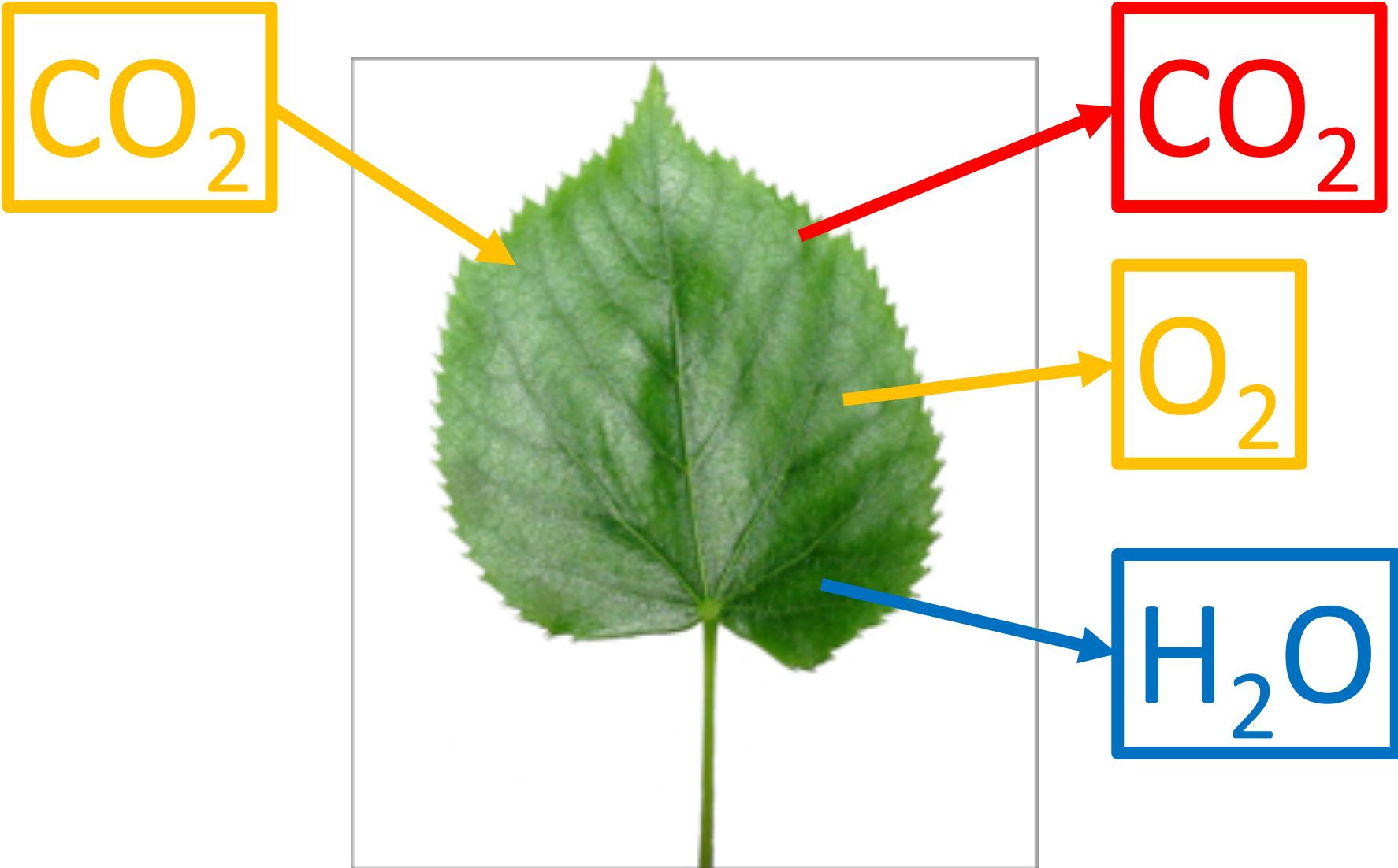


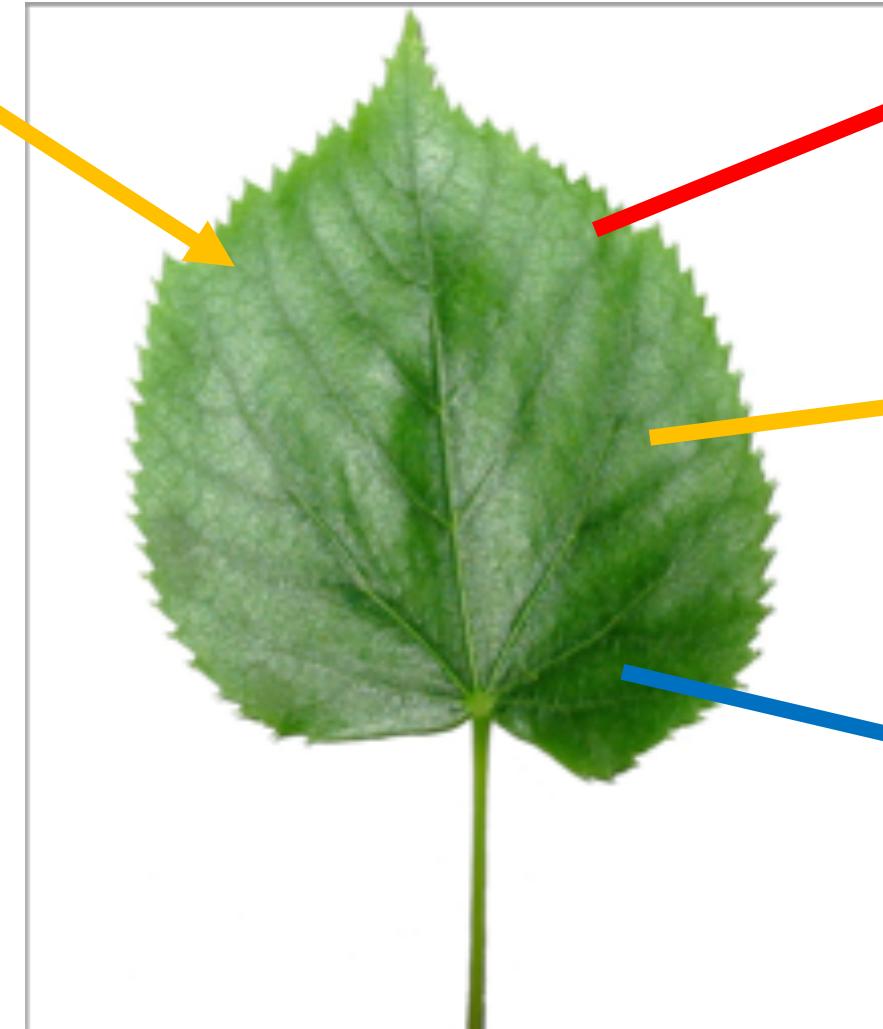
Plant gas exchange

Jan. 29, 2019

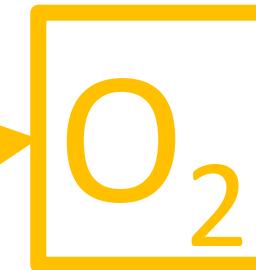
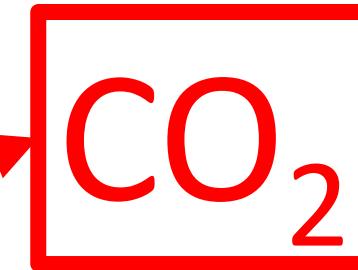




