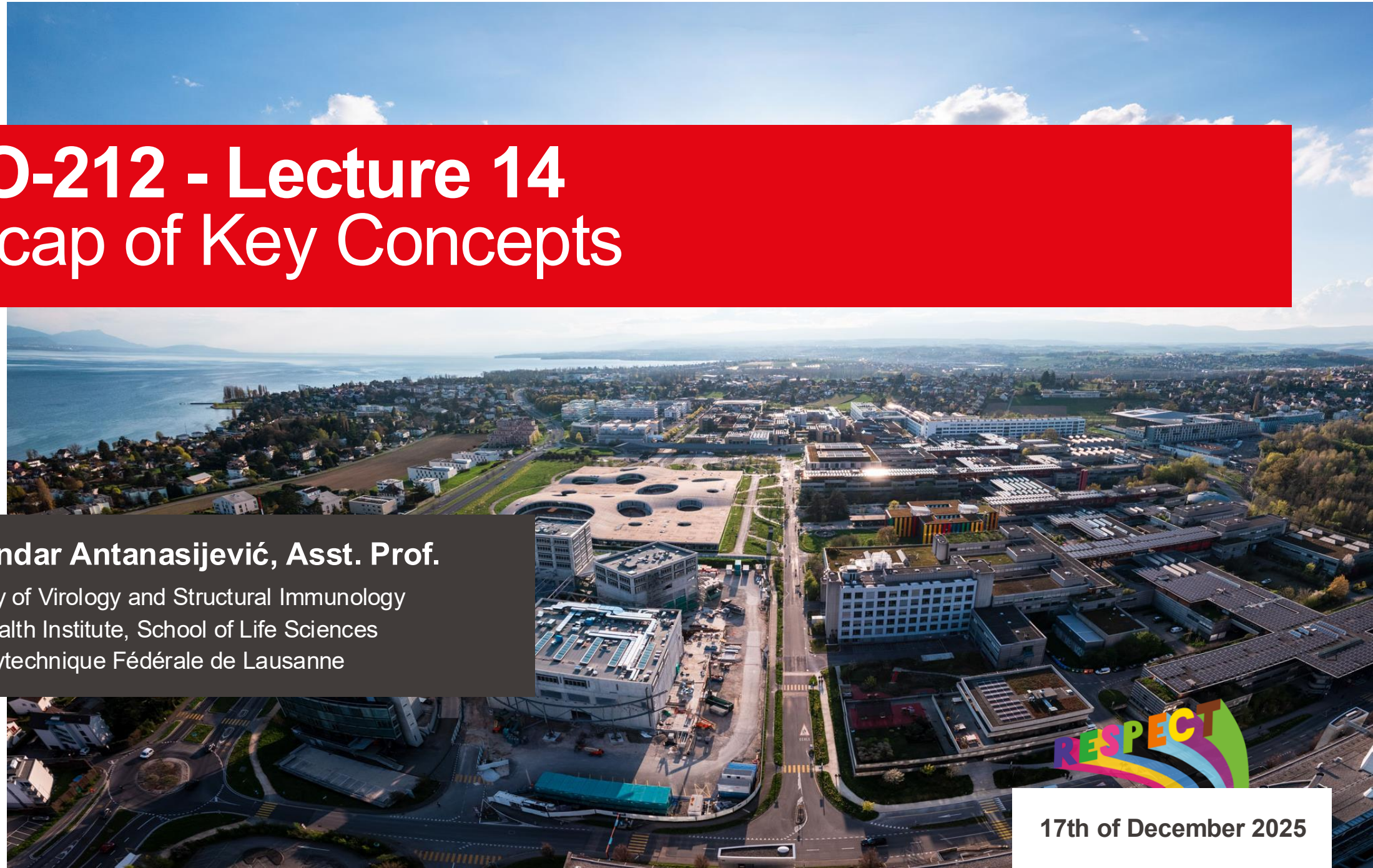
BIO-212 - Lecture 14
Recap of Key Concepts



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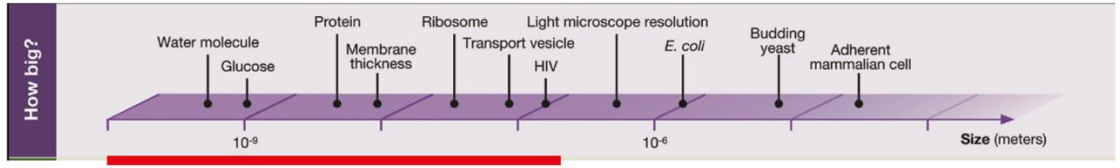
17th of December 2025

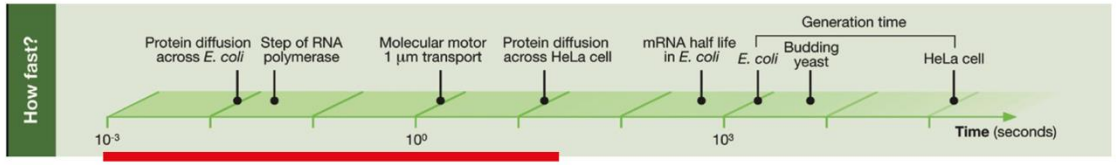
Lecture 1 – Basic concepts: Atoms and Interactionsz

- Biomolecules on the scales of life:

