MIT Department of Biology
7.014 Introductory Biology, Spring 2005

Recitation Section 4 Answer Key
February 14-15, 2005

Biochemistry—Energy and Glycolysis

A. Why do we care

In lecture we discussed the three properties of a living organism: metabolism, regulated growth, and replication. Today we will focus on metabolism and biosynthesis.

1. It was said in lecture that chemical reactions are the basis of life. Why do we say that?

2. Why is metabolism required for life?

3. Can an entity that performs no chemical reactions be considered "alive?"

4. Most reactions necessary for life are unfavorable, or do not proceed at an appreciable rate under physiological conditions. How do cells overcome this problem?

B. Thermodynamics

1. What is "free energy"?

2. Where is this energy stored?

We say that ΔG is a thermodynamic property, meaning that it is independent of the way that the conversion of reactants to products might proceed.

3. Based on how energy is stored in the molecules, explain why ΔG is independent of the path of the reaction.

4. If $\Delta G=0$, the reaction is at equilibrium. What then is the meaning of the magnitude of ΔG?

5. What is a favorable reaction? What would ΔG be for a thermodynamically favorable reaction?

6. What is an unfavorable reaction? What would ΔG be for a thermodynamically unfavorable reaction?

7. Not all thermodynamically favorable reactions proceed on their own. Why?

8. Catalysts overcome this problem. How do they do it?

9. Is the equilibrium of the reaction affected by the action of a catalyst? Why or why not?

10. Is the rate of the reaction affected by the action of a catalyst? Why or why not?

11. Why can the direction in which a reaction proceeds be influenced by the relative concentration of reactants and products?

C. Kinetics

As mentioned in lecture, effect of enzymes can be quantified. The measures commonly used, Km and Vmax are characteristic of different aspects of enzyme's actions. To illustrate these concepts, we will break into groups of four for the following experiment.

All members of the group will try to pick up from the desk and open as many eppendorf tubes as possible in a 45 second interval. One member in each group will use the hand with taped down thumb, another with the other four fingers taped together, and the last person will use a hand in a ski glove.

1. How many eppendorf tubes was each member of the team able to pick up and open in 45 seconds?

	hand	-thumb	-fingers	ski glove
low				
medium				
high				

2. What problems with enzyme functions does the demo represent?

Data gathered in an enzyme kinetics experiment can be represented on a graph of concentration of substrate vs. initial rate of the reaction.

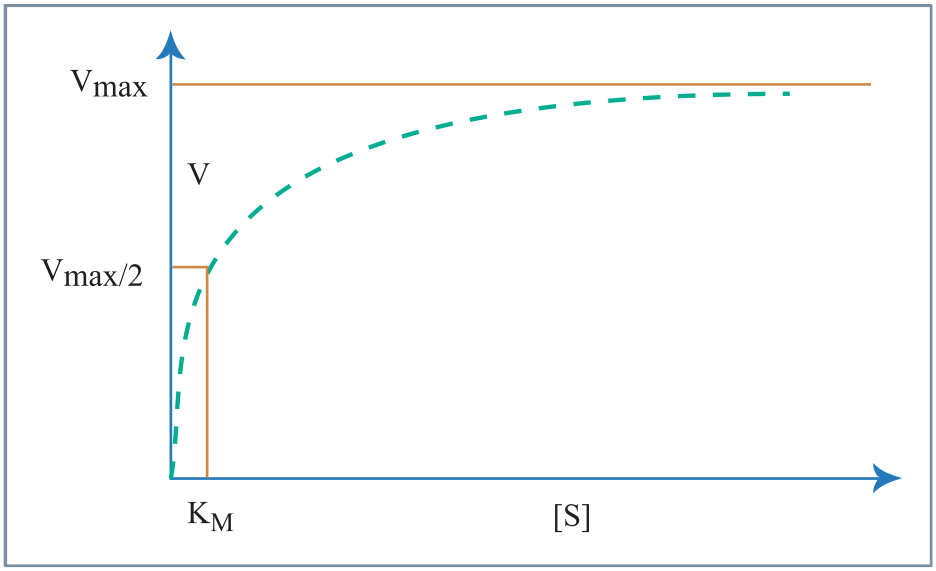

Figure by MIT OCW.

