put a basketball field here which is 10 feet. So certain neurons in say larger animals like giraffes can be very, very long. But of course, they are super thin. So that is just one example of certain exceptions.

Okay. Now let us look at certain shapes of cells. I have written here that the shape of the cell reflects its function. So here are three examples. Red blood cells are kind of flat and it does not even have a nucleus because it is utilizing all their area, whatever is present, the cell's entirety is filled up with hemoglobin and also carries oxygen, right? So it lacks a nucleus and it is kind of flattened and the nucleus is bulky. So it helps to get rid of the nucleus and it is flattened. That helps it to go through very, very narrow blood vessels to carry oxygen and give it to different parts of the body. So you can see that structure reflects its function. Nerve cells are another example. They are very thin but elongated. So to conduct electrical impulses and pollen cells, very, very interesting cells. It has bizarre, very beautiful structures and these pollen grains are kind of spiny, these kinds of structures because one of the reasons is that it increase in addition to the stigma, the female reproductive part in the plant. So if you want to stick the male reproductive part to the female of a plant, then it makes sense for pollen grains or pollen cells to be very sticky so that they can have different kinds of shapes that can stick to the stigma. So that is about different kinds of cells and also cells have different shapes.

So we are going to look more closely into what happens in the cell and what is the function of a cell. So cells are like tiny factories and the key here is they kind of perform different organelles perform different functions. So division of labour is the key to being so efficient. So cells are efficient. So let us look at some of the factory-like work that the cell does. So you have a cell membrane that covers the outside and acts like a gatekeeper. So cell membrane controls what goes in and what goes out of the cell so that acts as a gatekeeper.

The nucleus is the most important one of the most important structures in the cell. So that is like the operation center. A lot of decisions are made in the nucleus which contains DNA of course and that is like an instruction manual. Okay, if you want to produce certain material, these are the instructions to be followed and that is what DNA does. Mitochondria are the powerhouse of a cell of course. So you want to produce certain things so the energy is generated by mitochondria. Golgi complex on the other hand is a packaging unit. Okay, you have produced something, it has to be packed and it has to be delivered to a certain area. So Golgi packs the protein and wherever it has to go, it will send that to that particular region.

The endoplasmic reticulum, on the other hand, is the manufacturing unit of the cargo. So I am saying this as cargo so what I mean by cargo is various kinds of proteins and sugars and other things which are produced inside the cell. So the manufacturing unit happens in the endoplasmic reticulum. Suppose some cargo or protein needs to be degraded which happens in lysosomes and how do these things move from one part of the cell to another part of the cell or beyond outside the cell? This is facilitated by cytoskeleton tracks. So in the cytoplasm, there are cytoskeletons laid out, we will talk about this later in the talk about where on the tracks these cargos are, you know, it facilitates movement of the larger molecules.

Okay, so these are various functions of the cell. Of course, there are several other components inside the cell that I have not talked about but you can easily look them up in your textbook. So now let us look at, you know, the relative volume of, you know, various of these major intercellular components, how much of volume, percentage of total cell volume which is occupied by these intercellular components. This is concerning a liver cell. So large amount of it, 50%, slightly greater than 50% is cytosol, which is just the cell soup, right, and about half of it is around 20%, 22% is also occupied by mitochondria and you can see that ER and Golgi are all relatively small amounts, right, and even nucleus occupies a small amount.

So you might think that you know, the cell is largely kind of watery and, you know, most of it is empty but that is not the case. We will talk about how packed cells are in a bit but the other point I wanted to make was that when we, actually draw a cell, we are always used to drawing cells with one big nucleus and one mitochondria and one Golgi complex and stuff like that but remember that depending on the need of the cell or the type of cell, there are several mitochondria and so it is not that there is only one mitochondria, there are several of them and everything is connected to everything else. So all these intercellular components are connected and they are also extremely crowded. So this is, you know, this is the graphic representation of an image showing macromolecular crowding. So there are various kinds of macromolecules, there might be sugars, there are proteins, and cytoskeletal tracks which shows how compact and crowded cells are, and also within these molecules are moving fast.

So to give you an example, the inside of a cell is very crowded. So for example, an E. coli, Escherichia coli cell has around 400 mg per ml of macromolecules. So that is compact and there are a lot of things inside, inside a cell and because of this crowding, there are, you know, chances of molecules interacting with another molecule is very high. So for example, here this molecule is sitting with the next molecule, so it is constantly bombarding, colliding with the other molecules and it is also undergoing random walk, and because of that there is diffusion and that is how things are also moving.

And there are several small molecules and they are moving very, very rapidly. For example, small molecules like glucose moves, you know, can move around 200 miles per hour, and larger molecules or larger proteins are moving at 20 miles per hour. So this is, I am talking about miles per hour, of course, this is just to give a perspective of how fast cells, you know, macromolecules might be moving within the cell, but of course, it is not miles per hour inside the cell, but this is just to give you an example or put things in perspective. So of course it happens per second, it is very, very fast, and the movement of molecules inside the cell is very fast. Okay, so now we are switching gears and talking about how cargo, that is proteins here in this case, are transported from one region of the cell to another region of the cell.

