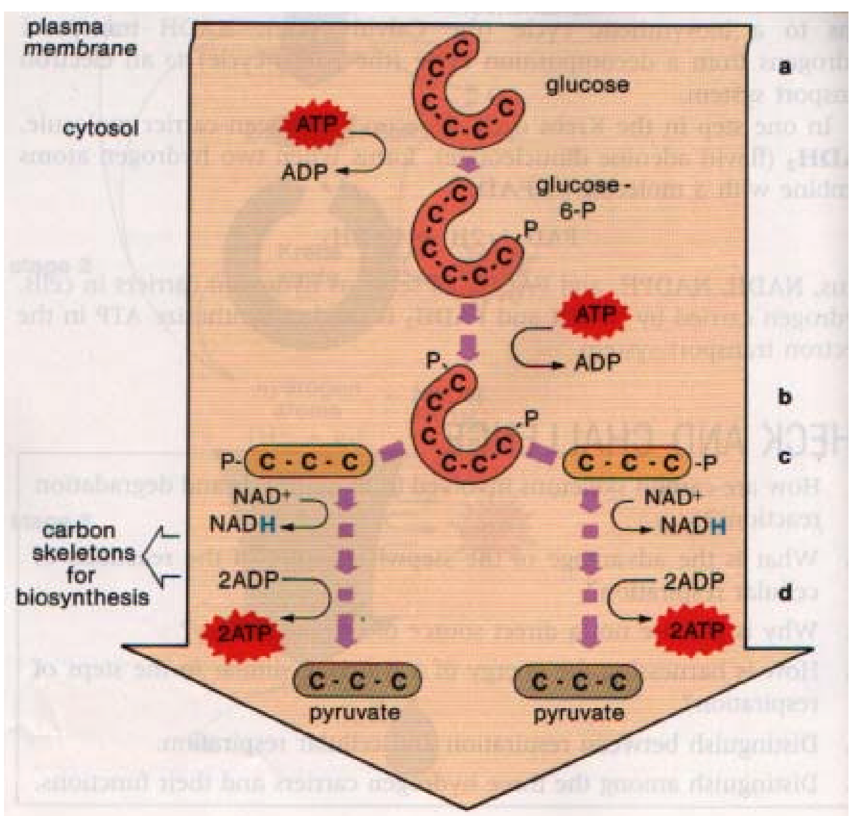
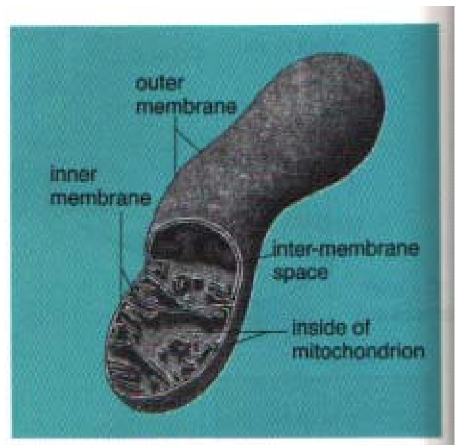
Chapter 8 – Respiration

1. **Respiration** – the removal of electrons from food molecules and their transfer to carriers
   The energy from respiration is used to synthesize ATP
   Aerobic Respiration – electrons are carried by O_2
   Anaerobic Respiration – electrons are carried by another carrier, such as N_2 or S
2. **Cellular Respiration** – the process of converting the high energy molecule glucose into ATP
   Organisms use O2 to maximize the amount of energy harvested from food molecules
   The process breaks down molecules into CO_2 and H_2O. Each step is catalyzed by an enzyme
   Besides glucose, it also breaks down lipids and proteins
   Total Products of Cellular Respiration per molecule of glucose – 38ATP
3. **Chemical Equation for Cellular Respiration** – $C_6O_{12}H_6 + 6O_2 \text{ --> } 6CO_2 + 6H_2O + 38ATP$
4. **Metabolism** – all the chemical reactions in an organism
   Synthesis – the building of materials. Energy is consumed in synthesis reactions. Example: Photosynthesis
      Uses carbon skeletons and energy to form more complex compounds
   Decomposition – the breaking down of materials. Energy is released. Example: Cellular Respiration
      Breaks down complex compounds to release energy and produce carbon skeletons
5. **ATP** – main energy molecule. 1 ATP molecule contains 7.3kcal/mol of energy. Created through cellular respiration
   Glucose contains too much energy (570kcal/mol). ATP is much more manageable
   Analogy: ATP is to glucose as quarters are to a $20 bill
6. **Stages of Aerobic Respiration**
   1. **Glycolysis** – The splitting up of glucose into two 3C compounds (pyruvate). Takes place in the cytosol.
      1. Glucose --> glucose – 6 – phosphate One molecule of ATP is required for this process
      2. Rearranges glucose-6-phosphate, consumes another ATP, creates glucose-6-5-phosphate
      3. Glucose-6-5-phosphate --> 2 molecules of pyruvate (3C) + 2ATP + 2 NADH
      4. When glycolysis finishes, the presense of oxygen will determine the next step
         If O_2 is available – Kreb's Cycle
         If O_2 is not available – Fermentation

