Basics of Biology
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Module 3: Cells in Biology
Lecture 14: Cell Division and Regulation

Hello everyone. This is Doctor Vishal Trivedi from Department of Biosciences and Bioengineering, IIT, Guwahati and what we were discussing, we were discussing about the living organisms and in this particular module we were trying to understand the different structural as well as the physiological properties of a particular cell and in this context, we have initially discussed about the prokaryotic cell.

And when we were discussing about the prokaryotic cell we discussed about the internal structure of the prokaryotic cell, so internal structure of a prokaryotic cell is very simple it does not have any membrane-bound organelles and in addition to that it does not have even any kind of boundaries between the different organelles with different structures.

So it has the electron transport chain, it has a genomic DNA and has the all other kinds of components, apart from that we also discuss about the flagella which is actually required into the prokaryotic cell for its movement and we also discuss about the cell wall and based on the cell wall the gram stain is being developed and that gram stain actually discriminate the bacterias into the two different classes the gram positive bacteria or to the gram negative bacteria.

Further to that we have also discussed about the differences between the prokaryotic cell as well as the eukaryotic cell and subsequent to that we also discuss about the different types of the eukaryotic cell, we discuss about the animal cell as well as the plant cell and we have also discussed about the differences between these two types of cells. Then we have taken up the organelles of what are present in the eukaryotic cell.

So, eukaryotic cell has several different types of membrane bound organelles. So in the previous two lectures you might have seen that we have discussed about the nucleus, we discuss about the chloroplast and we discuss about the mitochondria, we discuss about

the chloroplast and then we also discuss about the organelles what are responsible for the vesicular trafficking.

Where we have discussed about the endoplasmic reticulum, golgi bodies and the lysosomes and all these organelles are responsible for distributing the food material or the other kinds of proteinaceous material within the cell and we did not discuss the complicated mechanisms, how the vesicles from the endoplasmic reticulum or the from the golgis are being distributed throughout the cell.

Because that is a very big and detailed topic which can be discussed in a dedicated course to the cell biology, apart from that we also discuss about the plasma membranes and we discuss about the function of each of these organelles. So this we have understood the cellular as well as structural and as well as the physiological properties of prokaryotic as well as the eukaryotic cell.

In today's lecture we are going to discuss how we can be able to grow these eukaryotic cells or prokaryotic cell and how you can be able to monitor the growth of these cells.

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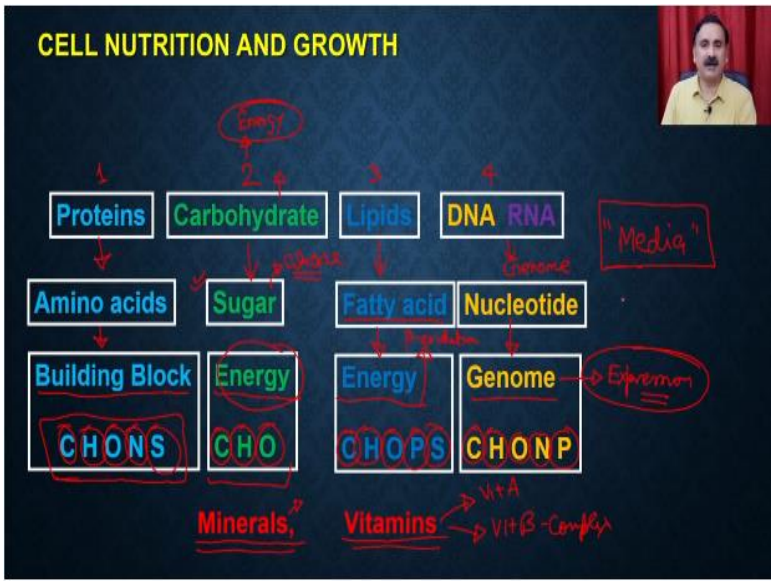

So let us start our discussion about how you can be able to grow the prokaryotic as well as the eukaryotic cells. So when we talk about the growth, we are talking about, we have to first discuss about the nutrition and then we can actually be able to talk about the how

we can actually be able to monitor the growth and what are the different phases, what are present within the growth when the cell is growing from the one cell to another cell.

So as you can see that the cells are actually growing and they require the basic nutrients for maintaining their cellular structures. So what are the different basic nutrients, what is required. So cell is actually been dependent on to the four macromolecules, the cells requires the protein, cells require carbohydrates, cells required lipids and then it also requires the DNA and RNA which is part of the genome.

So protein is the building block, it requires for the synthesis, for the communications for all other kinds of functions, carbohydrate is actually be a source of energy, so it is required for the energy, so carbohydrates like the sugar they are being required for the energy, so carbohydrate is required for the energy.

Lipid is also required for the energy production and the DNA and RNA is a part of the genome, so they are required for maintaining the genome of that particular organisms. As you can see that the protein is made up of the amino acids and all these biomolecules, whether it is a protein, carbohydrate, lipids or RNA we are going to discuss in our subsequent modules, so you do not have to worry about these terminologies.

So protein is made up of the amino acids and amino acids are made up of the single atoms and amino acids are a protein is the building block, it requires for the structural proteins, you can require the functional proteins and you require the all other kinds of proteins, so that is a building block and mostly the protein is made up of carbon, hydrogen, oxygen, nitrogen and sulfur, so you require these five atoms or the molecule which can actually be able to provide these atoms.

Similarly, in the case of carbohydrates, carbohydrate is made up of the sugar molecules, one of the classical examples is the glucose. So when we talk about the carbohydrate we are talking about the complex carbohydrates like the polysaccharides, these polysaccharides are made up of the sugar molecules such as the glucose which is called as the monosaccharide and these purpose of these carbohydrate is to provide the energy.

