Plant Developmental Biology
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Lecture - 01
Life Cycle of an Angiosperm

Hello everyone my name is Shri Ram Yadav from Department of Biotechnology IIT Roorkee. I welcome you all for this course of Plant Developmental Biology, for this course I was assisted by Mister Tushar Garg a PhD scholar in my laboratory.

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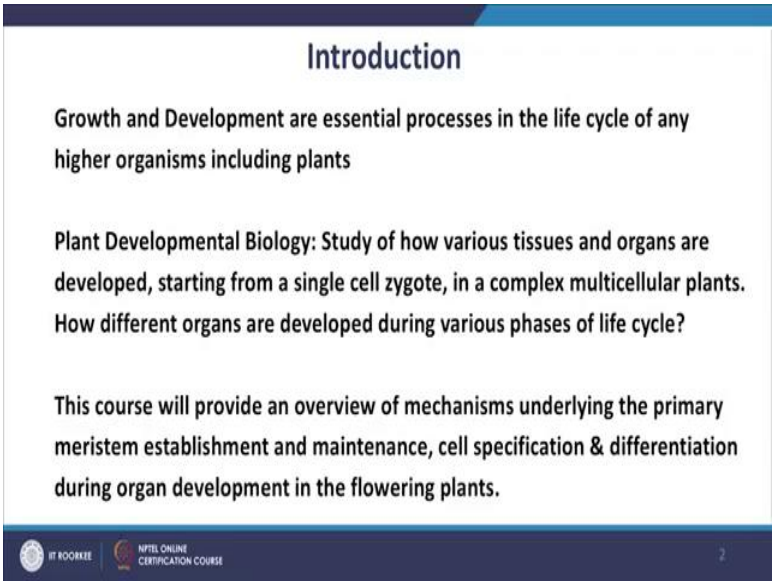

Coming to the introduction of plant developmental biology, so in plants or any higher organism growth and development are very important and essential processes. And plant developmental biology is a study of how various tissues and organs are developed starting from a single cell zygote in a complex multicellular plant. How different organs are developed during various phases of their life cycle?

So, this course will provide an overview of mechanisms underlying the primary meristem establishment and maintenance, cell specification and differentiation during various organ development in flowering plants.

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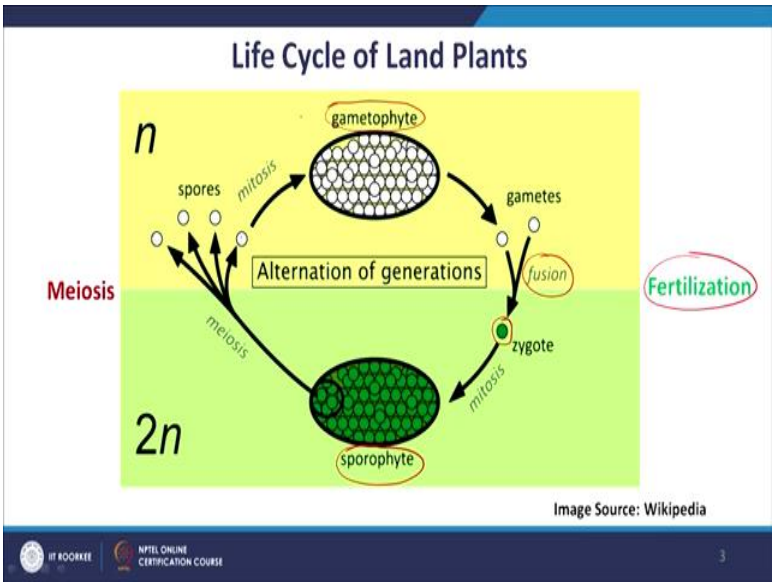

In general, if you look the life cycle of a land plant, it has two major phases: sporophytic phase and gametophytic phase. So sporophytic phase, is the diploid phase of life cycle and it starts from a single cell which is called zygote. This zygote is generated by the fusion or fertilization of male and female gametes. This diploid zygote cells undergo the process of cell division, typically mitosis cell division to generate multicellular sporophytic phase.

And then at some point of time in their life cycle this sporophytic phase undergo the process of meiosis and this meiosis generates many haploid spores. This haploid spores when they undergo the process of further mitotic cell division, they generate multicellular gametophytic stage. And this entire process is called alteration of generation in land plants.

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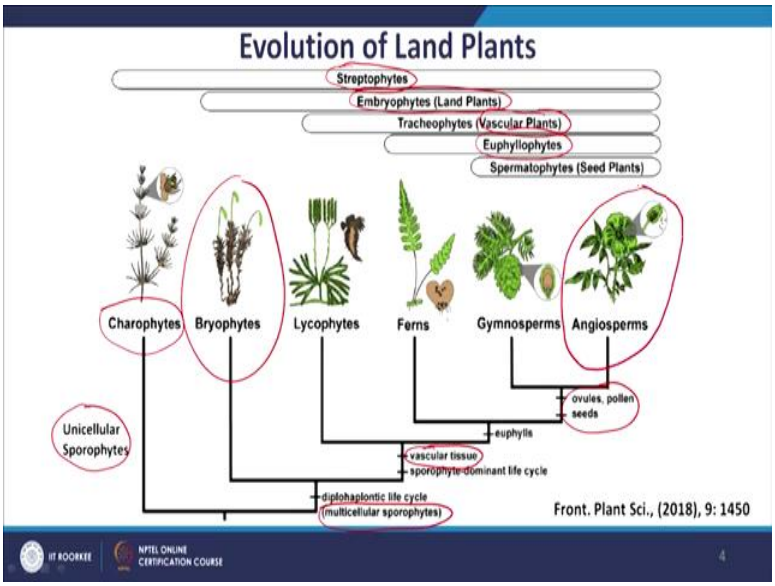

So, if you look the overall evolution of land plants. The land plants belongs to streptophytes clade of plant kingdom and this streptophyte clades includes charyophytes which is green algae and embryophytes which is typically called land plant. And one important thing is that in charyophytes the sporophytic stage is unicellular whereas, in all other land plants this is multicellular.

