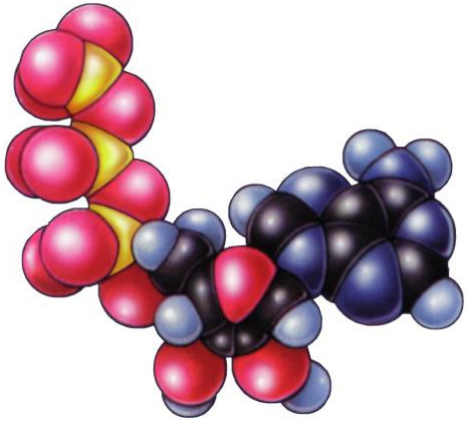
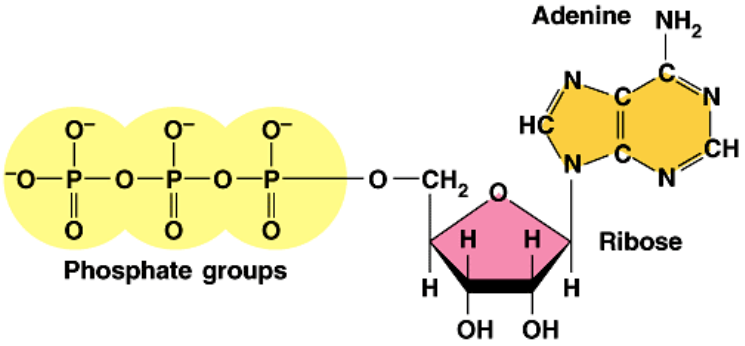
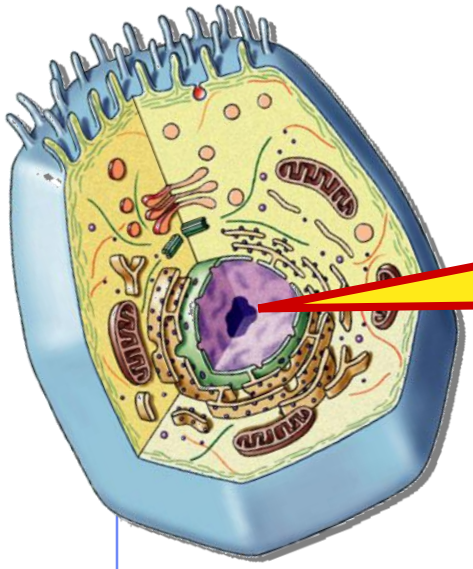


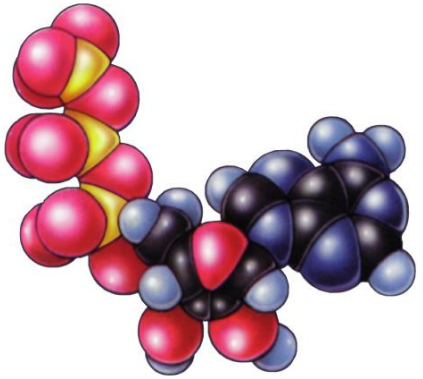


Cellular Respiration
Harvesting Chemical Energy

ATP

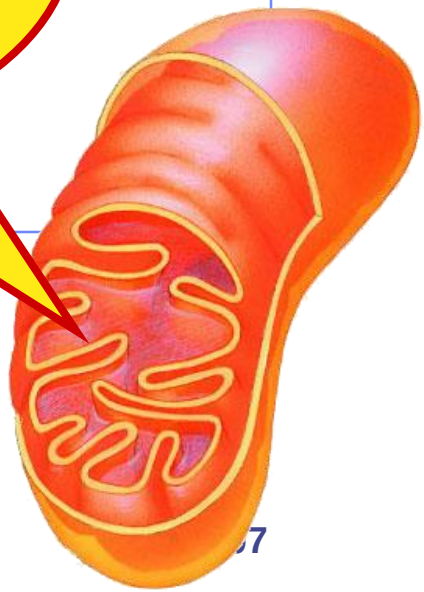


What's the point?



The point is to make ATP!

