Biology for Engineers and other Non-Biologists
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Lecture Number 14
Cell Division - Meiosis

So hi! Now today we are going to talk about the process of meiosis, and as I had mentioned in my previous video, we all know that we start our life as a single cell, and this single cell arises because of the fertilization of egg by a sperm.

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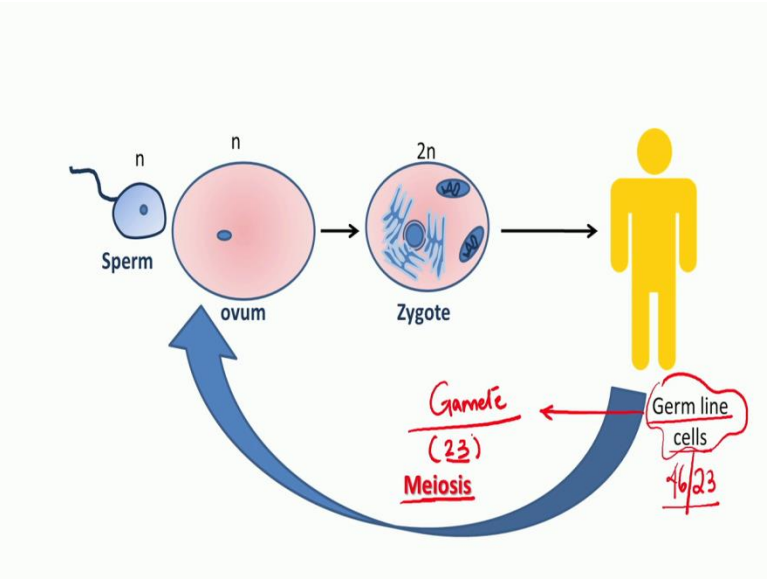

Now, what we have to remember is that when we start our life, we always get a set of chromosomes from our mother, and a set of chromosomes from our father. So if we have twenty-three pairs; for each pair we are getting one chromosome from the mother, and one chromosome from the father. So then, we are formed as a child and then as an adult, we end up having fourty-six chromosomes.

But, once one attains puberty and is now ready for formation of gametes, we find that certain specialized cells, called as the germ line cells, are capable of forming these gametes, so that we can pass on our characteristics to our children. So these germ line cells will contain fourty-six chromosomes or twenty-three pairs and then through the process of meiosis, these germ line cells divide and they give rise to gametes, right, with each gamete having twenty-three chromosomes,

wherein each chromosome is now represented only once. So, how does this process of meiosis takes place is what we are going to study in today's video.

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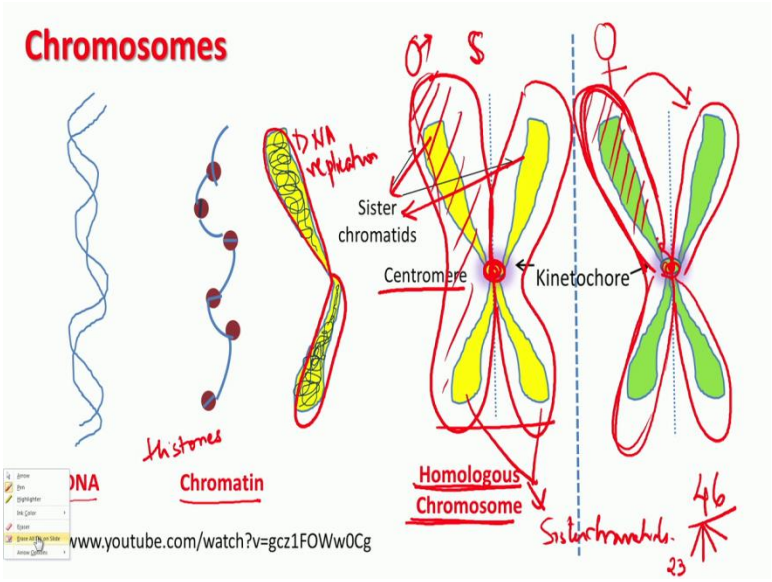

But before I get there, I again want to re-emphasize the arrangement of chromosomes. As I had mentioned during my mitosis video, the DNA normally condenses itself into chromatin with the help of proteins which we call as histones. Right? And then, each chromosome consists of a further condensation of this chromatin. And every time a chromosome undergoes duplication through the process of DNA replication, the duplicated chromosome in attached at the centre with the help of a structure called as 'centromere', where each of these then called as 'sister-chromatids'.

