**Biology for Engineers and other Non-Biologists**
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**Lecture Number 13**
**Cell Division - Mitosis**

Hello and welcome back. In our previous video, we spoke about cell cycle and we did talk about how much time a cell spends in preparing itself for cell division. In today's video, we are going to talk about cell division, and there are two different kinds of cell divisions, and one is mitosis and the other is meiosis, or 'Mayosis' as some people call it. So let me start by talking about our own origin.

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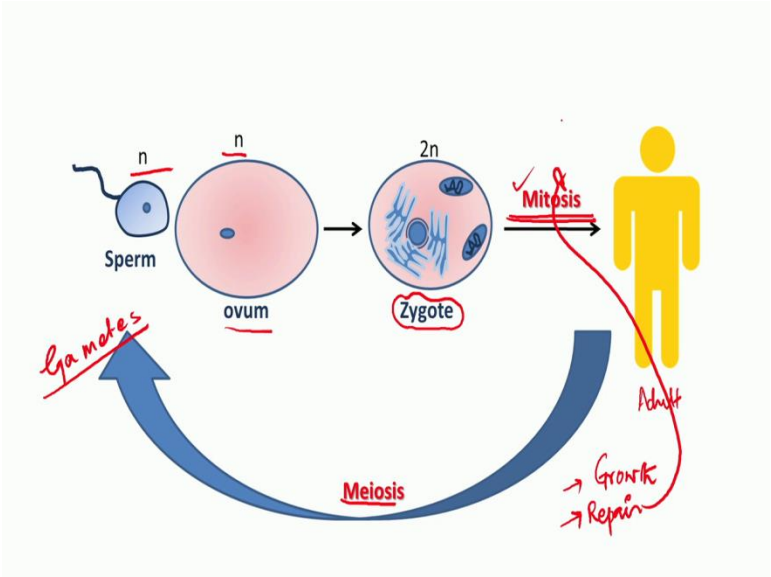


Now you would notice and we all know this that we start our life through the process of sexual reproduction, wherein there is fertilization of the egg, which is also what you call as the ovum by the sperm cells, and it is after fertilization that there is a formation of a zygote.

Now we all start our life as a single celled zygote, which then over the period of next nine months undergoes multiple duplications and divisions and gives rise to the full born baby, and then eventually we end up developing into a full adult. Now, what is intriguing is to know that we all start our life as a single cell, but we end up becoming a whole individual with more than billions of cells in our body. Now how is that possible? Now that process by which one daughter

cell, one cell gives rise to two identical daughter cells is what you call as the mitosis and we will study about this today.

And the other one is the process of meiosis. Now in this process, in the process of meiosis which happens only in the reproductive organs, the cells which are in the reproductive organs basically undergo reduction division and the give rise to gametes, that is, the formation of sperm and the ova, which has half the number of chromosomes. We will talk about meiosis in a separate video. Today, let us talk about mitosis. Now what is the importance of mitosis? As I just mentioned, it not only helps in the growth of an organism, here I have taken an example of human beings, but the same applies to almost all the other eukaryotic organisms.

Then, we also find that if there is a need for repair, for example, if you have injured yourself and there has, there is a wound on your skin that needs to be repaired, what you find is after a few days, the wound gets repaired and off-red skin reappears. Now this kind of a repair mechanism is possible because of mitosis. Similarly, if you look at some animals in our regular household, for example lizard, you will find that they easily regrow their clipped tails; and that is possible because the cells in the tail undergo the rapid process of cell division and that is again through the process of mitosis.

