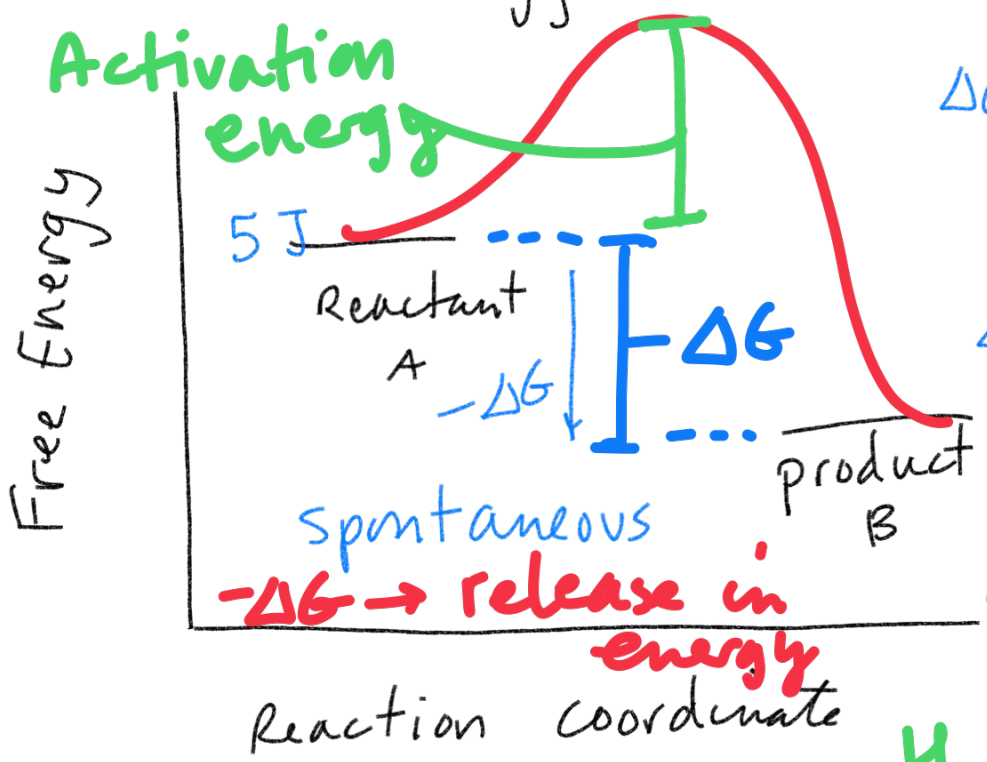
T-GB General Biology Week 21 2/13



ΔG = Ground state energy products − Ground state energy reactants