Now what we are going to introduce today is one more term which is called as the homologous chromosome. Now homologous chromosome is nothing but the pair. So let us assume this yellow chromosome is what this part, right, this part of the yellow chromosome before the cell entered S-phase was received from the father. Okay? Now after the process of cell, oh sorry, DNA replication has happened, the cell has undergone the S-phase, this chromosome that we had received from our father got duplicated and you had the sister-chromatid form which is now attached with the centromere.

Now the same chromosome, not identical though, but a chromosome which is coding from similar features will also receive it from our mother, right, so let us say that this green coloured

chromosome was a chromosome that we had received from our mother. So both this one, right, this part, is from the father, while this part we had received from our mother, and when this green coloured chromosome which we had received from our mother underwent DNA duplication, it again gave rise to sister-chromatid which is now the duplicated chromosome attached at the centromere.

So such chromosomes, which are basically this chromosome from father, and then this chromosome from the mother is called as the homologous chromosomes, because these chromosomes contain a set of genes which code for similar characters, say for example hair colour, where you will have a gene, having a chromosome having a hair colour gene from father, and a chromosome having a hair colour gene from the mother. So this set is what you call as the homologous chromosome, and then each of the homologous chromosome will then duplicate itself during the S-phase of the cell cycle and as a result, each homologous chromosome will have its own sister-chromatids. Right?

So this is important to know. So what happens in meiosis, is that we are going to separate these homologous chromosomes and we are going to each cell, each reproductive cell; mind you this process of meiosis does not happen in all the cells of the body, it happens in those cells which are capable of undergoing formation of gametes which are the cells found in testes and ovaries in human beings or animals. So, these cells will undergo the process of reduction division and the homologous chromosomes will get segregated into the gametes.

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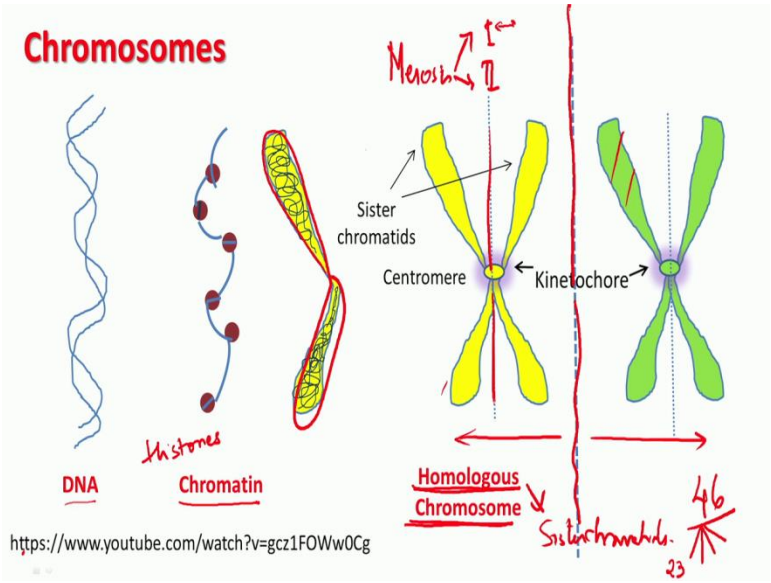

So the idea is, if you start with fourty-six chromosomes by the end of meiosis, you will have daughter cells, you will have four daughter cells with each daughter cell containing twenty-three chromosomes. So this is what happens in meiosis and we have to remember the terms, mainly the homologous chromosomes and sister-chromatids.

