Honors Biology Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
NDHS Per: \_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_

**Cellular Respiration**

Respiration = to breathe  
Breathing at the cellular level

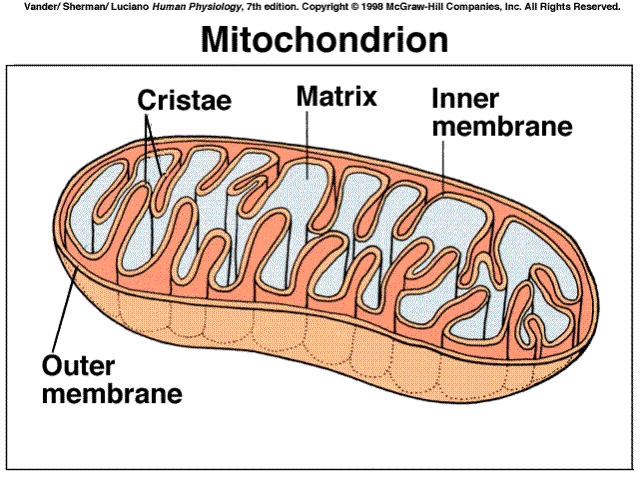
**Purpose**: to **generate ATP** for cellular work by transferring the **energy trapped in food molecules**

**HOW**: Food molecules are **broken down** and the **energy released as energyized electrons** is captured and **transferred to make ATP**

**Uses Hydrogen Acceptors**:  
 NAD+ – **nicotinamide adenine dinucleotide** FAD – **flavin adenine dinucleotide**

**Types of Cellular Respiration**:  
**Aerobic** – uses **oxygen** and requires **mitochondria** – in **Eukaryotic cells  
Anaerobic** – **does** **not use oxygen** and occurs in the **cytoplasm** – in **Prokaryotes and Eukaryotes**

**Structure of the Mitochondria**:



**Cellular Respiration Equation**:

C6H12O6 + 6 O2 🡪 6 H2O + 6 CO2

**Steps of Cellular Respiration:**

1. **Glycolysis**: Glucose is **split in half** – same as **anaerobic respiration**

- occurs in **cytoplasm**

2. **Krebs Cycle**:

- products of glycolysis are broken down **releasing CO2 and transferring electrons and hydrogens to NAD+ and FAD**

- occurs in **matrix of mitochondria**

3. **Oxidative Phosphorylation (Electron Transport Chain)**:  
 - energized electrons are used to make a **hydrogen gradient to make ATP**

- occurs in the **inner membrane and intermembranous space of the mitochondria**

**GLYCOLYSIS: THE DETAILS**:  
**Two Parts**:   
 1) **Energy Investment Stage**:

**2 ATP** molecules are used to **energize** a glucose molecule  
 This makes it **unstable** and it **breaks apart into two, 3 Carbon molecules**.

2) **Energy Payoff Stage**:   
 The phosphates from the 3 carbon molecules are used to make **4 ATP**.   
 Two NAD+ gain **electrons and hydrogens** to make **2 NADH**.   
 The end products are **2, 3 Carbon molecules called Pyruvate**.

|  |  |
| --- | --- |
| **Reactants** | **Products** |
| **Glucose 2 ATP 2 NAD+** | **2 Pyruvate – go to Krebs Cycle 4 ATP (Net of 2) 2 NADH – go to ETC** |

**Krebs Cycle:**

Occurs in the **Matrix** of the Mitochondria

Everything in the Krebs Cycle **happens twice** because there are **two pyruvates** from glycolysis.

1. Pyruvate enters the **mitochondria and immediately loses a CO2** and makes a **NADH** forming **acetic acid** which binds to an enzyme called **Co-enzyme A.**

