CELLULAR RESPIRATION

Dr. Bertolotti

Essential Question

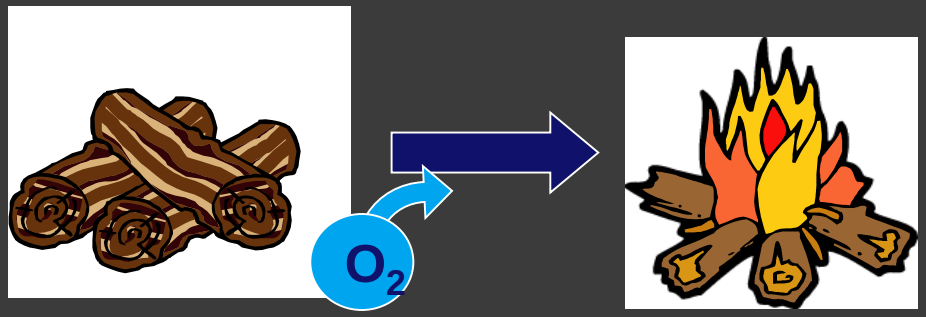
- **How do organisms obtain energy?**

What is cellular respiration?

“Burn fuels” to make energy

combustion

making heat energy by burning fuels in one step

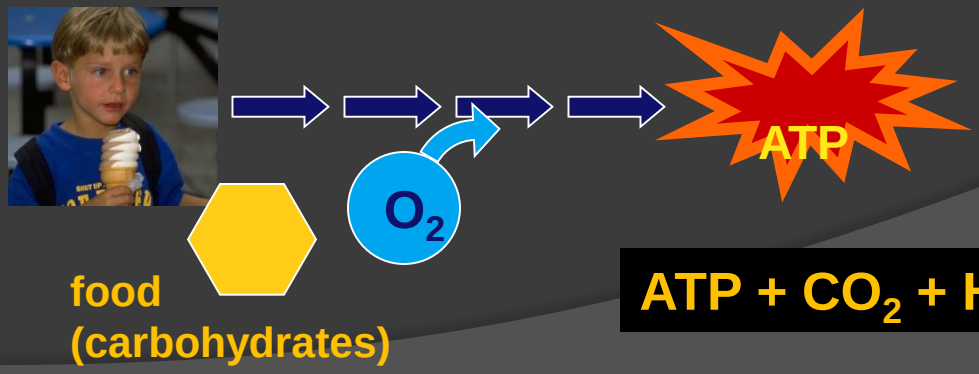


Fuel (carbohydrates)

$CO_2 + H_2O$ + heat

aerobic respiration

making ATP energy (& some heat) by burning fuels in many small steps

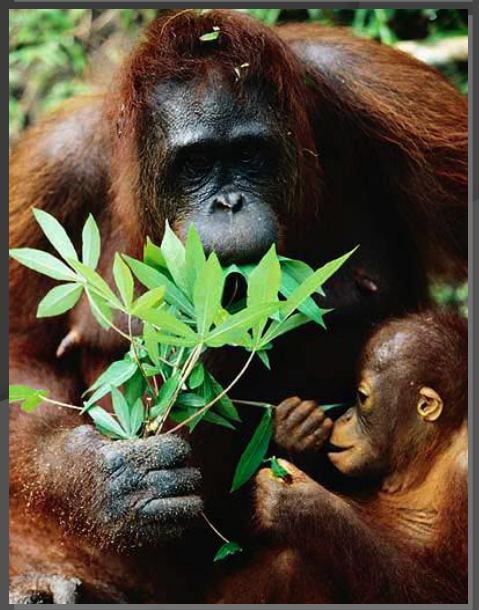


food (carbohydrates)

ATP + CO_2 + H_2O (+ heat)

Energy needs of life

- Animals are energy consumers
  - What do we need energy for?
    - synthesis (building for growth)
    - reproduction
    - active transport
    - movement
    - temperature control (making heat)



Where do we get energy?

- Energy is stored in organic molecules
  - carbohydrates, fats, proteins
- Animals eat these organic molecules → food
  - digest food to get
    - fuels for energy (ATP)
    - raw materials for building more molecules
      - carbohydrates, fats, proteins, nucleic acids

Overview of Cellular Respiration

- Cellular respiration is the process that **releases energy** by breaking down glucose and other food molecules in the presence of **oxygen in the cell**
- $6O_2 + C_6H_{12}0_6 \rightarrow 6CO_2 + 6H_2O$ + energy **OR**

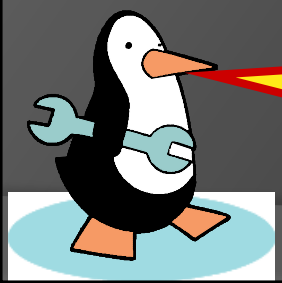
oxygen + glucose → carbon dioxide + water + energy

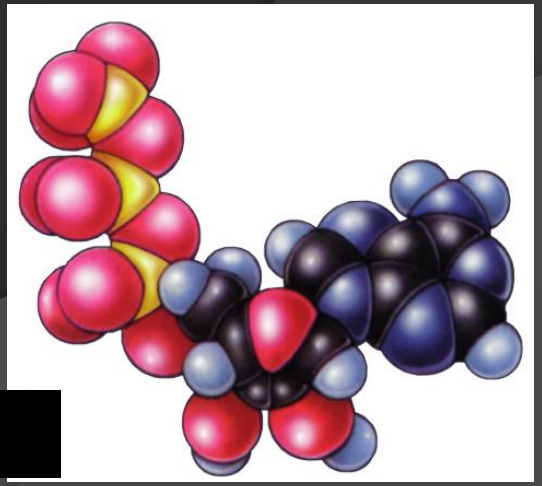
- The reactants are oxygen and glucose (monosaccharide or sugar)
- The products of cellular respiration are carbon dioxide, water, and energy.