So let me just erase this outer bit again, and then come back to what happens in meiosis a little more in (clarit), so that it clarifies your confusion again. Now, so the homologous chromosomes are the chromosomes that we are receiving each set, one set receiving from mother, and one set receiving from father. Now in meiosis, what happens is, there are, as I said, it is a reduction division. So in what we are going to study in meiosis is that, meiosis itself has got two parts; it is divided into meiosis one and meiosis two.

Alright? Now in meiosis one, the first part, the homologous chromosomes will get separated. So after meiosis one, you will have daughter cells while these chromosomes would have segregated. Alright? And then, in meiosis two, you will find that these are sister-chromatids which will get separated. Okay? So we will come back to this a little from now.

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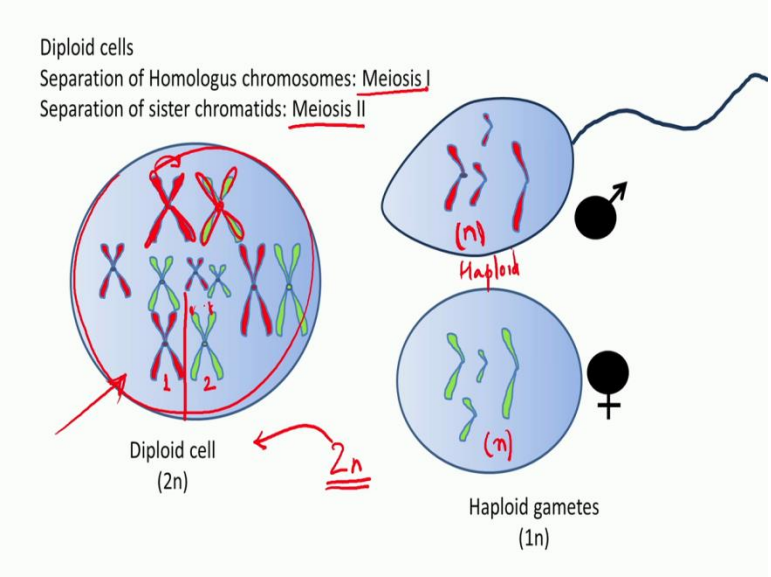

So let us go back to what is a diploid cell. As I mentioned, we all start our life through the process of fertilization where each gamete has one set of chromosomes. So such a cell is called as a haploid cell. Right?

So a sperm coming from father will have only twenty-three chromosomes, so it is a haploid cell. The sperm will then end up fertilizing an egg which again has a single set of chromosomes, and again it is a haploid cell. After fertilization, when these two cells fuse, you end up getting a diploid cell. So these will get mixed up, right? And then when this diploid cell undergoes DNA replication at the S-phase of cell cycle, each of the chromosome will then give rise to its copy, that is a sister-chromatid, it has attached at the centromere. Right? So, this is, this is going to be a starting point, right?

So after the process of cell cycle has happened, the process of DNA replication has taken place, we will be starting our process of meiosis from here. Okay? Now, so again meiosis has two processes; first is meiosis one; in meiosis one, these homologous chromosomes, for example you take this pair and this pair, they will first get separated and then you will have meiosis two, in which each of the sister-chromatids will get separated. So it is a reduction division.