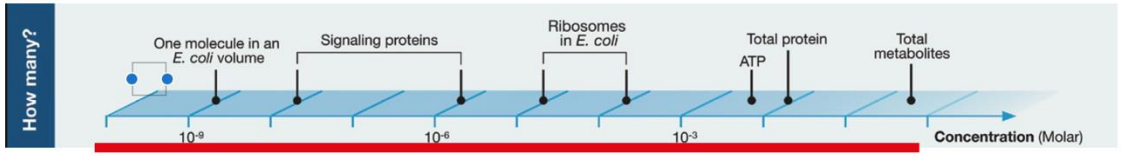


0.1nm — 100nm

1Å= 0.1nm



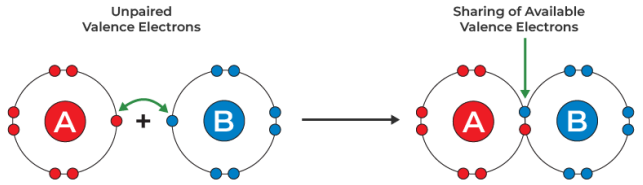
ns — s

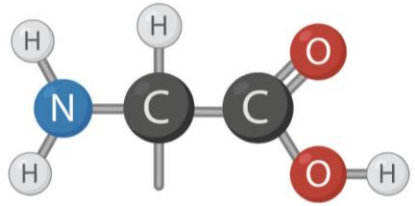


nM — M

- Atomic and molecular interactions in biomolecules

Covalent bonds

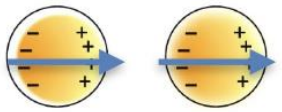




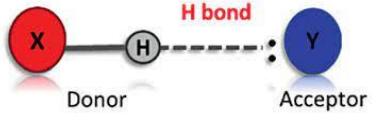
~100-800kJ/mol

Non-covalent interactions

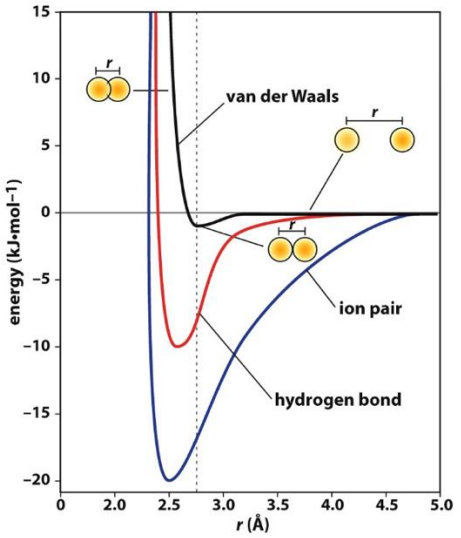
van der Waals interactions



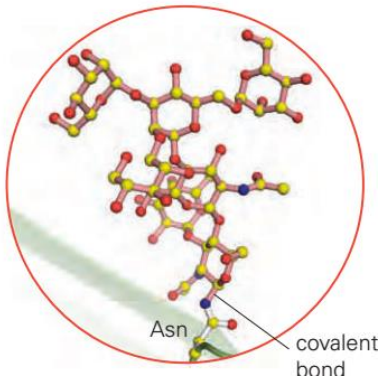
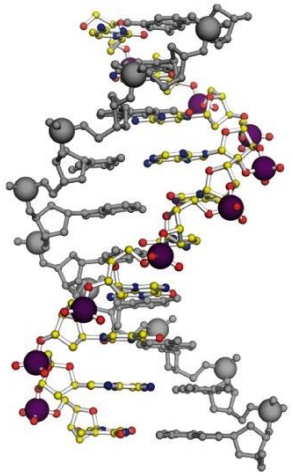
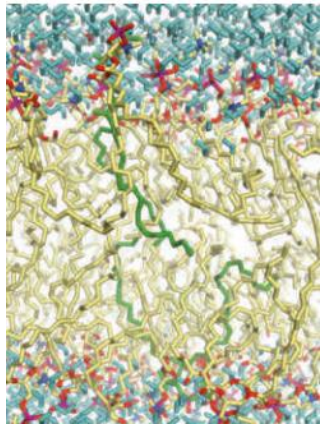
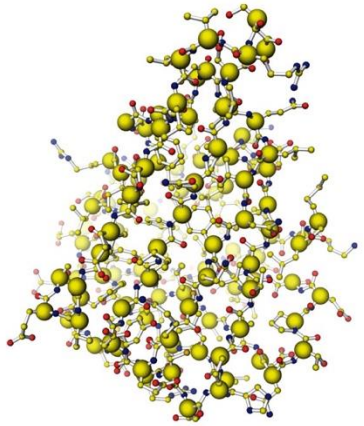
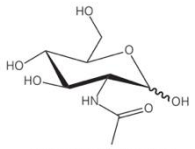
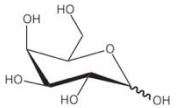
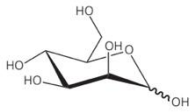
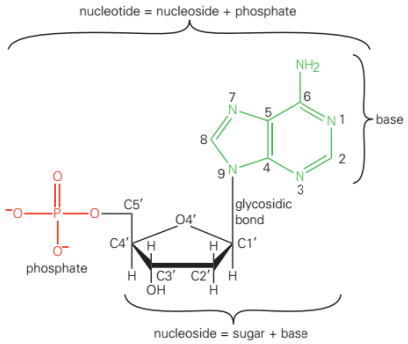
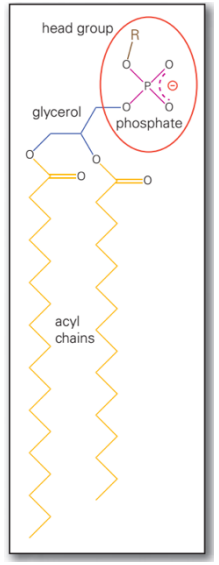
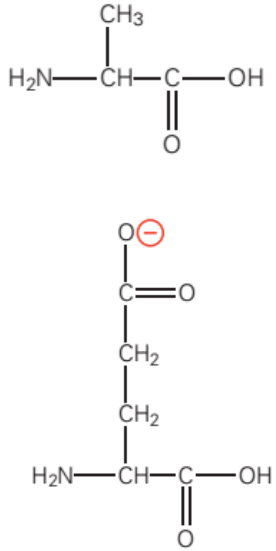
Hydrogen bonds



Ionic interactions



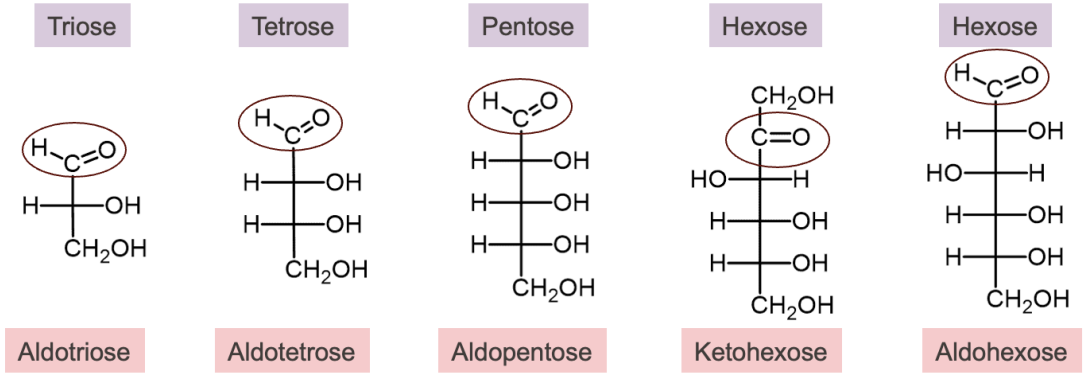
Lectures 2 - 5: The Molecules of Life

	Carbohydrates	Nucleic Acids	Lipids	Proteins
Macromolecular Structure				
Building Block	  			

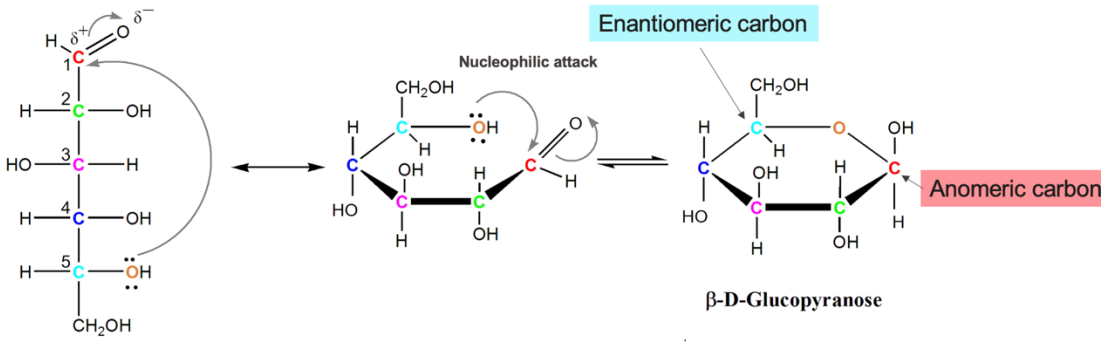
Lecture 2 – Carbohydrates

• Carbohydrate building blocks

Monosaccharides:

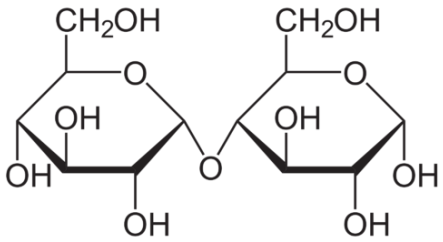


Hemiacetal and hemiketal forms in solution:

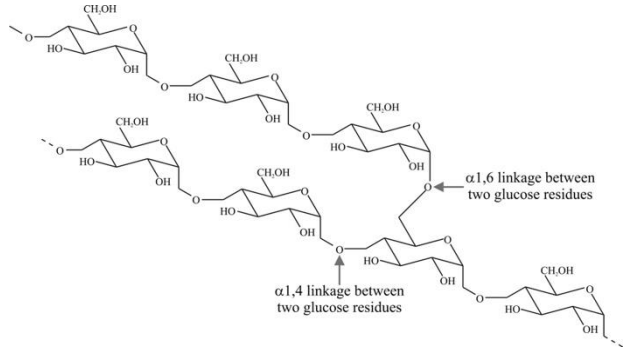


• Carbohydrate polymers and their roles

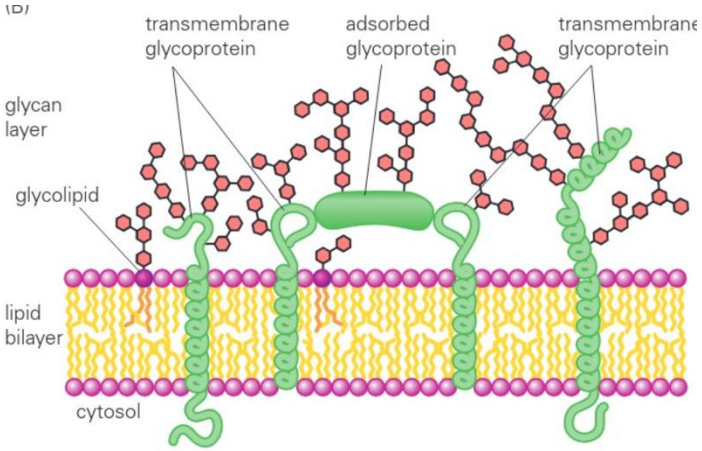
Disaccharide
(Maltose)



Polysaccharide
(Amylopectin)