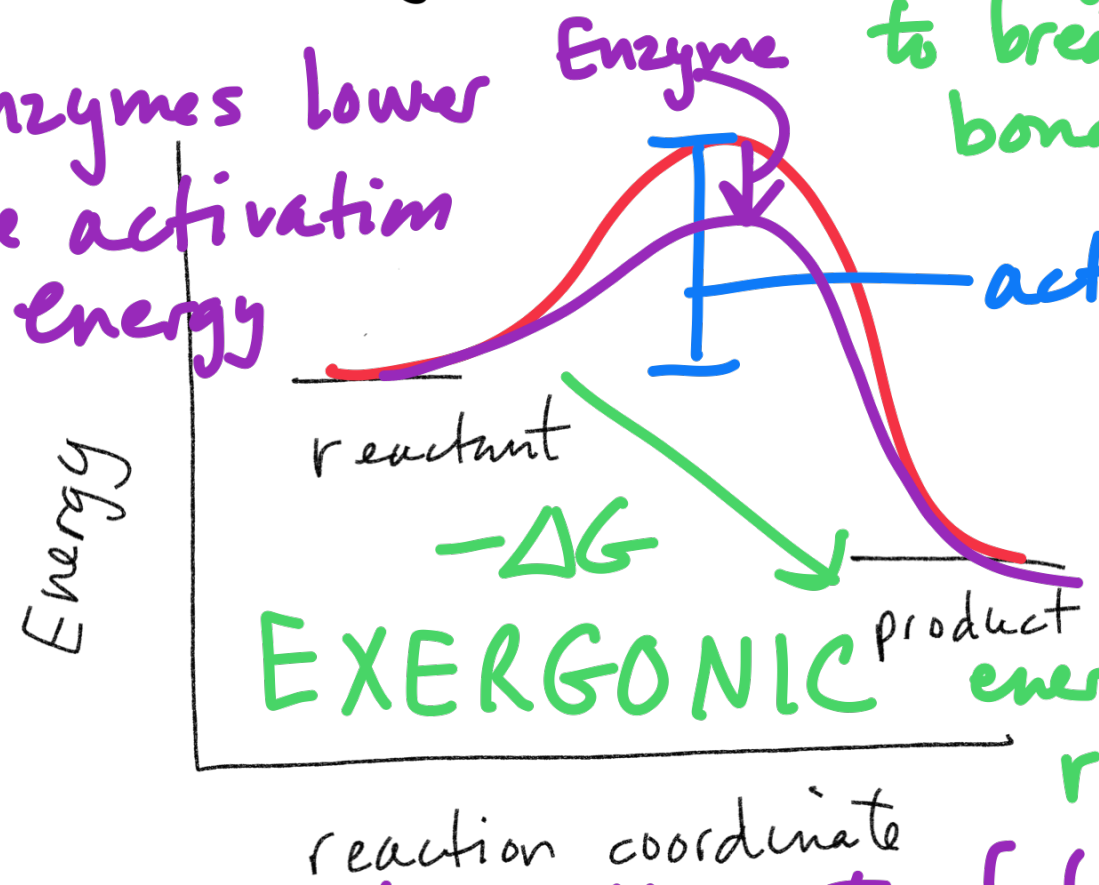
$\Delta G = 3J - 5J$

$-2J$

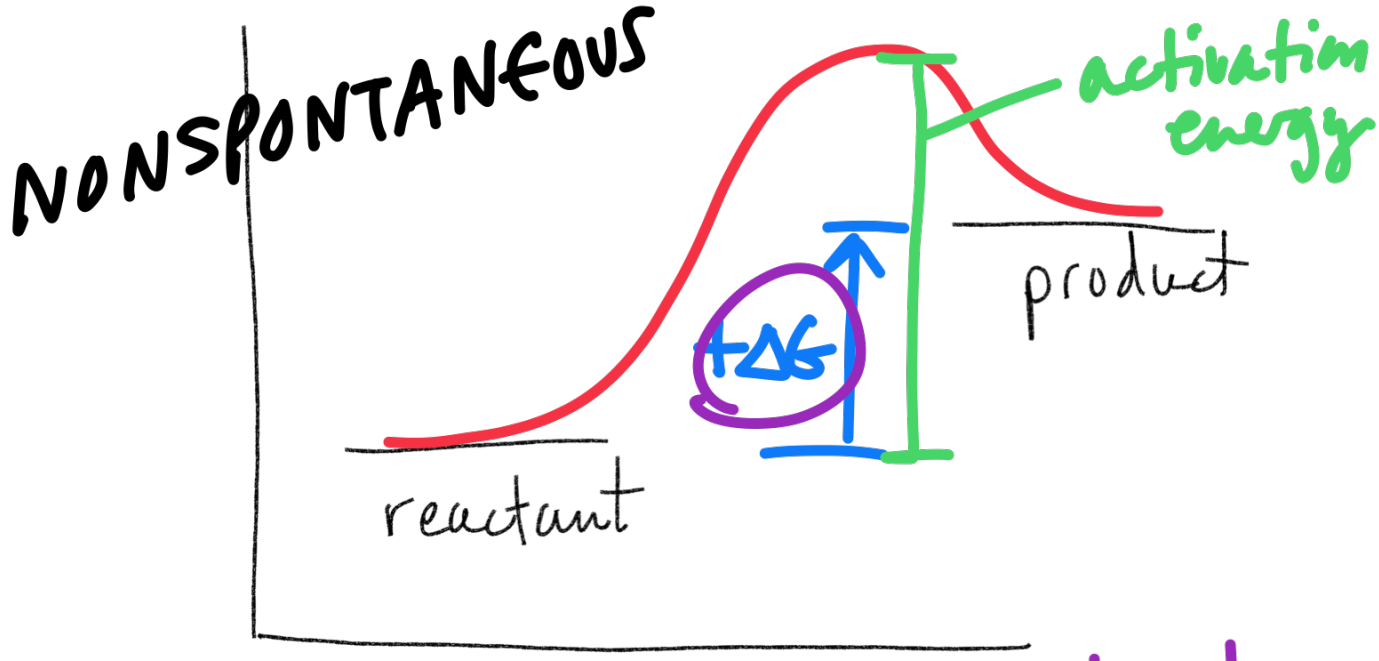
Activation energy is the initial energy required to break existing bond.