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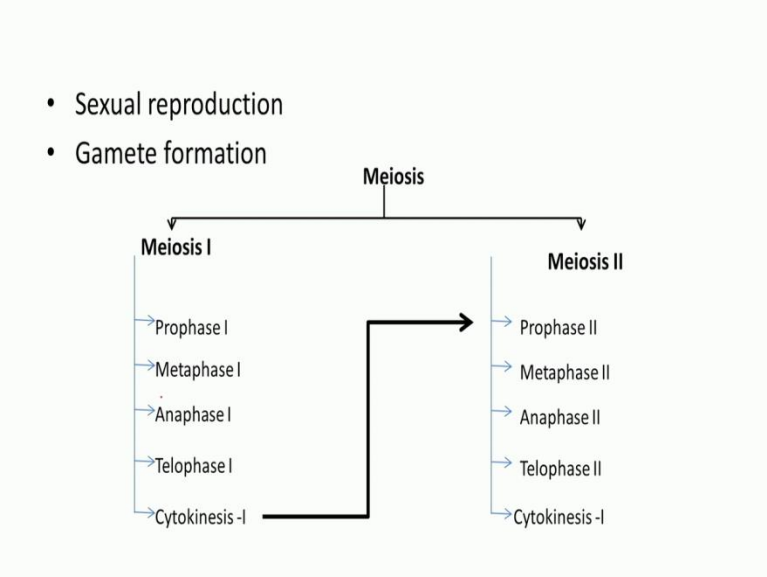

So, what is the importance of meiosis? See it is very important to maintain the chromosome number, you know if this process of meiosis does not happen, then in the next generation, what will happen is the mother cell will give rise to fourty-six chromosome and then the father cells, let us say have fourty-six chromosomes and they are fused together, you end up getting ninety-two chromosomes.

Now that is almost increasing the entire characteristic by two-fold and when the subsequent generation further increases, now that cannot be allowed right? So it has to maintain the same genetic information, the same number of chromosomes and for that, it is important that before an organism undergoes a process of sexual reproduction, its copy numbers are reduced to half, and then, after the process of sexual reproduction, it is restored back. So meiosis plays a very important role in sexual reproduction and it is this division which is responsible for gamete formation.

Now, similar to mitosis, in meiosis, each step of meiosis one, or meiosis two is divided into prophase, metaphase, anaphase, telophase, followed by cytokinesis one; so if once the cell undergoes meiosis one, let us say it starts with one cell; at the end of meiosis one, it will have two cells, alright? Then, each of these cells will then further undergo meiosis too, which again has its stages of prophase, metaphase, anaphase, telophase, followed by cytokinesis, and an each cell in turn give rise to two daughter cells. Alright? Same thing happens here. Right? So at the

end of meiosis, unlike mitosis, you have four daughter cells with half the number of chromosomes, okay? This is what happens in the process of meiosis. So let us see how it happens.

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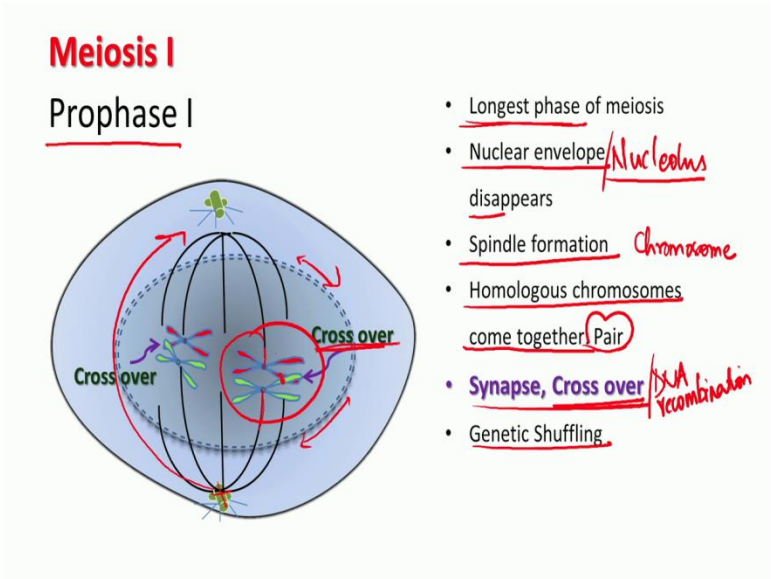

Now the first step of meiosis one which is prophase one is the longest phase of meiosis. Now in this phase, just like in mitosis, the nuclear envelope first disappears, that is why I have drawn this dashed line representing disappearance of the nuclear envelope. Even the nucleolus, remember nucleolus is the part of the nucleus which consists of ribosomes and other machinery also starts disappearing, and then, you find that the pair of centrioles have duplicated and one of them has reached the other end of the cell and then, these are leading to formation of spindles, right?