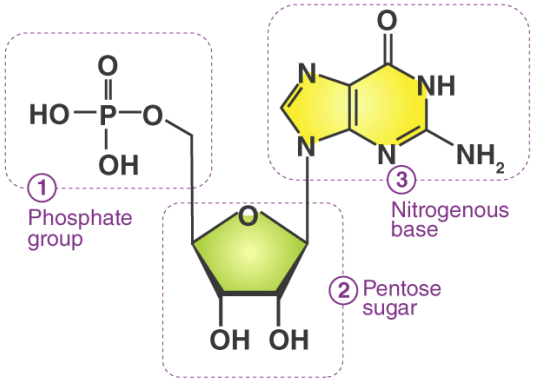
Glycolipids and glycoproteins



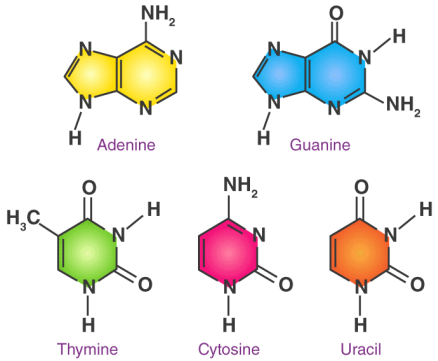
Lecture 3 – Nucleic Acids

• Nucleic Acid building blocks

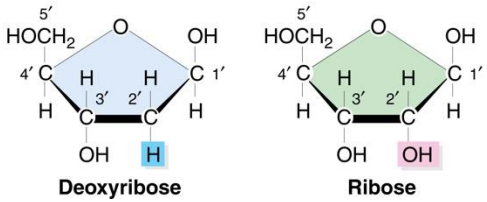
- 3 main components: **base, pentose, and phosphate**



- 5 base options



- 2 pentose options



- 2 x 4 sets of nuceotides to produce DNA and RNA

• Nucleic Acids (DNA and RNA)

- Linear **polymers of nucleotides**

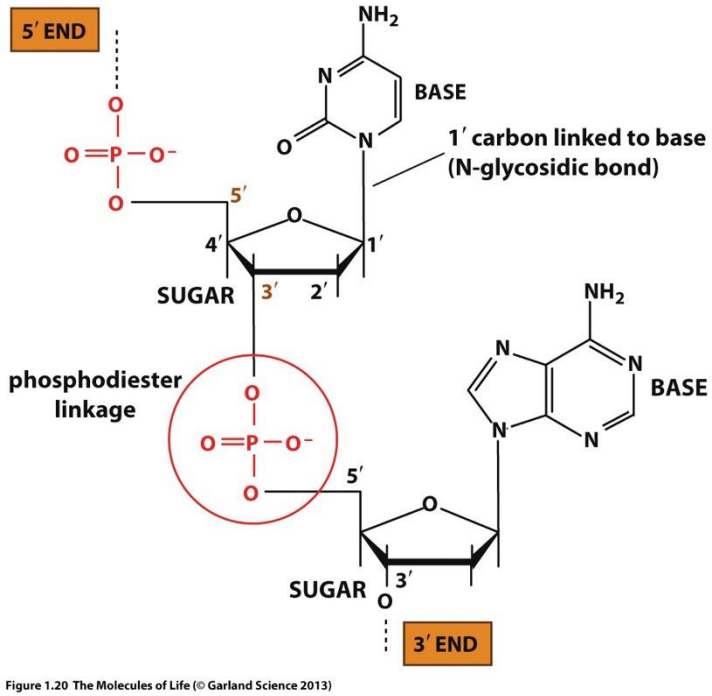


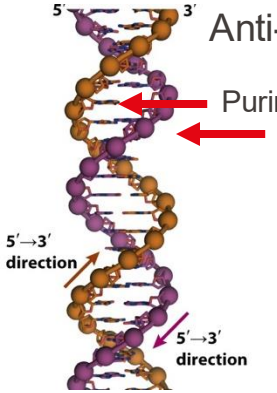
Figure 1.20 The Molecules of Life (© Garland Science 2013)

- 5'->3' directionality in addition of nucleotides
- Attachment via phosphodiester linkages

Lecture 3 – Nucleic Acids

• Nucleic Acid structure and assembly

- Double-stranded helical assembly of DNA (B form)

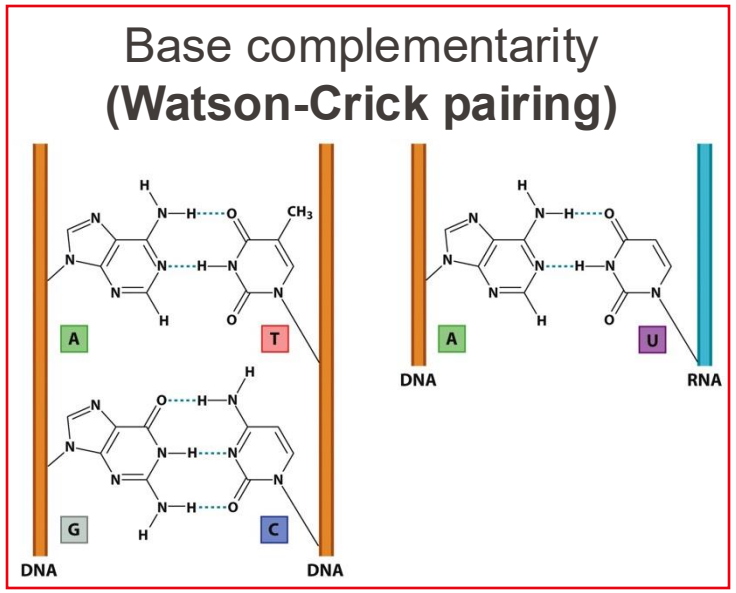


Anti-parallel complementary strands

Purine-Pyrimidine Base Pairs (inwards)

Phosphate-pentose backbone (outwards)

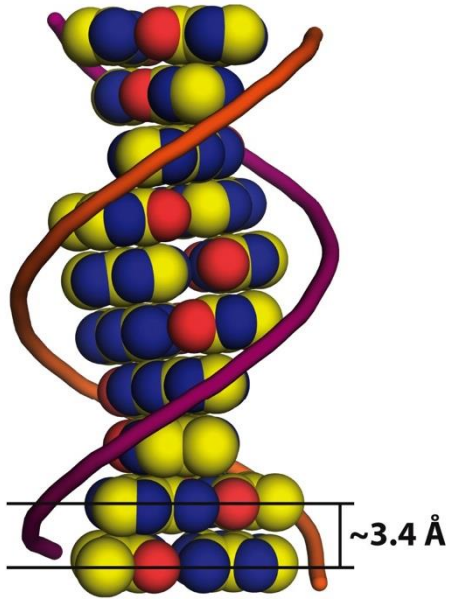
10 base pairs per helical turn



- RNA can be double- and single-stranded and features greater conformational and functional diversity

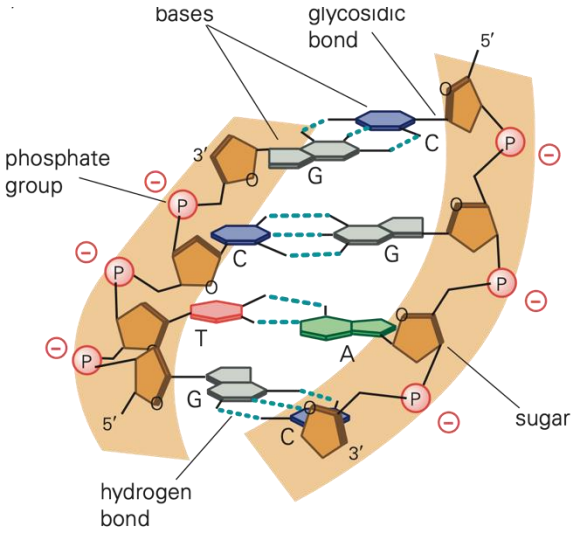
• Important non-covalent interactions

Van der Waals interactions (layered base stacking)



- Stacking of arromatic π-orbitals (π-π stacking)

Hydrogen-bond network (base pairing)

