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RESPIRATION

IN

PLANTS

Living things cannot withstand this sudden release of energy and so the energy rich molecules are made to release energy in a stepwise process. This process of release of energy by breaking down of organic molecules is called cell respiration.

Photosynthesis, of course, takes place within the chloroplasts , whereas the breakdown of complex molecules to yield energy takes place in the cytoplasm and in the mitochondria . The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called respiration.

The compounds that are oxidised during this process are known as respiratory substrates.

During oxidation within a cell, all the energy contained in respiratory substrates is not released free into the cell, or in a single step. It is released in a series of slow step-wise reactions controlled by enzymes, and it is trapped as chemical energy in the form of ATP.

DO PLANTS BREATHE?

each plant part takes care of its own gas-exchange needs. There is very little transport of gases from one plant part to another.

plants do not present great demands for gas exchange. Roots, stems, and leaves respire at rates far lower than animals do. Only during photosynthesis are large volumes of gases exchanged and, each leaf is well adapted to take care of its own needs during these periods.

distance that gases must diffuse even in large, bulky plants is not great. Each living cell in a plant is located quite close to the surface of the plant.

’ In stems, the ‘living’ cells are organised in thin layers inside and beneath the bark. They also have openings called lenticels.

GLYCOLYSIS

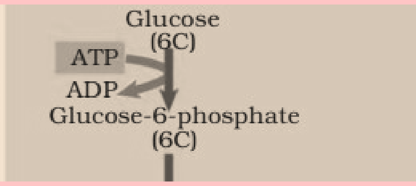
Glycolysis occurs in the cytoplasm of the cell and is present in all living organisms.

In this process, glucose undergoes partial oxidation to form two molecules of pyruvic acid. In plants, this glucose is derived from sucrose, which is the end product of photosynthesis, or from storage carbohydrates.

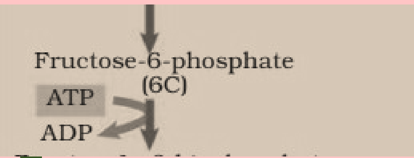
Sucrose is converted into glucose and fructose by the enzyme, invertase, and these two monosaccharides readily enter the glycolytic pathway.

Steps of glycolysis

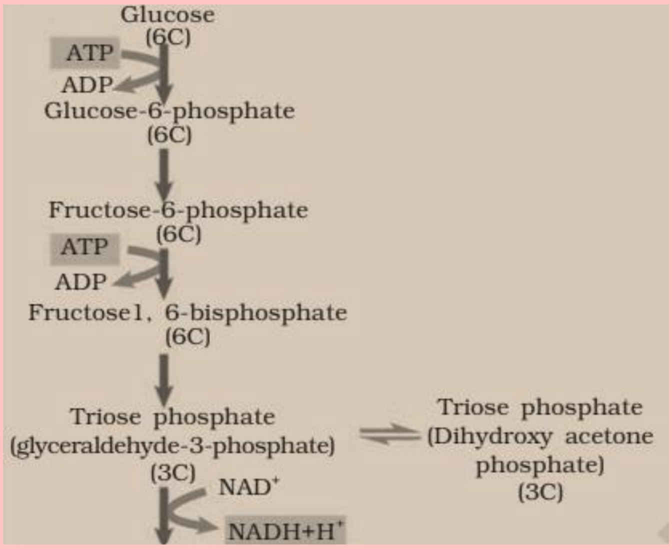
Glucose and fructose are phosphorylated to give rise to glucose-6- phosphate by the activity of the enzyme hexokinase



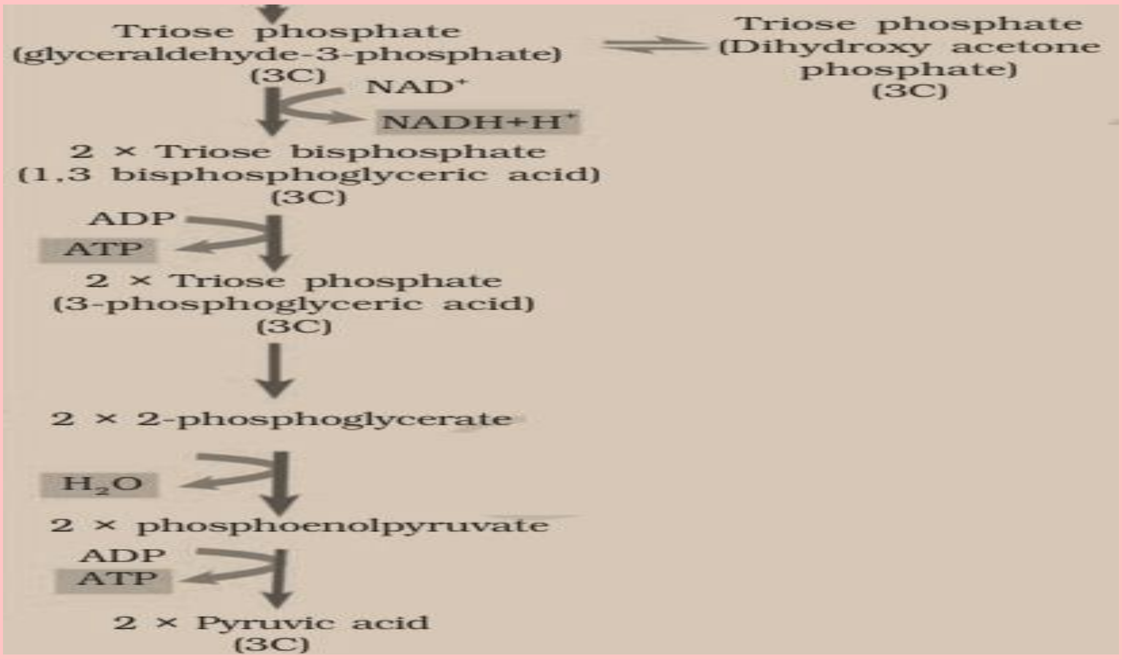
This phosphorylated form of glucose then isomerises to produce fructose-6- phosphate. Subsequent steps of metabolism of glucose and fructose are same.