      Produces 4ATP but 2ATP were needed to start the reaction, so Glycolysis produces a net gain of 2ATP
      In plants, starch and sucrose break down to glucose, then glycolysis occurs
      NADH – An energy molecule similar to ATP that will be used in the Kreb's cycle and e^- Transport System
         Formed by the reaction $NAD^+ + 2H$ (as $2e^- + 2H^+$) $\text{-->} NADH + H^+$
         NAD^+ -nicotinamide adenine dinucleotide

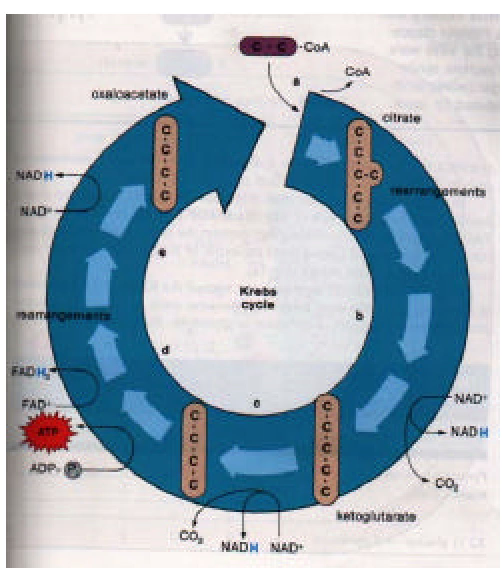


2. **Fermentation** – Occurs after glycolysis with no O_2 present
NADH + pyruvate --> NAD^+ and lactate (a 3 carbon acid) + a small amount of ATP
NAD^+ recycles back into the glycolysis cycle, and it continues until more O_2 is available
Very inefficient method of producing ATP, since glucose isn't broken all the way down
Fermentation in yeast is used to make wine. Produces ethyl alcohol
Plants produce ethanol, animals produce lactose
Humans ferment when cellular respiration doesn't produce enough energy to support the body
Responsible for the soreness after heavy exercise. The lactose produced causes soreness
3. **Mitochondria** – "power house of the cell" – contains enzymes needed for cellular respiration
The cell's energy requirements are directly related to the number of mitochondria in a cell
Outer membrane – similar to the fluid mosaic model (See Chapter 6)
Inner Membrane – Contains so many enzymes that it's more a protein than a lipid
Cristae – projections in the inner membrane that extend into the inside of the mitochondrion
Contains the enzymes for the e^- transport system, ATP formation, and part of the Kerb's cycle
Matrix – the inner space of the mitochondria, where Kreb's Cycle takes place

