Cell Respiration: Energy for Plant Metabolism
Production and consumption of ATP

Coupled reactions: Endergonic reactions are coupled to exergonic ones

Glucose is the originating molecule for respiration
These reactions proceed the same way in plants and animals. Process is called cellular respiration.
Mitochondrion structure and function

Glycolysis can happen in the chloroplast during the dark reactions
Aerobic Cellular Respiration

- Oxygen + piruvate =

  1. Glycolysis
  2. Kreb’s Cycle
     (Citric acid cycle)
  3. Electron Transport Chain

NAD+ Nicotinamide adenine dinucleotide
FAD+ Flavin adenine dinucleotide
Reduction reaction = NADH and FADH2
In the respiratory chain, the transfer of electrons from substrates to oxygen is coupled to translocation of protons across the membrane. The energy stored in the proton gradient is used to drive the synthesis of ATP by an ATP synthase.
• Most larger organisms resort to glycolysis only for short periods when oxygen is temporarily absent (plant roots) or diminished
  – Marshes, bogs, gut of animals, sewage treatment ponds
The rates of plant respiration are controlled by:

- Energy demand
- Substrate availability
- Oxygen supply (oxygenic, anoxia, hypoxia)
- Temperature
- Water stress
- pH
- Toxic levels of aluminum
25-70% accumulation of carbohydrates are used in respiration every day.

25% may be required to support microsymbionts.

Legume plants form nitrogen-fixing nodules in the symbiosis with soil bacteria (*Rhizobium, Bradyrhizobium, Azorhizobium, Mesorhizobium and Sinorhizobium*).

Mychorrizas on corn
Relative Growth Rate (RGR) is associated directly with N and P

N and P = Less invest of energy in roots
More invest of energy in photosynthetic organs
The respiratory quotient (RQ)

Ratio between number of released molecules of CO$_2$ and that of O$_2$ consumed

Ideal conditions of cellular respiration in plants:

Absence of biosynthetic processes in non photosynthetic tissues

Sucrose as only substrate

RQ = 1.0

Sucrose is 100% oxidized to CO$_2$ + H$_2$O

1 sucrose molecule = 60 ATP’s
The respiratory quotient (RQ)

*Triticum aestivum* (wheat)
carbohydrates storage seeds
RQ ≈ 1

*Linum ausitatissimum* (Flax)
Fat storing seed
RQ = 0.4
Back to the coupled reactions: Thermoregulation

1) Annona, 2) *Victoria amazonica* (amazonic lily), 3) *Nelumbo nucifera* (sacred lotus)

Air temperature 10 -30 °C
Flowers temperature 30 -35 °C
Temperature Regulation by Thermogenic Flowers

Oxygen Consumption (ml min$^{-1}$)

Receptacle Temperature ($^\circ$C)

Heat Production (W)

Ambient Temperature ($^\circ$C)

sacred lotus (*Nelumbo nucifera*)
The uncoupling proteins (UCPs) are transporters, integral membrane proteins present in the mitochondrial inner membrane.

UCP genes have also been found in fish and birds. There is also functional evidence to suggest their presence in fungi and protozoa. This wide distribution is an indication that physiological uncoupling may be a general strategy.
Uncoupling proteins and thermogenesis

An increased cellular demand for ATP results in an increased rate of substrate oxidation. Thermogenesis is achieved because UCP’s allows the re-entry of protons into the matrix and therefore uncouples respiration from ATP synthesis.
Plant mitochondria contain additional enzymes which do not pump protons.
Alternative oxidase, the cyanide radical

Membrane potential of a pea cell collapses when $CN^-$ is added to the external solution.

$CN^-$ poisons mitochondria, blocks ATP production, because $CN^-$ inhibits cytochrome c oxidase.
Cyanid resistant respiration

*Sauromatum gottatum* (voodoo lily)
Inhibition = red squares
E.g. ATP, NADH, Citrate, PEP

Activation = green arrows
E.g. ADP, P_i
Uncoupling protein

- Increases proton permeability of inner mitochondria membrane
- Acts as an uncoupler ➔ less ATP, more heat is produced
- Plants, animals, fungi, prokaryotes

Alternative oxidase pathway

- No ATP synthesis, so heat is generated
- Only in plant mitochondria

Role of alternative oxidase pathway

- Heat generation
- Regulation of ATP synthesis
- Regulation of metabolite synthesis
- Helps overcome environmental stress
Glycolysis, pentose phosphate pathway and citric acid cycle contribute precursors