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Class: 11
Subject: Biology
Topic: Photosynthesis in higher plants
No. of Questions: 25

Q1. What is the primary source of energy for living beings on earth?

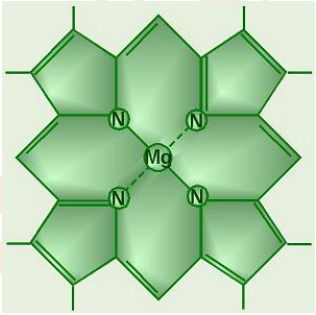
Sol: The sun, center of our planetary system and star of the milky way galaxy (our galaxy), is the source of the energy that is processed and consumed by living beings. Intense nuclear reactions in the sun liberate light and other energetic radiations into the surrounding space. Some of this energy reaches our planet.

Q2. Are there chloroplasts in cyanobacteria?

Sol: In cyanobacteria there are no chloroplasts and the chlorophyll layers are dispersed in cytosol.

Q3. Which chemical element is central in the chlorophyll molecule?

Sol: The chemical element that is central in the chlorophyll molecule is magnesium. One atom of magnesium is present in the center of an amalgam of eight nitrogen-containing carbon rings.



Q4. How do chloroplasts multiply?

Sol: Like mitochondria chloroplasts have their own DNA, RNA and ribosomes and they self-replicate through binary division.

Q5. How can the hypothesis that asserts that chloroplasts as well as mitochondria were primitive prokaryotes that associated in mutualism with primitive anaerobic eukaryotic cells be corroborated?

Sol: The described hypothesis is known as the endosymbiotic hypothesis about the evolutionary origin of mitochondria and chloroplasts.

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Mutualism is explained as: mitochondria and chloroplasts can offer energy and nutrients to the cell in exchange for protection. The hypothesis is strengthened since those organelles have their own DNA, RNA and protein synthesis machinery and they divide themselves through binary division like bacteria do.

Q6. What are the main structures of chloroplasts?

Sol: Chloroplasts are involved by two membrane layers, the outer and the inner membranes. Inside the organelle the formative unit is called the granum, a coin-shaped structure that, piled with others grana, forms several structures called thylakoids. The thylakoids fill the chloroplast and an intergrana membrane permeates the interior of the organelle.

Q7. In which chloroplast structure are chlorophyll molecules found?

Sol: Chlorophyll molecules are placed in an organized manner in order to enhance the exposure to light on the thylakoid surfaces.

Q8. What do ATP and ADP mean? What are the roles of these molecules for the cellular energetic metabolism?

Sol: ATP is an abbreviation of adenosine triphosphate, a molecule made of adenosine bound to three inorganic phosphates. ADP is an abbreviation of adenosine diphosphate, two molecules of phosphate bound to adenosine. ATP is a molecule that stores energy for the cell. When ATP hydrolyzes and becomes ADP energy is liberated and then consumed by several metabolic reactions of the organism.

Q9. What is ADP phosphorylation? What respectively are photophosphorylation and oxidative phosphorylation?

Sol: ADP phosphorylation is the addition of one inorganic phosphate in the molecule of adenosine diphosphate thus creating ATP (adenosine triphosphate) and incorporating energy. The phosphorylation is oxidative when the energy incorporated comes from the breaking of organic molecules having oxygen as reagent, as in aerobic cellular respiration. The reaction is called photophosphorylation when the energy source is light, as in photosynthesis.

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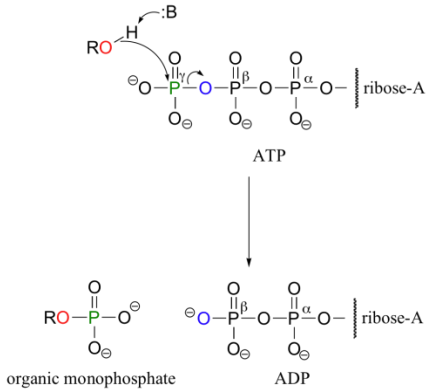

The energy incorporated into ATP is disposable (liberated) to other cellular reactions when ATP hydrolyzes and ADP is formed again.