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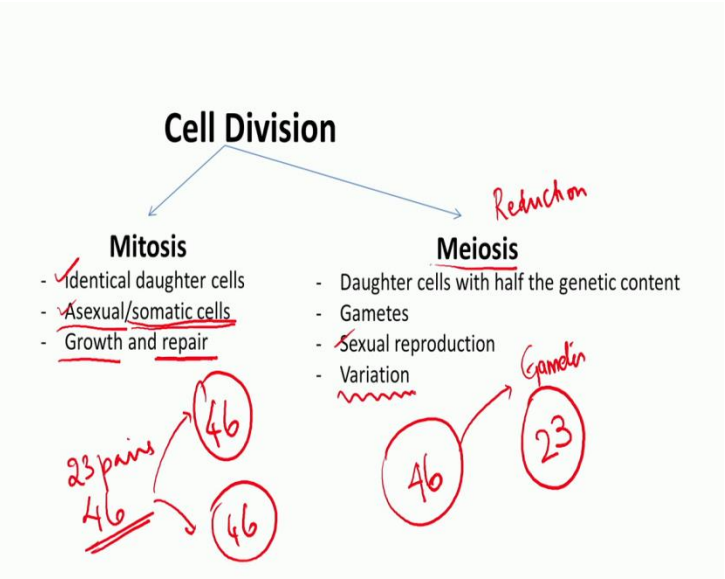


So mitosis is basically the cell division which plays an important role in repairing the damaged parts of the body and also in the growth of the organism. The difference between mitosis and

meiosis and cell division is that mitosis always gives rise to identical daughter cells with same number of chromosomes; for example in humans, we all know that we have twenty-three pairs of chromosomes, or in other words we have fourty-six chromosomes. So in mitosis, by the end of every round of mitosis, you will have two daughter cells, each one of them containing fourty-six chromosomes.

So mitosis is usually seen in somatic cells of our body, the cells which are actually not involved in the process of reproduction, and mitosis in lower eukaryotes is also responsible for the process of asexual reproduction. In contrast to that, meiosis is different. Meiosis is again a form of cell division, but it is also called as a reduction division. In this process, when a cell undergoes meiosis, what happens is that it gives rise to sex cells, which are also called as gametes with half the number of chromosomes. So we, if the germ cell of the ovary is starting, it will form, it will start with fourty-six chromosomes but after the end of meiosis, will give rise to an egg cell with half the number of chromosomes.

So this is the difference between mitosis and meiosis and when we talk about meiosis, I will also emphasize that it has a very crucial role to play, not only in sexual reproduction, but in inducing variations; and we will come to it when we talk about meiosis in another video. So let us come back to mitosis and before I get into the actual process of mitosis, it is very important to understand how our chromosomes are arranged.

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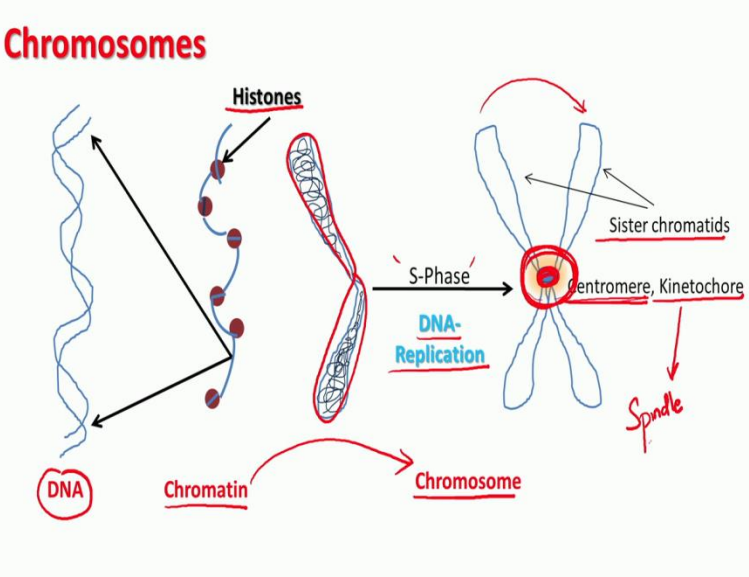

And we all know that our genetic material is encoded in DNA, but then a single strand, a single stretch DNA is way too long and it kind of gets package through multiple folding and wrappings around a set of proteins called as histones. So you have the DNA which wraps around this histones to form what is called as chromatin. Now each chromatin further twists and folds to form a very compact structure and that is what you call as chromosome. Now normally, in an (inter) cell which is undergoing interphase and DNA synthesis, the chromatin is relatively loosely arranged.

