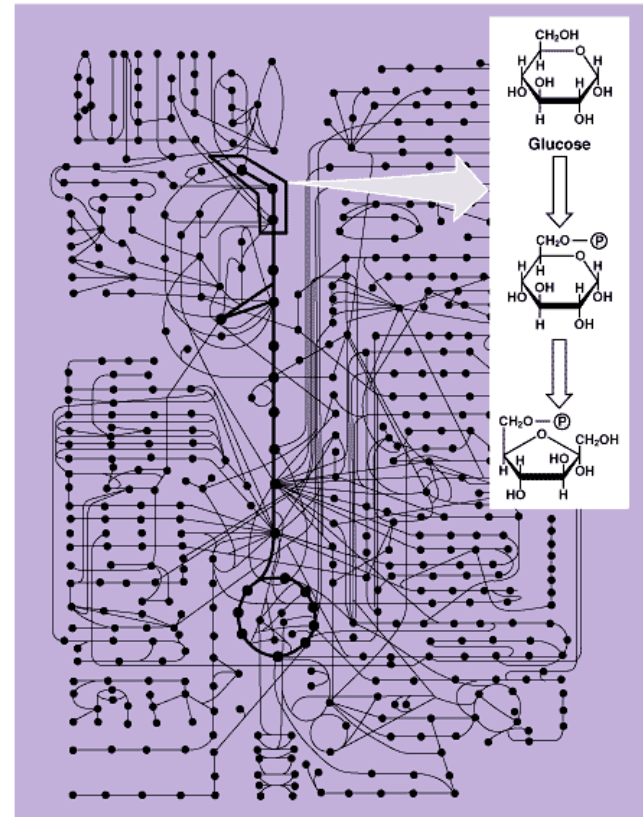


BI107 CHAP 6

metabolism

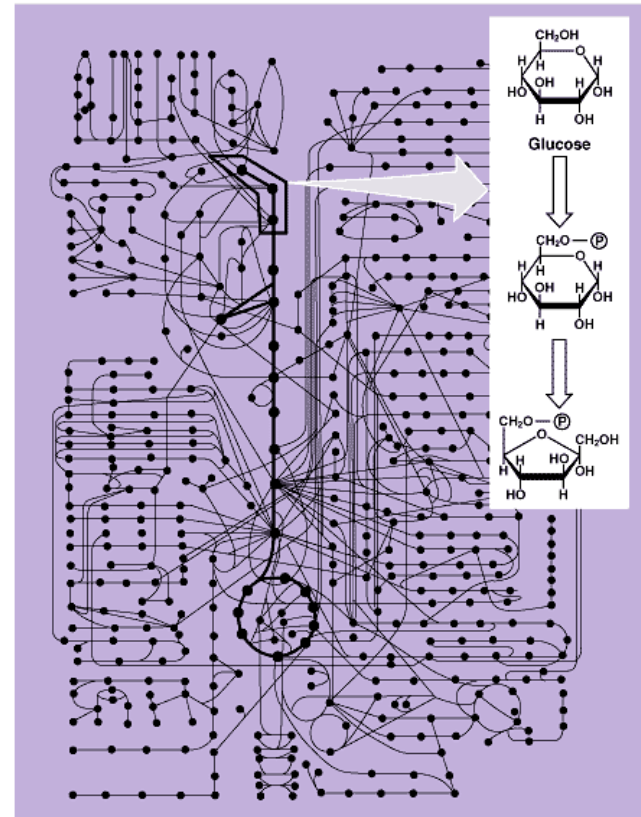
Metabolism, Energy & Life

- Metabolism – total of all chemical reactions in an organism
- Thousands of chemical reaction occur in the cell & reactions arranged in branching metabolic pathways where pathways alter molecules by series of steps



Metabolism cont.