And these spindle formation is important because it will allow and help the chromosomes to attach. So the chromosomes will start now condensing, as it happened in mitosis, the chromatin will condense into chromosomes, and the homologous chromosomes, remember one each coming from mother and one from the father, the pair, the homologous pairs will start coming together during the process of prophase one. And as they come together, they, so here if you look at this one, you find that one of them is from one parent and the green one is from the other parent.

They they start coming together, at the same time, they also, the homologous chromosomes start attaching themselves to the spindle formation, right? Here they are still not arranged at the

equatorial plane, and that happens in the metaphase; but in the case of prophase, there is one another important thing which happens, which does not happen in mitosis, is that, when the homologous pair of chromosomes come together. So assume this is one chromosome, and this is another chromosome, when they come together, they tend to undergo a process called as synapse, a cross over.

So you have a chromosome coming from father, and a chromosome coming from mother, and they are sitting here together. So this is two sister-chromatids, there are two sister-chromatids, they are coming together, and when they come together at the stage of synapse, there is an exchange of genetic material between these (sis) chromosomes, and this process of exchange of material is what is called as the cross over. Now that is important, because remember, I told you one important reason why there was advantage of sexual reproduction during evolution, is to bring in variation.

So what happens is because of this cross over, there is a genetic shuffling of some part of the mother's chromosome will exchange information with the father's chromosome, and there is an interchange of material; this process is also called as DNA recombination, right? Now what happens is, because of this, what will happen is the new daughter cells, which will have these chromosomes will not be an exact copy of the parent cells. So now because of the cross over, some characters of the father's chromosome have been exchanged with the mother's chromosome and vice-versa. So that kind of a shuffling of characters have happened, and that process is called as the cross over.

So prophase one involves few things; disappearance of the nuclear envelope, disappearance of the nucleolus, condensation of the chromatin into chromosome, homologous chromosomes coming together, attaching to the spindle fibre, and as they come together, they undergo the process of cross over. Now that is the most important difference from mitosis, because there the homologous chromosomes are not pairing together for cross over, it happens only in meiosis one. And thanks to this crossing over, new genetic shuffling takes place and as a result, these chromosomes have exchanged information in material with each other.

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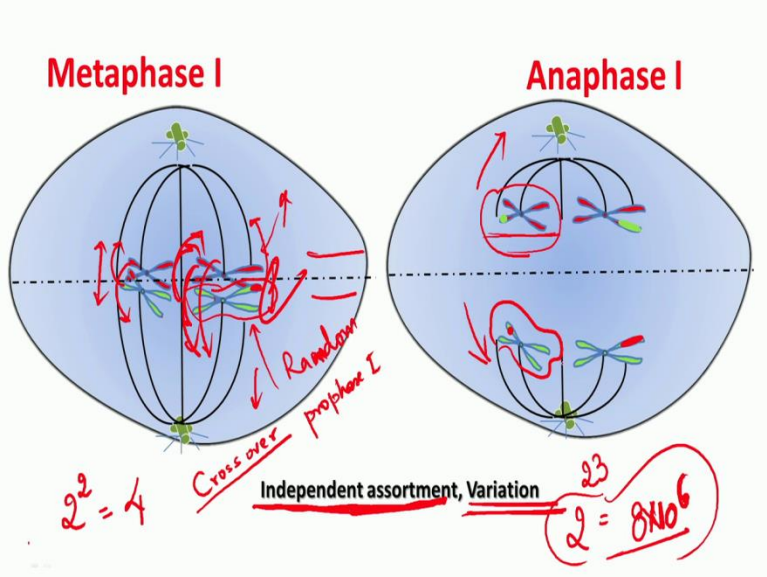

Then you come to metaphase. Now in metaphase, that each of these homologous pairs, they arrange at the equatorial plane, and you would find that by this time the cross over has already happened, the material has been already exchanged. So for example, this one chromosome is actually, it has already exchanged material with the other chromosome, and it has received some features of the other chromosome, right? So this arrangement happens. Now it is not necessary that every time the chromosomes for one parent will appear at one, will arrange at one half of the cell, and the other set of chromosome, let us say coming from mother will arrange at the other half.