So they will provide the energy by burning the carbohydrate molecule into the metabolic pathways such as the glycolysis, Kreb cycle, pentose phosphate pathway and electron transport chain and mostly the carbohydrates are made up of the three atoms like carbon, hydrogen and oxygen so you require the food material which actually be able to provide the carbon, hydrogen and oxygen.

Then similarly, the lipids, lipids are made up of the fatty acids and the glycerol and the fatty acids are also be required for the energy production, so they require the energy production because the fatty acid also you can burn in the beta oxidation and that is actually going to give you the huge quantity of the energy and just like the carbohydrates the lipids are also been made up of the carbon, hydrogen, oxygen, phosphorus and sulfur.

Similarly, the nucleotides, the nucleotides are required for maintaining the genome of that particular organism or it also requires for the expression by the help of the RNA, so you require whether to maintain the genome of that particular organism or to produce the RNA which is actually going to help in the expression of that particular gene.

As far as the nucleotide is concerned, they are made up of the carbon, hydrogen, oxygen, nitrogen and phosphorus. Apart from that you also require many minor quantities of the minerals like minerals means like different types of metals like zinc, iron, copper and all those kinds of minerals and then you also require the vitamins, like you might have seen the vitamins, you have a vitamin A, you have the vitamin B complex and also all.

So, these are the different types of vitamins what is required also for the cell to properly get the nutrition and then it is actually going to show you the growth. Now if you want to culture the eukaryotic cell what you have to do is you have to provide all these nutrients in the form of the media, if you want to culture these mammalian cells or if you want to culture these mammalian cells you have to provide these nutrients into a media.

So if you want to prepare a media what you are going to do is you are actually going to provide all these nutrients in a form which actually cell can take up and then it is actually going to assimilate that material and it is actually going to function.

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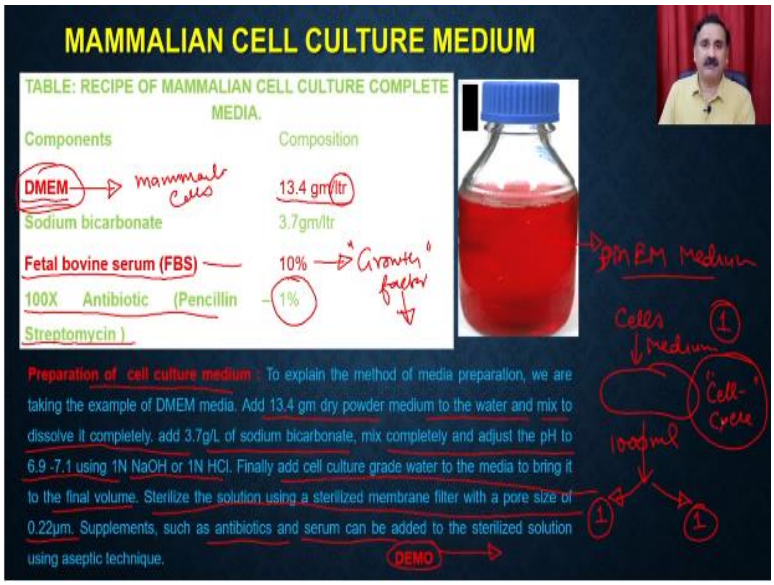

So let us see how you can be able to prepare the media for culturing for providing and nutrition into the mammalian cells. So if this is a just a simple recipe for one of the very popular media which is called as the DMEM media which is actually been used for culturing the different types of the mammalian cells in the laboratories and what you require is you require a DMEM powder which you are going to get from the company is 13.4 grams for one liter of media, what you see here is a, this is the DMEM medium.

So then you require the fetal bovine serum, so FBS, FBS is required because you require the growth factors, these growth factors are actually going to give the some kind of stimulus so that the cells will grow for the different rounds of divisions, then you require the antibiotics because the mammalian cell culture media is also sensitive for the antibiotics and how you are going to prepare the cell culture media.

You can actually take the like 13.4 grams of dry powder and you can mix it with the water and dissolve it completely and then you add the 3.7 grams of sodium bicarbonate, mix completely and adjust the ph to 6.9 to 7.1 using 1 NaOH or 1 HCl and finally you add the cell culture grade water to bring it to the final volume which is the 1000 Marlboro Lights.

And then you sterilize the solution using the sterilizing membranes because the mammalian cell culture media contains the vitamins, minerals, glucose, carbohydrates different types of amino acids, different types of fatty acids and different types of the nucleotides, so source of the nucleotides and that is why you cannot actually deautoclave the media, you cannot autoclave just like as we are going to prepare the microbiology media.

So you have to filter the media with a 0.22 micron filter, so that is actually going to sterilize the media and then you can actually add the sterilized antibiotic and serum and that's how your cell culture media is ready. Now once you incubate the cells, if you incubate the cells into the medium what will happen, the cell is actually going to take up this nutrient and then it is actually going to increase its size.

So it is actually going to increase its size, so imagine and then after some time the cell is actually going to go and divide, so you know that every cell is actually going to divide, so if you start with the one cell you can be able to get the two cell, so one is going to be the mother cell, the other one is going to be the daughter cell.

So what are the different events are happening when the cell is going through a growth phase and ultimately when it grows to the larger size then it actually divides. So when you want to go for these kind of events, these events are actually called as cell cycle, so cell is actually going through with the event of the reactions or event of these stages and these stages are collectively called as the cell cycle.