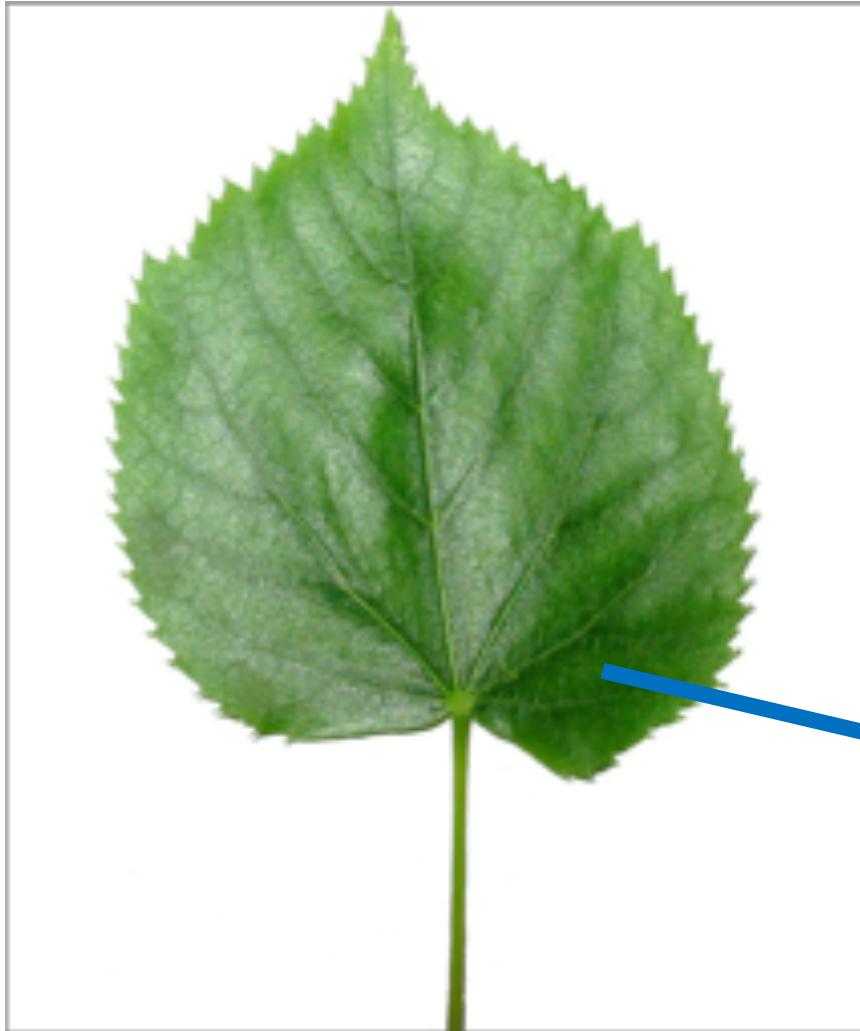
Photosynthesis



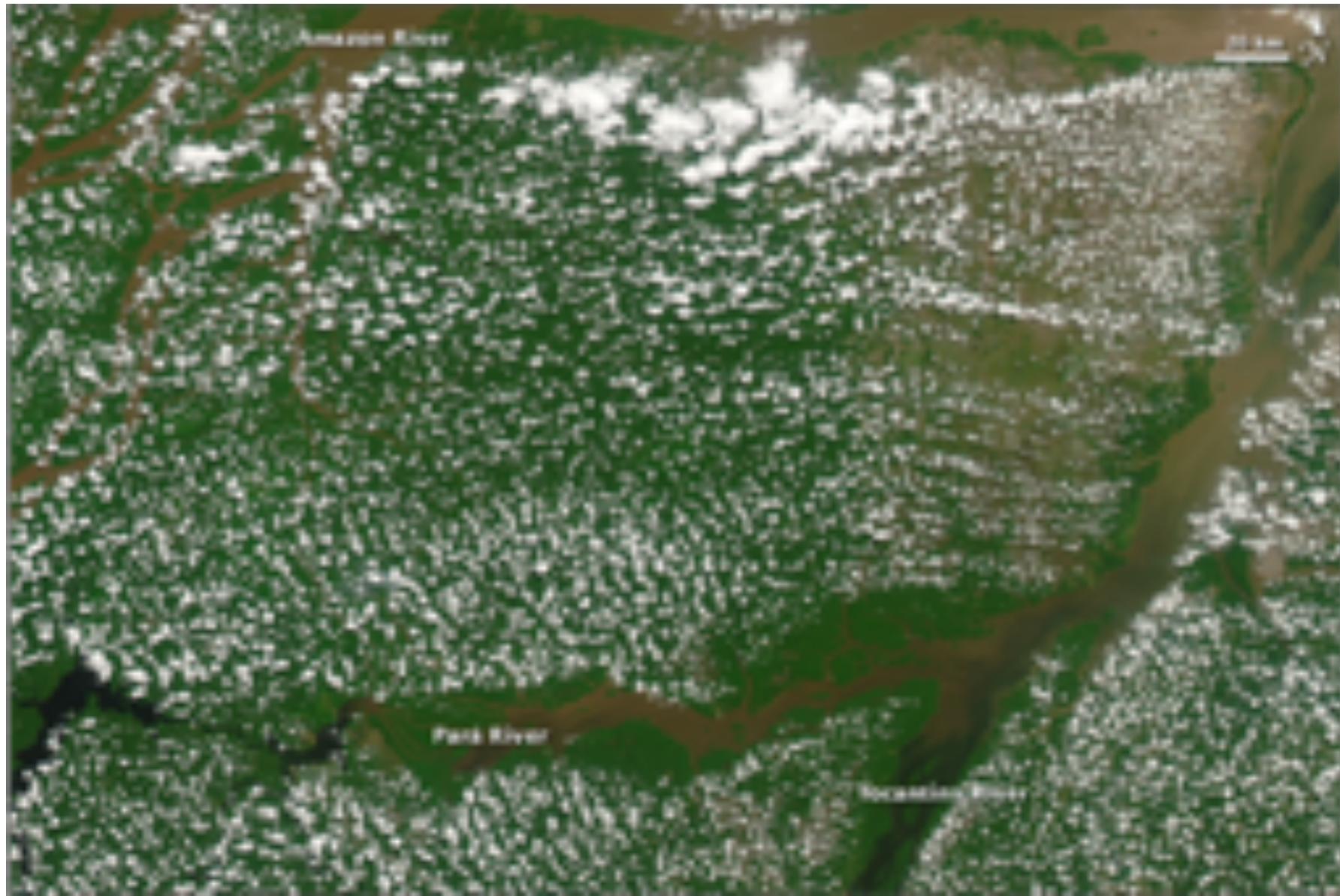
Respiration



Transpiration

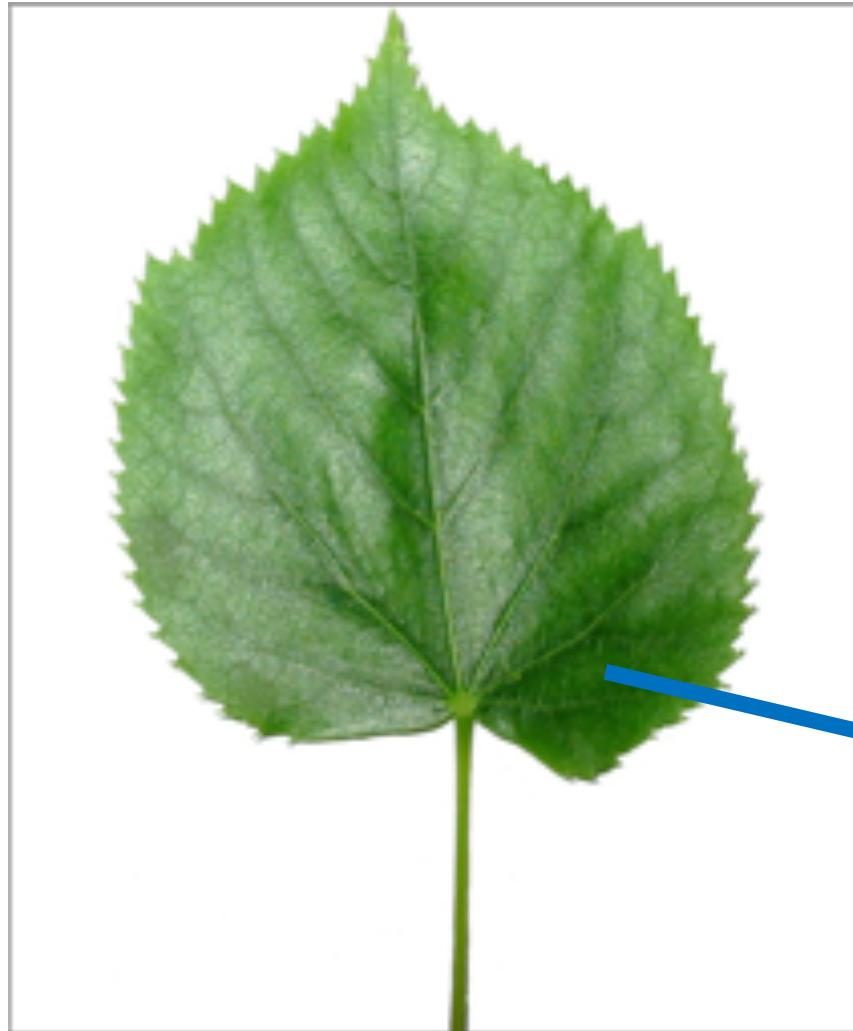


Transpiration



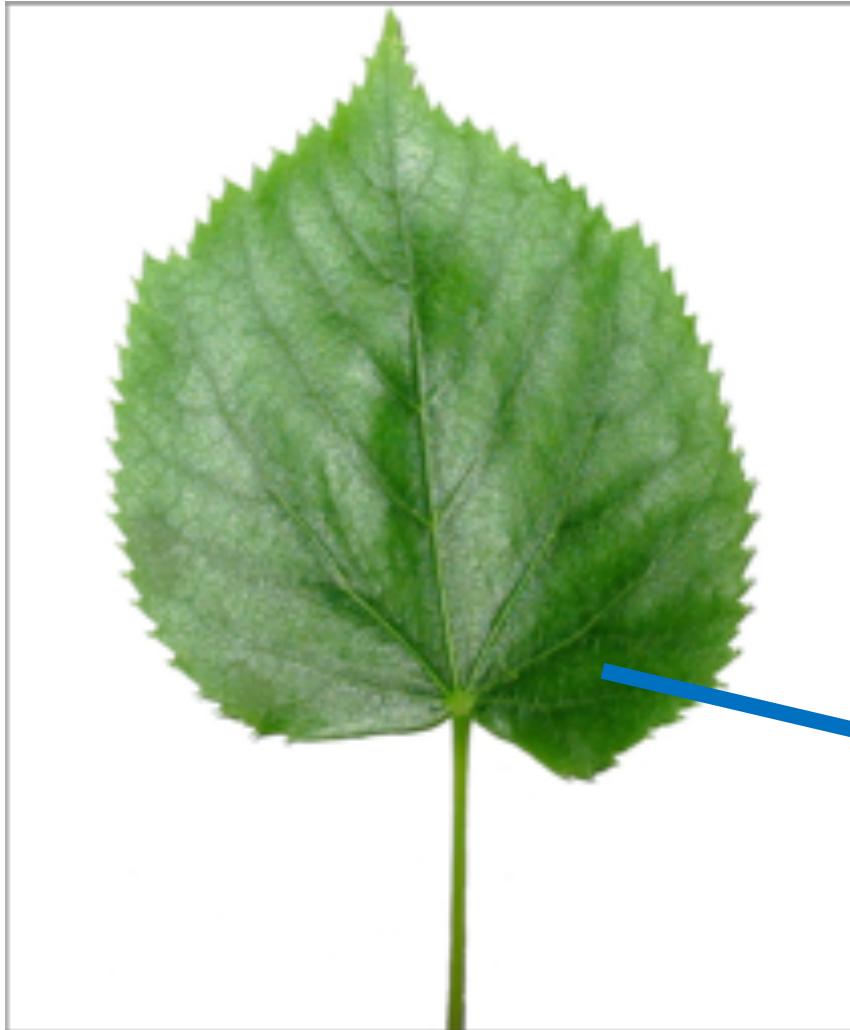
NASA

Why do plants transpire?



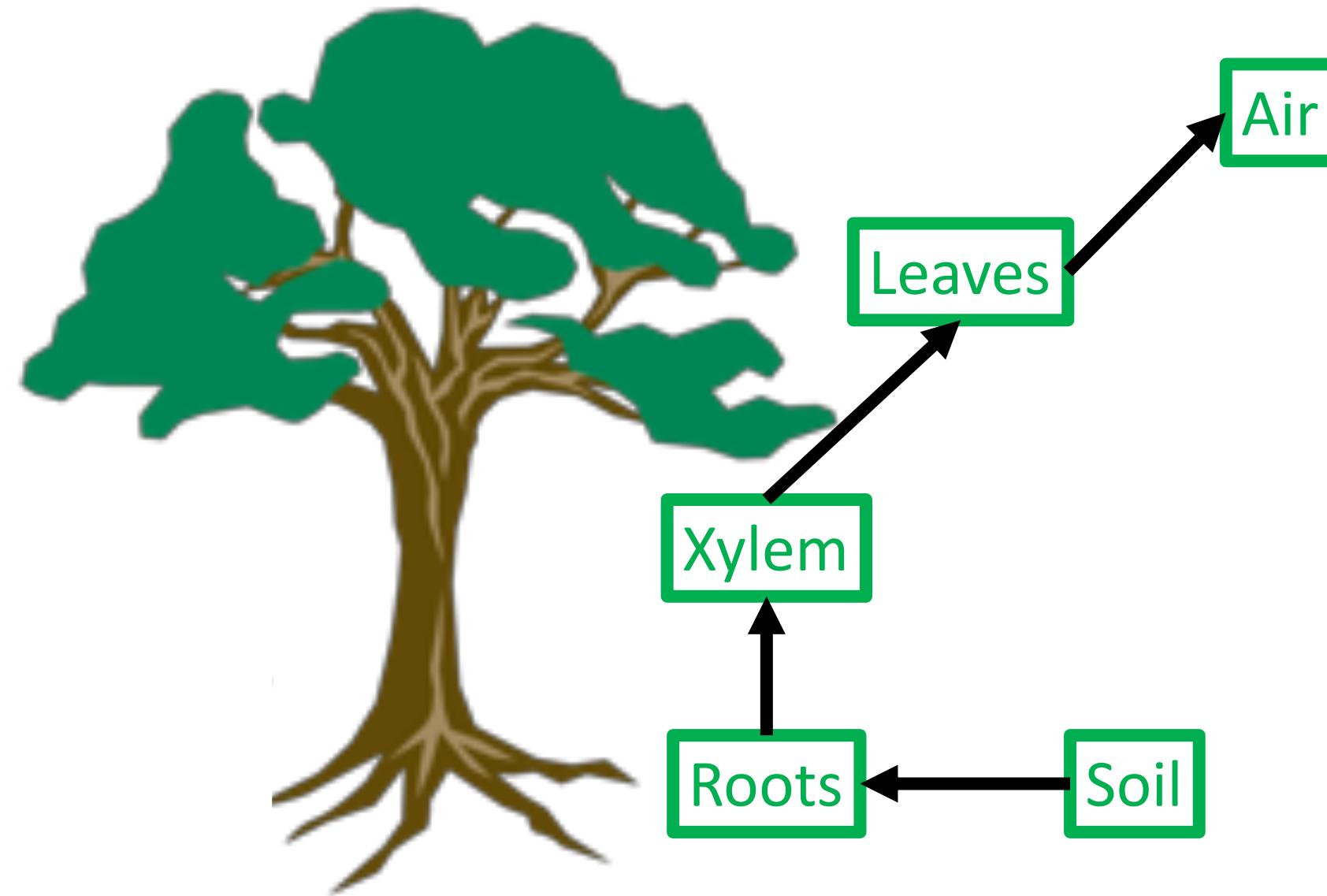
Transpiration

How do plants transpire?



Transpiration

Water potential gradients!

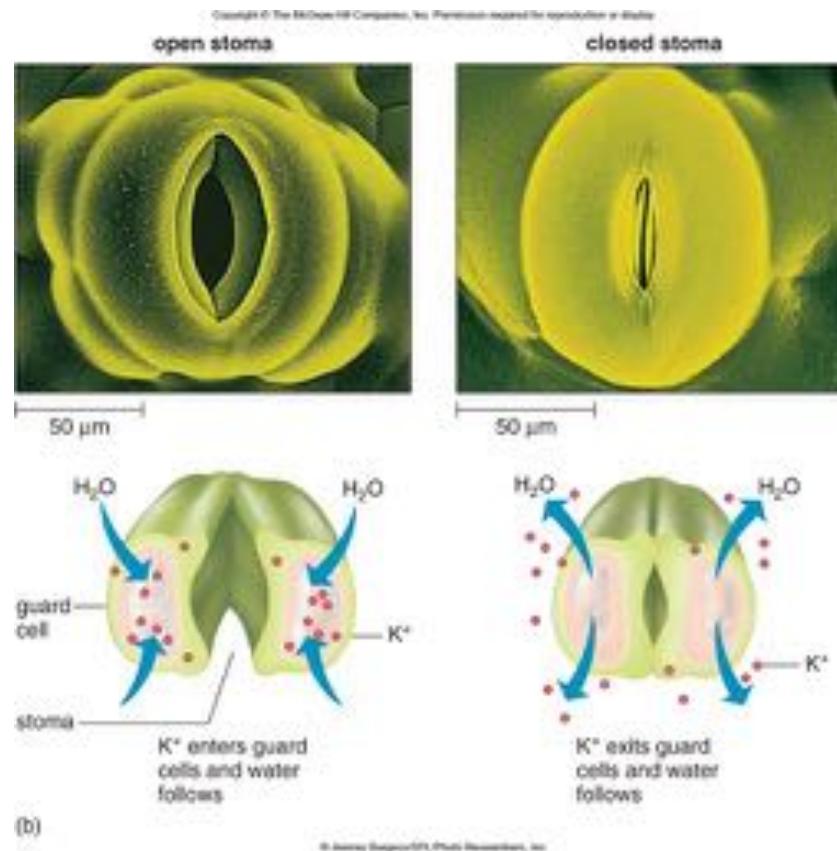


Lowest Ψ ("Dry")

Highest Ψ ("Wet")

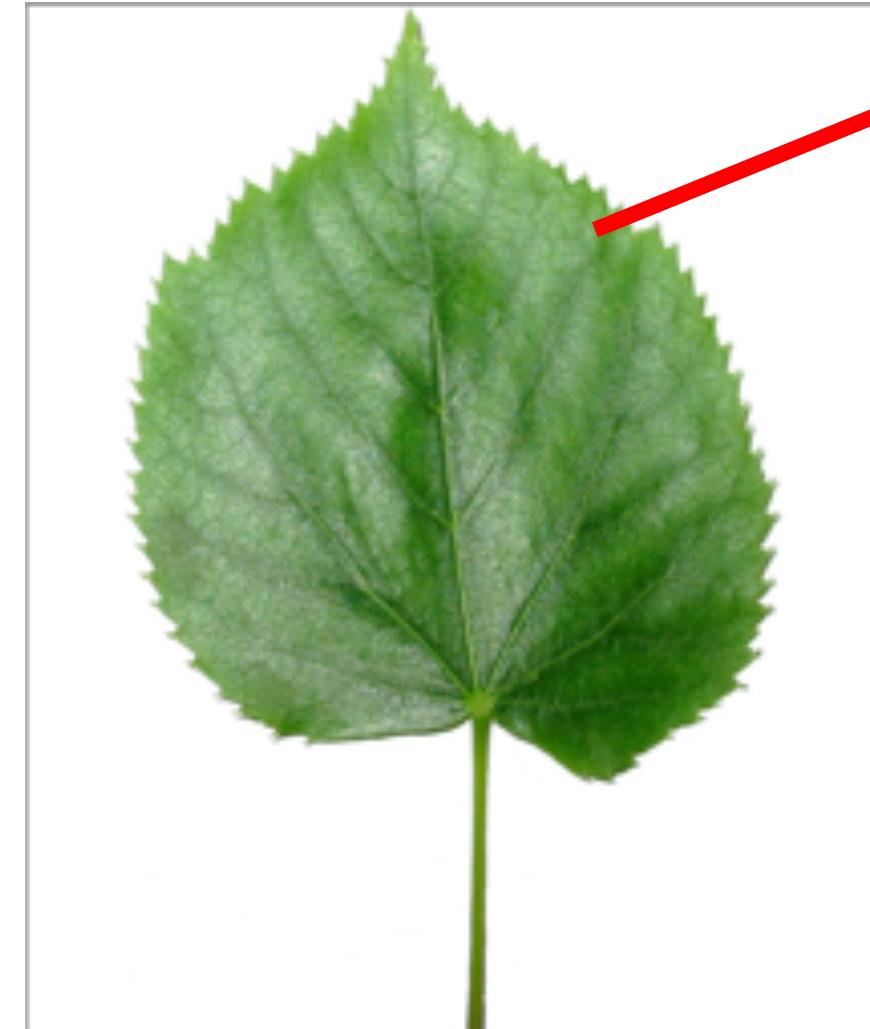
Transpiration regulation: Guard cells

- Create open or closed stomata by changing turgor pressure



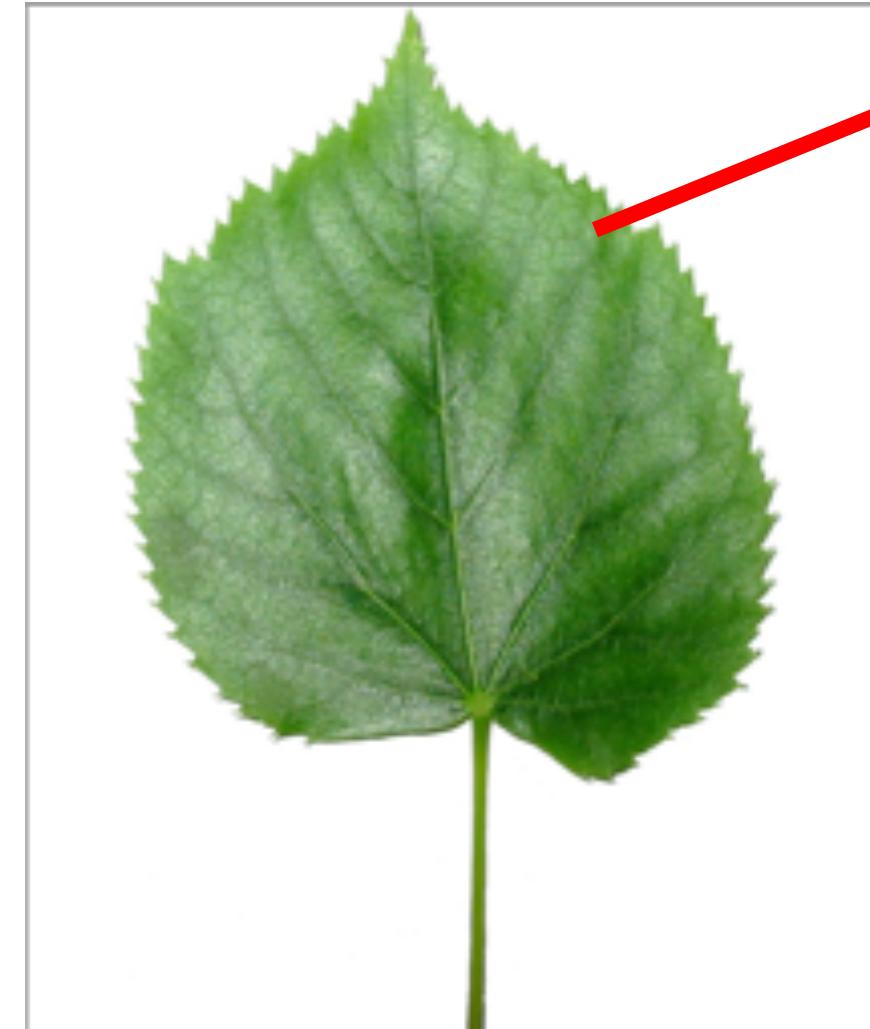
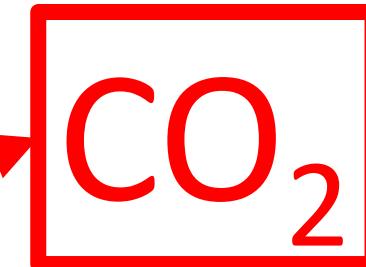
Respiration

CO_2



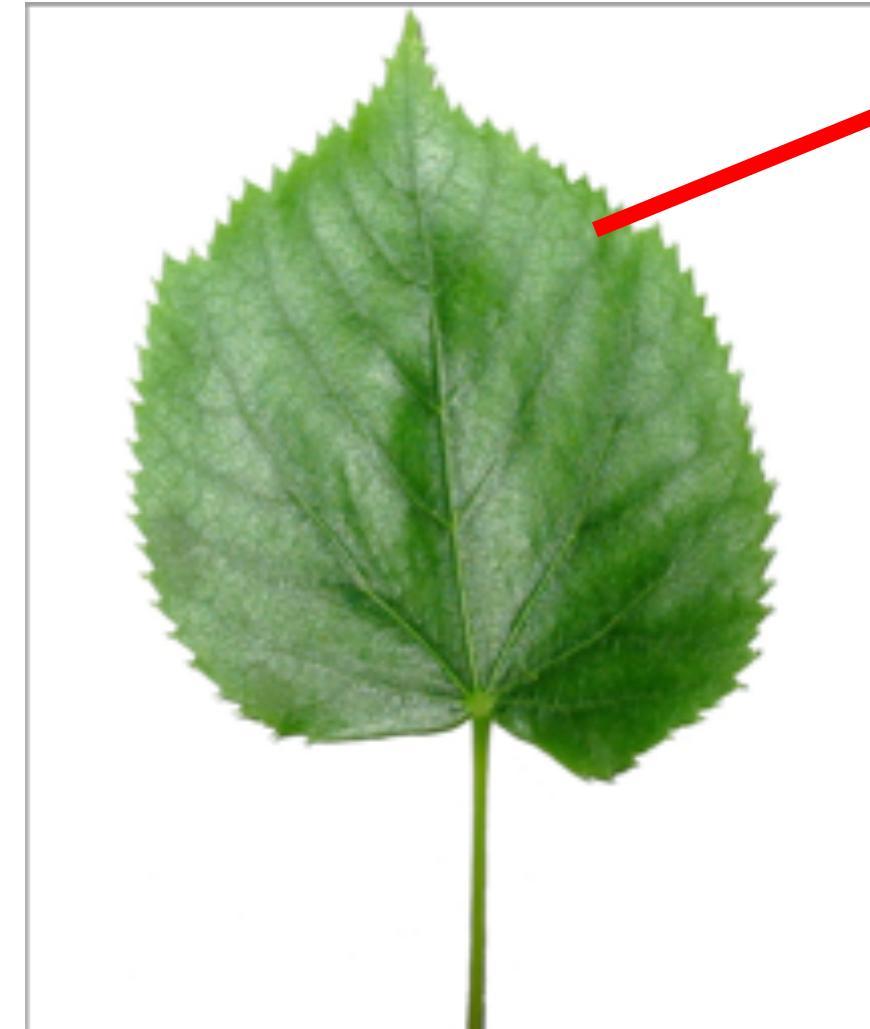
Why do plants respire?

