Physiology Related Effects in Late Planted Rice

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Rice History

Ancestors of the present rice plant originated 20,000 or more years ago and initially were perennial plants.

History

10,000 to 15,000 years ago during the Neo-thermal period changing climates producing alternating periods of drought and moisture and high and low temperatures tended to stimulate the development of annuals.

History

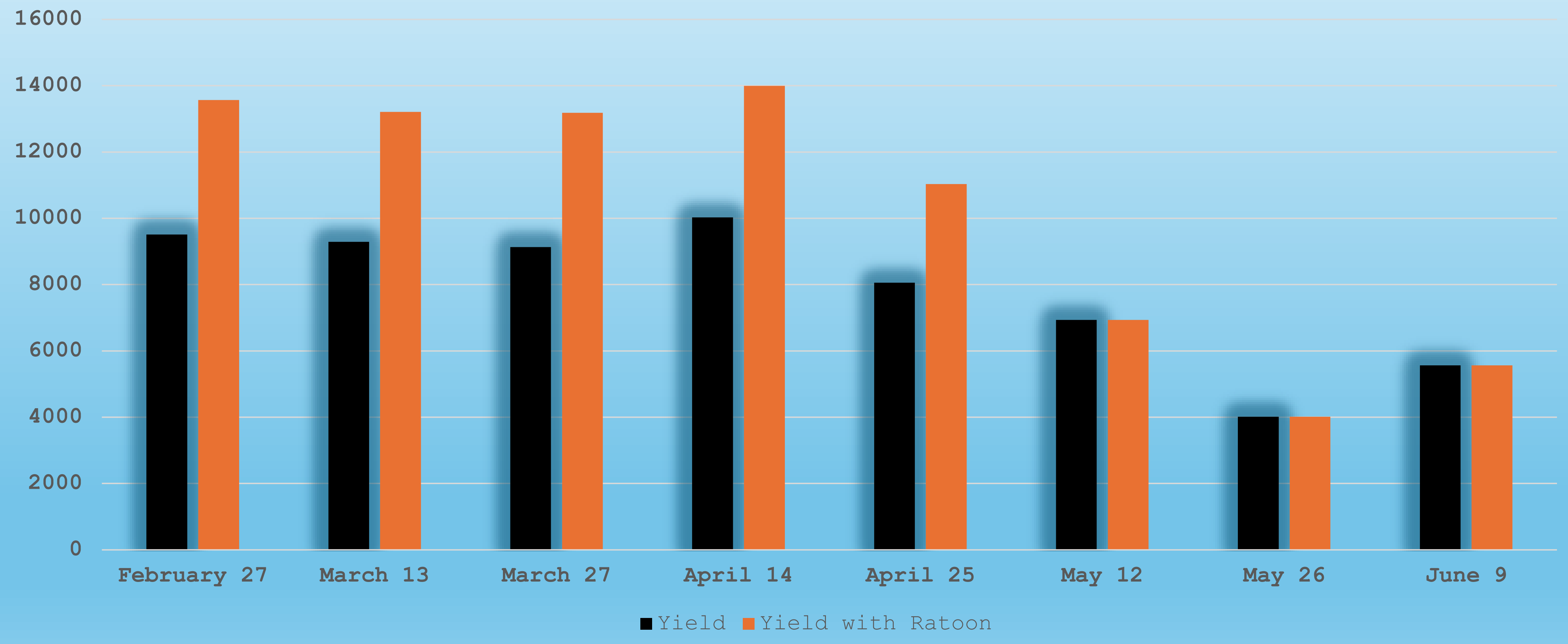
Temperate rice is grown in higher latitudes, where temperatures are generally lower. In these regions, the days are longer during the summer growing season, improving the chances of better crop growth and yield. Because of more sunlight hours. It is adapted to the temperate conditions through evolution.

Temperate Climate

Temperate climate is a type of climate that occurs in the middle latitudes of Earth, between the tropics and the polar regions. Temperate climates have mean temperatures above −3 °C (26.6 °F) but below 18 °C (64.4 °F) in the coldest month. Temperate climates are not as cold as subarctic climates or as warm as subtropical climates

