# RESOURCES FOR

# "HSC-I BOTANY"

# <u>ZUEB EXAMINATIONS 2021</u>

**PREFACE:**

The ZUEB examination board acknowledges the serious problems encountered by the schools and colleges in smooth execution of the teaching and learning processes due to sudden and prolonged school closures during the covid-19 spread. The board also recognizes the health, psychological and financial issues encountered by students due to the spread of covid-19.

Considering all these problems and issues the ZUEB Board has developed these resources based on the condensed syllabus 2021 to facilitate students in learning the content through quality resource materials.

The schools and students could download these materials from www.zueb.pk to prepare their students for the high quality and standardized ZUEB examinations 2021.

The materials consist of examination syllabus with specific students learning outcomes per topic, Multiple Choice Questions (MCQs) to assess different thinking levels, Constructed Response Questions (CRQs) with possible answers, Extended Response Questions (ERQs) with possible answers and learning materials.

**ACADEMIC UNIT ZUEB:**

1. **Extended Response Questions (ERQs)**

**HOW TO ATTEMPT ERQs:**

- Write the answer to each Constructed Response Question/ERQs in the space given below it.
- Use black pen/pencil to write the responses. Do not use glue or pin on the paper.

## *SECTION C ( LONG ANSWER QUESTIONS)*

1. Draw and describe the life cycle of Zygomycota or Ascomycota fungi

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| **1.** | Explain the life cycle of Moss (No diagram required) | LIFE CYCLE OF MOSS<br>The moss belongs to bryophytes, therefore its main plant body is gametophyte which is haploid (N) in<br>nature and it performs sexual reproduction.<br>**SEXUAL REPRODUCTION:**<br>In Moss the male reproductive organs are called Antheridia while female reproductive organs are called<br>Archegonia.<br>**Antheridia:**<br> Antheridia develop on the apical portion of main axis of male thallus.<br> They are found in clusters and their clusters are surrounded by paraphysis (hairy structures).<br> Each antheridium has a swollen part which has a basal multicellular stalk.<br> It is surrounded by a jacket layer. Inside this layer many antherozoid mother cells are found.<br> These cells develop into biflagellated male gametes which are known as antherozoids.<br> When antherozoids become mature, the jacket layer ruptures and the antherozoids are set free,<br>which swim in water and try to reach the archegonium.<br>**Archegonia:**<br> Archegonia develop at the apex of female thallus in the form of cluster.<br> Each archegonium is a flask-shaped body which has an upper neck and a lower venter.<br> Inside the neck few neck canal cells are found, while the venter contains only one venter canal cell<br>and an egg cell.<br> The upper part of the neck consists of thin walled cells, which are known as cover cells or lid cells.<br>**Fertilization:**<br> At the time of fertilization all the neck canal cells and venter canal cell are degenerated and form<br>mucilage inside the archegonium.<br> This mucilage applies a pressure on cover cells which ultimately leave their places, so the<br>mucilage starts to release.<br> The mucilage attracts the antherozoids towards the archegonium. In this way many<br>antherozoids enter into the archegonium but only one is succeeded to combine with egg cell<br>to form diploid (2N) zygote or Oospore.<br>**ASEXUAL REPRODUCTION:**<br> The diploid (2N) Oospore forms the sporophyte of Moss, which is attached with the<br>female gametophyte.<br> The sporophyte of Moss consists of following three parts.<br>**1. FOOT**: It is the basal part of sporophyte which remains embedded inside the gametophyte.<br>It absorbs water and minerals from gametophyte.<br>**2. SETA**: It is a long stalk which connects the foot with the capsule.<br>**3. CAPSULE**: It is the most<br>important part of sporophyte, in which a spore sac is found. | **K/A** | **M** |