In embryophytes this can be further divided into vascular plants and nonvascular plants. The bryophytes belongs to the nonvascular plants and then lycophytes onwards they belong to the vascular plants. And then at some time point during the evolution particularly there is a true leaf formation and then later on there is evolution of seeds like structure.

So, if you look at the important events during evolution of plants. One is the multicellularity in the sporophyte and then the formation of vascular tissue. This vascular tissues are very important because they forms the major transport system in land plants or in higher plants and it is very important for land plant since they are terrestrial and sessile. It is very important for them to have a very robust transport system, required to take minerals and water from the soil.

We will be mostly focusing our developments on the angiospermic plant. Further if you look the alteration of generation across the land plants. So, there are few important things which you can see.

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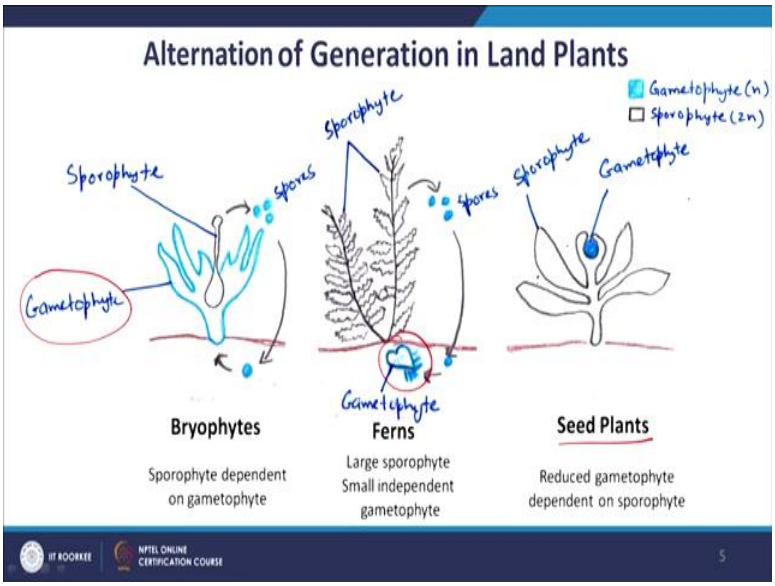

In bryophyte the major part of the bryophyte life cycle is the gametophyte. And sporophyte is dependent on the gametophyte. But in fern, the large form is the sporophyte and gametophyte is basically a small independent form. And in seed plants which includes gymnosperm and angiosperm, it has a reduced gametophyte which is basically dependent on the major large sporophytes.

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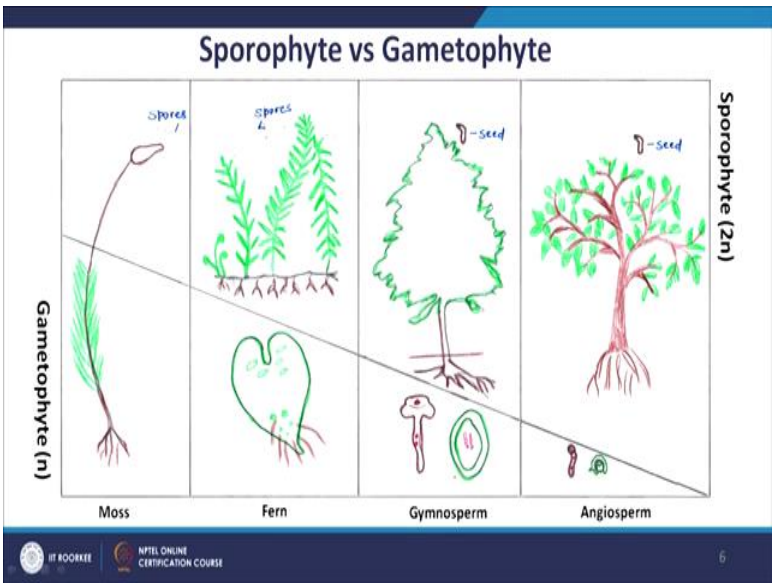

If you look the duration of their life cycle between sporophytic versus gametophytic stages. Mosses spend more duration of the life cycle in the gametophytic phase, less

duration in the sporophytic phase. Whereas, if you go across ferns, gymnosperm, angiosperm, the gametophytic stage is getting restricted and sporophytic stage is getting expanded.

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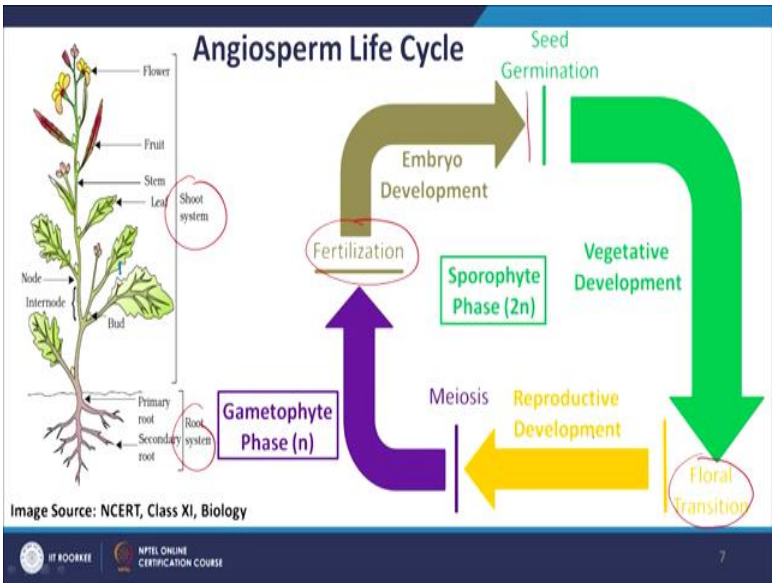

Now, we will discuss about the developmental events during angiospermic life cycle. Typically an angiosperm plant has two major part of the plant body; one is the root system, another is the shoot system. As we discussed earlier a sporophyte is the dominant phase of the angiosperm life and this entire sporophytic phase can be divided into three major phases: the embryo development, vegetative development and reproductive development.

