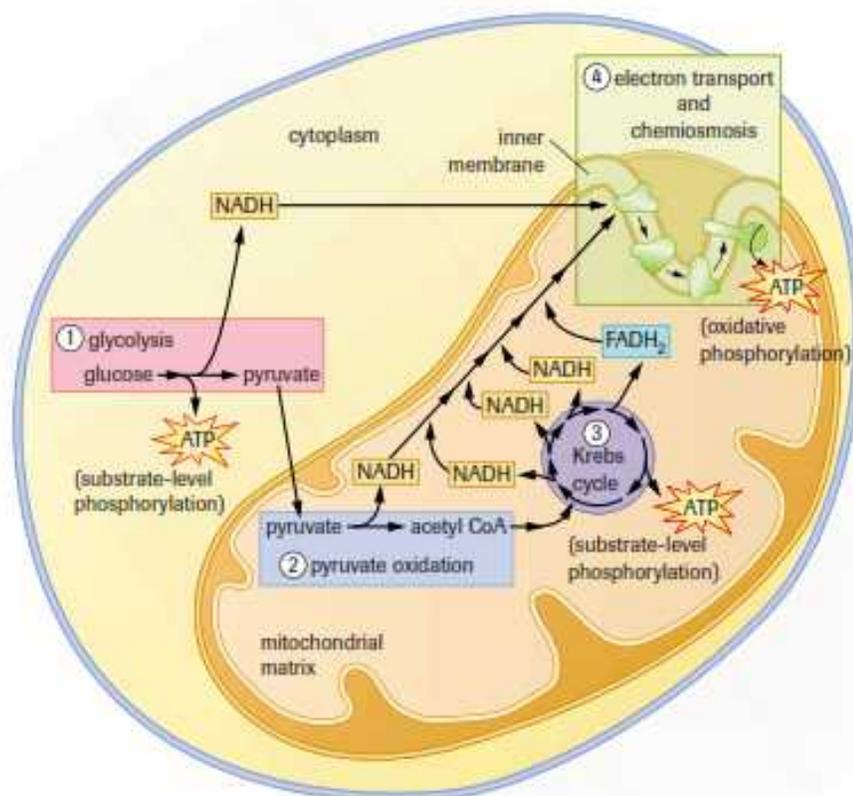


Cellular Respiration

What are the four phases of cellular Respiration?

All cells need energy all the time, and their primary source of energy is ATP. The methods cells use to make ATP vary depending on the availability of oxygen and their biological make-up. In many cases the cells are in an oxygen-rich environment. For example, as you sit and read this sentence, you are breathing in oxygen, which is then carried throughout your body by red blood cells. But, some cells grow in environments without oxygen (yeast in wine-making or the bacteria that cause botulism in canned food), and occasionally animal cells must function without sufficient oxygen (as in running sprints). In this activity you will begin to look at the aerobic and anaerobic processes that are used by all organisms to produce ATP.

Diagram 1 – Cellular Respiration



1. Cellular respiration occurs in four phases: **glycolysis**, **pyruvate oxidation (pyruvate decarboxylation)**, the **Krebs cycle**, and **oxidative phosphorylation and chemiosmosis**.

Examine diagram 1 and answer the following questions:

- a. Which phase of cellular respiration occurs in the cytoplasm of the cell?

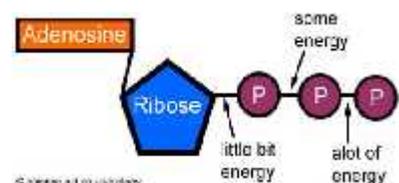
- b.* What is the initial reactant of this phase?
- c.* What is the final products of this phase?
- d.* Phase 2, Where is it taking place?
- e.* What is the initial reactant of phase 2?
- f.* What are the final products of phase 2?
- g.* One of the phase produces NADH, FADH₂ and ATP, what is this phase called and where is it occurring?
- h.* What is the initial molecule necessary for phase 3 and where does the final products used?
- i.* Where in the mitochondria you will find the Electron Transport Chain?
- j.* Phases 3 and 4 produce ATP, what are the specific process called?

2. Video 1- View the video by clicking on the link or copy and paste on your web browser, then answer the following questions based on the video.

