Chap 4. Growth and Metabolism

I. Terminology

1. **Growth – Irreversible increase in size**
2. **Development:**

   Morphogenesis - Morphological and anatomical development

   Differentiation - Physiological and biochemical specialization of plant tissues
3. **Metabolism: Synthesis and degradation of organic compounds**

   Anabolism - synthesis

   Catabolism – degradation (breakdown)

II. Major Chemical Processes of Plants

1. Photosynthesis

Chlorophyll

$$12\ H_2O + 6\ CO_2 + Light \xrightarrow[\text{Chloroplast}]{} C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$

(Water) (Carbon dioxide) (Energy) Chloroplast (Carbohydrate) (Oxygen) (Water)

2. Metabolism

(Enzyme)

$$C_6H_{12}O_6 + Mineral \xrightarrow[\text{(Cytoplasm)}]{} \text{Various Organic Compounds}$$

(Carbohydrate) (Fertilizer) (Cytoplasm) (Protein, fats, starch, hormones, etc.)

3. Respiration

(Enzyme)

$$\text{Organic Compds} + O_2 \xrightarrow[\text{(Mitochondria)}]{} CO_2 + H_2O + Energy + Mineral$$

(Substrates, Energy source) (Oxygen) (Mitochondria) (ATP) (Inorganic)

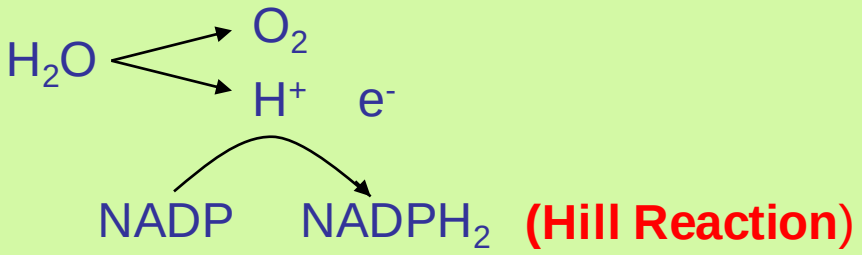
The energy released from respiration is used for growth and development of plants

How Do Plants Manufacture Their Own Food?