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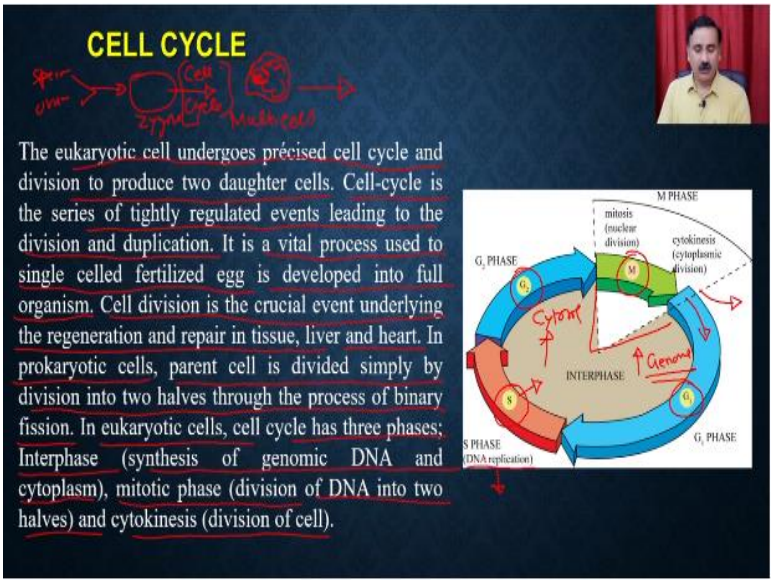

So let us see what are the different events are there in the cell cycle. So what you see here is the different events, what you have is the G1, then G1 is followed by the S phase and the S phase is followed by the G2 and the G2 is followed by the M phase and at the end of the M phase you are actually going to have the two cell, one daughter cell which is actually going to be pinched off from this and one mother cell which will again continue with the cell cycle.

So the eukaryotic cells undergoes the precise cell cycle and division to produce the two daughter cell, cell cycle is the series of tightly regulated event leading to the division and duplications. It is a vital process used to the single cell fertilized eggs is developed into the full organism.

So you can imagine that when the sperm and the ovum is mixed, when the sperm and ovum is mixed they are actually going to give you the single cell which is called as zygote and from this single cell it is actually going to acquire the multi cell stage, so it is going to form the blastula and all other kind of multi stage and then when it get differentiated.

So how the cell is single cell zygote is transforming into the multi cell by the event which is called as cell cycle and that has to be very, very precise otherwise it is going to give

you a irregulated divisions. So cell division is the crucial event underlining the regeneration and repair in the tissue, liver and heart. In prokaryotic cell the parent cell is divided simply by the division into the two halves through the process of binary fission.

So what we just said is actually a cell cycle which is applicable only for the mammalian cell, whereas in the case of prokaryotic cell, the cell is when it grows to a larger size it is getting divide into the two halves by a process which is called as the binary fissions. In eukaryotic cell, the cell has three phases.

One is called as the interface where it is going to have the synthesis of the genomic DNA and the cytoplasm then it has the mitotic phase which is where the division of the DNA into the two halves and the cytokinesis will take place. So you actually have the two phases, one is the interface where you have the three events that is the G1, S and G2 in this phase it is actually going to increase its genome size.

So it is actually going to increase the genome size and it also going to increase the cytosol, which means during this phase only the interface the cell is actually going to grow in size, it is actually going to increase its DNA, so it is going to use the S phase for synthesizing the new DNA and with the process of the DNA replications that also we are going to discuss in our subsequent lectures.

So you do not have to worry about how the DNA is getting synthesized and all that. So let us discuss about the events what is happening within the interface and then we are also going to discuss the events what is happening in the M phase.

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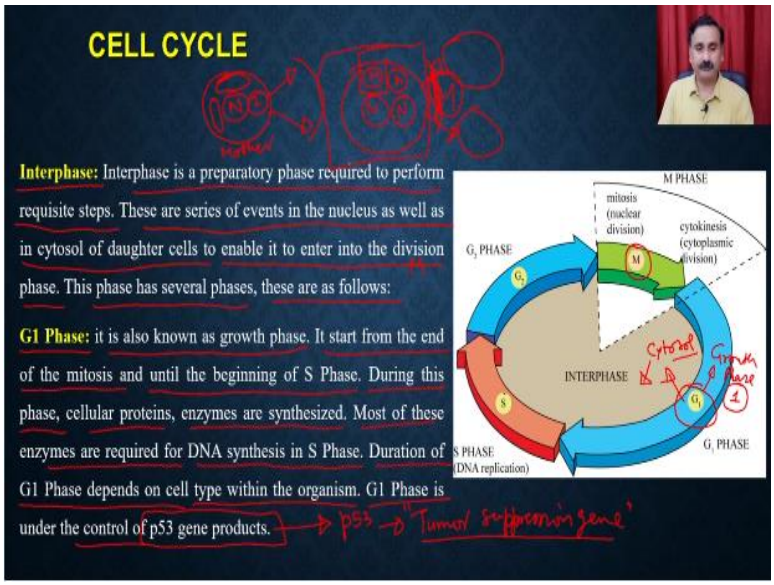

So in the interface, interface is the preparative phase required to perform the requisite steps, these are series of event in the nucleus as well as in the cytosol of the daughter cell to enable it to enter into the division phase, this phase has the several phases, these are as follows. So, the interface is actually a phase which is required to prepare the cell for the division phase, so this is the division phase, the M phase.

But before it actually go for the division phase it has to ensure that it has the adequate amount of genomic DNA, it has the adequate amount of the cellular machinery so that it actually can divide, what it actually require, suppose a cell is there, if this is a mother cell, it has one nuclear, so ideally it should have two nucleus, then only it actually can divide, it is like very simple.

If you have the only 100 rupees you cannot give those 100 rupees or you cannot share those 100 rupees with your friend but if you have 200 rupees then you can keep 100 rupees with you and you can give that next 100 rupees to your friend also. Similarly, it only going to have the limited number of mitochondrias, it also going to have the limited number of the lysosomes.

It also going to have the limited number of the golgi bodies and so on, so similarly it is like I give you the similar example suppose you have the limited number of shirts and

pants, so you cannot share those shirts and pants with your brother or you with your friends, if you have very huge number, if you have duplications if you have four shirts then you only use you can actually be able to share.