The embryo development starts after the process of fertilization and then it terminates by the seed dormancy. Then vegetative phase starts when seeds are germinate and then during the vegetative phase all the vegetative organs are formed. And then at the certain time point there is a phase transition which is called floral transition where vegetative phase get converted into the reproductive phase. During reproductive phase the reproductive organs like flowers are developed. And in this flower there is a sex organs which is basically anthers and carpel and there the process of gametophyte is restricted in case of angiospermic plant.

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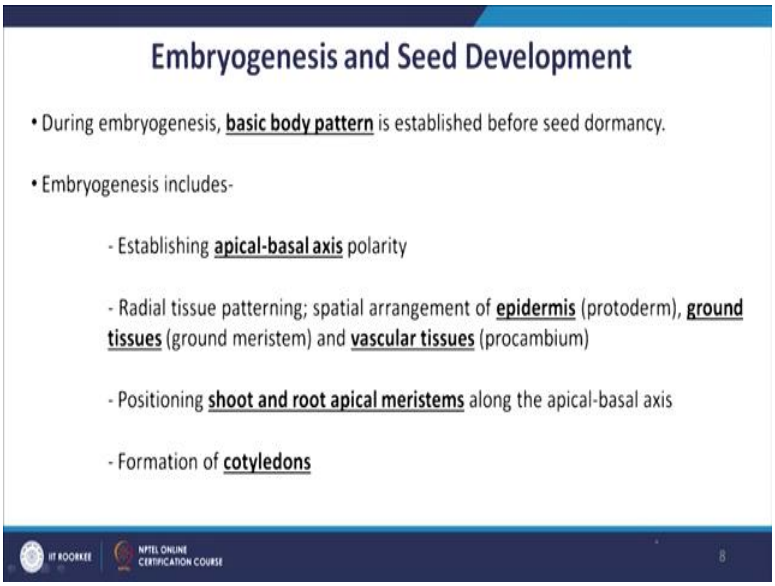

So, if you look the embryogenesis and seed development process. So, actually during embryogenesis process the basic body pattern is established before the seed dormancy. During embryogenesis process four major things are happening.

Number 1, the apical basal axis polarity is established, number 2 radial tissue patterning occurs which occurs through the spatial organization of the tissues particularly epidermis ground tissue and vascular tissues. Third is the positioning of shoot and root apical meristem along the apical basal axis and finally, there is formation of cotyledons.

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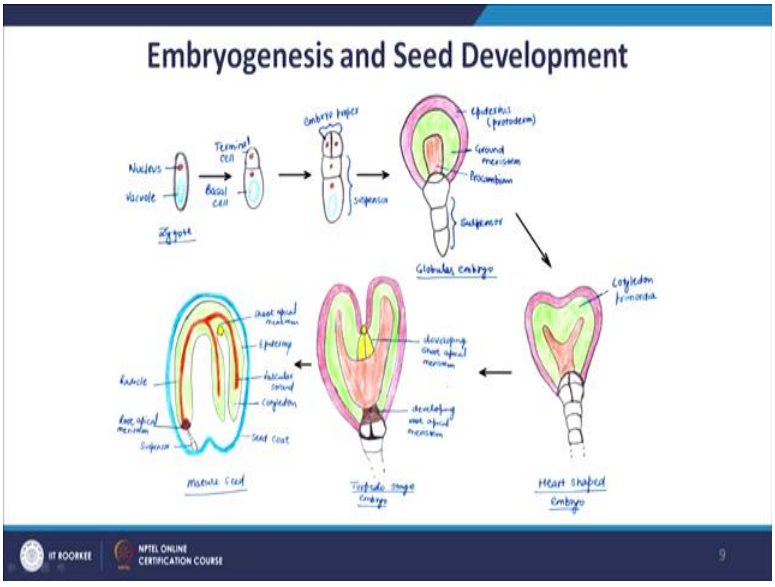

Embryogenesis typically begins with an asymmetric cell division of zygote which produces a small terminal cell and a large basal cells. The terminal cells makes proper embryo and basal cells produces suspensor. Eventually the suspensors generates a stock or a filament which attach proper embryo to the maternal tissues.

Initially the shape of embryo looks globular and this stage is called globular embryo. During globular embryo stage, the three major body tissues are established, the outer most layer which is called epidermis or protoderm, the middle layer is ground meristem or ground tissues and the inner most layer is procambium.

Later cotyledon primordia initiates and this results in the change of the shape of the embryo, now it becomes heart shape and further this heart shape get converted into torpedo stage embryo. And this is the stage around which the shoot apical meristem and root apical meristems are actually positioned at apex. Shoot apical meristems are positioned at the apical side and root apical meristems are positioned at the basal side.

A mature seeds has a seed coat and proper embryo which is attached with the suspensor and in this embryo we have the basic body plants. For example, root apical meristem, shoot apical meristem, pro vascular tissues. At this stage the embryo undergo the process of dormancy and it can stay for long period of time.

