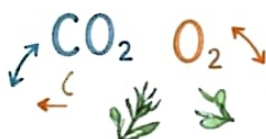


Prodigy Educlasses

Class - XI

CBSE

Topic: C3 and C4 Cycle



The Calvin Cycle

C3 Cycle

What is the Calvin Cycle?



- The Calvin Cycle, also called the C₃ Cycle, is the dark reaction of photosynthesis. It occurs in all photosynthetic plants in the stroma of the chloroplast.
- It does NOT require light directly — it uses ATP & NADPH made during the light-dependent reactions to convert CO₂ into sugar (glucose).



Three Stages of the C₃ Cycle:

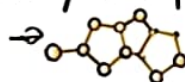
1. Carboxylation — CO₂ is added to RuBP (5-carbon molecule) via the enzyme Rubisco

- Forms 2 molecules of 3-PGA (3-phosphoglycerate), a 3-carbon compound → hence "C₃ Cycle"



2. Reduction

- 3-PGA is reduced using ATP & NADPH from light reactions
- Converted into G3P (glyceraldehyde-3-phosphate), a 3-carbon sugar



3. Regeneration

- Some G3P is used to regenerate RuBP using ATP
- Ensures RuBP is available to keep the cycle going



Key Points:

- Takes place in: the STROMA of the chloroplast
- Overall: $3 \text{ CO}_2 + 9 \text{ ATP} + 6 \text{ NADPH} \rightarrow \text{G3P} + 9 \text{ ADP} + 8 \text{ P}_i + 6 \text{ NADP}^+ + 3 \text{ H}_2\text{O}$

Stroma

Net Product:

G3P can be used to form glucose & other carbs!

Mnemonic: C → R → R = Carboxylation → Reduction → Regeneration

Carboxylation: The Most Crucial Step

★ Why this step?

→ First step of carbon fixation!

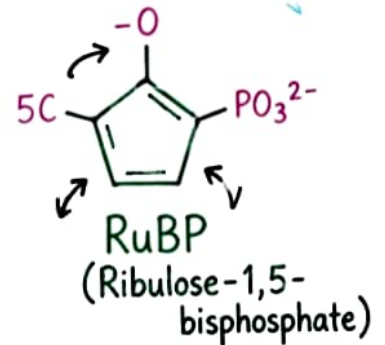


What happens?

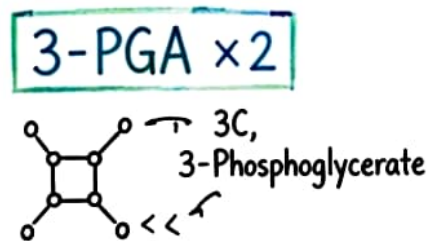
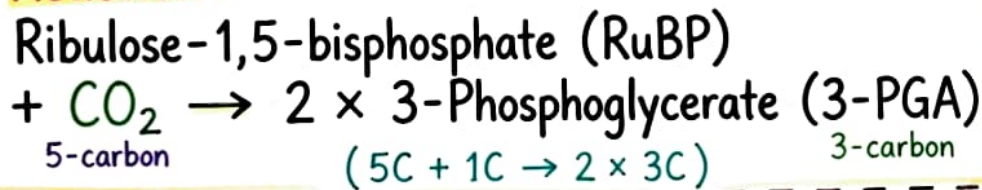
• CO_2 is utilised for carboxylation of RuBP
 CO_2 (from atmosphere)

• CO_2 combines with RuBP → forms 2 molecules of 3-PGA

• Catalysed by enzyme: RuBP carboxylase / RuBisCO ★



Reaction:



Key Points:

- Enzyme: RuBisCO = Ribulose-1,5-bisphosphate carboxylase/oxygenase
- Occurs in: Stroma of the chloroplast
- This is the rate-limiting step → controls rate of Calvin cycle

Remember!



* RuBisCO is the most abundant enzyme on Earth

what's next? →

3-PGA goes to Reduction phase
(next page → conversion to G3P)

Important:
carboxylation =
- CO_2 fixation!