So, that is what you require and that is a part of the interface where you are ensuring that you are actually going to have the two nucleus, you are going to have the two copies of the genome, you are actually going to have the two copies of the mitochondria, so that you can be able to divide among yourselves.

Similarly, you can have the adequate number of the lysosomes, you should have the adequate number of the golgi bodies and all other organelles then only you will say okay let us divide this and then you are actually going to have the individual cell, so this is the part where you are actually going to have the M phase but before that all these is called as the interface.

So these are the series of event in the nucleus as well in the cytosol of the daughter cell to enable it into the division phase or the M phase. This phase has several phases, so what is the phase in the G1 phase, so this is the G1 phase and it is also known as the growth phase, so in the G1 phase or this is called as the growth phase, you can easily remember G1 means growth phase one.

So, the phase where you are actually going to see the growth of the cell, it starts from the end of the mitosis, so mitosis is the M phase and until the beginning of the S phase. So G1 phase is the phase between the mitosis phase and as well as the S phase, during this phase the cellular proteins, enzymes are synthesized.

So you are actually going to see in a synthesis of the cytosol. Most of these enzymes are required for the DNA synthesis in the S phase, especially it is actually going to synthesize the enzymes what is required for the DNA synthesis, because it has to prepare the cell to enter into the S phase so that it can be able to prepare the two copies of the genomic DNA.

Duration of the G phase depends on the cell type within the organisms, G1 phase is under the tight control of another gene which is called as the p53, so p53 is also called as the

tumor suppressor gene. So tumor suppressor gene, so it is actually going to control the activity or it is actually going to control the G1 phase and that is how the G1 phase is going to enter into the another phase which is called as the S phase.

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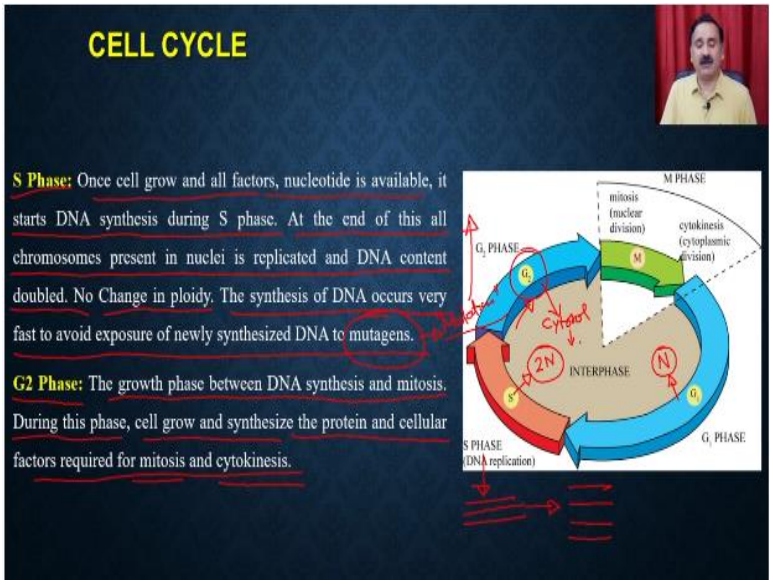

Now what is there in the S phase? Once the cells grow and all the factor and nucleotide is available it starts the DNA synthesis during the S phase at the end of this all the chromosome present in the nuclei is replicated and the DNA content is going to be double, which means in the S phase, so here you are going to have the one copy of the nucleus, whereas in the S phase you are actually going to have the two copy of the nucleus.

No change in the ploidy, the synthesis of the DNA occurs very fast to avoid the exposure of the newly synthesized DNA to the mutagens. So there will be a synthesis of DNA and this synthesis of DNA is going to be very fast so that the DNA which is, when we discuss about the DNA replication that time you will understand that how the DNA synthesis is going to happen.

So single copy of DNA is actually going to give you the two copies of the genome but during this process this DNA is going to be completely denatured and that is actually

going to provide the template for the synthesis of the new DNA, but as this side because it is getting exposed, it could get exposed to the different types of the mutagens.

Mutagens are the agents which are actually going to create the mutations, mutation means the change in the nucleotide sequence and if that happens it is actually going to be problematic for the new cell because the some of these mutations could actually cause the disruption into the cell cycle and that would be the ultimately be responsible for the development of the tumor.

So to avoid this what the cell is doing is it is actually opening a very short span of the DNA and also it is synthesizing the DNA very fast so that it get completely covered and there will be less chance of the mutagen to enter and do the mutations. Then once the S phase is over, then it is actually going to enter into another growth phase which is called as the G2 phase, so G2 phase the growth phase between the DNA synthesis and the mitosis.

During this phase the cells grow and synthesize the protein and the cellular factor required for the mitosis and the cytokinesis. So during the G2 phase it is again going to synthesize the factors what are present into the cytosol, especially it is actually going to start synthesizing the protein, what is responsible for the mitosis as well as the cytokinesis.