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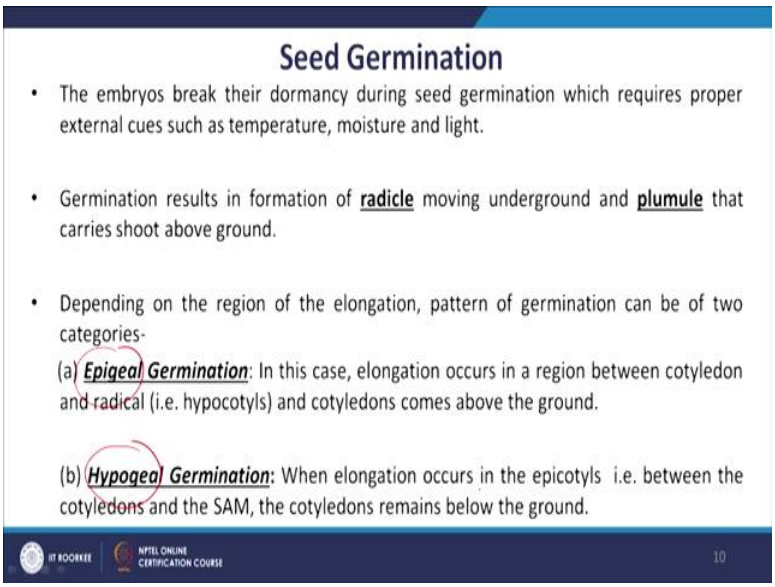

The embryo breaks their dormancy during seed germination which requires a proper external cues such as temperature, moisture and lights. Seed germination require extensive cell elongation, depending on the region of elongation the pattern of germination can be categorized into two types: epigeal germination and hypogeal germination.

In epigeal germination elongation occurs in the region between cotyledon and the radical which is also called hypocotyl and cotyledons comes above the ground. In Hypogeal type of germination, elongation occurs in the epicotyl region which means the region between the cotyledons and shoot apical meristem, the cotyledons remains below the ground in this case.

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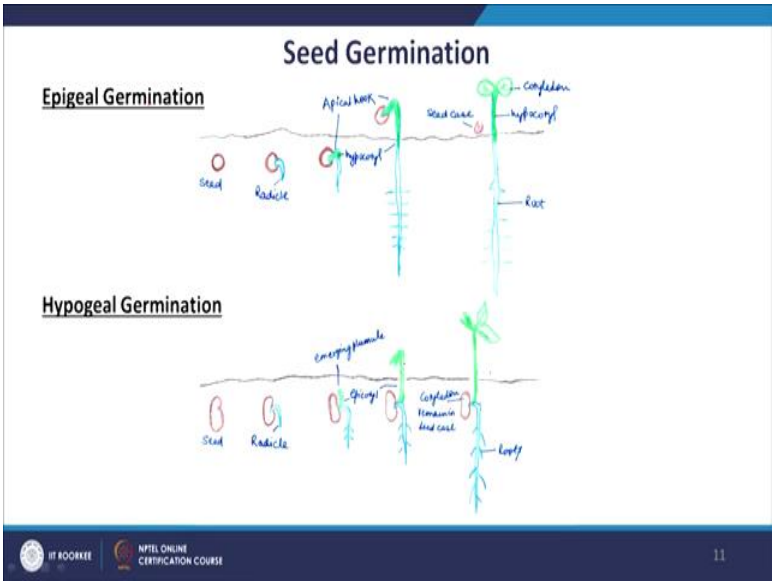

This is the typical example of epigeal germination and hypogeal germination as you can see here. In epigela germination the hypocotyl region (region between cotyledon and radicle) elongates and the cotyledons come outside. In case of hypogeal the region between shoot apical meristem and cotyledons elongates and the cotyledons remains underground.

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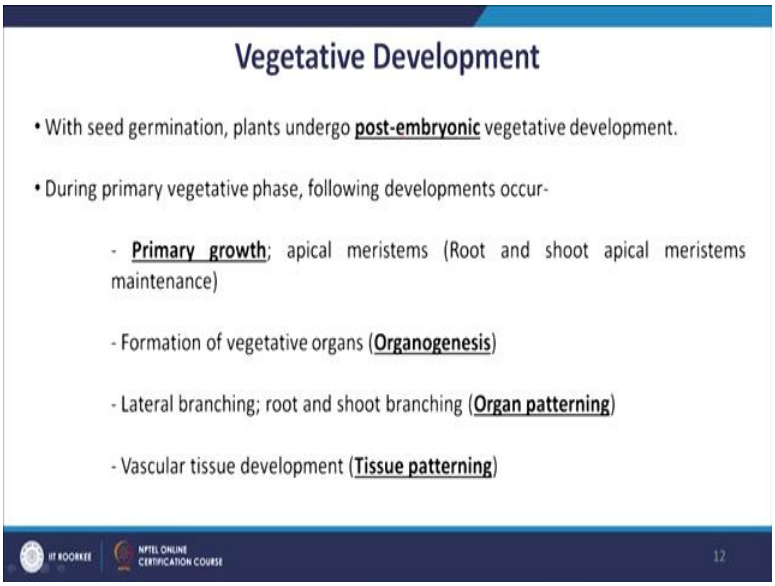

Next developmental stage is vegetative developmental stage. This starts with the seed germination and once you put seeds for the germination plants undergo mostly post embryonic vegetative development. During primary vegetative phase following developments occurs. First is the primary growth which occurs at the apical meristem, both shoot apical meristem and root apical meristem. For having continues growth it is very important that plant always maintains both the meristems throughout their life.

Next during vegetative development is the vegetative organ formation, the process is called organogenesis. Slightly lateral stages or at the same stage you will also have a process of organ patterning were special tissues are patterned in a proper configuration. And vascular tissues development which is also part of tissue patterning occur simultaneously.