ATP



Harvesting stored energy

- Energy is stored in organic molecules
  - carbohydrates, fats, proteins
- Heterotrophs eat these organic molecules → food
  - digest organic molecules to get…
    - raw materials for synthesis
    - fuels for energy
      - controlled release of energy
      - "burning" fuels in a series of step-by-step enzyme-controlled reactions

Harvesting stored energy

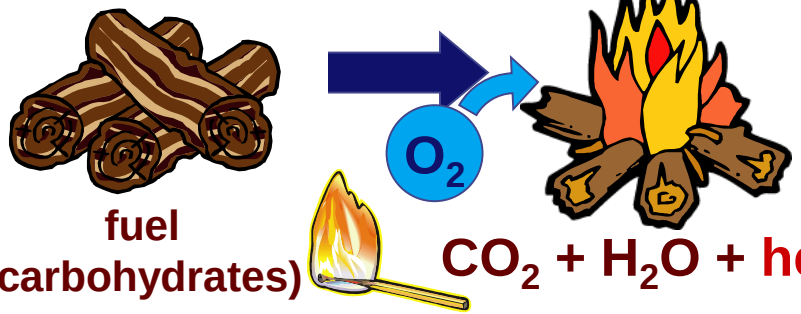
- Glucose is the model
  - **catabolism** of glucose to produce ATP

respiration

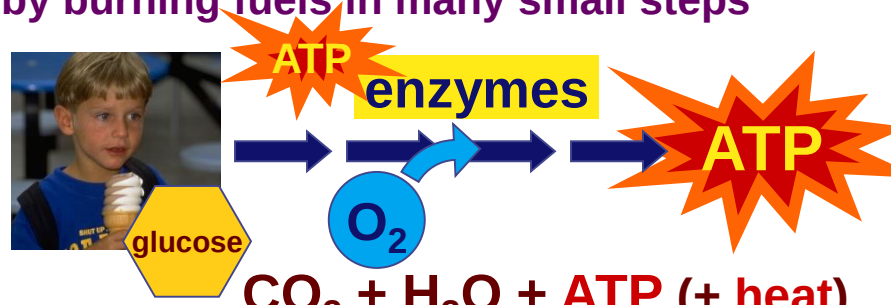
glucose + oxygen → energy + water + carbon dioxide

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

COMBUSTION = making a lot of heat energy by burning fuels in one step

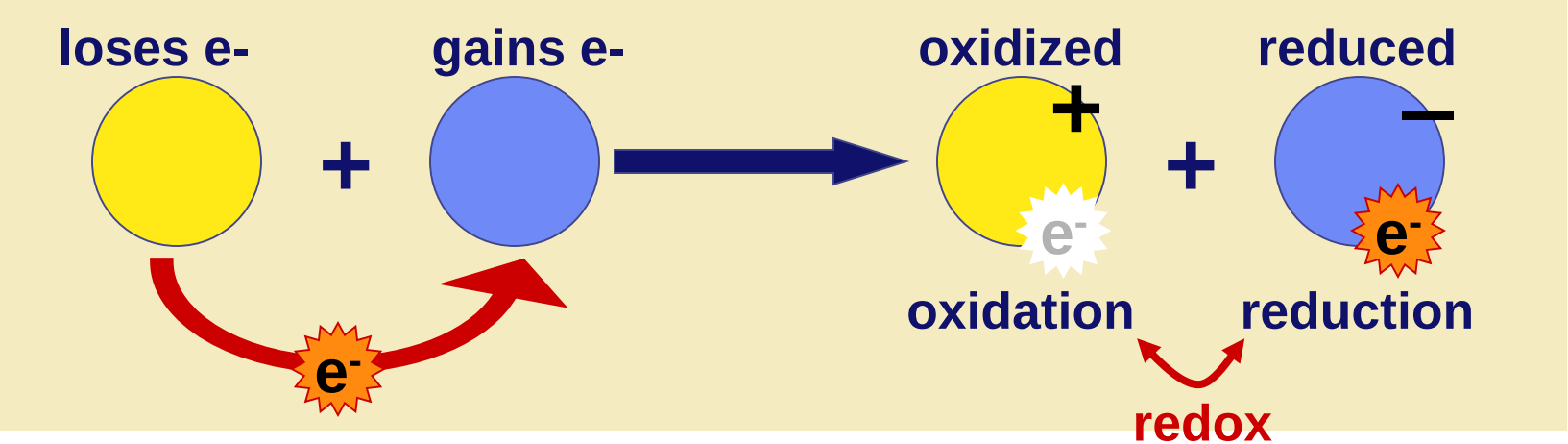


RESPIRATION = making ATP (& some heat) by burning fuels in many small steps



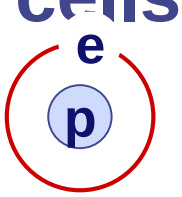
How do we harvest energy from fuels?