Reduction & Regeneration

Stage 2: REDUCTION — formation of G3P & glucose ↓

Reduction (per CO_2)

- 3-PGA is reduced to G3P (glyceraldehyde-3-phosphate)
- **REQUIRES:** 2 ATP (phosphorylation) + 2 NADPH (reduction) per CO_2
- $\text{ATP} \rightarrow \text{ADP} + \text{P}_i$ (phosphorylation, energy) ⚡
- $\text{NADPH} \rightarrow \text{NADP}^{+}$ (provides electrons/H for reduction) ☸

Summary: For EACH CO_2 molecule: 2 ATP + 2 NADPH are used to make G3P

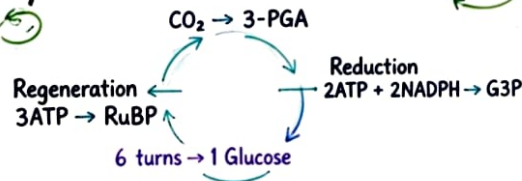
To make 1 glucose ($\text{C}_6\text{H}_{12}\text{O}_6$):

- Need 6 CO_2 molecules → requires 6 turns of the cycle ☆
 - $6 \text{ CO}_2 \times (2 \text{ ATP} + 2 \text{ NADPH}) = 12 \text{ ATP} + 12 \text{ NADPH}$ total for reduction
- Produces 12 G3P. Only 2 G3P are used to make 1 glucose. The other 10 G3P go to regeneration.

Stage 3: REGENERATION — RuBP is regenerated

- 10/12 of the G3P molecules are recycled to regenerate RuBP (the CO_2 acceptor)
- **REQUIRES:** 3 ATP → phosphorylates Ru5P to regenerate 3 RuBP
- RuBP is regenerated so the cycle can continue to fix more CO_2

Overall for 1 Glucose: ☺



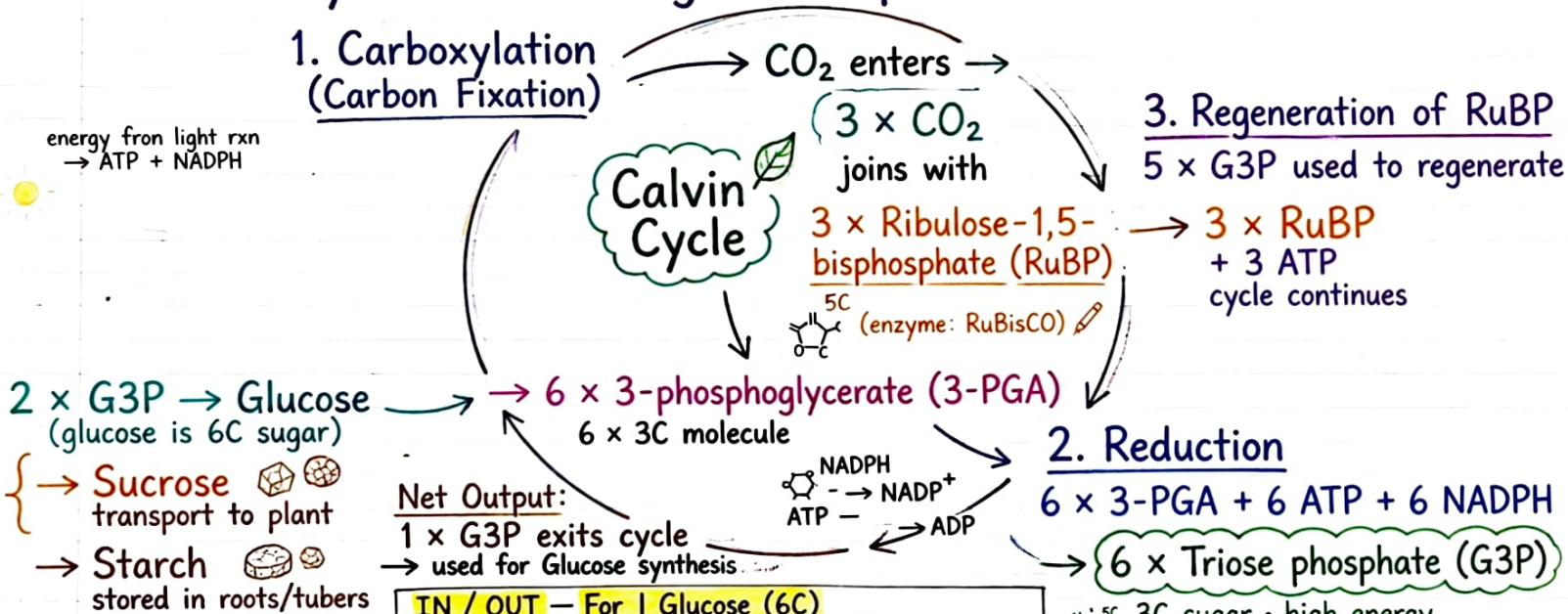
- 6 CO_2 enter the cycle (6 turns)
- Total used: 18 ATP + 12 NADPH
- 1 Glucose molecule formed ($\text{C}_6\text{H}_{12}\text{O}_6$) ☺