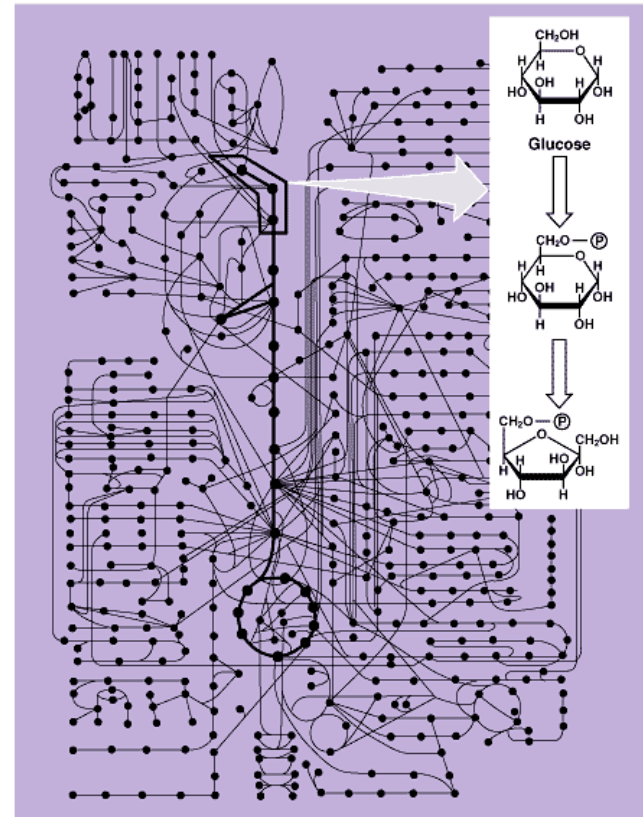
- Metabolism manages material & energy resources of the cell
- 2 types of pathways 1) – catabolic paths – release energy by breaking down complex molecules to simpler compounds called degradative pathways with cellular respiration being a major part – glucose degraded to CO_2 & H_2O & energy released to do work



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Metabolism cont.

- 2) anabolic pathways – use energy to build complex molecules from simple ones proteins built from amino acids
- Catabolic & anabolic pathways – energy released from downhill reactions of catabolism used to drive uphill reactions of anabolism – transfer of energy called energy coupling



Metabolism cont.

- Organisms transform energy
- Energy – capacity to do work – move matter against an opposing force
- Kinetic energy – energy of motion – moving objects perform work by imparting motion to other objects
- Potential energy – energy that matter has due to location or structure – chemical energy is a form of potential energy stored in molecules because of arrangement of atoms in molecules

Metabolism cont.

- Playground – potential energy transformed to kinetic energy to potential energy
- In food potential energy transformed to chemical energy then to kinetic energy
- Light is a form of kinetic energy harnessed to power photosynthesis in plants organisms are energy transformers



Metabolism cont.

- Energy transformations of light subject to 2 laws of thermodynamics – study of energy transformations occurring in collection of matter
- A system is studied along with the surroundings
closed system – isolated from surroundings
- Open system – energy can be transferred from system & surroundings
- Organisms are open systems – absorb energy – light energy or chemical energy in form of food molecules & release energy – heat & metabolic wastes – carbon dioxide

Metabolism cont.

- 1st law of thermodynamics
– energy of universe is constant – energy cannot be created or destroyed only transferred or transformed
- Light energy to chemical energy – green plants act as energy transformers & what happens to energy after it performs work



Metabolism cont.

- 2nd law of thermodynamics – entropy – measure of disorder or randomness
- Every energy transformation or transfer increases disorder of universe – order can increase only locally



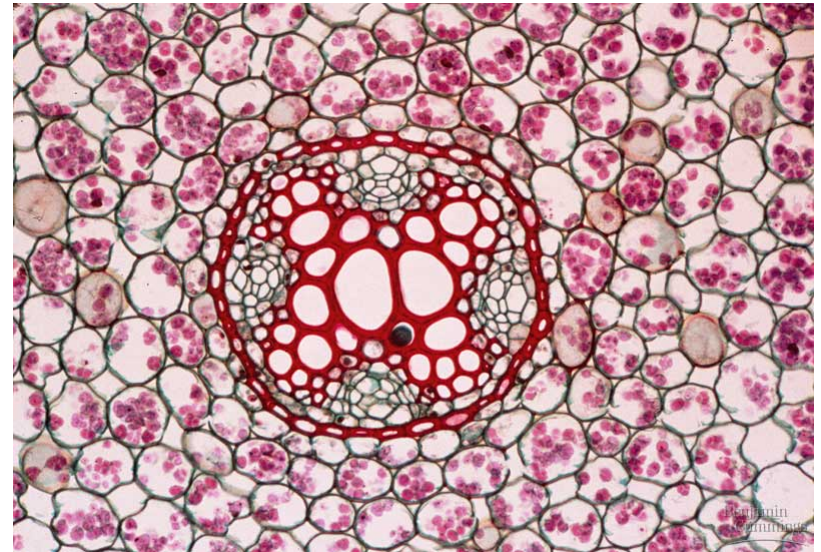
Metabolism cont.

