ENERGY

Energy is the ability to do work

Energy is considered to exist in two states
- **kinetic energy:** the energy of motion
- **potential energy:** stored energy

All the work carried out by living organisms involves the **transformation** of potential energy to kinetic energy

There are many forms of energy
- all energy can be converted to heat

- Heat energy is the most convenient form of energy to measure

Thermodynamics: the study of energy or heat changes

Organisms continually have energy changes.
Laws of thermodynamics govern these energy changes

- **1st Law of Thermodynamics**

  total amount of energy in universe remains constant
  energy can change from one state to another but it can never be created nor destroyed
  during the energy conversions, some of the energy is lost as heat energy

- **2nd Law of Thermodynamics**

  the amount of disorder, or **entropy**, in the universe is increasing
  the increasing disorder means that energy is spontaneously transforming from potential to heat energy

Chemical Reactions: the making or breaking of chemical bonds
- **Reactants/ substrates** the starting molecules of a reaction
- **Products:** molecules at the end of the reaction

For example: H20 + O2 = H2O2

2 kinds of chemical reactions

1. **Endergonic:** products w/ ↑↑ energy than reactants
   these reactions are not spontaneous

2. **Exergonic:** products with less energy than reactants
   these reactions are spontaneous

activation energy: required to start a reaction.

- stress existing chemical bonds

- Reactions become more spontaneous if their activation energy is lowered
- process called **catalysis**
- catalyzed reactions proceed much faster than non-catalyzed reactions

How Enzymes Work

Enzymes are catalysts used by cells

- bind specifically to a molecule
- stress the bonds so the rxn more likely to proceed
- **active site:** on surface of enzyme that binds to a reactant
- the site on the reactant where the enzyme binds is called the **binding site**
- **Enzymes are reused.**
- Temperature and pH affect enzyme activity
  - optimum temp range
  - when temp ↑, the shape of the enzyme changes due to unfolding of the protein chains
  - optimal pH range
  - most enzymes work best within pH range of 6 – 8
  - exceptions are stomach enzymes that function in acidic ranges

ATP: The Energy Currency of the Cell

Cells receive energy in forms they can not use directly (sun, food)
This energy must be transferred to a usable form.
adenosine triphosphate (ATP) is the energy currency of the cell
The structure of ATP suits it as an energy carrier.

- 3 parts to ATP molecule.
  a sugar
- an adenine nucleotide
- chain of 3 phosphate groups
  - phosphates are negatively charged. takes a lot of chemical energy to hold them together
  - the phosphates are poised to come apart

When the endmost phosphate group is broken off an ATP molecule, energy is released

ATP cycles in the cell with respect to its energy needs

photosynthesis

- some cells convert energy from the sun into ATP and then use it to make sugar where it is stored as potential energy
- chloroplasts

cellular respiration

- cells break down the potential energy in sugars and convert it ATP
- mitochondria

Chemical Rxns: the passing of e- from one atom/molecule to another

- **Oxidation:** an atom/molecule loses e-
- **Reduction:** an atom/molecule gains e-

these reactions always occur together

called **oxidation-reduction (re-dox) reactions**

the reduced form of an organic molecule has a higher level of energy than the oxidized form

Photosynthesis

- The process that captures light energy and transforms into the chemical energy of carbohydrates

- It occurs in the Plasma membranes of some bacteria, Cells of algae or the Leaves of plants

Photosynthesis take place in the chloroplast

- the chloroplast contains internal membranes called **thylakoids**

- thylakoids are stacked together in columns called **grana**

  Stroma: semiliquid substance surrounding the thylakloids

- The **photosystem** is the starting point of photosynthesis

- it is a network of pigments in the membrane of the thylakoid

- the primary pigment of a photosystem is **chlorophyll**

- pigments act as an antenna to capture solar energy

- individual chlorophyll pigments pass the captured energy between them

How Plants Capture Energy from Sunlight

Light is comprised of packets of energy called **photons**

sunlight has photons of varying energy levels

possible range of energy levels is represented by an **electromagnetic spectrum**

human eyes only perceive photons of intermediate energy levels
this range of the spectrum is known as **visible light**

Pigments are molecules that absorb light energy

- main pigment in plants is chlorophyll
- chlorophyll absorbs light at the end of the visible spectrum, mainly blue and red light

accessory pigments, absorb light levels that chlorophyll does not

- these pigments give color to flowers, fruits, and vegetables
- they are present in leaves too but masked by chlorophyll until the fall when the chlorophyll is broken down

<u>Photosynthesis takes place in three stages:</u>

- All 3 stages occur in the chloroplast
  - Capture light energy which energizes electrons
  - Produce high energy molecules (NADP and ATP) needed for the final stage
  - Use these high energy molecules to produce sugar
- Pigments are molecules that absorb light energy
- The pigment in human eyes is retinal

Absorption: ~ 380 (violet) – 750 (red) nm

- The main pigment in plants is chlorophyll
  - Chlorophyll *a* and chlorophyll *b*
  - Have slight differences in absorption spectra
- Carotenoids are accessory pigments
  - They capture wavelengths not efficiently absorbed by chlorophyll

$$6H_20 + 6CO_2 + \text{solar energy} = C_6H_{12}O_6 + 6O_2$$

Light Dependent Rxns

- Many molecules in chloroplast participate
- These reactions occur only when light strikes the chloroplast (thylakoid)
- E- pass from one molecule to another (from splitting H2O)
- The O2 released when H2O is split is the source of all atmospheric oxygen