<https://www.youtube.com/watch?v=OYQPQEOdCU8>

- a. What happens when there is not enough oxygen in the cell?
- b. What are the pathways of the two anaerobic respiration that occurs in cells? (please note further research is necessary). Draw the diagram in the boxes

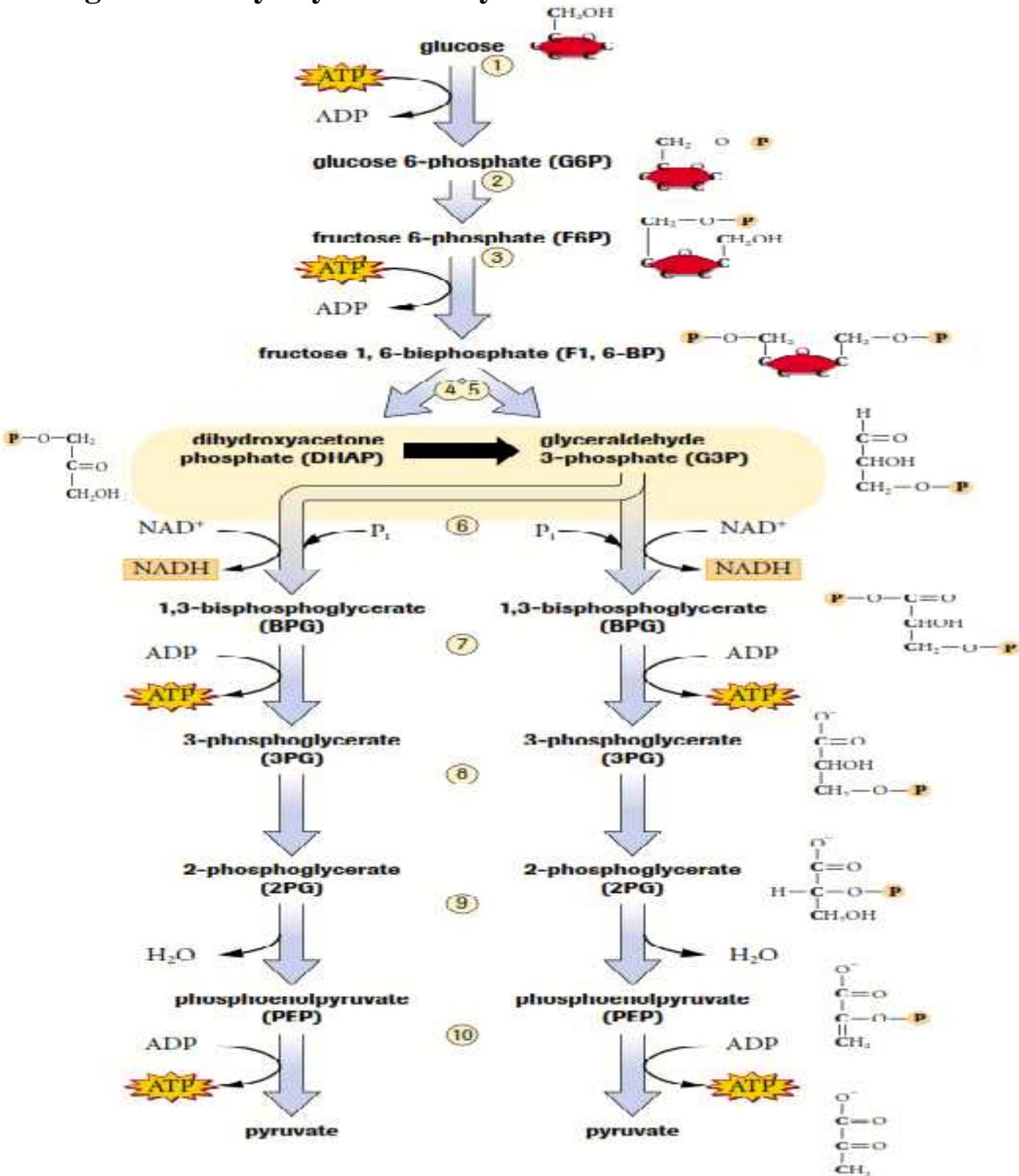
- c. What are the two names for the third phase of cellular respiration?
- d. Where is oxygen use in cellular respiration?
- e. How many ATP is produced at the end of cellular respiration? Explain.



Glycolysis

What reactions occur in the cell to turn glucose into carbon dioxide?

Diagram 2 – Glycolysis Pathway



ReadThis!

Glycolysis occurs in the cytoplasm of cells and does not require the presence of oxygen. Therefore, the process is **anaerobic**. It is the first step used by cells to extract energy from glucose in the form of ATP. ATP can be directly used by cells.

3. Refer to diagram 2
 - a. At what steps are ATP used? And explained the process.

 - b. At what steps are ATP produced?

 - c. What happens in steps four and five?