- Most energy transformations convert ordered forms of energy to heat – which is energy in most random form – energy of random motion
- Car – 25% energy – 75% heat
cells – 40% energy & 60% heat
all chemical energy transformed to heat



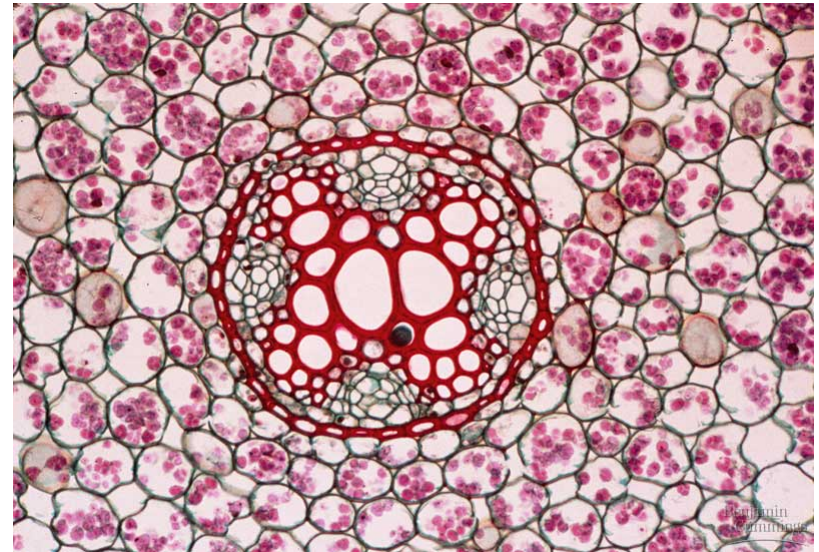
Metabolism cont.

- Quantity of energy in the universe is constant but quality of energy is not constant
- Unstoppable increase in entropy versus orderliness of life - cells create ordered structures from less ordered materials



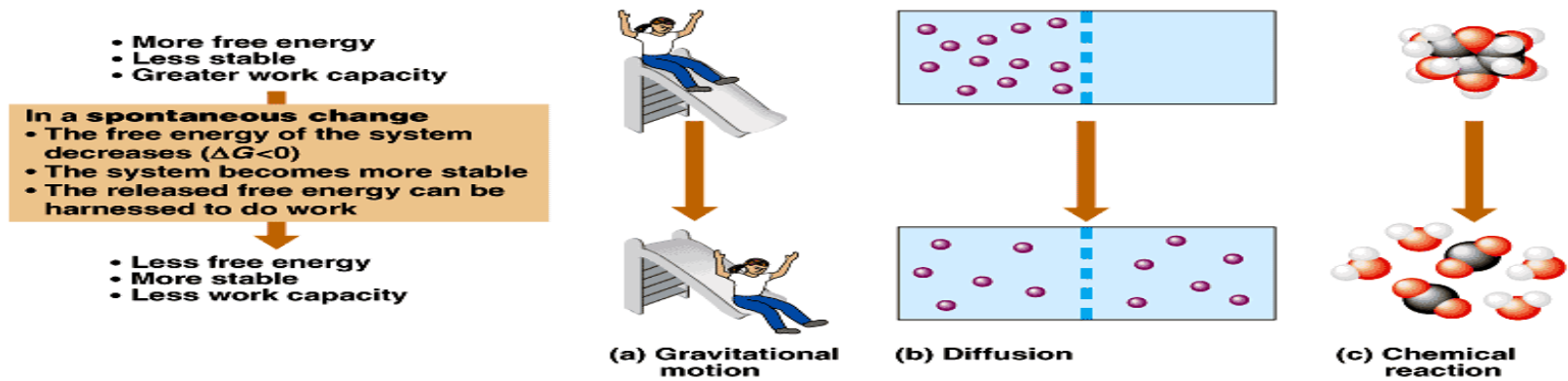
Metabolism cont.