What is energy in biology?

ATP

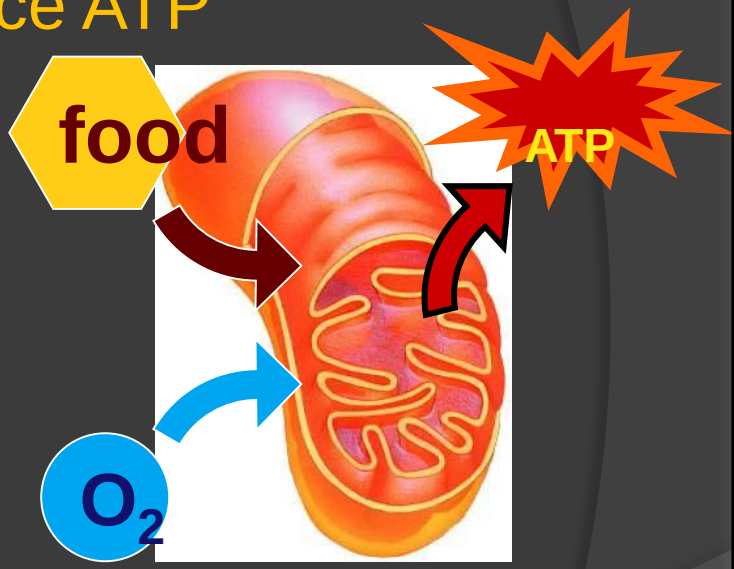
Adenosine TriPhosphate





Harvesting energy stored in food

- Cellular respiration
  - breaking down food to produce ATP
    - in mitochondria
    - using oxygen
      - "aerobic" respiration
  - usually digesting glucose
    - but could be other sugars, fats, or proteins

