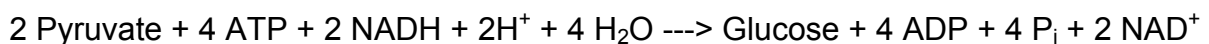


## Bioenergetics and Metabolism

1. Define the terms catabolism and anabolism.
2. Why is anabolism favored under conditions of high Energy Charge in the cell?
3. Name five mechanisms of metabolic regulation in higher organisms.
4. In 1783 Antoine Lavoisier used a crude calorimeter to demonstrate that the thermodynamic principles hold true in living systems. What were the results of his experiment and what thermodynamic principle was confirmed?
5. What is the Second Law of Thermodynamics and how does it apply to energy conversion systems in a living organism such as yourself?
6. What is the difference between  $\Delta G^\circ$  and  $\Delta G$ ? Write an equation that defines  $\Delta G^\circ$  when a reaction is at equilibrium. Why doesn't this equation apply to most metabolic reactions in a living organism?
7. Describe what happens to the metabolic flux of glucose before and after eating breakfast in terms of glycogen and pyruvate levels in liver cells, and the two peptide hormones that control blood glucose levels.
8. Glycolysis converts glucose to pyruvate by the following stoichiometry:



Gluconeogenesis converts pyruvate to glucose by the following stoichiometry:



What is the net result of these two reactions and what does this tell us about role of enzyme regulation in glycolysis and gluconeogenesis?

## Answers

1. Catabolism; breakdown of macromolecules for the purpose of ATP generation. Anabolism; biosynthesis of macromolecules for the purpose of life; this requires ATP
2. The energy charge of the cell refers to the relative concentrations of ATP, ADP and AMP. When the energy charge is high, it means that ATP concentrations are high relative to AMP and ADP. Anabolic pathways (biosynthesis) require ATP, therefore a high energy charge in the cell favors anabolism.
3. The five mechanisms of metabolic regulation are:
  1. Allosteric interactions.
  2. Covalent modification.
  3. Enzyme levels.
  4. Compartmentation.
  5. Metabolic specializations of organs.
4. Lavoisier found that the amount of metabolic heat given off by the guinea pig was the same amount of energy that would come from oxidation of fuels through combustion. This experiment confirmed the First Law of Thermodynamics that energy is neither created or destroyed, but rather converted from one form to another.
5. The Second Law of Thermodynamics states that all natural processes in the Universe tend toward disorder (entropy) in the absence of energy input. Many types of biochemical reactions in living organisms are maintained at a steady-state that is far from equilibrium with the environment. This is done by harnessing energy released from the Sun (thermonuclear fusion reactions) to generate chemical compounds such as ATP which is used in coupled reactions to restrain entropy as long as possible. Photosynthetic organisms convert sunlight into chemical compounds such as carbohydrates which are then used as chemical fuel by non-photosynthetic organisms.
6.  $\Delta G^{\circ}$  refers to the *standard* free energy change of a reaction under biochemical conditions when the reaction is allowed to go from 1M concentration of all reactants and products to equilibrium. The difference in free energy under these two conditions (1M concentration and at equilibrium) is expressed in units of kilojoules (kJ) or kilo Calories (kcal).  $\Delta G$  is the *actual* free energy change in a reaction that is calculated from the known  $\Delta G^{\circ}$  value and the steady-state concentrations of reactants and products in a living cell. When a reaction is at equilibrium,  $\Delta G = 0$ , and  $\Delta G^{\circ}$  is defined by the equation:

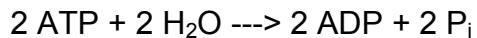
$$\Delta G = \Delta G^{\circ} + RT \cdot \ln [B]_{\text{actual}} / [A]_{\text{actual}} = 0$$

$$\Delta G^{\circ} = - RT \cdot \ln [B]_{\text{equilibrium}} / [A]_{\text{equilibrium}}$$

This reaction does not apply to most metabolic reactions in a living organism because life requires that reactions do not reach equilibrium with the environment, if they did, the organism would be dead.

7. Before breakfast, glucose levels are low in the blood due to a night of fasting (presumably) which triggers the release of glucagon from the pancreas. Glucagon receptors are activated in liver cells leading to an increase in glycogen degradation to produce free glucose, as well as, glucose synthesis from pyruvate (gluconeogenesis). Together these two metabolic pathways increase glucose export to maintain appropriate blood glucose levels for brain function (~5 mM). After breakfast, blood glucose levels rise leading to insulin release from the pancreas and stimulation of insulin receptor signaling in liver cells. Under these conditions, the metabolic flux of glucose is shifted toward glucose import and storage as glycogen and energy conversion from glucose to pyruvate to produce ATP (glycolysis).

8. Net reaction:



Enzyme regulation is critical in controlling these two opposing pathways otherwise ATP would be continually hydrolyzed leading to futile cycling and heat production. Coordinate control of glycolytic and gluconeogenic enzymes shifts the metabolic flux in the appropriate direction in response to glucose availability to prevent futile cycling.