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| | | This spore sac is filled with a large number of diploid spore mother cells.Each cell forms haploid (N) spores by meiosis. After germination these spores form haploid gametophytes of moss. | | |
| 2. | Describe adaptive characteristics of Bryophytes to land habitat. | **PLANTS ADAPTATION TO LAND HABITAT**<br>Plants adapted to land habitat due to change in environment for the following reasons.<br>1- Scarcity of water on land habitat as compare to marine habitat.<br>2- Carbon containing compounds are not available frequently on land.<br>3- Fluctuation of temperature on land habitat is much as temperature in the sea.<br>To overcome these problems plants adapted the following characters for their survival on land.<br>**1- Compact Multicellular Body:**<br>Formation of a compact multicellular plant body which helps in the conservation of water by reducing cell surface area exposed to dry land condition. Presence of cuticle further reduces loss of water by evaporation.<br>**2- Presence of Rhizoids:**<br>Plants produce rhizoids which are thin, long hair like structure attached on the lower surface of the plants for absorption of water from the soil and also helps in attachment.<br>**3- Conservation of Water:**<br>Plant body of bryophytes called thallus, which is many cell thick to conserve water. Moreover the outer and upper most layer of cell is covered with cuticle to slower down the rate of transpiration.<br>**4- Absorption of Carbondioxide:**<br>Land plants need effective exchange of gases from the environment. In bryophytes (e.g. *Marchantia*) on the upper surface lie small pores which open inside into air chambers containing photosynthetic cells present in a large area. The carbon dioxide from air diffuses into the cytoplasm of these cell and used in photosynthesis.<br>**5- Heterogamy**<br>Bryophytes produce morphologically different gametes termed as heterogametes, male gametes are motile and biflagellated while female gametes are non-motile having reserved food material.<br>This is the most successful reproduction in land plants.<br>**6- Protection of Sex Organs:**<br>Gametes are produced and protected by the special multicellular organs called antheridia (male) and archegonia (female). These are present on the apex of plant shoots along with hair like structure called paraphysis which prevent from dryness.<br>**7- Retention of Embryo:**<br>The fertilized egg is called **oospore**, which is formed inside the archegonium. An embryo develops from the oospore as it divides, still inside the protective coverings of the archegonia. These coverings protect the growing embryo from drying out and from mechanical injury. | K/R | E |

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| **3.** | Describe in detail the process of Glycolysis | **GLYCOLYSIS**<br>• The process in which a glucose molecule is converted into two Pyruvic acids is called Glycolysis.<br>• This process takes places in the cytosol of cytoplasm.<br>• This is the anaerobic stage of cellular respiration.<br>• It was first explained by Embden, MeyerHof and Parnas, therefore it is also called EMP pathway.<br>**THIS PROCESS IS COMPLETED IN THE FOLLOWING STEPS.**<br>• Glucose is converted into Glucose 6-Phosphate in the presence of Hexokinase enzyme. ATP is consumed to from ADP.<br>**Glucose + ATP ⟶Glucose 6-P + ADP**<br>• Now Glucose 6-Phosphate is converted into Fructose 6-Phosphate in the presence of Phosphoglucoisomerase enzyme.<br>**Glucose 6-P ⟷ Fructose 6-P**<br>• Fructose 6-Phosphate is converted into Fructose 1,6-diphosphate in the presence of Phosphofructokinase enzyme. ATP is also converted into ADP.<br>**Fructose 6-P + ATP ⟶Fructose 1,6-diphosphate + ADP**<br>• Fructose 1,6-diphosphate splits into two components, dihydroxyacetone phosphate (DHAP) and 3 phosphoglyceraldehyde (3PGAL) by the action of Aldolase enzyme. DHAP and 3 PGAL are the isomers of each other and they are interchangeable by isomerase enzyme.<br>**Fructose 1,6-di.P DHAP ⟶3 PGAL + DHAP**<br>• 3 PGAL is converted into 1,3-diphosphoglyceric acid, NAD+ is changed into NADH + H+. One phosphate is also released.<br>**3 PGAL + NAD+ ⟷1, 3-DiPGA + NADH + H+ + Pi**<br>• 1,3-diphosphoglyceric acid is converted into 3-phosphoglyceric acid by the action of phosphoglycerokinase enzyme. ADP is change into ATP.<br>**1,3 -DiPGA + ADP ⟷ 3-PGA + ATP**<br>• 3-Phosphoglyceric acid is converted into 2-Phosphoglyceric acid by the action of phosphoglyceromutase enzyme.<br>**3-PGA ⟷ 2-PGA**<br>• 2-Phosphoglyceric acid is converted into Phosphoenol Pyruvic acid in the presence of Enolase enzyme. H2O is also released.<br>**2-PGA ⟷ Phosphoenol pyruvic acid + H2O**<br>• Now finally phosphoenol pyruvic acid is converted into pyruvic acid by the action of enzyme phosphopyruvate kinase. ADP is converted into ATP.<br>**Phosphoenol pyruvic acid + ADP ⟷ Pyruvic acid + ATP** | **K/A** | **E** |