spontaneously $\longrightarrow$ B

Enzymes lower the activation energy



Enzyme speeds up the rate of the reaction



ENDERGONIC → Absorbs energy

Energy currency in cell: ATP

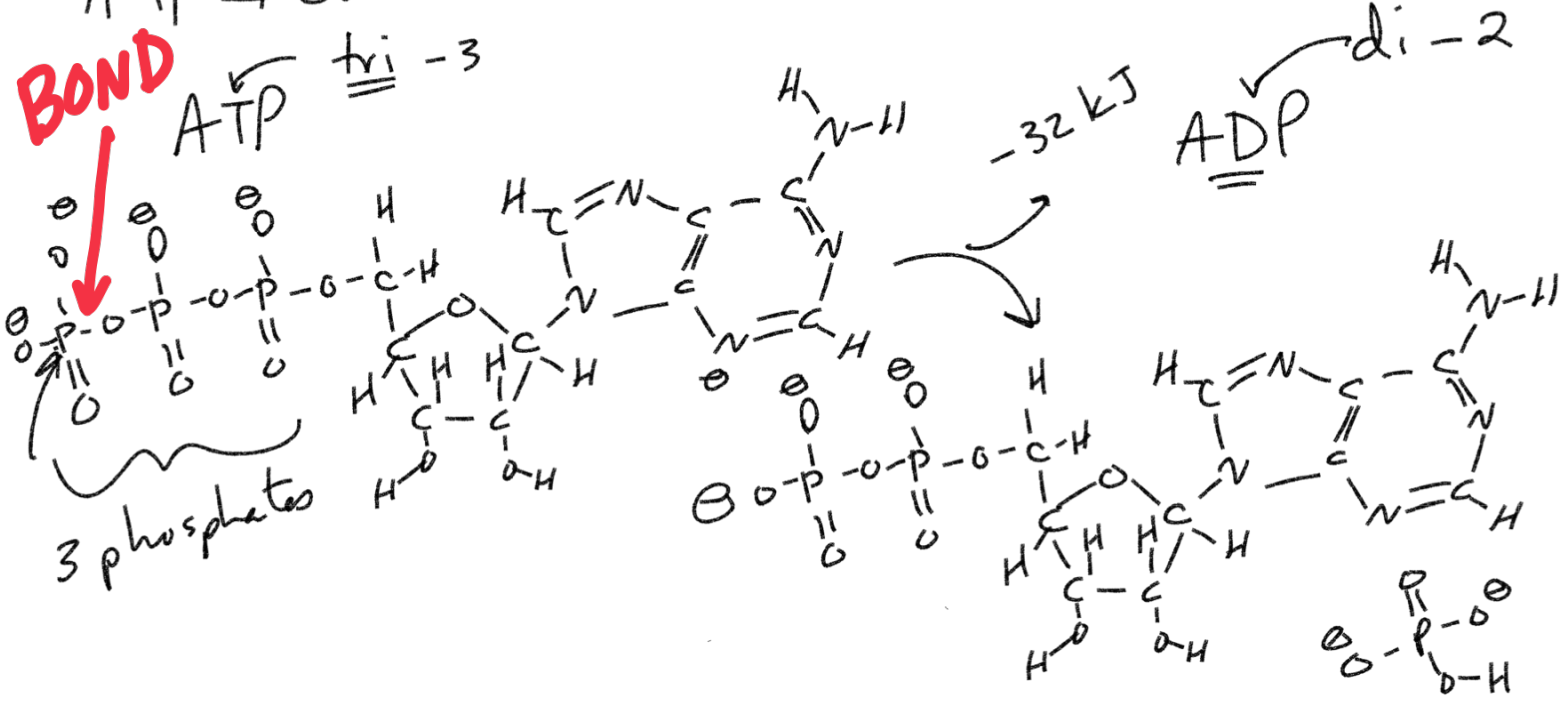
adenosine triphosphate

Breaking of the bond releases energy

$ATP \longrightarrow ADP + P_i$

releases energy -32kJ

hydrolysis of ATP → cut with water



BIG → energy SMALL

$-\Delta G$ → spontaneous

- **Catabolic pathways** release energy by breaking down complex molecules into simpler compounds
  - Eg. digestive enzymes break down food → release energy

$+\Delta G$ → nonspontaneous

- **Anabolic pathways** consume energy to build complex molecules from simpler ones
  - Eg. amino acids link to form muscle protein

small → big

invest energy

$ $

ENERGY = CAPACITY TO DO WORK

- **Kinetic energy (KE)**: energy associated with motion
  - *Heat* (thermal energy) is KE associated with random movement of atoms or molecules
- **Potential energy (PE)**: stored energy as a result of its position or structure
  - *Chemical energy* is PE available for release in a chemical reaction
- Energy can be converted from one form to another
  - Eg. chemical → mechanical → electrical

THE FIRST LAW OF THERMODYNAMICS (CONSERVATION OF ENERGY)

- The energy of the universe is constant
  - Energy **can** be transferred and transformed
  - Energy **cannot** be created or destroyed

(a) First law of thermodynamics

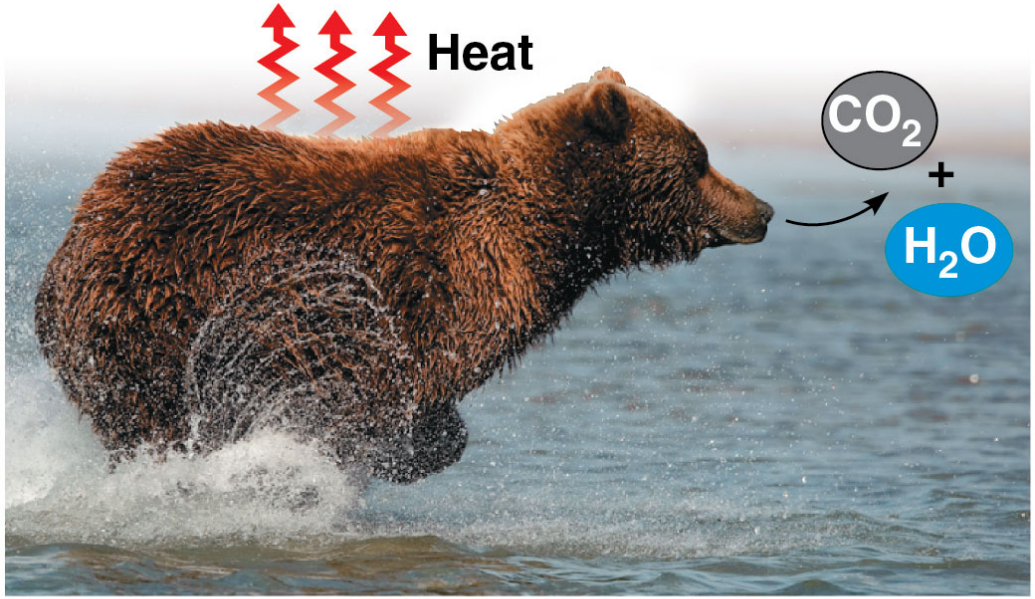
THE SECOND LAW OF THERMODYNAMICS

- Every energy transfer or transformation increases the entropy (disorder) of the universe

$\Delta G = \Delta H - T\Delta S$

BONDS − (temp)(entropy)

- During every energy transfer or transformation, some energy is *unusable*, often lost as **heat**



(b) Second law of thermodynamics

- **Free energy**: part of a system's energy available to perform work
  - ΔG = change in free energy
- **Exergonic reaction**: energy is released
  - Spontaneous reaction
  - $\Delta G < 0$ $-\Delta G$
- **Endergonic reaction**: energy is required
  - Absorb free energy
  - $\Delta G > 0$ $+\Delta G$