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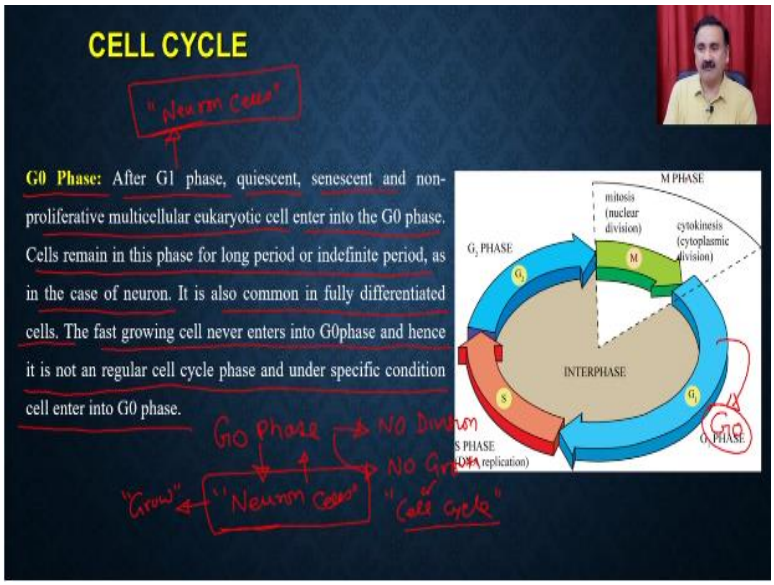

Then some of the cells are also having the G0 phase, so after the G1 phase, which means after the G1 phase they will enter into another growth phase which is called as the G0 phase. What is the unique about the G0 phase? It is actually going to be quiescent, senescent and non-proliferative multicellular eukaryotic cell enter into the G0 phase.

One of the classical examples is the neuron cells, so neuron cells are actually going to be synthesized at the fully matured cells and they do not divide, they actually get entered into a state where they are called as entered into the G0 phase because they are actually non-proliferative eukaryotic cells.

Cells remain in this phase for long period or the indefinite period as in the case of the neuron. It is also common in the fully differentiated cells; the fast-growing cells never enter into the G0 phase and hence it is not a regular cell cycle phase and under specific condition the cells are entering into the G0 phase.

So cells which are in the G0 phase are actually going to have the no division, which means they will actually going to no growth. So there will be no growth or cell cycle so that is why the G0 phase is not a part of the cell cycle, but the cells which are actually being entered into the G0 phase are either the fully matured and they do not require any more differentiation or they are actually the cell which are devoid of the duplications.

The classical example is the neuron cells and that is why you might have heard that if there will be a neural damage that cannot be repaired for example, if we get an injury into our hand, the hand cells are actually going to regenerate, they are actually going to regrow and that is how they are actually going to heal the wounds.

Whereas if there will be any injury into the brain or into the spinal cord then there will be no regeneration because the neural cells are not going to grow, they are not going to grow because they are within the G0 phase and because of that there will be no recovery and that is why it is considered to be that the neural damages are very, very serious.

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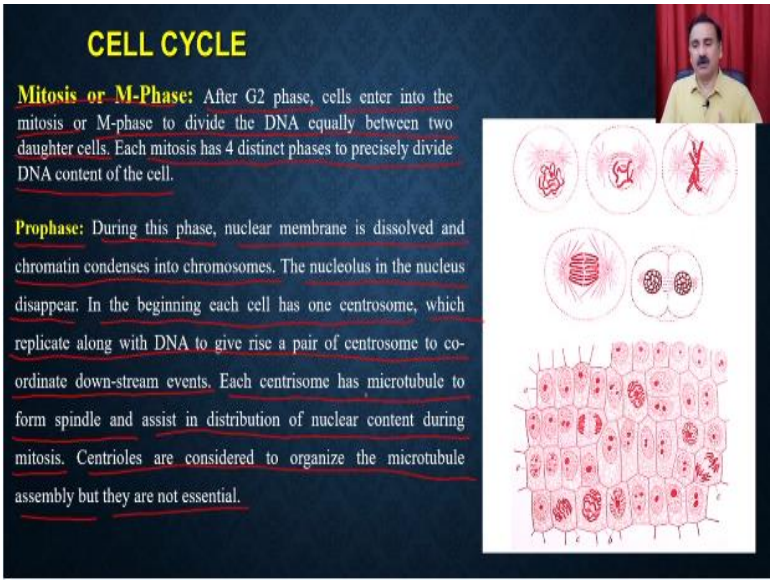

Now let us discuss about the mitosis and the cytokinesis or the M phase, so that is called as the M phase. So the mitosis or the M phase after the G2 phase the cells enter into the mitosis or the M phase to divide the DNA equally between the two daughter cells. Each mitosis has the four distinct phases to precisely divide the DNA content of the cell.

So the purpose of the mitosis is that it divides the nucleus, remember that in during the S phase the DNA is being synthesized so you have the two copy of the genome and now these two copies has to be divided equally between the two daughter cells, so that there will be no mismatch, so it should not be that somebody got the 75 percent genome and the other one is got as 125.

So it should not be, if you have 200 number it should be divided 100, 100. So that has the multiple phases, so the first phase is called as the prophase. So during this phase the nuclear membrane is dissolved and the chromatin condenses into the chromosomes, the nucleolus in the nucleus disappear.

In the beginning each cell has one centrosome which replicates along with the DNA to give rise a pair of centrosomes to coordinate the downstream events. Each centrosome has the microtubule to form the spindle and assist in the distribution of the nuclear content during the mitosis. Centrioles are considered to organize the microtubule assembly but they are not essential.

So what you see here is the different phases what is present in the mitosis and this is what you see here is a single film where so all these cells are dividing and that is how they are actually showing the different phases. So the prophase is actually a preparative phase where all the preparations are going to be done, so that it is actually going to go through with the division process.