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| **4.** | Light independent reaction (C3 cycle) of photosynthesis. | **DARK REACTION**<br>**Introduction:** This process takes place in the stroma of a chloroplast and it does not require light energy therefore it is also known as light independent reaction. The other names of the dark reaction are Calvin-Benson or reductive pentose cycle.<br>**Explanation:** The Calvin cycle consists of 13 main reactions which are catalyzed by 11 enzymes. The C3 cycle is divided into three distinct phases;<br>**i. Carboxylation:** It is also called fixation of CO2 into organic molecules. In this process ribulose 1,5- bisphosphate (RuBP) is combined with atmospheric CO2 in this presence of ribulose bisphosphate carboxylase / oxygenase (Rubisco) to produce an unstable six-carbon compound which breaks into two molecules of glycerate 3-phosphate (G3P).<br>**3CO2 + 3RuBP** ———→ *Rubisco* **G3P**<br>**ii. Reduction:** In these reactions phosphoglyceraldehyde (PGAL) OR 3-phoshpoglyceraldehyde (GA3P) is formed by the reduction of organic molecules. During this phase G3P is reduced to glycerate 1,3-bisphosphate (G1,3P) and then triose phosphate i.e. 3-phoshpoglyceraldehyde (GA3P) and dihydroxyacetone phosphate (DHAP).<br>**6G3P + 6ATP + 6NADPH** ——→ **6GA3P + 6ADP + 6NADP + 6Pi**<br>**iii. Regeneration:** Many carbon-rearrangements takes place during this phase. Three carbon compounds are rearranged to form 5-carbon units including the primary acceptor molecule i.e. RuBP.<br>**5GA3P + 3ATP** ——→ **3RuBP + 3ADP +2P**<br>**Above reactions can be described by the following steps.**<br>• Ribulose 5-phosphate is converted into Ribulose 1,5-diphosphate or ribulose bisphosphate (RuBP), in this reaction one ATP is consumed.<br>• Ribulose bisphosphate combines with CO2 to form a six carbon containing unstable compound in the presence of **ribulose bisphosphate carboxylase/oxygenase** (Rubisco) enzyme. This unstable compound splits into two 3-carbon containing compounds which are called 3-phosphoglyceric acid (3 PGA) or glycerate 3-phosphate (G3P).<br>• 3 PGA is combine with ATP to form 1,3-Diphosphoglyceric acid.<br>• 1,3-Diphosphoglyceric acid is combined with NADPH+H+ to form 3-phosphoglyceraldehyde (3PGAL) or glyceraldehydes 3-phosphate(GA3P).<br>• 3 PGAL is considered as a first stable compound of dark reaction and it can be utilize in the cycle by different ways.<br>I. **3-PGAL** reacts with Dihydroxyacetone phosphate and form fructose 1,6-diphosphate, release one of its phosphate to form fructose 6-phosphate.Then fructose 6-phosphate is converted into Glucose and when many molecules of glucose are combined Starch is produced. | **K/A** | **M** |

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| | | II. **3-PGAL** is combined with fructose 6-phosphate to form Erythrose 4-P and Xylulose 5-P.<br>III. **3-PGAL** reacts with Erythrose 4-phosphate to form Sedoheptulose 1,7-diphosphate. Sedoheptulose 1,7-diphosphate is converted into Sedoheptulose 7-P by releasing one of its phosphate.<br>IV. **3-PGAL** is combined with sedoheptulose 7-phosphate to form Ribose 5-phosphate and Xylulose 5-phosphate.<br>• Ribose 5-phosphate is converted into Ribulose 5-phosphate by the action of Isomerase enzyme.<br>Xylulose 5-phosphate is also converted into Ribulose 5-phosphate by the action of Epimerase enzyme. | | |
| **5.** | Define Ascent of sap. Describe root pressure theory and cohesion-tension theory | **ASCENT OF SAP**<br>The upward movement of water and dissolved substances (sap) from the lower parts towards the upper parts of a plant is called ascent of sap.<br>**MECHANISM OF ASCENT OF SAP:**<br>Inside the xylem vessels water and dissolved minerals flow upward at a rate of 15 meters per hour.<br>Following theories try to explain this movement.<br>i- Root pressure theory:<br>ii- Transpiration pull theory OR Adhesion – cohesion – tension theory OR Dixon's theory of cohesion.<br><br>**i. ROOT PRESSURE THEORY:**<br>**Introduction:**<br>This theory was present by Stephen Hales in 1727. According to hales, this force could be responsible for raising water to a height of 6.4 meters.<br>**Explanation:**<br>In the stem of a potted plant is cut little above the soil, the cut end dip in water exudes water for some time, suggesting that there is a force pushing water up to the stem from roots. This force is known as root pressure.<br>**Objections:**<br>• This is an insufficient force.<br>• Many tall trees do not generate root pressure.<br>**ii: TRANSPIRATION PULL THEORY:**<br>**Introduction:**<br>This theory was presented by Dixon and Jolly.<br>According to this theory; the transport of water over a long distance, the plants do not use their metabolic energy (No vital force is involved).<br>Forces like adhesion, cohesion and evaporating effect of sunlight are mainly responsible for upward condition of water. Thus ascent of | **K/A** | **E** |