III. Photosynthesis

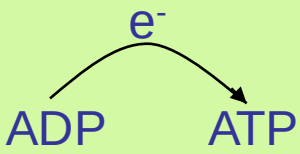
1. Light phase of photosynthesis

Photolysis – Cleavage of water into hydrogen and oxygen by light enery

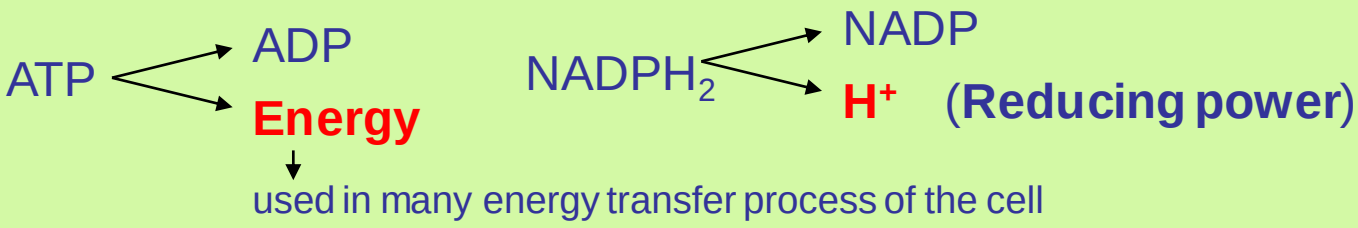


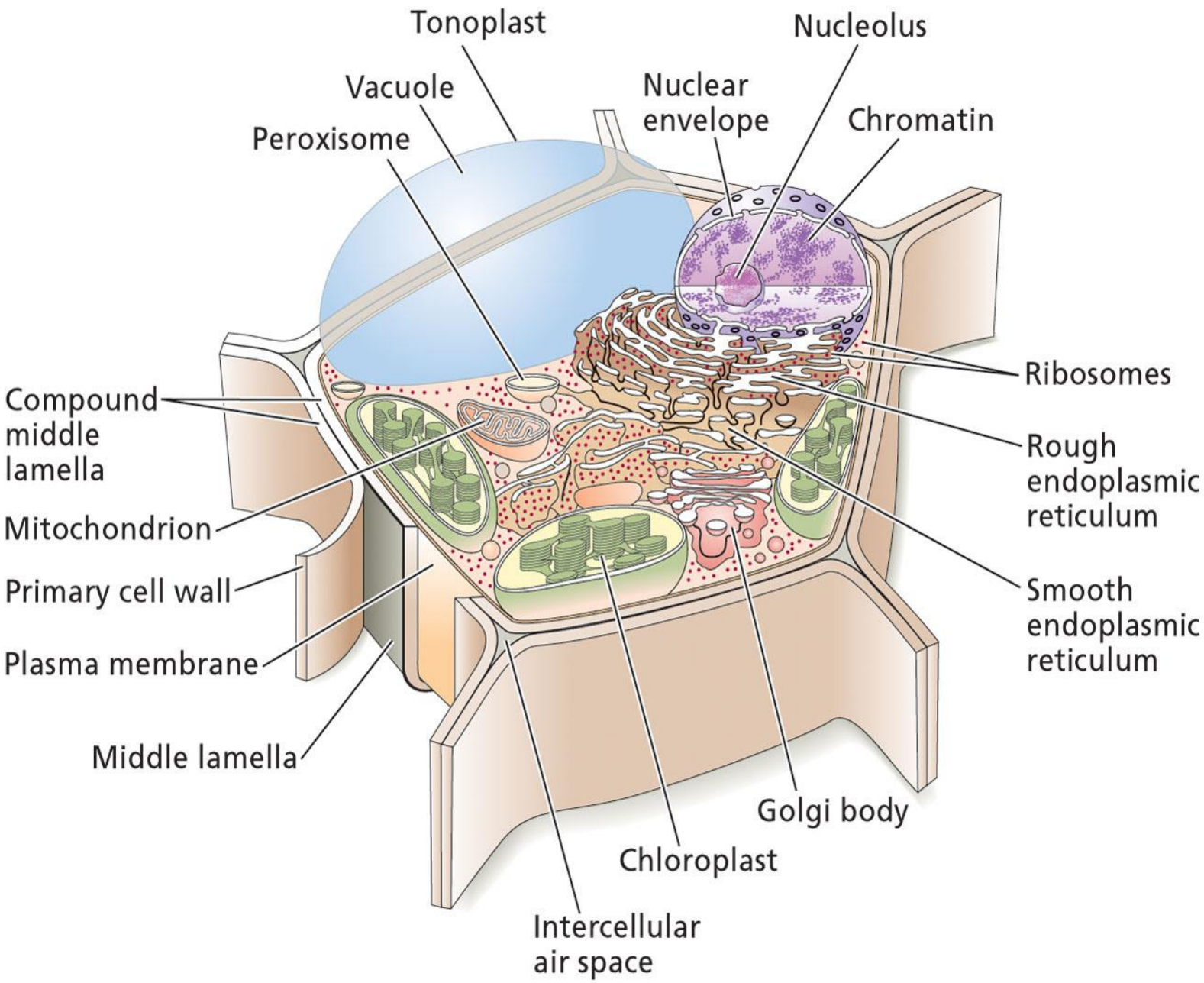
Photophosphorylation

Conversion of ADP to ATP by light energy