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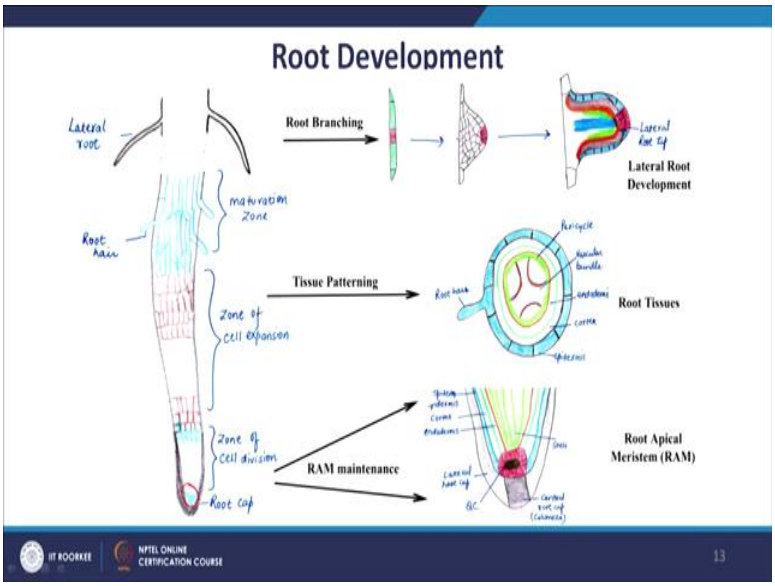

If you look at a typical example of root development. In a typically growing primary root, the primary root can be divided into three zones: the meristematic zone, elongation zone and maturation or differentiation zone. And root apical meristem is positioned at very tip of the growing root. And the root apical meristem has stem cells which generate the cell lineage for tissue patterning later on.

In higher region, tissue patterning occurs where you can have a clear different layers of the tissues arranged in a proper pattern. In differentiation zone one of the very important process occurs, called root branching. In root branching lateral roots are formed. You can see lateral root primordias are first specified then initiated and then finally, lateral root primordia emerge out.

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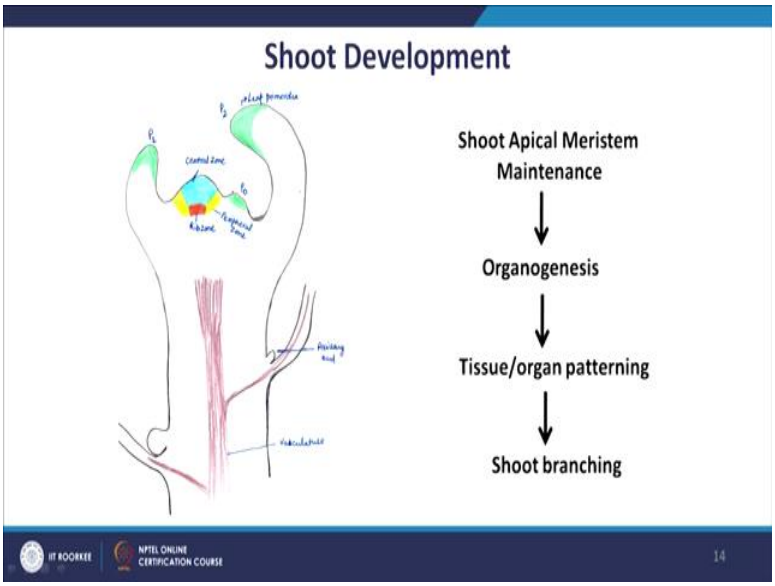

Similarly, if you look the shoot development, during shoot development, the stem cell maintenance occur in the region which is the shoot apical meristem. This is the region where stem cells are maintained and when the cells leaves the meristem in the peripheral zone, it undergo the process of differentiation. During vegetative phase the major organ which forms is the leaf you can see P 1 is the first leaf primordia, second leaf primordia, third leaf primordia.

So, during shoot development the important process which takes place is the root shoot apical meristem maintenance, organogenesis, tissue and organ patterning and then shoot branching. Shoot branching normally occurs through the axillary buds and of course, vasculature is equally important.

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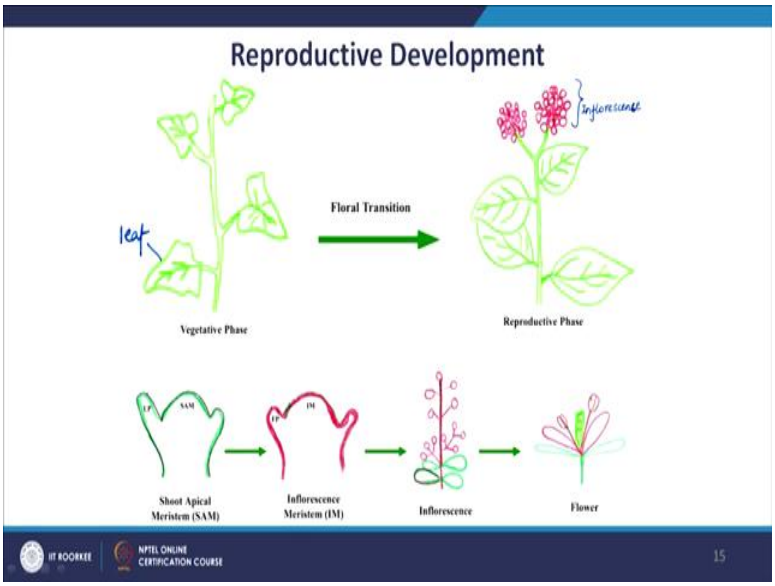

So, once the vegetative development is completed a major transition occurs in the life cycle of an angiosperm plant and this transition is from vegetative phase to reproductive phase. Lot of internal and external factor regulates this process, but once the decision is taken place the vegetative phase transit and it start making the reproductive organs which are basically flowers and flowers are typically arranged in form of inflorescence.

So, if you look at the meristem level. So, during vegetative phase the structure which is responsible for the growth is shoot apical meristem, but at the time of transition the identity of the shoot apical meristem is changed, now it becomes inflorescence meristem. The shoot apical meristem was making leaf at the flanks, but once its identity is converted to the inflorescence meristem the flanking primordia is now floral primordia.