Respiration



How do plants respire?

Respiration



Respiration - the recipe



Respiration - the recipe



Glucose
(primary substrate)



Respiration - the recipe

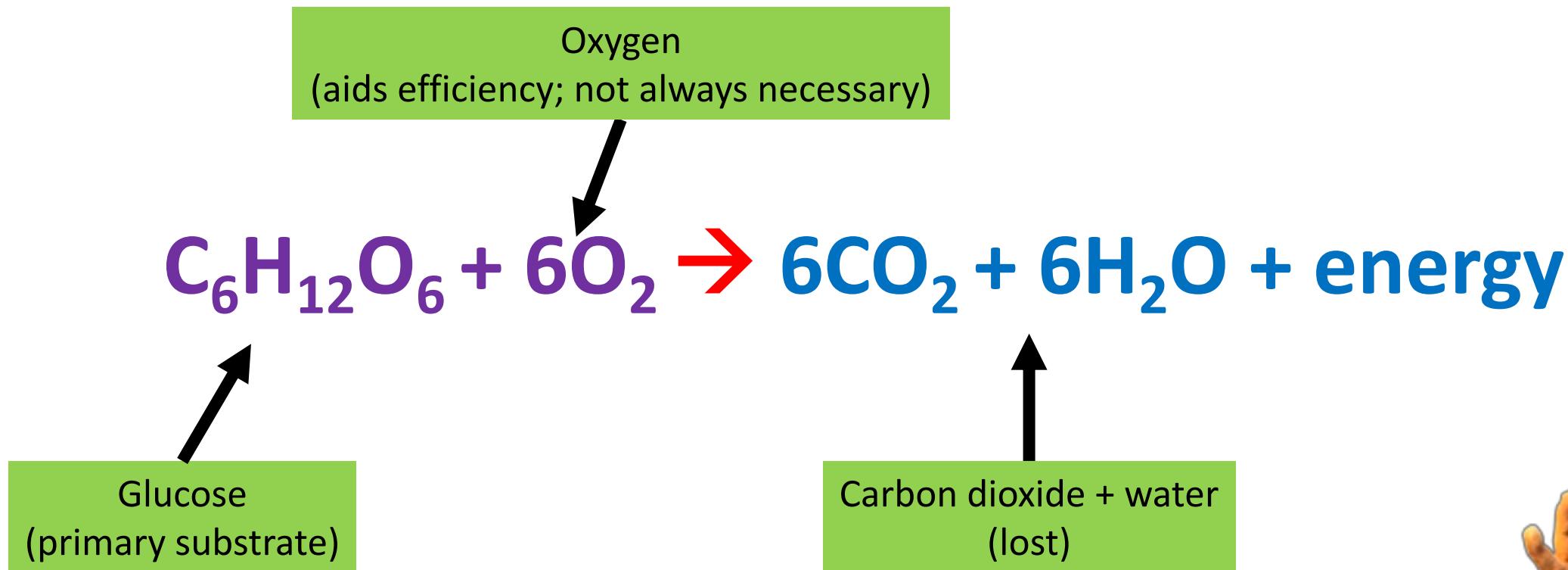
Oxygen
(aids efficiency; not always necessary)



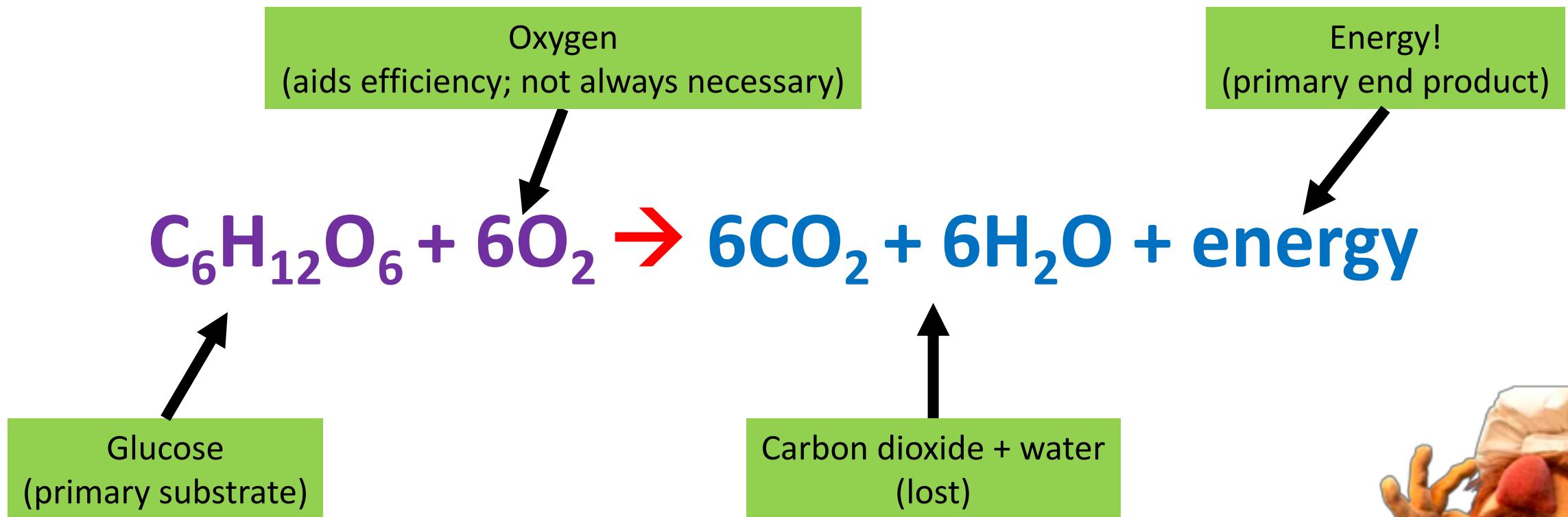
Glucose
(primary substrate)



Respiration - the recipe



Respiration - the recipe



Respiration – Main processes

1. Glycolysis

2. Citric Acid Cycle

3. Electron Transport System

Respiration – Main processes

1. Glycolysis

2. Citric Acid Cycle

3. Electron Transport System

Respiration – Main processes

1. Glycolysis

- function: make some ATP & substrate for making [x]H

2. Citric Acid Cycle

3. Electron Transport System

Respiration - Glycolysis

- Step 1: “Investment”

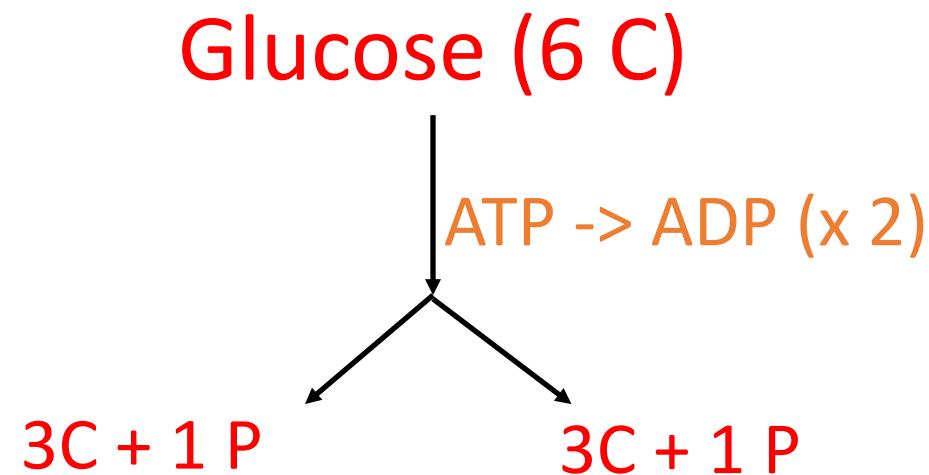
Respiration - Glycolysis

- Step 1: “Investment”
 - Use 2 ATP to create 2 phosphorylated 3-C sugars from glucose

Glucose (6 C)

Respiration - Glycolysis

- Step 1: “Investment”
 - Use 2 ATP to create 2 phosphorylated 3-C sugars from glucose



Respiration - Glycolysis

- Step 2: “Reward”

Respiration - Glycolysis

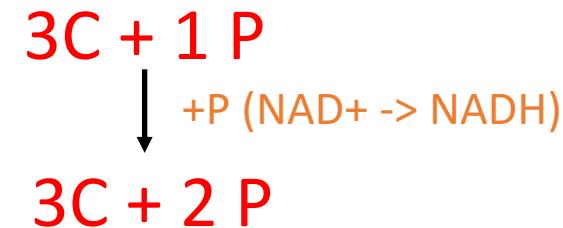
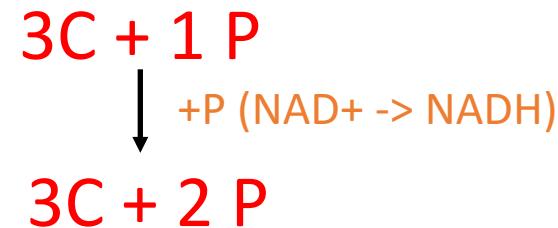
- Step 2: “Reward”
 - Use 2 phosphorylated 3-C sugars to create 4 ATP and Pyruvic acid

3C + 1 P

3C + 1 P

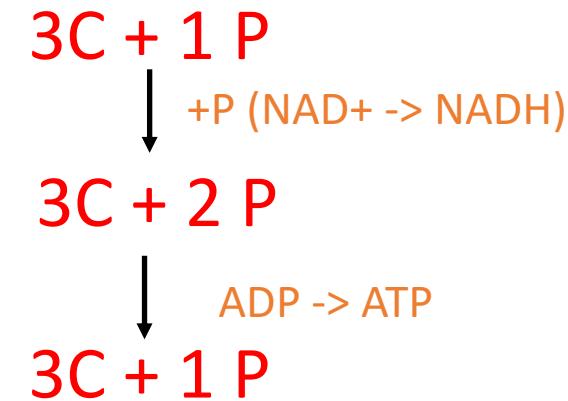
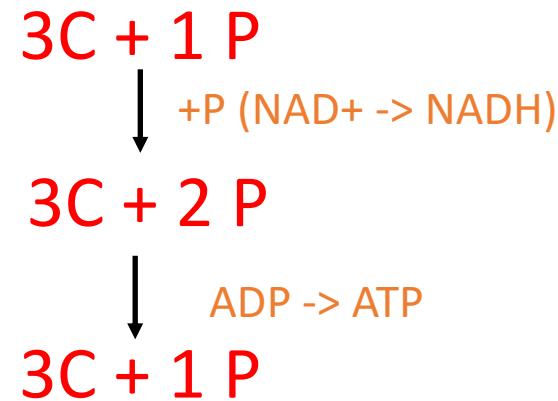
Respiration - Glycolysis

- Step 2: “Reward”
 - Use 2 phosphorylated 3-C sugars to create 4 ATP and Pyruvic acid



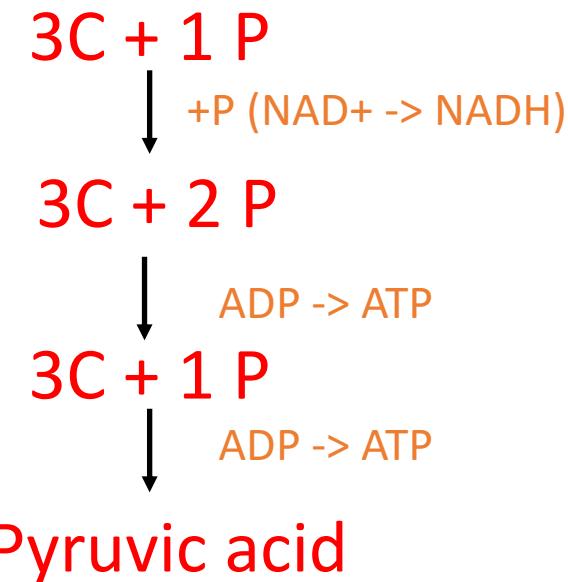
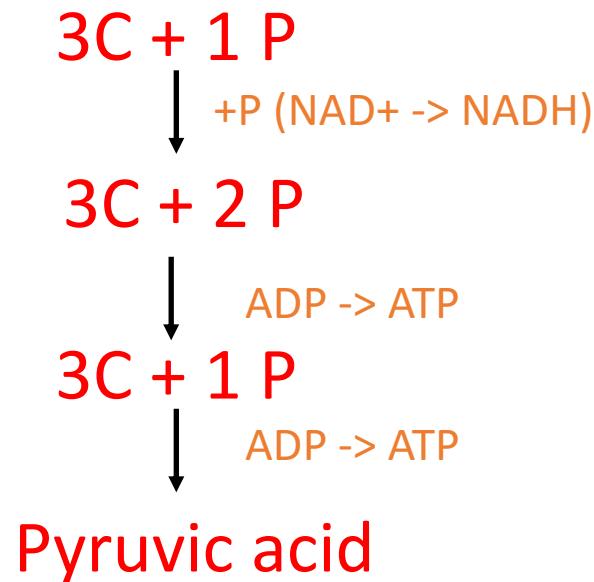
Respiration - Glycolysis

- Step 2: “Reward”
 - Use 2 phosphorylated 3-C sugars to create 4 ATP and Pyruvic acid



Respiration - Glycolysis

- Step 2: “Reward”
 - Use 2 phosphorylated 3-C sugars to create 4 ATP and Pyruvic acid



Respiration - Glycolysis

Ingredients

- Glucose
- ATP (2)

Outcomes

- Pyruvic acid
- ATP (4)
- NADH (2)