Sum: Conversion of light energy to chemical energy

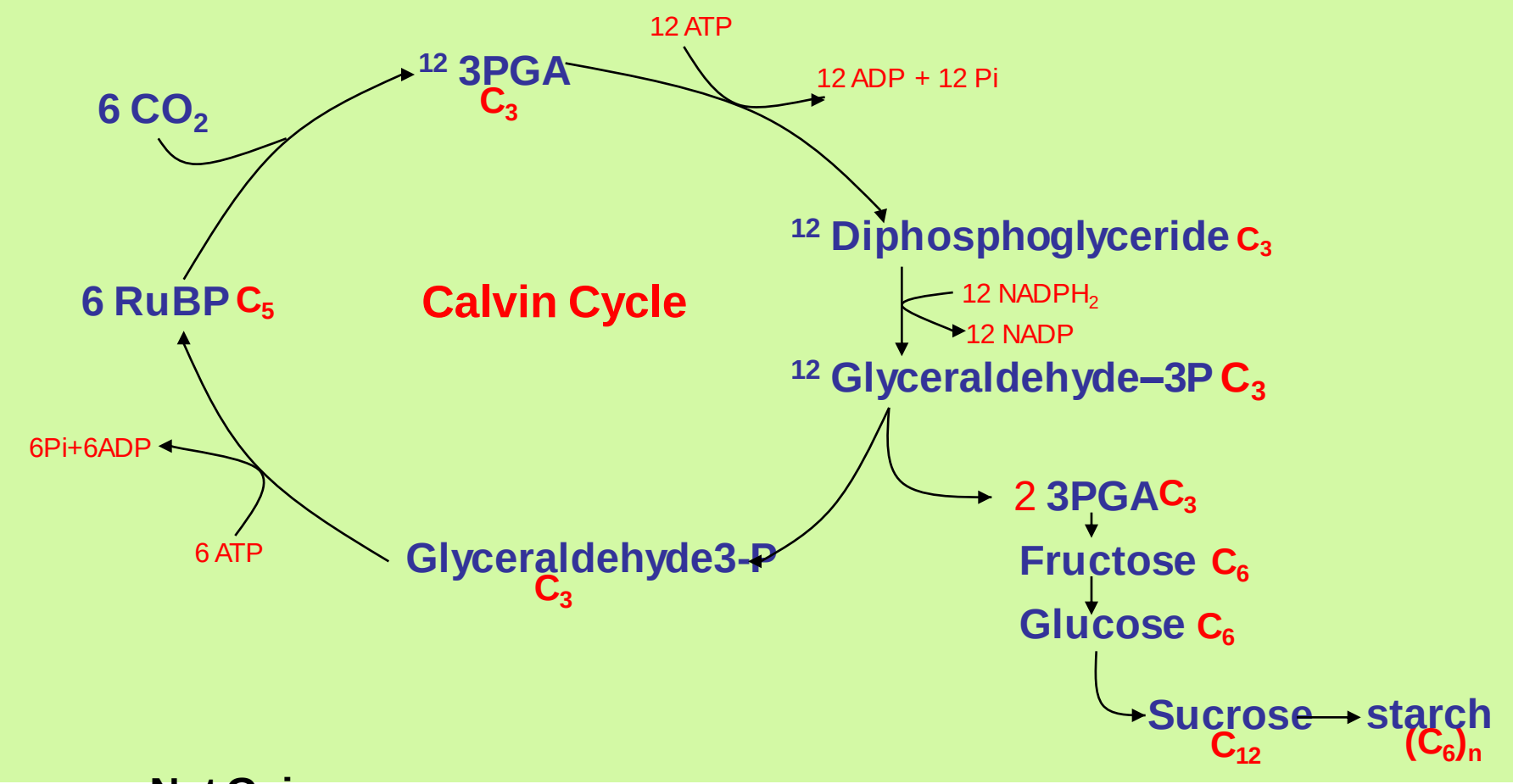




2. Dark Phase of Photosynthesis

Calvin Cycle

A series of enzymatically mediated reactions in which CO_2 reduced to 3-phosphoglyceraldehyde(3PGA) and the CO_2 receptor (Ribulosebiphosphate: RUBP) is generated