But right before it is ready to undergo cell division, the chromatin further condenses into chromosome. Now, there are two terms which are always confusing, so let me clarify that. So each chromosome is nothing but a set of condensed chromatin and after the chromosome has undergone DNA replication which usually happens during the S-phase of cell cycle, each chromosome gives rise to a copy of itself, right, because that is the purpose of DNA duplication or DNA replication.

So now this duplicated copy is also attached to the parent chromosome by a central structure which is called as the centromere and each of these are called as sister chromatids. So, these sister chromatids are nothing but the same duplicated DNA after the process of DNA replication in the S-phase, and they still remain connected at a central point which is called as the centromere.

Now the centromere is also surrounded by a second class of proteins, which is depicted as this (holl) halo around a centromere, which is what you call as the kinetochore. Now I will come back to this a little later but for the time being, just remember that it is usually surrounding the centromere and it is the protein complex which helps in attaching the chromosomes to a very important structure during cell division, which is called as the ‘spindle fibres’.

Now what are these ‘spindle fibres’? The spindle fibres are basically a set of structures which are formed by what is called as the centrosome. Now, in case of animal cells, what you find is each cell at one of its polar end has this structure called as the centrosome which actually is made up of centrioles. Now these centrioles are structures which are placed perpendicular to each other, and it is from this centrosome that you start having extension of microtubules. Remember we spoke about microtubules when we were talking about cell structure.

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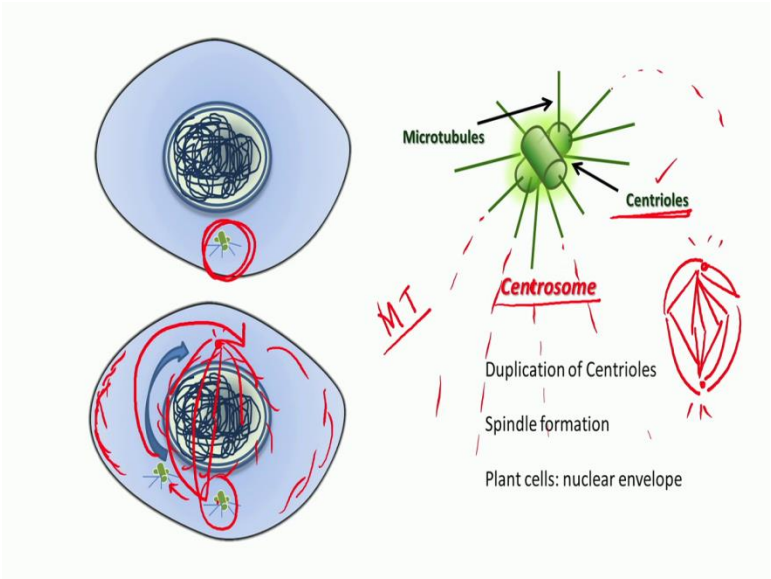


So each of these gives an extended structure which is called as the microtubules which then forms a spindle shaped, or a cage like structure of these microtubule fibres.

And I will come back to this when we are talking about how the chromosomes actually get separated. So in animal cells, there are centrioles, plants do not have it, but that does not mean that the plant cells do not form a spindle; they still form a spindle which is made up of microtubules, and that is because of some of the microtubules, filaments which extend outside of the nuclear envelope and also some of the filaments which originate from structures called as cortex, cortical actin rather form the region in and around the plasma membrane.

So what these tubules do is that they basically, during the process of cell division, the centrosome first replicates, and one of them goes and occupies the other end of the cell, and then, once it has organized to the other end of the cell, they also form fibres, or microtubules, this centrosome also forms microtubules and they form a cage or a mesh-work, I would say a cage like mesh-work of micro tubule fibres, and we will come back to this when we are talking about how the chromosomes get separated.

So two things I want you to bear in mind; one, that after interphase, or during the process of interphase, there is a very important step which happens which is the process of DNA

replication, and once the DNA replication has taken place, the chromosome duplicates itself and the duplicated chromosome is attached with the first one through a centrepoint called as the centromere, and each of these chromosomes are called as the sister chromatids.