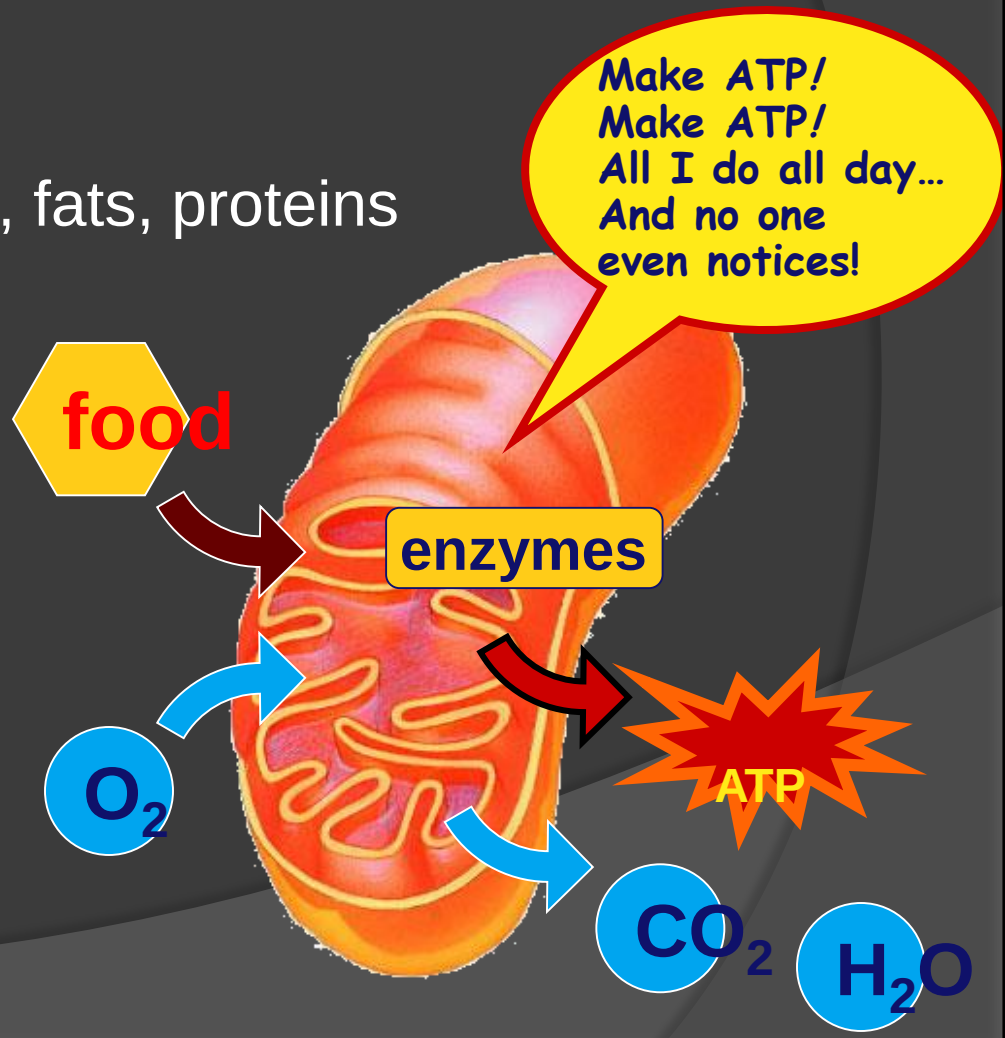


glucose + oxygen → energy + carbon dioxide + water

$$C_6H_{12}O_6 + 6O_2 \rightarrow ATP + 6CO_2 + 6H_2O$$

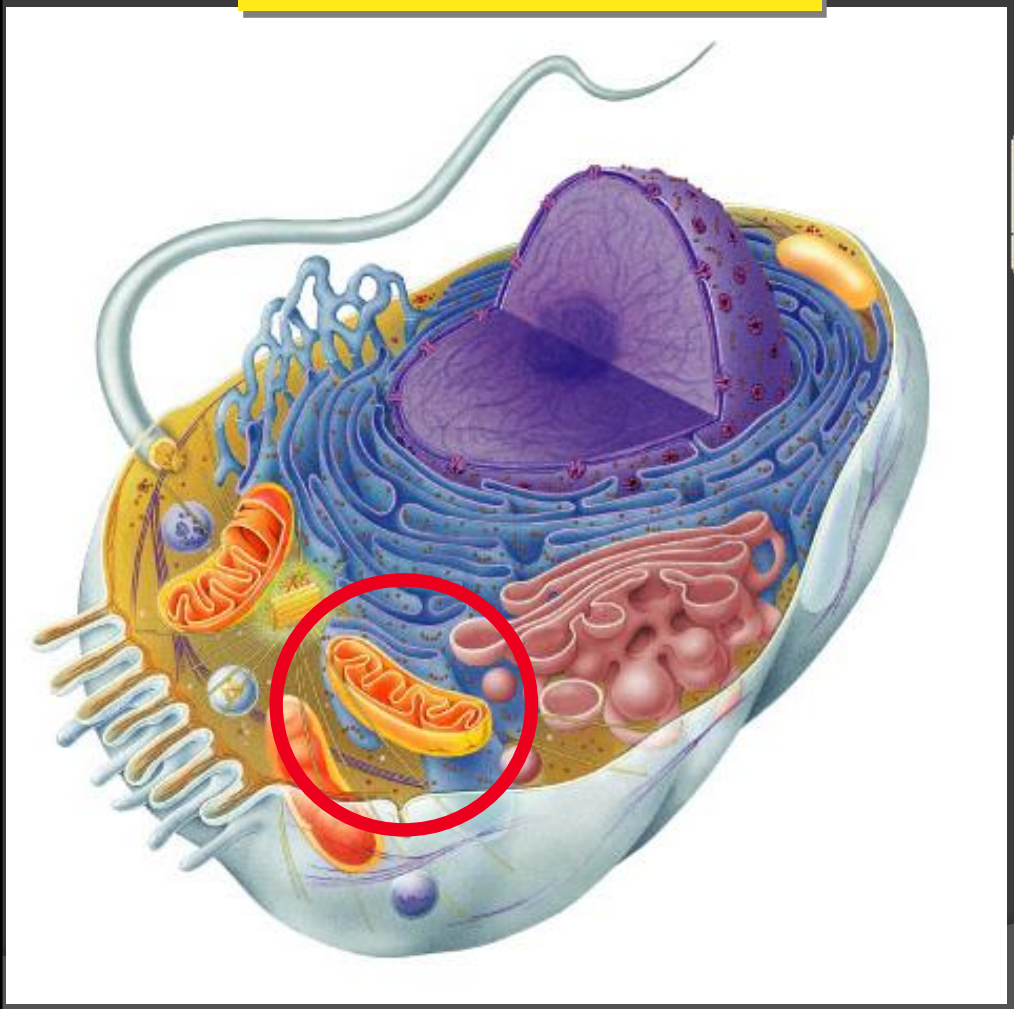
What do we need to make energy?