What happens to energy captured in this light dependent reaction? It is stored in

- ATP
- NADPH

These stable molecules are used for energy needed to run the LIGHT-INDEPENDENT reactions (these can take place when light is not present)

LIGHT INDEPENDENT REACTION

- Occurs in the stroma
- Creates complex organic molecules such as sugars out of atmospheric CO2

- Water + carbon dioxide + energy (in the presence of chlorophyll) produces sugar + oxygen

`Photosynthesis	Cell Resp
Plants Or any photosynthetic organism Energy is captured Consumes H2O, CO2 Produces Sugar + O2 Endergonic	Energy released Exergonic Consumes sugar + O2 Produces H2O + CO2 Energy for cell resp. comes from eating plants/animals that eat plants

Cellular Respiration

- Reverses photosynthesis
- splits C and H atoms from sugar molecules
- recombines them with O2 to make

$$C_6H_{12}O_6 + 6O_2 = 6H_2O + 6CO_2 + \text{energy}$$

overview of aerobic respiration

- Cells break down glucose & capture the released energy as ATP. 3 Steps

- **Anaerobic: in cytoplasm**
  Step 1: Glycolysis→2 ATP + 2 pyruvate
  f/b fermentation if no O2
  IF O2 present then on to aerobic respiration

- **Aerobic:**
  Step 2: Citric Acid Cycle(Krebs Cycle)
  Step 3: Electron Transfer (oxidative phosphorylation)

Glycolysis

- The anerobic generation of ATP
- Occurs in cytoplasm of cell
- Requires 2 ATP to start glycolysis of one glucose molecule
- Catabolic
- Produces 2 pyruvate + 2ATP + 2 NADH
- Can only continue if fermentation takes place

Fermentation

- Doesn't produce ATP BUT uses its products to make lactate molecules which make lactic acid
- Occurs in cytoplasm
- The products of fermentation permit glycolysis to occur again
- O2 debt: tired/burning

If O2 is present

- Pyruvate moves into mitochondria matrix
- Pyruvate's energy is harvested by
- 1st: Oxidizing pyruvate to form acetyl-CoA
- 2nd: Oxidizing acetyl-CoA in the Krebs cycle

Enzymes to do this are present within the mitochondria

Citric Acid Cycle/ Krebs Cycle

- Aerobic
- Products of glycolysis can be further metabolized this way
- pyruvate→ CO_2 + H_2O + ATP + NADH + $FADH_2$
- Glycolysis + Citric Acid Cycle → $6CO_2$ + 4ATP + 10 NADH + 8H + $2FADH_2$

Mitochondria use ***chemiosmosis*** to make ATP

- first proton pump use energetic electrons extracted from food molecules to pump protons across the cristae
- as the concentration of protons builds up in the ***intermembrane space***, the protons re-enter the matrix via ATP synthase channels
- ***their passage powers the production of ATP from ADP***
- This process goes on unti the last transport protein donates the electrons to hydrogen and oxygen in order to form water

Proton pump transports protons across inner memb from matrix to intermembrane space

[protons] in intermemb space ↑ causing a gradient.

Protons reenter matrix by diffusion through ATP synthase channels which produces lots of ATP

ATP pumped out to cytoplasm

Energy Totals for Cellular Respiration

Glycolysis →	Citric Acid Cycle→	E- Transport
2 ATP	2 ATP	32-34 ATP

Summary:
36-38 ATP generated from 1 Glucose Molecule
Depends on type of cell
•In Cells, Enzymes reduce the Activation energy required for cellular respiration.

By transferring energy to special energy carrying molecules, cells can capture about half of the energy released from breaking chemical bonds.

The rest escapes as heat, which helps maintain body temperature

Name _____ Lab Section T or TH

HOMEWORK # 2

Answer the questions below. This assignment is due on _____ at the start of lecture and will not be accepted late. You must hand write your answers and not exceed the space allotted. Students who cut and paste from online sources will receive ZERO points for this assignments.

Energy Questions:

1. Describe the structure of the chloroplast. You may draw a diagram.

2. Define:
carotenoids:

photon:

autotroph:

3. Explain the general function of
   a) the light dependent phase of the photosynthesis

   b) the light independent phase of photosynthesis

4. What are the
   a) reactants for photosynthesis?

   b) Products of cell respiration?

5. Where does glycolysis occur in the cells of animals?

6. Name the anaerobic process that follows glycolysis if no oxygen is available to the cell?

7. Draw a diagram of an animal cell's mitochondria. Label the inner and
   outer membrane, cristae, matrix and intermembrane space.

Cell Division Questions.

8. Draw a diagram of the cell cycle; Include all phases, subphases and check points.

9. Define:
Chromatid:

Homologous pair

Cytokinesis

Synapsis

Crossing Over

Independent Assortment

Centriole

Centromere

Somatic Cell

Germ Cell

Diploid

Haploid

Syngamy

End Product of Mitosis

End Product of Meiosis