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| | | sap is solar powdered.<br>**Explanation:**<br>Sunlight raises temperature of leaves so the water beings to evaporate from moist walls of mesophyll cells. The evaporated water is immediately replaced from water inside the cell. This is replaced with the water from neighboring cell deeper in the leaf. Ultimately, water is pulled from xylem to meet the loss of water. Thus water in xylem is placed under tension which is transmitted to root through vessels.<br>This downward transmission of tension is because of cohesive property of water columns in vessels and tracheids. Water column moves upward by mass flow due to transpiration pull. | | |
| **6.** | Define Transpiration and its types. Describe mechanism of stomatal transpiration. | **TRANSPIRATION**<br>The loss evaporation of water from the aerial parts of a plant in the form of vapours is called transpiration.<br>**TYPES OF TRANSPIRATION**<br>There are two main types of transpiration<br>1. Lenticular transpiration<br>2. Foliar transpiration<br>**1. LENTICULAR TRANSPIRATION**<br>• The transpiration by the lenticels of old stem is called lenticular transpiration.<br>• Lenticels are longitudinal pores, on stem which are produced during the secondary growth.<br>**2. FOLIAR TRANSPIRATION:**<br>The transpiration by the leaves is called foliar transpiration. There are two types of this transpiration.<br>i- Cuticular transpiration<br>ii- Stomatal transpiration<br>**i. CUTICULAR TRANSPIRATION**<br>• The transpiration by the cuticle of leaf is called cuticular transpiration.<br>• Cuticle is a waxy layer which is made up of a lipid called cuties.<br>**ii. STOMATAL TRANSPIRATION**<br>• The transpiration by the stomata of leaf is called stomatal transpiration.<br>• It is the most important type of transpiration because most of the water is lost in this transpiration (about 90%)<br>**STOMATA**<br>Stomata are microscopic pores which are found on the surface of leaves.<br>**NUMBER OF STOMATA ON SQ. MM OF LEAF**<br>• Mostly 50-300 stomata are found on a square millimeter of leaf surface.<br>• But according to **Eckerson** (1908), 14 stomata / mm2 are found on the leaf of wheat.<br>o According to **Yoccum** (1935) 1038 stomata/ mm2 are present on the leaf of scarlet plant. | **K/A** | **D** |