- The "Furnace" for making energy
  - mitochondria
- Fuel
  - food: carbohydrates, fats, proteins
- Helpers
  - oxygen
  - enzymes
- Product
  - ATP
- Waste products
  - carbon dioxide
    - then used by plants
  - water

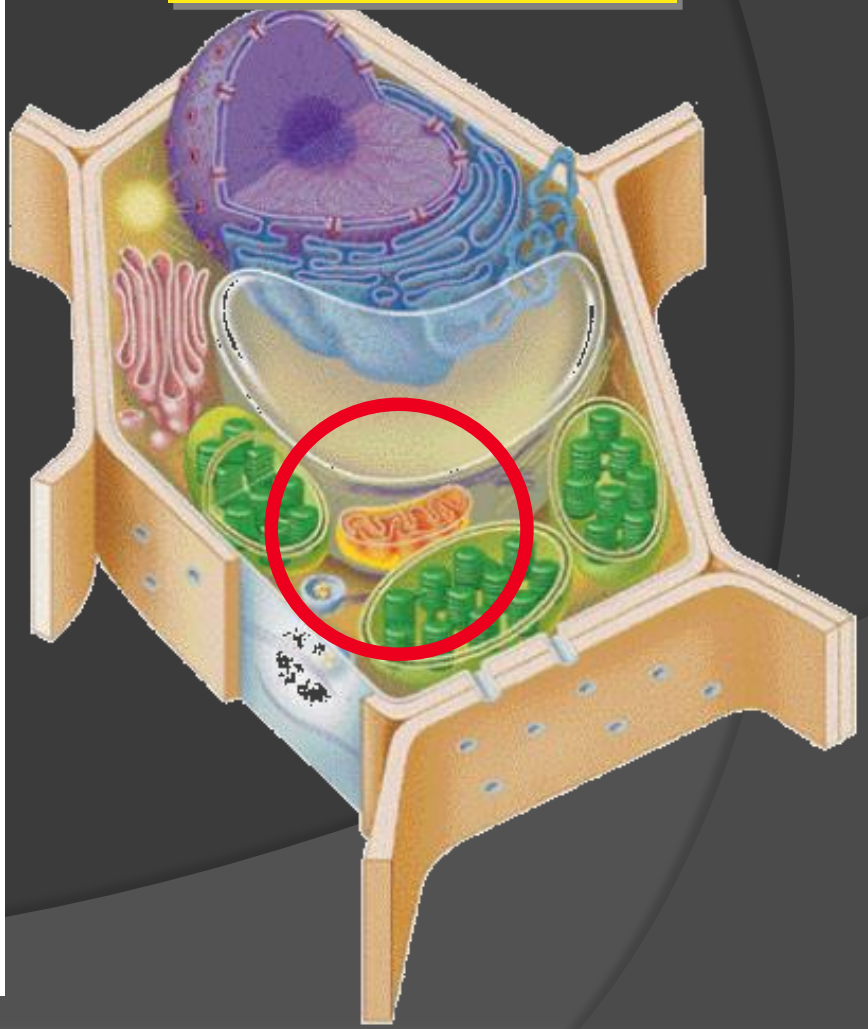


Mitochondria are everywhere!!

animal cells



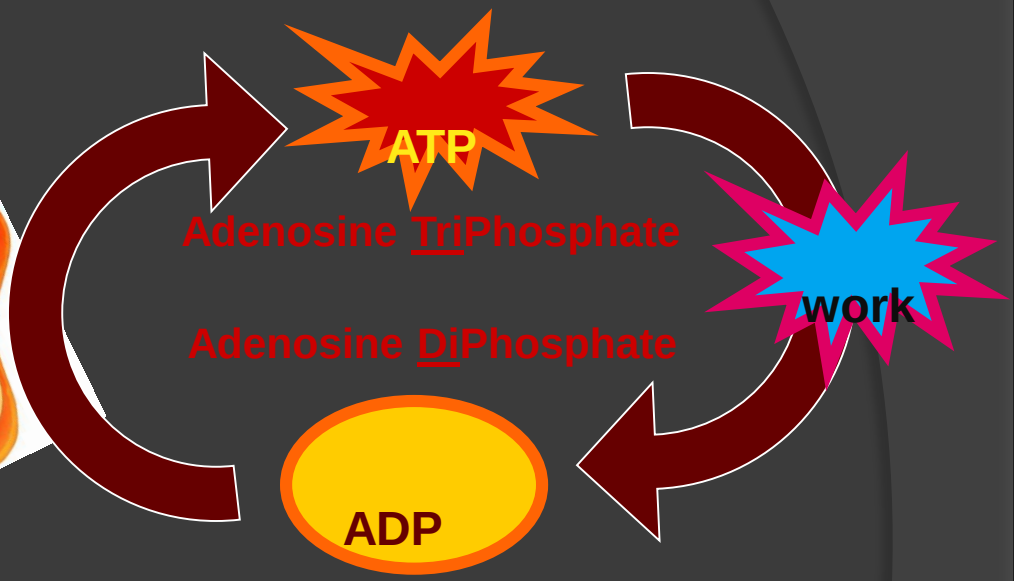
plant cells



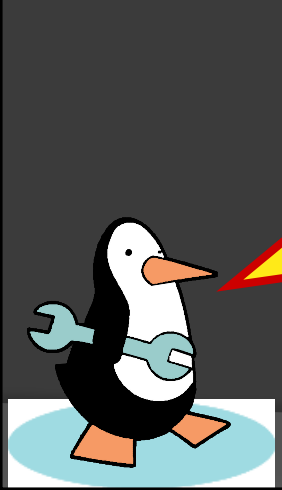
Using ATP to do work?