Q10. What are the stages into which photosynthesis is divided?

Sol: Photosynthesis is divided into the photochemical stage, or light reactions, and the chemical stage.

Q11. What are the processes of the photochemical stage of the photosynthesis process?

Sol: Photolysis of water, with liberation of molecular oxygen, and photophosphorylation of ADP, with production of ATP and NADPH, are the processes that occur during the photochemical stage of photosynthesis.

Q12. How is the photic energy absorbed by chlorophyll transferred to ATP molecules in photophosphorylation? How will be the resulting ATP used?

Sol: Light excites chlorophyll and energizes electrons that jump off the molecule. The energy liberated when these electrons escape is used in the phosphorylation of ADP, forming ATP. The enzyme that catalyzes the reaction is the ATP synthase.
The resulting ATP is then consumed in the next chemical stage of photosynthesis to energetically enrich carbon dioxide for the formation of glucose.

Q13. Is it correct to consider water decomposition by the action of light the basis of the photosynthesis process?

Sol: Besides ADP photophosphorylation, photic energy is also responsible for the breaking of water molecules during photosynthesis in a process known as water photolysis. In this reaction water molecules are exposed to photic energy and liberate protons (hydrogen ions), highly energetic electrons and molecular oxygen (O_2). Later the hydrogen atoms will be incorporated into carbon dioxide molecules to form glucose. Since water is the hydrogen donor for photosynthesis it is

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correct to say that the water photolysis is the basis of the process.

Q14. What are the chemical substances produced by water photolysis? What is the destination of each of those substances?

Sol: Free electrons, hydrogen ions and molecular oxygen are liberated, after the water photolysis. The electrons will replace those electrons lost by chlorophyll molecules in photophosphorylation. The hydrogen ions will be incorporated into hydrogen acceptor molecules (NADP) and later will be used in the synthesis of glucose during the chemical stage. Molecular oxygen is liberated to the atmosphere.

Q15. In sulfur photosynthetic bacteria what is the molecule that donates hydrogen for photosynthesis?

Sol: In sulfur photosynthetic bacteria the substance that donates hydrogen is hydrogen sulfide (H_2S) and not water. Therefore there is no liberation of molecular oxygen but there is production of molecular sulfur (S_2). (Oxygen and sulfur have same number of valence electrons.)

Q16. Why is it said that during photosynthesis carbon dioxide is enriched to form glucose?

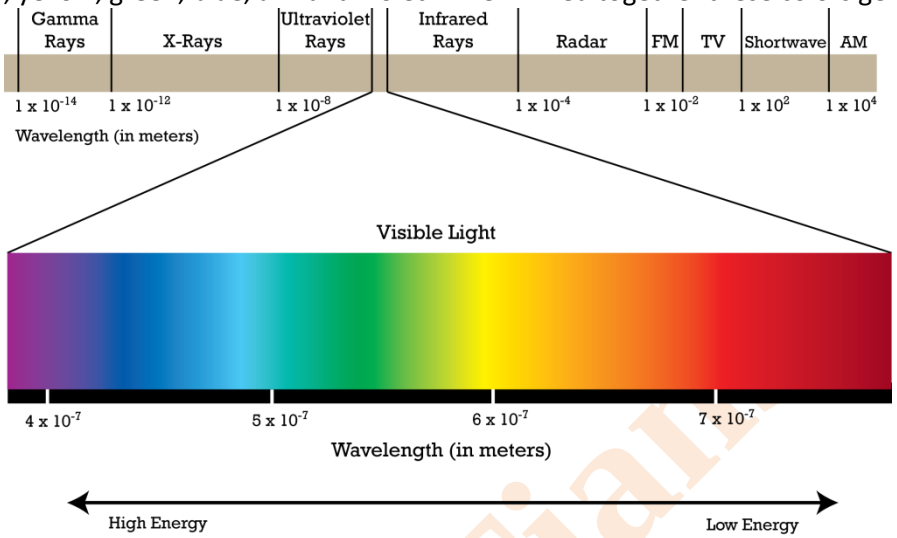
Sol: During photosynthesis carbon dioxide is energetically enriched with hydrogen from water. Water broken by photolysis is the hydrogen donor of the reaction. Glucose is made of carbon and oxygen atoms obtained from carbon dioxide and of hydrogen atoms obtained from water.