Date of Planting

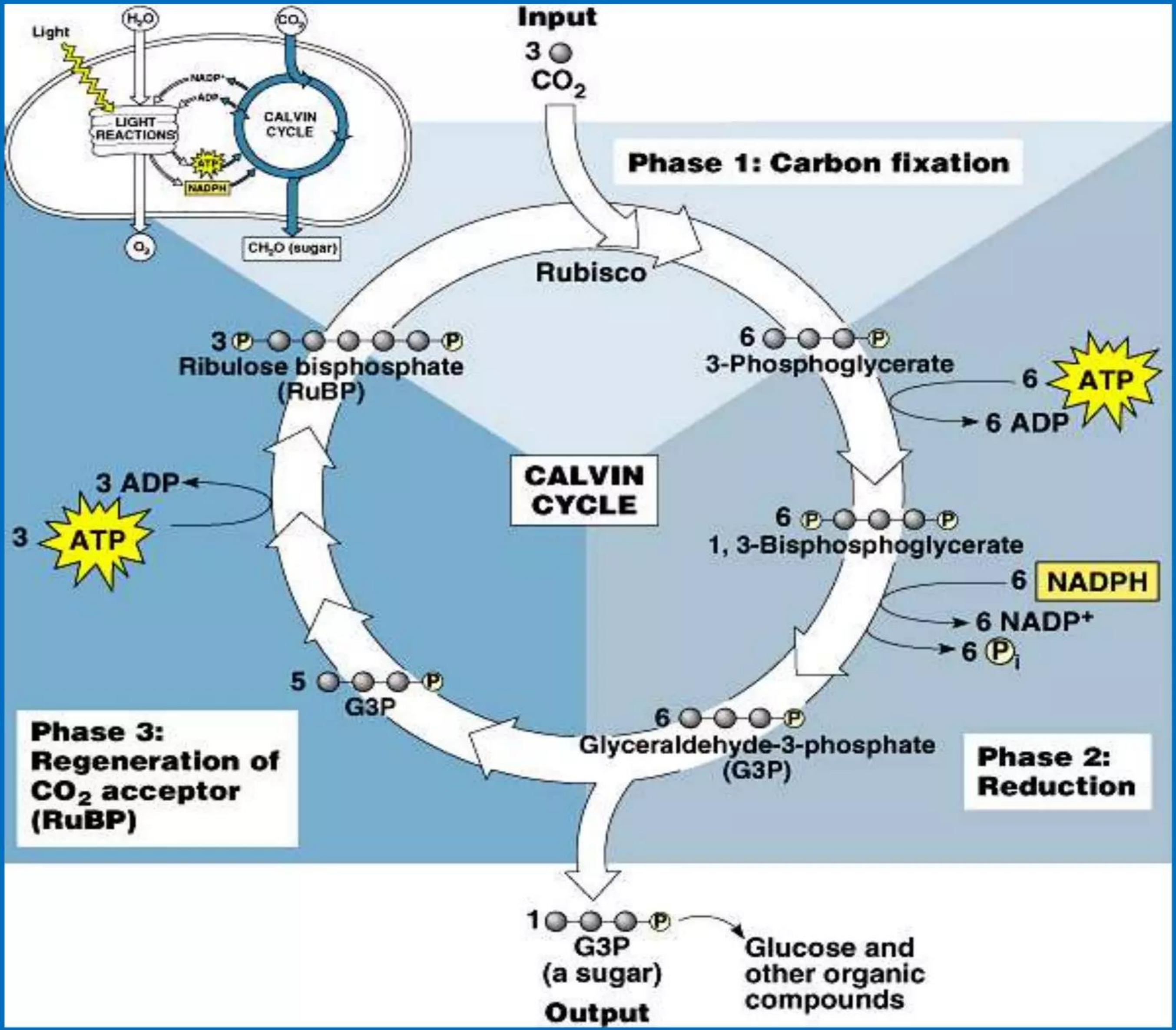
Date of Planting Study 2023

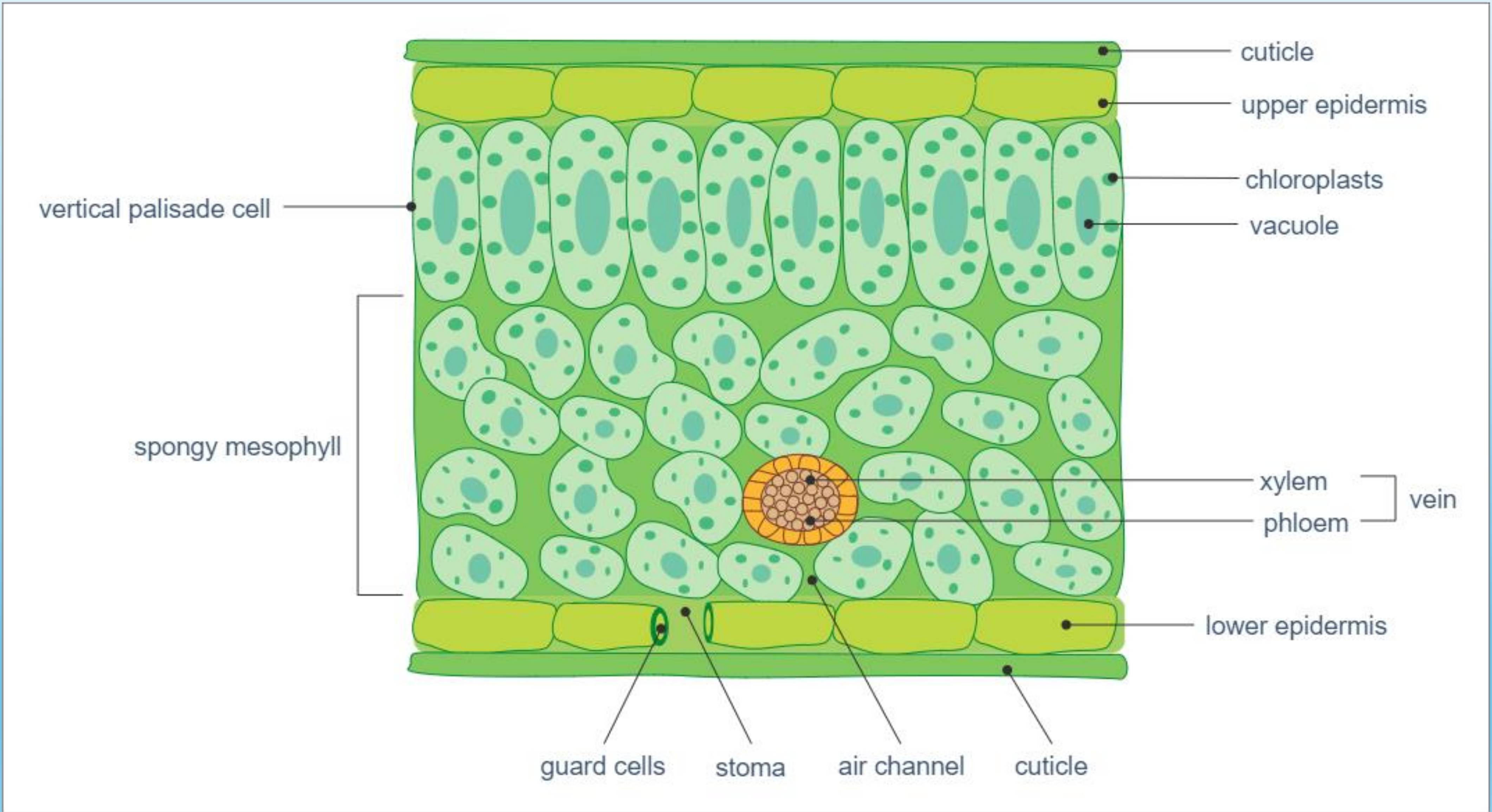


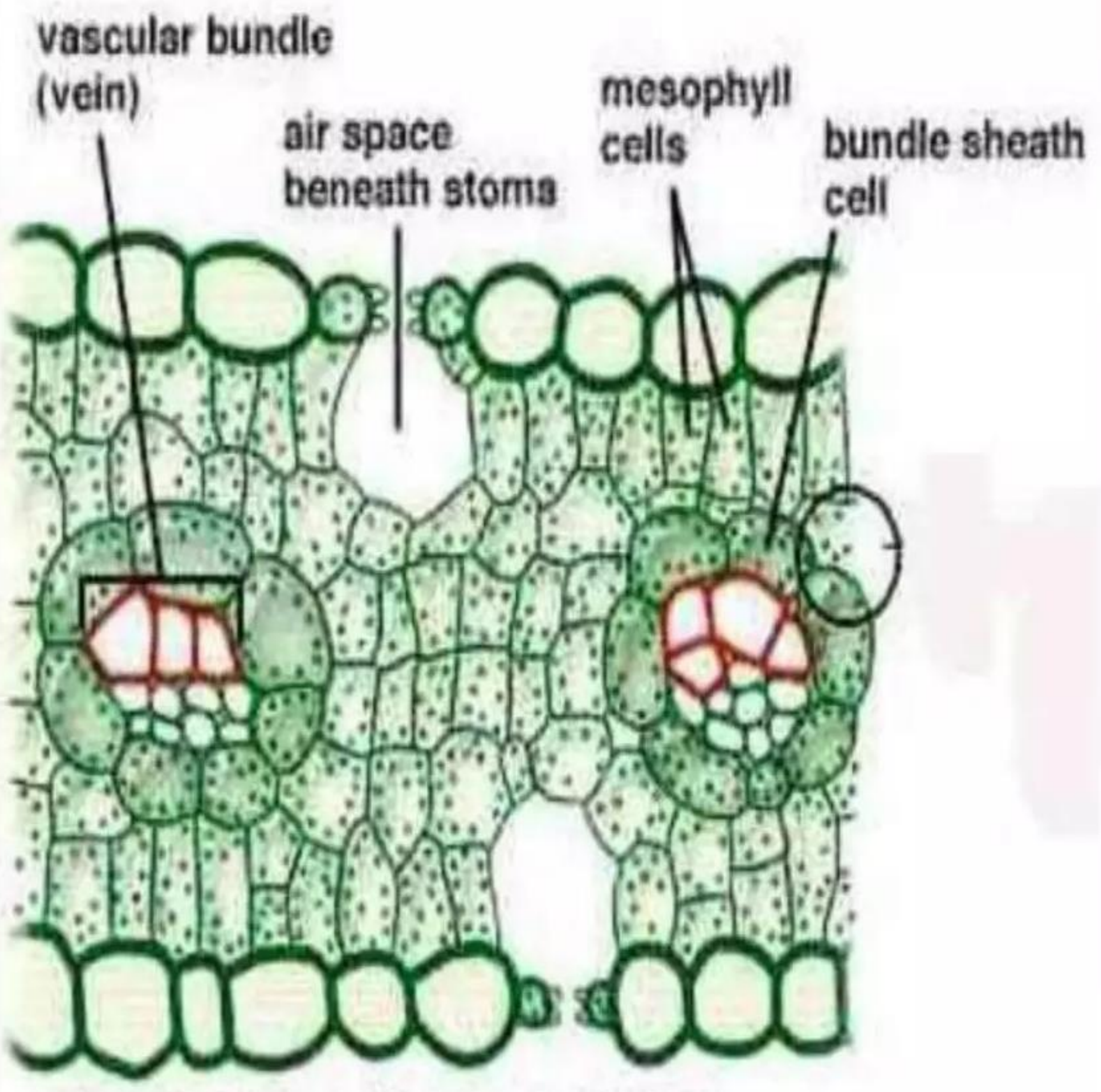
Rice Photosynthesis

Rice is a C_3 plant. Photosynthesis using the C_3 cycle, also known as the Calvin cycle, is a process in which plants use carbon dioxide and water to produce sugars, lipids and proteins.

It is the second stage of photosynthesis, and it involves three steps: carboxylation, reduction and regeneration. The C_3 cycle gets its


Light
H_2O
CO_2
LIGHT REACTIONS
CALVIN CYCLE
$NADP^+$
ADP
ATP
NADPH
O_2
CH_2O (sugar)
Input
3
CO_2
Phase 1: Carbon fixation
Rubisco
3 P P
Ribulose bisphosphate (RuBP)
6 P
3-Phosphoglycerate
6 ATP
6 ADP
CALVIN CYCLE
3 ADP
3 ATP
6 P P
1, 3-Bisphosphoglycerate
6 NADPH
6 $NADP^+$
