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Why are Plants Green? The Science behind their Colour and Light Interaction

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Have you ever wondered why plants appear green? The answer lies in how they interact with light - an interesting phenomenon in both physics and biology. Light is essential for plant photosynthesis, the process that enables plants to convert sunlight into energy. This interaction depends on the properties of light, particularly its spectrum and the pigments present in plants. Chlorophyll pigment that gives green colour to the plants helps in capturing light. However, not all light is used equally by plants. While red and blue light are absorbed for energy, green light is mostly reflected, which is why plants appear green to our eyes. Understanding this interaction helps explain the importance of light in plant health and growth, and how plants adapt to different environments.

The Electromagnetic Spectrum and Photosynthesis

Light is a part of the electromagnetic spectrum, encompassing a wide range of wavelengths, from gamma rays to radio waves. The visible light spectrum, which we can see, includes the colours of the rainbow: violet, indigo, blue, green, yellow, orange, and red. Each colour corresponds to a specific wavelength, with violet having the shortest and red the longest.

For photosynthesis, plants primarily use light in the red (longer wavelength) and blue (shorter wavelength) parts of the spectrum. Chlorophyll, the pigment that captures light energy for photosynthesis, absorbs red and blue wavelengths most efficiently. In contrast, green light is mostly reflected rather than absorbed, giving plants their green appearance. This reflection is a key feature of chlorophyll molecules, specifically chlorophyll a and b, located in the chloroplasts of mesophyll cells. The electromagnetic spectrum encompasses a wide range of wavelengths, including ultraviolet (UV), visible light, and near-infrared (NIR). Here's how plants interact with different parts of the spectrum:

1. Ultraviolet (UV) Light (<400 nm)

Excessive UV exposure can damage DNA and proteins, negatively impacting plant health. However, some plants produce protective compounds, such as flavonoids, to shield against UV radiation.

2. Visible Light (400–700 nm)

The visible spectrum is the only part of the electromagnetic spectrum that can be seen by the human eye.

- Blue light (short wavelengths, high energy) is crucial for regulating plant growth and morphology, such as leaf expansion and stomatal opening.
- Red light (longer wavelengths, moderate energy) drives photosynthesis by exciting electrons in chlorophyll molecules, initiating energy transfer for sugar production.
- Green light is less efficiently absorbed but can penetrate deeper into the leaf tissues, contributing to photosynthesis in shaded areas.

3. Near-Infrared (NIR) Light (>700 nm)

✚ NIR light is not absorbed by chlorophyll but penetrates mesophyll cells, where it is scattered and reflected. This reflective property helps protect plants from overheating and contributes to their cooling mechanisms.

4. Far-Infrared (>1000 nm)

✚ Wavelengths beyond NIR contribute to heat, which, in high amounts, can stress plants, affecting photosynthesis and water balance.

The Role of Chlorophyll in Light Absorption and Reflection

Chlorophyll is the main pigment in plants and plays a key role in absorbing light for photosynthesis. This process helps plants to convert sunlight into energy needed for their growth.

- ✚ How chlorophyll absorbs light: Chlorophyll is found in the thylakoid membranes of chloroplasts. They contain a porphyrin ring with a magnesium ion at the center, which is essential for light absorption. Chlorophyll a and b helps to absorb red and blue light for energy, while green light is reflected back, which is why plants look green.
- ✚ Mechanism of Light Absorption: When light strikes chlorophyll, it gives energy to the electrons inside the porphyrin ring. These energized electrons move through a series of steps, helping the plant create energy molecules like ATP and NADPH, which are necessary for photosynthesis. Chlorophyll absorbs blue and red light, while reflecting green light, which is why plants look green.
- ✚ Energy Use and Reflection of Light: After absorbing light, chlorophyll uses some of the energy for photosynthesis, but a large amount of energy, particularly green light, is reflected. This reflection helps in heat regulation, preventing overheating of plant tissues, which is essential for maintaining optimal conditions for growth.

Chlorophyll's Role in Photosynthesis and Plant Growth

Photosynthesis takes place in two main stages: the light-dependent and light-independent reactions (Calvin Cycle).

- Light-dependent reactions take place in the thylakoids, where red and blue light are absorbed and used to produce energy molecules like ATP and NADPH.
- In the light-independent reactions (Calvin Cycle), these energy molecules help convert carbon dioxide into sugars, which are used by the plant for growth and energy storage.

The absorption of red and blue light by chlorophyll fuels these reactions, while green light contributes indirectly by penetrating deeper into the leaf, allowing for more efficient light capture in shaded areas.

Adaptations to Light Environments

Plants have evolved several strategies to optimize light use:

- **Shade plants:** These plants have a higher concentration of chlorophyll b, which helps absorb more light in low-light environments.
- **Sun plants:** These plants have adaptations that allow them to tolerate higher light intensities and prevent photooxidative damage.

Chloroplasts and Mesophyll Cells: The Light Absorption Machinery

Chloroplasts in the mesophyll cells are the sites where photosynthesis takes place. These cells are packed with chloroplasts, each containing multiple thylakoids filled with chlorophyll. The leaf's structure is optimized for capturing light, with a high surface area to absorb as much light as possible. The stroma inside the chloroplast houses enzymes that facilitate the light-independent reactions.

Chlorophyll's Role in Protecting Plants

Chlorophyll also protects plants in several ways:

- **UV Light Protection:** Some plants produce pigments like flavonoids that protect against harmful UV light.
- **Near-Infrared (NIR) Reflection:** NIR light, which is not absorbed for photosynthesis, is reflected, preventing overheating of the plant tissues.

Impact of Light on Plant Health

Balanced exposure to light is critical for plant health:

- **Optimal Visible Light:** Red and blue light are most effective for photosynthesis and growth, while green light aids in light penetration to lower leaf layers.
- **Excessive UV Light:** Can harm cellular structures, but some plants adapt by developing protective pigments.
- **NIR Light:** Its reflection is important for preventing overheating and is often used in remote sensing technologies to monitor plant health.

Conclusion

Chlorophyll plays a dual role in both absorbing and reflecting light. It absorbs red and blue wavelengths efficiently for photosynthesis, while reflecting green light, which is less useful for the process. This selective absorption and reflection are critical for the plant's ability to harness energy from sunlight while also preventing damage from excessive light and heat. Through this physiological process, chlorophyll enables plants to convert light into the energy necessary for growth and survival, while also adapting to varying light environments and protecting themselves from light-induced damage.