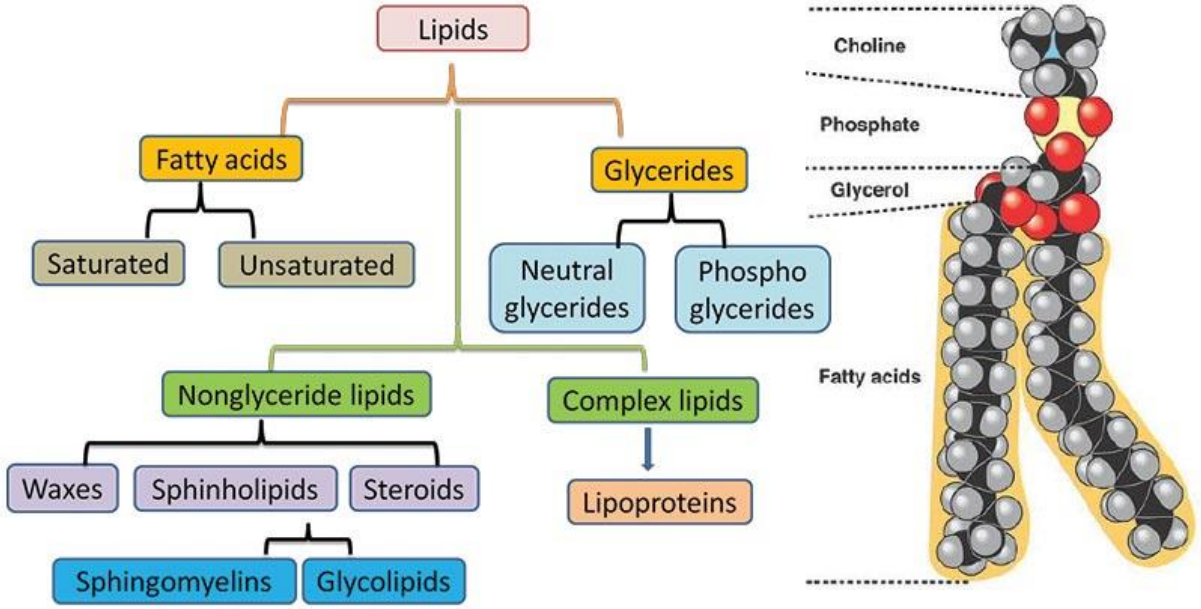


- Charged, polar backbone attracts water and positively charged ions

Lecture 4 – Lipids

• Main lipid types and roles

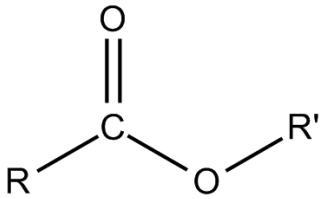
- Main lipid types based on chemical properties



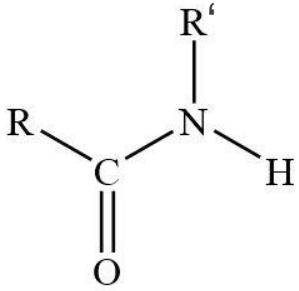
- There are >1000 building blocks which can assemble in different ways (very diverse)
- Their main roles include energy storage, assembly of biological membranes, cell and hormone signaling

• Important bonds and interactions

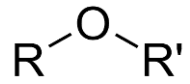
Ester bonds (triglycerides)

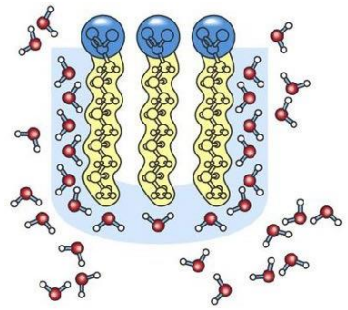


Amide bonds (sphingolipids)

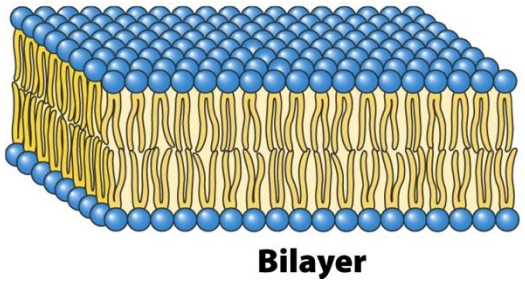


Ether bonds (head domains)





- Amphipatic molecules (polar and hydrophobic) that form bilayers in aqueous solutions

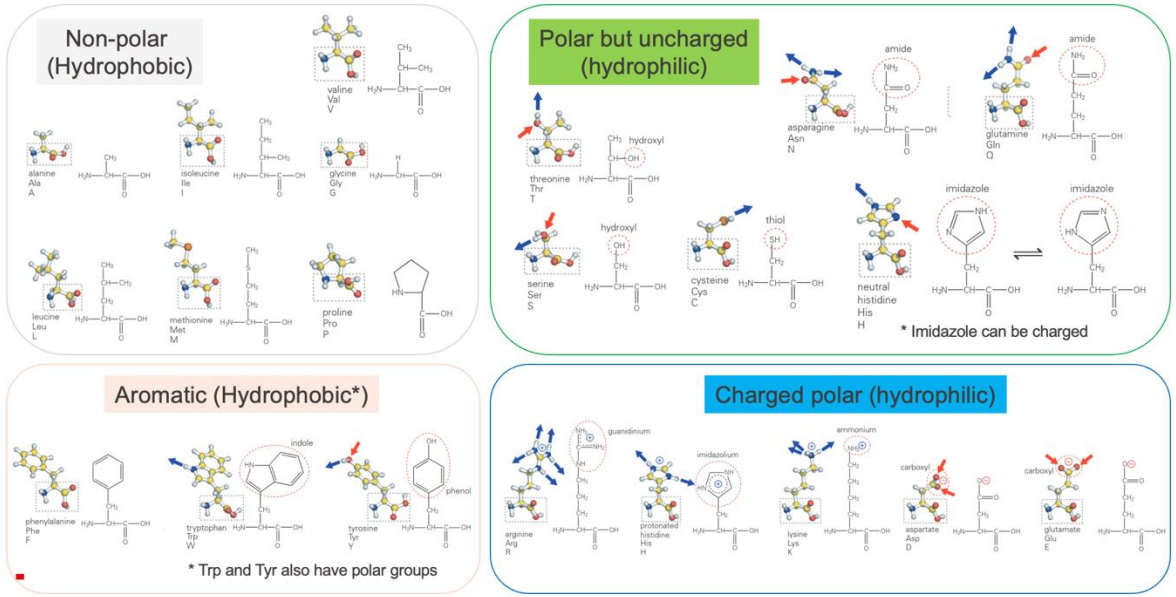


- Tail: vdW interactions
- Head: hydrogen bonding and charged interactions

Lecture 5 – Proteins

• Physicochemical properties of amino acids

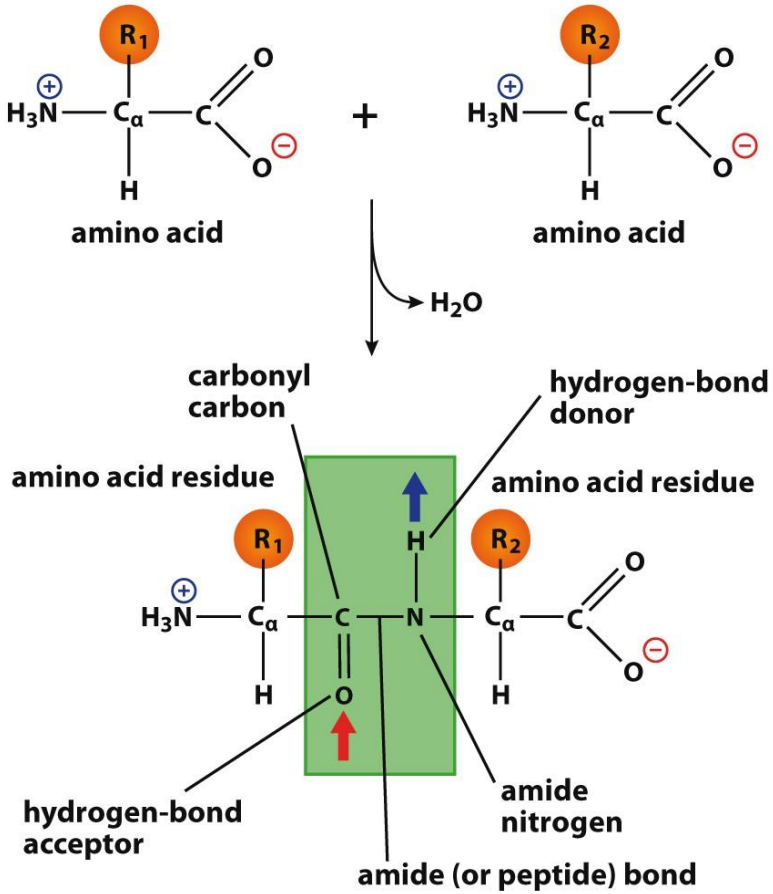
- 20 cannonical amino acids that assemble all proteins