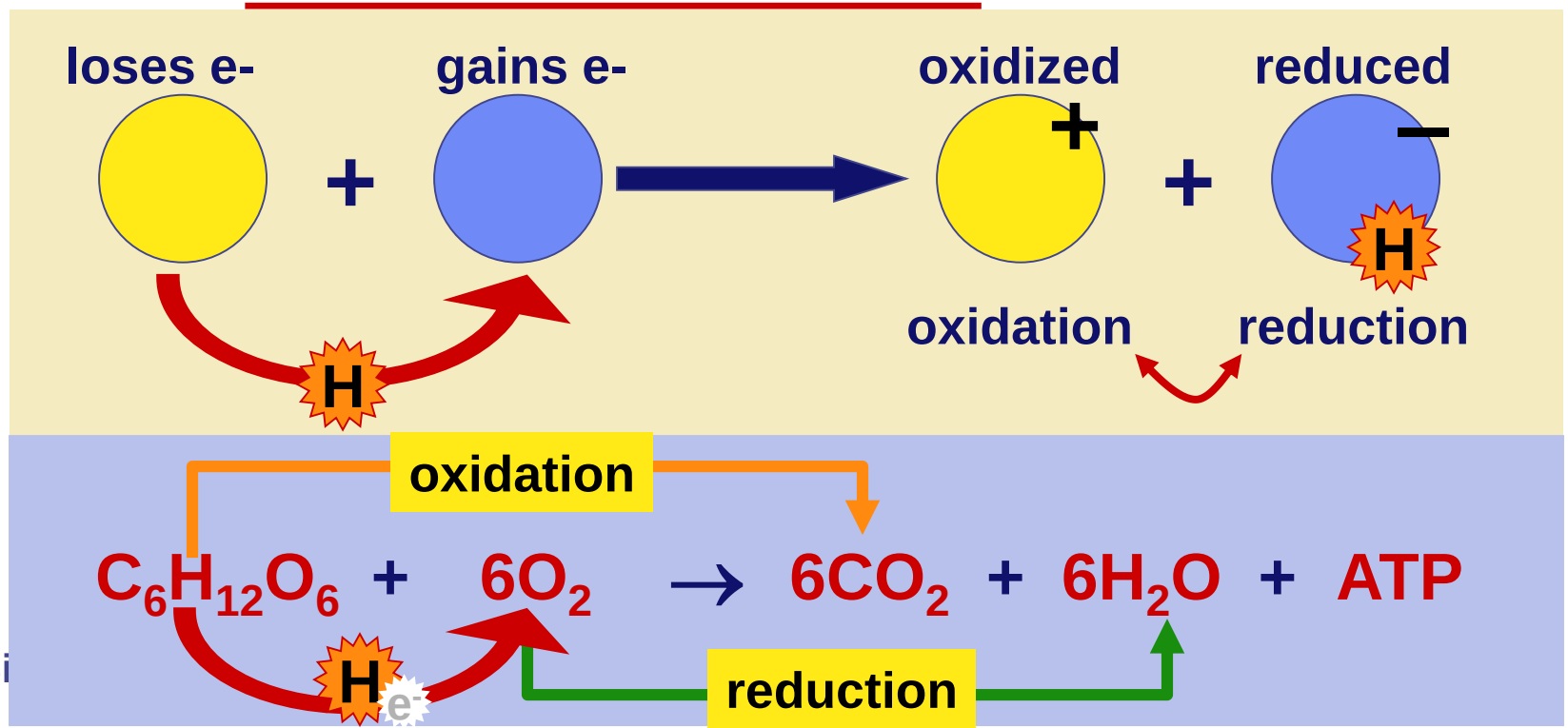
- **Digest large molecules into smaller ones**
  - **break bonds & move electrons from one molecule to another**
    - **as electrons move they "carry energy" with them**
    - **that energy is stored in another bond, released as heat or harvested to make ATP**



How do we move electrons in biology?