Respiration – Main processes

1.Glycolysis

2.Citric Acid Cycle

3.Electron Transport System

Respiration – Main processes

1. Glycolysis

2. Citric Acid Cycle

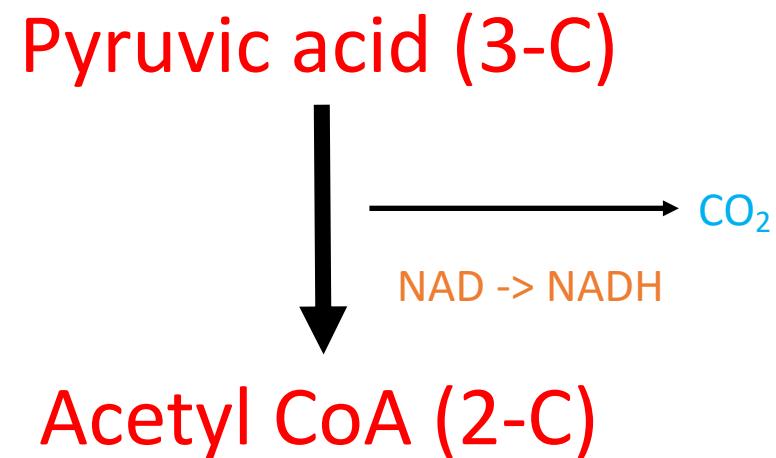
- function: make [x]H

3. Electron Transport System

Respiration – Citric Acid Cycle

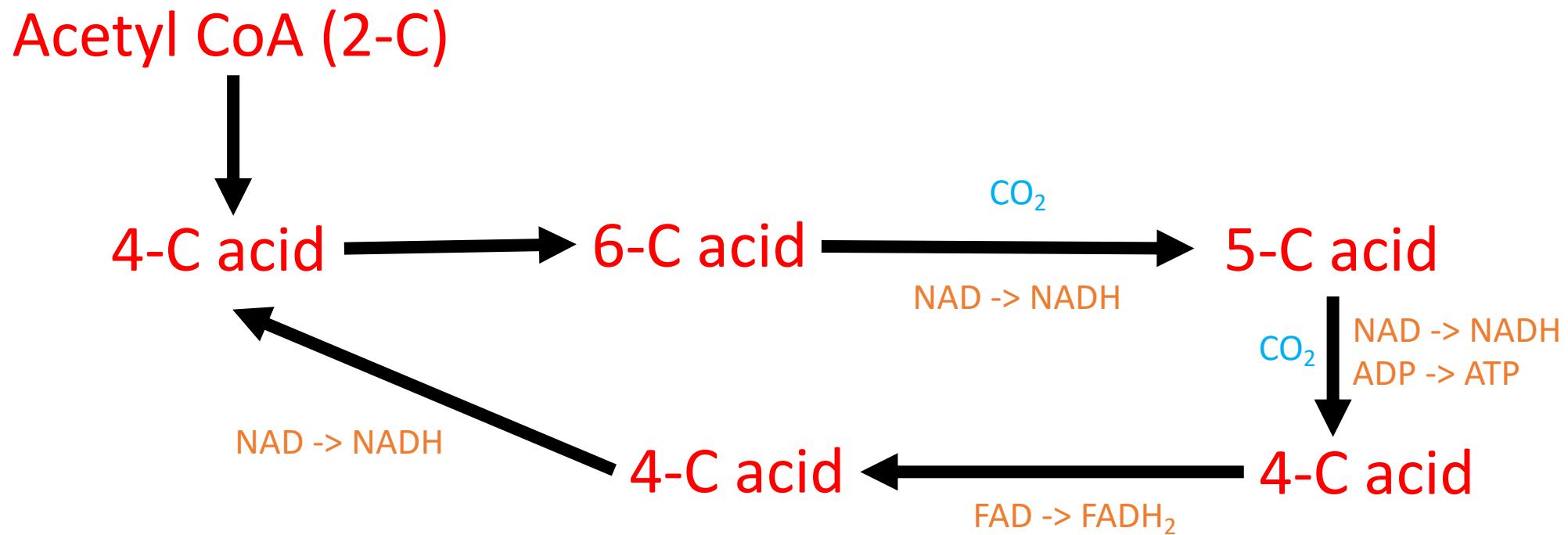
Respiration – Citric Acid Cycle

- Step 1: Production of Acetyl CoA from pyruvic acid (“Transformation”)
 - Produces CO₂ and NADH



Respiration – Citric Acid Cycle

- Step 2: Production of “energy packets” (NADH, FADH₂)



Respiration – Citric Acid Cycle

Ingredients

- Pyruvic acid

Outcomes

- NADH
- FADH_2
- ATP
- CO_2

Respiration – Main processes

1. Glycolysis

2. Citric Acid Cycle

3. Electron Transport System

Respiration – Main processes

1. Glycolysis

2. Citric Acid Cycle

3. Electron Transport System

- function: make ATP

“Cashing out” - Electron transport system



Respiration – Electron transport system

- Take reduced “energy packets” (**NADH**, **FADH₂**) and convert **ADP** to **ATP**
 - “Cashing in” electrons for ATP
 - Driven by a series of protein complexes along the mitochondrial membrane



Respiration - accounting

Respiration - accounting

1 Glucose => 36 ATP (net)

Respiration - accounting

1 Glucose => 36 ATP (net)

1760 kcal / 1 Glucose

Respiration - accounting

1 Glucose => 36 ATP (net)

1760 kcal / 1 Glucose

19 kcal / 1 ATP

Respiration - accounting

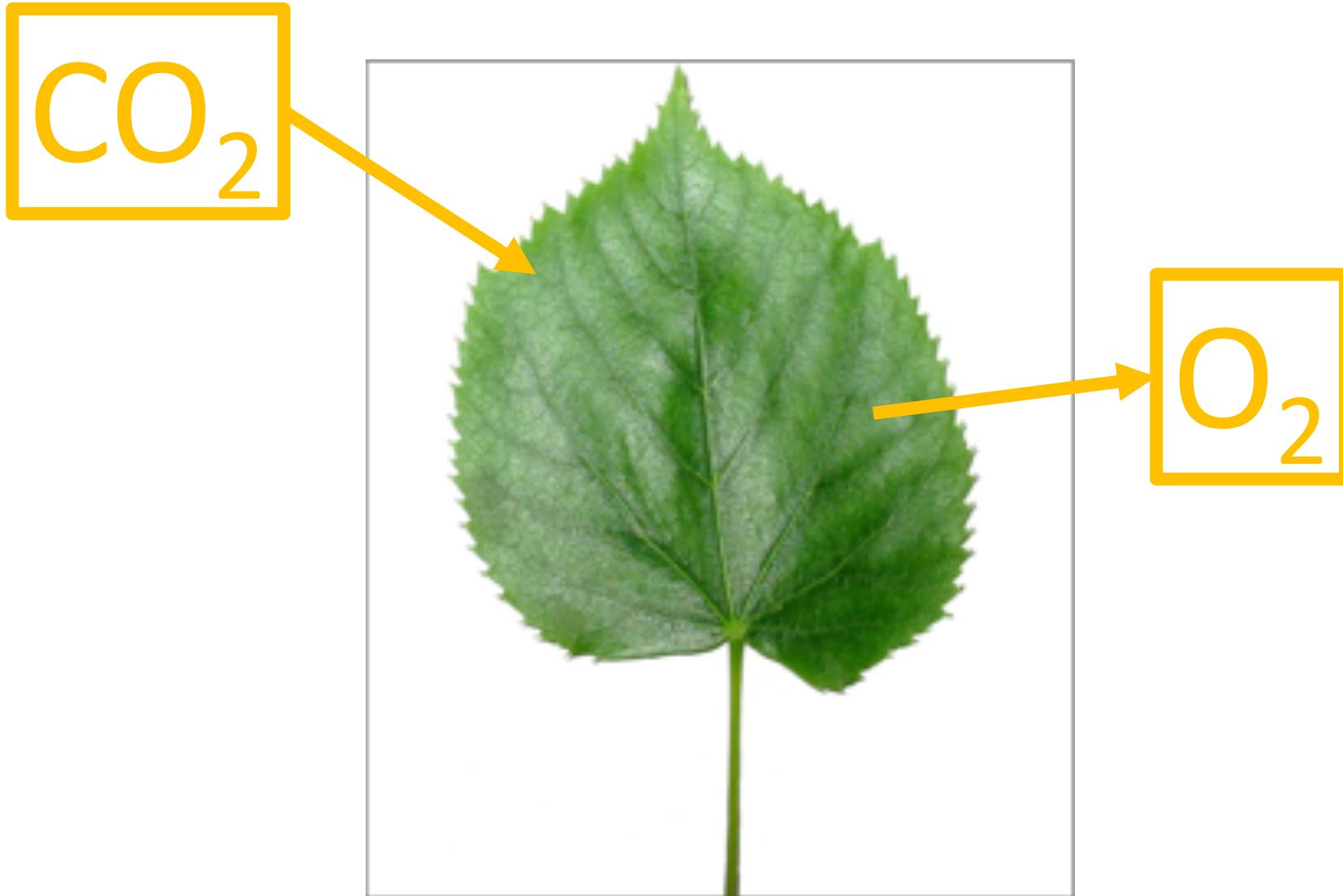
1 Glucose => 36 ATP (net)

1760 kcal / 1 Glucose

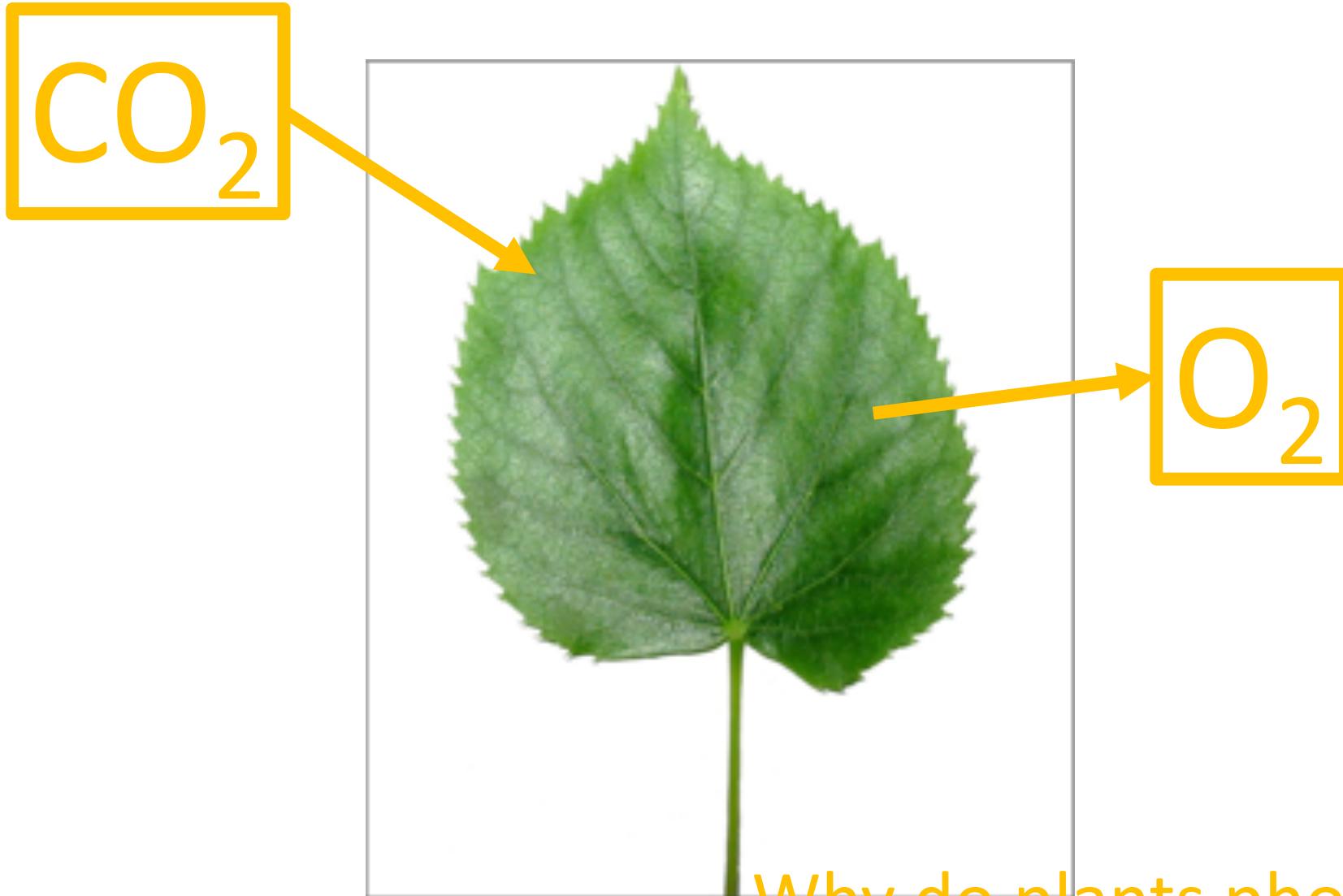
19 kcal / 1 ATP

$(19 * 36) / 1760 = 39\% \text{ total efficiency}$

Photosynthesis

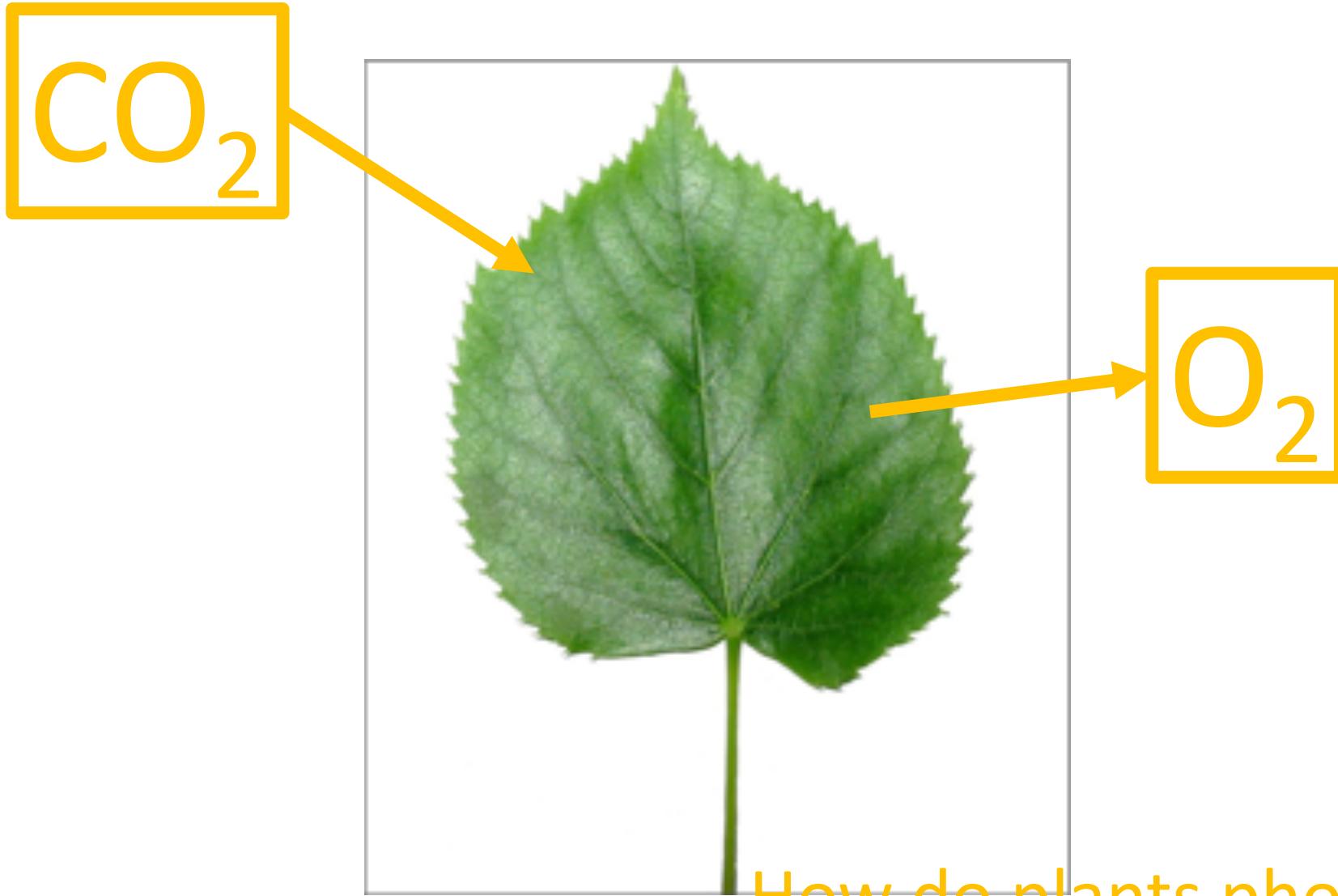


Photosynthesis



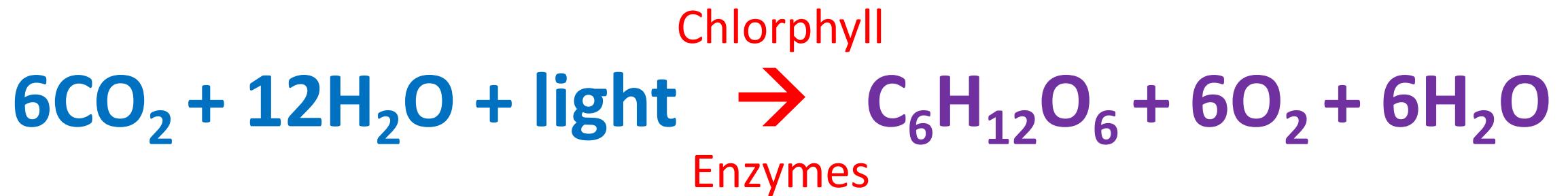
Why do plants photosynthesize?

Photosynthesis

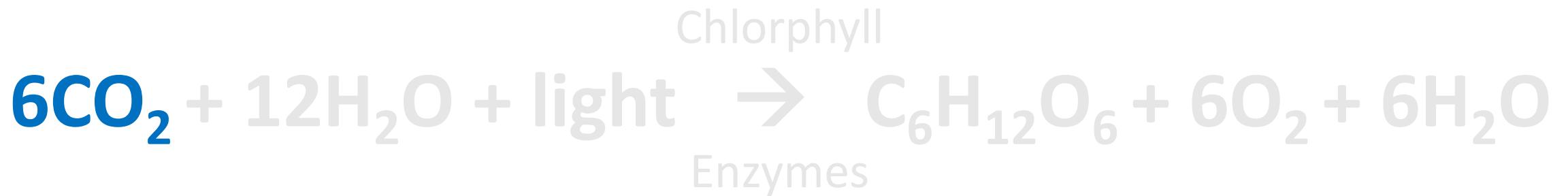


How do plants photosynthesize?