So I am not going to be talking about protein synthesis here, but once it is synthesized in the endoplasmic reticulum, how it moves, so these are actually, these are how it moves. This is particularly with keeping in mind an excretory or a secretory protein which kind of goes outside the cell, but similar principles apply even if the protein remains inside the cell. So first it is kind of synthesized with ribosomes and endoplasmic reticulum and then that is kind of moved to Golgi and from Golgi apparatus through several vesicles it is transported to the plasma membrane and then protein is secreted outside. So let us look at some of the large dynamics that happen to move cargo from one place to another place. Again, I am not going into details, but I am just going to talk about certain things you may not have heard about in a traditional textbook or your 12th grade.

So there are when proteins are produced or synthesized on the endoplasmic reticulum there is the movement of the cargo from the endoplasmic reticulum to the Golgi and from Golgi to back. So there is bidirectional traffic of material between membrane components. So this is endoplasmic reticulum and this is a Golgi complex and you see that these vesicles bud off, these are vesicles, these are extensions of these membranes. So all these organelles are membrane-bound. So the membranes bud off of ER and they are moved to Golgi and diffuse or delivered to the Golgi complex.
And then after the function of these vesicles is over, simultaneously these vesicles also bud off from the Golgi and they come back, and they are delivered back to the ER carrying with them trafficking proteins that need to be recycled for more rounds of transport. So new molecules are produced and they have to be transported from one organelle, intracellular to another. So they are carried by some other kind of protein material and they are carried to Golgi and then once that particular protein or cargo is out, the, you know, the proteins, the trafficking proteins are recycled back to the endoplasmic reticulum. So what I am saying here is there is continuous bidirectional traffic between different cellular compartments. What is interesting is that a few years back, people had thought that Golgi apparatus cannot be, you know, cannot be disassembled.

That means that Golgi is there in every cell, Golgi is just there, it cannot be, you know, destroyed, cannot be created or destroyed kind of a thing. But, you know, scientists have recently found that if you put in a drug called a Brefeldin A, it is a particular drug that makes the Golgi complex kind of explode, and all the fibers, all the Golgi complex disappears within seconds and the components, all the components of Golgi goes back to the ER. And of course, if you take away the drug, the new Golgi complex is formed, you know, from the enzymes that are present in the ER that facilitate the production of the new Golgi complex. So when I was reading this, I was fascinated by this information. So I just wanted to tell you about this, Golgi, it is not that Golgi is always present, but the Golgi complex can be blocked by a drug and it can be completely disassembled and of course, it can be also reassembled back.

That is just an extra information. So now let us look at some of the other organelles. Now I am talking about mitochondria and endoplasmic reticulum. So keep in mind, see I am talking about how various things move, right? So it is not like their organelles are static. We already talked about how, you know, very crowded cells are and how things are moving fast.

Even organelles are exchanging materials and also talking to each other. So here is a section of the picture here, which is kind of highlighted here. So this is a part of, there is mitochondria, the membrane of mitochondria, and also ER. So what happens is there are certain proteins known as tethering proteins, which means that they can kind of tie the ER and mitochondria together. Here, they bring the mitochondria and ER together to facilitate a greater exchange of things like lipids or calcium and whatnot.

So that is what is depicted here. These tethering proteins help the organelles to come close and they exchange materials. So during glucose deprivation, if the cell does not have enough glucose, mitochondria take up lipids and calcium from ER and in turn, you know, that helps downstream events. So this is just an example that you should not think about a cell as this static fixed, you know, kind of a unit where various organelles are present in it and it is not like that. A lot of things are happening. It is a dynamic interplay between these organelles that facilitates, you know, the production and movement of molecules from one place to another place.

Okay, next I wanted to tell you about how these organelles move through inside the cell, and that is facilitated by, you know, microtubules. Those are one of the examples of cytoskeletal filaments. This is a fluorescent microscopy image of a microtubule track. So imagine this is like a highway or it has many, many roads and there are certain highways also and organelles move on these networks, on these tracks. So to give you a better understanding, these are microtubules and there are proteins which are such as kinesin which are moving along the microtubule.

They are sprinting along the microtubule so you can see it almost looks like a step and they are also carrying different kinds of cargo or they are transporting membrane and different membrane-bound vesicles. So this is how organelles move from one place to another place through cytoskeletal tracks. Okay, so this is a video about the Golgi disintegration. Please make sure to watch this video. It is fascinating how Golgi disappears completely and then reappears when the drug is removed.

So to summarize, all living things are made up of cells. Cells are really small, they are limited by the surface area to volume ratio. They are three-dimensional, they are not as 2D as we depict in our textbooks. Cells function like miniature factories, they divide up work, different cellular organelles do different things, and inside cells are crowded molecules move very fast and there are various functions for various, you know, various organelles and structures determine the function of a cell. Thank you.