- Moving electrons in living systems
  - electrons cannot move alone in cells
    - electrons move as part of H atom
    - move H = move electrons

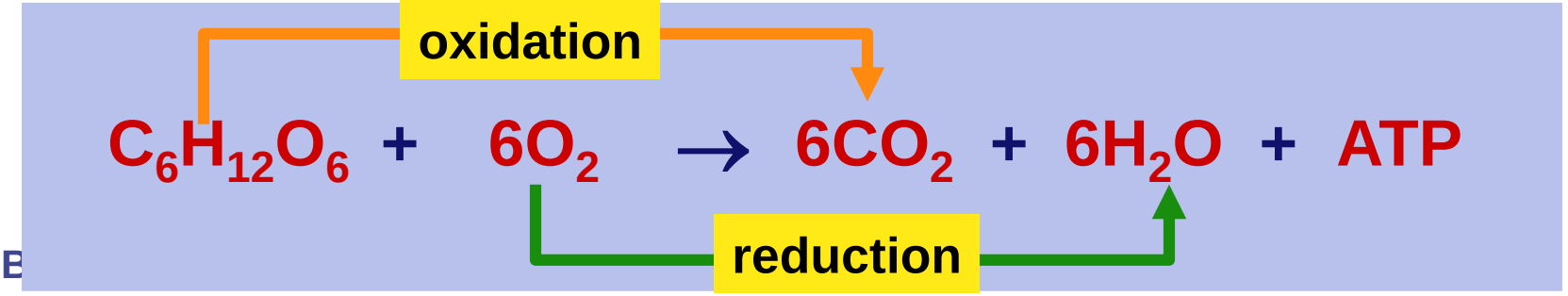




Coupling oxidation & reduction

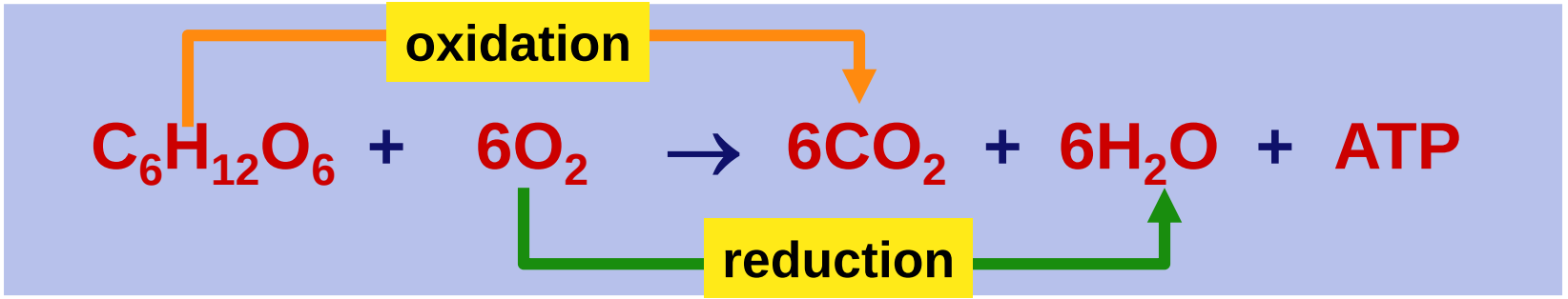
- **REDOX reactions in respiration**
  - release energy as breakdown organic molecules
    - break C-C bonds
    - strip off electrons from C-H bonds by removing H atoms
      - $C_6H_{12}O_6 \rightarrow CO_2$ = the fuel has been oxidized
    - electrons attracted to more electronegative atoms
      - in biology, the most electronegative atom?
      - $O_2 \rightarrow H_2O$ = oxygen has been reduced
  - couple REDOX reactions & use the released energy to synthesize ATP

