BIOLOGY 113 - MICROBIOLOGY

Lecture 6: Microbial Metabolism - Activities and regulation of enzymes

The term *metabolism* refers to the sum of all chemical reactions within a living organism. Metabolic activity can be divided into two classes of reactions:
- **Catabolic** reactions release energy and are employed for breaking down nutrients
  - Many catabolic reactions are hydrolysis reactions
  - An example of catabolism is hydrolysis of proteins to individual amino acids
- **Anabolic** reactions require energy and are used in synthesizing molecules needed by the cells
  - Many anabolic reactions are dehydration synthesis reactions
  - An example of anabolism is synthesis of proteins from amino acids
- **Adenosine triphosphate (ATP)** serves as a link between catabolism and anabolism (Tortora et al., Figure 5.1)
  - Catabolic reactions may be linked to dehydration synthesis of ATP from ADP and free phosphate; the energy released in the catabolic reaction is "stored" in the ADP-P covalent bond
  - The energy for anabolic reactions may be obtained by hydrolysis of ATP to ADP + phosphate.

The metabolic reactions of living systems are *catalyzed by enzymes*.
- By a catalyst, we mean something that increases the frequency of productive collisions in a chemical reaction.
- Enzymes, most of which are large globular protein molecules, are highly specific, affecting only certain substrates and certain chemical reactions.
- Many enzymes consist of both a protein portion, the *apoenzyme*, and a nonprotein *cofactor*; together, these make up a *holoenzyme* (Tortora et al., Figure 5.2)
  - If the cofactor is an organic molecule, it is called a *coenzyme*; most of the compounds that we refer to as "vitamins" act as coenzymes or components of coenzymes (Tortora et al., Table 5.2)
  - Many coenzymes act by serving as temporary acceptors or donors of chemical groups
    - Nicotinamide adenine dinucleotide (NAD+) and nicotinamide adenine dinucleotide phosphate (NADP+) serve in the transfer of electrons in association with *dehydrogenases*
    - Coenzyme A (CoA) serves as a carrier of *acetyl* groups
  - Ions of metals, including magnesium, manganese, zinc and cobalt, are also employed as cofactors of enzymes.
- Enzymes are thought to work through association of reactants (*substrates*) with the holoenzyme (Tortora et al., Figure 5.3)
  - The substrate(s) bind(s) to a specific region on the surface of the enzyme, the enzyme's *active site*, forming the *enzyme-substrate complex*
  - The configuration of the enzyme-substrate complex favors the catalyzed reaction, yielding the reaction *products*, which are released from the enzyme.
  - The enzyme can now go on to bind more substrate.
- Enzymes are classified according to the nature of the reaction that they catalyze (Tortora et al., Table 5.1); note that the names of enzymes usually end in "-ase".

The activity of an enzyme (the rate of the reaction catalyzed by the enzyme) is influenced by a variety of factors:
- Every enzyme has an optimum *temperature* at which its activity is highest (Tortora et al., Figure 5.4a)
  - As with noncatalyzed reactions, reaction rate tends to increase with increasing temperature.
  - At some point, reaction rate drops drastically with increasing temperature, as the enzyme
becomes *denatured* (Tortora et al., Figure 5.5)
- The *pH* of the environment in which an enzyme operates also influences activity Tortora et al., Figure 5.4b), mostly through ionization of carboxy and amino groups
- Enzyme activity varies with *substrate concentration* in a characteristic manner (Tortora et al., Figure 5.4c)
  - At some level of substrate, the enzyme is said to be *saturated*, as all active sites are "occupied"
  - Under normal cellular conditions, reaction rate is more likely to be determined by substrate concentration than by enzyme concentration
- Enzyme activity is also influenced by (and, in living systems, is often regulated by) *inhibitors* (Tortora et al., Figure 5.6)
  - *Competitive inhibitors* are molecules that compete with the normal substrate for the enzyme's active site (Tortora et al., Figure 5.6b)
  - *Noncompetitive inhibitors* bind to a part of the enzyme other than the active site (Tortora et al., Figure 5.6c)
    - The binding site of a noncompetitive inhibitor is called an *allosteric site*
    - In some cases, allosteric binding of a compound can actually *activate* enzyme activity
  - *Feedback inhibition* (Tortora et al., Figure 5.7) is an important biochemical control mechanism involving allosteric noncompetitive inhibitors
    - In feedback inhibition, the end-product of a reaction sequence acts as an allosteric inhibitor of an enzyme catalyzing a reaction early in the reaction sequence
    - Feedback inhibition is especially important in regulating levels of metabolic intermediates