6 P_i
5 P
G3P
6 P
Glyceraldehyde-3-phosphate (G3P)
Phase 3: Regeneration of CO_2 acceptor (RuBP)
Phase 2: Reduction
1 P
G3P (a sugar)
Output
Glucose and other organic compounds


cuticle
upper epidermis
chloroplasts
vacuole
vertical palisade cell
spongy mesophyll
xylem
phloem
vein
lower epidermis
guard cells
stoma
air channel
cuticle



PORTION OF A CROSS SECTION
OF A LEAF WITH C_4 PHOTOSYNTHESIS

Photosynthesis

Ribulose Bisphosphate (RuBP) oxygenase-carboxylase [rubisco], a key enzyme in photosynthesis.

In the process of carbon fixation, rubisco incorporates carbon dioxide (CO_2) into an organic molecule during the first stage of the Calvin cycle.

Rubisco is so important to plants that it makes up 30% or more of the soluble protein in a typical plant leaf. But rubisco also has

Photorespiration

Photorespiration is a wasteful pathway that occurs when the Calvin cycle enzyme rubisco acts on oxygen rather than carbon dioxide. The majority of plants are C3 plants, which have no special features to combat photorespiration.

Photorespiration wastes energy and steals carbon

Photorespiration begins in the chloroplast, when rubisco attaches O_2 to RuBP in its oxygenase reaction.

Two molecules are produced: a three-carbon compound, 3-phosphoglycerate, and a two-carbon compound, phosphoglycolate.

Phosphoglycolate cannot enter the cycle, so its two carbons are removed, or "stolen,"

Photorespiration

The enzyme rubisco can use either CO_2 or O_2 as a substrate. Rubisco adds whichever molecule it binds to a five-carbon compound called ribulose-1,5-bisphosphate (RuBP).