Can't store ATP

- too unstable
- only used in cell that produces it
- only short term energy storage
  - carbohydrates & fats are long term energy storage



A working muscle recycles over 10 million ATPs per second



QUESTION AND ANSWER

What is cellular respiration?

What happens during each stage of cellular respiration?

A Body's Energy Budget

eat food

1 make energy

ATP

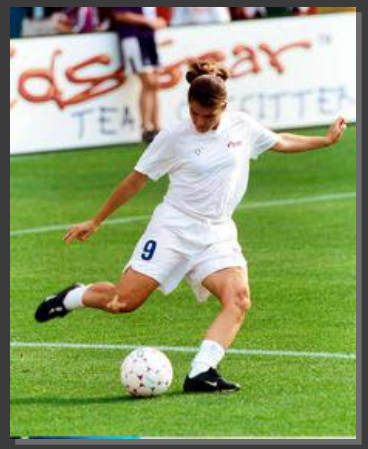
- energy needed even at rest
- activity
- temperature control

2 synthesis (building)

- growth
- reproduction
- repair

3 storage

- glycogen (animal starch)
- fat

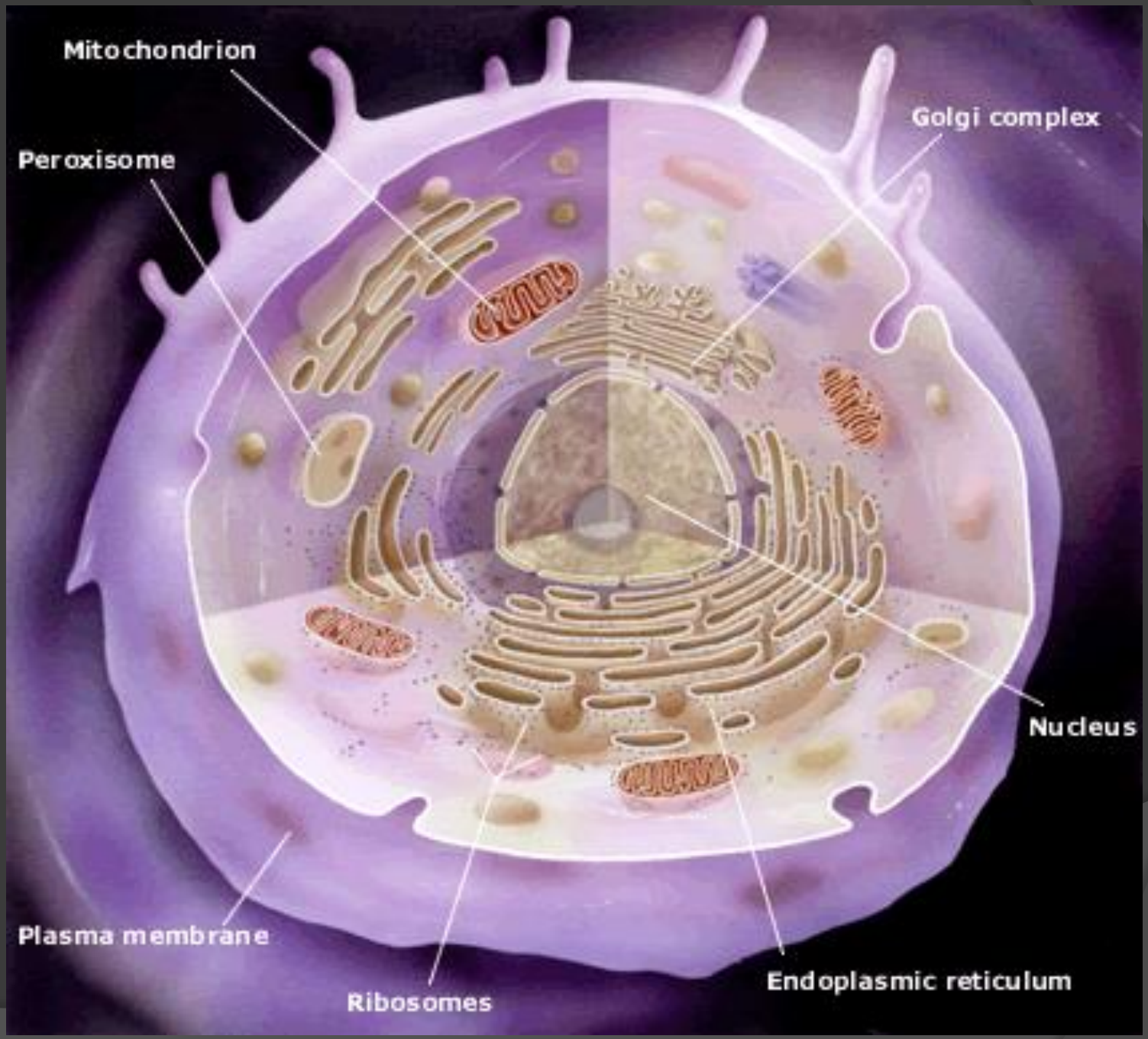


Steps in Cellular Respiration

- When oxygen is present, there are 3 steps in cellular respiration
  - 1. Glycolysis
  - 2. Krebs Cycle
  - 3. Electron transport chain
- These 3 steps ensure that energy is not lost as heat or light and that energy is released gradually or over a longer time (thus improving efficiency and effectiveness)
- Because this pathway requires oxygen, it is said to be **aerobic**

