

1. to best utilize a dollar bill at the laundry mat is to break it into quarters

(to utilize glucose best you must do the same thing)

2. in photosynthesis we assemble, in respiration we take apart. Both slow and deliberate

3. Potential energy released in two ways:

a. all at once- not efficient, most lost as heat (rockets vs. toyota)

b. slowly but surely- more efficient less lost as heat (rockets vs. toyota)

## UNIT FIVE: RESPIRATION, ENERGY HARVEST

Upon completion of this unit you will be able to:

**1. Write the balanced equation for the aerobic oxidation of one molecule of glucose.**

**2. Define oxidation and reduction.**

3. Rank the organic molecules in regard to chemical bond energy and order in which they are utilized in respiration.

**4. List the sequence of events which occur in glycolysis.**

5. Explain what is significant about the bridge between glycolysis and the citric acid cycle.

**6. Describe the events in the Krebs Cycle (citric acid cycle).**

**7. Explain the workings of the electron transport system (cytochrome).**

8. List the functions of NAD, FAD and coenzyme-A.

**9. Account for 38 ATP gained from the aerobic decomposition of one molecule of glucose.**

10. Follow a molecule through the steps of interconversion of fats, proteins and carbohydrates: outline the metabolism of fats & proteins.

**11. Contrast aerobic and anaerobic respiration.**

**12. Provide examples of fermentation.**

**13. List several end products resulting from aerobic and anaerobic respiration.**

**14. Compare the efficiencies of aerobic and anaerobic respiration.**

**15. Explain why only about one-half of the chemical bond energy in a substrate molecule such as glucose can be used by the cell.**

16. Explain why cytochrome poisons are of serious consequence.

**17. Explain why the substrates employed for energy on planet earth must be in a reduced state (explain why the oxidation of NADH is necessary for the maintenance of life.**

18. Compare biochemical diversity with structural diversity on earth.

Unit References: [Text Chapter 6](#), [Chapter 25 has good nutritional info](#)

[www.mhhe.com/enger13](http://www.mhhe.com/enger13)

[An Online Biology Text Book](#)

35mm slides - Respiration

### Unit 5: Respiration, Energy Harvest

**RESPIRATION** (Cellular oxidation/ Biological Electron Transfer)

Slow, deliberate breakdown of fuels to release stored energy [text pg 116](#)

**Oxidation-Reduction** major reaction, alters # of electrons controlled by atom; these

occur simultaneously (Objective #2) text pg 37

\*Chemical bond energy: breakage of bonds ---> release of energy

### Objective #3

Energy containing substances Order of Utilization as Energy

(best to worst)

(most used to least used for energy)

1. Fats

1. sugars/starches

2. Sugars/starches

2. fats

3. Proteins

3. Proteins

**Question to carry with you this unit: Why do all substrates used for energy need to be in a reduced state? Objective #17**

Respiration- way of obtaining energy (biology's bookkeeping)



( Objective #1) text pg 117-118

Energy for all life's activities- growth, movement, active transport, synthesis, cell division, etc.

**\*\*\*As in Unit four your book has multiple descriptions of this process, each description including greater complexity from the one prior but essentially still describing the same process.**

## **I. AEROBIC RESPIRATION (w/ Oxygen) All but the smallest organisms prefer to do this.**

### **A. Major Players in Respiration (Objective #8)**

1. **dehydrogenase**- removes H<sup>+</sup> and electrons from substrates

2. **NAD<sup>+</sup>** (niacin, B<sub>3</sub> : milk, poultry, yeast, cereal) Investment molecule  
-coenzyme of dehydrogenase, hydrogen and electron carrier

\*\*Each NADH<sub>2</sub> (reduced NAD) will produce 3 ATP

3. **FAD<sup>+</sup>** (riboflavin, B<sub>2</sub> : milk, green veggies, liver, eggs) Investment molecule  
-coenzyme of dehydrogenase, hydrogen and electron carrier

\*\*Each FADH<sub>2</sub> (reduced FAD) will produce 2 ATP

4. **Pyruvic Acid** CH<sub>3</sub>--C--C--OH

-produced by glycolysis, breakage of glucose gives two pyruvic acid molecules

5. **Coenzyme A**- key in transition between glycolysis and Krebs cycle.  
Transfers pyruvic acid into Krebs

## B. Glycolysis- sugar splitting **\*\*takes place in cytoplasm of cell**

(Objective #4) text pg 118, 120, 122

1. Glucose split into 2 PGAL molecules; ATP used to provide energy for reaction
2. PGAL becomes pyruvic acid (pyruvate)
3. ANAEROBIC PROCESS. Glycolysis does not require Oxygen
4. Products: 2 pyruvic acid molecules  
2 ATP  
2 NADH<sub>2</sub>

**Check Out:**

### Glycolysis- The Universal Energy Pathway

### Glycolysis Intermediates

## C. Bridge between Glycolysis and Krebs Cycle (movement of molecules from cytoplasm to mitochondria) (Objective #5)

\*takes place at membrane of mitochondria

\*allows other substances (fats, proteins) to enter cycle

1. Pyruvate enters mitochondria (remember: there are 2!!!)
2. carbon removed in form of CO<sub>2</sub> (waste product)
3. removal creates a 2 carbon molecule ---> acetic acid (acetate) from each pyruvate
4. Hydrogen transferred to NAD<sup>+</sup> ---> NADH
5. Products: 2 NADH<sub>2</sub>  
2 acetate molecules  
2 CO<sub>2</sub> waste

\*\*\*remember 1 glucose makes 2 pyruvates, therefore, 2 acetates and 2 CO<sub>2</sub>