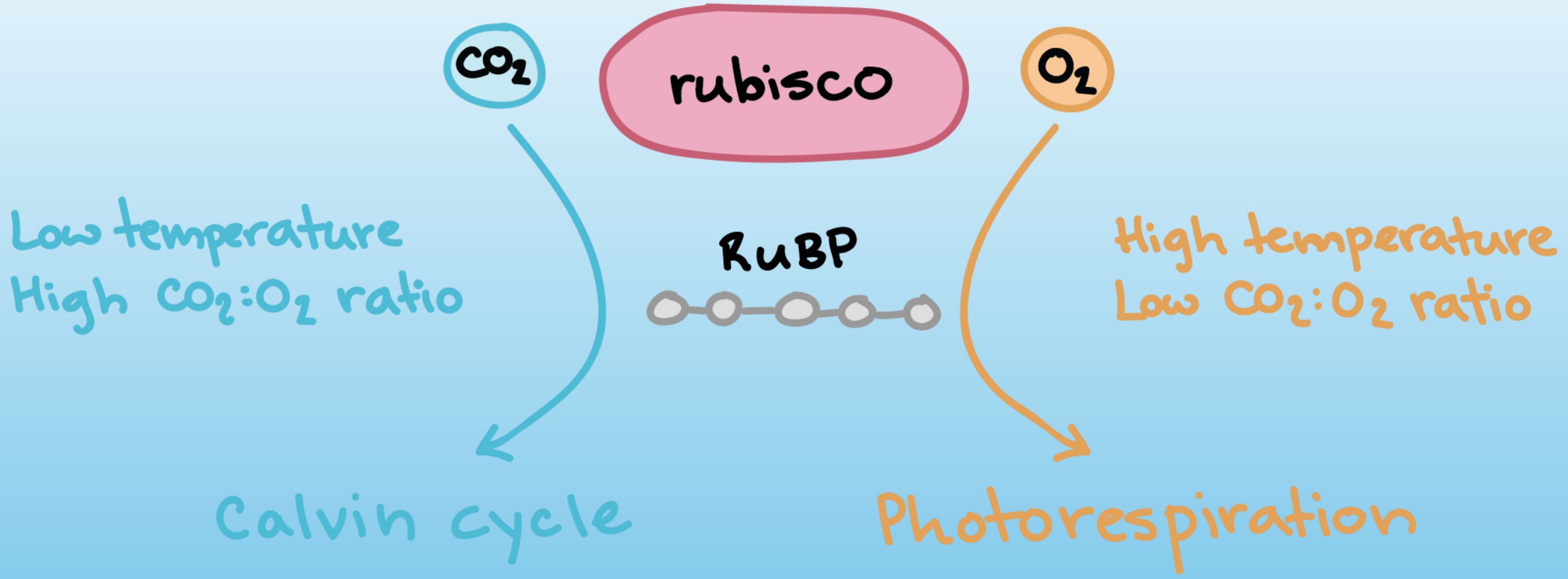
The reaction that uses CO_2 is the first step of the Calvin cycle and leads to the production of sugar.

The reaction that uses O_2 is the first step of the photorespiration pathway,

Photorespiration

This side reaction initiates photorespiration, which, rather than fixing carbon, actually leads to the loss of already-fixed carbon as CO_2.

Photorespiration wastes energy and decreases sugar synthesis, so when rubisco initiates this pathway



CO_2
rubisco
O_2
Low temperature
High CO_2:O_2 ratio
RuBP
High temperature
Low CO_2:O_2 ratio
Calvin cycle
Photorespiration

Photorespiration

What determines how frequently each substrate gets "chosen"?

Two key factors are: relative concentrations of O_2 and CO_2 and the temperature.

Photorespiration

When a plant has its stomata, or leaf pores, open CO_2 diffuses in, O_2 and water vapor diffuse out, and photorespiration is minimized.

However, when a plant closes its stomata—for instance, to reduce water loss by evaporation— O_2 from photosynthesis builds up inside the leaf.

Photorespiration

At mild temperatures, rubisco's affinity for (tendency to bind to) CO_2 is about 80 times higher than its affinity for O_2.