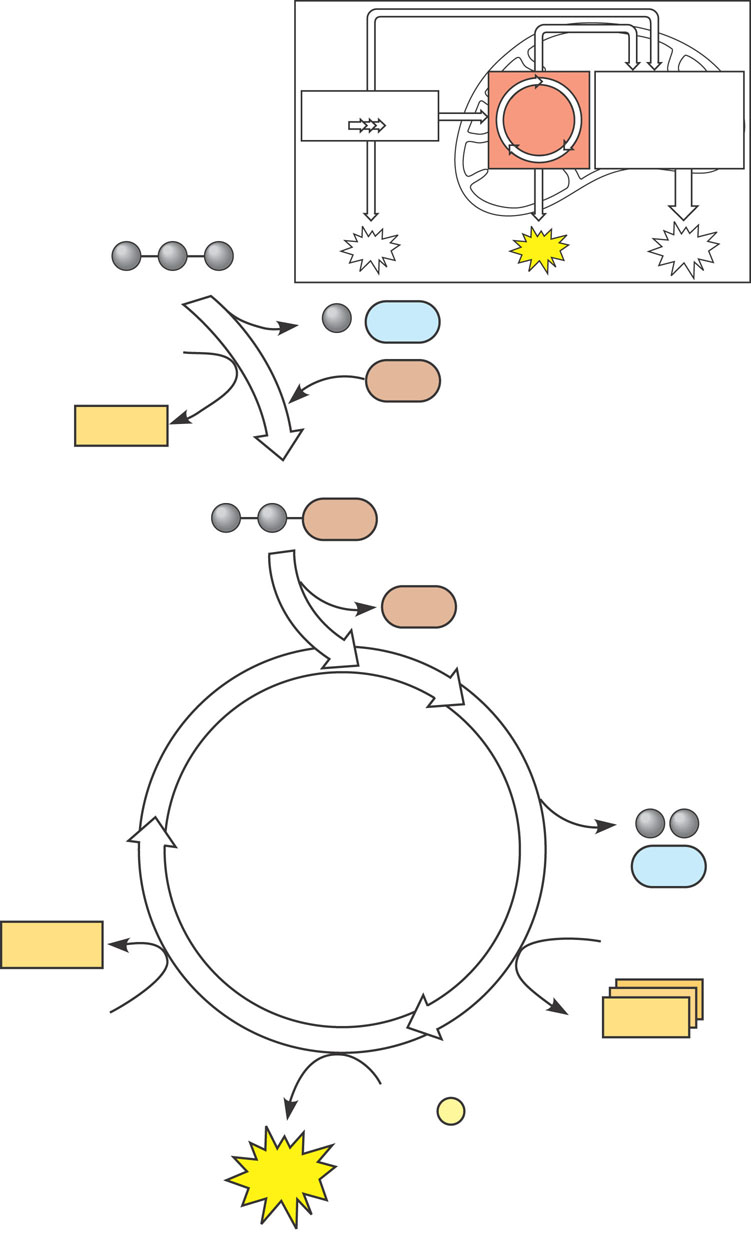
CO2

NAD+

NADH

Pyruvate Acetic Acid + Coenzyme A 🡪 Acetyl CoA

1. Acetic CoA bonds with a **4 carbon** compound called **oxaloacetate** to make **Citric Acid** (Krebs is also called the Citric Acid Cycle)
2. Citric undergoes many changes and releases **2 CO2 molecules, 1 ATP, and 3 NADHs and 1 FADH2**.
3. At the end the 4 carbon compound, oxaloacetate, is **remade = cycle.**



ATP

2 CO2

3 NAD+

3 NADH

+ 3 H+

ADP + P i

FAD

FADH2

**Citric  
acid  
cycle**

CoA

CoA

Acetyle CoA

NADH

+ 3 H+

CoA

CO2

**Pyruvate**  
(from glycolysis,  
2 molecules per glucose)

ATP

ATP

ATP

Glycolysis

Citric  
acid  
cycle

Oxidative  
phosphorylation

|  |  |
| --- | --- |
| **Reactants** | **Products** |
| 2 Pyruvate 8 NAD+ 2 FAD 2 ADP 2 Phosphates | 6 CO2 8 NADH 2 FADH2 2 ATP |

**Electron Transport Chain:**

Where: **Inner membrane, Matrix, and Intermembranous Space**

What Happens:

**Energized electrons** from **NADH and FADH2** enter the ETC and **pump Hydrogen ions** into the **intermembranous space**.  
Hydrogen ions pass through **ATP Synthase to make ATP**.  
Electrons pass from the **ETC to Oxygen** which then combines with **Hydrogen ions to make water**.

The whole process is called **Chemiosmotic Phosphorylation**.

Chemiosmosis = osmosis of chemicals  
 Phosphorylation = adding phosphates

Intermembranous Space

Matrix

NADH

NAD+ + H+

FAD + 2 H+

FAD

**e-**

**e-**

**e-** + 2 H2O

O2 + 4 H+ +

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

H+ ions

ADP + P

ATP

H+ ions

**ATP Yields**:  
Each NADH **= 3 ATP**  
Each FADH2 = **2 ATP**

Totals: 10 NADH x 3 = **30 ATP**  
 2 FADH2 x2 = **4 ATP**

Total = 34 ATP

|  |  |
| --- | --- |
| **Reactants** | **Products** |
| 10 NADH 2 FADH2 ADP + Phosphate Oxygen Hydrogen Ions | 10 NAD+ 2 FAD 34 ATP H2O |

**Total Energy Yield for 1 Glucose:**Glycolysis = **2 ATP**  
Krebs Cycle = **2 ATP**  
ETC = **34 ATP**  
Total = **38 ATP**

**Anaerobic Respiration**

Prokaryotes just use **glycolysis**. Each glucose yields **2 ATP.**

Eukaryotes use Aerobic Respiration unless the cells become starved of **oxygen**.

Lack of oxygen shifts metabolism from **aerobic respiration to fermentation (anaerobic).**

This is done to keep the cell alive until **oxygen is restored**.

**Types of Fermentation:  
Alcoholic Fermentation: Yeast cells**Cells take **pyruvate and remove a CO2 molecule making acetic anhydride**.   
NADH is used to convert the **acetic acid into ethyl alcohol and NAD+.**   
The NAD+ can be used in glycolysis to make **ATP keeping the cell alive**.

|  |  |
| --- | --- |
| **Reactants** | **Products** |
| Pyruvate NADH | Ethanol NAD+ CO2 |

**Lactic Acid Fermentation: Muscle Cells**

Pyruvate uses **NADH to make lactic acid and NAD+**NAD+ is used in glycolysis to make **ATP**.   
Lactic acid causes the muscles to **burn**, slowing you down, allowing more **oxygen** **to get to the cells**.

|  |  |
| --- | --- |
| **Reactants** | **Products** |
| Pyruvate NADH | Lactic Acid NAD+ |