Concept 3:  Analyzing cell metabolism and enzyme function

Chapter 8, AP Investigation 12

**An Introduction to Energy Metabolism**

* The key role of ATP in energy coupling.
* That enzymes work by lowering the energy of activation.
* The catalytic cycle of an enzyme that results in the production of a final product.
* The factors that influence the efficiency of enzymes.

**Lab 2: Enzyme Catalysis**

* The factors that affect the rate of an enzyme reaction such as temperature, pH, enzyme concentration.
* How the structure of an enzyme can be altered, and how pH and temperature affect enzyme function.
* How to name an enzyme, its substrate and products, and then design a controlled experiment to measure the activity of a specific enzyme under varying conditions.
* How to calculate the rate of reaction.

METABOLISM

**Metabolism** is the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_of an organism’s chemical reactions

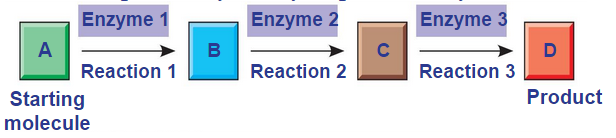
* **Catabolic pathways** \_\_\_\_\_\_\_\_\_\_energy by breaking down complex molecules into simpler compounds

Example:

* **Anabolic pathways** \_\_\_\_\_\_\_\_\_\_\_\_energy to build complex molecules from simpler ones

Example:

A **metabolic pathway** begins with a specific \_\_\_\_\_\_\_\_\_\_\_\_and ends with a \_\_\_\_\_\_\_\_\_\_\_\_\_. Each step is catalyzed by a specific enzyme.



In order to have these reactions occur, you need \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

ENERGY: Energy is the capacity to cause \_\_\_\_\_\_\_\_\_\_\_\_\_. Energy exists in various forms, some of which can perform \_\_\_\_\_\_\_\_\_\_\_.

**Kinetic energy** is energy associated….

**Heat (thermal energy)** is kinetic energy associated with …

**Potential energy** is energy that matter possesses because of its…

**Chemical energy** is potential energy available for release in a …..

Energy can be converted from one form to another.

THE LAWS OF ENERGY TRANSFORMATION

**Thermodynamics** is the study of energy \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. Organisms are energy ­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

THE FIRST LAW OF THERMODYNAMICS

According to the **first law of thermodynamics**, the energy of the universe is \_\_\_\_\_\_\_\_\_\_\_\_\_\_:

For example, BC Hydro does NOT *create* energy… they transform it to a form that we use in our homes.

THE SECOND LAW OF THERMODYNAMICS

During every energy transfer or transformation, some energy is unusable, and is often lost as \_\_\_\_\_\_\_\_.

According to the **second law of thermodynamics**:

Every energy transfer increases the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_of the universe. Therefore, the universe is unstoppable in its increasing randomness.

BIOLOGICAL ORDER AND DISORDER

* Cells create \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ structures from less ordered materials
* Organisms also replace ordered forms of matter and energy with \_\_\_\_\_\_\_\_\_\_\_ ordered forms.
* Energy flows into an ecosystem in the form of \_\_\_\_\_\_\_\_\_and exits in the form of \_\_\_\_\_\_\_\_\_.

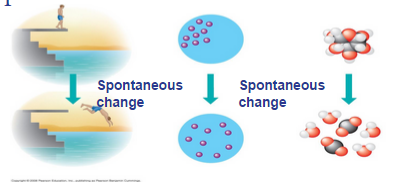
FREE-ENERGY CHANGE,Δ*G*

A living system’s **free energy** is energy that can do \_\_\_\_\_\_\_\_\_\_\_when temperature and pressure are \_\_\_\_\_\_\_\_\_\_\_, as in a living cell. It can be thought of as a measure of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

For example…

EXERGONIC AND ENDERGONIC REACTIONS IN METABOLISM

An **exergonic reaction** proceeds with a net release of free energy



and is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

An **endergonic reaction** absorbs free energy from its surroundings

and is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

HOW DOES A CELL DO WORK?

A cell does three main kinds of work:

* Chemical.  Example….
* Transport. Example….

* Mechanical. Example…

To do work, cells manage energy resources by**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**, the use of an exergonic process to drive an endergonic one. Most energy coupling in cells is mediated by \_\_\_\_\_\_\_\_\_\_\_\_– a molecule with a very high free energy

The bonds between the phosphate groups of ATP’s tail can be broken by \_\_\_\_\_\_\_\_\_\_\_\_. Energy is released from ATP when the terminal phosphate bond is broken. This release of energy comes from the chemical change to a state of\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, not from the phosphate bonds themselves.

THE REGENERATION OF ATP

ATP is a renewable resource that is regenerated by addition of a ­­­­­\_\_\_\_\_\_\_\_\_\_\_\_ group to ADP. The rate of renewal is VERY fast.

* 10 million ATP molecules are turned over every second in every one of your cells… if this didn’t happen you would use up your body weight in molecules in one day.

ENZYMES

A **catalyst** is a chemical agent that speeds up a reaction without \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

An **enzyme** is a **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.**

* Hydrolysis of sucrose by the enzyme sucrase is an example of an enzyme-catalyzed reaction

Even though the reaction is “spontaneous”/exergonic/releases free energy, it would happen WAY to slow (years) without help from the enzyme due to its very high energy of activation.  With the enzyme, the reaction takes seconds.