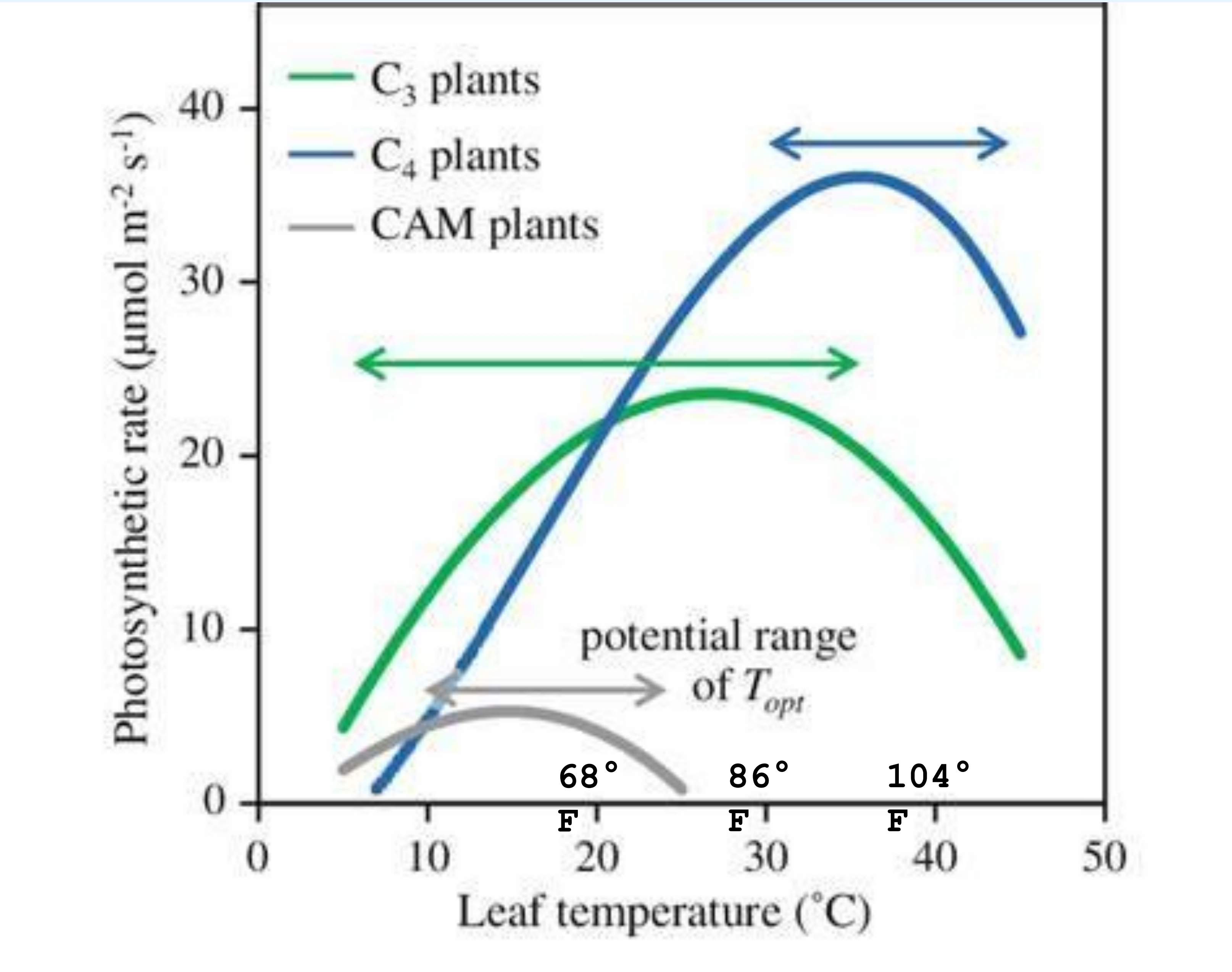
At high temperatures, however, rubisco is less able to tell the molecules apart and grabs oxygen more often.