Garbage

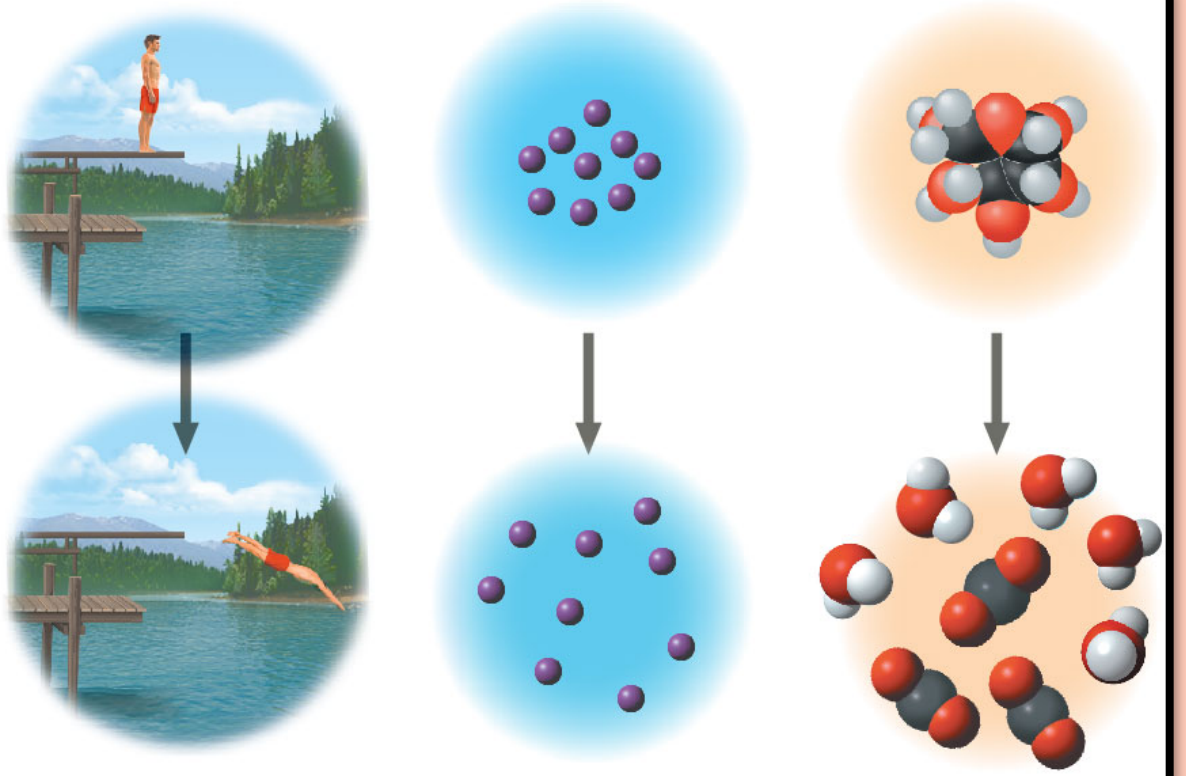
Garbage → Empty Bin

$-\Delta G$ $\boxed{\$50,000}$

- More free energy (higher *G*)
- Less stable
- Greater work capacity

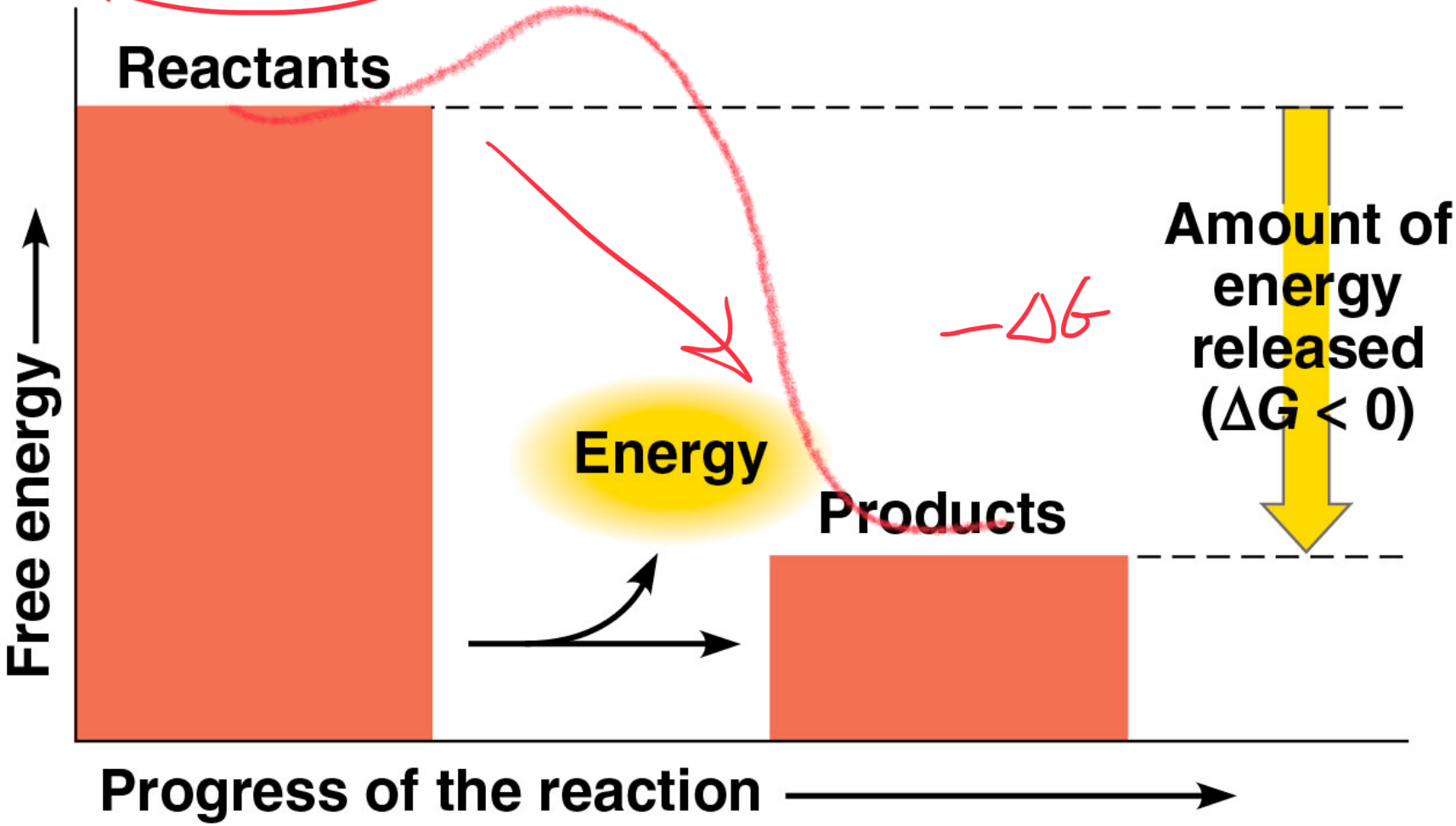
In a spontaneous change
- The free energy of the system decreases ($\Delta G < 0$)
- The system becomes more stable
- The released free energy can be harnessed to do work