Glycolysis

- Occurs in the cytoplasm
- Is the process in which one molecule of glucose is broken in 1/2, producing 2 molecules of pyruvic acid (or pyruvate)
- It is an energy releasing process as 2 ATP molecules are used to create or produce 4 ATP molecules, thus the net gain is 2 ATP molecules
- NAD+ is the electron carrier in glycolysis
  - NAD+ accepts a pair of electrons, creating NADH
- The advantage of the glycolysis process is
  - 1. it is fast as thousands of ATP molecules are produced in milliseconds and,
  - 2. the process itself does not require oxygen


Mitochondrion
Golgi complex
Peroxisome
Nucleus
Plasma membrane
Ribosomes
Endoplasmic reticulum

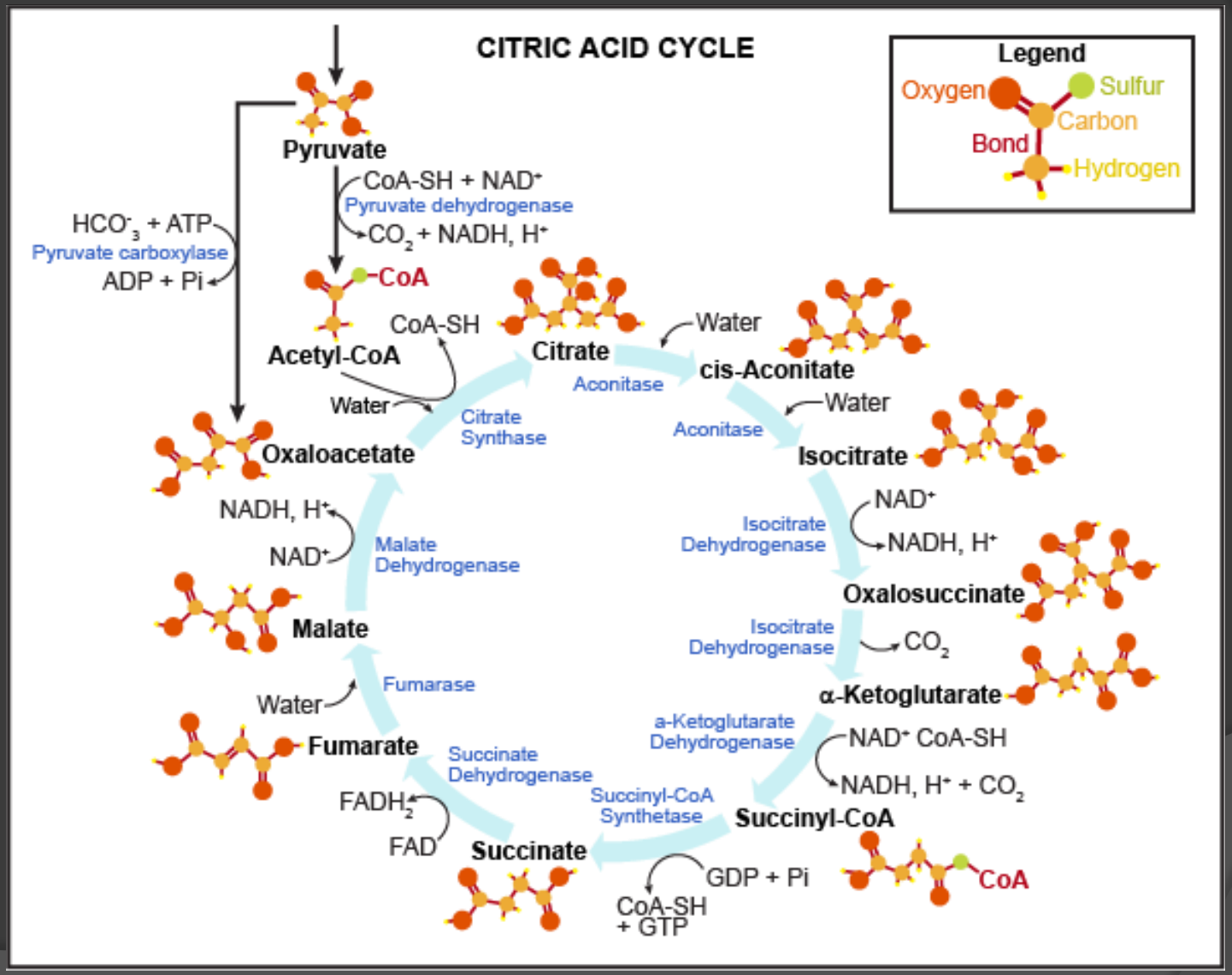
The Krebs Cycle/ Citric Acid Cycle

- Occurs in the mitochondria
- After glycolysis and in the presence of oxygen, pyruvic acid (pyruvate) is used in the Krebs Cycle.
- Here pyruvic acid (pyruvate) is broken down into acetyl Co-A and carbon dioxide in a series of energy extracting reactions
- Citric acid is the first product of the Krebs Cycle, hence its use as the alternative name citric acid cycle

The Krebs Cycle (continued)

- Involves the electron carriers NAD+ and FAD
- The carbon dioxide released is the source of all the carbon dioxide in your breath
- The products are carbon dioxide, NADH, ATP, and $FADH_2$.

