Unit 3: Energy

Capacity: Transforming Energy
How is energy transformed by a system?

<u>Cellular Work comes in three forms…</u>

1) Mechanical – moving cell structures
    * chromatid movement during mitosis

2) Transport – pumping across membranes
    * active transport pumps

3) Chemical – endergonic reactions
    * making polymers from monomers
    * photosynthesis

<u>Energy coupling powers most cell work.</u>

- utilizes energy produced during exergonic reaction to power another reaction
- Adenosine triphosphate (ATP) serves as the energy molecule of cells
    - Structure: 3 phosphates, 1 ribose, 1 adenine
    - Function: energy is released during breaking of bond between phosphates
        - Phosphates are broken off one at a time by hydrolysis
        - Often phosphate binds to another molecule in the process called <u>phosphorylation</u>

<u>The making of ATP is also called phosphorylation.</u>

- Substrate level

- Oxidative

- Photophosphorylation

<u>What metabolic pathways make ATP?</u>

Cell Respiration and Photosynthesis

Unit 3: Energy

Capacity: Bioenergetics
How do living organisms process energy?

Metabolism – total of all chemical reactions that use or create energy

<u>Living organisms use different modes of acquiring energy.</u>

- ❖ Autotrophy – organisms that create their own energy source
  - ➢ Photoautotroph – use light energy and CO_2 to create an energy source
    - ▪ Photosynthesis
    - ▪ Plants and algae
  - ➢ Chemoautotroph – oxidize inorganic molecules and process CO_2 for energy
    - ▪ Some prokaryotes (mainly archae)

- ❖ Heterotroph – must obtain their organic energy source from another source
  - ➢ Photoheterotrophs – use light energy and carbon from organic molecules to create a food source
    - ▪ Some prokaryotes (mainly archae)
  - ➢ Chemoheterotrophs – consume organic molecules and produce CO_2
    - ▪ Cell respiration

<u>Living organisms vary on their use of oxygen to metabolize energy.</u>

- ❖ Obligate aerobes – use oxygen gas for cell respiration and cannot prolong life without it
  - ➢ Some prokaryotes
  - ➢ Most fungi, all plants and all animals

- ❖ Facultative anaerobes – can use oxygen if available, but can prolong life without it using fermentation
  - ➢ Some prokaryotes
  - ➢ Plants and animals do fermentation for short spans, however cannot prolong life on this for long.

- ❖ Obligate anaerobes – oxygen is toxic to these organisms, only use fermentation
  - ➢ Some prokaryotes

<u>The flow of energy through animals is called bioenergetics.</u>

- ❖ Carnivores – “meat eaters”, eat other animals
  - ➢ Protein heavy diet

- ❖ Omnivores – eat both animals and plants
  - ➢ Diet is mixture of protein and carbohydrates

- ❖ Herbivore – eat only plants
  - ➢ Diet is mainly carboyhdrates

Unit 3: Energy

Capacity: Bioenergetics

Thermoregulation varies among animals.

- What is thermoregulation?
  - Maintain an internal body temperature within a safe range

- Ectotherm – use mainly heat gained from their environment
  - Body temperatures fluctuate with environmental temperature
  - Behaviors, such as basking in the sun to gain heat
  - Most invertebrates, fish, amphibians, many reptiles

- Endotherm – use mainly heat gained from internal metabolism
  - Body temperatures can still fluctuate, but usually less drastically
  - Mammals, birds, some reptiles, some fish, some insects

Metabolic rate – amount of energy used in a unit of time

- Basal metabolic rate (BMR) – resting rate for an adult endotherm
  - We call this "caloric intake" when dieting
    - average male 1800 Calories
    - average female 1500 Calories

- Standard metabolic rate – resting rate for non-stressed adult ectotherms
  - Must be done at a specific temperature

Capacity: Cell Respiration

How does cell respiration provide energy for living organisms?

