Bio-inspired Materials and Mechanisms

Hello future engineer. I know you have an exam tomorrow, so we are going to strip away the biology fluff and look at this like a system of inputs, outputs, mechanisms, and efficiency.

Here is your **Bio-inspired Materials and Mechanisms** module, decoded for a PCM student.

TOPIC 1: PHOTOSYNTHESIS (The Biological Solar Factory)

Physics Analogy: Think of a plant leaf as a **factory**.

1. **Input:** Solar energy (photons), Water (), Carbon Dioxide ().

2. **Machinery:** Chloroplasts (containing Chlorophyll pigments).

3. **Process:** Photoelectric effect (Light Reaction) + Chemical Synthesis (Dark Reaction).

4. **Output:** Glucose (Chemical Potential Energy) + Oxygen (By-product).

A. The Equation

B. Light Reaction (The Z-Scheme / Electron Flow)

Occurs in Thylakoids (membrane discs inside chloroplast). **Goal:** Charge the battery. Convert light energy into chemical batteries: **ATP** (Energy) and **NADPH** (Electron carrier).

Mechanism (Step-by-Step):

1. **Excitation:** Light hits **Photosystem II (P680)**. Electrons get excited (Photoelectric effect) and jump out.

2. **Water Splitting (Photolysis):** To replace the lost electrons, water is split: . **This is where Oxygen comes from.**

3. **Transport:** Electrons flow through an "Electron Transport Chain" (like a circuit) to **Photosystem I (P700)**.

4. **Re-excitation:** Light hits PSI, exciting electrons again.

5. **Storage:** Electrons are used to convert into **NADPH**. Simultaneously, proton gradient drives **ATP** synthesis.

Visual Z-Scheme: (Imagine a Z-shape graph where Y-axis is Energy)

- **Up:** PSII excites electron.
- **Down:** Electron loses energy flowing to PSI (making ATP).
- **Up:** PSI excites electron.

• **Down:** Electron stored in NADPH.

C. Calvin Cycle (The "Dark" Reaction / C3 Cycle)

Occurs in Stroma (fluid filling the chloroplast). **Goal:** Use the "batteries" (ATP + NADPH) to build sugar from . **Analogy:** The manufacturing floor using the electricity generated earlier.

3 Phases:

1. **Carboxylation:** binds to a 5-carbon sugar (RuBP).
   ◦ **Enzyme: RuBisCo** (Most abundant protein on Earth, the "manager").
   ◦ Result: Unstable 6-carbon compound splits into two 3-carbon molecules (3-PGA).

2. **Reduction:** ATP and NADPH are used to convert 3-PGA into **G3P** (a 3-carbon sugar). This is the precursor to glucose.

3. **Regeneration:** Most G3P is recycled to make RuBP again so the cycle continues. Requires ATP.

D. Types of Photosynthesis

• **Oxygenic:** Releases . Uses as electron donor. (e.g., Plants, Algae, Cyanobacteria).

• **Anoxygenic:** Does **NOT** release . Uses other donors like . (e.g., Green/Purple bacteria).

🔑 **EXAM NOTES: Photosynthesis**

• **Location:** Mesophyll cells Chloroplasts Thylakoid (Light Rxn) / Stroma (Dark Rxn).

• **RuBisCo:** The enzyme that fixes Carbon.

• **Products:** Light Rxn = ATP, NADPH, . Dark Rxn = Sugar (G3P).

• **Common Mistake:** "Dark reaction" does not happen at night. It just doesn't require *direct* light; it depends on the products of the light reaction.

TOPIC 2: PHOTOVOLTAIC (PV) CELLS vs. PHOTOSYNTHESIS

Physics Concept: The **Photovoltaic Effect**. A semiconductor (Silicon) absorbs photons, knocking electrons loose to create a current.

Components of a Solar Cell:

1. **n-type Silicon:** Doped with Phosphorus (Extra electrons).

2. **p-type Silicon:** Doped with Boron (Extra "holes").

3. **p-n junction:** Creates an electric field to separate charges.

4. **Anti-reflective coating:** Minimizes light loss (Nitride/TiO2).