## D. Krebs Cycle (citric acid cycle) (Objective #6) text pg 118-119, 120, 123-125

**Check Out:**

The Krebs Cycle

Animated Krebs

Citric Acid Cycle

## What is the Krebs Cycle?

1. acetate combines w/citric acid to briefly produce a 6 carbon acid
2. CO<sub>2</sub> removed twice
3. remember: there are 2 acetate molecules entering cycle
4. Products: 4 CO<sub>2</sub> (waste)  
2 ATP  
6 NADH<sub>2</sub>  
2 FADH<sub>2</sub>

## **E. Electron Transport System (Cytochrome System) Cash in on investment; River system (Objective #7) Text pg 119, 121, 125-126**

1. utilizes energy created by NAD and FAD accepting H<sup>+</sup> from glycolysis and Krebs
2. H<sup>+</sup> transferred to ETS via NADH<sub>2</sub> and FADH<sub>2</sub>
3. As H<sup>+</sup> removed from carriers the electrons are shuttled to higher energy levels and eventually help ADP + P → ATP
4. Oxygen serves as final acceptor of the H<sup>+</sup> and e<sup>-</sup> broken from NADH<sub>2</sub> and FADH<sub>2</sub> to produce water (waste)
5. FAD and NAD are recycled

### **Check Out:**

### The Electron Transport System of Mitochondria

### Mitochondria Research Society

## **OK BUSINESS MAJORS, LET'S BALANCE THE BOOKS!**

## **OVERALL PRODUCTION FOR ONE GLUCOSE MOLECULE (Objective #9)**

	Energy Used	Energy (face value)	Created Carriers (investment)
Glycolysis	2 ATP	4 ATP	2 NADH <sub>2</sub>
Bridge (X2)	----	----	2 NADH <sub>2</sub>

Krebs (X2) -----	2 ATP	6 NADH <sub>2</sub> 2 FADH <sub>2</sub>
<hr/>		
NET ENERGY	4 ATP	10 NADH <sub>2</sub> 2 FADH <sub>2</sub>

\*\*Oxidation of each NADH<sub>2</sub> provides 3 ATP: 10 NADH<sub>2</sub> ----> 30 ATP

\*\*Oxidation of each FADH<sub>2</sub> provides 2 ATP: 2 FADH<sub>2</sub> ----> 4 ATP

Grand Totals: Glycolysis 2 ATP  
 Bridge 0 ATP  
 Krebs 2 ATP  
 ETS 34 ATP

Total = 38 ATP per glucose molecule

**38 ATP per glucose is the accepted "theoretical" production for a prokaryotic cell, eukaryotic cells typically average 36 ATP**

**CONSIDER THIS: (Objective #16)**

\*if oxygen not available everything after Glycolysis shuts down

\*if cytochrome poisons (unit 3) present ETS shuts down

How many ATPs will be produced without the ETS?

**F. Respiration of Fats and Proteins (Objective #10) text pg 128-130**

1. **Fats**- broken down to glycerol and 3 Fatty acids
  - a. glycerol is altered to pyruvate and enters at glycolysis side of bridge
  - b. fatty acids broken by 2s to acetate and enter at Krebs side of bridge
  - c. everything after they enter is the same as for glucose

Can you determine why fats can produce more energy than glucose?

Can you figure out why we don't use fats to make alcohol?

**2. Proteins**

- a. broken to amino acids
- b. amino acids altered to fatty acids by removal of amino
- c. enters Krebs as acetate

\*\*\*if you are utilizing your stored proteins energy source (primary) you are in trouble!!

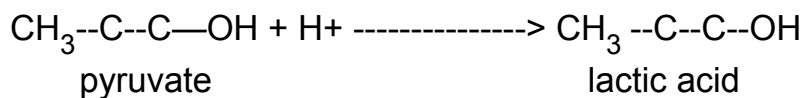
## ANAEROBIC RESPIRATION- energy harvest in the absence of oxygen (Objectives 11, 12, 13, 14, 15) text pgs 126-128

A. **Fermentation**- rather than oxygen becoming the final acceptor of H<sup>+</sup>, pyruvic acid becomes the final acceptor.  
-glycolysis only pathway working

### 1. Lactic Acid Fermentation

\*Animals, bacteria pyruvate + H<sup>+</sup> ---> lactic acid (pg 127)  
-if Oxygen is not in sufficient supply (oxygen debt) then pyruvate becomes lactic acid

\*under normal conditions, of course, pyruvate broken further



\*soreness and fatigue

### 2. Alcoholic Fermentation

\*yeast, plant cells (text pg 127)  
pyruvate + H<sup>+</sup> -----> alcohol + CO<sub>2</sub>

alcoholic fermentation  
-disadvantage to yeast, concentration of 15% lethal (ethyl)

B. **Products** of Anaerobic Respiration (Objective #13) text pg 127

1. muscle cells ---> rapid burst of ATP  
-lactic acid accumulation, pH changes ---> soreness, fatigue
2. ethyl alcohol ---> alcoholic drinks, ethanol

**Check Out:**

## ENERGY YIELD: AEROBIC VS. ANAEROBIC (Objective #14, 15) text pg 127

\***Aerobic**- due to presence of oxygen, glucose will not only go through glycolysis but Krebs and ETS ---> 38 ATP produced  
This represents ~ 39--> 44% of available energy

\***Anaerobic**- glucose can only go through glycolysis because there is no oxygen to transfer hydrogen to.  
(pyruvate smallest molecule), only 2 ATP  
This represents 2-5% of available energy.

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