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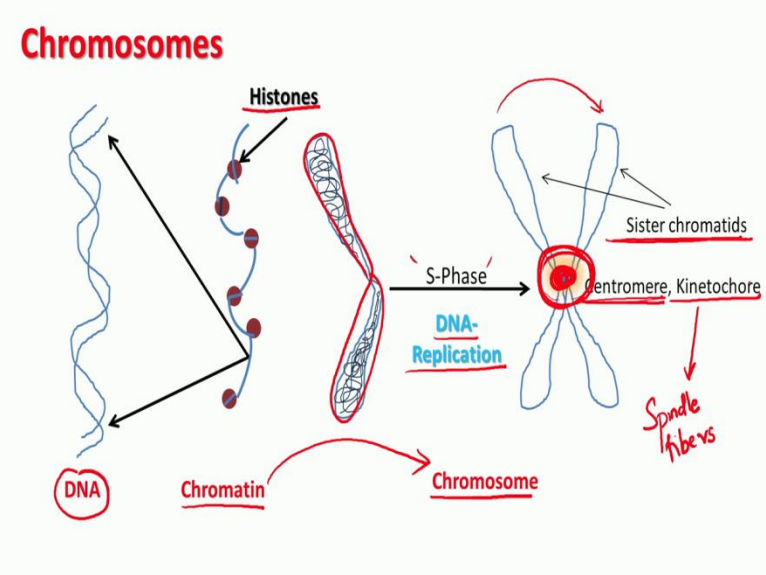


The centromere is also surrounded by a cloud of proteins, it is like a coat of proteins which is called as the kinetochore, and this kinetochore is very important when a chromosome has to attach itself to the spindle fibres. How are the spindle fibres made? In animal cells, they are made, thanks to the presence of centrioles, and it is organized in a structure called centrosome. So, these spindle fibres which are made up of microtubules, extend from one pole to the other pole of the cell like a cage like structure, and we will come back to this when we are actually looking at the separation of chromosomes.

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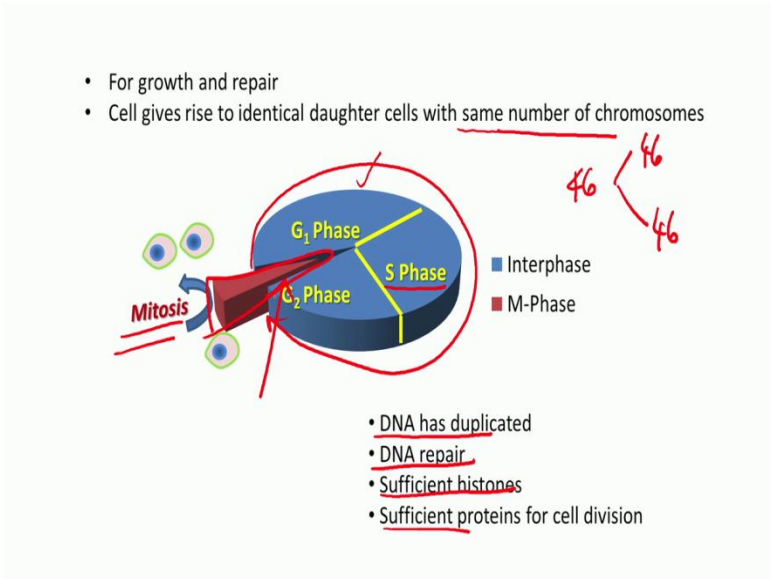


So what is mitosis? As I said, it is a process in which one cell gives rise to two exact daughter cells, it is a process of (copy) cell copying itself with exact number of chromosomes and it is important for growth and repair and what you notice is that, it gives rise to daughter cells with same number of chromosomes. So if a cell starts with fourty-six chromosomes, each daughter cell will end up having fourty-six chromosomes.

So, when we go back to cell cycle, I told you that majority of the time, a cell exists in the interphase; and the interphase is of, in very huge importance because it is during this stage that the cell grows in size, duplicates its organelles, it also ends up duplicating its DNA, which happens during the S-phase, and then during the G2-phase, the cell ensures that the DNA has been copied exactly, there are no errors in DNA replication, if at all there are any errors in, errors in DNA replication, the process of DNA repair will take place.