O
2



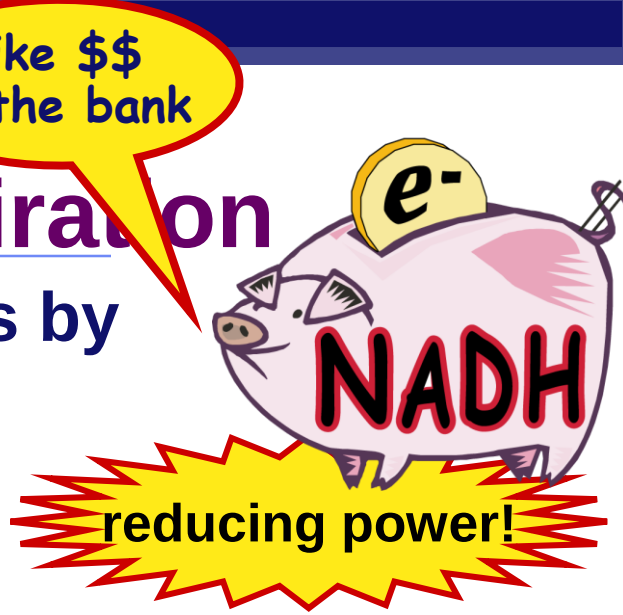
Oxidation & reduction

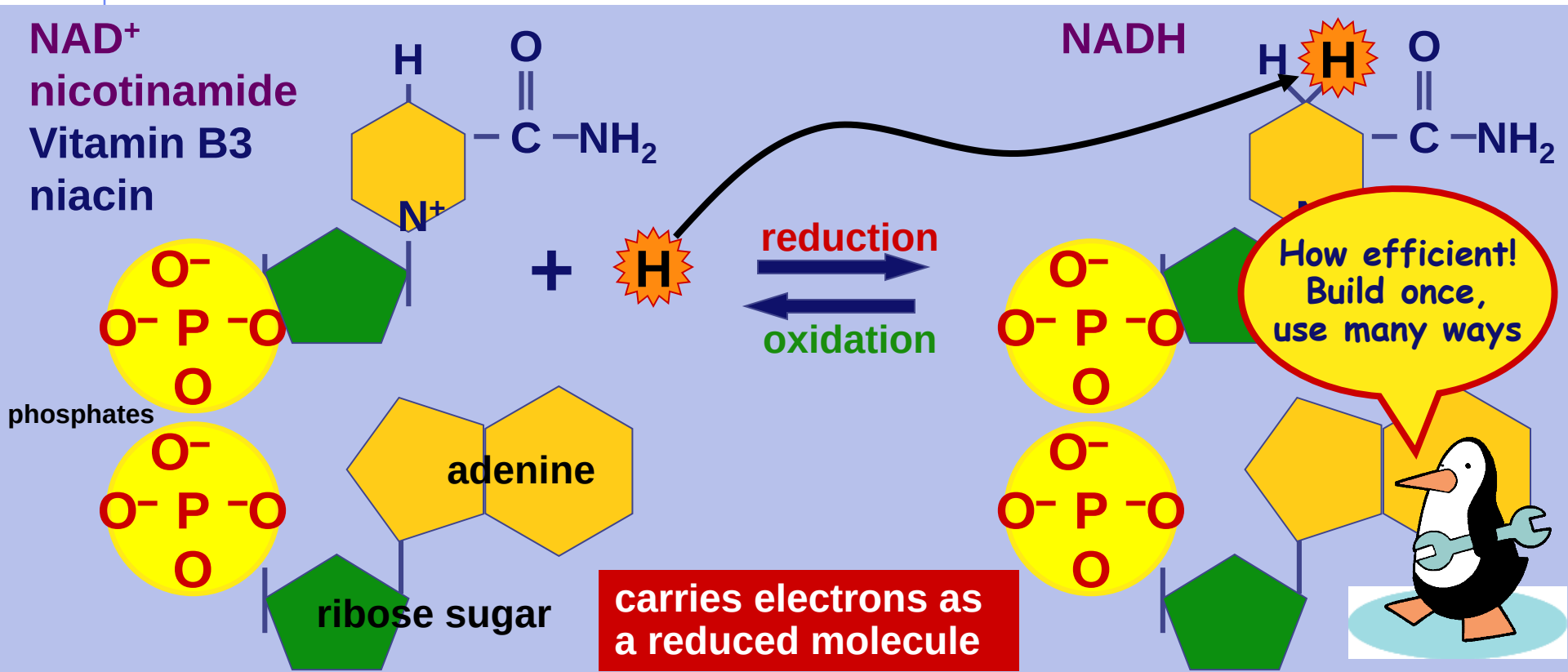
- **Oxidation**
  - adding O
  - removing H
  - loss of electrons
  - releases energy
  - exergonic
- **Reduction**
  - removing O
  - adding H
  - gain of electrons
  - stores energy
  - endergonic