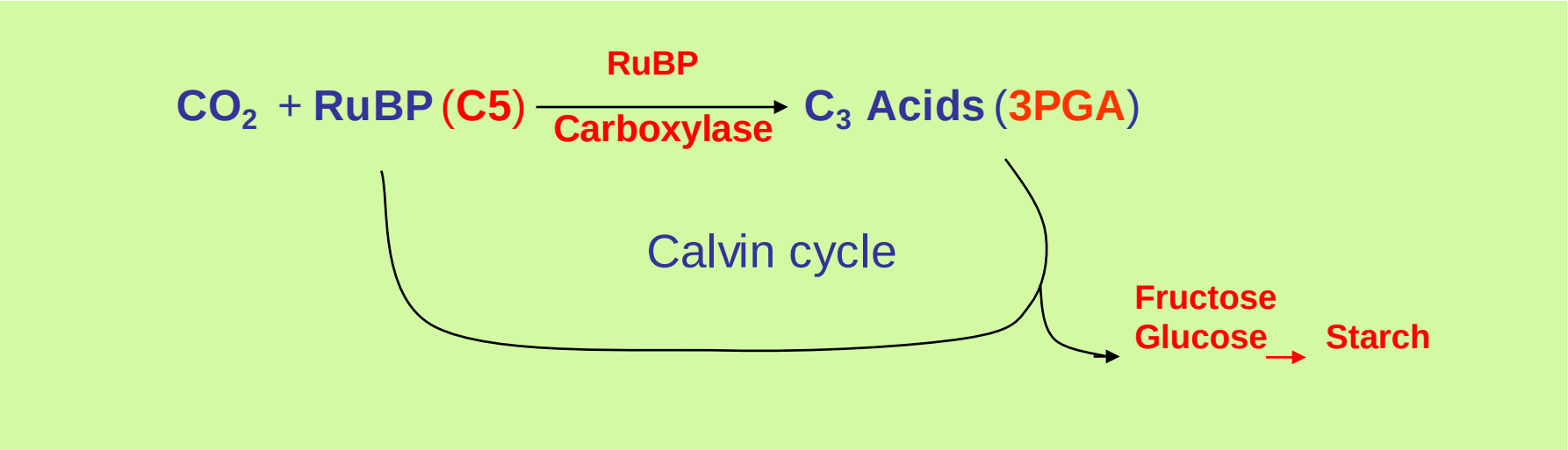
Net Gain

$$6\ CO_2\ (6C) + 12\ H_2O + light \longrightarrow C_6H_{12}O_6\ (C_6) + 6\ O_2 + 6\ H_2O$$