Photosynthesis – the recipe



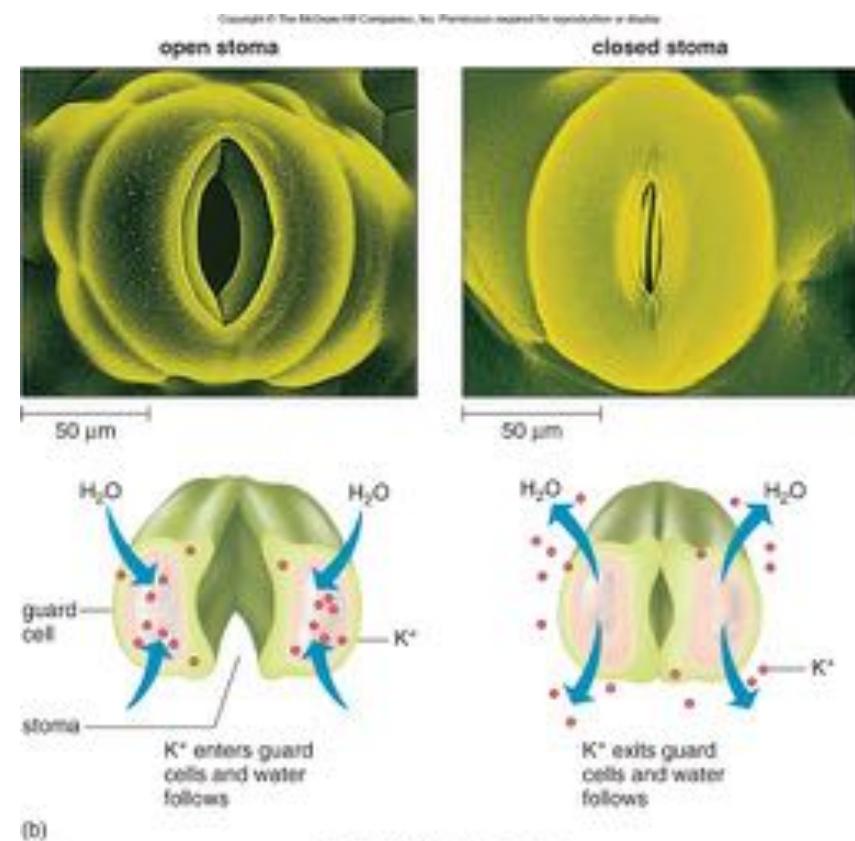
Photosynthesis – the recipe



Photosynthesis – CO₂

Photosynthesis – CO₂

- CO₂ diffuses into plant leaves through **stomata**
- Ultimately reaches the chloroplasts
- Function: provides C

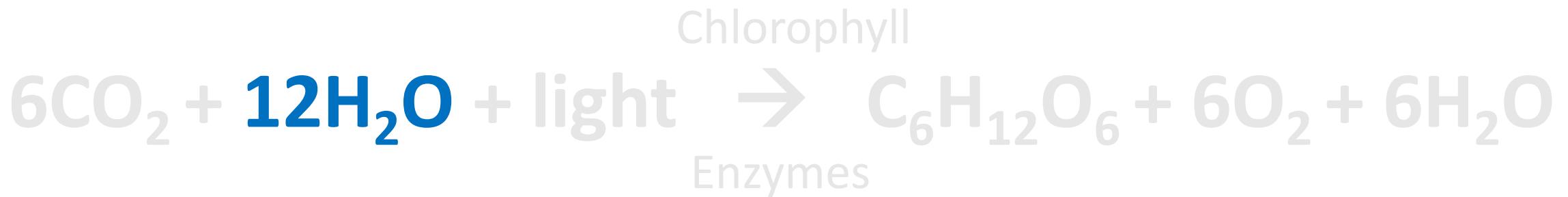


Photosynthesis – CO₂

- 1 acre corn plot takes up > 5000 lbs of CO₂ a year

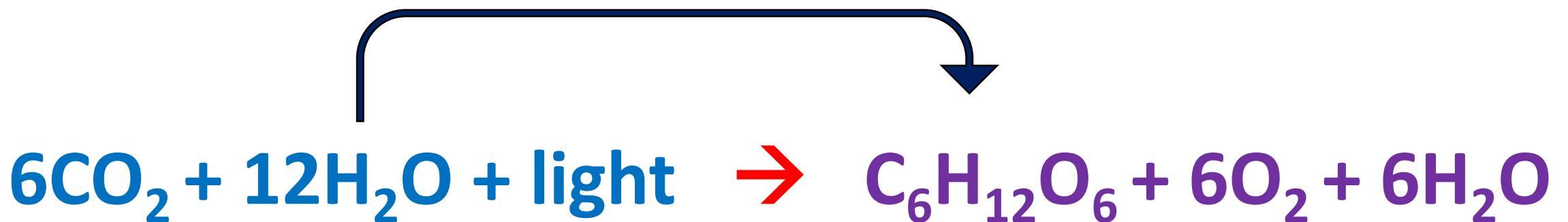


Photosynthesis – the recipe

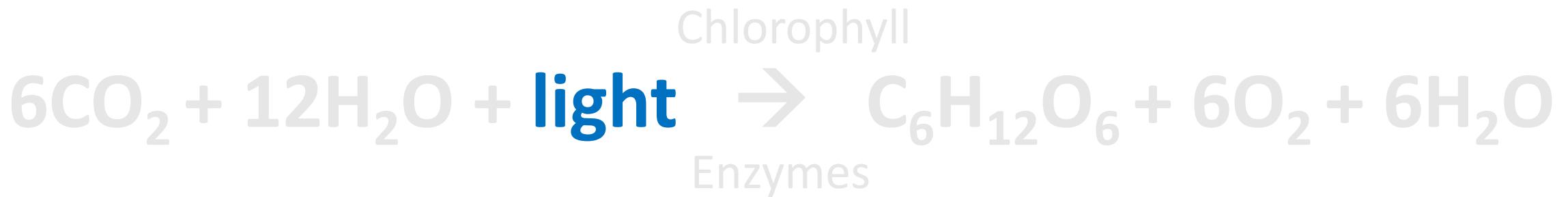


Photosynthesis - Water

- Solution for CO₂ to dissolve
- Source of the electrons involved

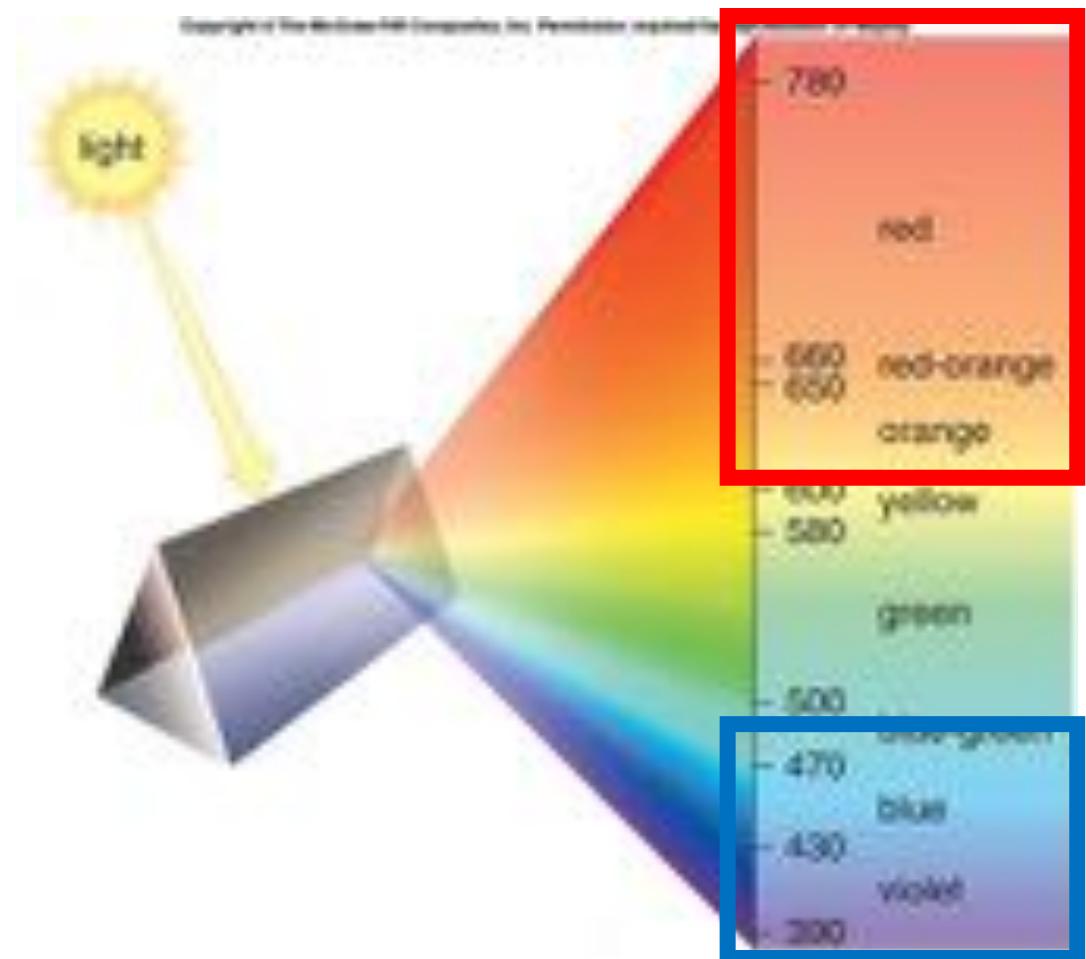


Photosynthesis – the recipe



Photosynthesis - Light

- Provides the energy for photosynthesis
- Absorbed in the red and blue portion of the spectrum



Photosynthesis – the recipe

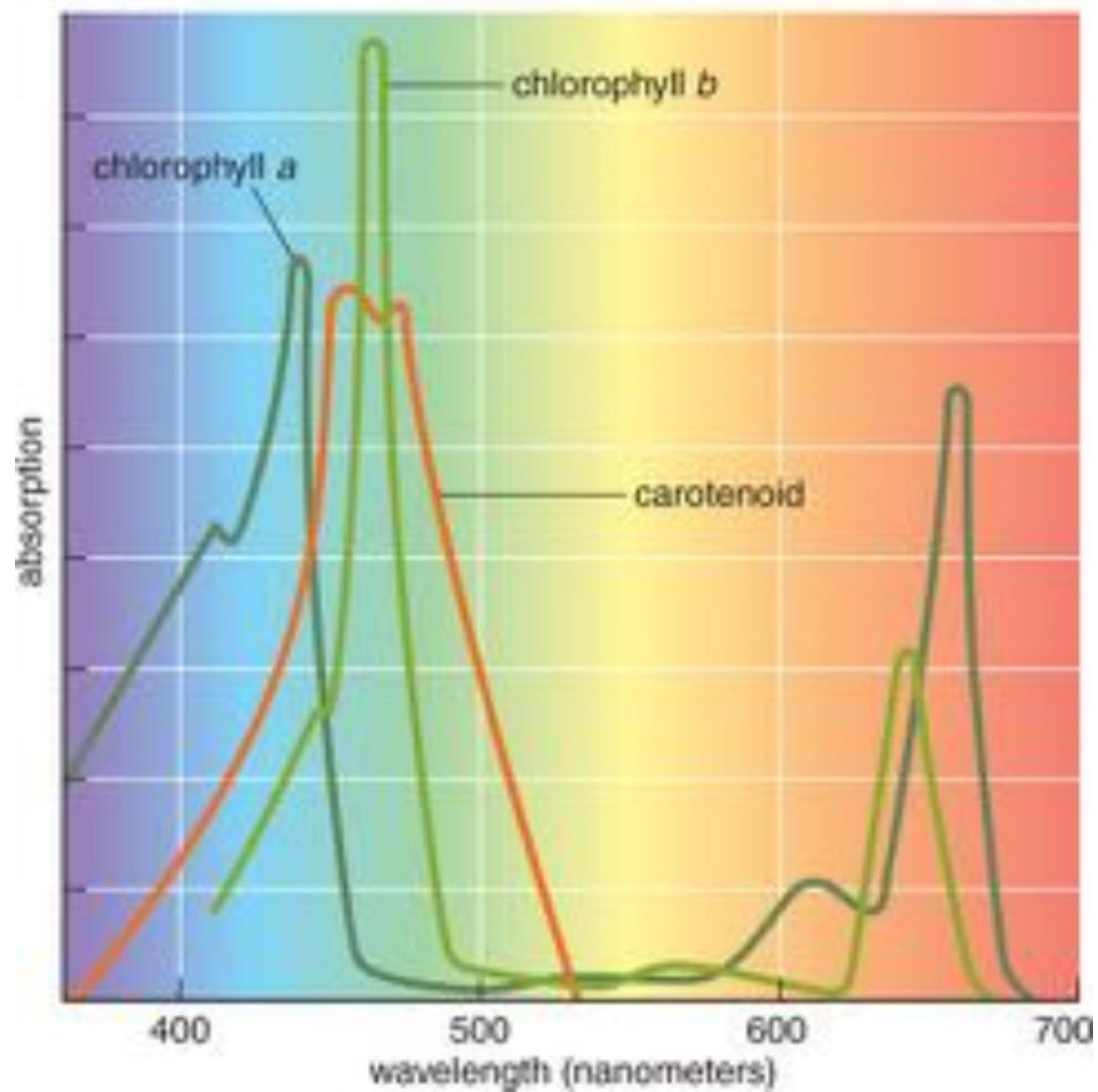


Chlorophyll



Photosynthesis - Chlorophyll

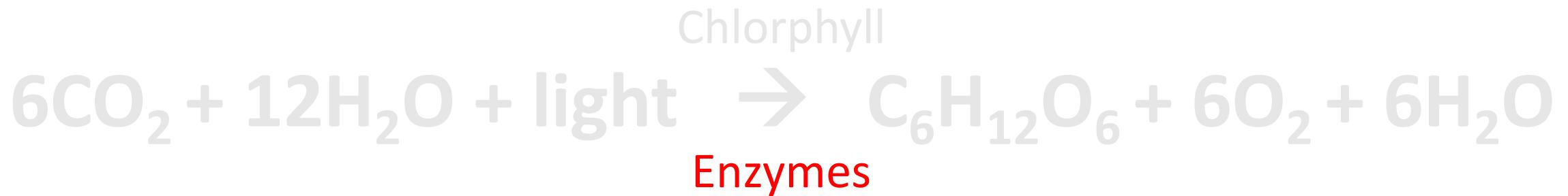
- Molecules that absorb light
- Come in different flavors
 - Absorb in different portions of the spectrum



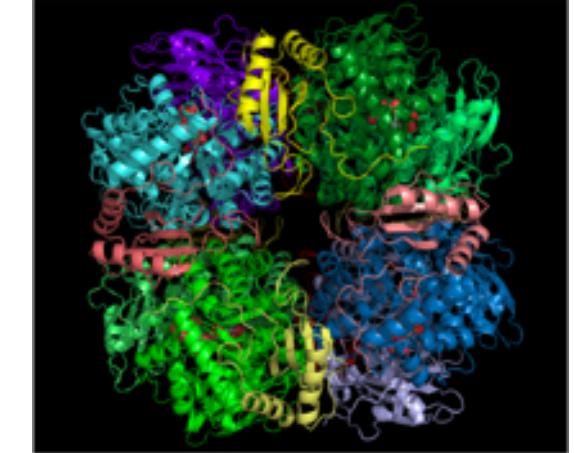
Movie time! (Chlorophyll and green leaves)