Overview of Cell Respiration

- all eukaryotes use cell respiration (even plants!)
- occurs in a mitochondria
- Glucose → ATP energy + water + carbon dioxide

- Glycolysis (cytoplasm)
- Kreb's (matrix of mitochondria)
- Electron Transport Chain (inner membrane of mitochondria)

Unit 3: Energy

Capacity: Cell Respiration

<u>Pathways involved in the processing of organic molecules for energy</u>

1. Glycolysis
   - Location:
   - Where does it get its name?
   - Reactants (what goes in?):
   - What happens?
   - Outcomes/Products (what comes out?):
   - Other Details:

2. Kreb's Cycle
   - Location:
   - Where does it get its name?
   - Reactants (what goes in?):
   - What happens?
   - Outcomes/Products (what comes out?):
   - Other Details:
     - Acetyl CoA is made in cytoplasm
     - CoA = coenzyme A… it carries acetyl molecule to Kreb's cycle, it does NOT enter the mitochondria and cycle directly

Unit 3: Energy

Capacity: Cell Respiration

3. Electron Transport Chain
   - Location:
   - Where does it get its name?
   - Reactants (what goes in?):
   - What happens?
   - Outcomes/Products (what comes out?):
   - Other Details:
     - NADH enters chain at a membrane protein
     - Hydrogen protons (H+) move to the outer compartment of mitochondria
     - $FADH_2$ enters at a special point… called Q
     - Electrons move through membrane proteins
     - Oxygen attracts the electrons down the chain
     - H+ move through ATP synthase (membrane ion channel)
     - Ions moving through the channel make ATP
     - This process is called chemiosmosis. Mechanical spinning of channel creates the energy that attaches a phosphate onto ADP
     - Electrons, H+, and oxygen form water

<u>Draw a picture of ETC "the dance"</u>

Capacity: Cell Respiration

4a. Alcoholic Fermentation

- Location:
- Where does it get its name?
- Reactants (what goes in?):
- What happens?
- Outcomes/Products (what comes out?):
- Other Details:

4b. Lactic Acid Fermentation

- Location:
- Where does it get its name?
- Reactants (what goes in?):
- What happens?
- Outcomes/Products (what comes out?):
- Other Details:

Capacity: Cell Respiration
Adding it all up...
<u>Aerobic Cell Respiration</u>

- Glycolysis
    - Uses 2 ATP to start… - 2 ATP
    - Makes 4 ATP
    - Makes 2 NADH
- Pyruvate turns into Acetyl CoA
    - Makes 2 NADH (one for each pyruvate)
    - Moving the NADH from cytoplasm to ETC Uses 2 ATP… - 2ATP
- Kreb’s Cycle
    - Makes 2 ATP
    - Makes 6 NADH
    - Makes 2 FADH2
- Electron Transport Chain
    - Makes 3 ATP for each NADH
        - _______ X <u>3 ATP</u> = _________ ATP
    - Makes 2 ATP for each FADH2
        - ______ X <u>2 ATP</u> = __________ ATP

	ATP Produced	Type of Phosphorylation
Glycolysis		
Pyruvate → Acetyl CoA		
Kreb’s Cycle		
Electron Transport Chain		
Lost ATP (Moving NADH)		
Total ATP		

Unit 3: Energy

Capacity: Cell Respiration
Adding it all up
<u>Anaerobic Respiration</u>

- Glycolysis
    - Uses 2 ATP to start… - 2 ATP
    - Makes 4 ATP
    - Makes 2 NADH

- Fermentation turns pyruvate into alcohol or lactic acid
    - Uses 2 NADH
    - Makes NO ATP
    - Simply allows for Glycolysis to continue

	ATP Produced	Type of Phosphorylation
Glycolysis		
Fermentation		
Total ATP		

Capacity: Photosynthesis
How does photosynthesis provide energy for living organisms?

<u>Overview of Photosynthesis</u>

- it is very similar to cell respiration, just in reverse
- used by photoautotrophs (includes some prokaryotes, algae, and plants)
- occurs in chloroplast
- light energy + water + carbon dioxide → glucose + oxygen

- Light reactions (thylakoid membranes)
- Calvin Cycle (stroma of chloroplast)

Unit 3: Energy

Capacity: Photosynthesis
Photosynthesis uses energy from the sun… so let's talk about that first.

Sunlight: used to excite electrons and eventually the making of ATP and NADPH

- composed of small particles called <u>photons</u> that travel in waves

- part of the electromagnetic spectrum
    - includes gamma rays (higher energy, shorter wavelengths), X-rays, UV light, visible light, infrared, microwaves, and radiowaves (lower energy, longer wavelengths)

    - visible light is used by chlorophyll and other pigments during photosynthesis
        - purple = shortest wavelengths, highest energy
        - red = longest wavelengths, lowest energy

- light can be reflected, transmitted, or absorbed by matter
    - Pigments appear the color of the REFLECTED light, the light wavelengths not being used by the pigment.
        - Energy from photons excites the electrons in the pigment. They move to higher energy level.
        - When electrons fall back to their ground state, they reflect back light and heat.
        - Example: A red shirt contains pigment that is reflecting red light wavelengths, but absorbing the other visible wavelengths