3. Two Different CO_2 Pathways

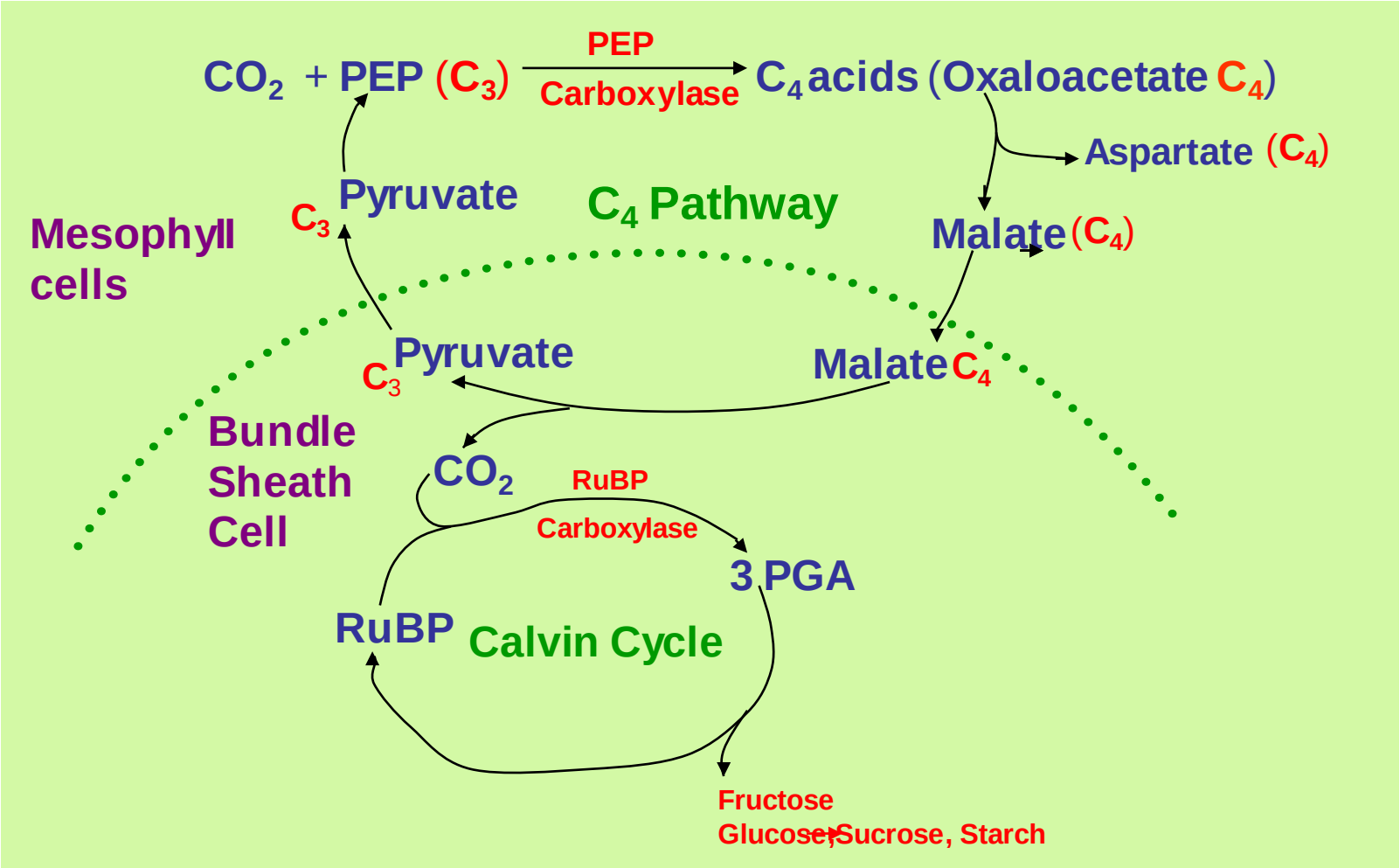
C_3 Pathway

- C_3 Plants (many dicots: soybean, tomato, apple, etc.)
- The 1st product of CO_2 fixation is C_3 acids
- Only the Calvin Cycle operates
- Photorespiration exists

