

Hello Students I welcome you all to the program S.Y.BSc. Subject Botany Semester 4, Course code BOC One Zero Four, Course title plant Physiology. Unit 5, photosynthesis module name C3 and C4 pathway of carbon fixation. I am Dr. Suraksha Dongrekar assistant professor at St. Xavier's College, Mapusa- Goa. Outline C3 pathway of carbon fixation, C4 pathway of carbon fixation and difference between C3 and C4 plants. Learning outcomes defines photosynthesis, Explains C3 and C4 Pathway of carbon fixation differentiates between C3 and C4 plants. Introduction photosynthesis as we know is a process by which green plants synthesize organic matter in the presence of light, during photosynthesis light energy is converted into chemical energy and is utilized to fix carbon in the form of carbohydrate along with oxygen as an end product process requires raw materials such as carbon dioxide, water, light and pigments. The most important one is chlorophyll *a*. Now photosynthesis is completed in two steps. We have a light dependent reaction and we have a light independent reaction. In the case of light dependent reaction since it depends on the light we call it as a light reaction or it is also called as photophosphorylation. Now this reaction takes place in the thylakoid of the chloroplast, and here the synthesis of energy rich molecules like ATP and NADPH takes place. In the case of the light independent reaction, as it is independent of the light, we call it as a dark reaction or it is also called as Calvin cycle or C3 cycle Or it is also called as photosynthetic carbon reduction cycle. This takes place in the stroma of the chloroplast. Here the glucose is synthesized. C3 pathway of carbon fixation or Calvin Cycle was first observed by Melvin Calvin in the year 1957 in *Chlorella*, which is unicellular green alga. Calvin was awarded Nobel Prize for this work in 1961; the first stable compound in Calvin cycle is C3 carbon compound i.e. phospho glyceric acid.

So the cycle is called as C3 cycle. It is also known as biosynthetic pathway because the ATP and NADPH are produced in the light reaction utilized to synthesize sugar or carbohydrate as a byproduct. The examples of C3 plants are barley, oats, rice, wheat, cotton, eucalyptus, sunflower, soybean, sugar, beets, potatoes, tobacco, etc. Now this cycle is completed in three steps. The first is carboxylation second reduction and the third one is regeneration. As you can see in this particular diagram here, carboxylation is the step in which the carbon dioxide is Fixed with the help of an enzyme called Rubisco to produce the first stable C 3 carbon compound. In the reduction stage that is second step, the three carbon compound which is formed is reduced with the help of any energy rich source like ATP and NADPH, into two aldehyde, from which the glucose molecule will be synthesized and in the regeneration stage aldehyde is further reduced to regenerate the carbon dioxide acceptor that is RuBP so that the another molecule of carbon dioxide can be fixed. Now how this cycle takes place that we will see in the next slide. Here you can see the carbon dioxide enters the plant mesophyll layer of the Leaf when the stomata opens so this carbon dioxide when enters it is accepted by the five carbon compound which is present in the plant body i.e. ribulose 1,5 bisphosphate. It reacts with carbon dioxide in the presence of an enzyme called Rubisco, and there is a synthesis of first stable three carbon compound that is 3 phosphoglycerate or we also call it as phosphoglycerate. Now this is the carboxylation stage. Once the three Phosphoglycerate is formed, it will undergo the second step that is reduction. So reduction involves a number of reactions where first the three phosphoglycerate will undergo phosphorylation were in the six ATP molecules are utilized to add one inorganic phosphate in the phosphoglycerate molecule to get 1, 3 diphosphoglycerate. Now, this 1, 3 diphosphoglycerate will be further reduced with the help of 6 molecules of NADPH to get and aldehyde called as glyceraldehyde. That is C3 phosphate glyceraldehydes which is 3 carbon compound. Now these

are the six molecules of three phosphoglycerate right. Now from this six molecule 1 molecule will enter into the formation or synthesis of the glucose molecule and remaining 5 molecules of glyceraldehyde 3 phosphate will enter into the third step, that is regeneration, where in this glyceraldehyde 3 phosphate undergo various reactions and produce 5 molecules of ribose 5 phosphate and this ribose 5 phosphate which is C5 carbon compound. Then with the help of three molecules of ATP undergoes phosphorylation that is addition of 1 inorganic phosphate to get the carbon dioxide acceptor molecule that is ribulose 1,5 bis phosphate.

So this is how the C3 cycle takes place in the plant body. Now we have taken here three molecules of carbon dioxide. So 3 molecules produce 1 molecule of three carbon sugar. So to get a glucose molecule we require six carbons. Ok, so this cycle will be repeated 2 times, so in one cycle if 9 ATP then in the case of two cycles, 18 ATP will be utilized and NADPH net utilization will be 12.

