Photosynthesis in Higher Plants - NCERT Exercise Answer Key

1. By looking at...C_3 or C_4?

Answer: By external observation alone, it's difficult to definitively distinguish between C_3 and C_4 plants. However, some general indicators can help:

C_4 Plant Characteristics:

- Often tropical grasses (maize, sugarcane, sorghum)
- Adapted to hot, dry climates
- More efficient in bright sunlight and high temperatures
- Generally show better growth in arid conditions

C_3 Plant Characteristics:

- Most trees, shrubs, and temperate crops
- Better adapted to moderate temperatures
- More common in temperate and cooler regions

Why External Observation is Limited: External features don't reliably indicate photosynthetic pathway since plant morphology is influenced by many factors beyond photosynthetic type. Definitive identification requires internal anatomical examination.

2. By looking at...C_3 or C_4?

Answer: The definitive way to distinguish C_3 and C_4 plants is by examining their **leaf anatomy**, specifically looking for **Kranz anatomy** in C_4 plants.

C_4 Plant Internal Structure (Kranz Anatomy):

- Large bundle sheath cells surrounding vascular bundles
- Bundle sheath cells have numerous chloroplasts
- Thick walls in bundle sheath cells, impervious to gas exchange
- No intercellular spaces in bundle sheath
- Two distinct cell types for CO_2 fixation

C_3 Plant Internal Structure:

- Normal mesophyll cell arrangement
- No specialized bundle sheath cells
- Uniform chloroplast distribution
- Single cell type performs entire Calvin cycle

Method: Cut vertical leaf sections and observe under microscope. The presence of prominent bundle sheath cells indicates C_4 pathway.

3. Even though a...highly productive?

Answer: C_4 plants are highly productive despite having Calvin cycle in only bundle sheath cells due to several advantages:

CO_2 Concentration Mechanism:

- C_4 acids from mesophyll cells concentrate CO_2 in bundle sheath cells
- Higher CO_2 concentration ensures RuBisCO functions as carboxylase
- Eliminates energy wastage through photorespiration

Spatial Separation Benefits:

- Initial CO_2 fixation by PEP carboxylase (high CO_2 affinity)

- Efficient CO_2 delivery to Calvin cycle
- Reduced oxygenase activity of RuBisCO

Environmental Adaptations:

- Better performance at high temperatures
- Efficient water use in dry conditions
- Higher light use efficiency

Overall Result: Though fewer cells perform Calvin cycle, the concentrated CO_2 supply makes the process much more efficient than in C_3 plants.

4. RuBisCO is an...C_4 plants?

Answer: RuBisCO carries out more carboxylation in C_4 plants due to the **CO_2 concentrating mechanism** that creates favorable conditions for its carboxylase activity.

RuBisCO's Dual Nature:

- Active site can bind both CO_2 and O_2 competitively
- Higher affinity for CO_2, but O_2 can compete when abundant
- CO_2:O_2 ratio determines which substrate binds

C_4 Plant Advantage:

- C_4 acids (malate/aspartate) transported to bundle sheath cells
- Decarboxylation releases CO_2 in bundle sheath, creating high local concentration
- High CO_2:O_2 ratio favors CO_2 binding over O_2
- RuBisCO functions primarily as carboxylase, minimizing oxygenase activity

C_3 Plant Limitation:

- RuBisCO directly exposed to atmospheric CO_2:O_2 ratios
- Significant O_2 competition leads to photorespiration
- Energy loss through oxygenase activity

5. Suppose there were...carry out photosynthesis?

Answer: Plants with high chlorophyll b but lacking chlorophyll a **would not carry out photosynthesis** effectively.

Why Chlorophyll a is Essential:

- Only chlorophyll a can serve as reaction center pigment
- P680 and P700 are specialized chlorophyll a molecules
- Direct involvement in photochemical reactions
- Cannot be replaced by other pigments

Role of Chlorophyll b and Accessory Pigments:

- Function as light-harvesting antenna pigments
- Absorb light at different wavelengths
- Transfer energy to chlorophyll a reaction centers
- Extend the range of useful light wavelengths
- Protect chlorophyll a from photo-oxidation

Energy Transfer System: Accessory pigments → Chlorophyll b → Chlorophyll a (reaction center)

Conclusion: Chlorophyll b and accessory pigments are essential for efficient light harvesting and protection, but chlorophyll a is irreplaceable for the actual photochemical conversion.