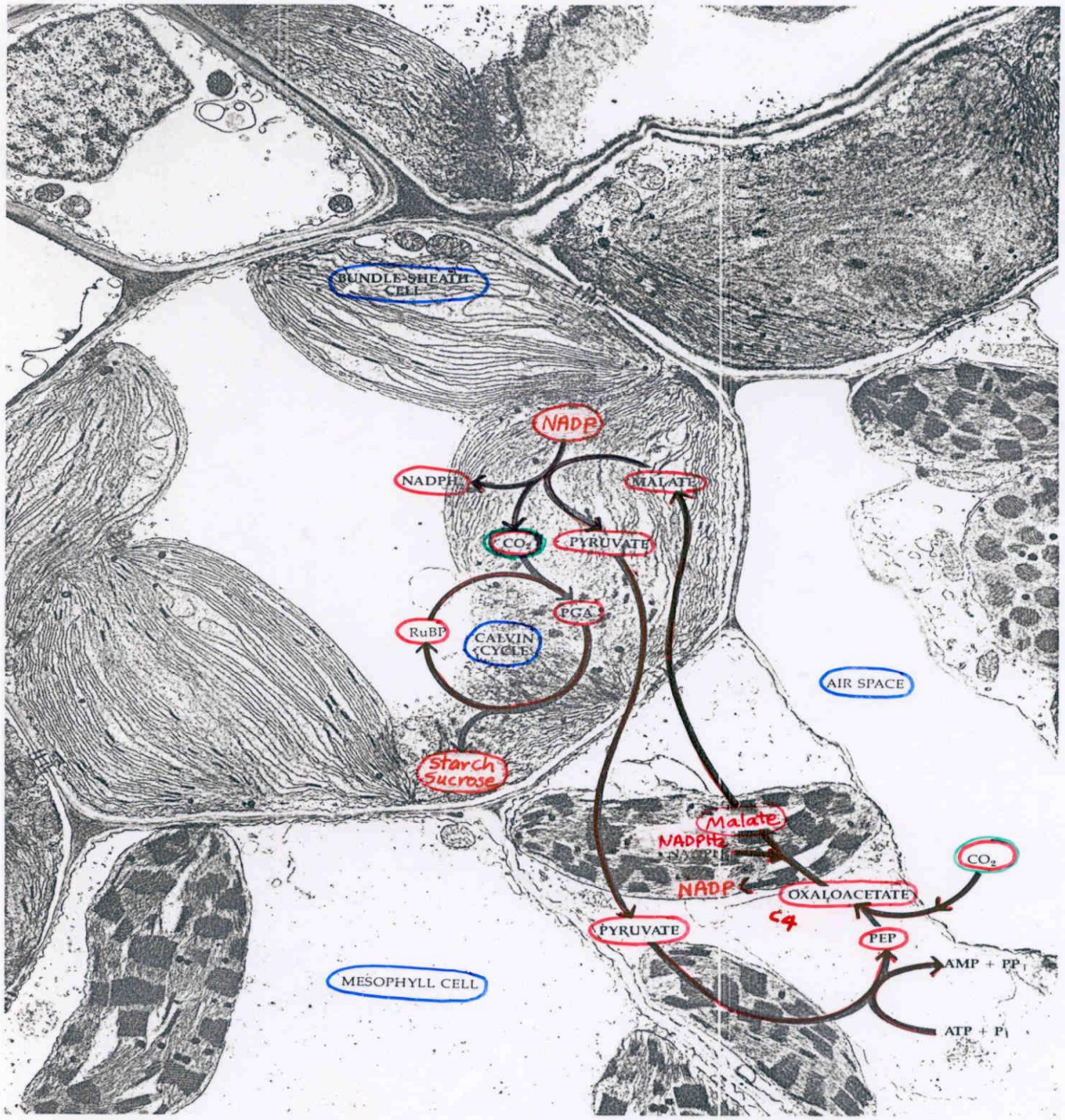


C_4 Pathway

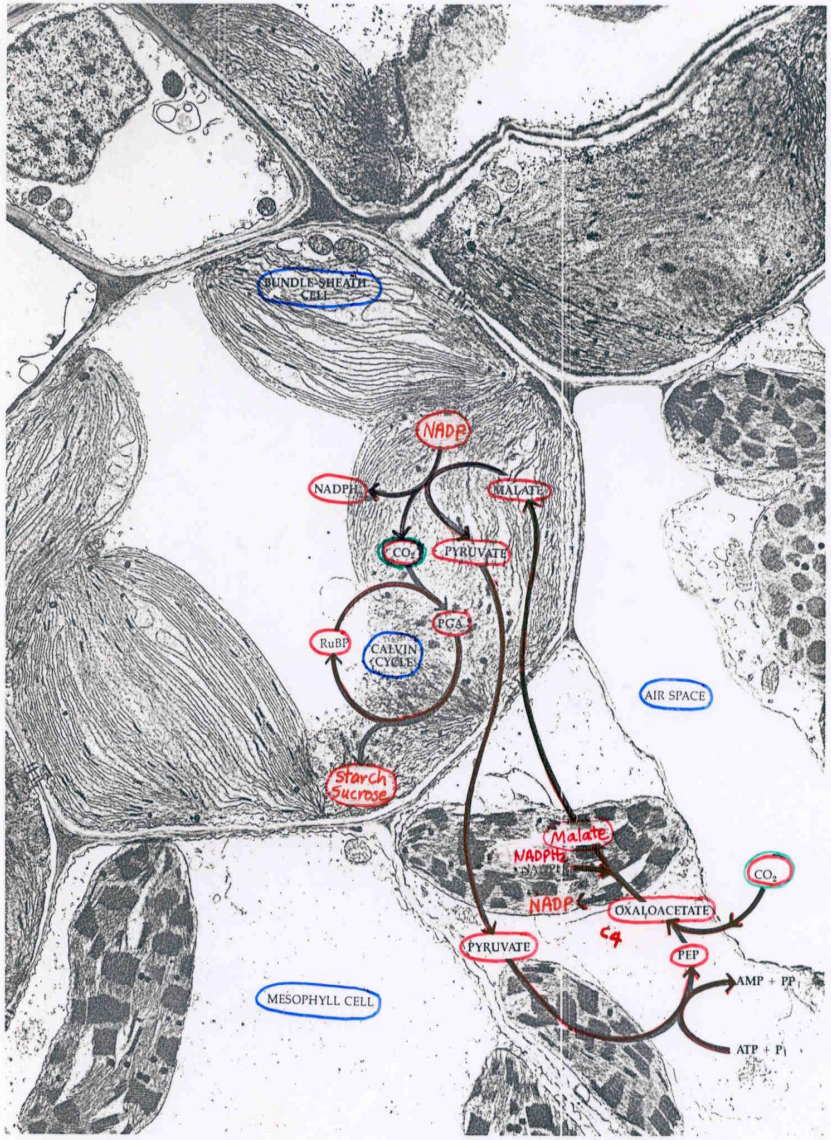
- C_4 Plants (Tropical grass, corn, sugarcane, some dicots like amaranth, Atriplex)
- First product of CO_2 fixation is C_4 acids
- Both C_4 pathway and Calvin cycle operate
- Lacks photorespiration
- C_4 plants grow faster than C_3 plants, due to efficient use of CO_2