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| | | **SIZE OF STOAMATAL APERTURE WHEN IT IS FULLY OPEN:**<br>• In ***Phaseolus vulgare*** the size of stomatal aperture is 7x3 μ.<br>• In ***Avena sativa*** its size is about 38 x 8 μ<br>**STRUCTURE OF STOMATA:**<br>• Each stoma is an opening between the two bean shaped cells, called guard cells.<br>• The part of the cell of guard cells adjacent to stoma is hard and non-elastic, while the part away from stoma is thin and highly elastic.<br>• Inside the guard cell a nucleus and many small chloroplasts are present.<br>**OPENING AND CLOSING OF STOMATA:**<br>• The opening and closing of stomata depends upon the turgidity of guard cells.<br>• According to **Sayre** (**1923**), in the presence of sunlight stomata are opened because in the presence of light photosynthesis takes place in the guard cells.<br>• In this process CO2 is absorbed in the guard cells.<br>• CO2 is an acidic gas which decreases the pH of guard cells and an enzyme (i.e. phosphorylase) becomes active which converts starch into glucose 1-Phosphate.<br>• Glucose 1-Phosphate is highly soluble in water so it increases the concentration of the solution in the guard cells.<br>• Therefore endosmosis takes place in these cells. And finally they become turgid.<br>• In turgid condition, the outer walls of guard cells move outward while the inner walls more inward and become concave.<br>• In this way, the passage between the two guard cells (stoma) is opened.<br>• In the absence of light the whole above sequence is reversed and guard cells become flaccid. So the stoma is closed.<br>• In some plants the concentration of K + ions also plays an important role in this process. During the day time the guard cells actively transport K + ions from the neighboring cells. Accumulation of K + ions lowers the water potential of guard cells, so they intake water by endosmosis. | | |
| **7.** | Define nutrition. Mention and explain the two types of nutrition with the help of chemical equations. | **NUTRITION:**<br>Nutrition is a process by which the organisms obtain energy to maintain the function of life, to build the matter and maintain the structure. Nutrients are food or any substance which supplies elements and energy to the living body for its metabolic activity.<br>**TYPES OF NUTRITION**<br>1. Autotrophic nutrition.<br>2. Heterotrophic nutrition. | **K/A** | **E** |

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| | | **AUTOTROPHIC NUTRITION**<br>In this nutrition the organism has the ability to synthesize its food inside the body. There are two types of autotrophic nutrition.<br>1. Phototrophic Nutrition<br>2. Chemotrophic Nutrition<br>**PHOTOTROPHIC NUTRITION:**<br>❖ The organisms which have the ability to convert solar energy into food energy are called phototrophic organisms and this nutrition is known as phototrophic nutrition.<br>❖ Phototrophic organisms require green pigments i.e. chlorophyll a and chlorophyll-b to absorb sunlight in the presence of this sunlight, these organisms synthesize food energy in the form of simple carbohydrates. This process is called photosynthesis.<br>**$6CO_2 + 12H_2O$**<br>***Chlorophyll***<br>***Sunlight*** $\longrightarrow$ **$C_6H_{12}O_6 + 6H_2O + 6\ O_2$**<br>❖ Some bacteria are also capable to prepare their food by the process of “Photosynthesis”. These bacteria were discovered by Von Neil in 1930. They contain different type of chlorophylls which are called bacterio-chlorophyll and chlorobium chlorophyll.<br>❖ In photosynthetic bacteria $H_2S$ gas is used instead of $H_2O$. Therefore these bacteria release sulphur during photosynthesis. Green sulphur bacteria and purple sulphur bacteria are the examples of photosynthetic bacteria.<br>**$CO_2 + 2H_2S \longrightarrow$ *light* $(CH_2O)n + H_2O + 2S$**<br>**CHEMOTROPHIC NUTRITION:**<br>In this type of nutrition energy is produced by the oxidation of certain inorganic substance such as ammonia, nitrates, nitrites Ferrous ions etc. this energy is used for the synthesis of carbohydrates. This process food manufacturing is called chemosynthesis.<br>Example:<br>1. $NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 2H_2O + 4H^+ + Energy$<br>2. $2NO_2^- + O_2 \longrightarrow 2NO_3 + Energy$ | | |
| **8.** | Draw and describe the life cycle of Zygomycota or Ascomycota fungi | **LIFE CYCLE OF RHIZOPUS(Zygomycota)**<br>Asexual reduction takes place by spores and these spores are produced during the favourable conditions.<br>**1- ASEXUAL REPRODUCTION**<br>**i- SPORANGIOPHORES**<br>At the time of reproduction the mycelium produces so many erect hyphae, which are known as sporangiophores.<br>**ii- SPORANGIUM:**<br>At the tip of each sporangiophore a rounded body appears, in which cytoplasm, nuclei and oil droplets are transferred from the mycelium. Then this rounded body is differentiated into a upper broad portion, which is known as sporangium, and a lower smaller known as sporangium, | **K/A** | **E** |

and a lower smaller portion or columella. Sporangium is nucleated while the columella is nonnucleated.

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**iii- SPORES:**

Each nucleus of sporangium is surrounded by a small amount of cytoplasm and then it is coved by a wall. In this way numerous, unicellular bodies are developed inside the sporangium, which are known as spores.

