

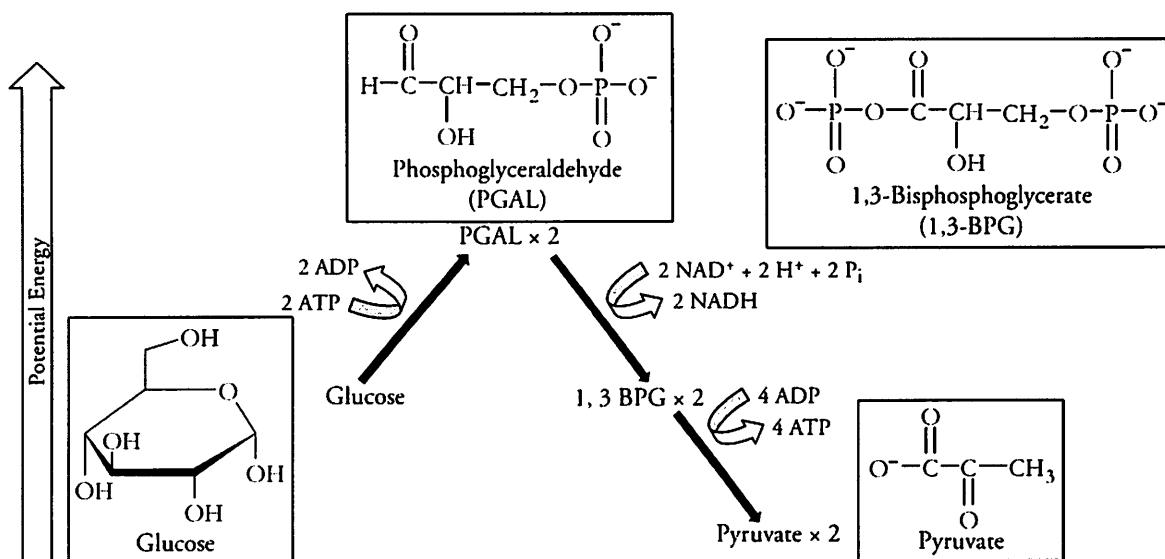
Glycolysis and the Krebs Cycle

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

Why?

Glucose is a high potential energy molecule. Carbon dioxide on the other hand is a very stable, low potential energy molecule. When a glucose molecule is converted to carbon dioxide and water during cellular respiration, energy is released and stored in high potential energy ATP molecules. The three phases of cellular respiration that oxidize the glucose molecule to carbon dioxide are **glycolysis**, the **Link reaction** and the **Krebs cycle**.

Model 1 – Glycolysis



- Refer to Model 1.
 - What molecule from food is the primary reactant for glycolysis?
 - How many carbon atoms are in that reactant molecule?
- The carbon atoms from glucose end up in pyruvate molecules as a product of glycolysis.
 - How many carbon atoms are in a pyruvate molecule?
 - How many pyruvate molecules are made from each glucose molecule?

3. Does the process of glycolysis require an input of energy? Provide specific evidence from Model 1 to support your answer.



4. Refer to Model 1. Propose an explanation for why the author of this activity put PGAL at the highest point in the Model 1 diagram.

5. Does pyruvate have more or less potential energy than glucose? Provide specific evidence from Model 1 to support your answer.