- Cells also break down ordered structures to carbon dioxide & water both of which store less chemical energy
- Ecosystem energy enters as light & leaves as heat – entropy of a particular system may decrease as long as entropy of universe increases



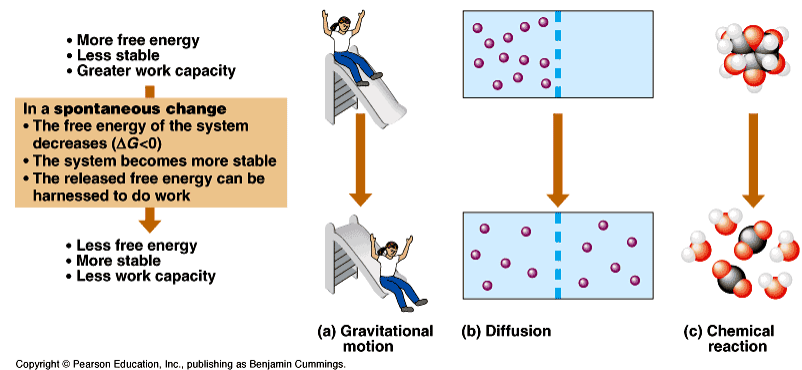
Metabolism cont.

- Organisms live at expense of free energy
- Some events occur spontaneously but others do not – why
- Spontaneous process is a change that occurs without outside help – when spontaneous process occurs in nature stability of system increases



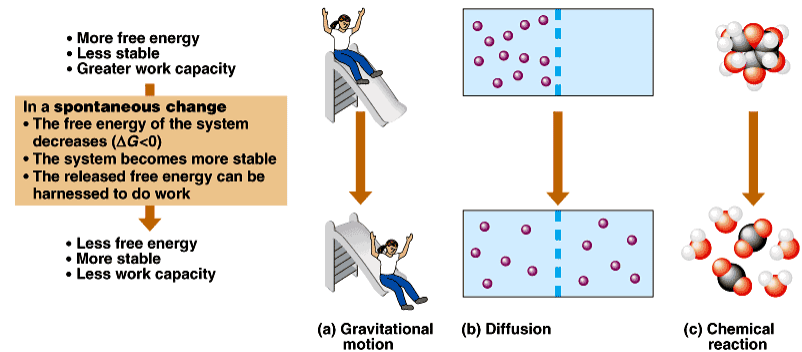
Metabolism cont.

- Standard for spontaneity based on system alone called free energy – portion of system's energy that can perform work when temp. of system is uniform – example is living cell



Metabolism cont.

- Called free energy since it is available to do work
- Organisms can live only at expense of free energy acquired from surroundings