3. Why does the curve level off?

K_m is the measure of how well an enzyme binds the substrate—the less substrate it takes to achieve half maximal speed, the better is the affinity of the enzyme for the substrate.

4. How would the curve below change for the mutants described in the demo?

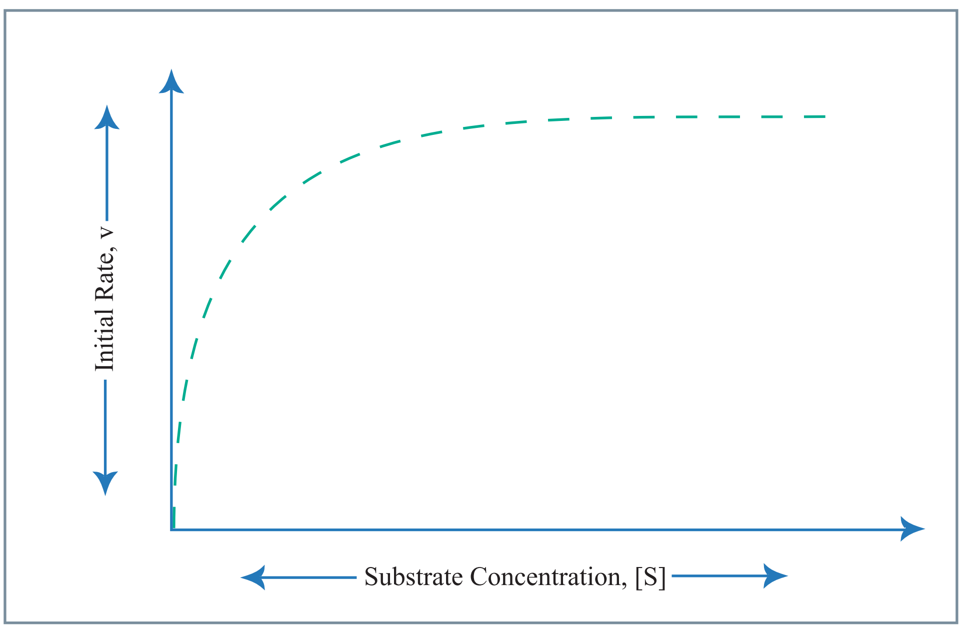

Figure by MIT OCW.

D. Energy currency

Enzymes can not make thermodynamically unfavorable reactions proceed. But they do lower the activation energy of a reaction in both directions.

1. What strategy can a cell use to drive slightly thermodynamically unfavorable catalyzed reactions? How can this be achieved in a cell?

Sometimes the reaction is just too thermodynamically unfavorable to be driven by such tricks.

2. What is the strategy used by the cell to drive such reactions?

We say that ATP is the energy currency of the cell.

3. Why does it make sense to have energy currency?

4. Where in ATP is the energy available to do work stored?

5. What makes ATP a good candidate for the position of energy currency in the cell?

ATP is also a building block of RNA.

6. Given what you know about the early history of life on Earth, why does this make sense?

E. Glycolysis

Glycolysis is an ancient pathway. It is critically important for producing ATP. It is an incremental pathway, meaning that it takes a number of steps (10) to get from the initial reactant (glucose) to the final products. Below in the energy diagram of glycolysis.