 - d. What is the final product of this pathway?

 - e. Hydrogen-carrying molecules are also produced during glycolysis. What is the name of these hydrogen-carrying molecules and how many are produce from one molecule of glucose?

 - f. How many carbon atoms are in one molecule of glucose?

 - g. How many carbon atoms are in one molecule of pyruvate?

 - h. Does glycolysis occurs inside or outside the mitochondria?

 - i. What molecule acts as an electron acceptor in glycolysis?

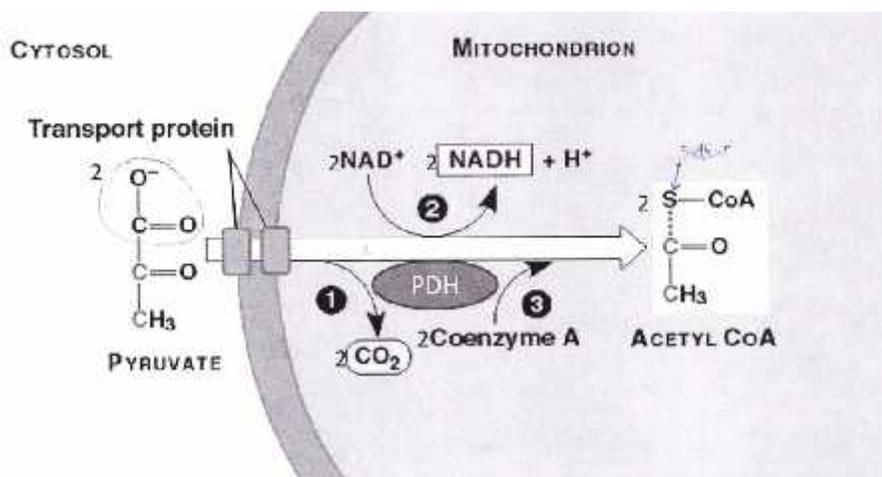
 - j. Fructose 1,6 biphosphate- what does the 1,6 mean in this molecules?

- k. Does pyruvate have more or less potential energy than glucose? Provide specific evidence from Diagram 2 to support your answer.

Video 2- Watch the following video by clicking on the link or copy and paste on your web browser. <https://www.youtube.com/watch?v=8Kn6BVGqKd8>

4. Refer to video 2
- What is the purpose of the first five steps of glycolysis?
 - What does the enzyme kinase do?
 - Which reactions are reversible and which are irreversible?
 - What enzyme catalyzed NADH?

Diagram 3 – Pyruvate Oxidation (The Link Reaction)



5. Refer to the diagram
- According to the diagram where is this process taking place?

b. Why is the number 2 used in this diagram?

c. Why is a transport protein needed for this link reaction?

d. During the link reaction, the pyruvic acid molecule is **decarboxylated**. What molecule is removed during this process?

8. Coenzyme A carries the remainder of the pyruvate molecule to the site of the Krebs cycle.

a. What is the name of decarboxylated pyruvic acid?

b. *How* many carbons of the pyruvate molecule remain when it is attached to Coenzyme A?

c. *When* coenzyme A bonds to the decarboxylated pyruvic acid what molecule is produced?

e. The connection between Coenzyme A and the acetyl group is weak. How is this illustrated in Diagram 3?