The cell will also ensure that there is a sufficient histone proteins which are available for the process of cell division to take place. So by the end of G2-phase, before a cell actually enters the process of mitosis which is in this part of the pie-chart, the cell ensures that the entire machinery is ready and is willing to commit itself to the actual process of mitosis. So, what is mitosis and how is it divided?

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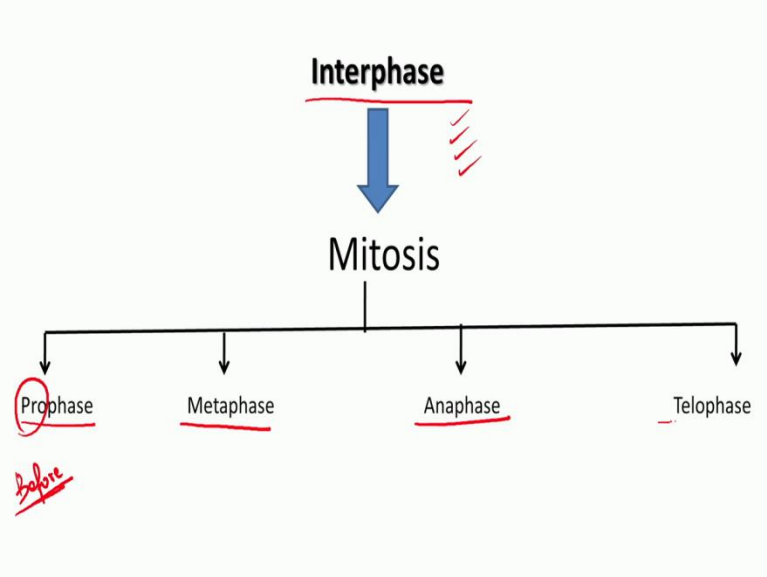


Mitosis follows right after a interphase, provided all the processes have been checked and the cell is convinced that everything is in order to undergo the process of mitosis. The mitosis is divided into four major phases; prophase, pro as I told you means before, so you can take this as the first step, the prophase. The metaphase, the anaphase and the telophase. So, let me show you in one figure exactly how it happens.

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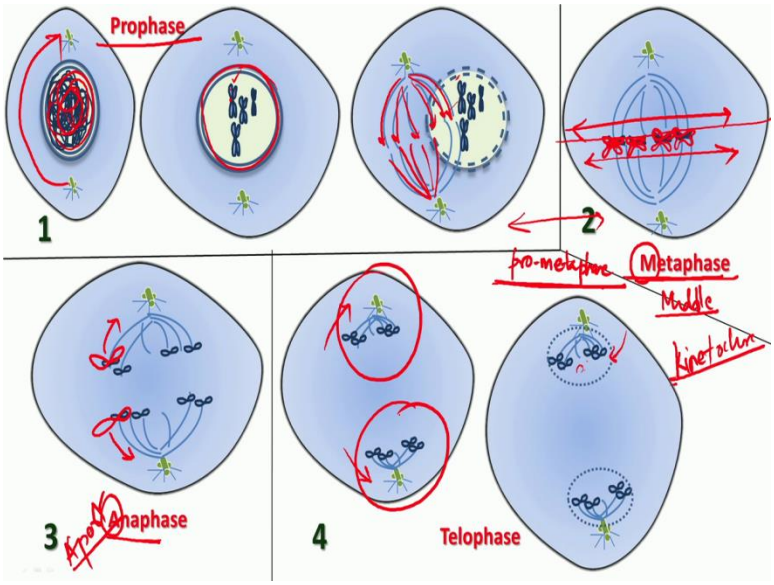

So what happens in prophase? Now the interphase is over, the DNA has duplicated itself, there are sufficient histone proteins available and now the nucleus is ready to divide. So what happens in the first step is that as I mentioned, the centrosome has already duplicated and the other centrosome has gone to the other pole of this cell. You also find that the chromatin, right, this is a duplicated DNA, starts condensing itself into a much better organized structure, which is what you call as the chromosomes, and you will notice that each chromosome is now consisting of two sister chromatids, which are held together at the centromere.