**iv- DISPERSAL AND GERMINATION OF SPORES**

When the spores become mature inside the sporangium, the columella, starts to swell and applies a pressure on the sporangial wall, ultimately the sporangial wall sutures and all the spores are dispersed into the air these spores are very small in size, and they fall on organic matter of germinate to form new mycelia.

**2- SEXUAL REPRODUCTION**

Sexual reproduction appears during the unfavourable condition. In this reproduction different the hyphae of different strains come close to each other. Then both of them produce small out growths (papillae) which grow and fused together. In this condition they are called progametangia. Each progametangium divides into two parts is due to the formation of a septum. The front part is gametangium and the part behind gametangium is called suspensor.

The wall between the two gametangia is dissolved and the protoplasm of both gametangia is fuse to form a diploid (2n) zygote. The zygote produces a cyst around it to become a zygospore.

This type of sexual reproduction is known as heterothallic conjugation.

**GERMINATION OF ZYGOSPORE:**

The zygospore germinates during the favourable conditions and forms an erect hypha or promycelium, on which sporangium is produced. Inside the sporangium haploid (n) spores are developed by meiosis, these spores are dispersed when the sporangial wall is ruptured and germinates to form new mycelia.

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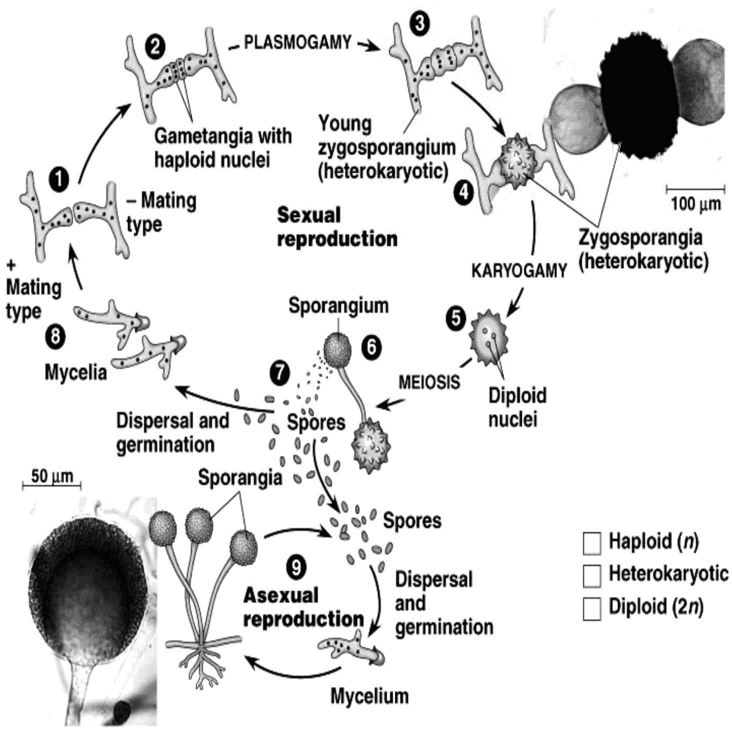
| | |  | | |
| **9.** | Describe the life cycle of fern. Illustrate your answer with reference to alternation of generations. | **LIFE CYCLE OF FERN**<br>The life cycle of fern consists on two phases.<br>1. Sporophyte phase (asexual reproduction)<br>2. Gametophyte phase (sexual reproduction).<br>**SPOROPHYTE PHASE (Asexual Reproduction):**<br>• The large leafy fern plant is the diploid sporophyte phase.<br>• The sporophyte of fern is a diploid body, consists of adventitious roots, underground stem (rhizome) and pinnately compound leaves.<br>• In these plants asexual reproduction takes place by spores, which are produced in sporangia located in clusters on the under side of some leaves, these leaves are called sporophylls.<br>• There are three types of sporophyll in ferns.<br>i- Sporophylls looking like the non-reproductive leaves.<br>ii- Sporophylls looking quite different from vegetative leaves.<br>iii- Highly modified sporophylls, which do not look like leaves.<br>• Most advanced ferns are homosporous.<br>• After germination the spores develop into gametophytes, which are haploid in nature because the spores are formed by meiosis. | **K/A** | **E** |

