Cell Biology: Cellular Organization, Division and Processes

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Lecture 29

The Plant Cell

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Hello everyone, this is Debolina. I hope you all are doing well. And today I am here to discuss with you all about another topic that is the plant system. So let us start from the very beginning. In 1665 English Botanist Robert Hooke first observed honeycomb like structure in cork, under the compound microscope. Those were nothing but empty lumen of dead cells, surrounded by the cell wall. Robert Hooke described those structures as cell and thus he was the first one to coined the term cell. Cells are building blocks of all the living organism. So it is true for the plant system as well.

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Now, we all know that there is a huge diversity among the plant shapes, sizes, their growth conditions and so on. Yet regardless of various adaptations, the body composition of all the seeding plant is based on common architectural plan. The body is composed of mainly three organs. The root, the stem and leaf. The leaf remains attached to the stem at a region, which is called node and the space between two consecutive notes is called internode.

The primary function of a root is anchorage and absorption of water and minerals that of a stem is to provide support and the primary function of a leaf is photosynthesis. Plant growth is often concentrated in a localised region of cell division. These regions are often referred to as meristem. The most active meristem in a young plant is the apical meristem, which is present at the shoot apex at the tip of the shoot the root apex and also at the axillary or lateral bud, which is also a growth point for the branch shoots.

Now you can categorise all the seeding plants in two different groups, the gymnosperms and the angiosperms. The word gymnosperm comes from the Greek for naked seeds incline these are the non flowering plants, for example Pine, Redwood etcetera. The term angiosperms comes from the Greek for vessel seeds, which means that these are the flowering plants.

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Plants are multicellular organisms composed of millions of cells with specialised functions. But all these cells have a common eukaryotic organisation. For example, they contain a nucleus with typical porous nuclear membrane, nucleolus, nucleoplasm and the genetic material. It also contains cytoplasm with different membrane-bound subcellular organelles, like the endoplasmic reticulum, Golgi body, mitochondria, ribosomes and so on.

The additional key feature that makes a plant cell different from most of the other animal cells is the presence of the chloroplast. Also plant cell contains a large vacuole and a notable cellulosic cell wall.

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The cell wall is an extracellular matrix, which in case of plant cells can be divided into different layers. The first one is the middle lamella, highlighted here in the yellow colour you can also visualise it in this more detailed structure. The middle lamella is composed of magnesium and Calcium pectate and this is the layer, which is first deposited during the cell division. Middle lamella is a glue-like structure that adheres the two adjacent plant cells.

Next comes the primary cell wall, which is present at the inner side of the middle lamella. Thus, middle lamella is present between the primary cell walls of two adjacent plant cells. The primary cell wall is a thin flexible and expandable structure and is present in the growing plant cells. It is mainly composed of cellulose microfibrils along with hemicellulose, pectin and different soluble proteins.

Next comes the secondary cell wall, which is often deposited between the primary cell wall indicated in the black colour and the plasma membrane. The secondary cell wall is present in the cells, which have stopped their growth. The secondary cell wall is also composed of cellulose microfibrils, which are arranged in a more ordered manner and they contain lignin, which replaces the pectin in the secondary cell wall.

As a whole, the cell wall is important to maintain the cellular integrity. They also act as a pressure vessel to stop the over expansion of the cell when water enters the plant cell. Another key feature, which is present in the plant cell wall is plasmodesmata. This is a cytoplasmic channel, which connects the cytoplasm of two adjacent cells. This channel helps in the transport of nutrients, stimuli and several other materials.

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Next up is another mostly plant-specific organelle, chloroplast. Chloroplast belongs to a group of double membrane bound organelles called plastids. They are surrounded by an outer membrane and inner membrane. Apart from these two membranes chloroplast also contain another third membrane system, that is the thylakoid membrane. The coin like structure is referred to as thylakoid and a stack of thylakoids is often referred to as Grana.

The thylakoid membrane is the region many proteins and pigments that participate in the photochemical events of photosynthesis remain embedded. The grana are surrounded by aqueous matrix, which is often referred to as stroma. The grana are also connected with each other by Stroma Lamellae. The chloroplast derives its name from its characteristic pigment chlorophyll. Plasmids also contain a high concentration of carotenoids, they are called chromoplast and they are often responsible for the characteristic colours of orange, yellow of different fruits.

The nonpigmented plastids are called leucoplasts, for example amyloplasts that is a starch storing plastid.

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So the main function of chloroplast is photosynthesis. What does photosynthesis mean? The word photosynthesis literally means synthesis using light. Life on Earth thrives on the energy primarily derived from the Sun. And photosynthesis is the only biological process that can harvest the solar energy. The photosynthetic organisms, utilise the light energy and synthesise carbohydrates from carbon dioxide and water with the generation of oxygen.

The reaction of photosynthesis can be summarised in the following equation: that is $6CO_2$ + $6H_2O$ in presence of chlorophyll and water produces $C_6H_{12}O_6$ that is a carbohydrate and 6 oxygen molecules. The most active tissue in the higher plants that participates in photosynthesis is the mesophyll of leaves and they contain the chloroplasts which in turn have chlorophyll.