* Note: G3P = key 3-carbon product.
Can be exported to make glucose, starch, sucrose *

☞ Key idea: Reduction uses ATP + NADPH from Light Reactions. Regeneration uses ATP to recycle RuBP. ☀

The Calvin Cycle (C₃ Cycle) ↓

Photosynthesis → Light-Independent Reactions



* To make 1 glucose:
the cycle runs 6 times
→ uses 6 CO₂, 18 ATP, 12 NADPH

★ Key reminder: Calvin Cycle occurs in the stroma of the chloroplast ☁
* Doesn't need light directly, but uses ATP & NADPH from Light Reactions

Summary:
Carbon fixation → Reduction
→ Regeneration

★ Kranz Anatomy - C4 Plants

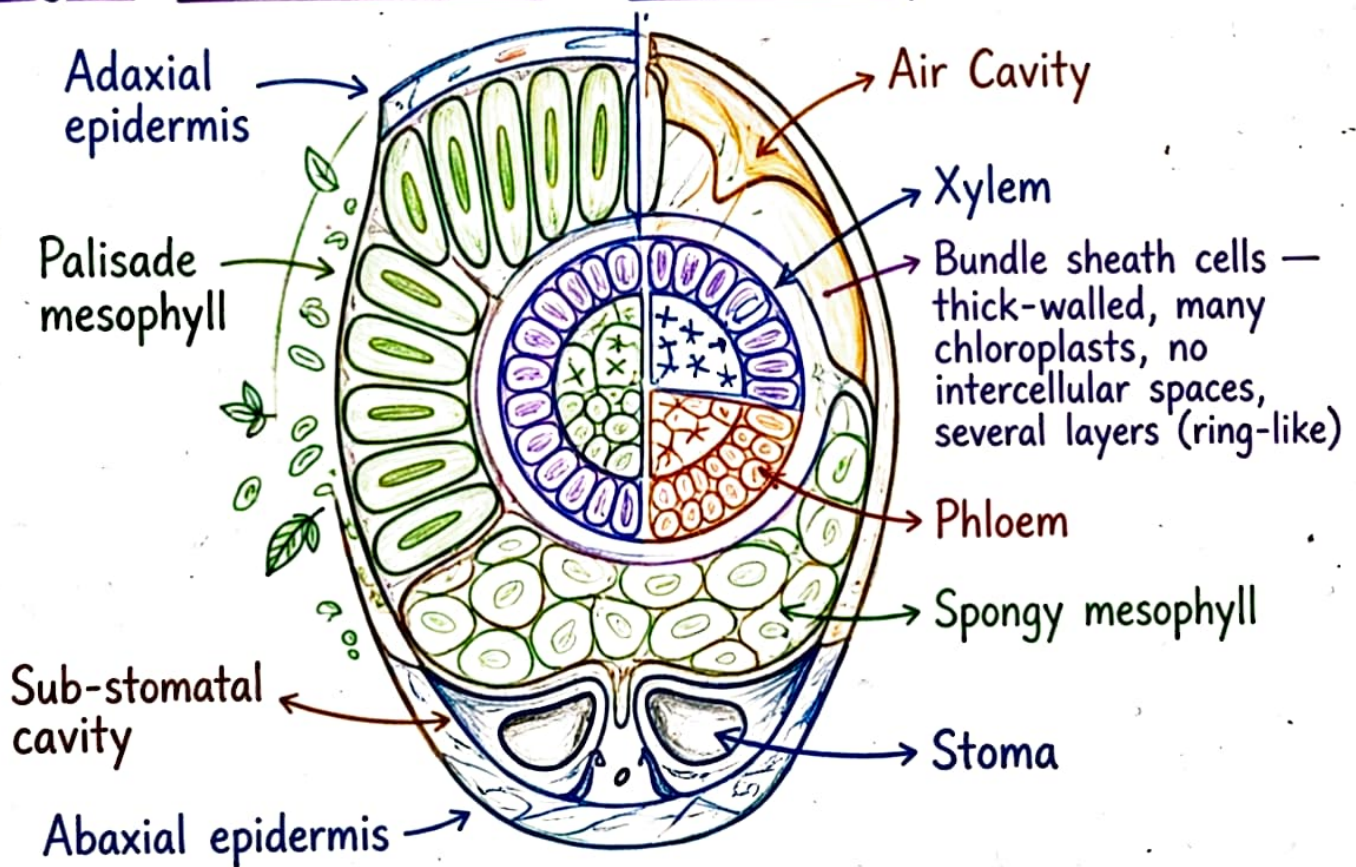
★ C4 Plants — Key Feature: Kranz Anatomy