Also, during the prophase, you find that the duplicated centromere starts forming a spindle fibre which is with the help of these microtubule filaments which are extending from one end to the other. At the same time, the nuclear envelope, right, starts disappearing, even the nucleiolus, which is the section where the nucleus prepares a large amount of ribosomes is also disappearing, so it is like the nuclear envelope disappears and the entire spindle formation happens within the cytoplasm nuclear mix, and you find that the chromosomes have condensed and they are now ready for the next step. And what is the next step?

At the next step, you find that the chromosomes start arranging in the spindle and this happens somewhere in between prophase and metaphase, and there is the intermediary step which is also called as the pro-metaphase. So in the pro-metaphase stage, what happens is that the chromosomes have now start arranging themselves in a fashion that they start connecting themselves and attaching themselves to the spindle fibres, and now how do they attach themselves to the spindle fibres? As I told you, they do that through this structure called as the kinetochore. Right? I am sorry. So this is the kinetochore structure with which the chromosomes will now attach themselves to the spindle fibres.

Now during the metaphase, these chromosomes start arranging right at the equatorial plane of the cell. So I would say you remember metaphase as it is a point where the chromosome starts meeting in the middle of a cell, M for middle. So, you find that in metaphase, the condensed chromosomes start arranging themselves along the equatorial plane, and now each of these chromosomes are connected to the spindle fibres through the kinetochore. Then comes the third step which is the anaphase. Now it is at the anaphase that these attached chromosomes, which are sitting on a spindle network and you have the chromosomes sitting at the equatorial plane, that you now start seeing that this (spin), the microtubules of the spindle fibres start pulling apart.

It is almost like a tug-of-war which is happening between the two ends of the spindle, and as a result, the sister chromatids now start getting separated. So one set goes here, the next set is starting to get pulled apart at the other end, thanks to the contraction of this spindle network. So in anaphase, the actual separation of these chromosomes or sister chromatids which were attached all this while starts getting segregated. And then by the time you come to telophase, the chromosomes have separated, they have reached the other two ends of the cell, and at this point of time, you also start seeing the reappearance of the nuclear envelope and the nucleolus.

So, you start in prophase where for the single cell, you find that the first, there is a movement of the centrioles to the other end, there is a disappearance of the nuclear envelope, there is the condensation of the chromosomes and there is the formation of the spindle fibre. The prophase is followed by the prometaphase, at which, these chromosomes start attaching to the spindle fibres, and by the time the cell reaches the metaphase, all these chromosomes are arranged along the equatorial plane and they all are attached to the spindle fibre through this structure which is with the help of a kinetochore.

Then comes the anaphase and at the stage of anaphase, the spindle starts contracting and the chromosome starts getting pulled apart. So you can say that ‘A’ for cells, sorry chromosomes moving apart. And then finally, by the end of it, the chromosomes have reached the other two ends and as a result, you find that these separated chromosomes now start getting enclosed in the newly formed nuclear envelope.

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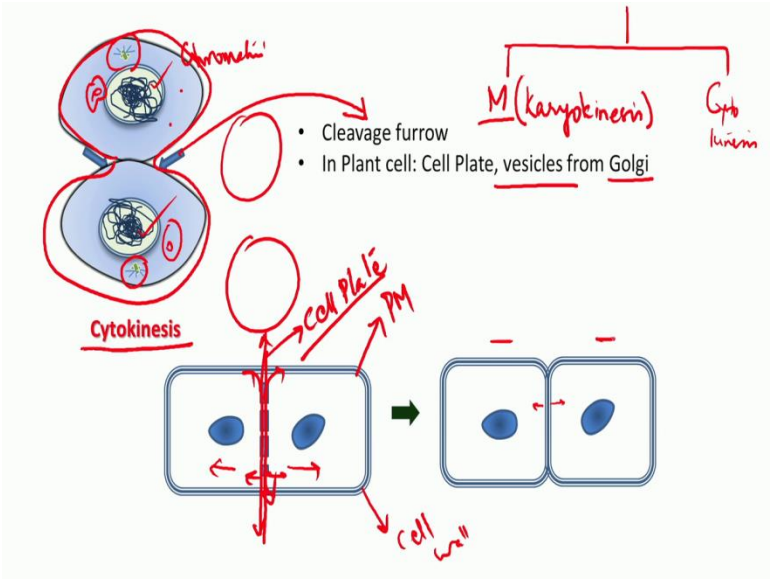