Moving electrons in respiration

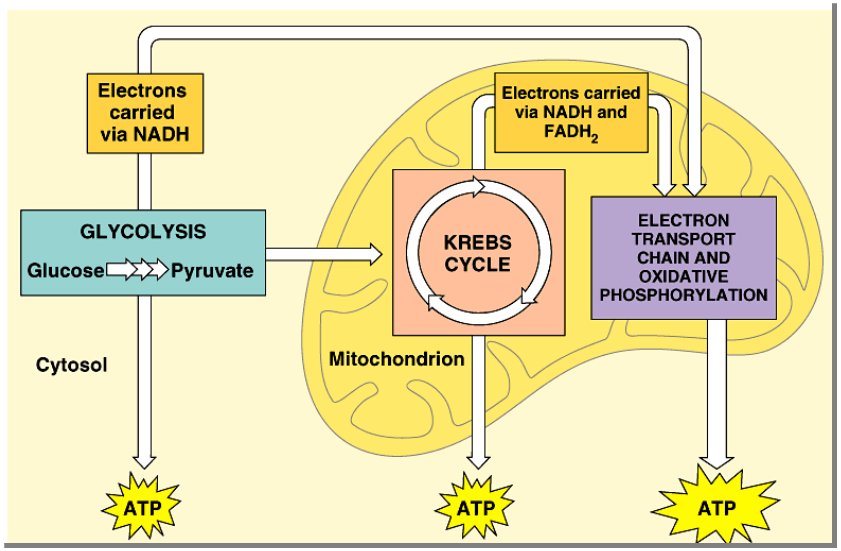
- **Electron carriers** move electrons by shuttling H atoms around
  - $NAD^+ \rightarrow NADH$ (reduced)
  - $FAD^{+2} \rightarrow FADH_2$ (reduced)



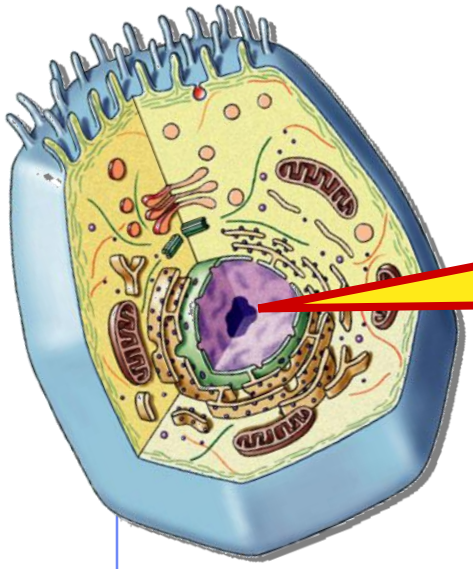


Overview of cellular respiration

- 4 metabolic stages
  - **Anaerobic respiration**
    1. **Glycolysis**
       - respiration without O_2
       - in cytosol
  - **Aerobic respiration**
       - respiration using O_2
       - in mitochondria
    2. **Pyruvate oxidation**
    3. **Krebs cycle**
    4. **Electron transport chain**



$$C_6H_{12}O_6 + 6O_2 \rightarrow ATP + 6H_2O + 6CO_2 (+ \text{heat})$$



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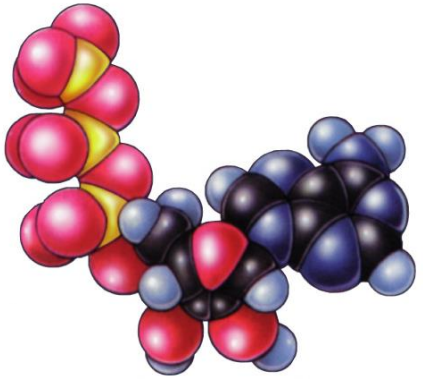
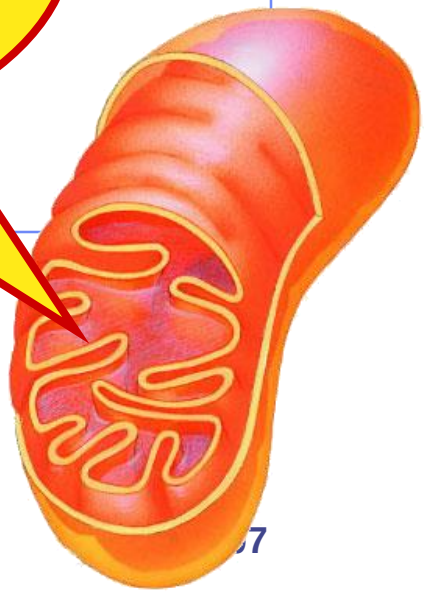