Q17. What is an example of a lab experiment that shows the variation of the photosynthesis efficiency in relation to different photic energy frequencies to which the reaction is exposed? Was it expected that green light frequency favored the reaction?

Sol: The experiment: Plants of same species and ages are placed each under (respecting their photoperiods) light sources emitting only one of the colors of the light spectrum (violet, anil, blue, green, yellow and red). The experiment is executed with each of the colors and after days each plant's development is compared. Those plants whose development was normal performed satisfactory photosynthesis while those with abnormal development underused the offered light.
Chlorophyll is green because it reflects the green light frequency, i.e., it does not “use” the green range of the electromagnetic spectrum. Thus green light does not favor photosynthesis (curiously green is the light that plants “dislike”).

Q18. What are the divisions of white light according to the electromagnetic spectrum? Which are the two most efficient colors for photosynthesis?

Sol: The color divisions of the electromagnetic spectrum in decreasing order of frequency are: red, orange, yellow, green, blue, anil and violet. When mixed together these colors generate white.



Experimentally it is verified that the most useful colors for photosynthesis are blue and red.

Q19. What is NADP and NADPH?

Sol: NADP is the abbreviation of the nicotinamide adenine dinucleotide phosphate cation, a hydrogen acceptor. NADPH is made when NADP binds to one hydrogen atom and it is the form that actually transports hydrogen.

Q20. Photosynthesis is the most important producer of molecular oxygen (O_2) on our planet. From which molecule do oxygen atoms liberated by photosynthesis come? From which other molecule could one suspect they have come? What are the destinations of those oxygen atoms?

Sol: The oxygen atoms liberated as molecular oxygen by the photosynthesis process come from water.
One indeed could suspect that those oxygen atoms would have come from carbon dioxide. Oxygen atoms from carbon dioxide however are incorporated into glucose molecules and into water molecules liberated in the chemical stage of photosynthesis.

Q21. Where do the photochemical and the chemical stages of photosynthesis occur?

Sol: The photochemical stage of the photosynthesis process occurs mainly on the thylakoids (the green part) and the chemical stage occurs in the stroma (the colorless framework) of the chloroplasts.

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Q22. Which are the sub products of the photochemical stage that are essential for the chemical stage of photosynthesis?

Sol: The chemical stage of photosynthesis depends on NADPH and ATP produced in the "light reactions" (photochemical stage).

Q23. What are the roles of NADPH and ATP in the chemical stage of photosynthesis?

Sol: NADPH acts as reductant of carbon dioxide, it delivers highly energetic hydrogens to precursor molecules during the glucose formation process. ATP is an energy source for the reactions of chemical stage.

Q24. Why is the nickname "dark reactions" not entirely correct for the chemical stage of photosynthesis?

Sol: "Dark reactions" is not a correct name for the chemical stage of photosynthesis since the reactions of the chemical stage also occur in the presence of light.

Q25. What is the general chemical equation of photosynthesis? Why doesn't that equation clearly show the real origin of the molecular oxygen liberated?

Sol: The general equation of photosynthesis is:
$6\ CO_2 + 6\ H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6\ O_2$
Water molecules are also produced in the chemical stage of photosynthesis as the following complete equation reveals:
$6\ CO_2 + 12\ H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$
Water molecules are present in the reagent side as well in the product side of the equation. Pure mathematical simplification of stoichiometric coefficients however leads to elimination of water from the product side and it then seems that 6 molecules of molecular oxygen (O_2), i.e., 12 atoms of oxygen, are made for each 6 molecules of water, i.e., 6 oxygen atoms, in the reagent side. Thus a false impression that 6 other oxygens come from carbon dioxide is created.