    - Absorption spectrum – graphic of a pigment's light absorption versus wavelength

    - Photosynthetic Pigments found in a chloroplast
        - Chlorophyll a – reflects blue-green
            - absorbs violet-blue and red light

        - Chlorophyll b – reflects yellow-green
            - Absorbs blue and orange-red

        - Carotenoids – reflect yellow or orange
            - Absorbs violet and blue-green light
            - Provide ability to do photosynthesis in fall, causing change of leaf color
            - Provide protection for chlorophyll pigments by absorbing excessive light energy

Capacity: Photosynthesis

Light Reactions: composed of photosystems, harvest the light energy

- Found in the thylakoid membrane
- Photosystems contain pigment molecules attached to proteins, a reaction center, and primary electron acceptor
- Two types exist: Photosystem II and photosystem I
  - Photosystem II – occurs first in noncyclic electron flow
    - Reaction center contains chlorophyll *a* molecules that best absorb 680nm light waves
    - aka… P680 or PS II
  - Photosystem I – discovered first, however occurs second in non-cyclic electron flow
    - Reaction center contains chlorophyll *a* molecules that best absorb 700nm light waves
    - aka… P700 or PS I
- Light reactions come in two patterns: Noncyclic and Cyclic
  - Noncyclic Electron Flow: looks like a 'N'
    - Light excites electrons in the pigments of PS II and I. They "jump" up to the primary acceptor.
    - Water molecule splits as electrons leave to fill the holes left by the excited pigment electrons.
      - Produces oxygen gas and hydrogen ions
    - Excited electrons from PS II travel through an E.T.C. in membrane. Eventually filling the hole left by electron in PS I.
      - Produces ATP
      - ATP travels to the Calvin cycle
    - Excited electrons from PS I bind with NAD+ and hydrogen ions.
      - Produces NADPH
      - NADPH travels to the Calvin cycle
  - Cyclic Electron Flow: looks like a circle
    - Only involves PS I
    - Light excites electrons in PS I. They "jump" to the primary acceptor.
    - The electron falls back down through the E.T.C. in the membrane.
      - Produces ATP
    - Does not produce NADPH
    - Does not use water or produce oxygen

Unit 3: Energy

Capacity: Photosynthesis

<u>Calvin Cycle: aka "dark reactions" because they do not directly require light .</u>

- occurs in the stroma (open fluid of the chloroplast)
- directly produces a 3 Carbon sugar called glyceraldehyde-3-phosphate (G3P)
- divided into 3 phases
    1. Carbon fixation: addition of carbon using CO_2
        - Done by an enzyme known as rubisco
        - Must be done 3 times to create the 3 carbon sugar produced by Calvin cycle
    2. Reduction: the molecule from phase 1 gains electrons to be reduced
        - ATP adds phosphates
        - NADPH adds electrons
        - Produces the G3P (3 carbon sugar)
    3. Regeneration of CO_2 acceptor (RuBP):
        - Must create the acceptor molecule (a 5 Carbon molecule known as ribulose biphosphate – RuBP)

<u>Problems with carbon fixation: PHOTORESPIRATION</u>

- C_3 plants follow the "normal" pathway of carbon fixation, using rubisco
    - Rice, wheat, and soybeans are examples of C_3 plants
- C_3plants have a problem, oxygen can also bind in the active site of rubisco, altering carbon fixation
    - instead of allowing for the production of a 3 carbon sugar, the oxygen creates a 2 carbon molecule (waste)

- Two alternative carbon fixation pathways have evolved in the plant kingdom
    - C_4plants: spatial separation of carbon fixation and Calvin cycle
        - Contain extra layer of cells, called bundle-sheath cells
        - Initial carbon fixation occurs in mesophyll cell using different enzyme (PEP Carboxylase)
            - Produces malate
        - Malate travels into bundle sheath cell to enter Cavlin cycle
        - Examples: sugarcane and corn plants

    - CAM plants: temporal separation of carbon fixation and Calvin cycle
        - Crassulacean Acid Metabolism
        - Open stomata during the night, allowing carbon dioxide in when it is cooler
            - This minimizes water loss due to transpiration
        - Initial carbon fixation occurs at night by a different enzyme (PEP Carboxylase)
            - Produces malate
        - Malate is stored in a vacuole until the day when light reactions are providing other ingredients for Calvin Cycle.

- Examples: cacti, pineapple, jade plant