The Krebs Cycle (continued)



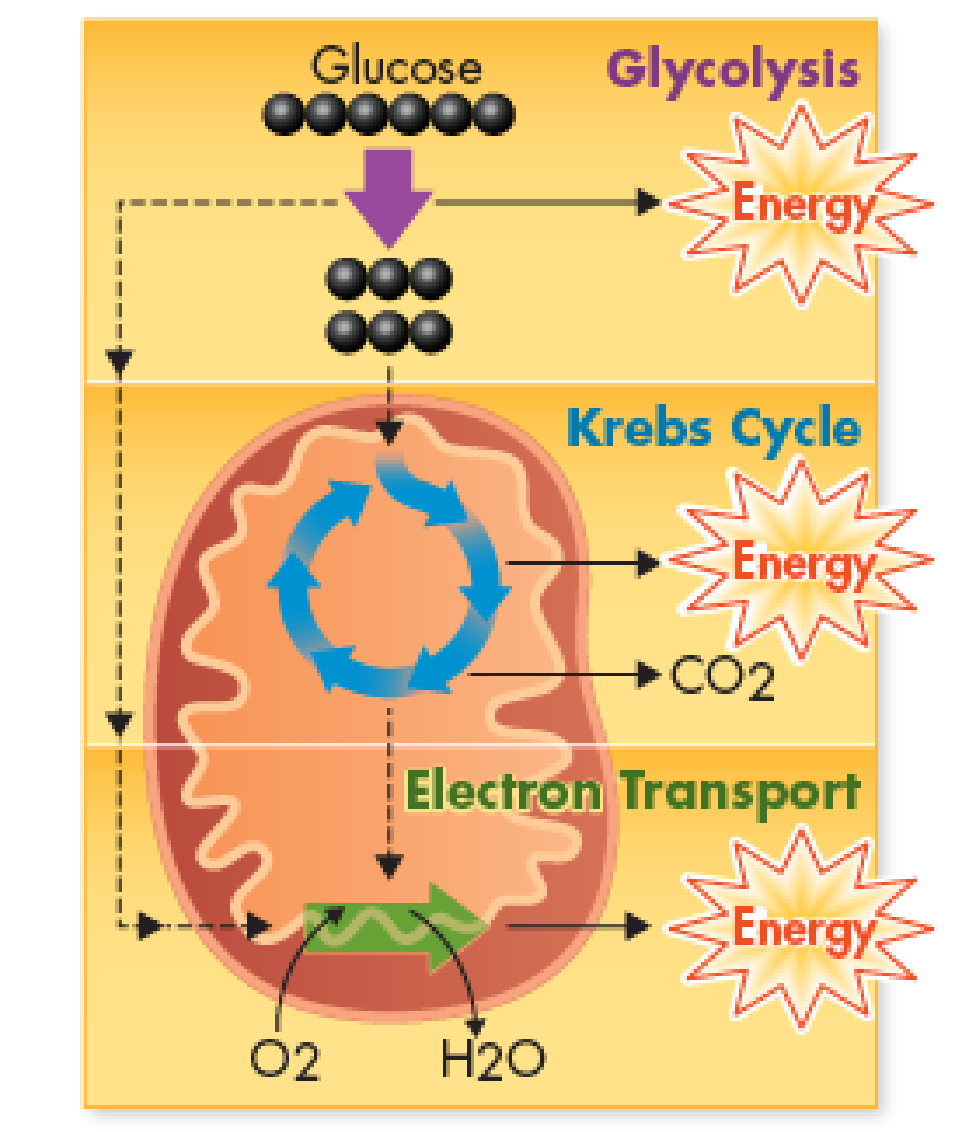
Electron transport

- Occurs along the carrier proteins in the inner membrane of the mitochondria
- 3rd process in cellular respiration in the presence of oxygen
- Uses high energy electrons from the Krebs Cycle to convert ADP to ATP. ATP synthase is used to generate ATP from ADP.
- Each pair of high energy electrons provides enough energy to produce 3 molecules of ATP from ADP.

TOTALS

- Glycolysis- 2 ATP (net gain)
- No oxygen- not as much energy can be extracted when compared with cellular respiration
- Krebs Cycle and electron transport- 34 ATP per glucose molecule
- *Entire net gain cellular respiration process*: 36 ATP molecules (38 total)
- 62% of energy lost as heat, only 38% used to produce energy

Stages of cellular respiration



QUESTION AND ANSWER

What happens during each stage of cellular respiration?

How do organisms generate energy when oxygen is not available?