So, if you look at typically growing inflorescence you will have lot of flowers and then the flowers will have floral organs which is sepal, petal, stamen and carpels. And a very special tissues or very special cells of stamen and carpels have a restricted gametophytic phase.

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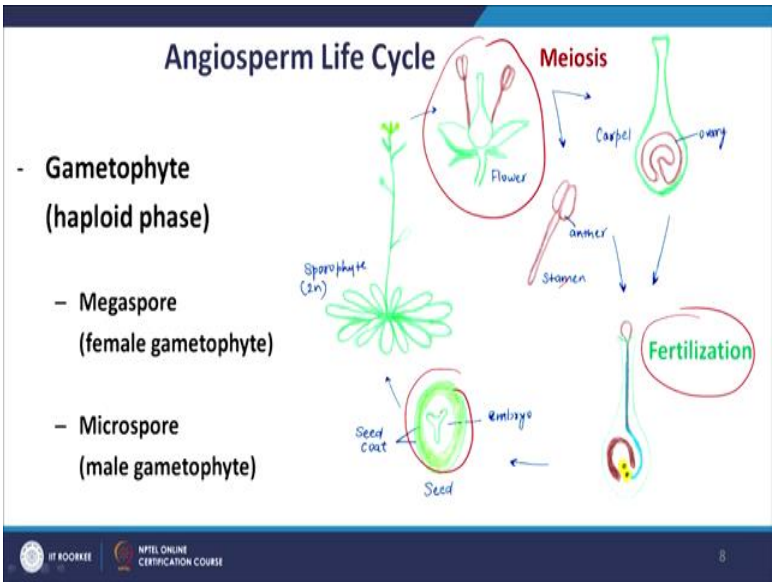

If you look this plants, so this is a typical angiospermic flower. In flower there are four organs mainly the sepals, petals, stamen and carpels. The stamen is male reproductive organ, carpel is female reproductive organ. The process of gametophytic stages initiate from here when anthers which is a male part of stamen produces pollen grains and carpels which has ovule produces embryo sac. When they undergo the process of fertilization they makes seed which contains embryo.

And the seeds has all the information, all the basic body plan in embryo and when we take the seeds, germinate it makes the complete plant. So, the process of gametophytic development therefore, can be divided into two classes; one is the megasporogenesis and second microsporogenesis.

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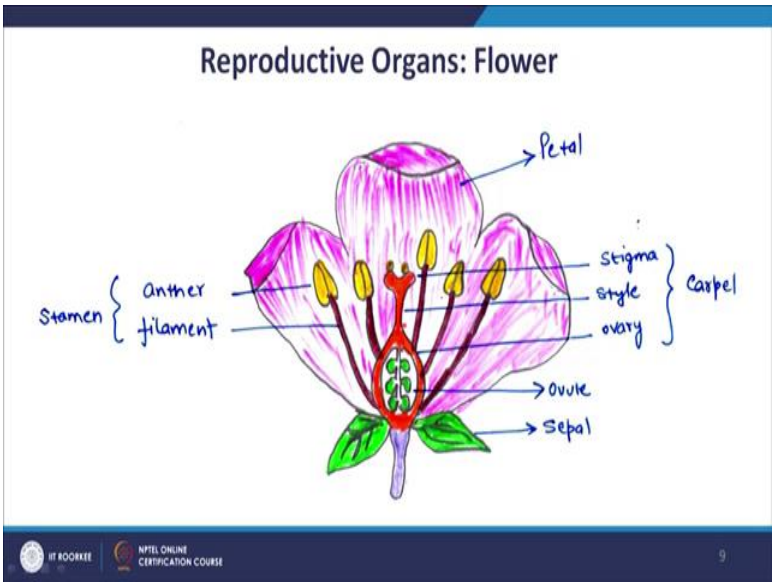

This is flower, which is the reproductive organ. So, as I said earlier flower has sepals, petals, stamens and carpels. Stamens and carpels are the reproductive organ whereas, sepals and petals they are accessory organ. Though sepals and petals they do not directly get involved in the process of reproduction, but they play a very important role in successful completion of the reproduction.

And in a flower all these organs are properly organized and arranged, in the form ogf whorl. So, during the development it is not only the organ it is not only the identity, but their patterning is also equally important. So, if you look sepals they makes the first organ, then petal, stamens and carpel and we will also see in this course that how this floral organ patterning is happening.

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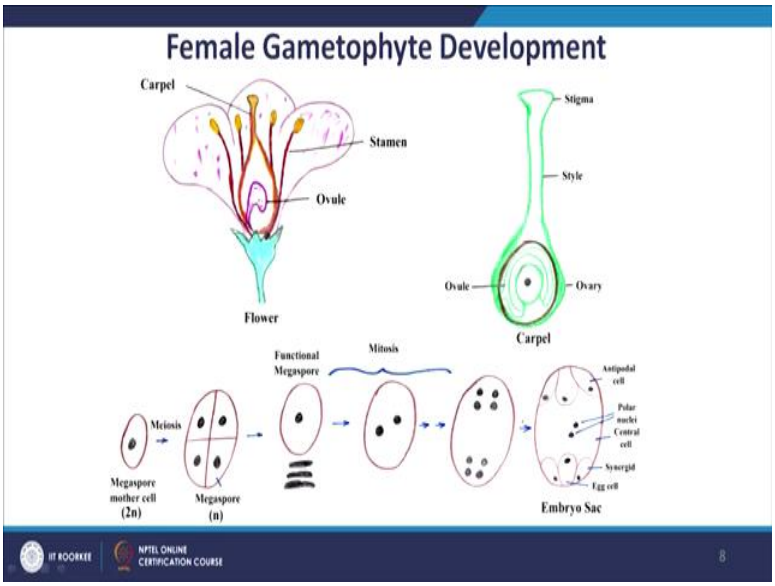

Now, during the gametophytic phase, so we will look how female gametophyte developments occurs. So, if you look the female reproductive organ which is carpel in angiosperm, the carpel has three regions the stigma, style and ovary. In ovary there is a structure called ovule and in ovule we have megaspore mother cell.