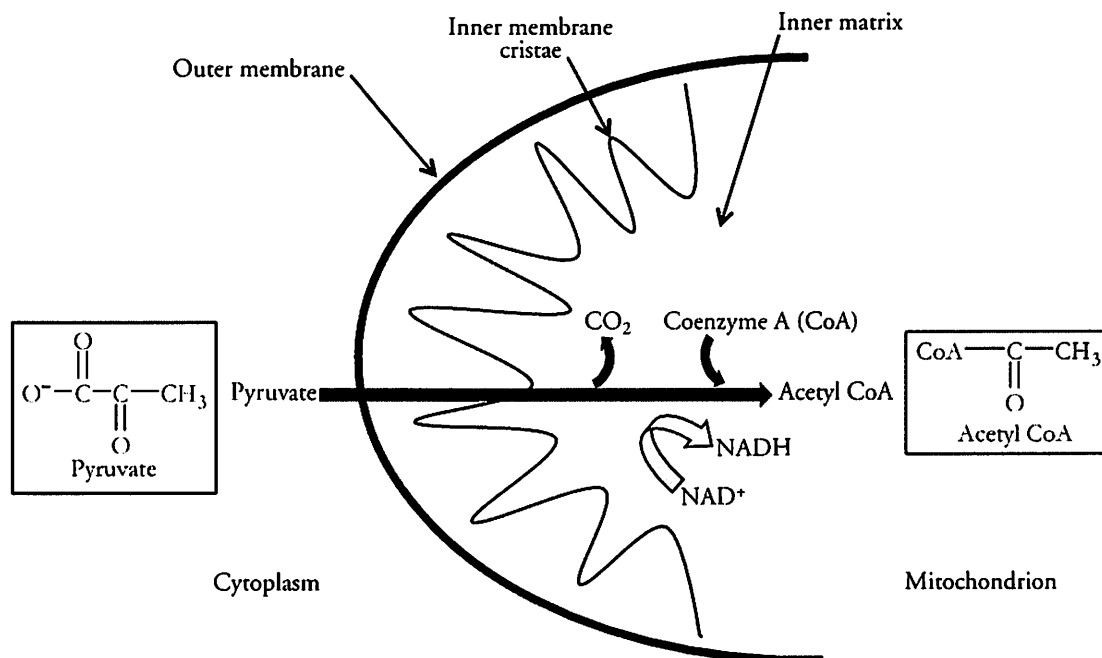
6. What is the net production of ATP by glycolysis?

7. What molecule acts as an electron acceptor in glycolysis?

8. In the last steps of glycolysis 4 ATP molecules are produced. Analyze Model 1 to find the source of the four inorganic phosphates (P_i) that are added to the ADP molecules to make the four ATP molecules. Describe the origins of the four inorganic phosphates here.



Model 2 – The Link Reaction



9. According to Model 2, where in a cell does the link reaction take place?

10. Consider the pyruvate molecule.
 - a. Is the pyruvate molecule likely to move across the mitochondrial membranes by diffusion? (Your answer should include a comment about polarity.)

 - b. Propose a method by which the pyruvate molecule moves across the mitochondrial membrane.

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



12. 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?
- d.* The connection between Coenzyme A and the acetyl group is weak. How is this illustrated in Model 2?

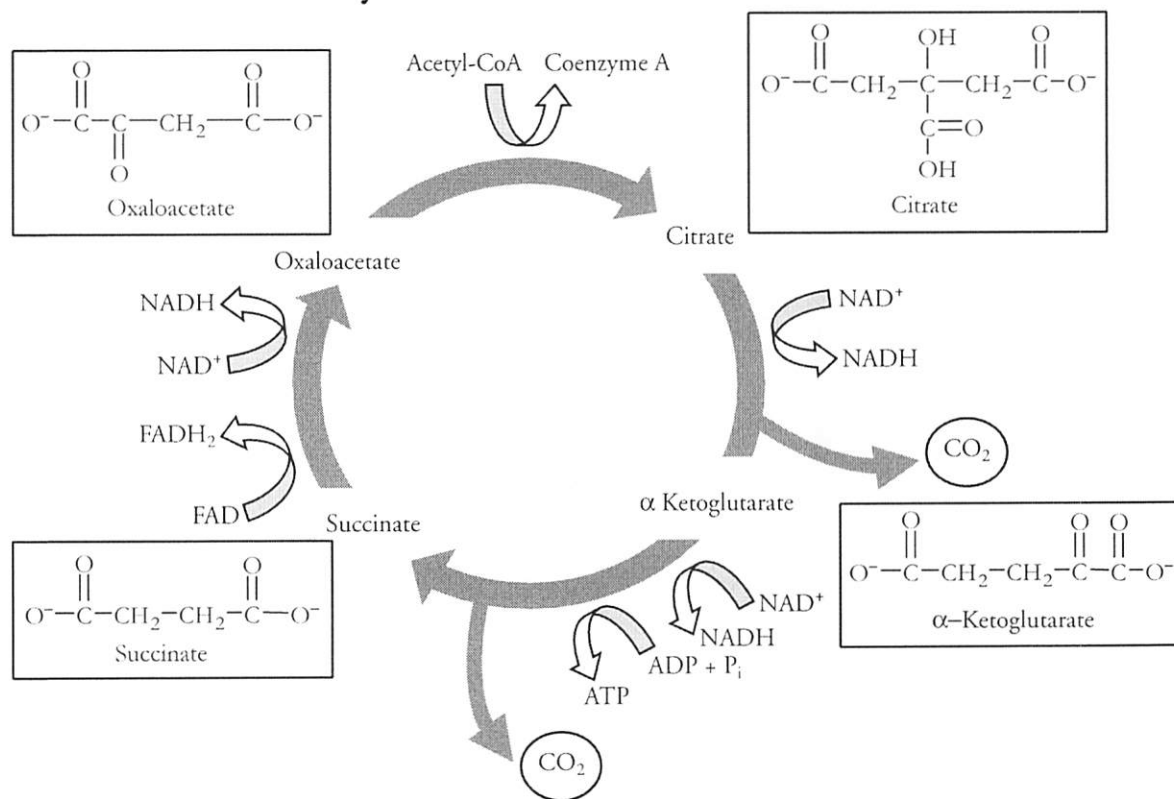
13. Has any ATP been used or produced during the link reaction?