- Less free energy (lower *G*)
- More stable
- Less work capacity

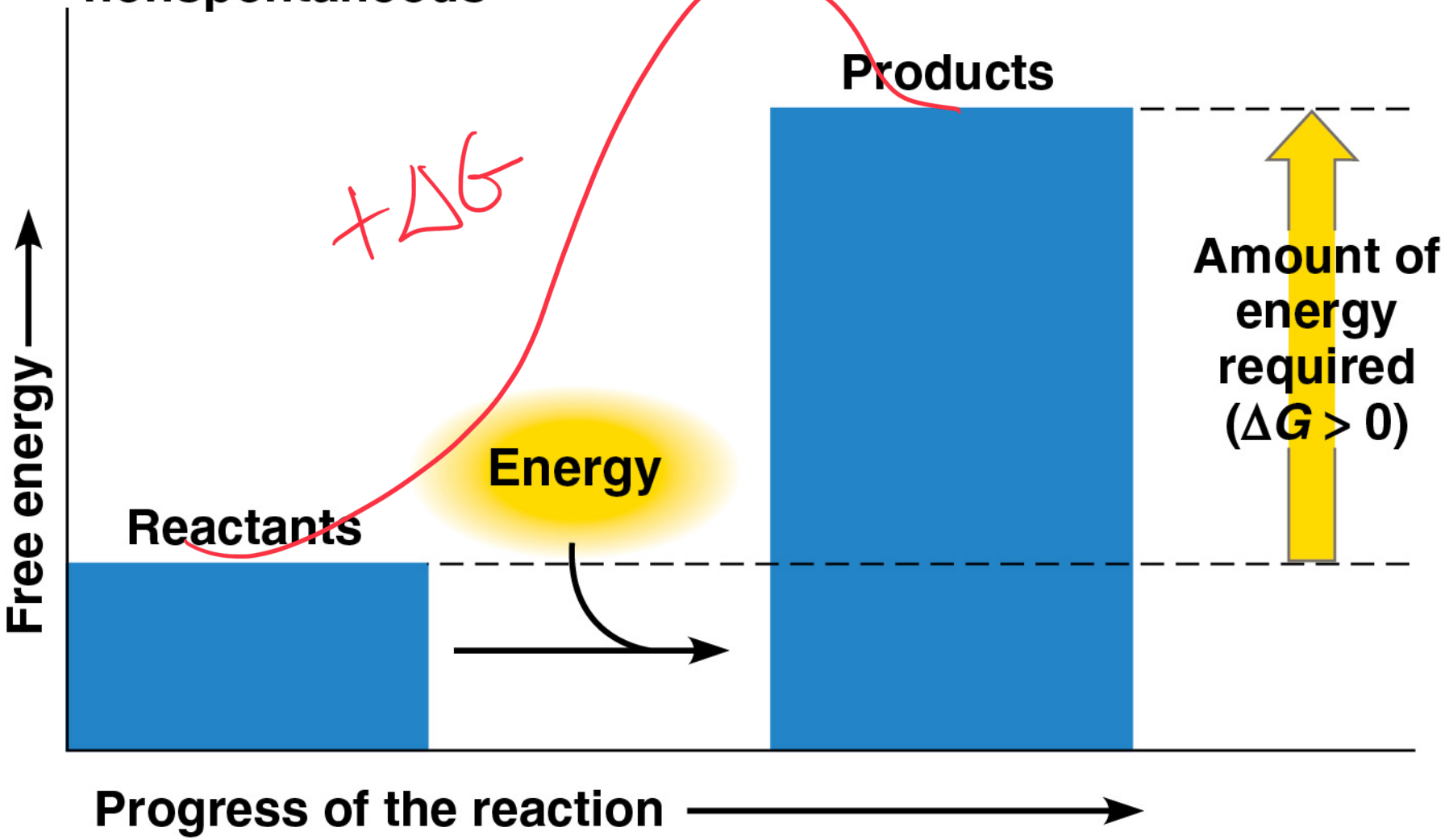


(a) Gravitational motion (b) Diffusion (c) Chemical reaction

(a) Exergonic reaction: energy released, spontaneous



(b) Endergonic reaction: energy required, nonspontaneous



- A living cell is NOT at equilibrium
  - Constant flow of materials in/out of cell

- A cell does three main kinds of work:
  1. Mechanical
  2. Transport
  3. Chemical