It can, it is a random arrangement. So right now, though I have shown in this slide, green chromosomes on this side and the red chromosomes on that side, it is not necessary. It can just be that this pair can be flipping over, right, so if this pair flips over, excuse me; so this side can flip over and the red chromosome can be at this end and the green chromosome can be at the other end, it does not matter, but this arrangement is a random arrangement, and thanks to this random arrangement, you end up getting independent assortment.

Now let me give this to you with an example, now in this case, we have taken two pairs of chromosomes; so, each pair of, so you have two chromosomes, so there are two raised to power two possibilities by which these four chromosomes can arrange themselves. There are four different ways in which these chromosomes can arrange themselves with two (red), excuse me,

with two red chromosomes on this end, two green chromosomes on this end, or, this green chromosome arranges here, and the red chromosome arranges here, while this remains this way, or, it is this red (chromo), green chromosome going up, and then this red chromosome going down, it does not matter.

The point is, these four chromosomes can arrange themselves in permutations and that itself is called as independent assortment. Now imagine this we are talking with just two pairs of chromosomes, if you have twenty-three pairs of chromosomes, you have two to the power twenty-three possibilities in which, these chromosomes can arrange at the equatorial plane, and this is close to about eight million different combinations, right?

Now that is interesting, and I will come back to this a little later. You have ten to the power six, eight into ten to power six different possibilities in which after the cross over has taken place, the homologous pairs can arrange themselves. So that happens in metaphase. Having done that, and this independent assortment and this multiple combinations is what leads to variations, alright?

And so there are two things which leads to variation; one, as I mentioned, is the cross over, and this cross over happens during prophase one of meiosis one, and the second one is the independent assortment of the homologous chromosomes. That in turn gives rise to about eight million different possibilities in which these chromosomes will arrange themselves along the equatorial plane. So that happens in metaphase.

After they have arranged themselves at the equatorial plane, just like in mitosis, in anaphase, these homologous pairs start moving apart. Now you will notice that this chromosome, thanks to the crossing over has changed, it is not the complete red chromosome, what it was in the beginning. Similarly, this chromosome has received some information due to the cross over. So you find that this is introducing variations.

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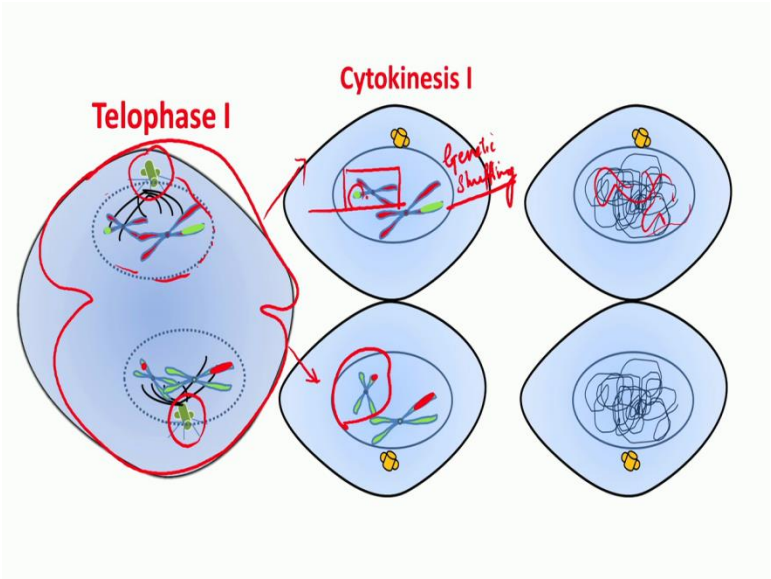