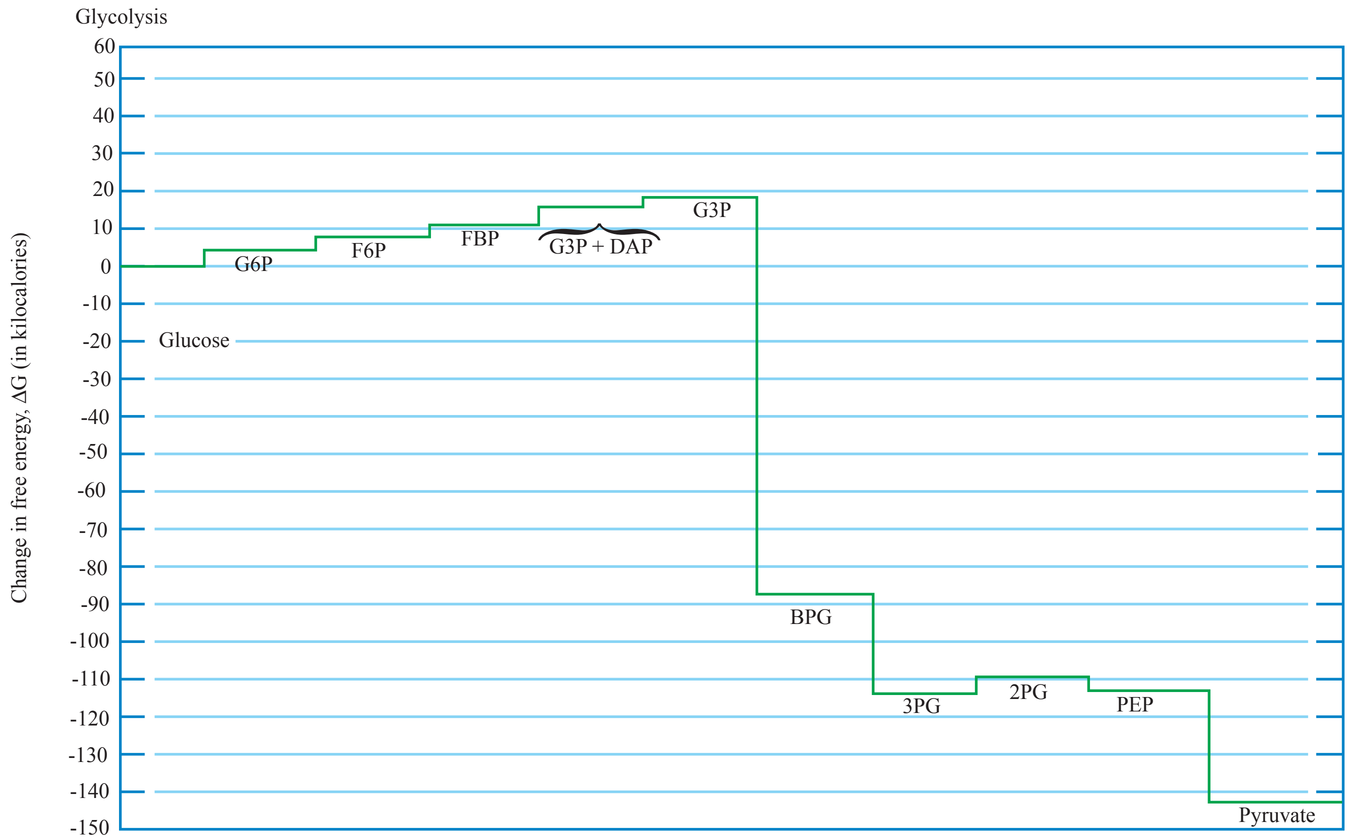

Figure by MIT OCW.

As you can see from the diagram, the overall reaction is very favorable ($\Delta G < -130$).

1. Why do the first six steps of the pathway have a positive ΔG?

2. Is this the most efficient way to design a pathway glucose$\rightarrow$ pyruvate? If you were able to design it *de novo*, would you be able to come up with a better way?

3. As we mentioned a number of times, this pathway is highly evolutionarily conserved. Why?

4. Speculate about how this pathway might have arisen.

5. What is the energy gain from the glycolysis pathway?

6. Is this enough energy to allow for the development of the diverse set of organisms populating the biosphere?