- Their side-chains give them different properties (e.g., water solubility, charge, hydrogen bonding capacity).
- They exist as L- or D- stereoisomers, but the proteinogenic amino acids are all all L

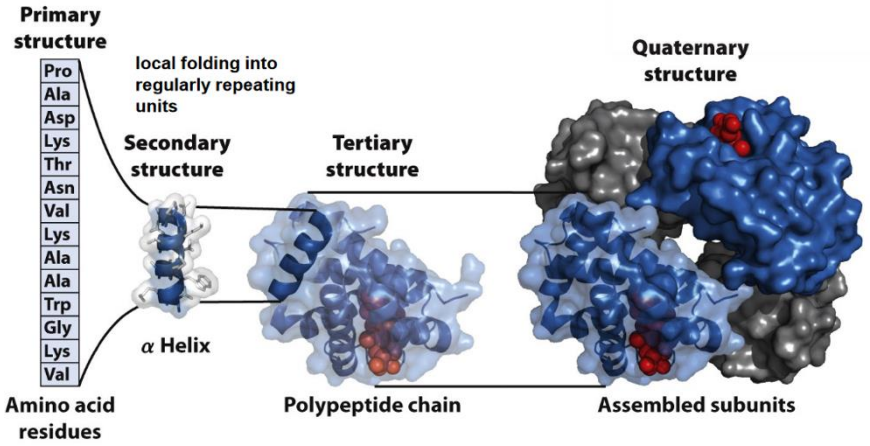
• Proteins are formed by linking amino acids

- Amino acids are connected via peptide (amide) bonds

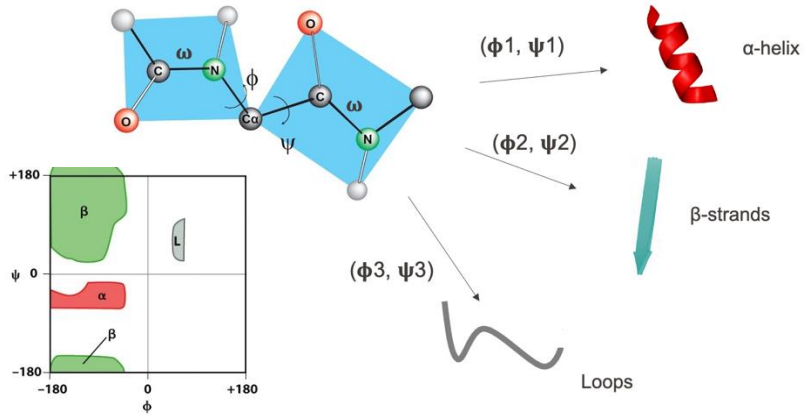


Lecture 5 – Proteins

• Proteins fold into functional quaternary entities

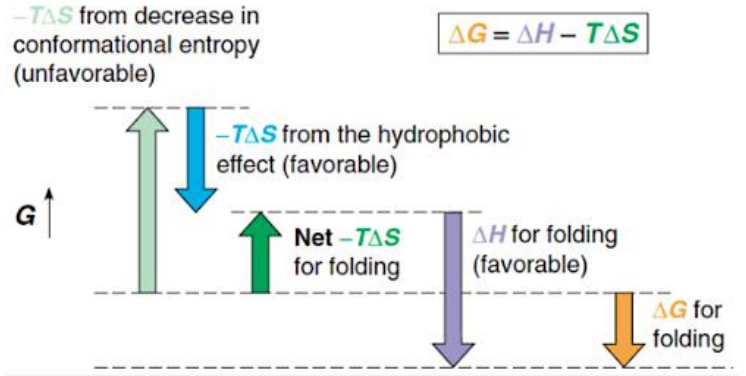


- Torsions around different bonds are predefined by the surounding chemical groups

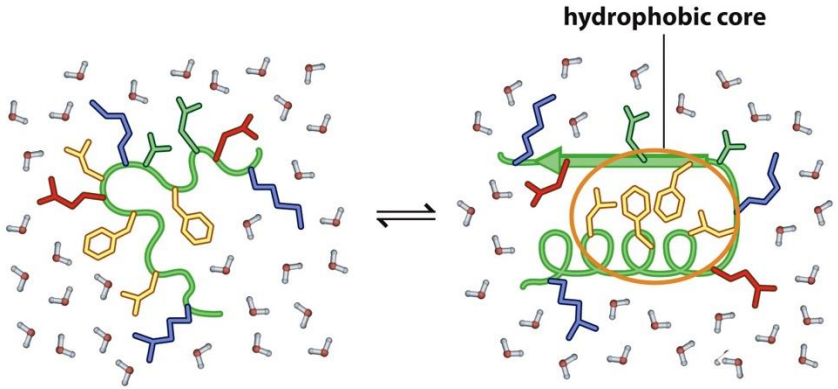


• Protein folding process

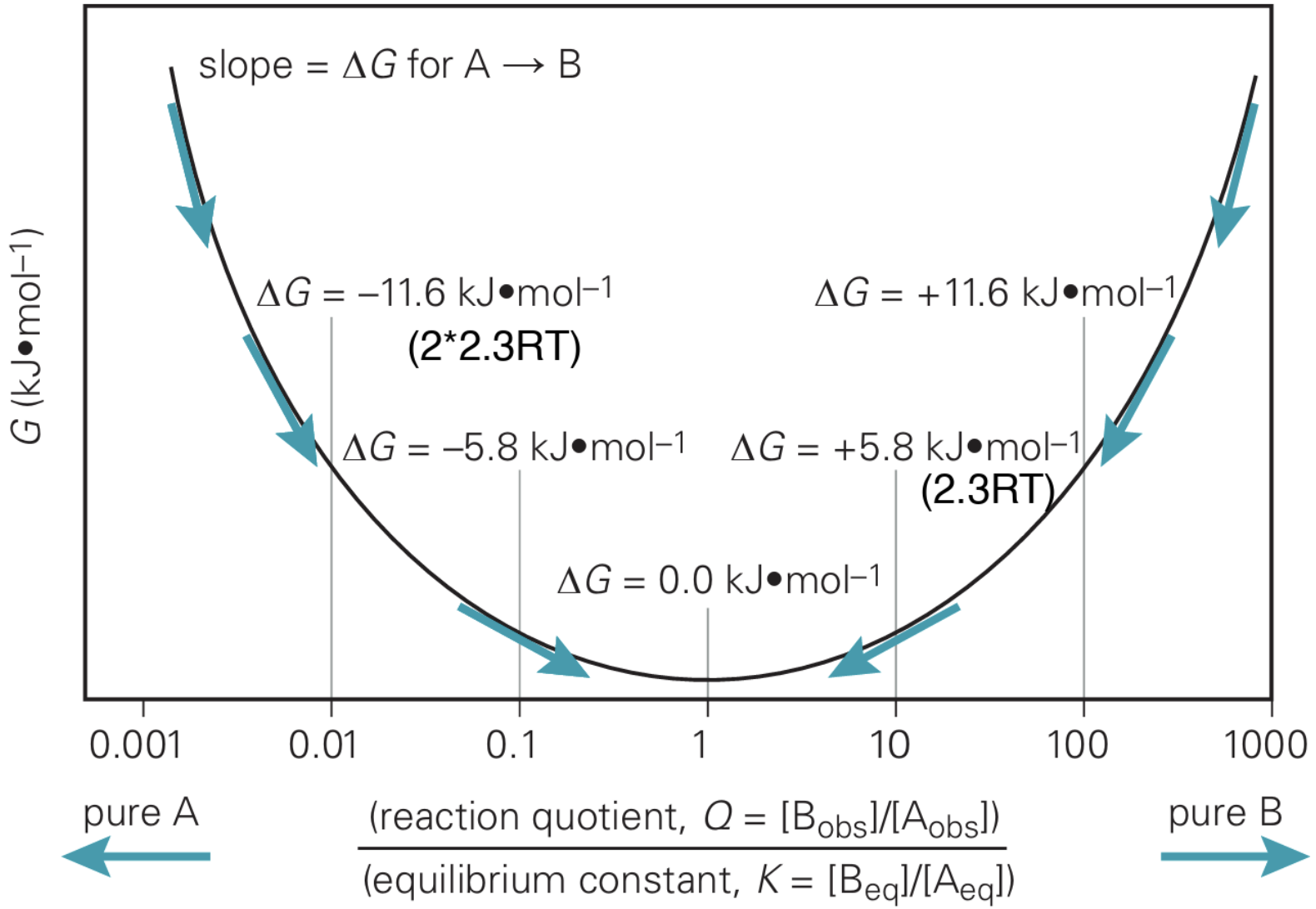
- Protein folding is a process driven by thermodynamic tendency to optimize Gibbs free energy