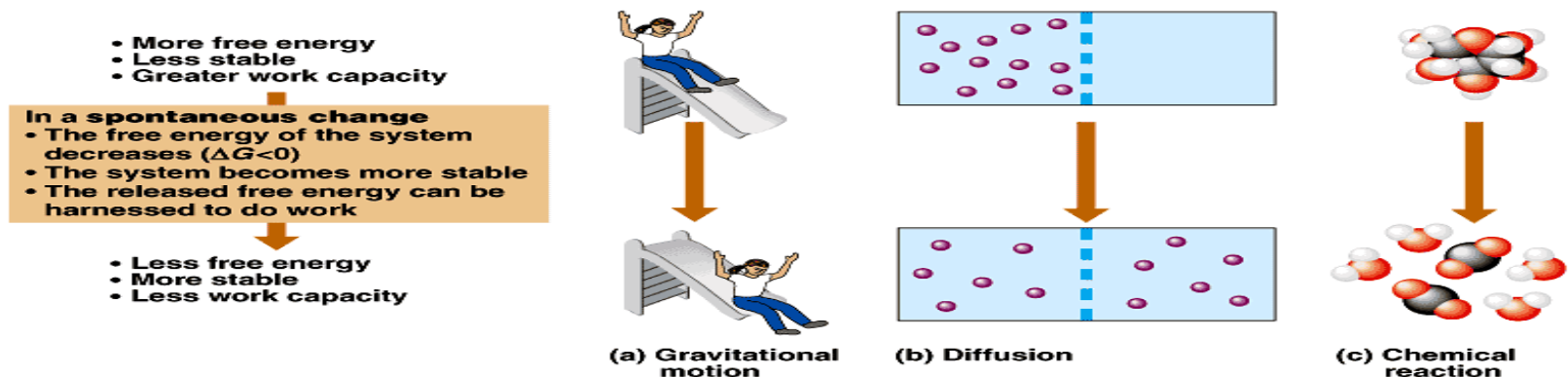
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Metabolism cont.

- G = free energy of a system
- Has 2 components -
 H = total energy &
 S = entropy
- $G = H - TS$ T =
absolute temperature
in Kelvin units
 $K = ^\circ C + 273$
- Temperature amplifies entropy since temperature measures intensity of random molecular motion
- Increase in temperature causes increase in random molecular motion

Metabolism cont.

- Not all energy is available for work – only free energy available for work
- Free energy relates to the spontaneity of a system as free energy G is a measure of system's instability – tendency to change to a stable system - systems rich in free energy are unstable - highly ordered structures such as complex molecules are rich in free energy



Metabolism cont.

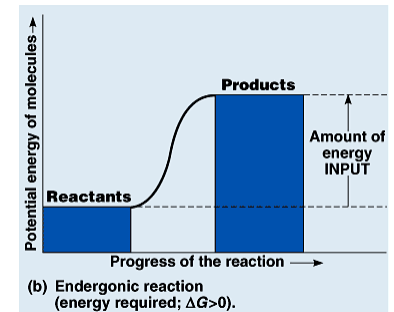
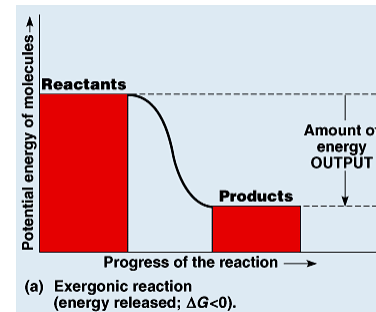
- Systems that change spontaneously have high energy, low entropy or both
- In any spontaneous process the free energy decreases
- $\Delta G = G_{\text{final state}} - G_{\text{starting state}}$ or $\Delta G = \Delta H - T\Delta S$
- When process occurs spontaneously system must give up energy (decrease in H), give up order (increase in S) or both
- ΔG must be negative & greater the decrease the greater the maximum amount of work can be done by spontaneous system

Metabolism cont.

- State of maximum stability is called equilibrium
- Relation between free energy & equilibrium including chemical equilibrium at equilibrium $\Delta G = 0$ no net change
- Moving toward equilibrium is spontaneous
- Moving away from equilibrium is nonspontaneous & occurs only if energy applied

Metabolism cont.

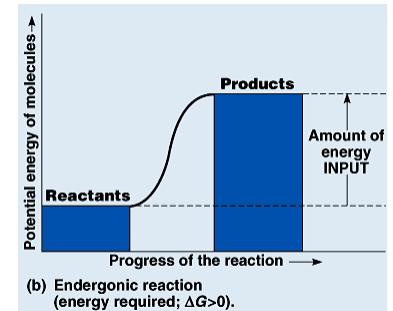
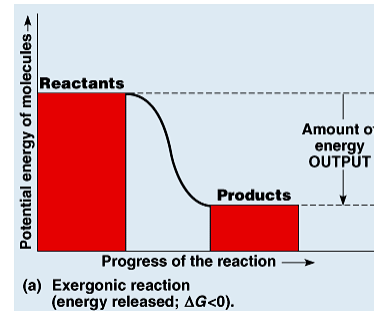
- Free energy & metabolism – based on free energy changes chemical reactions occur as 2 types – exergonic & endergonic



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Metabolism cont.