C4 pathway of carbon fixation. It is the alternate pathway of C3 cycle for carbon dioxide fixation. The pathway is also called as Hatch and Slack as they have worked out the pathway in 1966 and it is also called as this C4 dicarboxylic acid pathway. The first formed stable compound is C4 carbon compound that is oxaloacetic acid and that is why the name given as C4 cycle. This pathway is commonly seen in many grasses in sugar cane, maize, sorghum, Amaranthus etc. C4 pathway shows different type of leaf anatomy. The chloroplasts are dimorphic in nature in the leaves of these plants the vascular bundles are surrounded by bundle sheath of larger parenchymatous cells. These bundle sheath cells have chloroplasts. These chloroplasts of bundle sheath are larger and they lack grana and contain starch grains. The chloroplasts in mesophyll cells are smaller and always contain grana. This peculiar anatomy of leaves of C4 plant is called as Kranz anatomy. As you can see in this particular diagram, there is a presence of a bundle sheath covering the vascular bundle and outside the vascular bundle we have the presence of the mesophyll cells. Under some environmental conditions the Rubisco, which is one of the important enzymes instead of acting as a carboxylase, it acts as an oxygenase that is it fixes oxygen instead of carbon dioxide and this particular process is referred to as photorespiration. In the plant metabolism where enzyme Rubisco oxygenates. But instead of that, it wastes the energy which is produced in the photosynthesis. So this process reduces the efficiency of photosynthesis, potentially reducing photosynthetic output by 24 to 25% in C3 plants. So to avoid photorespiration, plants show modification in carbon dioxide fixation process called as C4 cycle.

So C4 cycle involves 2 carboxylation reactions, one taking place in the chloroplast of the mesophyll cells and another in the chloroplast of the bundle sheath. Here the PEP carboxylase that is phosphoenol pyruvate carboxylase enzyme occurs in the mesophyll cell, which fixes carbon dioxide from the atmosphere into four carbon compound which then enters the bundle sheath cell in the bundle sheath cell. It reacts with Rubisco to undergo C3 cycle for carbon fixation to produce the glucose molecule. Now here we see how the exactly C4 cycle takes place. First, the carbon dioxide enters mesophyll cells where it will react with the water molecule to produce carbonic acid. With the help of an enzyme, carbonic anhydrase. This carbonic acid then dissociates into one molecule of hydrogen, is given out and bicarbonate. This bicarbonate is then accepted by PEPCK and with the help of phosphoenol pyruvate carboxylase.

Carboxylation takes place and fixation of carbon dioxide takes place. In the first step stable four carbon compound that is oxaloacetic acid, this oxaloacetic acid, then, with the help of an enzyme Malic anhydrase, gets reduced to malic acid. This malic acid then diffuses out of the mesophyll cell and enters into the bundle sheath where it dissociates into or it gets decarboxylated into pyruvate and one molecule of carbon dioxide is given out. This is with the help of an enzyme called malate. Now this carbon dioxide is then accepted by RuBP present in the plant body in the bundle sheath cells, and then it will enter into the C3 cycle to produce one molecule of glucose. So in the C4 cycle one glucose molecule synthesized with the help of 1 carbon dioxide molecule, 2 ATPs are required. So for six carbon dioxide molecules, 12 ATP's are required in C4 cycle and in C3 cycle as we know there are 18 ATPs requirement so altogether 30 ATPs are required for the C4 cycle.

Now coming to the difference between C3 and C4 pathway of carbon fixation. In C3 plants the carbon fixation pathway is simple pathway. That is the Calvin cycle. But in C4 plants it is the C4 cycle or C4 dicarboxylic acid pathway or we also call it as Hatch Slack pathway. The first stable compound which is formed in C3 plants is C3 carbon compound PGA. But in C4 it is C4 carbon compound that is OA. In C3 plants, the leaves have only diffused mesophyll type of chloroplasts. But in C4 plants it shows Kranz anatomy that is dimorphic chloroplasts with compact Mesophyll around the bundle sheet. Here in C3, plants of photorespiration occur in C4 plants. No photorespiration occurs in C3 plants. Carbon dioxide acceptor is RuBP in the mesophyll tissue. In C4 plants PEP in Mesophyll and RuBP in the bundle sheath. Carboxylation takes place only once in C3 plants in C4 plants carboxylation takes place twice photosynthetically. C3 plants are less efficient and C4 plants are more efficient. 18 ATP is used to synthesize 1 glucose molecule in C3 plants whereas 30 ATPs are you used to synthesize 1 molecule of glucose in C4 plant. Examples of C3 plants are rice, sweet potato etc and C4 plants, maize, sugar, cane, sorghum etc. Here are some of the references. Thank you.