So, this megaspore mother cell which is diploid in nature, it first undergo the process of meiosis to generate four haploid megaspores and then during later stages three of this megaspores degenerate, only one remains as functional, which is called functional megaspores. And this functional megaspores undergo the process of three round of mitosis without cytokinesis to generate a cell with 8 haploid nuclei. And then later on this haploid nuclei they get rearranged and they make a structure called embryo sac.

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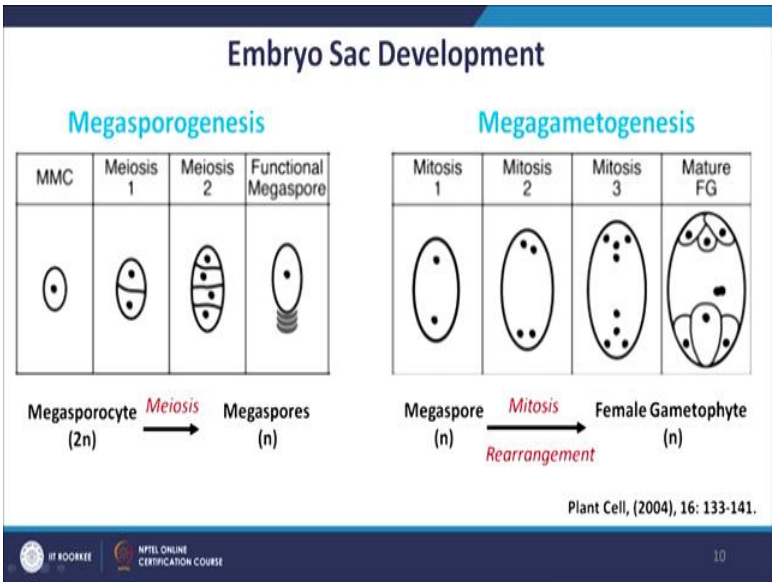

Embryo sac development: The entire process of embryo sac development can be clearly divided into two groups or two stages. The first stage is megasporogenesis, where megaspore mother cells divides through the meiosis to generate haploid functional megaspores. Then another stage is megagametogenesis where this megaspores undergo the process of mitosis cell division and rearrangement to generate a female gametophyte.

The female gametophyte which is also called embryo sac, it contains three antipodal cells on the apical region of embryo sacs, two synergids and one egg cells at the basal end of the embryo sac and then a central cell containing two haploid polar nuclei.

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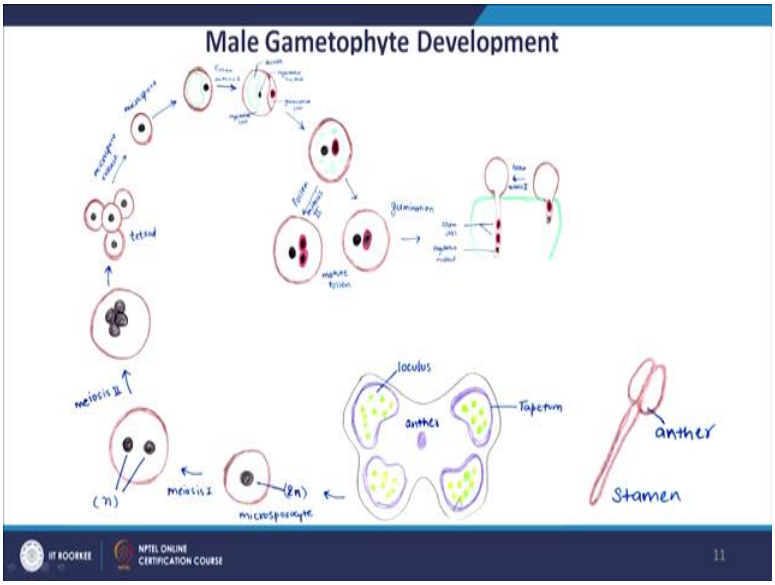

Similarly, if you look at the male gametophyte development. The male organs are stamens; stamen has filaments and anther. It has microsporocyte's which is diploid in the chromosome content and this microsporocyte's when it undergo the processes of meiosis I it generates 2 haploid nuclei, then meiosis II and it makes a tetrads. This tetrads release and then later on this microspores they undergo the process of another round of mitosis and they generate two asymmetric cell; one is called vegetative cell another is called generative cells.

Later on this generative cells migrate inside and they makes a kind of cell within cell appearance. Here there are two category, in first category the generative nuclei they undergo the process of mitosis II and generate 2 nuclei before the germination or before the pollination. But in second case this they remains in this form and when they get attached with the stigma of carpel, then this division takes place. Ultimately because of this divisions two sperm cells are generated.

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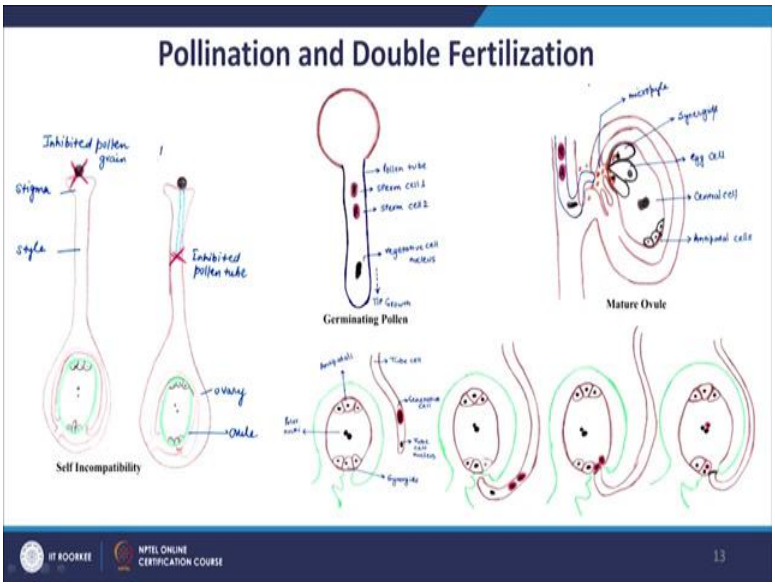

Next stage of the life cycle is pollination and fertilization, once the pollens are ready. So a typical germinating mature pollen has two sperm cells and one vegetative cell nucleus. In mature ovule cells you can clearly see there are antipodal cells, synergids, egg cells and polar nuclei.