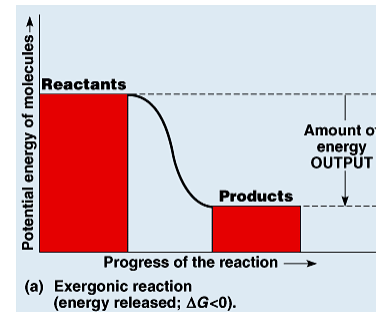
- Exergonic – reaction proceeds with net release of free energy
chemical mixture loses free energy so ΔG is negative
- Exergonic reactions occur spontaneously & magnitude of ΔG is max. amount of work reaction can do



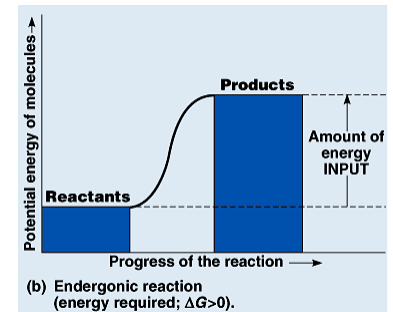
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Metabolism cont.

- 1 mole of glucose broken down by cellular respiration 686 kcal of energy is available for work – products store 686 kcal less energy than reactants

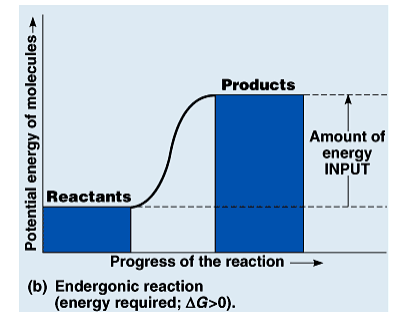
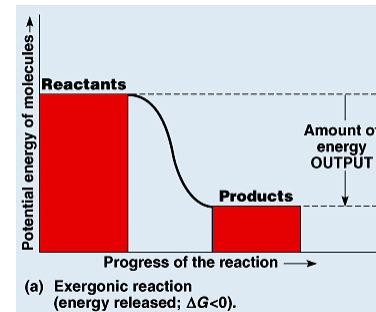


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Metabolism cont.

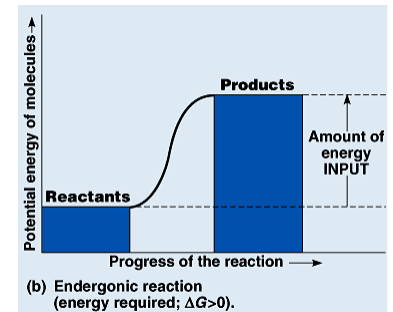
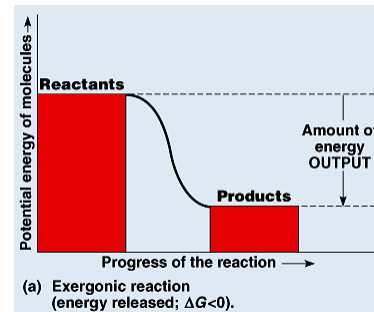
- Endergonic reactions absorb free energy from surroundings
- Stores free energy in molecules so ΔG is positive & these reactions do not occur spontaneously & magnitude of ΔG is amount of energy needed to drive the reaction



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Metabolism cont.