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| | | **GAMETOPHYTE PHASE (Sexual Reproduction):**<br>• The gametophyte of fern is a tiny (less than one centimeter wide) and often more or less heart shaped.<br>• It is non-vascularized, free living and can survive only at moist places.<br>• It bears two types of reproductive organs i.e. antheridia and archegonia.<br>**1:- Antheridia**<br>• Antheridia are the male reproductive organs.<br>• Each antheridium is surrounded by a sterile jacket layer, which encloses a number of antherozoid mother cells.<br>• Each antherozoid mother cell forms two male gametes which are called antherozoids or sperms.<br>**2:- Archegonia**<br>• Archegonia are the female reproductive organs.<br>• Each archegonium is a flask-shaped organ which is composed of a neck and a venter.<br>• Inside the neck few neck canal cells are present while the venter keeps a venter canal cell and an egg cell. The egg cell is the female gamete.<br>**Fertilization:**<br>• At the time of fertilization the sperms are liberated from the antheridia and start to swim in water by the help of flagella.<br>• Mean while the neck canal cells and the venter canal cell of archegonium are degenerated and form a mucilaginous fluid, this fluid is released from the archegonium. It contains malic acid which attracts the sperms towards the archegonium. So a large number of sperms are entered into the venter, but only one is succeeded to fuse with the egg cell to form a diploid zygote<br>• The zygote germinates into a diploid sporophyte. | | |

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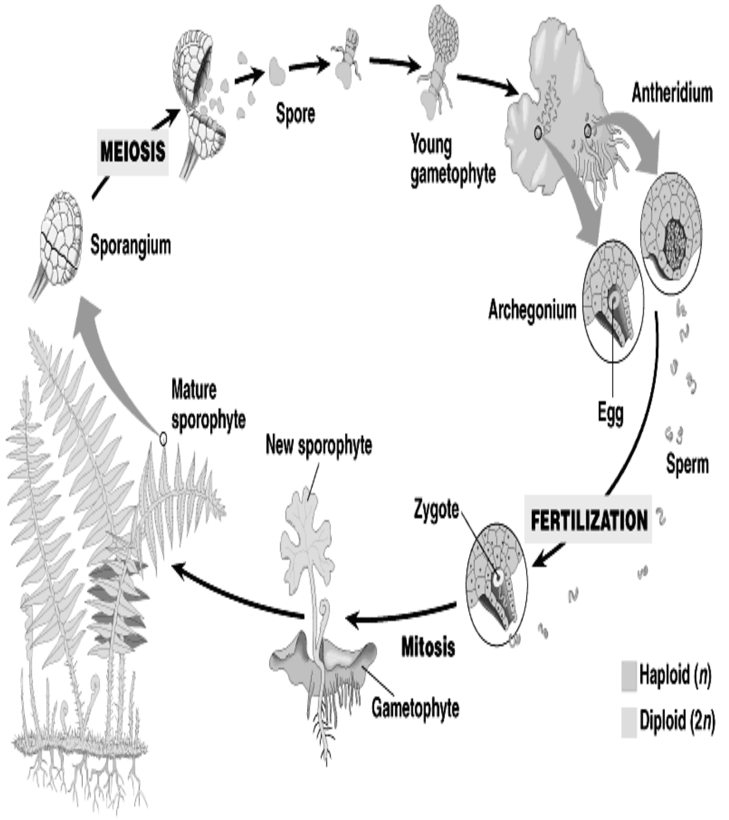
| | |  | | |
| **10.** | Define Photosynthesis. Describe light reaction | **LIGHT REACTION**<br>• The initial information about light reaction was given by R. Hill in 1939. So the light reaction is called "**Hill-Reaction**". In light reaction there is no participation of CO2 but light is so essential. This is the first step of photosynthesis in which ATP and NADPH+H are synthesized which is utilized in the dark reaction.<br>• This process takes place on the thylakoid membrane. Four major complexes are present for the light reaction on this membrane;<br>**1. Photosystem I (PS-I)**<br>**2. Photosystem II (PS-II)**<br>**3. Cytochrome b/f complex**<br>**4. ATPase complex**<br>• In between these complexes electron acceptor molecules are also present. These electron acceptors are **plastoquinone**, **plastocyanin** and **ferredoxin**. | | |

