Section 5.1: Photosynthesis: An Introduction

Research This: Experimenting with Jan Baptist van Helmont, page 213

A. (i) Jan Baptist van Helmont's willow tree experiment took 5 years.

(ii) He transplanted a 2.5 kg willow shoot into a pot containing 91 kg of dried earth. He buried the pot in the ground and put a metal lid on top of the pot to keep airborne dust from mixing with the earth. He watered the earth when necessary with rainwater (not with well water, which might contain dissolved earth). After five years, he recorded the mass of the tree and the earth again.

(iii) The expected result was that the earth would lose a quantity of mass equal to the mass gained by the tree. At the end of five years, the tree weighed 76.5 kg, but the mass of the earth had only decreased by 56 g. Since so little soil was consumed, van Helmont assumed that the mass that the tree gained in wood, bark, and roots had come from the water alone.

(iv) He did not account for the air being a source of mass in his experiment. We now know that a large proportion of the mass of the tree comes from atmospheric carbon dioxide, which, in conjunction with water, is turned into carbohydrates during photosynthesis.

B. The experiments of van Helmont were the first known quantitative experiments in biology. He did not rely on casual observations. He took careful measurements and tried to control all variables (at least the ones he knew about).

C. (i) Since he added only water, van Helmont concluded that only water was needed for the tree to grow. His conclusion illustrates the challenge of designing experiments. His experimental design did not account for all confounding variables and, therefore, led to an erroneous conclusion. It is important to ensure that all possible variables are identified and eliminated or controlled in an experiment to prove causality.

(ii) His hypothesis was that only water was needed for plant growth, so to accurately test that hypothesis, he should have used a pot filled only with water to grow his tree. Since water alone lacks the essential nutrients the tree needs to grow, the tree would likely have grown poorly or died in water alone, thereby disproving his hypothesis.

D. More than 100 years after van Helmont's willow tree experiment, Nicolas-Theodore de Saussure used controlled experimentation to show that the increase in mass of a plant as it grows cannot be entirely due to water uptake, but must also be a result of carbon dioxide uptake from the air. He enclosed plants in glass containers and recorded the mass of both the plants and the enclosed carbon dioxide before and after his experiments.

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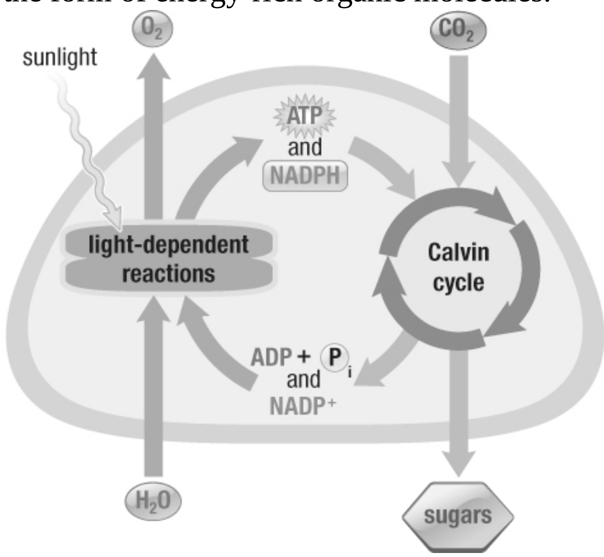
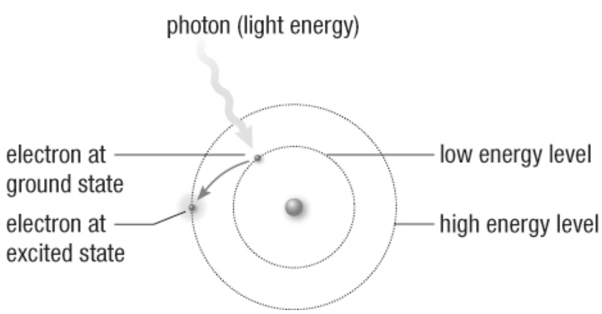
1. Photoautotrophs are considered to be primary producers because they use photosynthesis to produce food for themselves and consumers at higher trophic levels.

2. The diagram illustrating the relationship between the two stages of photosynthesis should show how the products of one stage are used in the reactions of the second stage. In the light-dependent stage, light energy is captured and used to generate high energy NADPH and ATP. In the light-independent stage (the Calvin cycle), these high energy products are used to fix carbon in the form of energy-rich organic molecules.



3. The diagram illustrating the relationship between the absorption of light energy and electron energy levels within an atom should show how electrons absorb a photon of light and jump from a ground state (lower energy level) to an excited state (higher energy level). The three possible fates of an electron after it has jumped to a higher energy state are 1) it may return to its ground state by releasing a less energetic photon (fluorescence) or by releasing energy as thermal energy, 2) it may return to its ground state by transferring its energy to a different electron in a neighbouring pigment molecule, or 3) it may move to another molecule.



4. (a) I would expect these species of marine algae that live in low light at depths of up to 100 m or more to have less chlorophyll than green algae because chlorophyll appears green in colour. Since these algae appear red when brought to the surface, they would have more red pigments, such as carotenoids.
(b) I would expect these species to perform photosynthesis more efficiently under a green light source versus a red light source because the red pigments reflect red light but absorb green light.
(c) The fact that water absorbs red light more effectively than blue light (making things appear bluish underwater) means that very little red light reaches deep water species. Therefore, they have evolved the ability to absorb more light at the opposite end of the spectrum. When brought to the surface they reflect red light, but in their living setting there actually is little or no red light.
5. Thylakoids are flattened, closed sacs inside the chloroplasts that house the pigments and other molecules where the light-dependent reactions of photosynthesis take place. They are important for photosynthesis because the thylakoids are where light energy is actually absorbed to begin the process of photosynthesis.
6. Answers may vary. Sample steps for an experimental procedure for Engelmann's famous action spectrum of living algae investigation are:

- Prepare a wet mount of a single strand of filamentous alga.
- Add aerobic bacteria to the solution surrounding the alga.
- Use a light source and prism to expose the strand of alga to different wavelengths along its length.
- With a microscope, carefully observe the surrounding liquid noting areas where the bacteria are more or less concentrated.

7. The absorption spectrum of a pigment shows the amount of light absorbed by a specific pigment at different wavelengths. The action spectrum for photosynthesis shows which wavelengths of light are the most effective at driving photosynthesis. The action spectrum is influenced by the many different pigments within the chloroplasts of the organism. The cumulative absorption spectrum of the photosynthetic pigments matches the action spectrum of plants, indicating that the pigments are involved in the absorption of light for photosynthesis.
8. The graph of the action spectrum of the main pigments in the leaves in Figure 11 should show a dip in the level of photosynthesis around the red and blue wavelengths compared to other wavelengths. The leaves are purplish, so it reflects more red and blue light than other colours. As a result, the light effectiveness in those areas of the spectrum will be the lowest.