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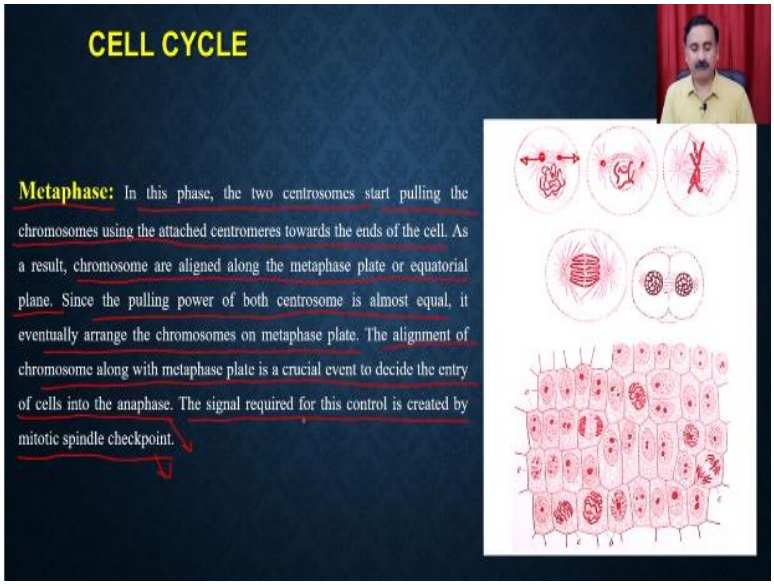

Then we have the metaphase. In this phase the two centrosomes start pulling the chromosomes during the attached centrosome towards the end of the cell. So what happen is you have the two copy of the genome, two copies of the chromosomes, all

these two copies of the chromosomes are actually going to be attached to the centrosome and then these centrosome are actually going to be pulled onto the corner of or the end of the cell, so that is why they are actually going to be segregated.

So as a result along the chromosomes are aligned along the metaphase plate or the equatorial plate and what you see here is actually that the two chromosomes are being aligned onto the and these are the centrosome which are being pulled on towards the end of the cell and since the pulling power above centrosome is almost equal it eventually arrange the chromosome onto the metaphase plate.

The alignment of the chromosome along with the metaphase plate is a crucial event to decide the entry into the second phase, that is called as the anaphase. The signal required for this control is created by the mitotic spindle checkpoints.

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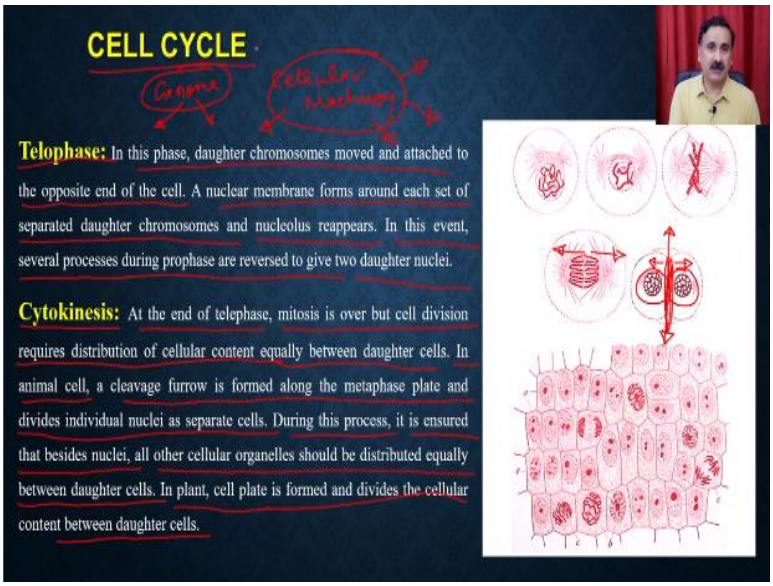

Then we have the anaphase. So the protein attached to the each chromatins are cleaved and the sister chromatids are separated as the daughter chromosomes. The chromosome lined onto the metaphase flares are pulled by the microtubules, so you can see right the chromosomes that have been arranged onto the metaphase plates are then will be pulled onto each corner of the cell and they will be go to the respective centrosome.

Although the exact mechanism of generating the force required for the centrosome movement is unknown, it is suggested that the rapid assembly and breakdown of microtubules may provide the force for this moment. At the end of this phase the chromosomes are being prepared for the distribution between the two daughter cells.

Then it enters into the telophase and the telophase and this phase the daughter chromosomes moved towards attached to the opposite end of the cell, so they will initially be attached here and then they will move towards the both ends of the cell and that is eventually there will be two nucleus or the two chromosome which are going to be distributed among the two daughter cells.

As the nuclear membrane forms around each set of the separated daughter chromosome and the nucleolus reappear in this event the several processes during prophase are reversed to give the two daughter cells. So that is what happen, it is going to be the nuclear membrane is going to be developed against that particular daughter chromosome and the nucleus reappear and that is why you see the two nucleus are going to be formed.

Now once the two nucleus are going to be formed then what the next event is that you should divide this cell and that event is called as the cytokinesis. So we have discussed we have distributed the genome now we are going to distribute the cellular machinery, because if you want to make the new cell you have to do the distribution of the genome so that we have done with the help of the mitosis.

Now we are going to use the cytokinesis to distribute the cellular machinery and that is how it is eventually going to give you the two daughter cells. So at the end of the telophase mitosis is over but the cell division required the distribution of the cellular content equally between the daughter cell.

In animal cell a cleavage furrow is formed during the metaphase plate and divides the individual nuclei as the separate cell, during this process it is ensured that the besides nuclear all other cellular organelles should be distributed equally between the daughter cell. So what happen is during the metaphase itself there will be a cleavage furrow which is going to be formed and that furrow is only going to be advanced further.

Because that is the phase from where you can be able to divide the two nuclei completely, but when it does so it also ensure that there will be an equal distribution of the cellular content, like you can get the equal amount of the mitochondria, you can actually divide the equal number of lysosomes and so on.

So in the plant also we have the similar kind of processes except that the instead of forming a furrow it actually uses the cell plate and that divide the cellular content between the daughter cells. Now the question comes what is the role of the cell cycle, why it is important that the cell cycle should follow the discrete steps.

Like it should start with the interface, where it has the G1 and S and G2 phase and then it enters into the mitosis and then within the mitosis also it has the different phases and so on and then eventually the one cell is going to divide into the two cell by sharing its genomic content and as well as its cellular machinery.