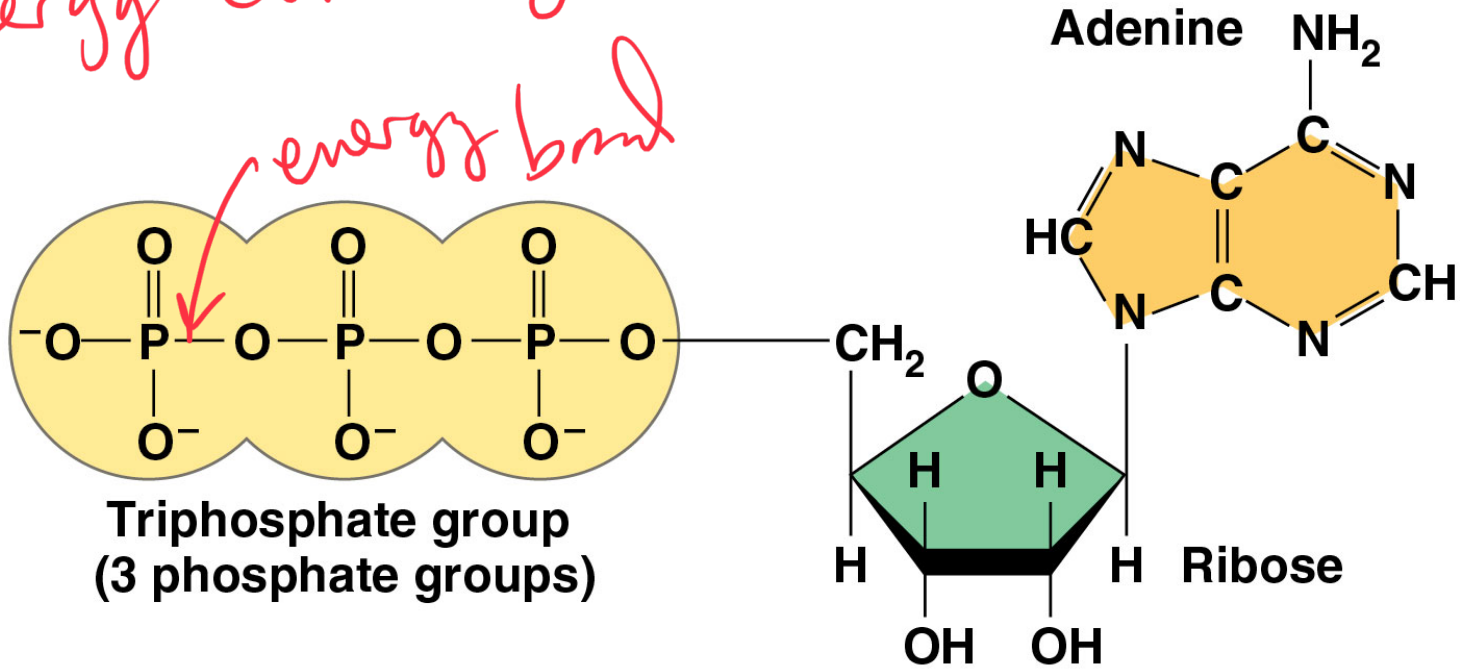
- Cells manage energy resources to do work by energy coupling: using an ***exergonic*** process to drive an ***endergonic*** one

job

pay $$

- **ATP** (**adenosine triphosphate**) is the cell's main energy source in energy coupling
- ATP = adenine + ribose + 3 phosphates

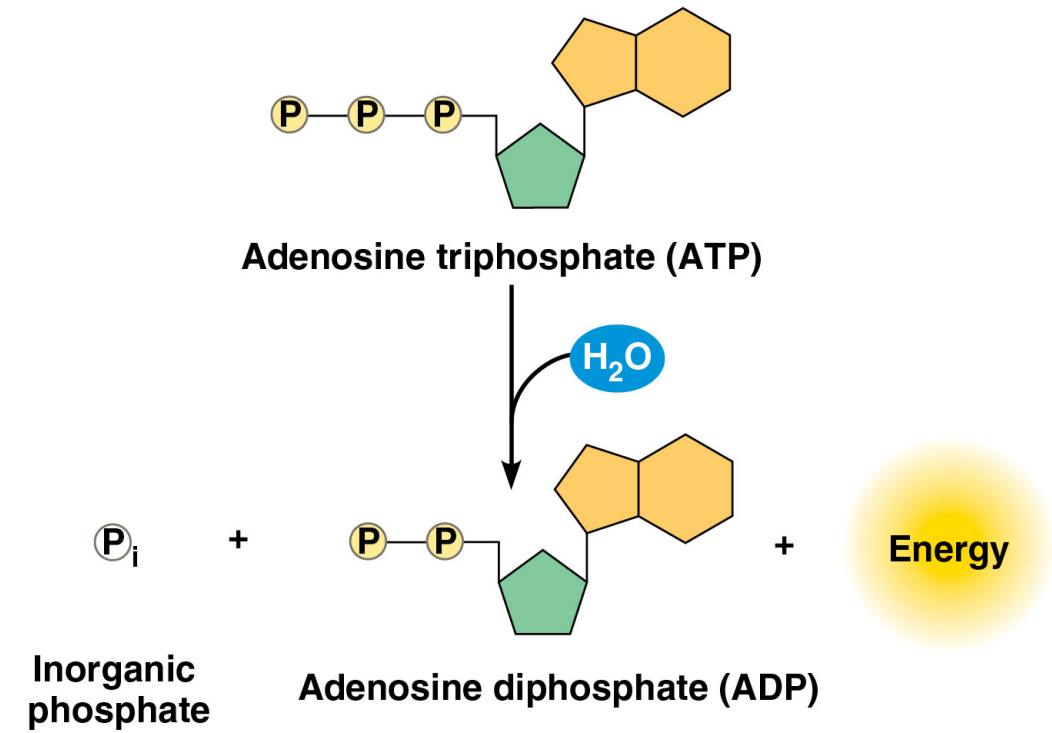
Energy currency → $$



(a) The structure of ATP

- When the bonds between the phosphate groups are broken by hydrolysis → ***Energy is released***
- This release of energy comes from the chemical change to a state of lower free energy, not in the phosphate bonds themselves