Fermentation

- After glycolysis occurs, if **no Oxygen (O_2)** is present, fermentation occurs
  - Fermentation is an anaerobic process because it occurs in the absence of oxygen
- Fermentation is the process by which cells release energy in the absence of oxygen
- During fermentation, NADH is converted to NAD+ by passing high energy electrons back to pyruvic acid (pyruvate)
- A facultative anaerobe is an organism that makes ATP by aerobic respiration if oxygen is present, but is capable of switching to fermentation or anaerobic respiration if oxygen is absent

Fermentation

- There are 2 main types of anaerobic respiration or fermentation:
    1. Alcoholic fermentation
    2. Lactic acid fermentation
- Alcoholic fermentation
  - Used by yeast
  - Creates ethyl alcohol (alcohol) and carbon dioxide as waste and regenerates NAD+
  - Causes bread dough to rise
- Lactic acid fermentation
  - Used by bacteria and animals
  - Produces lactic acid, carbon dioxide, and NAD+
  - Is produced by muscles during rapid exercise when the body cannot supply enough oxygen to the tissues

What if oxygen is missing?

- No oxygen available = can't complete aerobic respiration
- Anaerobic respiration
  - also known as fermentation
    - alcohol fermentation
    - lactic acid fermentation
  - no oxygen or no mitochondria (bacteria)
  - can only make very little ATP (4 ATP)
  - large animals cannot survive

Anaerobic Respiration

- Fermentation
  - alcohol fermentation
    - yeast
      - glucose → ATP + CO_2 + alcohol
      - make beer, wine, bread
  - lactic acid fermentation
    - bacteria, animals
      - glucose → ATP + lactic acid
      - bacteria make yogurt
      - animals feel muscle fatigue

Tastes good… but not enough energy for me!

Energy & Exercise

- Quick energy – Lactic Acid fermentation is used to get quick energy and gives off lactic acid as a by product, thus the muscle pain.
- Long-Term Energy – Use cellular respiration to produce energy. Exercising or activities that last for at least 15 to 20 minutes. Best form for weight control.

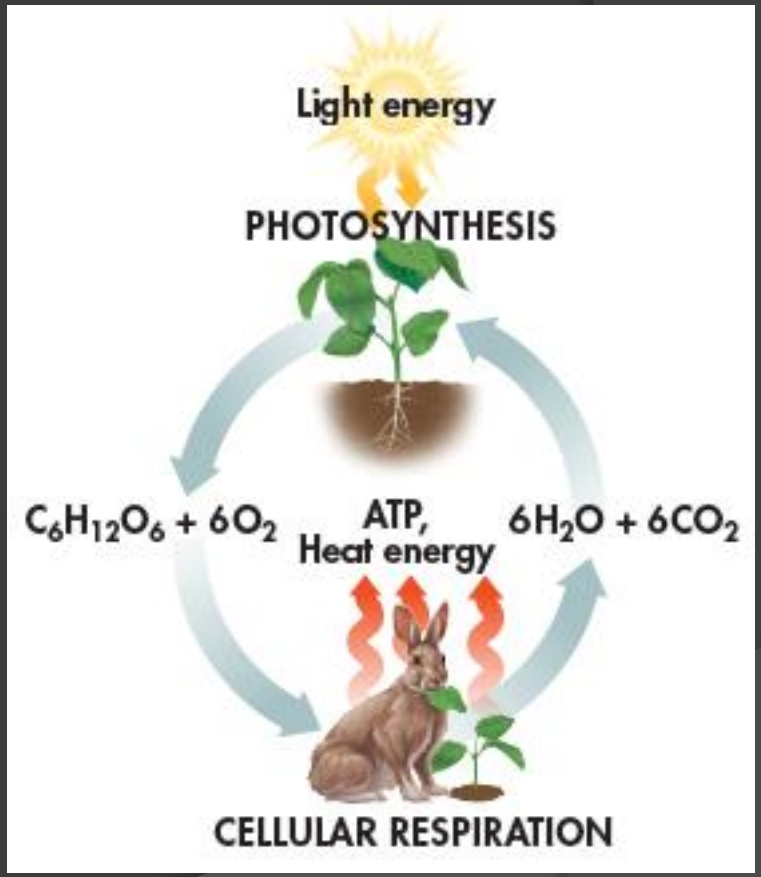
QUESTION AND ANSWER

How do organisms generate energy when oxygen is not available?

Compare Photosynthesis and Cellular Respiration

Comparing Photosynthesis and Cellular Respiration

- Photosynthesis and cellular respiration are opposite processes.
- The energy flows in opposite directions. Photosynthesis “deposits” energy, and cellular respiration “withdraws” energy.
- The reactants of cellular respiration are the products of photosynthesis and vice versa.
- The release of energy by cellular respiration takes place in plants, animals, fungi, protists, and most bacteria.
- Energy capture by photosynthesis occurs only in plants, algae, and some bacteria.



Comparing Photosynthesis & Respiration

	Photosynthesis	Cellular Respiration
Function	Energy Storage	Energy Release
Location	Chloroplasts	Mitochondria
Reactants	CO_2 and H_2O	$C_6H_{12}O_6$ and O_2
Products	$C_6H_{12}O_6$ and O_2	CO_2 and H_2O
Equation	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

QUESTION AND ANSWER

Compare Photosynthesis and Cellular Respiration

Essential Question

- **How do organisms obtain energy?**