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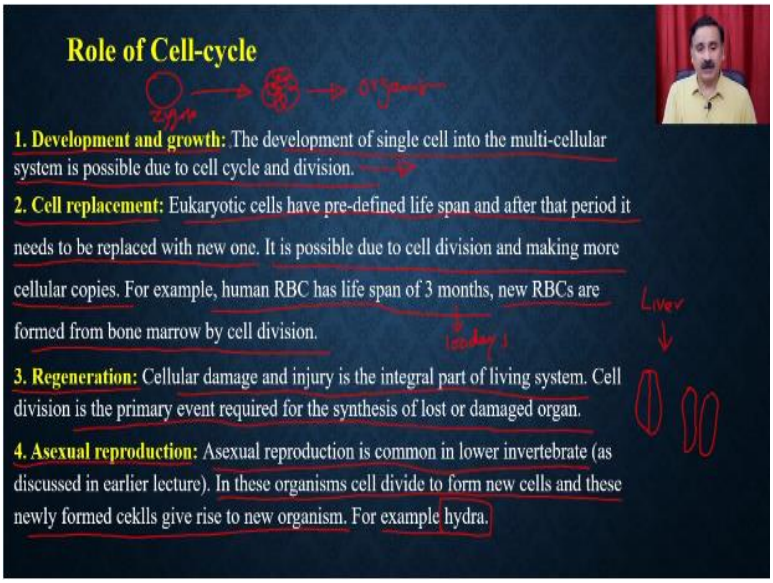

So what is the importance of the cell cycle for the eukaryotic cells. The cell cycle is actually been required for the development as well as the growth. So the development of the single cell into the multicellular system is possible due to the cell cycle and the division, as I said we have a single zygote which actually get first converted into the

multicellular system and then eventually that get converted into the full organism, so that gives the full organisms.

So that is possible because the single zygote actually can go with the precise cell cycle and divisions and that is how it actually can contribute into the development and growth. Then the cell replacement, eukaryotic cells have the predefined lifespan and after that period it needs to be replaced with the new one.

So cell cycle actually ensure that some cells actually going to be having the limited time span, so they should be replaced by the new one and how they are going to be replaced by the new one because they are actually going to go through with the cell cycle and during that phase the mother cell is actually get converted into the two daughter cells and that is how it is actually reappearing himself.

So the old cells are actually going to be renewed by the new daughter cells. It is possible due to the cell division and making the more cellular copies, for example, human RBCs have a lifespan of 3 months or approximately 100 days, a new RBCs are formed from the bone marrow by the cell division and that is important because you have to continuously supply the new and fresh RBCs so that they should be able to do the function properly.

Same is true for the muscle cell, same is true for the liver cells and so on, except the neural cells the all-other cells are could be replaced. Then it also required for the regenerations so cellular damages and injury is the integral part of the liver system, living system, the cell division is the primary event required for the synthesis of the lost or the damaged organ.

You remember that the liver is actually can repaired, you have the five lobes of the liver and it is considered that even if you have the less than 50 percent liver that also is good enough to regenerate himself into the full liver in due course and how that happens, because the liver will go through with the several ground of the cell cycle and cell division and that is how it is actually going to recover its original size.

Then it also is important for the asexual reproduction, so asexual reproduction is common in the lower invertebrates, if you remember when we were discussing about the porifera,

silentreta and even the all other lower invertebrates, amoeba, these things were very, very common, so where one single organisms is for example, euglena is actually getting the transverse division and that is how you have the two euglena molecules or two euglena daughter cells.

In these organisms cells divide to form the new cell and these newly formed cells give rise to the new organism. For example, the hydra, so we have also discussed about the cell division in the hydra, euglena, amoeba and all other kinds of those organisms. Now see, we have the different types of events, we have interface, we have G1 phase, G2 phase, S phase, M phase and within the M also we have the different types of stages.

So how the cell will ensure that all these events are actually going to be governed in a regulated manner so that the there will be no problem? Because you can imagine that if there will be any problem into any of these phases either there will be no equal distribution of the nuclei content or there will be a problem of the not equal distribution of the cellular content or there could be an accumulation of the different types of mutations. So that is why the cell cycle has to be precisely regulated, so how we are going to regulate the cell cycle.

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So control of the cell cycle. Cell cycle at different step is tightly regulated or controlled by the cell cycle checkpoints. These checkpoints are used to ensure the completion of different step and repair of the DNA damage. The main checkpoints are present at the G1 to S phase, G2 to M phase and the M phase.

So you can remember, remember that you have the cell cycle where you have the G1 phase, that G1 phase goes up to this and then you have the S phase and then it goes and then it there is the G2 phase and then G2 phase is entering into the M phase and then after the M phase again the cells are entering into the G1 phase and then you are actually getting the…, so what are the checkpoints? Checkpoints are here, checkpoints are G1 to S phase, then S to G2 and then G2 to M.

Why it is important? The checkpoint means you might have seen, we have the checkpoints even for traffic also, we have the checkpoints for many such activities, why it is important, it is important to ensure that all the preparation in the G1 phase is over, you might have heard, what is the preparation, you require you require the synthesis of the cellular content so that you can actually be able to produce the required amount of protein, so that you can be able to do the replications.

So imagine that if the required amount of protein is not been produced during the G1 phase and the cells enter into the S phase then it will not going to be able to synthesize the DNA and that is why there is a checkpoint, there is a protein which actually going to check whether the cell is under that stage where it has synthesized all the requisite machinery to synthesize the DNA, it has the adequate amount of nucleotides, it has the adequate amount of other cellular machineries required for the applications and so on.