C4 Pathway


BUNDLE SHEATH CELL
NADP
NADPH
MALATE
CO_2
PYRUVATE
PGA
RuBP
CALVIN CYCLE
AIR SPACE
Starch Sucrose
Malate
NADPH
NADP
CO_2
OXALOACETATE
C4
PYRUVATE
PEP
AMP + PP
MESOPHYLL CELL
ATP + P

C4 Pathway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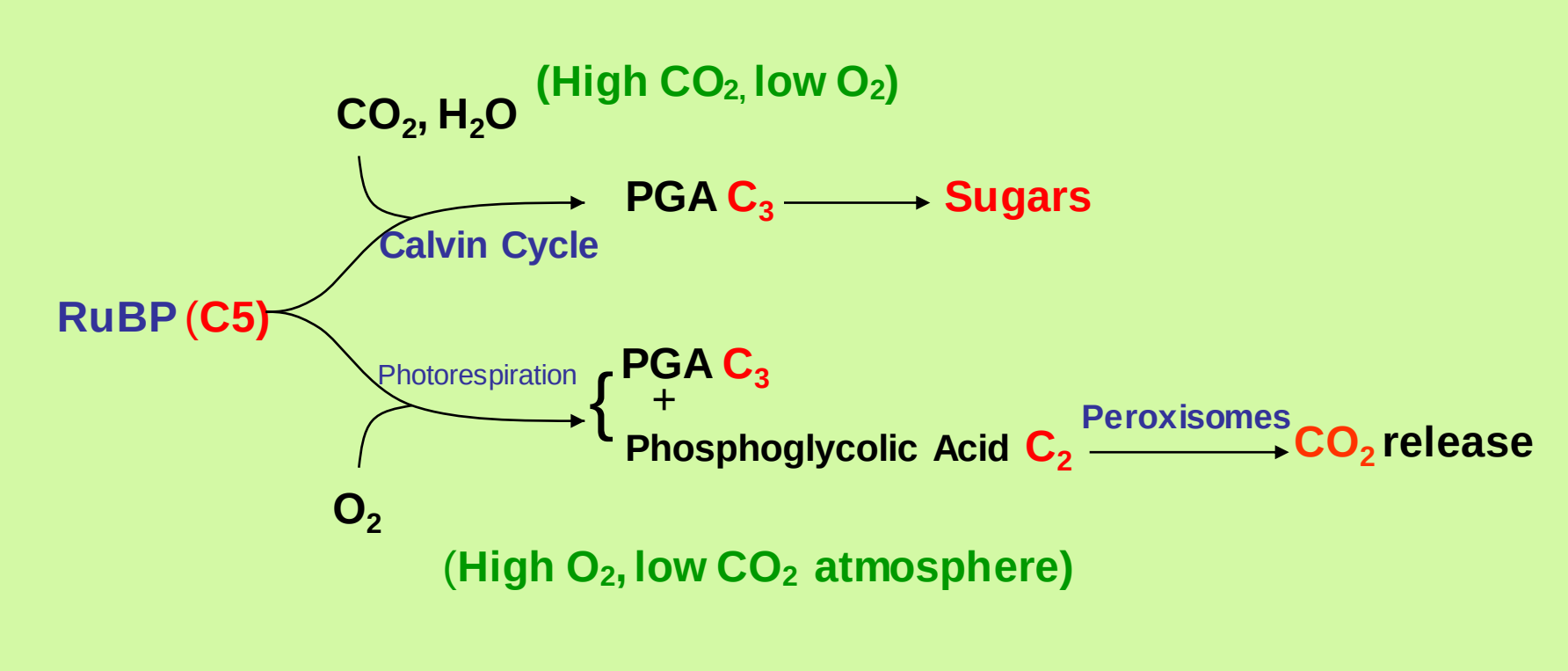
CO_2
PYRUVATE
PEP
AMP + PP
ATP + P
MESOPHYLL CELL