- Mesophyll cells clustered around bundle-sheath cells in a ring-like arrangement 🌿
- Found in: maize, sorghum (typical C4 plants) — warm, high-light environments ☀️
- Bundle sheath cells: several layers thick around vascular bundles

- Large number of chloroplasts in bundle sheath cells
- Thick cell walls — impervious to gaseous exchange
- No intercellular spaces between bundle sheath cells

Function: Limits gas exchange → reduces photorespiration → efficient CO₂ fixation 🌿

Diagram: Leaf Cross-Section — Kranz Anatomy 🌿



* Ring of bundle sheath cells surrounds the vascular bundle = Kranz arrangement * .

Summary: Kranz anatomy = ring of bundle sheath cells around vascular bundle
→ isolates CO₂ fixation → C4 pathway

— efficient for hot/dry conditions ✓

★ What is C4 Photosynthesis?

- Adaptation to hot, dry environments → reduces photorespiration
- Found in plants like corn, sugarcane, sorghum — warm climate grasses

① Primary CO₂ Acceptor (Mesophyll Cells):

- Phosphoenolpyruvate (PEP) is the primary CO₂ acceptor
- PEP is a 3-carbon molecule (3C) $\triangle$ (3C) 3-carbon

② Mesophyll Cells:

- Located in the outer mesophyll cells of the leaf
- Contain enzyme: PEP carboxylase (PEPcase)
- Mesophyll cells LACK RuBisCO $\otimes$
- PEPcase fixes CO₂ to PEP → forms 4-carbon compound: Oxaloacetate (OAA) →
- OAA is converted into → Malic acid OR Aspartic acid ∇
 ∇ Aspartic acid (4C)

③ Transport to Bundle Sheath Cells:

- The 4-carbon compounds (malic acid/aspartic acid) are transported
→ move via plasmodesmata into bundle sheath cells →

④ Inside Bundle Sheath Cells:

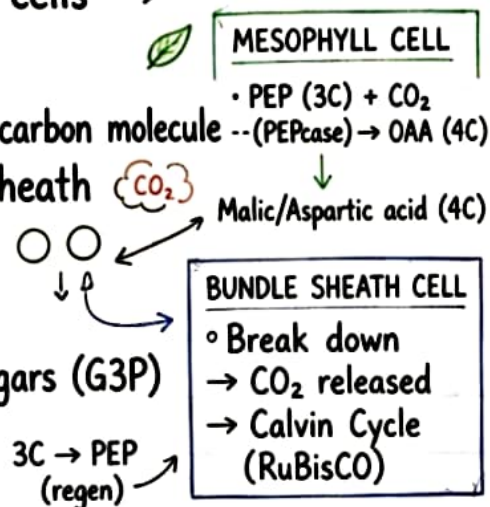
- 4-carbon acids are broken down → release CO₂ + 3-carbon molecule
- Released CO₂ is now concentrated inside bundle sheath

⑤ Calvin Cycle (C3 Pathway) begins:

- CO₂ enters the Calvin cycle (C3 pathway)
- CO₂ is fixed by RuBisCO to a 5C RuBP → makes sugars (G3P)
- Produces glucose & other carbohydrates

⑥ Regeneration:

- The 3-carbon molecule (from breakdown) is transported back to mesophyll cells
→ converted back into PEP using ATP
- PEP is regenerated to continue the cycle