One, it will ensure that okay that is the case then the cell will enter into the S phase and once it will enter into the S phase during the S phase what will happen, it is actually going to synthesize the two copies of genome, so it is actually going to ensure at this checkpoint whereas the G2 to S checkpoint that the DNA is been synthesized.

And then at the G2 to M phase it is going to be ensured the same way that all the cellular machinery is actually going to be synthesized which is required for the mitosis as well as

the cytokinesis and so on. So each checkpoint is controlled by the mutual interaction between the two protein, one is called as the cyclin proteins which is actually going to be present at each checkpoint and keep checking the cellular stage.

And then the cyclin protein is also been associated between the cyclin-dependent protein kinase. p53 gene products are also known to control the many events through the G1 and S, G2 M checkpoints. So this is all about the cell cycle and its control, now the question comes what if there will be any event goes wrong, even when we have the cyclin and cyclin independent protein kinases.

We have several types of checkpoints, sometimes there will be a dysregulation, there will be a problem and because of that if that happens then how it is actually going to affect that particular cell and in totality how it is actually going to affect the organism as well. So the dysregulation of the cell cycle and the control mechanism give rise to the tumor or the cancer.

So one of the mechanism through by which the cancer is going to be developed is because the these cells are not following these control checkpoints, so you can imagine that if a cell has to go through with these phases, it should be divide or it should stop dividing because it should not divide and but if it actually overrule these checkpoints or control points then what will happen is it will start replicating at a rapid rate.

And because of that the single cell is actually going to give you a mass of cells and these masses of cells are nothing but the tumor, so that is a main reason why the cells are developing into the tumor. After certain number of cell division every cell enter into the G0 phase and seizes the cell division.

In the case of tumor, the cell lost the control mechanism and multiply indefinitely to give rise to the cell mass, these cells are taking nutrition but they are not performing the function. So what is the problem, for example, if this is the liver cell, even if it grows and give you a tumor within the liver cell these are not the liver cells, they are actually non-functional liver cells, they will only take up the nutrition from the organisms but they are not going to perform the functions.

And so for example, the RB cells like the retinoblastoma cells, p53 are the crucial cellular factors responsible for the cell cycle control and they play a crucial role in the tumor development. So all these retinoblastoma cells or the p53 both are called as the tumor suppressor cells, so if you have a very high quantity of the retinoblastoma protein or the p53 they are actually going to keep the cells not been go for the extraordinary proliferations and that is why they are being considered as the tumor suppressors.

If you want to read more about or if you want to study more about the cell cycle control because what I have discussed I have discussed in brief about the cell cycle in the eukaryotic cell, you can be able to go through with this particular article and it actually is going to tell you about in detail about the cell cycle checkpoints and how it is they are actually been governing the each and every events.

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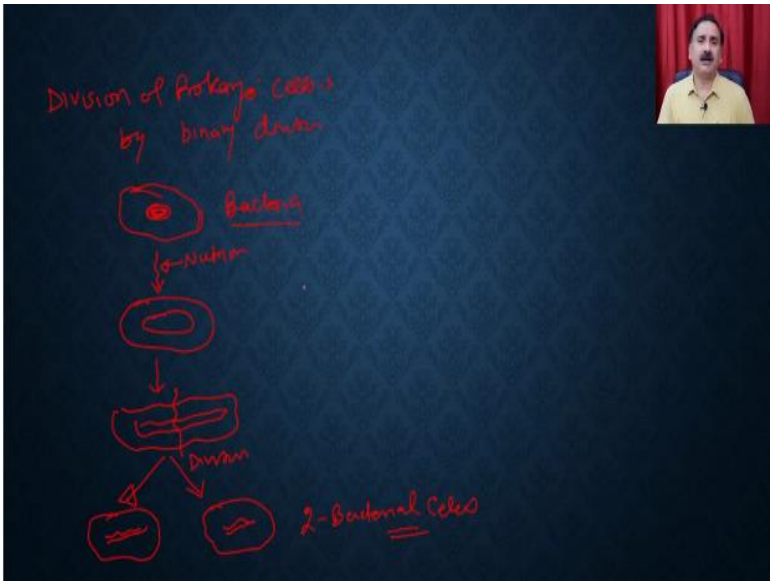

Now we are going to discuss about the division within the prokaryotic cell. So the division within the prokaryotic cell is as I think we discussed, prokaryotic cell is by the binary fission, so by a binary division, so what is binary division? So you can imagine that you have a bacterial cell which has chromosome, so it is not a nucleus, you know that the bacteria does not have the nucleus, it has a chromosome.

Now when it goes through with the cell division, so what happen is the bacteria is actually going to take up the nutrition from the outside and that is how it is actually going to grow. So when it is going to grow in size it is also going to start dividing the nucleus, so what happen is the nucleus is also going to be grow in size or I will say not the nucleus but the genome, the genome of the bacteria is also going to grow in size.

And after some time, it becomes very big, it becomes very big and the genome is going to be completed like this and at this stage you are actually going to have the division and that is how it is going to be divide in the center and it is going to be have the cytosol, it is going to have the cytosol or the cellular machinery and it also going to have the single copy of genome.

Same is true for the other cell, so it is going to have the genome, so that is how you are actually going to have the two bacterial cells at the end of one division, so that is how you can be able to do the division within the prokaryotic cell. And with this we have discussed about the different details of the cells, we have discussed about the prokaryotic cell, we discussed about the eukaryotic cell and at the end we have also discussed about the cell division as well as the regulations.

And what we have discussed so far in this module is we have given you a detail about the structural and the functional details of the prokaryotic or the eukaryotic cell and we have also at the end we have also discussed about how the cells are dividing and increasing its number.

So with this I would like to conclude my lecture here, in a subsequent lecture we are going to discuss about the biomolecules and so that you will be able to understand the role of the different types of biomolecules into the cellular physiology.

So with this I would like to conclude my lecture here, thank you.