The pollination is a process through which the pollen grains get attached with the stigma of carpel and then they germinate, but it is not always the case. So, all the pollens cannot fertilize or cannot pollinate with any kind of carpel. There is some self incompatibility issue. So, if pollens are not compatible with the carpel they may not result in the successful pollination, where either their germination itself is inhibited or even though if it start germination, but they cannot reach to the ovule and they cannot fertilize the embryo sac.

Eventually what happens in the case where the fertilization is successful, the pollen germinates and it makes a structure called pollen tube, and reach the micropyle of the ovule. The synergid cell secrete some kind of signals and this signal is very important for pollen tube to reach to the embryo sac.

And once it reach to the embryo sac it releases two of the sperm cells. One sperm cells it goes and fertilize the egg cells and makes diploid zygote. Another sperm cell it goes and fuses with the two polar nuclei and it makes a triploid cells which eventually generates

the endosperm. And that is why this process is called double fertilization because there are two round of fertilization occurring.

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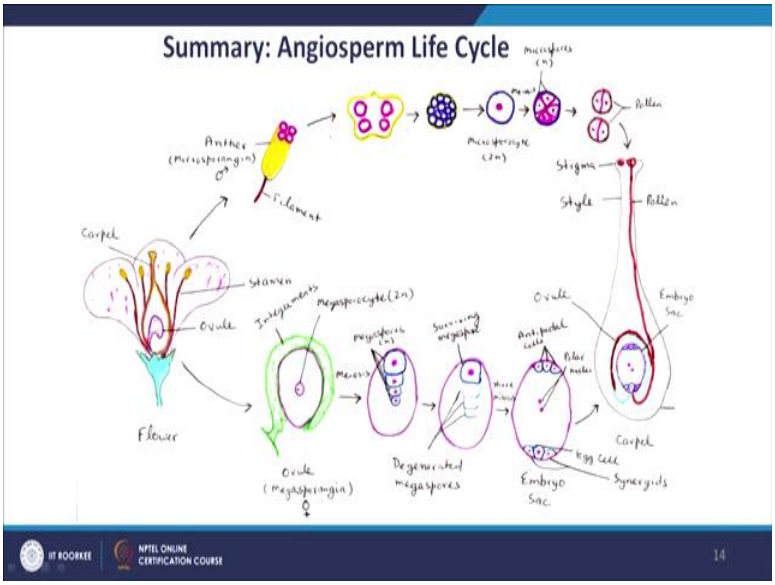

So, at the end if I summarize the life cycle of angiosperm plant. So, as I said that flowers are the organs where we have the reproductive organs, male reproductive organs as a stamen, and female reproductive organs as carpel. The male reproductive organs, they generates microspores/ haploid pollens through the process of microsporogenesis.

Female reproductive organs they generates embryo sac which contains egg cell and polar nucleoid through the process of megasporogenesis. And then the process of pollination results in double fertilization and forms seed.

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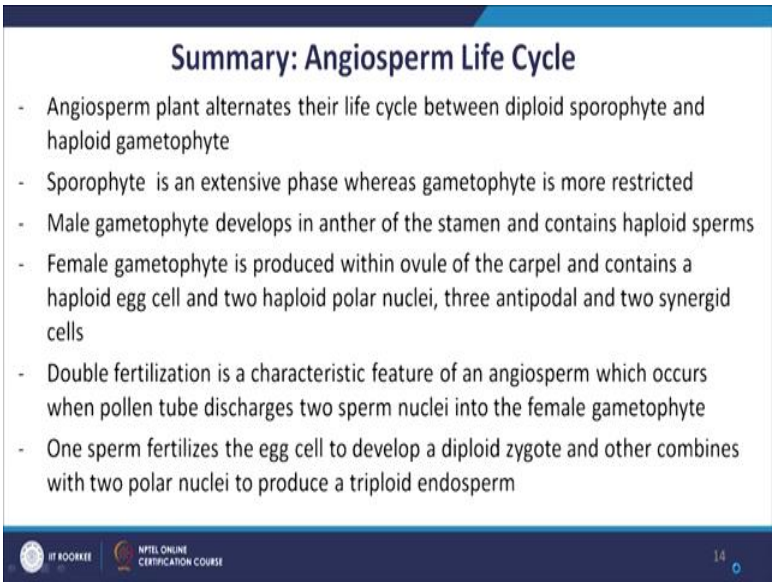

So it is evident that angiosperm plants alternates their life cycle between diploid sporophyte and haploid gametophyte. Sporophyte is an extensive phase whereas, gametophyte is more restricted. Male gametophyte develops in anther of the stamens and contains haploid sperms. Female gametophyte is produced within ovules of the carpel and contains haploid egg cell, two haploid polar nuclei, three antipodal and two synergid cell.

Double fertilization is characteristic feature of an angiosperm which occurs when pollen tube discharges two sperm nuclei into the female gametophyte. One sperm fertilizes the egg cell to develop a diploid zygote and other combines with two polar nuclei to produce a triploid endosperm. So, this is all for this class in next class we will discuss about characteristic of plant development.

Thank you.