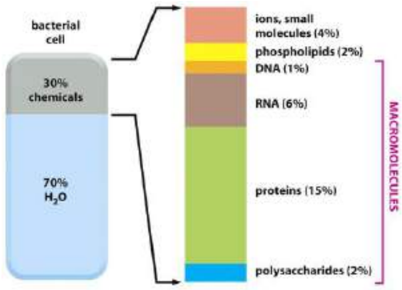
TM1

MOLECULES OF THE CELL

What is life?

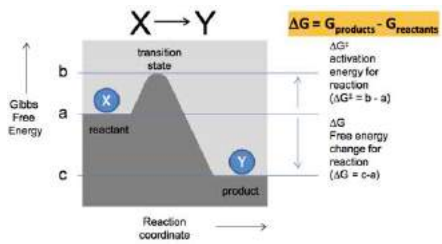
- "Living things, though infinitely varied when viewed from the outside, are fundamentally similar on the inside" (Alberts 5ed p 1.)
- Astonishing **variety** in individual particulars: appearance/form
  - Tiger, seaweed, bacterium, tree
- Astonishing **constancy in fundamental mechanisms**
  - DNA, transcription, translation, protein synthesis, metabolism
- Astonishing **constancy at a molecular level**
  - Structure of biological molecules
  - Physicochemical properties
  - How they interact
  - Energetic basis for self-assembly, folding, enzyme catalyzed reactions
- Don't need magic, Ka, vital spark, Odic force
  - Hydrogen, carbon, nitrogen, oxygen, sulfur, phosphorus etc.
  - Covalent and noncovalent interactions
- Life exists because the molecular processes (self assembly and inheritance) are spontaneous under the appropriate conditions: hydration, concentration, temperature, pressure etc.

Life of earth is protein-based



- 'Final' products of gene expression
- Major dry weight component of cells
- Major structural 'building block' in cells
- Most cell functions performed by proteins
- Protein structures are fascinating and beautiful
- Proteins act/execute:
  - ***As building blocks*** e.g. cytoskeletal actin filaments, viral capsids
  - ***Chemical reactions*** e.g. enzymes: lysozyme, chymotrypsin
  - ***As Channels and pumps*** e.g. Ca2+ pump or Ca2+ ATPase Proteins
  - ***Transmit cell signals*** e.g. EGFR, Src, Ras GTPase
  - ***As molecular machines*** e.g. motor proteins: myosin, kinesin
  - ***Other specialised proteins act as:*** Antibodies, toxins, hormones, antifreeze, elastic fibres, ropes, luminescence
- DNA Mutation → protein evolution (i.e fluorescent protein in different colours (cyan, yellow, blue))
  - Sequence → Structure → Chemistry → Activity

THERMODYNAMICS



- Gibbs free energy depicts how the reaction of reactants and products are going to happen
- It is the energy of the reaction available to do work
- Also called the "available" energy (note temperature dependent (K))

Enthalpy = Heat Energy
Entropy = Disorder
Gibbs free energy takes account of enthalpy and entropy

$$\Delta G = \Delta H - T\Delta S = G_{products} - G_{reactants}$$

SPONTANEOUS REACTIONS

- **If ΔG is negative, then the reaction is spontaneous**
- Given by:
    - **Big negative ΔH (Exothermics)**
    - **Big positive ΔS (increase in entropy)**

Exergonic: ΔG is negative: Free energy released: Favourable: Spontaneous
Endergonic: ΔG is positive: Free energy absorbed: Unfavourable: Not Spontaneous

Exothermic: ΔH is negative: Heat released
Endothermic: ΔH is positive: Heat absorbed

FREE ENERGY AND EQUILIBRIUM

aA + bB ↔ cC + dD $$K_{eq} = \frac{[C]^c_{eq}\,[D]^c_{eq}}{[A]^c_{eq}\,[B]^c_{eq}}$$

- K_{eq} is the thermodynamic equilibrium constant for the reaction
- It describes the "position" of the reaction ***at equilibrium***
    - i.e. the relative concentrations of components at equilibrium
- $[X]_{eq}$ is the concentration of component X at equilibrium
- Little k is the rate constant

$$\Delta G = \Delta G^o + RT\,ln\frac{[C]^c_i\,[D]^d_i}{[A]^a_i\,[B]^b_i}$$

- ΔG is the actual free energy change for the reaction;
- It describes how much work the reaction can do; and it depends on:
    - (i) ΔG^o the standard free energy change
        - A constant for the particular reaction; measured under standard conditions
    - (ii) The initial concentrations of the reactants and products
        - $[X]_i$ is the initial concentration of component X
- Further away from equilibrium you start; the more work is done before you get there
- R is the universal gas constant; T is the temperature in K
- At equilibrium, ΔG = 0; The reaction can do no more work
- Rearranging the equation gives:

$$\Delta G^o = -RT\,lnK_{eq}$$

STANDARD CONDITIONS

ΔG^o	$\Delta G'^o$
• Use of standard conditions allow free energy changes to be easily compared Chemistry and Physics standard conditions –very general ○ 298 K (25 °C) ○ Gases at a partial pressure of 101.3 kPa (1 atm) ○ Reactants and products at 1 M concentrations ○ i.e.$[H^+]$=1M→pH 0	• Biochemistry standard conditions –rather specific • As above except: reaction occurs in a well buffered aqueous solution at pH 7 ○ [H+] and Mg^{2+} ▪ » $[H^+] = 10^{-7}$ ▪ » Mg^{2+} = 1 mM (needed for enzymes) • **For all biochemical reactions, assume biochemical standard state**