- Link

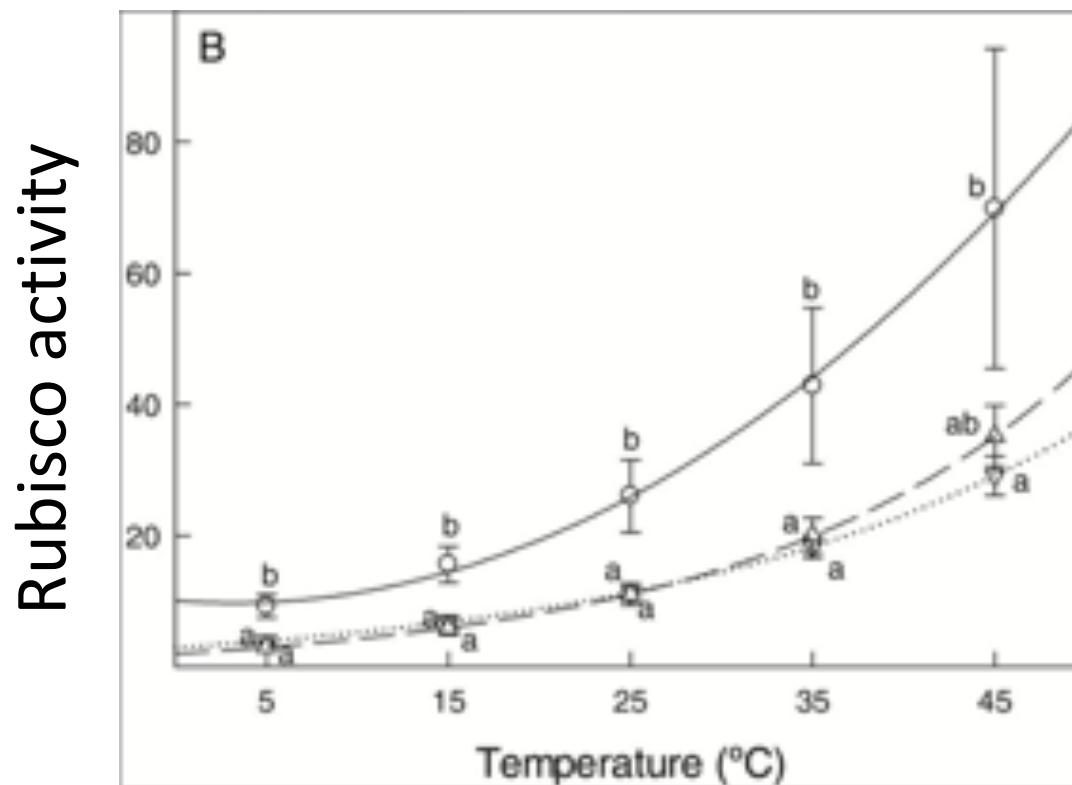
Photosynthesis – the recipe



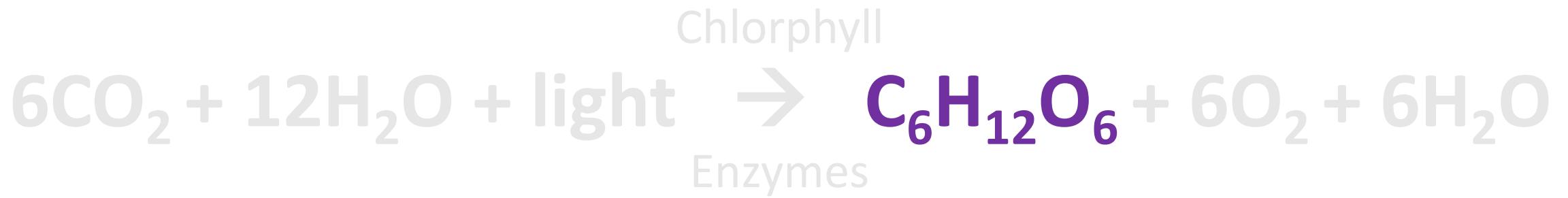
Photosynthesis - enzymes



- Function: to catalyze the reactions
- Very temperature sensitive
- Example --> Rubisco

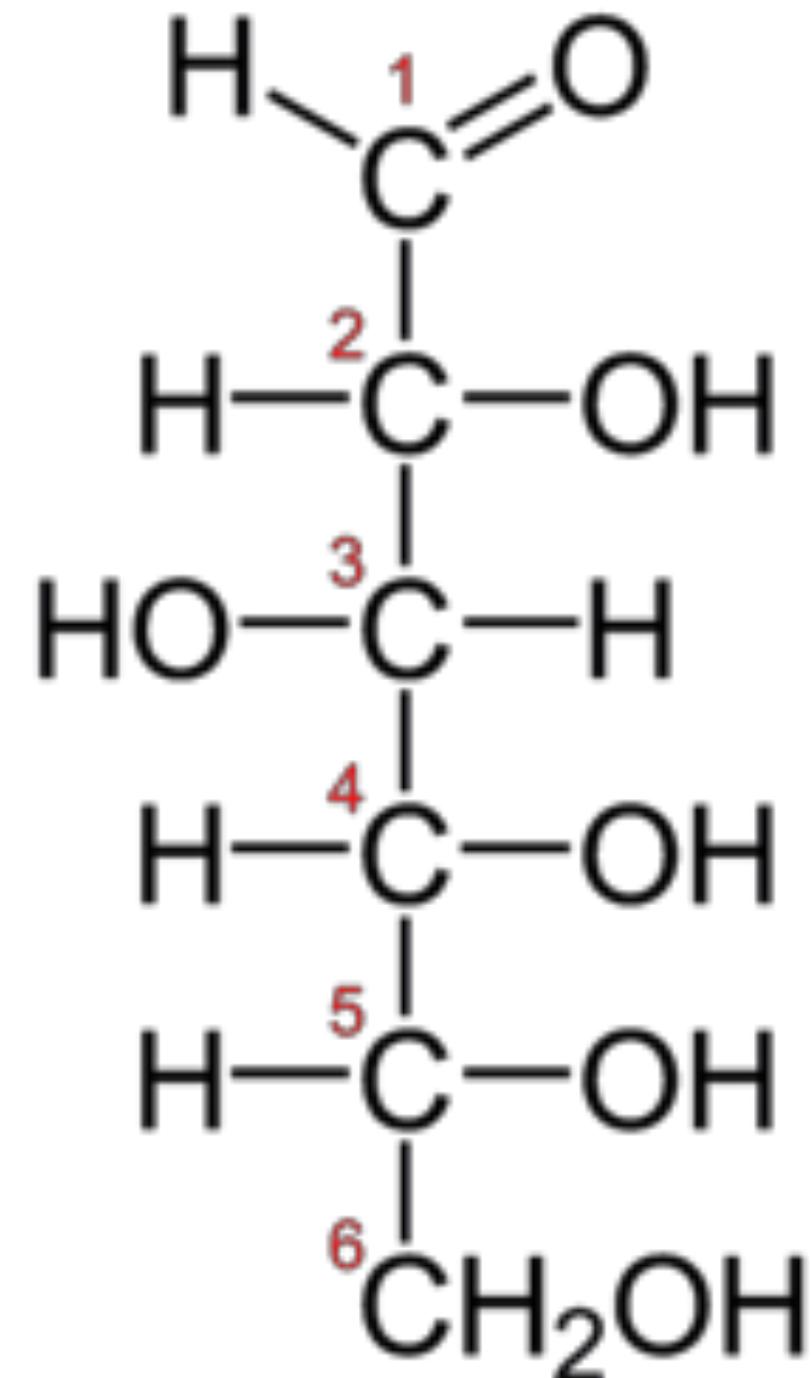


Photosynthesis – the recipe

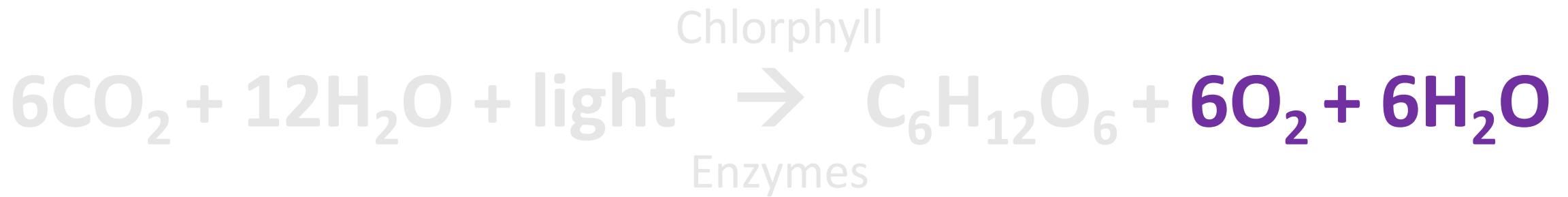


Photosynthesis - glucose

- Not actually the first product!
- Functions:
 1. Produce energy during respiration
 2. Lipid and starch formation
 3. Plant structure formation



Photosynthesis – the recipe



Photosynthesis – Oxygen and Water

- By products
- May be recycled or emitted as gas through leaves



Two phases of photosynthesis

1. Light-dependent reactions
2. Light-independent reactions
(aka Dark reactions)

Light-dependent reactions

Light-dependent reactions - Steps

1. Photons of light are absorbed
2. Electrons are excited! (boosted to higher energy level)
3. Water is split
 - Releases electrons, hydrogen ions, and oxygen gas
4. Electrons flow down electron transport chain
5. ATP and NADPH are produced (stored energy)

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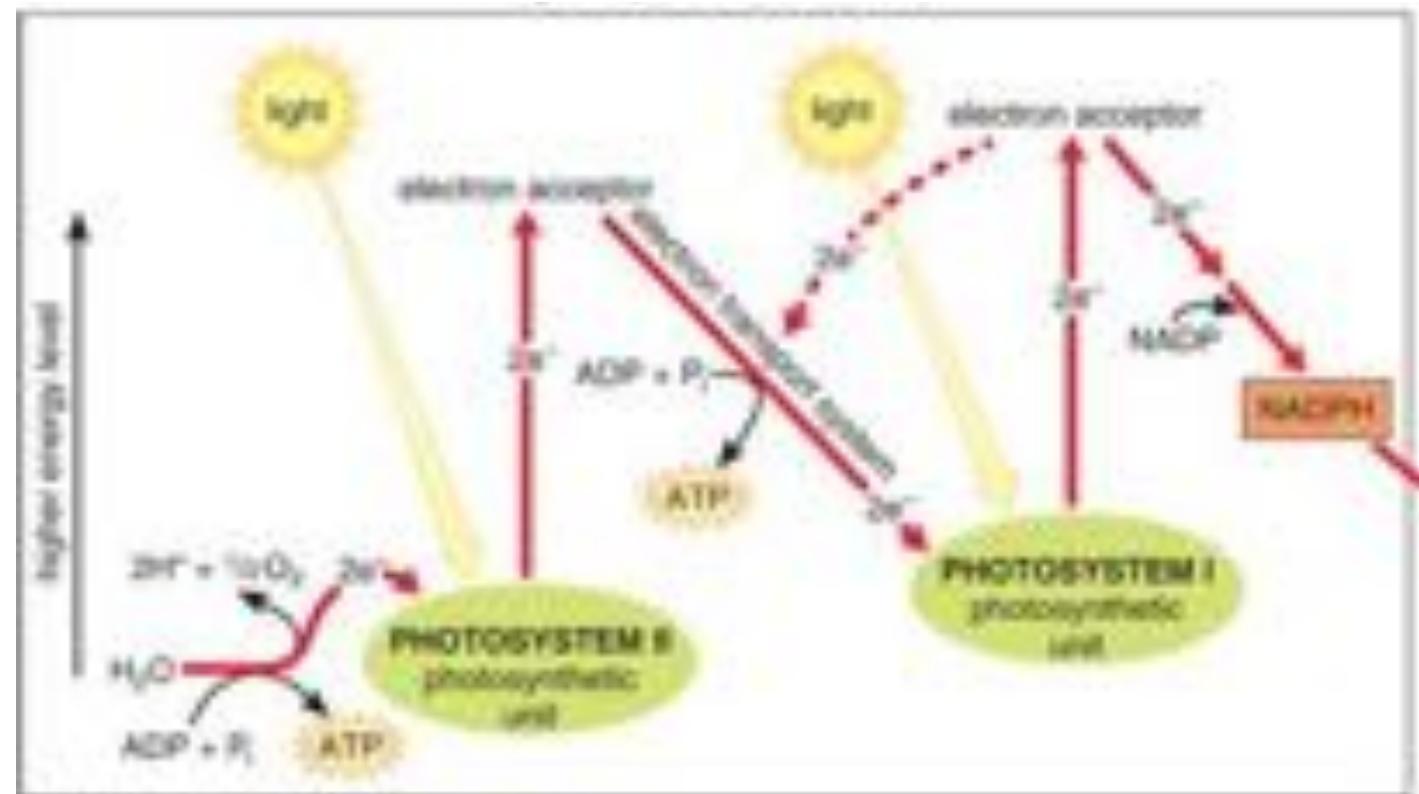
Light-dependent reactions