So during anaphase, the chromosomes will move apart, and by the time they come to telophase, you start seeing that the nuclear envelope starts reappearing, and, the daughter nuclei are getting formed, and one pair of centrioles on one end, another pair of centrioles at the other end, and this would be followed by formation of a cleavage furrow after telophase one, leading to cytokinesis and two daughter cells.

Now what you will notice is that in these daughter cells, you have received slightly newer version of the chromosomes, thanks to the process of genetic shuffling or the synapse. Right? So, the meiosis one ends with the separation of homologous chromosomes, so this is one part, this is another; so this is one homologue, this is the another homologue, and mind you again, each of these homologues are slightly different from their starting material because of the cross over.

Now after cytokinesis one, there is a brief period before which the cell again goes back to meiosis two, and then again, it just loosens up the DNA, which is the chromatin, and then, immediately, there is no more further DNA replication now. Whatever DNA replication had to happen has already happened during the S-phase of cell cycle, it is not happening anymore.

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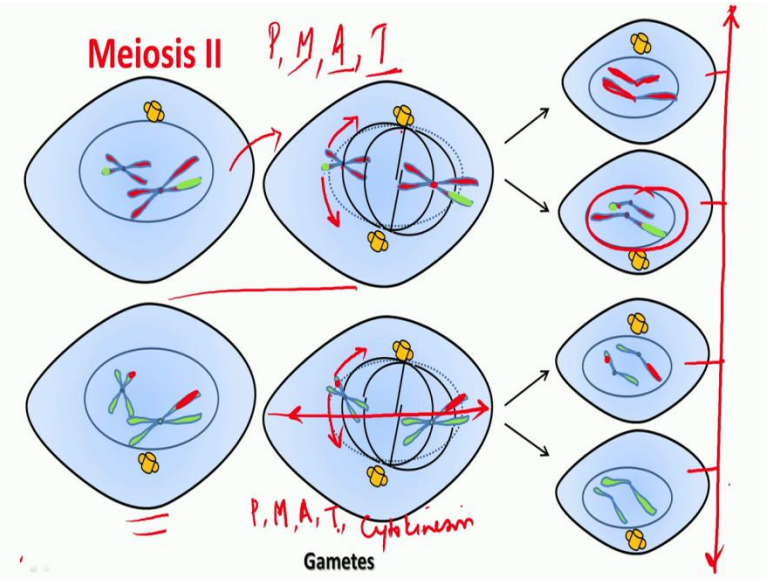

Now, the after cytokinesis one, the cell then undergoes the process of meiosis two, and meiosis two again, as I said, contains prophase, metaphase, anaphase and telophase. Now each of these cells, so you will notice, here the homologous pairs are separated, right? Now in this, meiosis again, this cell again undergoes the process of prophase, where the nuclear envelope disappears each chromosome, still attached to its centromere. Right? It is attaching to the spindle fibre and it aligns to the equatorial plane during the metaphase. Right?

So, you find that in prophase, the chromosome start attaching to the spindle fibre through the centromere, they will arrange at the equatorial plane at the metaphase, and then at the anaphase, they start separating apart. And, by the telophase, and then, followed by cytokinesis, which have not shown in this cartoon, but it is like a continuous process. After the metaphase, you have the anaphase taking place, then you find that the two chromatids have separated.

So this chromatid, like we just rub the soap again. Okay. So let me go back to the pen. So what has happened after the anaphase has taken place, after the telophase has taken place; this chromatid has gone onto this side, and this chromatid has gone onto the other side, and then the telophase happens, cytokinesis takes place, and now you have the new daughter cell with the chromosomes.