−32 kJ/mol

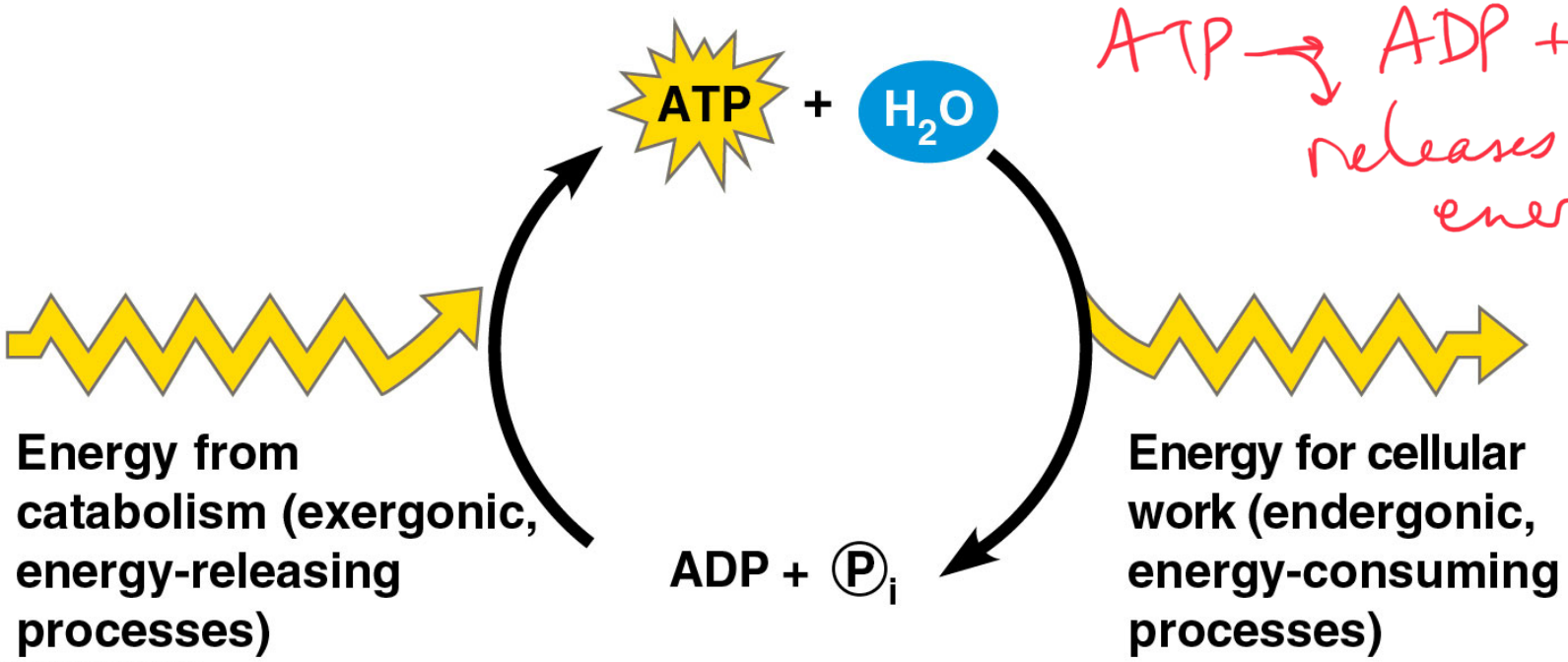


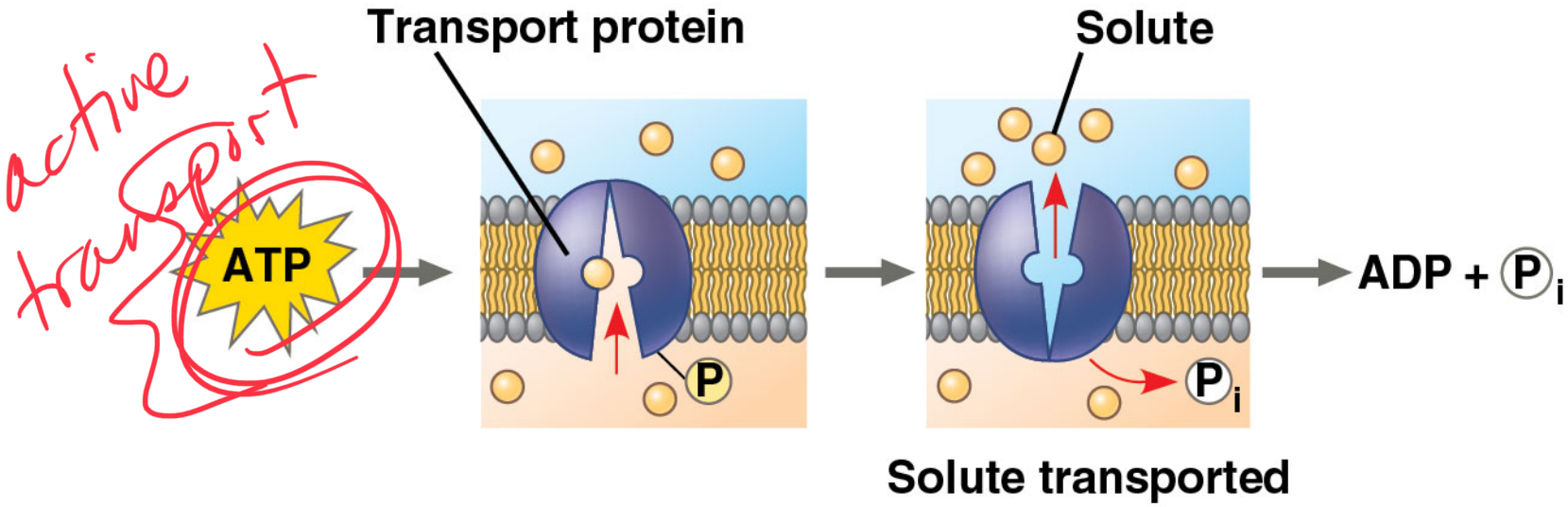
(b) The hydrolysis of ATP

HOW ATP PERFORMS WORK

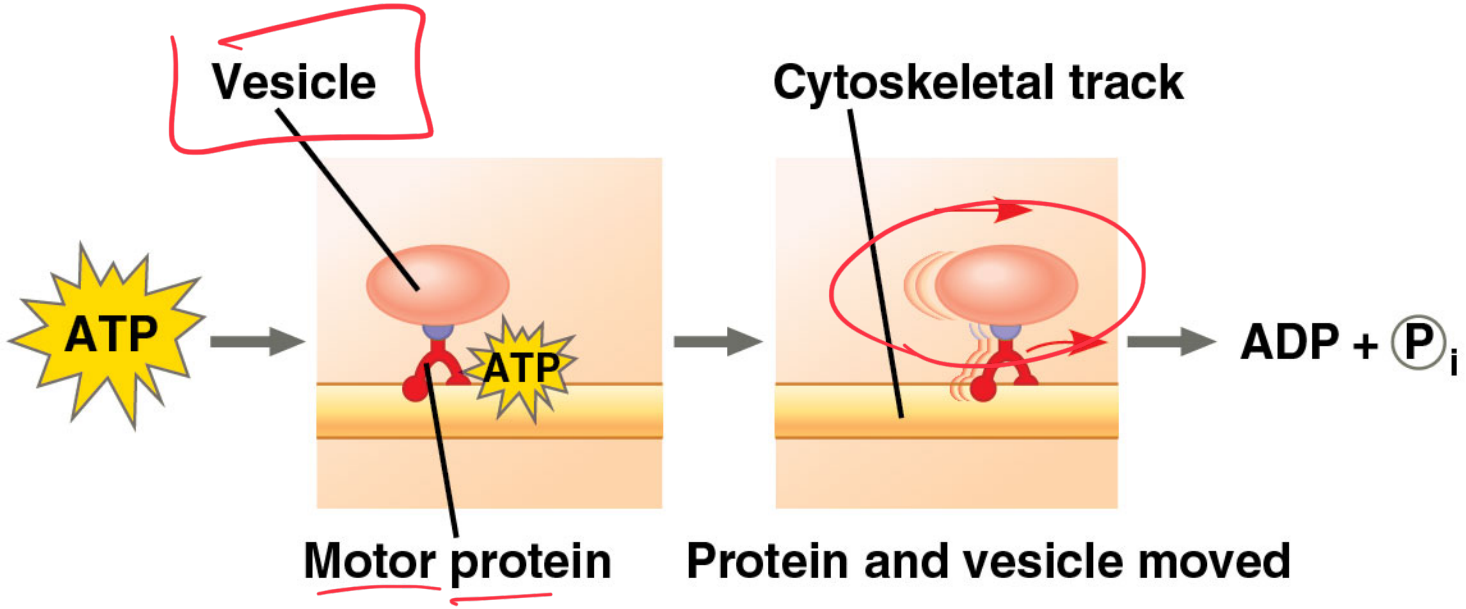
- ***Exergonic*** release of P_i is used to do the ***endergonic*** work of cell "coupling"
- When ATP is hydrolyzed, it becomes ADP (adenosine diphosphate)