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| | | • The light dependent reactions that occurs in the thylakoid membranes require the participation of two light gathering units called photosystem-I (PS-I) and photosystem-II (PS-II). Both the photosystems contain an antenna complex or light harvesting complex. The light harvesting complex contains 200 to 300 pigment molecules and collects light energy. Different pigments collect light of different wavelengths, making the photosystem more efficient. All the energy is transferred from molecule to molecule and finally to a specialized form of chlorophyll-a known as P700 in PS-I and P680 in PS-II. Their absorption peaks are at wavelength of 700 nm and 680 nm respectively.<br>**EXPLANATION OF LIGHT REACTION:**<br>**Arnon** and his co-workers proposed a theory of Cyclic and Non-Cyclic Photophosphorylation.<br>**CYCLIC PHOTO PHOSPHORYLATION**<br>The cyclic electron pathway begins after the PS-I pigment complex absorbs solar energy. In this pathway, high energy electrons leave the PS-I reaction centre chlorophyll-a molecule but eventually return to it.<br>Before they return, enter an electron transport system. The electron from P700 is passed to primary electron acceptor, then to ferredoxin (Fd), to the cytochrome b/f complex and from there continue on to the P700 chlorophyll. In cyclic photophosphorylation ATP is generated by the coupling of electron transport chain by chemiosmosis. There is no production of NADPH and oxygen.<br>**NON CYCLIC PHOTOPHOSPHORYLATION**<br>1. **PHOTOSYSTEM-II AND 1ST ELECTRON TRANSPORT CHAIN:** When light strikes the chlorophyll molecules, its energy causes an electron in the reaction centre chlorophyll P680 to be boosted.<br>The electron is said to be excited because it posses greater energy than the normal one. The absorbed light energy causes the chlorophyll molecules of P680 to give up a pair of electrons. Each of the photo excited electrons passes from primary electron acceptor of PS-II i.e. pheophytin to PS-I via an electron transport chain. This chain consists of an electron acceptor molecule or plastoquinone (PQ), cytochrome-b (cyt-b), cytochrome-f (cyt-f) and a copper containing protein or plastocyanin (PC).<br>2. PRODUCTION ATP: As electrons pass through the chain their energy goes on decreasing and is used by the thylakoid membrane to produce ATP from phosphate and ADP. **This ATP generated by light reactions will provide chemical energy for the synthesis of sugar during Calvin cycle.**<br>3. **PHOTOSYSTEM-I:** When P700 molecule absorbs a photon of light. Electrons are boosted to a higher energy level. P700 molecule passes the electron to a primary electron acceptor, creating a "hole".<br>The hole of P700 is filled by a pair of electrons received from the P680 via electron transport chain of PSII. | | |

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| | | 4. **2ND ELECTRON TRANSPORT CHAIN:** The primary electron acceptor of PS-I passes the photoexcited electrons to a second electron transport chain. The electrons are accepted by ferredoxin (Fd). It is an iron containing protein. An enzyme called NADP reductase transfers the electrons from Ferredoxin to<br>Page 100<br>NADP+, which is combined with hydrogen ions to form NADPH+H+**. The NADPH+H+ will provide reducing power for the synthesis of sugar in the calvin cycle.**<br>**NADP+ + 2e- + 2H+⟶NADPH+H+**<br>5. **PHOTOLYSIS OF WATER:** The deficiency of electrons in PS-II is full filled by the electrons of water molecule. Each water molecules in the lumen of thylakoid splits into a pair of H+ ion, a pair of electrons and oxygen gas. This process is known as photolysis of water.<br>**H2O⟶2H+ + 2e- + ½ O2**<br>6. **CHEMIOSMOSIS:** Energy released from electrons traveling through the chain of acceptors is used to pump protons (H+ ions) from the stroma across the thylakoid membrane and into the thylakoid interior space (lumen). Moreover the photolysis of water also increases the concentration of protons (H+ ions) in the lumen of thylakoid. Thus these factors results in the formation of a proton gradient across the thylakoid membrane. The gradient has a great deal of free energy because of its low entropy. The thylakoid membrane is impermeable to H+ ions except through certain channels formed by an enzyme called ATP synthase complex. When the protons flow out of the thylakoid space by the way of ATP synthase complex, energy is provided for the ATP synthase enzyme to produce ATP form ADP and Pi. This is called **chemiosmotic ATP synthesis**. The transport of three protons through the ATPase complex is normally required for the production of one ATP molecule. | | |