THE ACTIVATION ENERGY BARRIER

Every chemical reaction between molecules involves bond breaking and bond forming

The initial energy needed to start a chemical reaction is called the **free energy of activation**, or **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** (to contort the bonds)

Activation energy is often supplied in the form of heat from the surroundings

*HOW ENZYMES LOWER THE EA BARRIER?*

*SUBSTRATE SPECIFICITY OF ENZYMES*

The reactant that an enzyme acts on is called the enzyme’s \_\_\_\_\_\_\_\_\_\_\_\_\_

The enzyme binds to its substrate, forming an\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

The **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**is the region on the enzyme where the substrate binds.

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**of a substrate brings chemical groups of the active site into positions that enhance their ability to catalyze the reaction. Most enzymes are capable of 1000 substrate actions per second!

*CATALYSIS IN THE ENZYME’S ACTIVE SITE*

In an enzymatic reaction, the substrate binds to the active site of the enzyme.

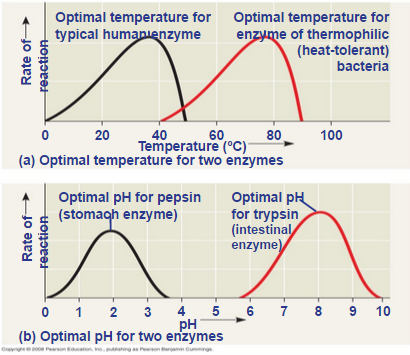
*Think* of four mechanisms which allow the active site to lower an EA barrier…

1. Orienting substrates correctly – providing a place for \_\_\_\_\_\_\_\_\_\_\_\_\_ to find each other
2. Straining substrate bonds – \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_reactants towards transition state through weak H and ionic interactions from the R groups in the protein
3. Providing a favorable microenvironment – ex) acidic conditions via acidic R-groups
4. Covalently bonding to the substrate – this covalent bonding is temporary… it is released in subsequent reactions

EFFECTS OF LOCAL CONDITIONS ON ENZYME ACTIVITY

An enzyme’s activity can be affected by:

* Substrate concentration activity increases with increasing substrate concentration until the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_point is reached (where all active sites are occupied)
* General environmental factors, such as\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Chemicals that specifically influence the enzyme.



EFFECTS OF TEMPERATURE AND PH

Each enzyme has an optimal temperature in which it can function.

Each enzyme has an optimal pH in which it can function.

COFACTORS

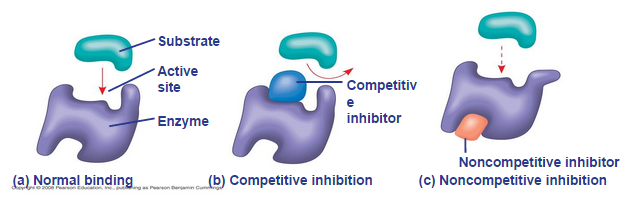
* Cofactors are \_\_\_\_\_\_\_\_\_\_\_\_enzyme helpers
* Cofactors may be inorganicvv(such as a metal in ionic form) or organic
* An organic cofactor is called a coenzyme
* Coenzymes include \_\_\_\_\_\_\_\_\_\_\_

ENZYME INHIBITORS

**Competitive inhibitors** bind to the \_\_\_\_\_\_\_\_\_\_\_\_ of an enzyme, competing with the substrate.

**Noncompetitive inhibitors** bind to another part of an enzyme, causing the enzyme to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and making the active site less effective.

Examples of inhibitors include toxins, poisons, pesticides, and antibiotics.



REGULATION OF ENZYME ACTIVITY HELPS CONTROL METABOLISM

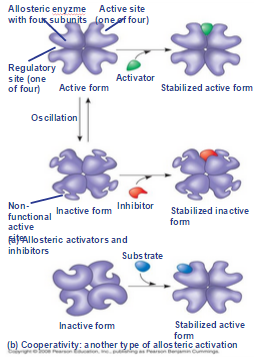
Chemical chaos would result if a cell’s metabolic pathways were not tightly \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

A cell does this by switching on or off the \_\_\_\_\_\_\_\_\_\_\_\_ that encode specific enzymes or by regulating the activity of enzymes.

ALLOSTERIC REGULATION OF ENZYMES

**Allosteric regulation** may either \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

Allosteric regulation occurs when a regulatory molecule binds to a protein at one site and affects the protein’s function at another site



*ALLOSTERIC ACTIVATION AND INHIBITION*

Most allosterically regulated enzymes are made from polypeptide subunits.

Each enzyme has \_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_ forms. The binding of an

activator \_\_\_\_\_\_\_\_\_\_\_\_\_the active form of the enzyme. The binding of an

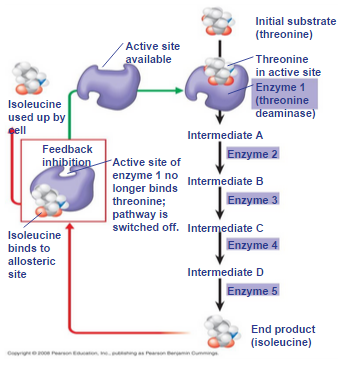
inhibitor stabilizes the inactive form of the enzyme.

**Cooperativity** is a form of allosteric regulation that can \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

In cooperativity, binding by a substrate to one active site stabilizes favorable conformational changes at all other subunits.

Allosteric regulators are attractive drug candidates for enzyme regulation

Inhibition of proteolytic enzymes called caspases may help management of inappropriate inflammatory responses.



In **feedback inhibition**, the end product of a metabolic pathway \_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_ the pathway.

Feedback inhibition prevents a cell from wasting chemical resources by

synthesizing more product than is needed.

SPECIFIC LOCALIZATION OF ENZYMES WITHIN THE CELL

Structures within the cell help bring order to metabolic pathways. Some enzymes act as structural components of membranes. In eukaryotic cells, some enzymes \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_specific organelles; for example, enzymes for cellular respiration are located in mitochondria.