1. Ingredients

- Light
- H₂O
- NADP⁺
- ADP
- P

2. Outcomes

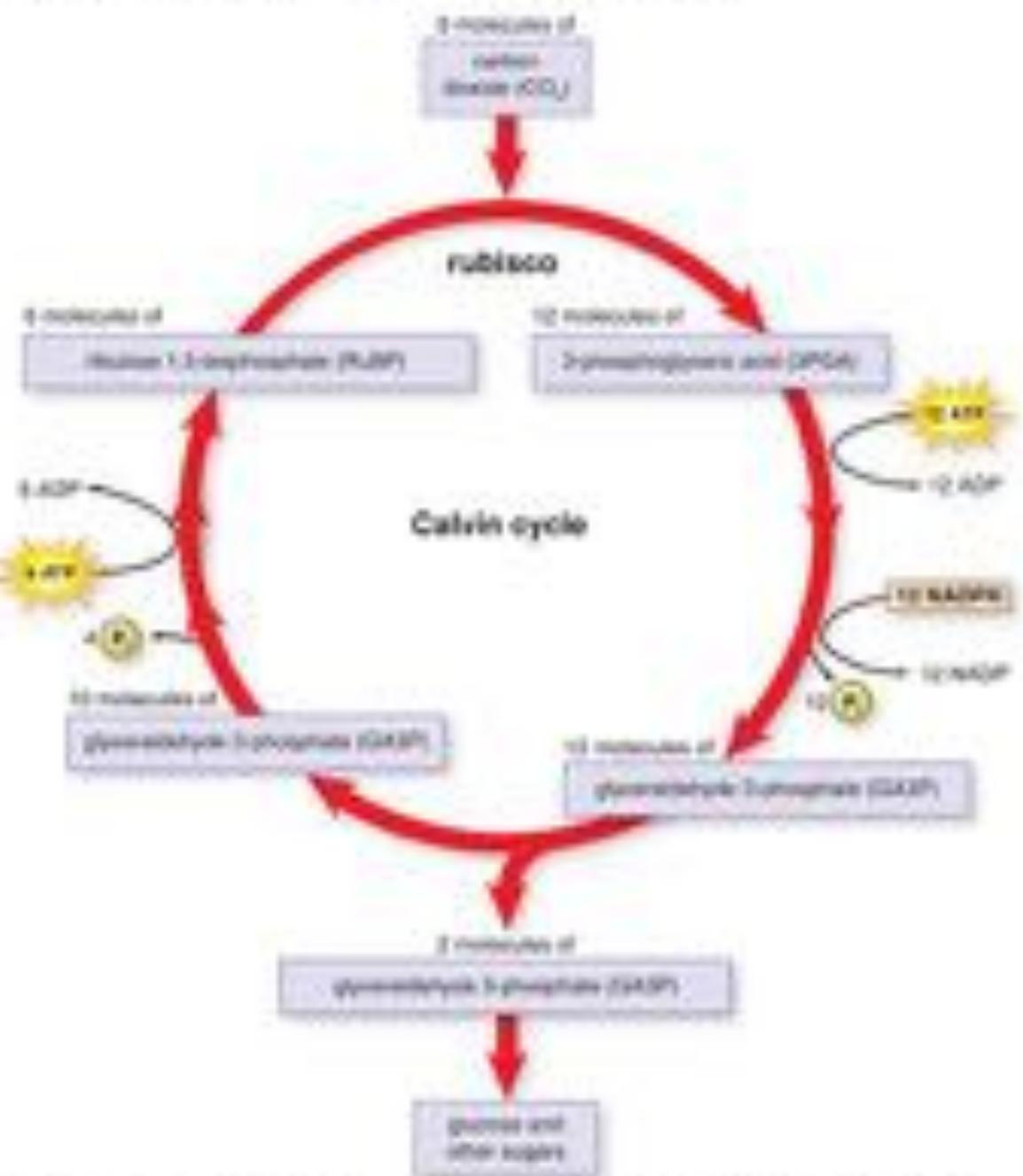
- ATP
- NADPH
- O₂
- H⁺



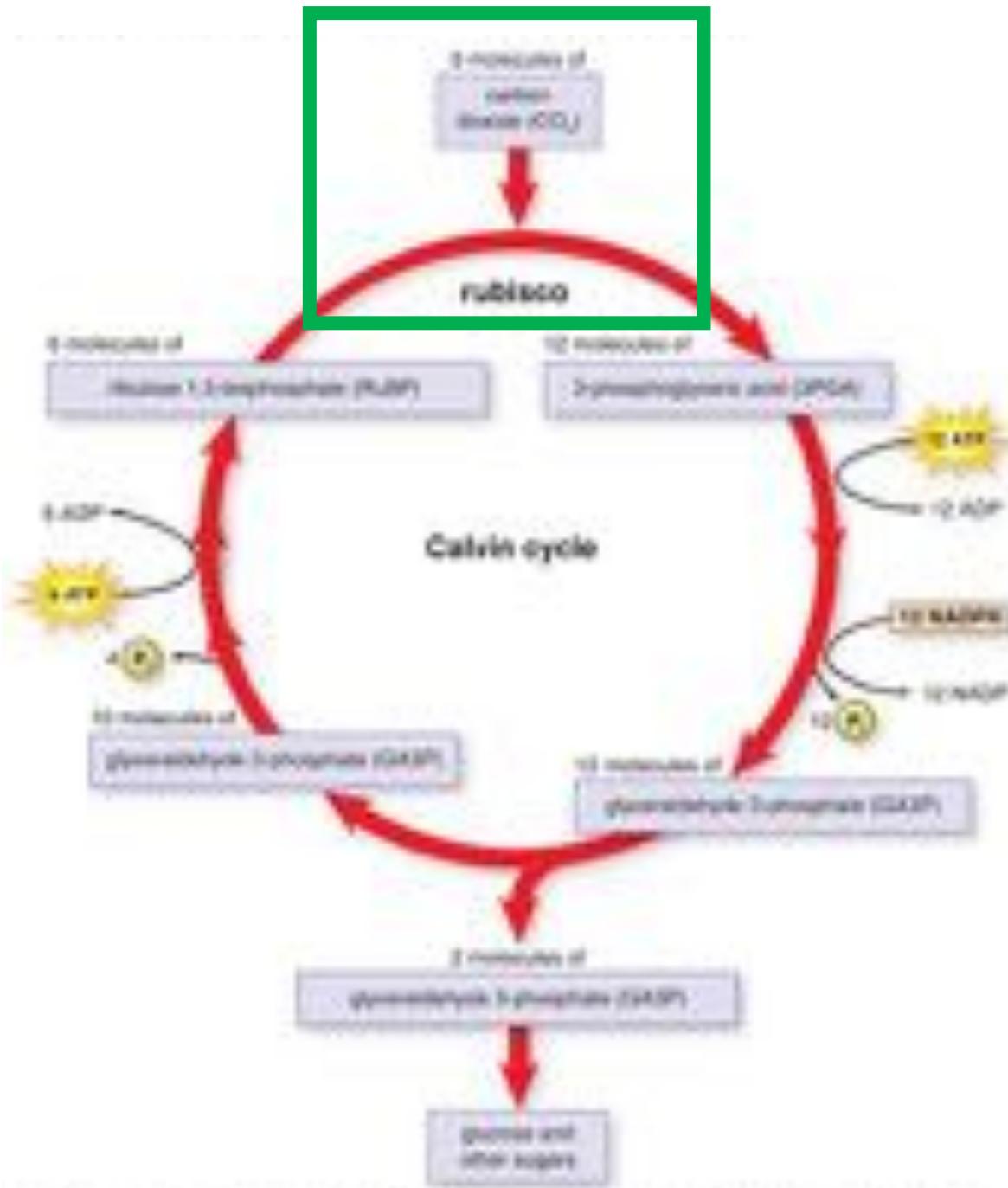
Light-independent reactions
("dark reactions")

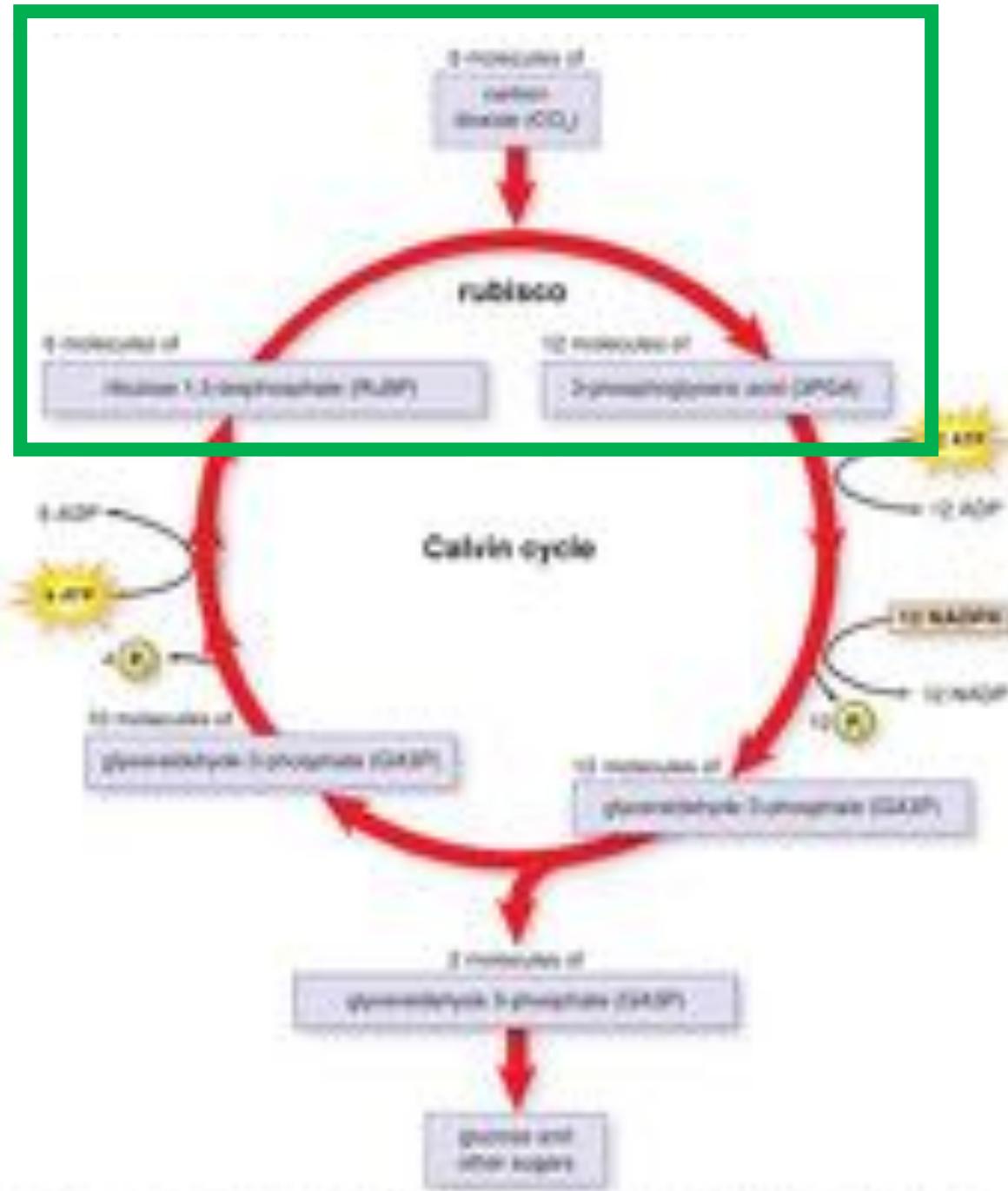
Light-independent reactions - Steps

1. Take ATP and NADPH from light-dependent reactions
2. Convert CO_2 into sugars
3. Restart the cycle



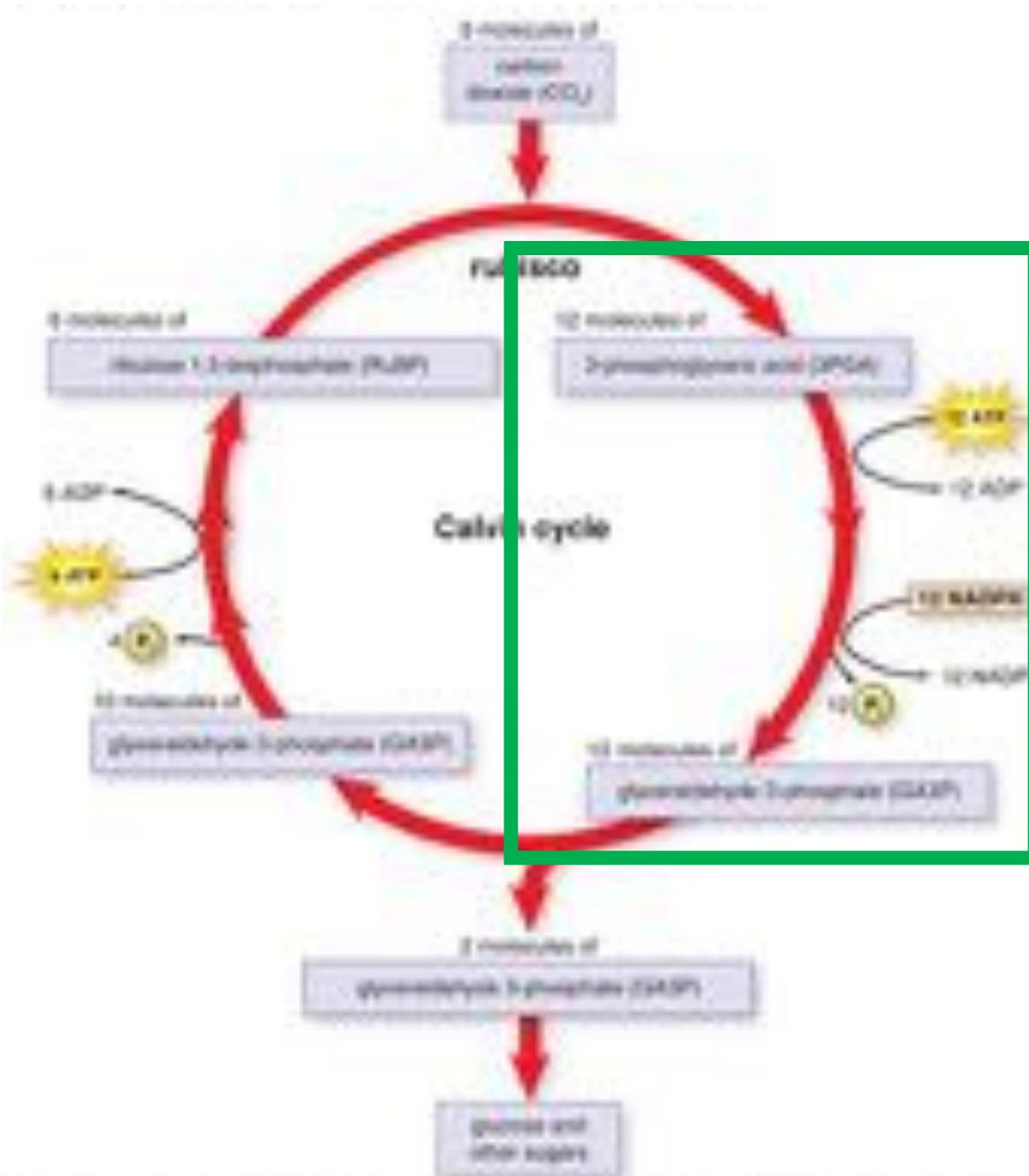
1. Rubisco grabs CO₂ (1 carbon)

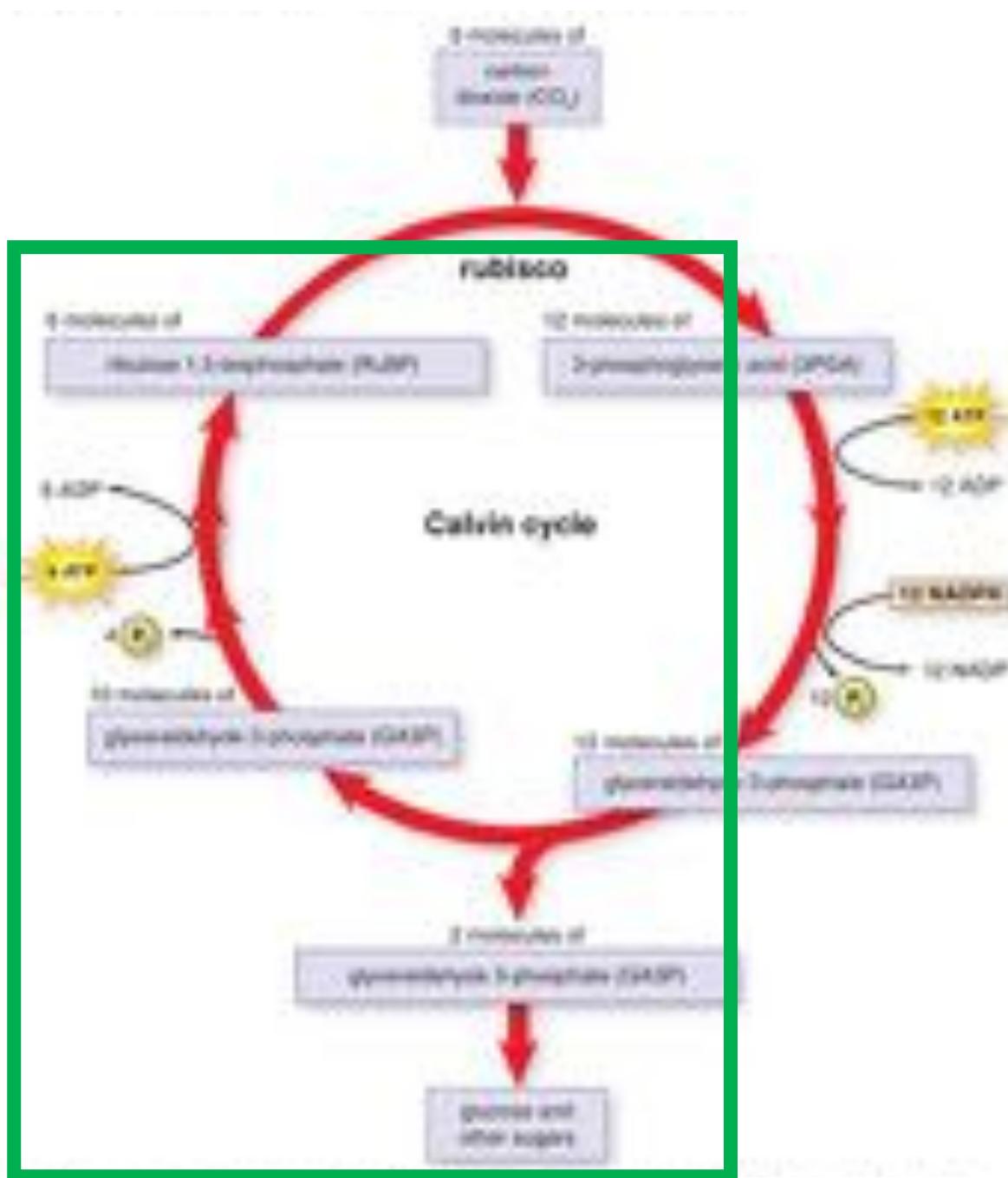




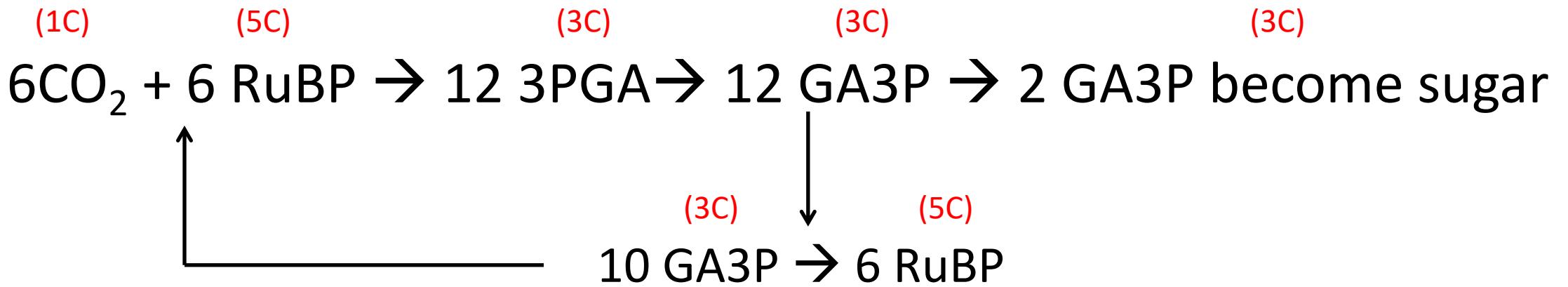
2. CO_2 (1 carbon) combines with RuBP (5 carbon)