9. Has any ATP been used or produced during the link reaction?

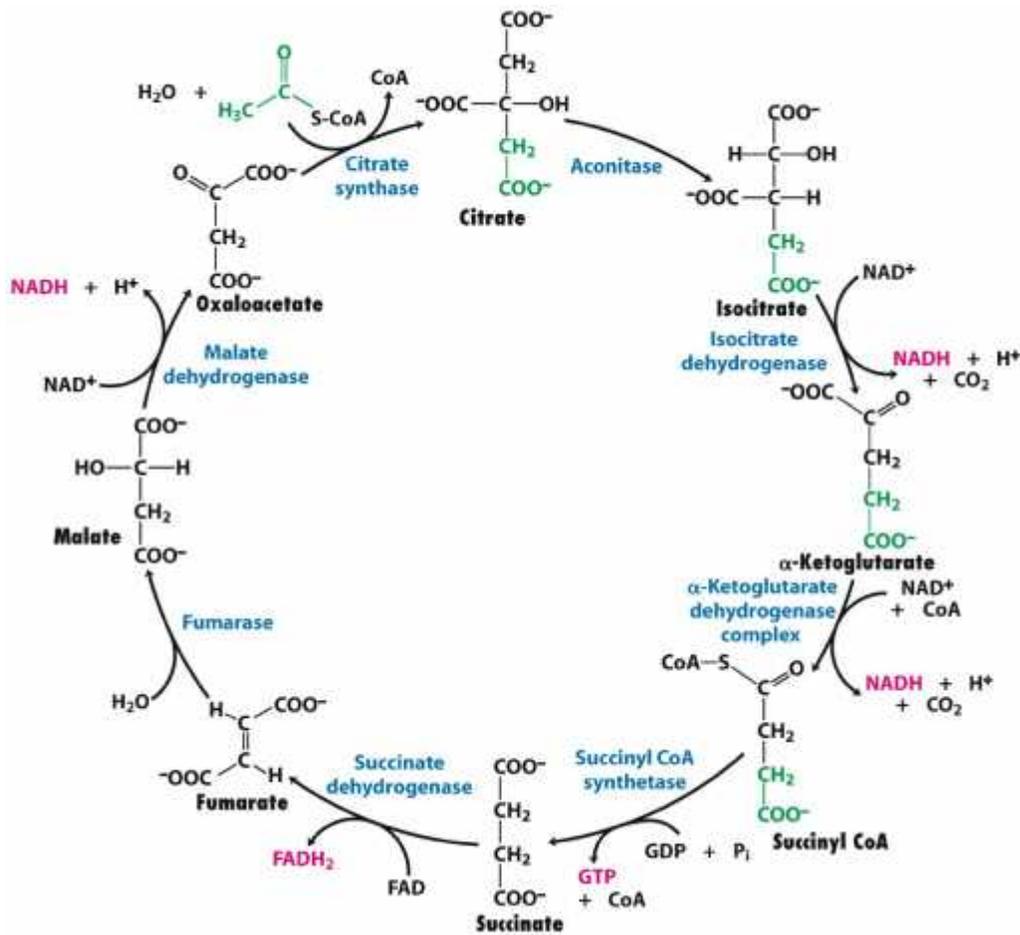
10. Have any other high potential energy molecules been produced during the link reaction?

11. How many acetyl-CoA, carbon dioxide, and NADH molecules are produced in the link reaction for each glucose molecule that undergoes cellular respiration?



Diagram 4 – The Krebs Cycle

Examine this diagram closely and number the steps involved in this cycle starting with the number one.



12. Where in the cell does the Krebs cycle take place?

13. What molecule is introduced to the Krebs cycle from the link reaction?
14. Is oxygen needed as a reactant in the Krebs cycle?
15. Compare the oxaloacetate molecule with the citrate molecule.
 - a. How many carbon atoms are in oxaloacetate?
 - b. *How* many carbon atoms are in citrate?
 - c. *Where* did the extra carbon atoms come from to convert oxaloacetate into citrate?
16. Compare the citrate molecule with the α -ketoglutarate molecule.
 - a. How many carbon atoms are in alpha- ketoglutarate?
 - b. *Where* did the missing carbon atom go during the conversion of citrate to α -ketoglutarate?
17. Compare the α -ketoglutarate molecule with the succinate molecule.
 - a. How many carbon atom are in succinate?
 - b. *Where* did the missing carbon atom go during the conversion of α -ketoglutarate to succinate?

18. Throughout the Krebs cycle, energy is transferred to other high potential energy molecules. List those molecules and indicate the number produced with one “turn” of the cycle.
19. Which molecule in the Krebs cycle has the highest potential energy—citrate, α -ketoglutarate, succinate or oxaloacetate? Provide specific evidence from Model 3 to support your answer.
20. Which molecule in the Krebs cycle has the lowest potential energy—citrate, α -ketoglutarate, succinate or oxaloacetate? Provide specific evidence from Model 3 to support your answer.
-  21. Considering your answers to the previous three questions, what can you conclude about the potential energy of the acetyl group that is carried from the link reaction to the Krebs cycle by coenzyme A? Does this group of atoms have a high potential energy or a low potential energy? Explain your reasoning.

22. How many “turns” of the Krebs cycle occur for every glucose molecule ($C_6H_{12}O_6$) that undergoes cellular respiration?

23. How many of each of the molecules below are produced in the Krebs cycle of every glucose molecule that undergoes cellular respiration?

CO_2

ATP

NADH

$FADH_2$

28. Was oxygen used as a reactant in any of the processes explored in this activity—glycolysis, the link reaction or the Krebs cycle?

Video 4- The Krebs Cycle

<https://www.youtube.com/watch?v=XJiYpa3hwEA>



Electron Transport Chain to Follow