4. Photorespiration

The process of respiration that consumes oxygen and releases CO_2 in the presence of light

- **Does not produce ATP**
- **Consumes the reducing power for reducing O_2 to CO_2**
- **Reduces photosynthetic efficiency**
- **Occurs in C_3 plants**



5. Carbon Dioxide Compensation Point

A steady state of CO_2 concentration in the air at which CO_2 taken up by plants via photosynthesis is the same as the CO_2 given off via respiration

- **At CO_2 compensation point, no growth occurs**
- **Below compensation point, plants will degrade**
- **C_3 plants have higher CO_2 compensation points than the C_4 plants**

CO_2 Compensation Points:

Soybean (C_3 plant) - - - - - 50 ppm at 25 ^oC

Corn (C_4 plant) - - - - - - - - - 10 ppm at 25 ^oC

Ambient CO2 concentration: 300 ppm (0.03 %)

- **Same principles apply to Light Compensation Points**

Net Photosynthesis = Gross Photosynthesis-Respiration

IV. Nutrient Absorption and Translocation

1. Plant Nutrients
   - 16 elements
   - Macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K) Calcium (Ca), Magnesium (Mg), Sulfur (S)
   - Micronutrients: Boron (B), Chloride (Cl), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn)

2. Ability to Manufacture Food
   - Most green plants are autotrophic

   Autotrophic – Capable of manufacturing its own food from minerals

   Heterotrophic – Incapable of manufacturing its own food Depends on other sources for organic matter

   (Immature embryo, dodder, human)

Heterotrophic (Parasitic) Plants

Cuscuta species (Dodders)

3. Nutrient and Water Movement

- **Diffusion** – Movement of molecules (a substance) from a region of high concentration to the region of low concentration

- **Osmosis** – Diffusion of water through differentially permeable membrane

  Reverse osmosis (RO) water- purified water low in salt content

- **Translocation** – Movement of inorganic and organic solutes from one part to another part of the plant

  Water conduction and mineral movement via xylem

  Carbohydrate translocation through phloem

- **Transpiration** – Loss of water vapor from the leaf via stomata
- **Evaporation –** Loss of water by vaporization
- **Evapo-transpiration** – Loss of water by evaporation and transpiration

V. Plant Respiration

1. Reverse of Photosynthesis

The process of releasing energy, CO_2 and water from organic materials by oxidation

$C_6H_{12}O_6 + 6\ O_2$ ----------► $6\ H_2O + 6\ CO_2$ + Energy

2. Chemical Process

Glycolysis – Conversion of C_6 sugars to CO_2 and pyruvic acid

Citric Acid Cycle (Kreb Cycle) – Oxydation of pyruvic acid to H^+, e^- and CO_2 (occurs in mitochondria)

3. The Q_{10}

- **The rate of respiration doubles when temperature rises 10 °C (18 °F)**
- **Respiration can be reduced by lowering O_2 and increasing CO_2 concentrations**

Application: a) CO_2 storage of apples and pears

b) Hypobaric storage of flowers and fruits

(Low atmospheric pressure)

VII. Plant Constituents

- Carbohydrates
  - **Monosaccharides - simple carbohydrates (pentose C_5, hexose C_6)**
  - **Disaccharides – maltose (glu-glu), sucrose (glu-fru) C_{12}**
  - **Olygosaccharides -1-10 monosacchrides lined together**
  - **Polysaccharides – starch (poly glu), cellulose, hemicellulose, insulin, etc.**
- Lipids (**fats, phospholipids, waxes**)
- Proteins **(structural, soluble)**
- Aromatic Compounds **(Vanillin, flavonoids)**
- Terpenoids and Steroids
- Non-Protein Nitrogen Compounds **(DNA, RNA, Bases)**
- Vitamins (**Vitamin C, Thiamin B_1**)