Photosynthesis, Part Two (dark rxns)

Making sugar from CO\(_2\): Calvin cycle (dark reaction)

- Occurs in the stroma, 13 reactions divided into three phases:
  1) Carbon Fixation =
  2) Carbon Reduction
  3) Ribulose bisphosphate (RuBP) Regeneration

**Carbon fixation:**

\([-\text{CO}_2\text{ joined to 5C sugar, }____]\); Catalyzed by \(____\); Resulting 6C splits into 2X 3C product, 3-phosphoglycerate

**Reduction:** [ -3-phosphoglycerate is \(____\) to form a sugar, glyceraldehyde 3-phosphate \(____\) ] uses ATP and NADPH (from \(____\)) to convert CO\(_2\) to \(____\)

**Regeneration:**

\([-5X 3C\text{ sugars become }3X 5C\text{ }____\)]

The C\(_3\) Pathway - Fixation of Carbon dioxide: CO\(_2\) is added to RuBP, the resulting 6 carbon compound is immediately split into 2 molecules of \(____\). This reaction is catalyzed by ribulose bisphosphate carboxylase (\(____\)).

**Reduction:**

\(\triangleright\) input of \(____\) from ATP and \(____\) from NADPH used to convert PGA molecules to glyceraldehyde-3-phosphate \(____\)

Each G3P is \(\frac{1}{2}\) a sugar molecule, the reaction of 2 G3P molecules leads to the formation of glucose or fructose.

What happens to the G3P that ends up as a product of the Calvin cycle?

- Approximately 1/3 is made into \(____\) which is stored in the chloroplast and
serves as a source of glucose
• 2/3 is converted into sucrose which is transported out of the leaf to other organs in the plant and will be hydrolyzed into ___________________________
• The carbon in glucose is incorporated into other macromolecules

Phase 3: ____________ of RuBP
• The remaining G3P molecules undergo a series of reactions to produce ________ (5 carbon compound with which the cycle started)
• Requires an input of ATP (from ____________)

Calvin cycle - summary
➢ takes 18 ATP, 12 NADPH to make 1 sugar, and regenerate 1 RuBP
• Three Phases:
  – Carbon fixation: CO2 molecule attached to 5 carbon sugar (RuBP) ribulose bisphosphate, catalyzed by Rubisco, this 6 carbon molecule splits immediately to form 2 molecules of 3-phosphoglycerate
  – Reduction: 3-phosphoglycerate gets a phosphate group from ATP, this is then reduced by the transfer of electrons from NADPH… making G3P
  – Regeneration: 10 molecules of G3P are rearranged into 3 molecules of RuBP, which takes 6 more molecules of ATP
➢ The light reaction and the dark reaction are __________________ upon one another
➢ ____________ [that provides CO2] is also ____________ to photosynthesis [which provides __________________]

III. Photorespiration
• Stomata = adjustable pores
  • Open (CO2 in – H2O out),
  • Closed (H2O in – O2 stays in, CO2 stays out) Occurs under certain conditions

Some of the intermediates involved in the Calvin cycle are degraded to CO2 and H2O when Oxygen is present

Both Oxygen and CO2 bind to rubisco
Rubisco active site has a __________________ than CO2, especially at high temperature
Instead of fixing carbon dioxide into a complex sugar, the plant has made extra work for itself in creating phosphoglycolate, ____________________________.
Photorespiration – ______________

• No CO₂ available, RuBP fixed using _____
• RuBP + O₂ → glycate
• Glycolate converted to CO₂ in peroxisome

But, CO₂ is released instead of being fixed

_____________ thus, in hot, dry weather,______ plants consume ATP and destroy RuBP → ______________

IV. Bypassing photorespiration – C4 plant pathway

Corn & crabgrass, Bermuda grass, sugarcane

• Use a ___________carbon-fixation pathway
  – Initial CO₂ fixation step can function even at low levels of CO₂ and high temp.; high [CO₂] in ________ cells allows rubisco to bind CO₂ instead of _______ → Calvin cycle

They have ______________ for fixation in different chloroplasts in 2 different locations

• (1) Mesophyll Cells of C4 plants = _______________________
  – Doesn’t have ______________ for Oxygen, only CO₂
  – Produces oxaloacetate (C4)
  – 4 C products exported to bundle sheath cells (via plasmodesmata), where they release CO₂

2) Bundle Sheath cells have rubisco

• Oxaloacetate is decarboxylated, releasing CO₂ at a high concentration
• CO₂ then fixed normally by Rubisco into the 3PG… ______________

C4 plants ______________ within the bundle-sheath. This reduces photorespiration and improves the water-use-efficiency.

V. CAM plants fix CO₂ at night (processes separated by time rather than in space as in the case for C4)

• CAM (crassulacean acid metabolism) plants ______________ (all others only during day) to minimize ______________
• ______________Use PEP carboxylase to fix CO₂ into malic acid
• During day, CO₂ removed from malic acid by a decarboxylation reaction, making CO₂ available for Calvin cycle