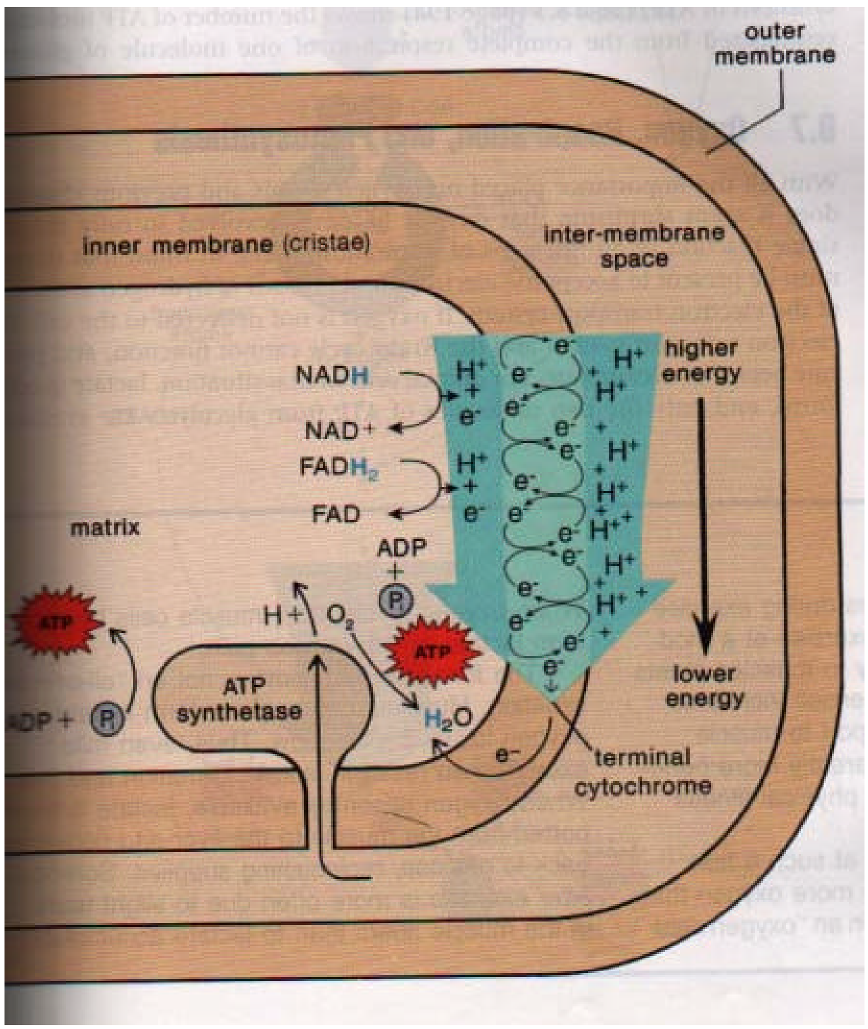


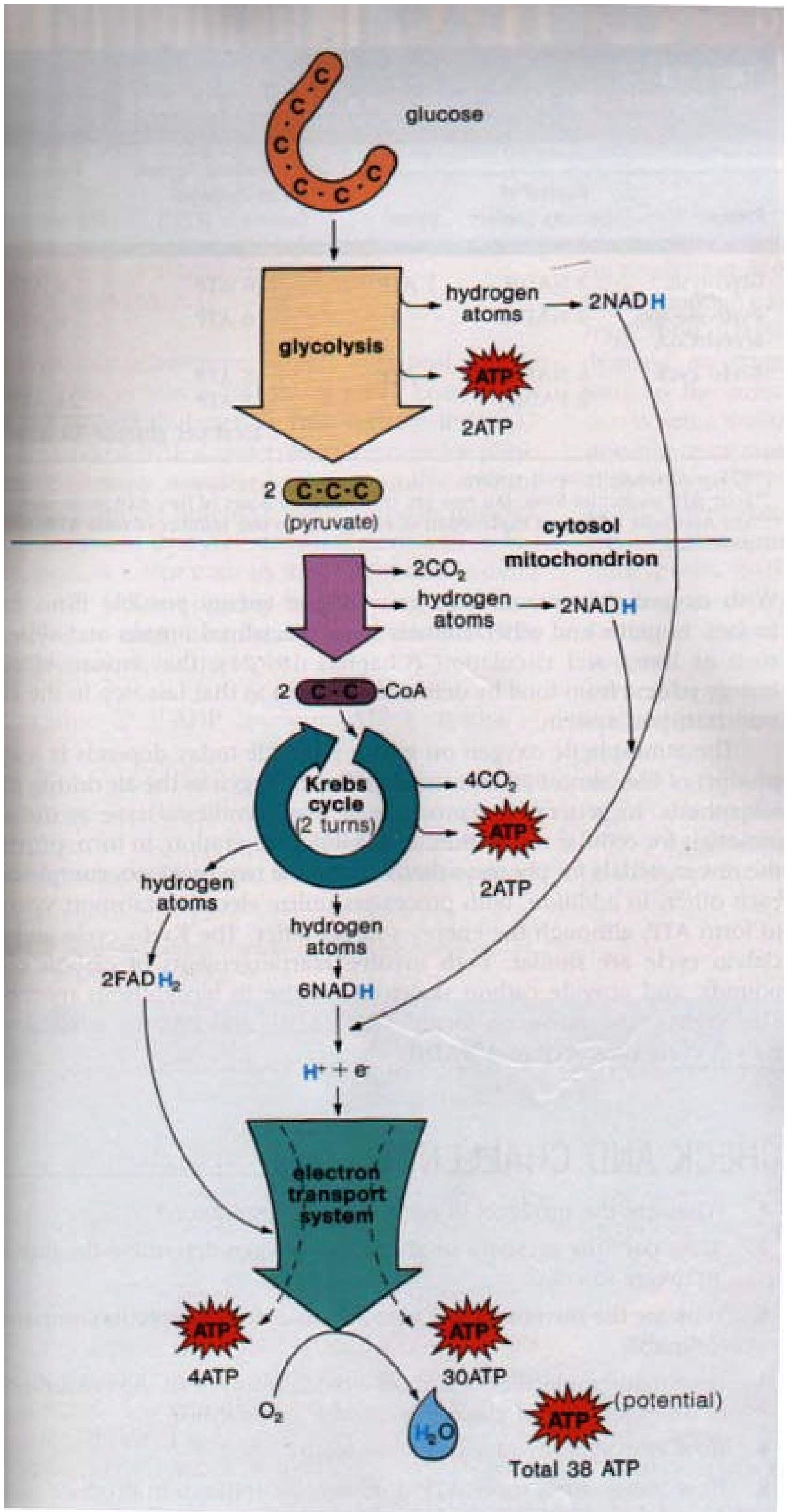
4. **Kreb's Cycle** – the breaking down of the 2C molecules, releasing more CO_2 – Occurs in mitochondria
If O_2 is present after glycolysis, pyruvate (3C) – ethanol - acetyl CoA (2C) + CO_2 + NADH
This step is NOT part of the Kreb's Cycle
1. 2C Acetyl CoA + 4C Acid oxaloacetate --> 6C acid Citrate. CoA is released
2. 6C acid Citrate --> 5C acid ketoglutarate + CO_2+ NADH
3. 5C acid ketoglutarate --> 4C carbon + CO_2 + NADH
4. 4C carbon is rearranged twice, producing 1ATP + 1$FADH_2$
5. Finally, 4C acid --> oxaloacetate + NADH
6. The oxaloacetate reenters the cycle, and the trend continues
7. Since each molecule of glucose --> 2 molecules of pyruvate, Kreb's cycle occurs twice / glucose