ATP is utilised at two steps: first in the conversion of glucose into glucose 6-phosphate and second in the conversion of fructose 6-phosphate to fructose 1, 6-bisphosphate



The fructose 1, 6-bisphosphate is split into dihydroxyacetone phosphate and 3phosphoglyceraldehyde (PGAL).



Two redox-equivalents are removed from PGAL and transferred to a molecule of NAD+ . PGAL is oxidised and with inorganic phosphate to get converted into BPGA.

The conversion of BPGA to 3-phosphoglyceric acid (PGA), is also an energy yielding process; this energy is trapped by the formation of ATP.

Another ATP is synthesised during the conversion of PEP to pyruvic acid.

FERMENTATION

the incomplete oxidation of glucose is achieved under anaerobic conditions by sets of reactions where pyruvic acid is converted to CO2 and ethanol. The enzymes, pyruvic acid decarboxylase and alcohol dehydrogenase catalyse these reactions.

In both lactic acid and alcohol fermentation not much energy is released; less than seven per cent of the energy

in glucose is released and not all of it is trapped as high energy bonds of ATP.

AEROBIC RESPIRATION

Aerobic respiration is the process that leads to a complete oxidation of organic substances in the presence of oxygen, and releases CO_2 , water and a large amount of energy present in the substrate

Pyruvate, which is formed by the glycolytic catabolism of carbohydrates in the cytosol, after it enters mitochondrial matrix undergoes oxidative decarboxylation by a complex set of reactions catalysed by pyruvic dehydrogenase. The reactions catalysed by pyruvic dehydrogenase require the participation of several coenzymes, including NAD^+ and Coenzyme A.

Two molecules of NADH are produced from the metabolism of two molecules of pyruvic acid.

The acetyl CoA then enters a cyclic pathway, tricarboxylic acid cycle, more commonly called as Krebs' cycle.

Tricarboxylic Acid Cycle OR Krebs' cycle

The TCA cycle starts with the condensation of acetyl group with oxaloacetic acid (OAA) and water to yield citric acid.

The reaction is catalysed by the enzyme citrate synthase and a molecule of CoA is released.

Citrate is then isomerised to isocitrate.

It is followed by two successive steps of decarboxylation, leading to the formation of α-ketoglutaric acid and then succinyl-CoA.

During the conversion of succinyl-CoA to succinic acid a molecule of GTP is synthesised.

In a coupled reaction GTP is converted to GDP with the simultaneous synthesis of ATP from ADP.

Also there are three points in the cycle where NAD^+ is reduced to $NADH + H^+$ and one point where FAD^+ is reduced to $FADH_2$.

The continued oxidation of acetyl CoA via the TCA cycle requires the continued replenishment of oxaloacetic acid, the first member of the cycle.

In addition, it also requires regeneration of NAD^+ and FAD^+ from NADH and $FADH_2$ respectively.

Electron Transport System (ETS) and Oxidative Phosphorylation

The metabolic pathway through which the electron passes from one carrier to another, is called the electron transport system (ETS).

Electrons from NADH produced in the mitochondrial matrix during citric acid cycle are oxidised by an NADH dehydrogenase (complex I), and electrons are then transferred to ubiquinone located within the inner membrane.

Ubiquinone also receives reducing equivalents via $FADH_2$ (complex II)

The reduced ubiquinone (ubiquinol) is then oxidised with the transfer of electrons to cytochrome c via cytochrome bc 1 complex (complex III).

Cytochrome c is a small protein attached to the outer surface of the inner membrane and acts as a mobile carrier for transfer of electrons between complex III and IV.

When the electrons pass from one carrier to another via complex I to IV in the electron transport chain, they are coupled to ATP synthase (complex V) for the production of ATP from ADP and inorganic phosphate.

Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while that of one molecule of FADH2 produces 2 molecules of ATP.

Oxygen acts as the final hydrogen acceptor. Unlike photophosphorylation where it is the light energy that is utilised for the production of proton gradient required for phosphorylation, in respiration it is the energy of oxidation-reduction utilised for the same process. It is for this reason that the process is called oxidative phosphorylation.

AMPHIBOLIC PATHWAY

Breaking down processes within the living organism is catabolism, and synthesis is anabolism. Because the respiratory pathway is involved in both anabolism and catabolism, it would hence be better to consider the respiratory pathway as an amphibolic pathway.

RESPIRATORY QUOTIENT

during aerobic respiration, O2 is consumed and CO2 is released. The ratio of the volume of CO2 evolved to the volume of O2 consumed in respiration is called the respiratory quotient (RQ) or respiratory ratio.

$$RQ = \frac{\text{volume of CO evolved}}{\text{volumeof O consumed}}$$

The respiratory quotient depends upon the type of respiratory substrate used during respiration. When carbohydrates are used as substrate and are completely oxidised, the RQ will be 1, because equal amounts of CO2 and O2 are evolved and consumed.