- Protein folding usually starts with a hydrophobic core



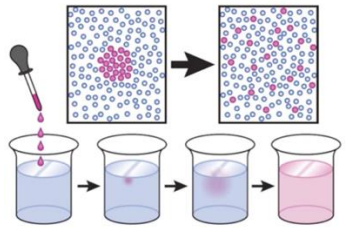
Lectures 6 - 7: Biomolecule thermodynamics



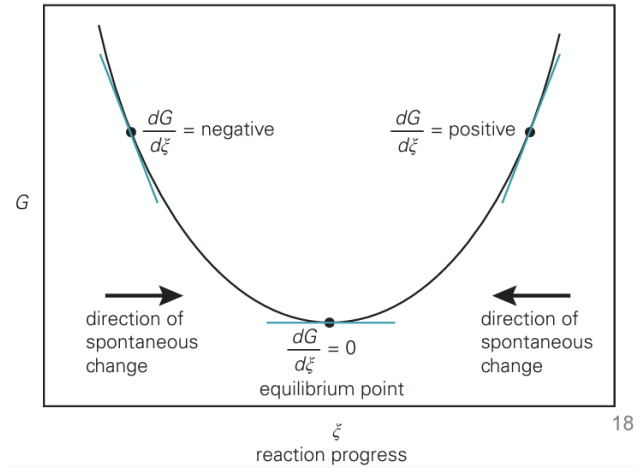
Lecture 6 – Basic thermodynamic concepts

• Gibbs free energy and chemical potential

- Gibbs free energy (ΔG)



$$dG = dH - TdS$$



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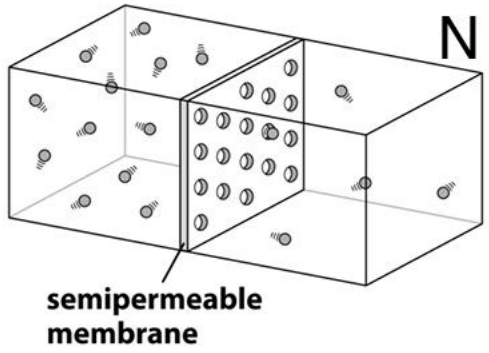
- Chemical potential (μ) defines the concentration conditions for biological processes in equilibrium.



$$\Delta\mu = \mu_2 - \mu_1 = RT\ln\left(\frac{C_2}{C_1}\right)$$

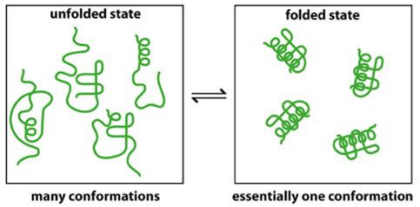
• Equilibrium in different contexts

Chemical reaction

$$ATP + H_2O \rightarrow ADP + P_i$$

$$K = \frac{[ADP][P_i]}{[ATP]}$$

Protein Folding



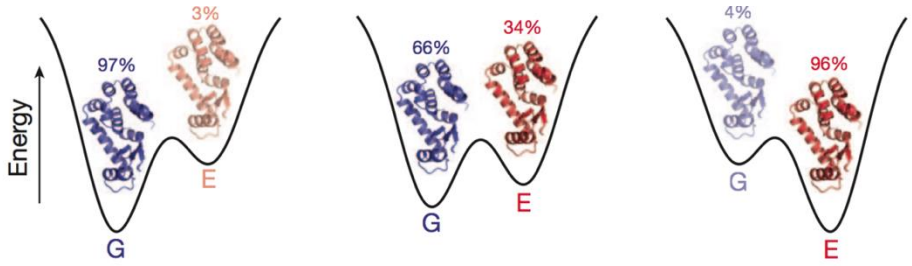
$$K_{folding} = \frac{[F]}{[U]}$$

Acid-Base Eq.

$$HA \rightleftharpoons H^+ + A^-$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

- Boltzmann distribution and equilibrium

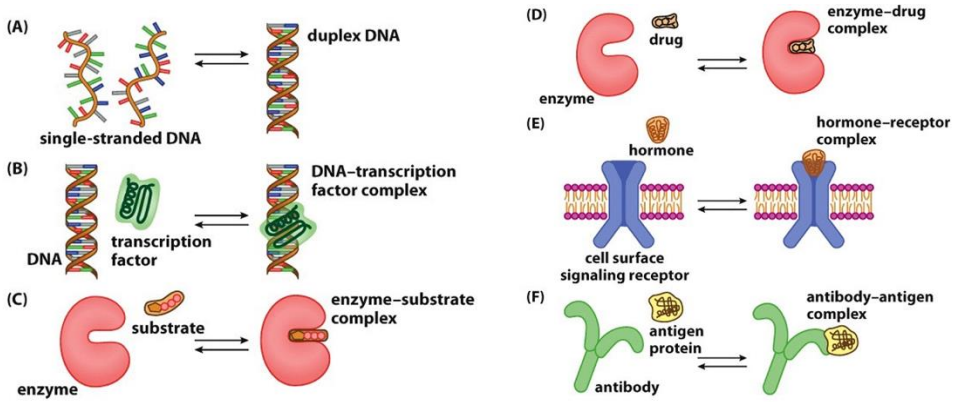


$$\frac{[E]}{[G]} = e^{-\frac{\Delta G_{G\rightarrow E}}{RT}}$$

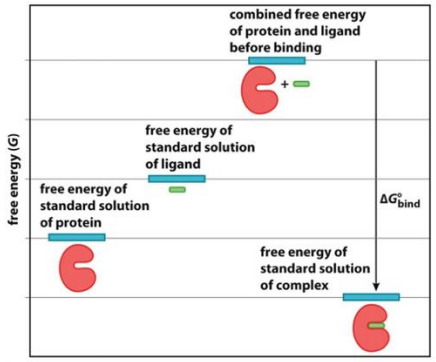
Lecture 7 – Thermodynamics of molecular interactions

• Biomolecular interactions (binding)

- Binding in different contexts



- Gibbs free energy and equilibrium constants (K)



$$P + L \rightleftharpoons P \bullet L$$

$$K_D = \frac{[P][L]}{[P \bullet L]} = \frac{1}{K_A}$$

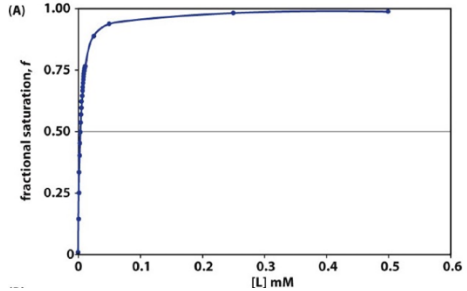
$$\Delta G^{o}_{bind} = -RT \ln K_A$$

$$\Delta G^{o}_{bind} = +RT \ln K_D$$

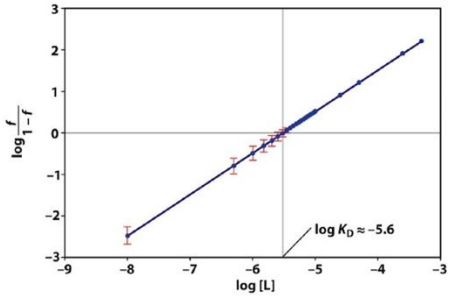
• Different ways of presenting binding curves

- Fractional saturation (f):

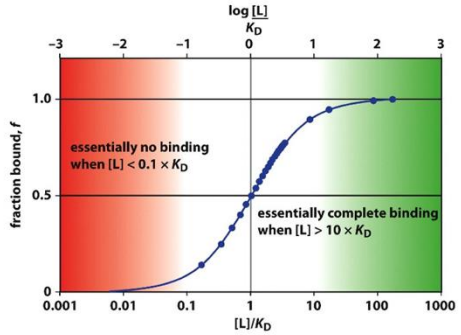
$$f = \frac{\text{concentration of protein with ligand bound}}{\text{total protein concentration}}$$



f ~ [L]