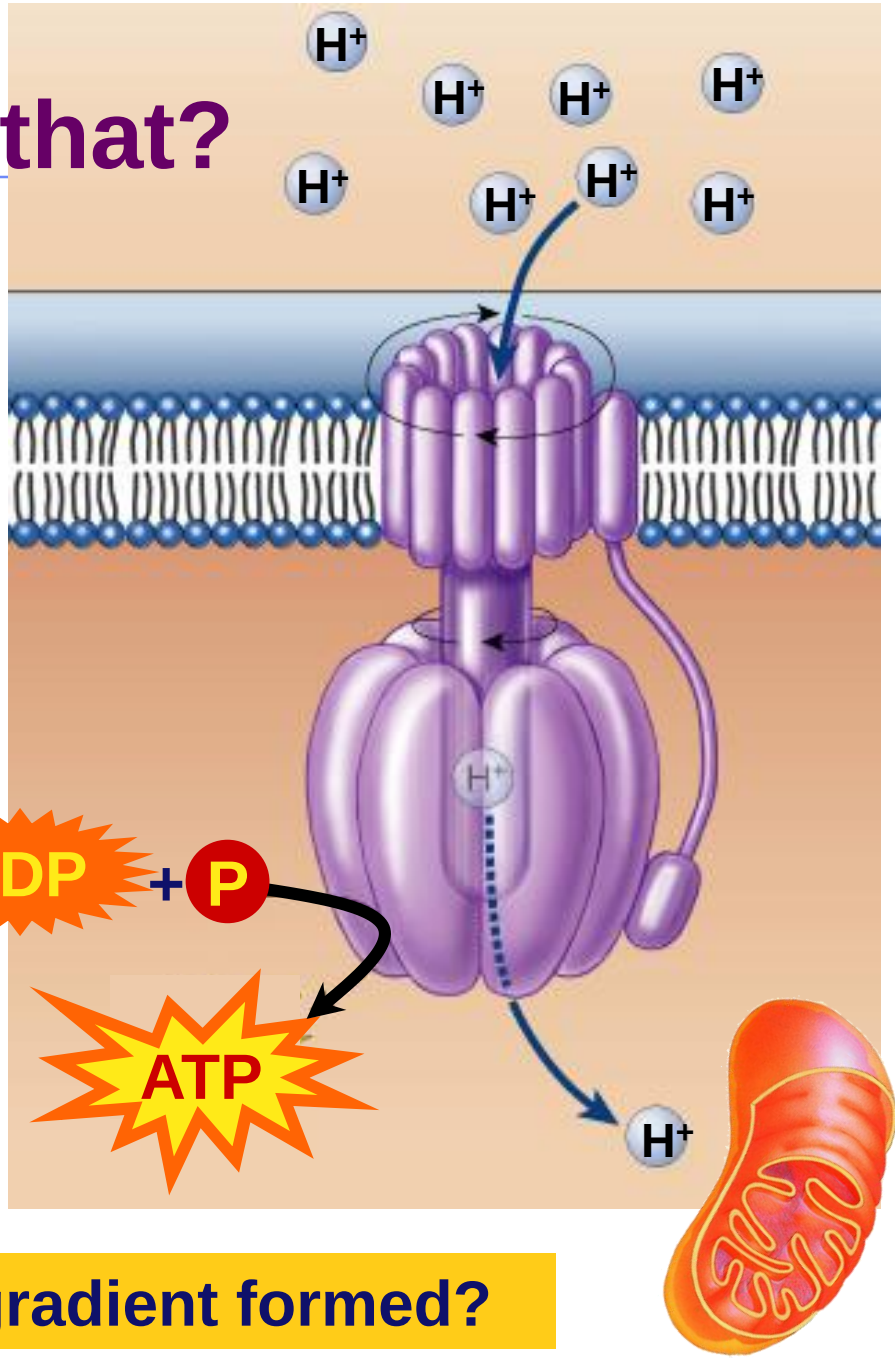
The point is to make ATP!

ATP



And how do we do that?

- **ATP synthase enzyme**
  - H^+ flows through it
    - conformational changes
    - bond P_i to ADP to make ATP
  - set up a H^+ gradient
    - allow the H^+ to flow down concentration gradient through ATP synthase
    - $ADP + P_i \rightarrow ATP$



But… How is the proton (H^+) gradient formed?

Got to wait until the sequel!
Got the Energy?
Ask Questions!