CHAPTER

11 Respiration in Plants

Introduction

- All the energy required for 'life' processes is obtained by oxidation of food.
- **Cellular respiration** is the mechanism of breakdown of food materials within the cell to release energy, and the trapping of this energy for synthesis of ATP.
- The compounds that are oxidized during this process are known as respiratory substrates.
- Usually carbohydrates are oxidised to release energy, but proteins, fats and even organic acids can be used as respiratory substances.
- Plants need oxygen for respiration, which is released during light reaction of photosynthesis in green parts. Other parts receive it by gaseous exchange through lenticels.

Glycolysis

- Also called EMP pathway.
- Breakdown of glucose in cytoplasm into two molecules of 3-C Pyruvate (partial oxidation).
- Present in all living organisms (aerobic as well as anaerobic).
- Two phases: Preparatory and Pay-off.
- Net end-products: **2 ATP, 2 NADH + H^+, 2 Pyruvate**

Fate of Pyruvic acid

- If oxygen is not available, it undergoes fermentation (incomplete oxidation of glucose), which may be of two types:
  - **Alcoholic fermentation:** In yeast, pyruvate is converted to ethanol and CO_2 catalysed by pyruvic acid decarboxylase and alcohol dehydrogenase.
  - **Lactic acid fermentation:** In some bacteria and animal cells, pyruvate is converted to lactic acid, catalyzed by lactate dehydrogenase.
- In fermentation there is a net gain of only two molecules of ATP for each molecule of glucose degraded to pyruvic acid.
- If oxygen is available, pyruvate is transported to mitochondria for aerobic respiration.

Aerobic respiration

- Occurs in mitochondria
- The crucial events in aerobic respiration are:
  - The complete oxidation of pyruvate by the stepwise removal of all the hydrogen atoms, leaving three molecules of CO_2.
  - The passing on of the electrons removed as part of the hydrogen atoms to molecular O_2 with simultaneous synthesis of ATP.
- Pyruvate is oxidatively decarboxylated in mitochondrial matrix to form Acetyl Co. A, catalysed by pyruvic dehydrogenase, require the participation of several coenzymes, including NAD^+ and Coenzyme A. **Two molecules of NADH + H^+** are produced from 2 molecules of pyruvate by this step.
- Acetyl Co. A enters the TCA cycle.

Tricarboxylic Acid Cycle

- Also called Krebs' Cycle.
- Citrate synthase catalyses the condensation of Acetyl Co. A with OAA to form Citrate.
- Two steps of decarboxylation, formation of several intermediates lead to release of CO_2, and regeneration of OAA.
- Net end-products from two molecules of Acetyl Co. A: **2 GTP, 6 NADH + H^+, 2 $FADH_2$**.

Electron Transport System (ETS) and Oxidative Phosphorylation

- NADH + H^+ and $FADH_2$ are oxidised through the electron transport system and the electrons are passed on to O_2 resulting in the formation of H_2O, thus producing ATP (Oxidative Phosphorylation).
- ETS is present in the inner mitochondrial membrane and consists of 5 complexes:
  - **Complex I: NADH dehydrogenase:** takes e^- from NADH and transfer to Ubiquinone. 4 H^+ transported to inter-membranal space of mitochondria.
  - **Complex II: Succinate dehydrogenase:** takes e^- from $FADH_2$ and transfer to Ubiquinone.
  - Ubiquinone transports the e^- from complex I and II, and donate them to complex III.
  - **Complex III: Cytochrome b-c_1 complex:** takes e^- from Ubiquinone. 4 H^+ transported to inter-membranal space of mitochondria.

- **Complex IV: Cytochrome c oxidase complex:** cytochrome c transports e^- from complex III to complex IV. Complex IV finally donates the e^- to O_2 thus producing water. 2 H^+ transported to inter-membranal space of mitochondria.
- **Complex V: ATP synthase:** A trans-membrane enzyme which synthesizes ATP due the breakdown of proton gradient during the movement of H^+ from the inter-membranal space to the matrix of mitochondria.

The respiratory balance sheet

Table. 1: ATP yield in complete oxidation of one molecule of glucose by aerobic respiration

Source	$FADH_2$ Produced	NADH Produced	ATP Yield
Glycolysis			2 ATP
Glycolysis		2 NADH	6 ATP
Pyruvate to acetyl CoA		2 NADH	6 ATP
Krebs cycle			2 ATP
Krebs cycle		6 NADH	18 ATP
Krebs cycle	2 $FADH_2$		4 ATP
Total			**38 ATP**
A balance sheet accounting for ATP production from glucose by aerobic respiration. Total ATP production can vary between 36 to 38 ATP for each glucose processed.			

Amphibolic pathway

- Apart from catabolism of glucose, respiration is also involved in the synthesis of sevral compounds from the intermediates of aerobic respiration.

Respiratory quotient

- The ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration is called the respiratory quotient (RQ) or respiratory ratio.
- RQ of glucose is 1, tripalmitin is 0.7, for proteins is approximately 0.9, and more than 1 for organic acids.