6. Why is the...pale green?

Answer: Leaves kept in dark become yellow or pale green due to **chlorophyll degradation** and **synthesis inhibition**.

Chlorophyll Breakdown in Darkness:

- Chlorophyll molecules are unstable and continuously degraded
- Normal degradation requires constant synthesis for replacement
- Chlorophyll synthesis requires light energy
- In darkness, synthesis stops but degradation continues

Pigment Stability:

- **Carotenoids** are more chemically stable than chlorophylls
- Yellow carotenoids persist longer than green chlorophylls
- As green pigments disappear, yellow pigments become visible

Process Called: Etiolation - abnormal plant growth in absence of light **Result:** Yellow/pale green appearance as chlorophyll content decreases while more stable carotenoids remain.

Recovery: When returned to light, chlorophyll synthesis resumes and green color is restored.

7. Look at leaves...darker green?

Answer: Leaves on the **shady side** or plants kept **in shade** typically have **darker green** coloration.

Reason for Darker Green:

- Higher chlorophyll concentration per unit area
- More chloroplasts per cell in shaded conditions
- Compensation for reduced light availability

Shade Adaptation Mechanism:

- Plants increase light-harvesting capacity in low light
- More antenna pigments to capture available photons
- Larger, thinner leaves with more chloroplast-rich mesophyll
- Higher chlorophyll a:b ratio in some cases

Sunny Side Characteristics:

- Lighter green due to lower chlorophyll density
- Thicker leaves with more structural tissues
- Protection against excessive light damage
- May have more accessory pigments for photoprotection

Evolutionary Advantage: Shade plants maximize light capture efficiency while sun plants balance light capture with protection from photodamage.

8. Figure 11.10 shows...following questions:

(a) At which point/s...limiting factor?

Answer: Light is a limiting factor at **point A** in the curve.

Explanation:

- At low light intensities (point A), photosynthesis rate increases linearly with light intensity
- The direct relationship shows light availability directly limits the process
- Increasing light immediately increases photosynthesis rate

(b) What could be...region A?

Answer: In region A, the limiting factor is **light intensity**.

Why Light is Limiting:

- All other factors (CO_2, temperature, water) are sufficient
- Photosynthesis rate directly proportional to light availability
- Linear relationship indicates light-dependent limitation
- Other factors are not yet saturated

(c) What do C...the curve?

Answer:

- **Point C:** Light saturation point where light is no longer limiting
- **Point D:** Maximum photosynthesis rate under given conditions

Beyond Point C:

- Further light increase doesn't increase photosynthesis rate
- Other factors (CO_2 concentration, temperature) become limiting
- May even show decline if light becomes excessive and damaging

9. Give comparison between...following:

(a) C_3 and C_4 pathways

C_3 Pathway:

- First product: 3-phosphoglyceric acid (PGA)
- CO_2 acceptor: Ribulose bisphosphate (RuBP)
- Calvin cycle occurs in mesophyll cells
- Photorespiration present

- Temperature optimum: 20-25°C
- Examples: Rice, wheat, most trees

C_4 Pathway:

- First product: Oxaloacetic acid (OAA)
- CO_2 acceptor: Phosphoenol pyruvate (PEP)
- Spatial separation: mesophyll and bundle sheath
- No photorespiration
- Temperature optimum: 30-40°C
- Examples: Maize, sugarcane, sorghum

(b) Cyclic and non-cyclic photophosphorylation

Non-cyclic Photophosphorylation:

- Involves both PS I and PS II
- Electrons flow linearly (Z-scheme)
- Products: ATP + NADPH + O_2
- Water splitting occurs
- Primary pathway for biosynthesis

Cyclic Photophosphorylation:

- Only PS I involved
- Electrons cycle back to PS I
- Product: ATP only (no NADPH or O_2)
- No water splitting
- Supplementary ATP production

(c) Anatomy of leaf...C_4 plants

C_3 Leaf Anatomy:

- Normal mesophyll arrangement
- Uniform chloroplast distribution
- No specialized bundle sheath cells
- Single cell type for photosynthesis
- Intercellular spaces throughout

C_4 Leaf Anatomy (Kranz):

- Specialized bundle sheath cells
- Large chloroplasts in bundle sheath
- Two distinct photosynthetic cell types
- Thick-walled bundle sheath cells
- No intercellular spaces in bundle sheath
- "Wreath-like" arrangement around vascular bundles