Rubisco has a higher affinity for O_2

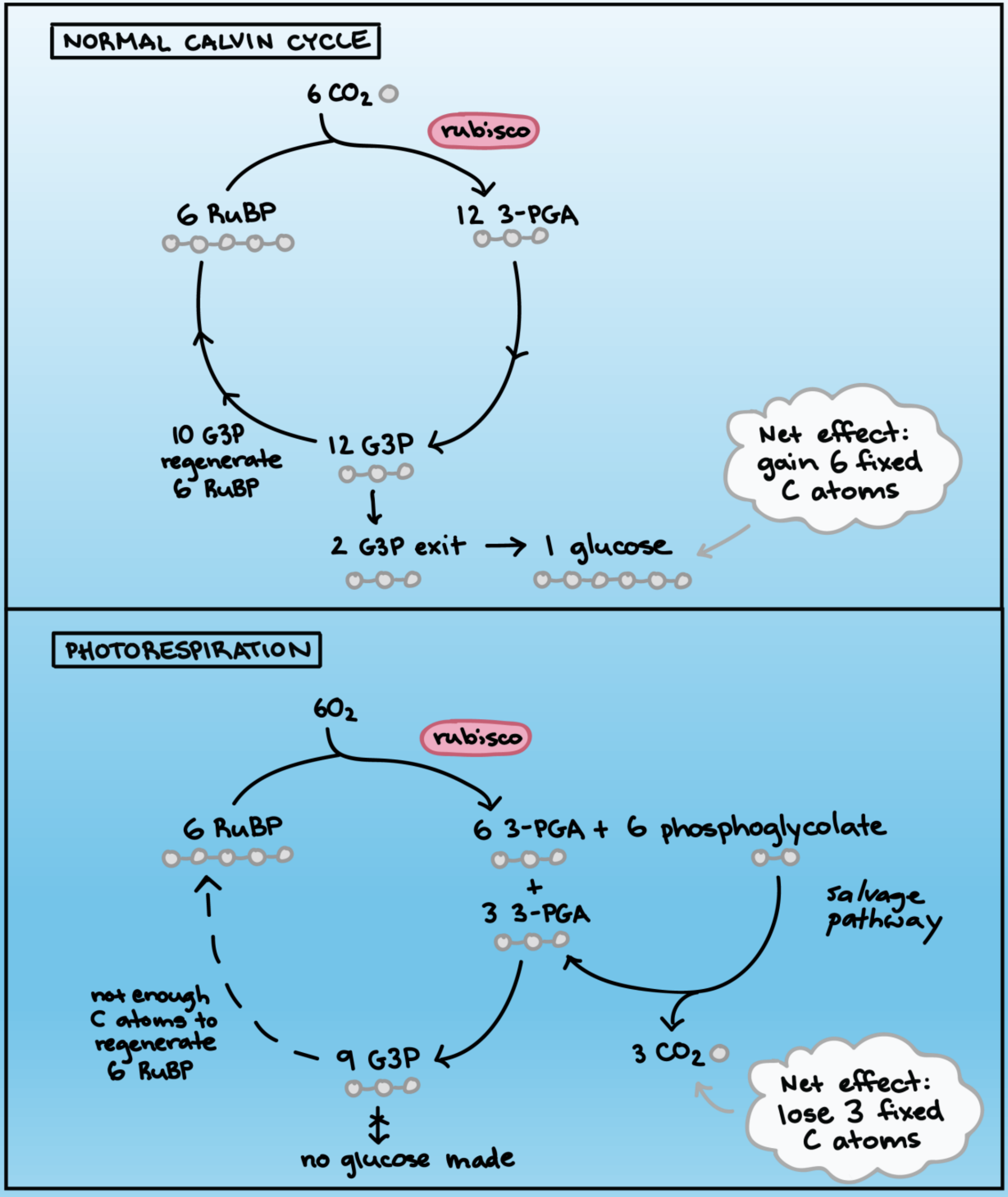
Photorespiration

Photorespiration results in a loss of 3 fixed carbon atoms under these conditions, while the Calvin cycle results in a gain of 6 fixed carbon atoms.

In C_3 plants, the optimum temperature for photosynthesis is very low (64 to 75 degrees



C3 plants
C4 plants
CAM plants
potential range of T_{opt}
68° F
86° F
104° F
Photosynthetic rate (μmol m-2 s-1)
Leaf temperature (˚C)
0
10
20
30
40
50


NORMAL CALVIN CYCLE
6 CO_2
rubisco
6 RuBP
12 3-PGA
10 G3P regenerate 6 RuBP
12 G3P
2 G3P exit → 1 glucose
Net effect: gain 6 fixed C atoms
PHOTORESPIRATION
6O_2
rubisco
6 RuBP
6 3-PGA + 6 phosphoglycolate
+
3 3-PGA
salvage pathway
not enough C atoms to regenerate 6 RuBP
9 G3P
3 CO_2
no glucose made
Net effect: lose 3 fixed C atoms

Photorespiration

Photorespiration is definitely not a win from a carbon fixation standpoint. However, it may have other benefits for plants. There's some evidence that photorespiration can have photoprotective effects (preventing light-induced damage to the molecules involved in photosynthesis), and support plant immune defenses.

Dark Respiration

The dark reaction is the actual phase where food is synthesized by the plants, and it uses the energy generated by the light reactions.

Dark Respiration

Dark respiration is a process in which plants consume oxygen and release carbon dioxide during the night or in the absence of light. It is an essential process that generates energy for plant growth and development.

The study found that the yield loss in rice by high night temperature is mainly due to higher dark respiration, which increases the consumption of photoassimilates and thereby

Dark Respiration

In rice, about 30-60% of the carbon assimilated during photosynthesis is lost through respiration (Cannell and Thornley, 2000). This percentage may increase with rising temperatures.

Respiration is positively correlated with temperature in the physiological temperature ranging from 32 to 100°F.

A 10% yield reduction was reported in rice when the minimum nighttime temperature increased by 1° C or 1.8°F during the growing season (Peng et al., 2004).

Consistent with this interpretation, ATP content and dry matter weight were significantly decreased in plants under moderate high-temperature conditions suggesting that energy produced under high-temperature condition was mainly allocated to maintenance rather than growth.

Dark Respiration

Studies found that moderate high temperature causes significantly increases respiration in rice plants.

With moderate high temperature, most of this energy is allocated to maintenance respiration, resulting in an overall decrease in efficiency.

May be the primary contributor to yield losses in a high-temperature climate.

Evapotranspiration

Evapotranspiration (ET) is the combined processes which move water from the Earth's surface into the atmosphere. It covers both water evaporation (movement of water to the air directly from soil, canopies, and water bodies) and transpiration (evaporation that occurs through the stomata, or openings, in plant

Evapotranspiration

Through the pores called stomata in their leaves, plants take in carbon dioxide from the atmosphere that they use for photosynthesis. They then give off water through the stomata in a process called evapotranspiration which cools the plant just as perspiration cools human beings.

Evapotranspiration

CO_2 is one of the gases that can be exchanged during this process. In C_3 plants, the rate of photosynthesis is limited by the availability of CO_2. As the stomata open to allow CO_2 to enter the plant, water vapor is released into the atmosphere through transpiration.