Now you will notice that the chromosomes are different; for example this daughter cell has received a different version of the chromosome than the starting material, right? So, you find,

same thing happens with the other cell. This cell also undergoes the process of prophase, where the nuclear envelope disappears, spindle formation takes place, the chromosomes with the sister-chromatids is attaching to the spindle fibre; then the metaphase happens where each of these chromosomes try to arrange at the equatorial plane, followed by anaphase, at which each of these chromatids will separate, they will reach the polar ends in the telophase, and this will be then followed by cytokinesis.

So what has happened is after meiosis two, you end up getting four different cells. With half the number of chromosomes, and most importantly, none of them, none of these gametes are an exact copy of each other. Right? And why it is so? The reason they are not an exact copy of each other is thanks to the crossing over which has taken place in prophase one of meiosis one.

And this is one of the reasons why, though we have characters which are similar to our parents, we are still not an exact carbon copy of our parents. We may receive some features from our parents, and some features from our mother, and even the features that we receive from our mother is not an exact carbon copy, it is still a slight variation, because of the process of crossing over.

So what have we learnt in today's video is that meiosis is a process which allows for reduction of chromosome, it happens only in the reproductive cells which are responsible for formation of gametes, and meiosis is divided into two stages, meiosis one and meiosis two. In meiosis one, the homologous chromosomes get separated, while in meiosis two, the sister-chromatids get separated.

In meiosis one, prophase one is the longest step and it is one of the most critical step which sets it apart from mitosis because it is in prophase one that the homologous pairs come together, they undergo a process of crossing over, and because of the process of crossing over, you introduce new variations. And that is the reason why none of us are an exact copy of our parents, though we have characters which are similar to our parents.

The other important thing to note is that in meiosis one, during the process of metaphase, there is various, two to the power twenty-three possibilities by which these homologous chromosomes can arrange themselves. Now that is a huge combination of independent assortment, which further tells you why two different, two siblings of a given parents are not exact copy of each

other. So, meiosis is very important in the process of cell division because it is meiosis which is responsible for variation, and for maintaining the chromosome number from one generation to another, because it is meiosis which is responsible for, for first reducing the chromosome numbers into the gametes, and then as the sexual reproduction which brings back these chromosome numbers to the constant number for a given species.

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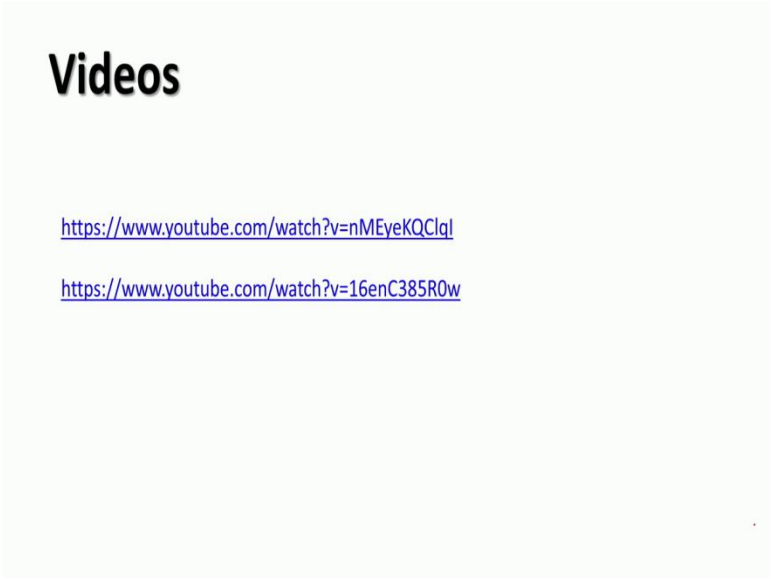

I hope this video has been helpful; I would also recommend you to go through some of the interesting videos on YouTube. Some of them have got very good animations; I would like you to go through them which beautifully explains the process of meiosis. Thank you and see you later.