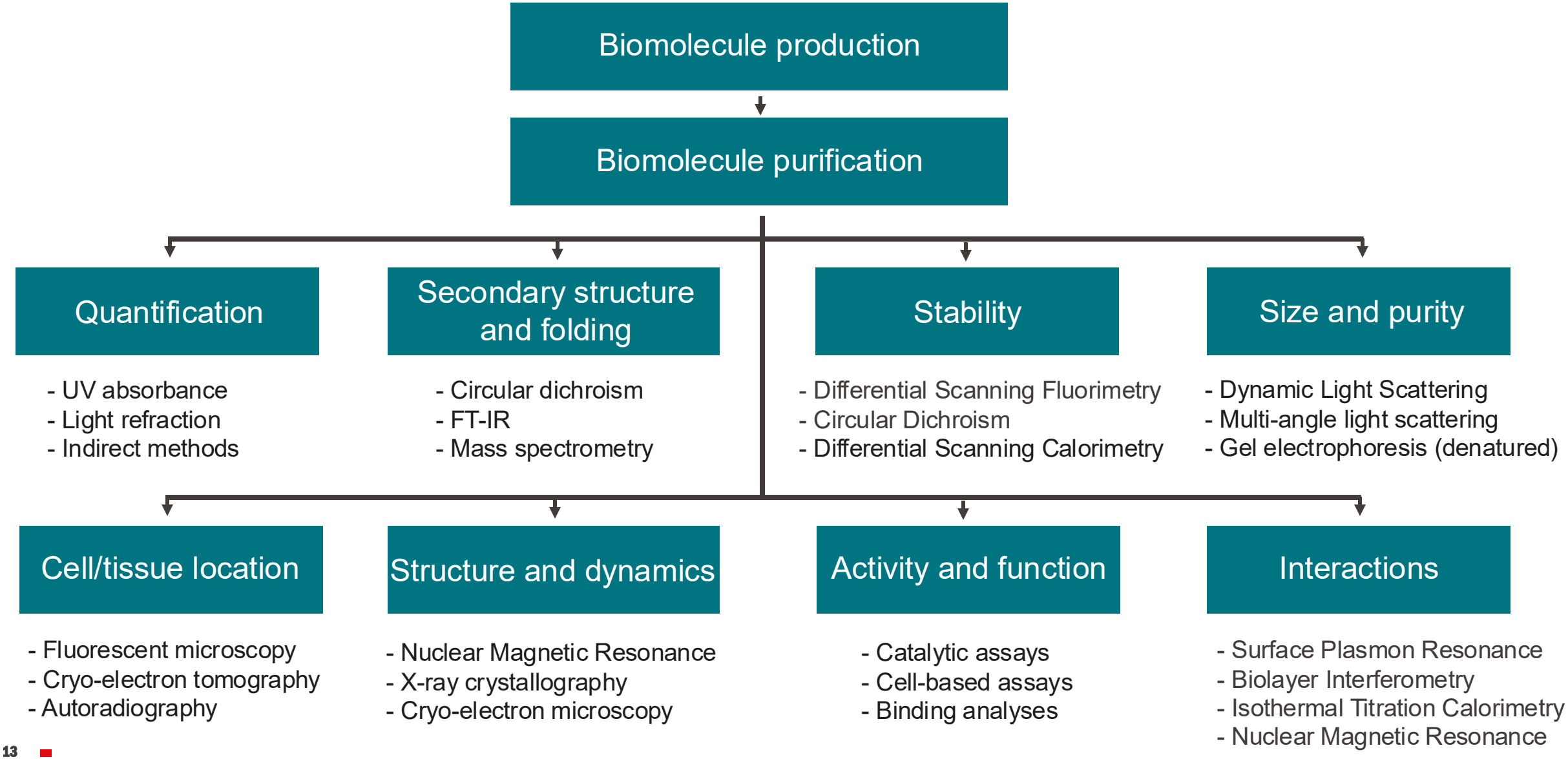


log f/(1-f) ~ log [L]



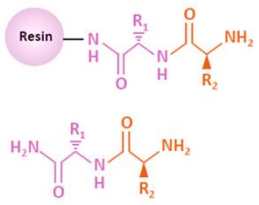
f ~ [L]/Kd

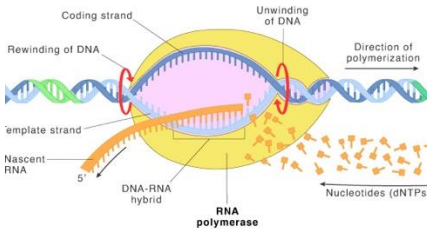
Lectures 8 - 13: Working with biomolecules



Lecture 8 – Biomolecule Production and Purification

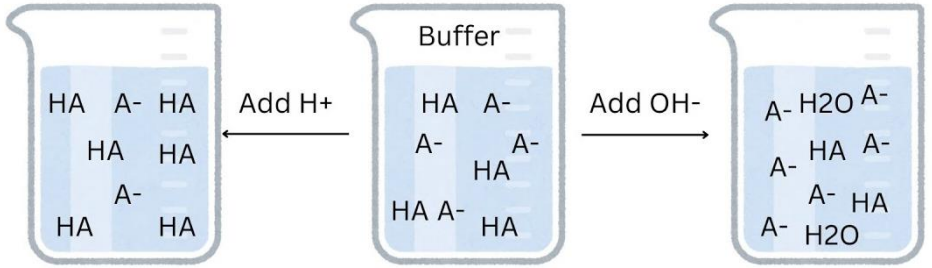
• Biomolecule production methods





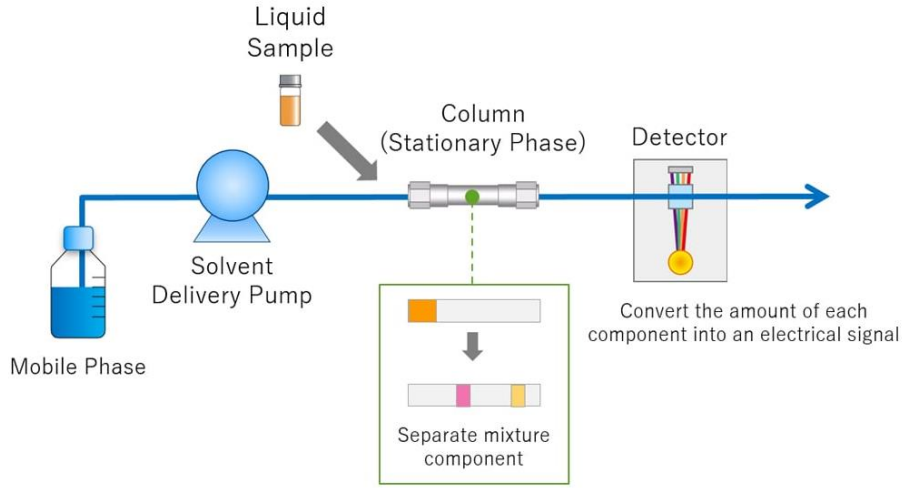
Chemical Enzymatic Cell-based

• Buffers and buffer components

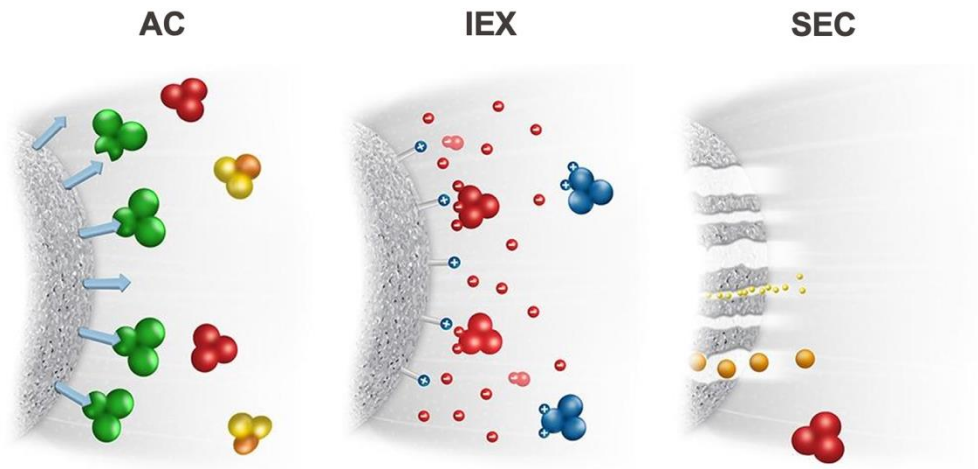


- Maintaining pH and ionic strength of the solution
- Other components can be added for LC or stability