Total Products of Kreb's Cycle per Glucose (2 cycles) – $6CO_2$, 8NADH, 2 $FADH_2$, 2 ATP
$FADH_2$ – An energy molecule produced that will be used in the E- Transport System
Formed by the reaction FAD + 2H --> $FADH_2$



5. **The Electron Transport System** – Produces most of the ATP, requires oxygen
    1. Hydrogen atoms, carried by NADH and $FADH_2$, are transported to e^- transport system
    2. **Cytochromes** – a series of electron carriers consisting of enzymes and other proteins
        - Embedded in the cristae membranes of the mitochondria
    3. Hydrogen atoms are separated into protons and electrons
    4. Electron carriers transfer the electrons step by step to the terminal cytochrome
    5. The cytochrome combines the electrons with protons and molecular oxygen, forming water
    6. Only this final step of respiration uses oxygen
    7. At each step the electrons release free energy, some used for active transport
        - Energy used to actively transport protons from the matrix across the cirstae to the membrane
        - Results in a high concentration in the inner membrane, creates concentration gradient
        - Diffusion tends to move the protons back to the matrix of the mitochondrion
        - As they diffuse back, they pass thorough ATP synthetase enzyme, where ATP is made
            - ADP + P --> ATP
        - Each molecule of NADH can make up to 3 molecules of ATP
        - Each molecule of $FADH_2$ can make up to 2 molecules of ATP
    8. The electron transport system produces a maximum of 34 ATP





7. **The importance of Oxygen** – Oxygen must be present for cellular respiration to occur
   - Oxygen must be present to accept the electrons and protons of hydrogen at the end of the e^- transport system
   - Without oxygen, the electron transport system and Kerb's cycle cannot function
   - Without oxygen, fermentation occurs, producing ethanol in plants and lactose in animals, and 2ATP
8. **Photosynthesis and Cellular Respiration complement each other**
   - Photosynthesis creates the raw materials for cellular respiration, and vice versa
9. **The Kreb's cycle in Fat and Protein Metabolism** – Fats and Proteins can go through Kreb's Cycle to make ATP
   - Proteins are broken down into amino acids, which then become urea, which leaves the body as urine
   - However, the carbon skeletons remaining from some of the amino acids undergo changes
     - Forms 4 or 5 carbon acids (oxaloacetate or ketoglutarate) that enter the Kreb's cycle