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

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



Model 3 – The Krebs Cycle



16. Where in the cell does the Krebs cycle take place?
17. What molecule is introduced to the Krebs cycle from the link reaction?
18. Is oxygen needed as a reactant in the Krebs cycle?
19. 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?

20. Compare the citrate molecule with the α -ketoglutarate molecule.
- How many carbon atoms are in α -ketoglutarate?
 - Where did the missing carbon atom go during the conversion of citrate to α -ketoglutarate?
21. Compare the α -ketoglutarate molecule with the succinate molecule.
- How many carbon atoms are in succinate?
 - Where did the missing carbon atom go during the conversion of α -ketoglutarate to succinate?
22. 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.
23. 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.
24. 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.
-  25. 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.

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

27. 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?



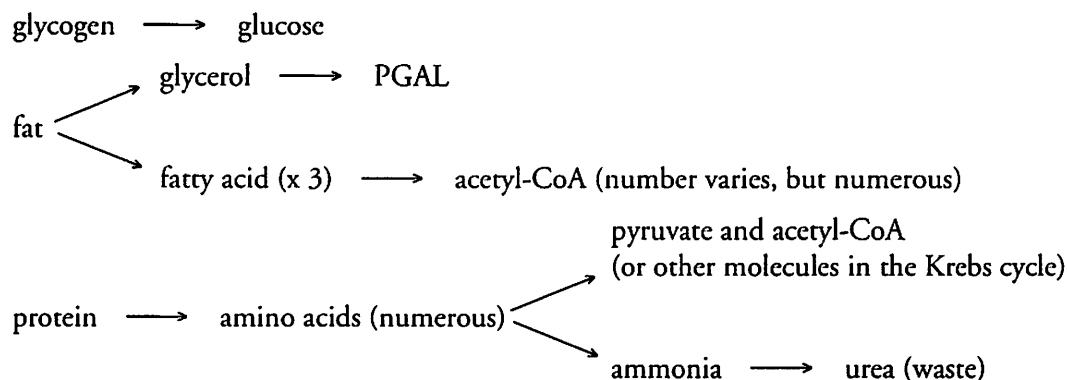
Read This!

Glycolysis will occur in a cell with or without oxygen present. If oxygen is present, the link reaction, Krebs cycle, and oxidative phosphorylation will complete the process of oxidizing glucose and maximizing the energy output. However, without oxygen, glycolysis is coupled with fermentation processes to provide a continual supply of energy to the cell. It is important to note that even though the link reaction and Krebs cycle do not use oxygen as a reactant, they will not occur in the cell without oxygen present.

Extension Questions

29. Identify two places in the Krebs cycle where a decrease in free energy is coupled with an increase in free energy.

30. When the body runs out of readily available carbohydrate (glucose) molecules, it will turn to stored glycogen, then fats, and finally proteins as an energy source. The pathways below illustrate how these molecules are prepared to enter the cellular respiration pathway.



- a. For each of the products above (excluding urea) identify the phase of cellular respiration where the molecules would enter the cellular respiration process.
- b. Glucose has six carbons. A fat molecule could have ten times that many carbons. Predict how the number of ATP molecules produced would differ between a glucose molecule and a fat molecule.
- c. Consider where proteins are “stored” in your body. What types of tissues would be affected if your body needed to use protein as an energy source?