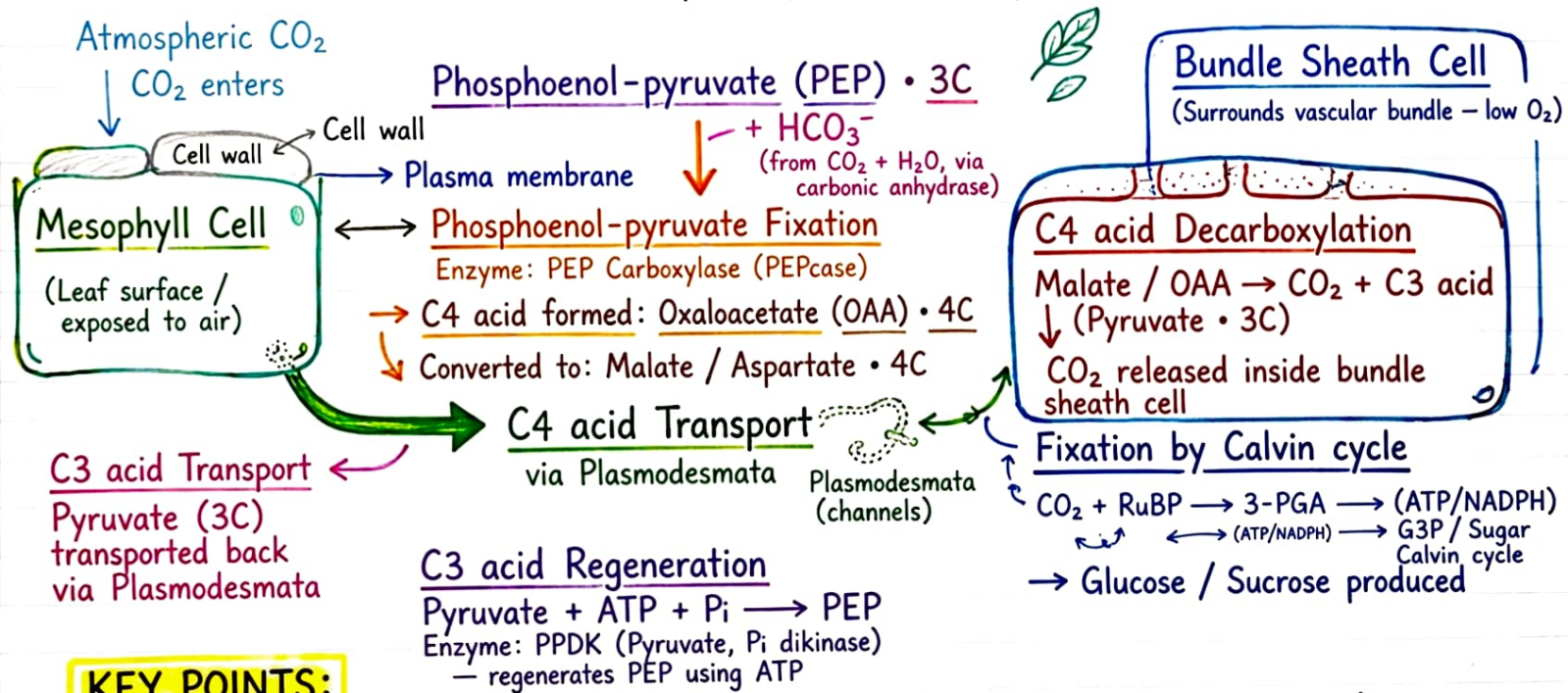
Summary: C4 Cycle

Mesophyll (PEPcase) → fixes CO₂ to 4C compounds → transported → transported
Bundle Sheath (RuBisCO) → Calvin cycle → 3C back to PEP

* Key Advantage: Concentrates CO₂ around RuBisCO → less photorespiration → efficient in hot/dry climates!

C4 Pathway — Hatch & Slack Pathway

Also called the Hatch-Slack Pathway • Adaptation to hot, dry environments • Reduces photorespiration



KEY POINTS:

- C4 pathway separates CO_2 fixation (Mesophyll) from Calvin cycle (Bundle Sheath)
- PEPcase has high affinity for $\text{CO}_2 \rightarrow$ efficient at low CO_2 / hot conditions
- Minimizes photorespiration by concentrating CO_2 around Rubisco
- Example plants: Maize, Sugarcane, Sorghum

★ Advantage: Works better in heat & dry climates vs C3 pathway ★