Provides the building blocks of biosynthetic pathways, which are needed to build other molecules

In animals, they make the building blocks for many molecules

Those that cannot be synthesized must be taken as food, such as vitamins and minerals

It is worth noting that the synthesis pathways are NOT the reverse of the decomposition pathway

Example, carbohydrates can be converted to fat, but not vice versa

10. **Respiration and Heat Production** – cellular respiration releases heat, which is important to keep animals warm

    Some of the free energy from the electrons are released as heat

    Especially true in warm blooded animals. Hibernating animals have brown fat

    Brown Fat – fat with high mitochondria concentration, produces heat rapidly

    Snow around a tree has a “ring” of melted snow, due to the ATP Production of Cellular Respiration

    In a certain plant, the heat from cellular respiration initiates a reaction to give off different odors
11. I prokaryotic cells, enzymes of the e^- transport system are in the membranes. Some use anaerobic respiration
12. Glucose is usually in the blood, transported to cells. When blood glucose is low, uses stored glycogen

    Glucose is stored at glycogen in muscles and the liver

Chapter 8 Important Concepts

1. Name and describe the 2 categories of metabolism

   Metabolism consists of two distinct categories: synthesis and decomposition. Synthesis is the building of materials such as glucose in the process photosynthesis. Synthesis consumes energy. Decomposition is the breaking down of materials such as glucose, in the process cellular respiration. Decomposition reactions release the energy stored in the chemical bonds of the materials broken down

2. Explain why the process of cellular respiration is so important for the existence of life on Earth

   Cellular respiration is the process of synthesizing ATP, an energy carrier that serves are the energy unit for all living cells. Since glucose contains far too much energy, Cellular respiration creates 38 molecules of ATP for every molecule of glucose. ATP is much more manageable and efficient, for it supplies just enough energy for a cell to carry out its functions. Also, cellular respiration in part provides some of the raw materials required for photosynthesis.

3. Name the two types of respiration. How are they similar/different?

   The two types of respiration are aerobic, which requires oxygen, and anaerobic, which does not require oxygen. Anaerobic respiration is much less efficient, and is also known as fermentation. Fermentation breaks glucose down half way, for the Kreb Cycle and the Electron Transport system cannot operate without oxygen. Hence, only 2 ATP are released. Fermentation involves breaking down glucose to form ethyl alcohol in plants, and lactose in humans.

   Aerobic respiration is cellular respiration. After glycolysis, the pyruvate is transformed in acetyl CoA, which then enters the Kreb Cycle, creating ATP and NADPH, which enter the electron transport system to make a maximum of 38ATP from only 1 molecule of glucose. Aerobic respiration breaks down glucose completely (into carbon dioxide and water)

4. Write the balanced chemical equation for respiration

   $C_6H_{12}O_6 + 6O_2$ --> $6CO_2 + 6H_2O$ + 38ATP

5. Explain what happens during the process of glycolysis

   Glycolysis takes glucose, and splits it into two molecules of a 3C carbon acid known as pryuvate

6. Describe how fermentation is different in plant cells and animal cells

   Fermentation in plants produces ethyl alcohol, while in animals it produces lactose

7. List the 3 main states of aerobic respiration. Describe the major events that occur in each state

   Glycolysis – Glucose turned into pyruvate and ATP and NADPH

   Kreb Cycle – pyruvate undergoes a series of change that repeats, twice for 1 molecule of glucose

   Produces ATP, NADPH, CO_2, and $FADH_2$

   Electron Transport System – produces most of the ATP

8. Explain why the presence of oxygen makes respiration so much more efficient in producing ATP than fermentation

   The Kreb Cycle and the Electron Transport System cannot function without oxygen. Fermentation breaks down glucose only about halfway into ethyl alcohol. Hence, much energy is still stored in the bonds of ethyl alcohol. However, with oxygen, glucose is broken down completely into CO_2 and H_2O, so much more energy is released.

9. What is the relationship between respiration and heat production?

   Cellular respiration produces heat, since in the electron transport system, some of the energy is lost as heat. The heat is used to keep animals warm, especially warm blooded animals.

10. Describe the structure and function of mitochondria

    See picture of mitochondria above

    The mitochondria is where the Kreb cycle and electron transport system takes place. Hence, it is where most of the ATP is synthesized. Known as the power house of the cell