ATP → ADP + P_i releases energy



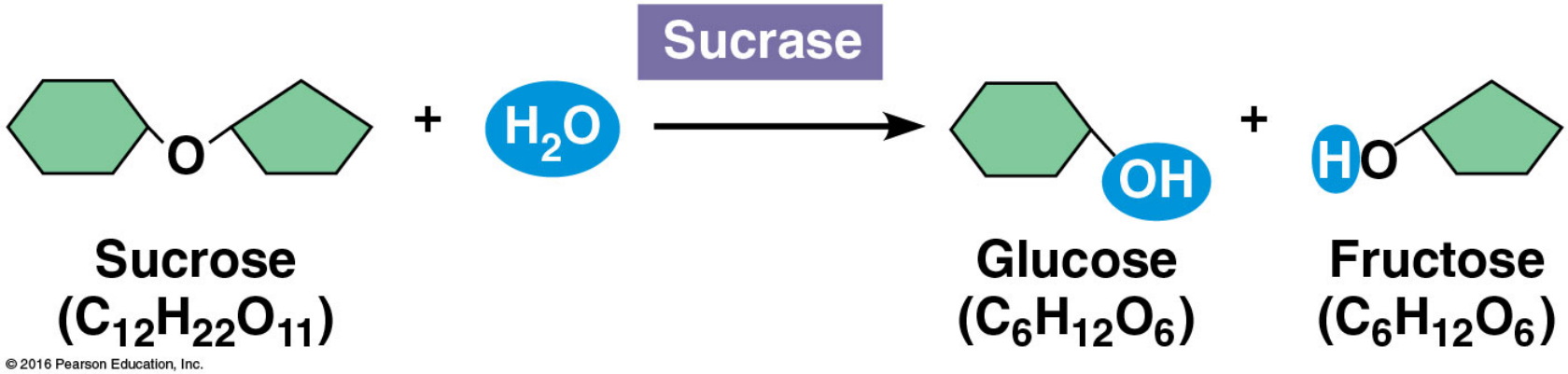


(a) Transport work: ATP phosphorylates transport proteins.



(b) Mechanical work: ATP binds noncovalently to motor proteins and then is hydrolyzed.

- Catalyst: substance that can change the rate of a reaction without being altered in the process
- Enzyme = biological catalyst



- breaking bonds)