Photosynthesis involves numerous reactions that can be divided into two stages. The first one is the light stage or the thylakoid reaction. Second one is the dark stage of the carbon fixation reaction. The thylakoid reactions of photosynthesis take place in the specialised internal membranes of the chloroplast called the thylakoids. The series of reactions are initiated by the absorption of light energy by the chlorophyll and are used to drive a series of electron transfers, ultimately producing ATP, the adenosine triphosphate, and the electron donor reduced nicotine adenine dinucleotide phosphate or NADPH. During the dark stage, the ATP and NADPH formed in the light capturing reactions, reduce carbon dioxide to organic carbon compounds, often sugars. This assimilation of inorganic carbon into organic compounds is called carbon fixation.

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So let us discuss about the different aspects of mitotic cell division in plant cells. Mitosis has been explain to you all in great detail by Professor Laloraya in previous lectures. Here, I will give you a brief idea about certain key features that are unique to the plant mitotic cell division. So, mitosis is a process where the previously replicated chromosomes get aligned, separated and distributed in an orderly fashion to the new-born daughter cells. And microtubules play an important role during the entire process. In case of plant cells, before the beginning of mitosis, the microtubules depolymerise and before the beginning of prophase they repolymerize to form a structure called preprophase band. This preprophase band is present around the nucleus and is often responsible for designating the position for the cell wall. The preprophase band is also thought to regulate the plane of cell division.

The prophase is marked by the condensed chromosome, nucleolus disappearance, and also the appearance of prophase spindle. These spindles are assembled at two different foci present at the opposite pole of the cell. Plant cells do not contain centrosomes, but these two foci serve the same function. The premetaphase is marked by the disassembly of the preprophase band, the fragmentation of the nuclear envelope, and also the appearance of the mitotic spindle.

The mitotic spindles are assembled at the diffuse foci regions of the opposite poles. They do not contain the centrosomes. So, in case of animal cells because of the centrosomes the mitotic spindle assumes an ellipsoidal structure. But in case of the plants cells they assume more like a box structure. During the metaphase, the chromatids get aligned at the metaphase plate and some of the mitotic spindle microtubules get attached to the kinetochore of the chromatids. These microtubules are called kinetochore microtubule. The free microtubules are referred to as polar microtubules. After metaphase comes the anaphase where the chromatids are separated and pulled towards the pole, which is caused by the shortening of the kinetochore microtubules. This then leads to the telophase of the cell cycle. Telophase is marked by the cell plate growth, chromosome decondensation and the nuclear envelope reappearance, which then leads to the cytokinesis of the cell leading to the formation of 2 new daughter cells.

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Next comes another topic, which needs to be discussed if we are talking about the plant system that is the plant hormones or phytohormones. In plant system, the phytohormones are classified in different categories. The first one is the auxin kind, they promote stem elongation, inhibit growth of lateral buds. For example Indole Acetic Acid is an auxin class of hormone.

Next is Gibberellin, they promote stem elongation and the classical example for Gibberellin is Gibberellic acid. Next come the cytokinins, they promote cell division, example Zeatin. Apart from these three classes, there are two more phytohormones. They are the abscisic acid, which promotes seed dormancy by inhibiting cell growth. And then comes ethylene, which promotes ripening of fruit and crops.

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Depending on the mechanism of action of auxin hormone in the plant cell, a technique has been standardized to eliminate a protein of interest from an experimental model system. This technique is referred to as the Auxin inducible degron system. A degron is a short amino acid sequence or a structural motif or exposed amino acid that regulates the protein degradation. A degron is a part of the protein itself.

The function of an inducible degron can be controlled externally by addition of the inducing compound. In this case it is Auxin. The inducible degron systems are used to control the expression of a protein at various conditions and the Auxin inducible degron system is easy to operate and has various advantages over the other inducible degron systems, for example the N-end rule degron.

The several advantages of Auxin inducible degron are they can be tagged at both N and C-terminal of the protein. This system is otherwise biologically silent and has no measurable physiological changes. The Auxin inducible degron system can be applied in different eukaryotic model systems like yeast, mammals, mice etcetera. But they cannot be applied in the plant system.

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Auxin is responsible for regulating certain gene expression in plant system that in turn is involved in the growth of the entire system. So let understand the mechanism of action of Auxin in the plant system. So plant system contain an E3 ubiquitin ligase called the SCF complex where the F-box protein is the transport inhibitor response one or the TIR1 protein. So in the presence of Auxin this E3 ubiquitin ligase, that is the a SCF-TIR1 complex interact with the Auxin repressor protein molecules, which basically repress the transcription of certain genes.

Once the interaction happens, this E3 ubiquitin ligase then recruits E2 conjugating enzyme leading to the polyubiquitination of the repressor protein leading to its proteasomal degradation. In the Auxin inducible degron system a similar mechanism is followed. Here we express the TIR1 gene in the genomic background of the model system. This TIR 1 protein then uses the native SCF complex of this system. We also fuse the Auxin inducible degron tag with the target protein. Now if we add Auxin in the medium, that will lead to the interaction between this E3 ubiquitin ligase and our target protein leading to the polyubiquitination of the protein and the proteasomal degradation. So, in this way we can easily eliminate about protein of interest from the system to understand its function.

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This brings us to the end of this short lecture and so far we have learned the different parts of plant body, the plant cell and its organelles, and the cell wall composition, chloroplast, different aspects of photosynthesis, mitosis, plant hormones, and ultimately the Auxin inducible degron or AID system. So that is all for today. Hope you all learnt something new today and all the best and thank you.