2. GA3P (3 carbon) is produced





3. Some GA3P (3 carbon)
are used for sugars, others
restart the chain



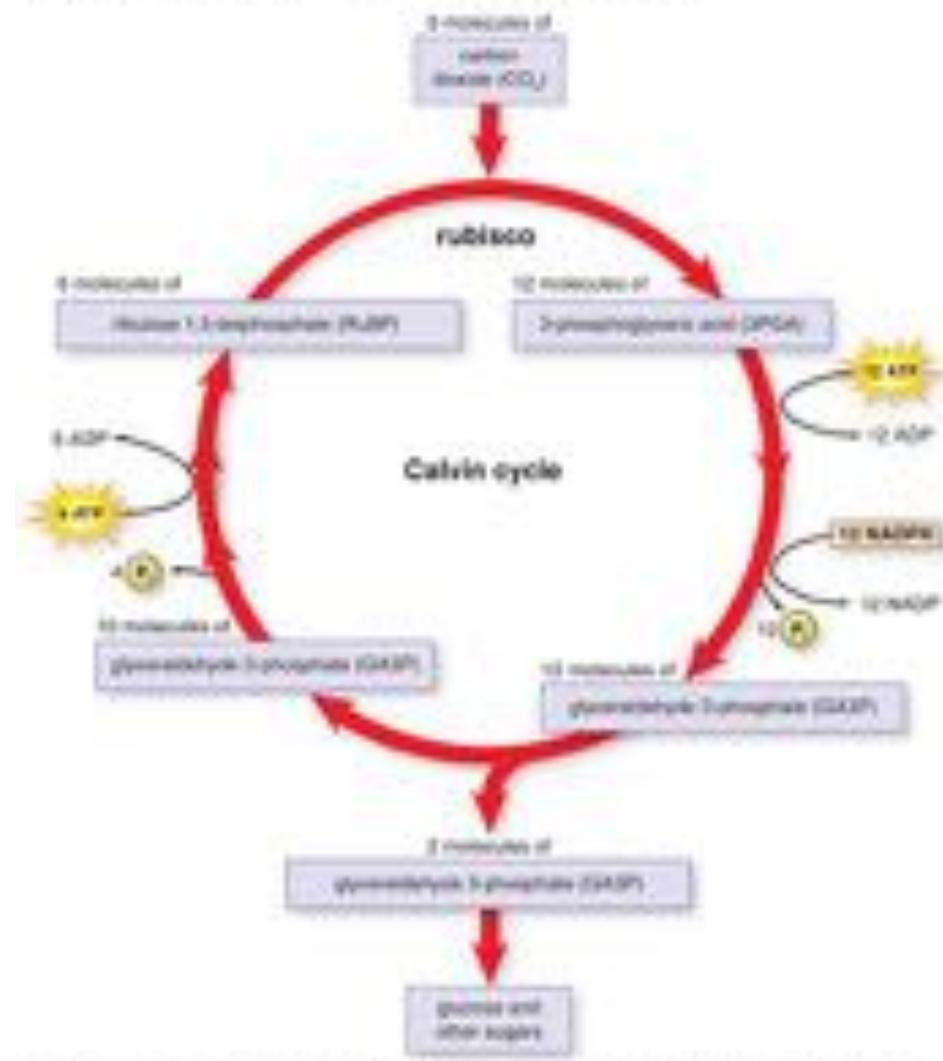
Light-independent reactions

1. Ingredients

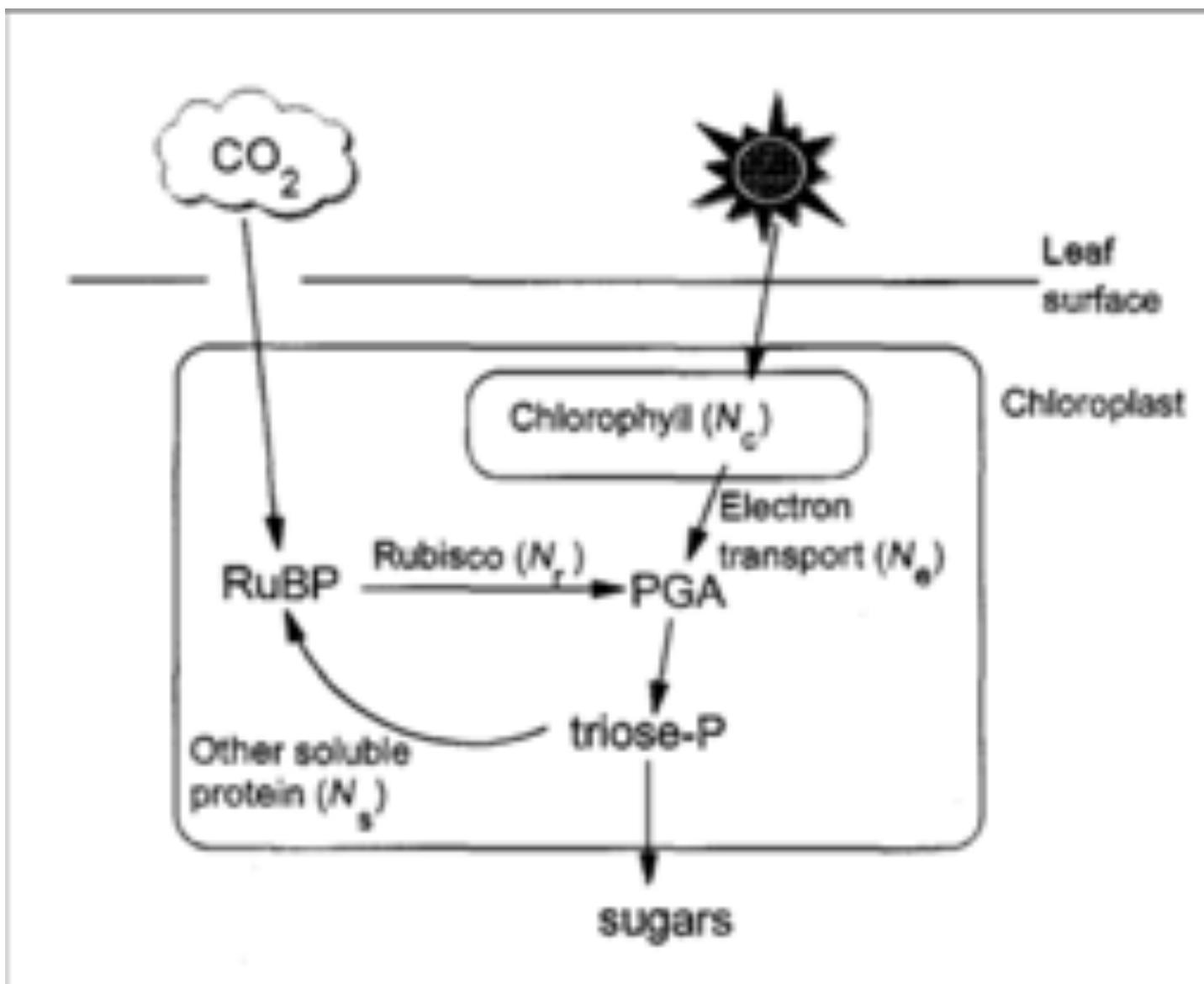
- CO₂
- RuBP
- NADPH
- ATP

2. Outcomes

- ADP
- NADP
- Sugars
- RuBP



All together now!



Photorespiration

Photorespiration

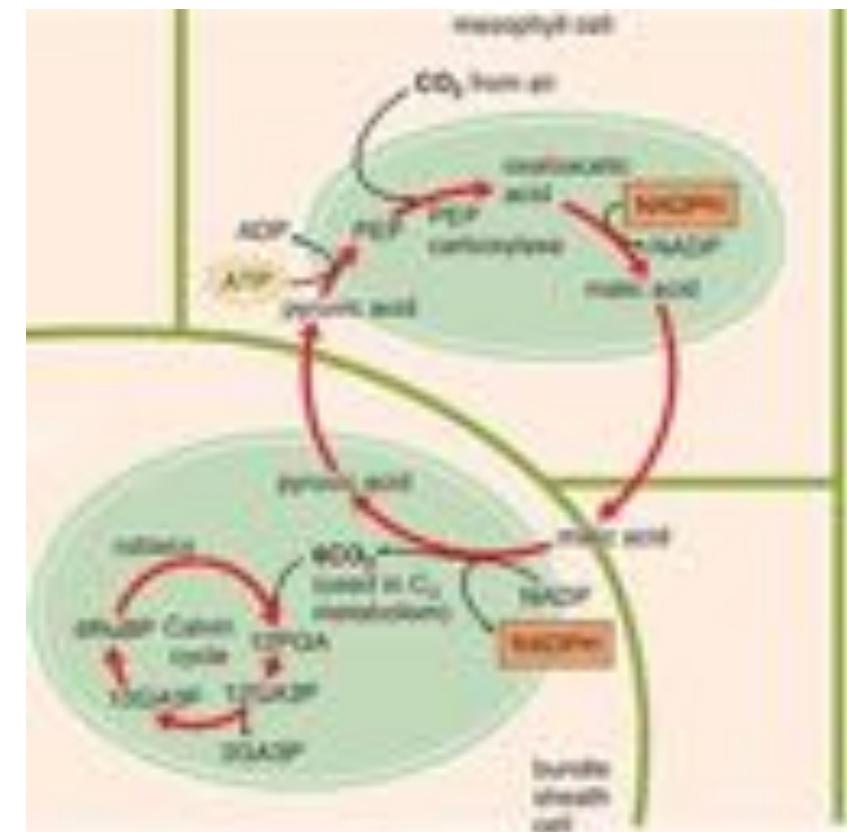
- Rubisco : RibUlose – 1,5 – BISphosphate Carboxylase and Oxygenase
- Catalyzes CO₂ and O₂
- Catalyzing O₂ leads to “wasteful” respiration (loss of CO₂)
- Increases as O₂ increases
- Increases with temperature

3 types of photosynthesis systems

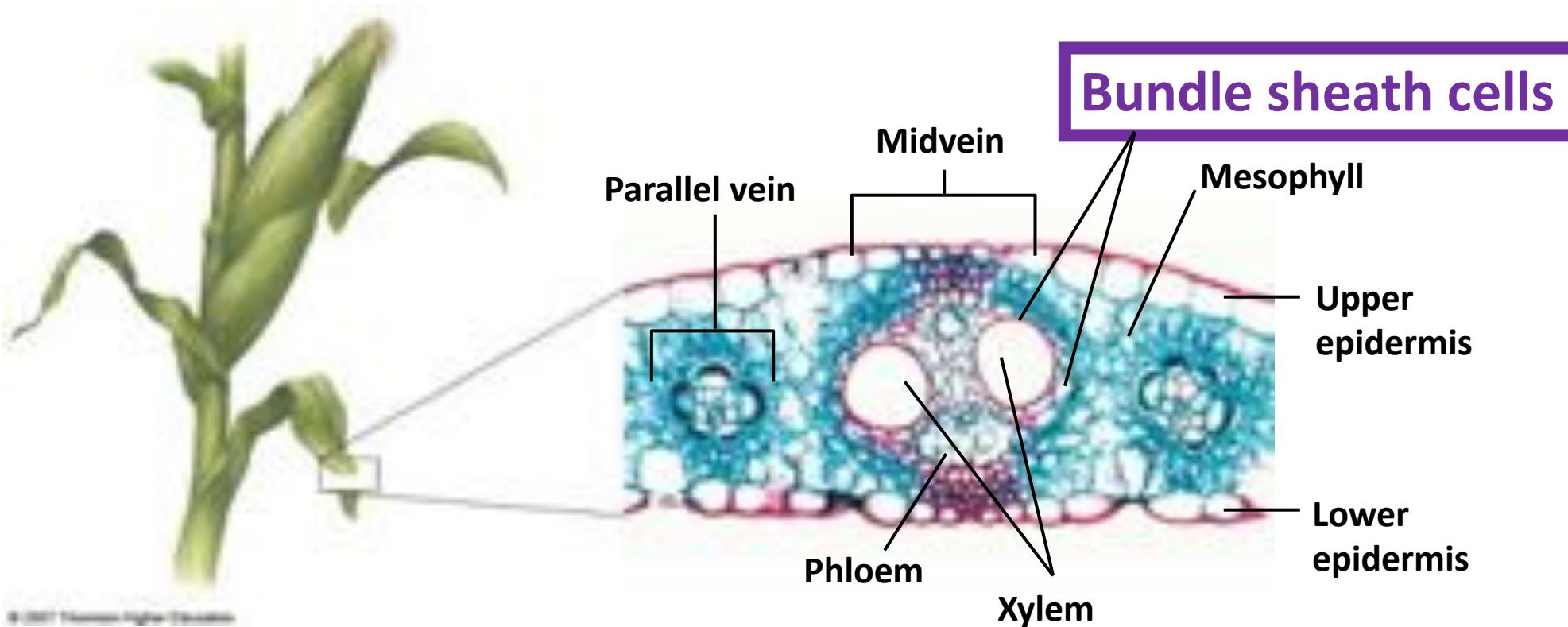
- C_3 : what we already covered
 - Most plants
- C_4 : Separate carbon acquisition and sugar creation in space
 - Typically grasses
- CAM: Separate carbon acquisition and sugar creation in time
 - E.g., Cacti

C4 photosynthesis

- PEP carboxylase captures CO_2 and creates a 4 carbon sugar **in mesophyll**
- Moves sugar **to bundle sheath**, where CO_2 is removed
 - Bundle sheath cells surround veins
- Calvin cycle progresses as normal
- “Costs” two extra ATPs



C4 photosynthesis – why the bundle sheath?



C4 photosynthesis - benefits

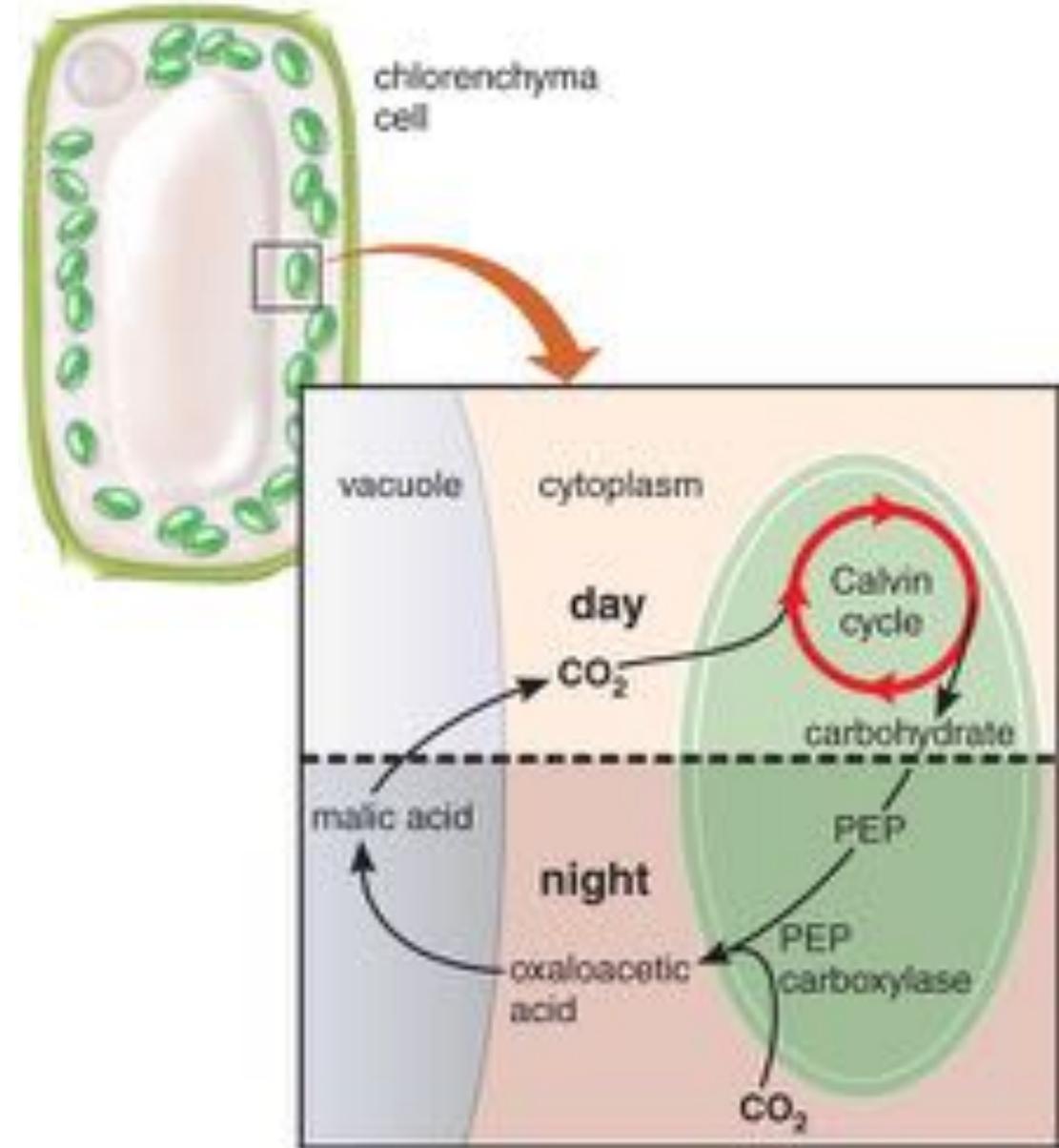
PEP carboxylase is not an oxygenase

- Good at capturing CO₂
- Good in low CO₂ environments
- Good in hot, dry environments
 - Can close stomata



CAM photosynthesis

- Opens stomata during the night
 - PEP carboxylase captures CO_2 and creates a 4 carbon sugar
- Closes stomata during the day
 - Calvin cycle



How is (C3) photosynthesis altered by
the environment?

Von Caemmerer and Farquhar (1981)