So by the end of telophase, what happens is that you end up having almost two daughter nuclei and these two daughter nuclei now have equal amount of chromosome, and the chromosomes have now started to rewind and unwind into chromatin. Right? The cell organelles, it is not shown in this cartoon, but all the cell organelles like the mitochondria, the Golgi complex also gets equally distributed. One set of centrioles go to one side, then the other set of centriole goes to the other side, and now you have a cell which has got two nuclei, or two daughter nuclei, and now the cell actually needs to divide.

Now, this tag, where, once a daughter nuclei have been formed, the cell actually starts constricting at the centre, right, and this constriction happens, thanks to the fluidic nature of the plasma membrane, this is what you also call as the cleavage furrow. You find that once the daughter nuclei have reached the other two ends, there is a formation of cleavage furrow, the cytoplasm divides and then, the cell pinches of into two daughter cells. This process, where the cytoplasm also divides, is what you call as the cytokinesis. So, the cell division consists of basically two things; it consists of the mitotic phase, and the cytokinesis.

Now mitosis is nothing but also a stage which we also call as karyokinesis, right? And it is in mitosis that the DNA gets separated and two daughter nuclei are formed, and once the two daughter nuclei has been formed, the cytoplasm divides, and that leads to cytokinesis. Now, there

is a issue when it comes to plant cells because the plant cells are also surrounded by this rigid structure which is what we call as the cell wall.

So in addition to a plasma membrane, what happens in plant cells is they have this outer covering made up of cellulose, which is what you call as the cell wall. So for a plant cell, it is not easy to undergo this cleavage furrow; instead what happens in case of plant cells is once the daughter nuclei have separated and being pulled apart right at the centre of the cell, there is a newly foundation laid for a newer cell wall which is called as the cell plate.

Now this cell plate, the components of the cell plate comes from various organelles like Golgi and the vesicles found within the plant cell. So in case of plant cells, you do not see the classical cytokinesis as you see in animal cells. Instead, what you see is once the daughter nuclei have segregated, there is a formation of cell plate right at the centre of the cell and then the cell plate starts growing in a fashion that it starts basically moving in this direction and as it goes on growing, it ends up meeting the original cells cell wall and ten you end up having two daughter cells, again, each daughter cell having the same number of chromosomes as what it started with in the parent cell.

So, what did we study today, what we observed today is that mitosis is that form of cell division which plays a very important role in cell growth and cell repair. In this form of cell division, the number of chromosomes which are passed on to the daughter cells remain the same. So if you start with fourty-six chromosomes as in case of human beings, and in our somatic cells, the daughter cells will also have fourty-six chromosomes, and, the (mitos) the cells in mitosis, there are four different stages; prophase, metaphase, anaphase and telophase, and the reason it is able to segregate the chromosomes equally is because the chromosomes align at the equatorial plane and that is because the chromosomes can attach to the spindle fibres with the help of kinetochore and then there is a tug-of-war between the two ends of the spindle fibre.

As a result, the chromosome starts getting pulled apart, and the sister chromatids move to the two sides, and then there is a formation of daughter nuclei, and the daughter formation of daughter nuclei is then followed by the process of cytokinesis when the cytoplasm divides, while in case of plants, you end up having formation of a cell plate.

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So if for those who are interested to see certain animations which can explain this whole thing in a better fashion, I will recommend you to go through this video on youtube, and there is also a very nice fun rap song by Glenn Wolkenfeld, I would invite you to see that as well. Thank you and I will see you later in another video. We will talk about meiosis.