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TEACHING MATERIAL ON

Botany

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PIGMENTS IN PHOTOSYNTHESIS BY DR KAMAL KANT PATRA, ASSOCIATE PROFESSOR, DEPARTMENT OF BOTANY, SCHOOL OF SCIENCE, YBN UNIVERSITY, RANCHI

Introduction to Photosynthetic Pigments

Photosynthesis is the process by which green plants, algae, and some bacteria convert light energy into chemical energy stored in glucose. This process primarily occurs in the chloroplasts of plant cells and requires the presence of pigments. These pigments play a crucial role in absorbing light energy from the sun and initiating the photosynthetic process.

What are Photosynthetic Pigments?

Photosynthetic pigments are molecules that absorb light energy at specific wavelengths and use this energy to drive the reactions of photosynthesis. These pigments are located in the thylakoid membranes of the chloroplasts.

Types of Photosynthetic Pigments

Photosynthetic pigments can be classified into three main categories:

1. **Chlorophylls**
2. **Carotenoids**
3. **Phycobilins**

1. Chlorophylls

Chlorophylls are the primary pigments involved in photosynthesis. They are green in color and are responsible for the characteristic green appearance of plants.

Types of Chlorophyll

1. **Chlorophyll a**:

- Found in all photosynthetic organisms except some photosynthetic bacteria.
- Absorbs light in the blue-violet and red regions of the spectrum (wavelengths: ~430 nm and ~680 nm).
- Essential for the photochemical reactions of photosynthesis.

2. **Chlorophyll b**:
    - Accessory pigment found in higher plants and green algae.
    - Absorbs light in the blue and orange regions (wavelengths: ~450 nm and ~640 nm).
    - Transfers absorbed light energy to chlorophyll a.

Structure of Chlorophyll

- **Porphyrin Ring**: Contains a magnesium ion at its center, which is responsible for light absorption.
- **Phytol Tail**: A long hydrocarbon chain that anchors the molecule to the thylakoid membrane.

2. Carotenoids

Carotenoids are accessory pigments that are orange, yellow, or red in color. They play a supporting role in photosynthesis by capturing light energy and protecting the chloroplasts from photo-oxidative damage.

Types of Carotenoids

1. **Carotenes**:
    - Hydrocarbon molecules (e.g., β-carotene).
    - Absorb light in the blue-green region (wavelengths: ~400-500 nm).
2. **Xanthophylls**:
    - Oxygenated derivatives of carotenes (e.g., lutein, zeaxanthin).
    - Absorb light similar to carotenes and assist in energy transfer.

Functions of Carotenoids

- Expand the range of light absorption.
- Quench excess energy to protect chlorophyll molecules from damage (photoprotection).

3. Phycobilins

Phycobilins are water-soluble pigments found in cyanobacteria and red algae. They are not present in higher plants.

Types of Phycobilins

1. **Phycocyanin**:
    - Blue pigment.
    - Absorbs orange and red light.
2. **Phycoerythrin**:
    - Red pigment.
    - Absorbs green light.

Role of Phycobilins

- Efficiently capture light in aquatic environments where other wavelengths are filtered out.
- Transfer energy to chlorophyll a.

Absorption Spectrum and Action Spectrum

Absorption Spectrum

- Shows the specific wavelengths of light absorbed by each pigment.
- Example: Chlorophyll a absorbs most strongly in the blue and red regions.

Action Spectrum

- Shows the effectiveness of different wavelengths of light in driving photosynthesis.
- Matches the combined absorption spectra of chlorophylls and accessory pigments.

Organization of Pigments in the Chloroplast

Photosystems

Photosynthetic pigments are organized into complexes called photosystems in the thylakoid membranes. There are two main types:

1. **Photosystem I (PSI)**:
    - Reaction center chlorophyll: P700.
    - Absorbs light optimally at 700 nm.
2. **Photosystem II (PSII)**:
    - Reaction center chlorophyll: P680.
    - Absorbs light optimally at 680 nm.

Light-Harvesting Complexes (LHCs)

- Accessory pigments (chlorophyll b, carotenoids) are organized into LHCs.
- Transfer energy to the reaction center chlorophyll (chlorophyll a).

Importance of Photosynthetic Pigments

1. **Absorption of Light Energy**: Pigments allow plants to capture light energy efficiently across a broad range of wavelengths.
2. **Energy Transfer**: Accessory pigments transfer energy to chlorophyll a for the photochemical reactions.
3. **Photo-Protection**: Carotenoids protect the chloroplasts from damage by excess light energy.

Conclusion

Photosynthetic pigments are essential for capturing light energy and driving the process of photosynthesis. Chlorophylls are the primary pigments, while carotenoids and phycobilins act as accessory pigments. Understanding the roles and properties of these pigments helps us appreciate how plants adapt to different light conditions and maintain the energy flow in ecosystems.