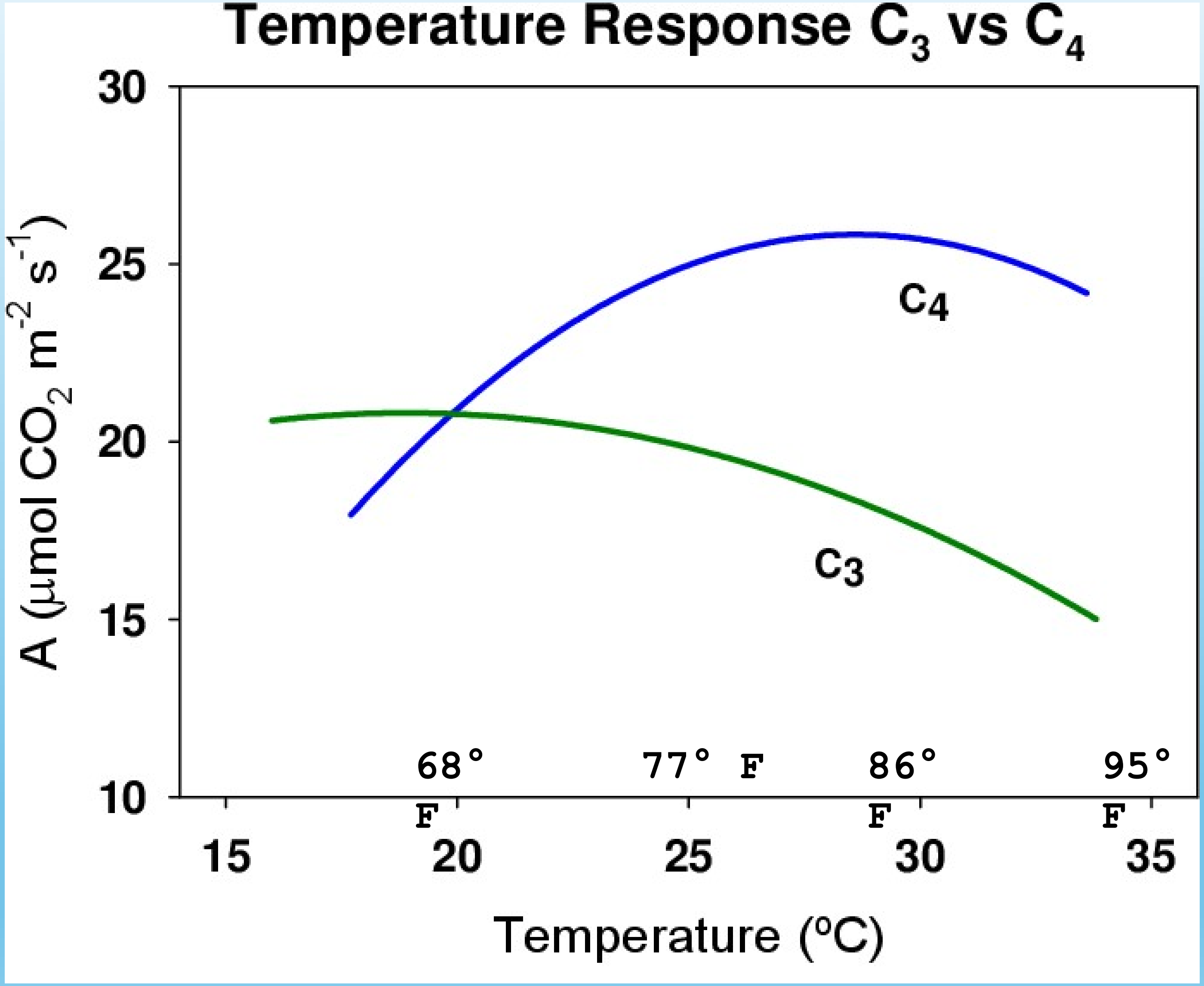
CO_2 Is Only 0.04% of the Atmosphere

When stomata are open to let carbon dioxide in, they also let water vapor out, leaving C3 plants at a disadvantage in drought and high-temperature environments.

The heat effect from evapotranspiration on CO_2 is that it can cause a decrease in the concentration of CO_2 in the leaf

Stomates control the volume of CO_2 entering the intercellular air spaces of the leaf for photosynthesis. They also plays a key role in minimizing the amount of water lost.

Although the cumulative area of stomatal pores only represents a small fraction of the leaf surface, typically less than 3%, some 98% of all CO_2 taken up and water lost passes through these pores.


Temperature Response C3 vs C4
30
25
20
15
10
A (μmol CO2 m-2 s-1)
C4
C3
68° F
77° F
86° F
95° F
15
20
25
30
35
Temperature (oC)

Questions?

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