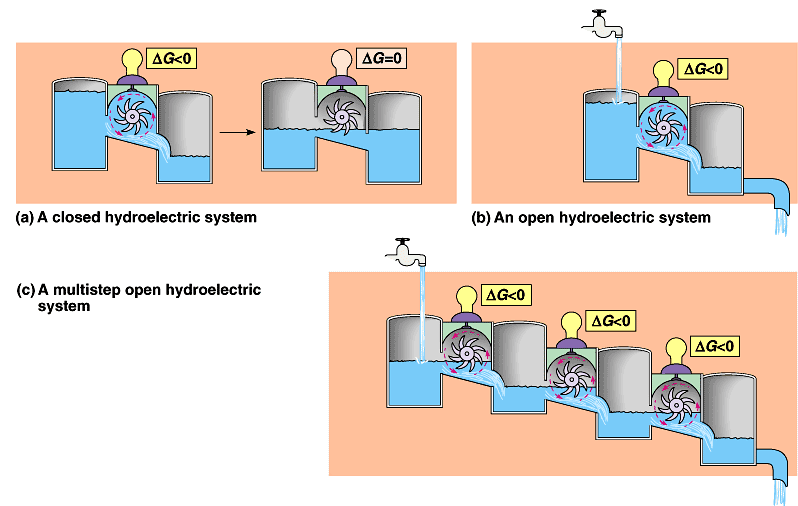
- Reversible chemical process must be downhill (exergonic) in 1 direction & uphill (endergonic) in opposite direction
- $\Delta G = -686$ kcal for cellular respiration so production of glucose from CO_2 & H_2O must require $+686$ kcal so $\Delta G = +686$ kcal for photosynthesis – powered by energy of sun



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Metabolism cont.

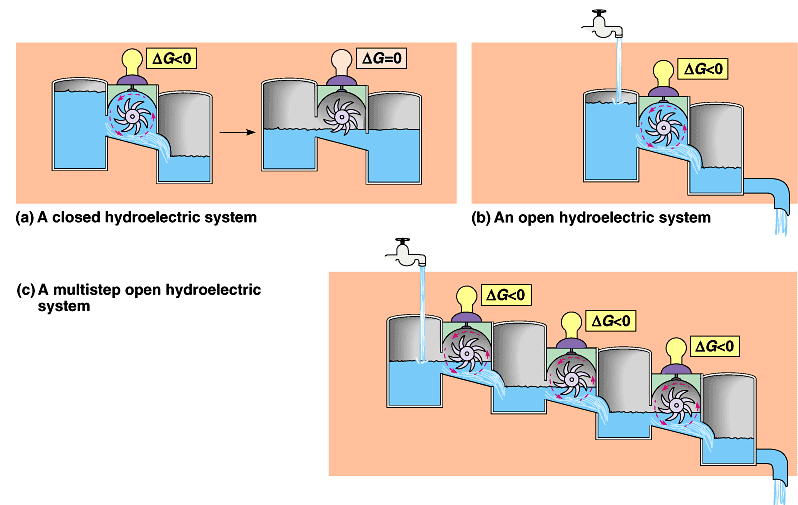
- Metabolic disequilibrium
– reactions in closed systems reach equilibrium & do no work
– chemical reactions of metabolism are reversible & would reach equilibrium in a test tube (closed system)
– systems at equilibrium have $\Delta G = 0$ & do no work



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Metabolism cont.

- The cell is in disequilibrium since it is an open system as metabolic pathways never reach equilibrium since have constant flow into & out of cell
- Disequilibrium sustained since products never build up – product of 1 reaction is substrate for next reaction



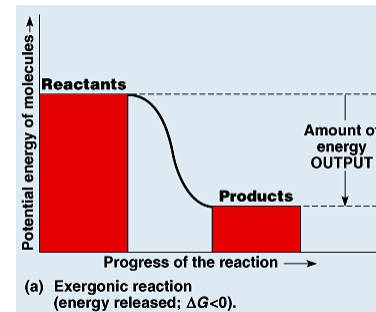
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Metabolism cont.

- Metabolic disequilibrium is a defining characteristic of life
- Huge difference in free energy between glucose on the uphill end of metabolic pathway & CO_2 & H_2O on downhill end
- Difference keeps the process going
- Organisms are open systems – sun provides daily free energy source for photosynthetic organisms & nonphotosynthetic organisms depend on this free energy transfusion in form of organic products of photosynthesis

Metabolism cont.

- Cell performs the work of life by using a key feature of bioenergetics called energy coupling – use of exergonic process to drive endergonic process



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