• Liquid Chromatography for biomolecule purification



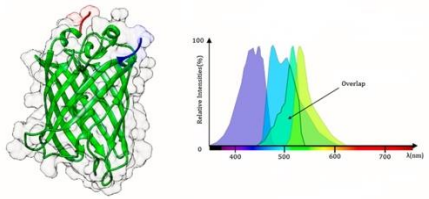
• Basic chromatography methods



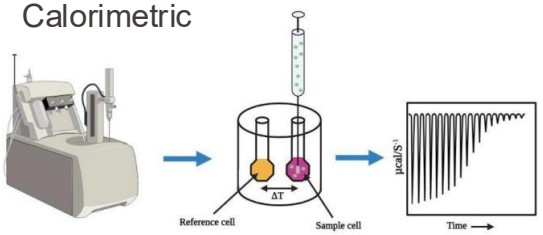
Lecture 9 – Biomolecule Characterization

• Different types of measurements

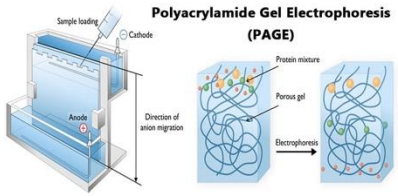
Spectroscopic



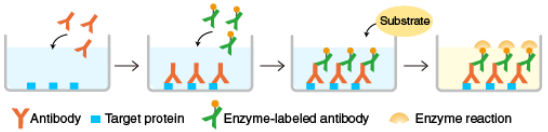
Calorimetric



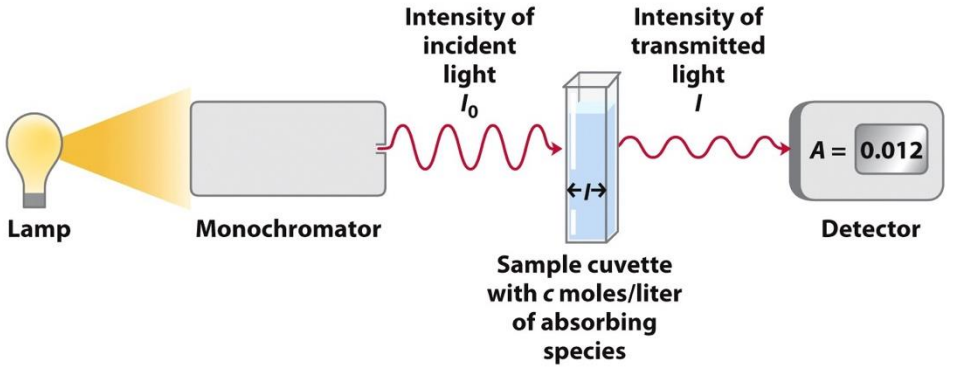
Electrophoretic



Enzyme-based

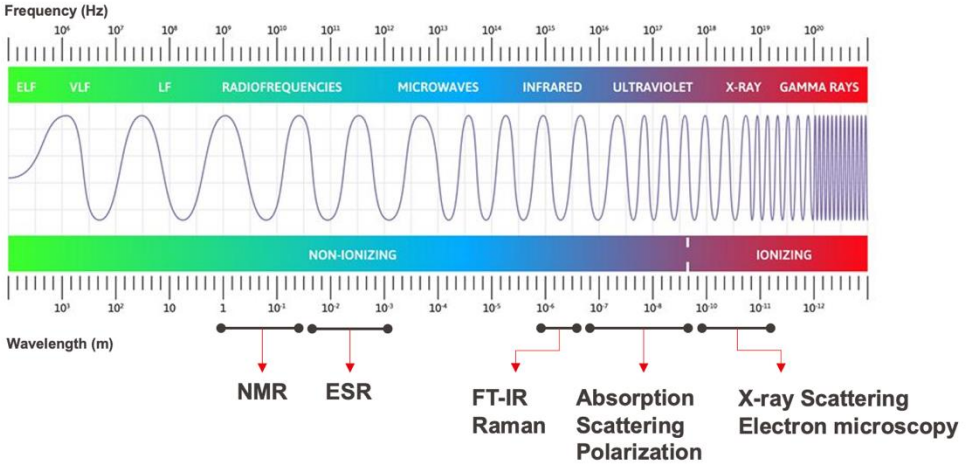


• Spectroscopic / Spectrometric methods

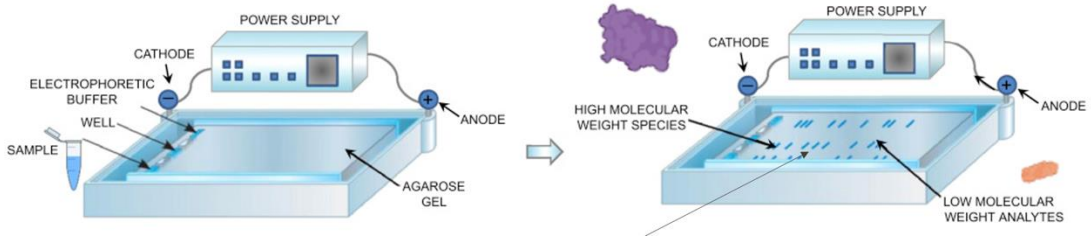


UV/Vis, FT-IR, CD, Fluorescence, DSF, DLS

• EM spectrum and biophysical methods



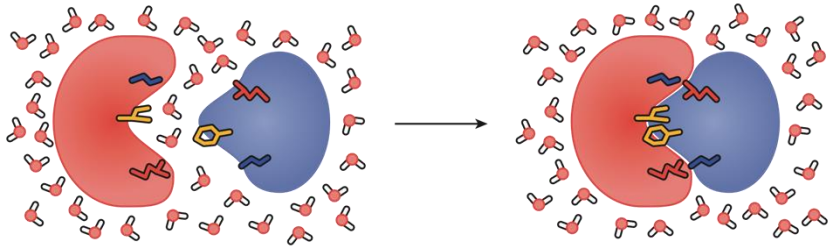
• Gel electrophoresis

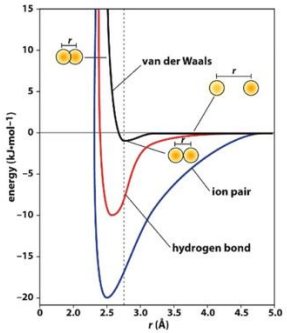


SDS PAGE, Agarose gels

Lecture 10 – Measuring Biomolecular Interactions

• Biomolecular interactions and binding





- Small energy contributions from hydrogen bonds, vdW, ionic and hydrophobic interactions
- Water can have a positive and negative impact on binding

• Dissociation constants and affinity

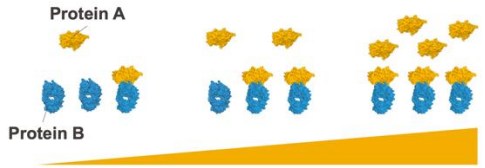
$$\Delta G^\circ = RT \ln K_D = \Delta H - T\Delta S$$

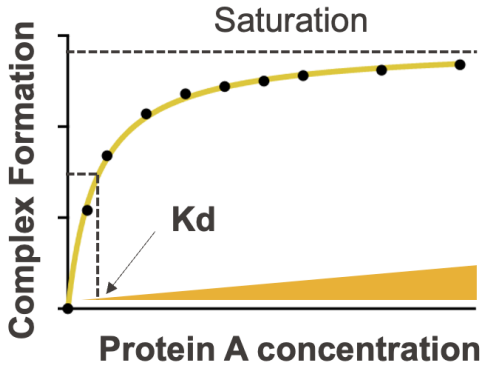
$$\frac{k_d}{k_a} = \frac{k_{off}}{k_{on}} = \frac{[P][L]}{[P \bullet L]} = K_D = \frac{1}{K_A}$$

- Thermodynamic and kinetic analysis of binding

• Experimental methods for Kd determination

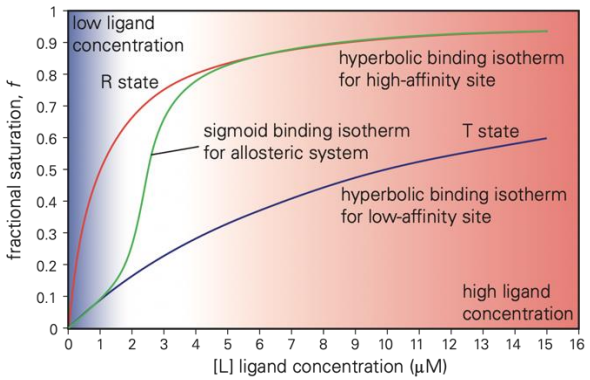
- Titrate one binding partner and measure complex formation

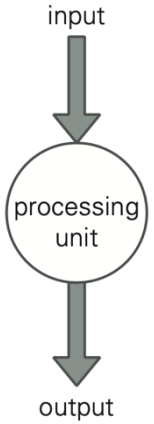




- Calorimetric (ITC) or spectroscopic (FP, SPR, NMR) measurements

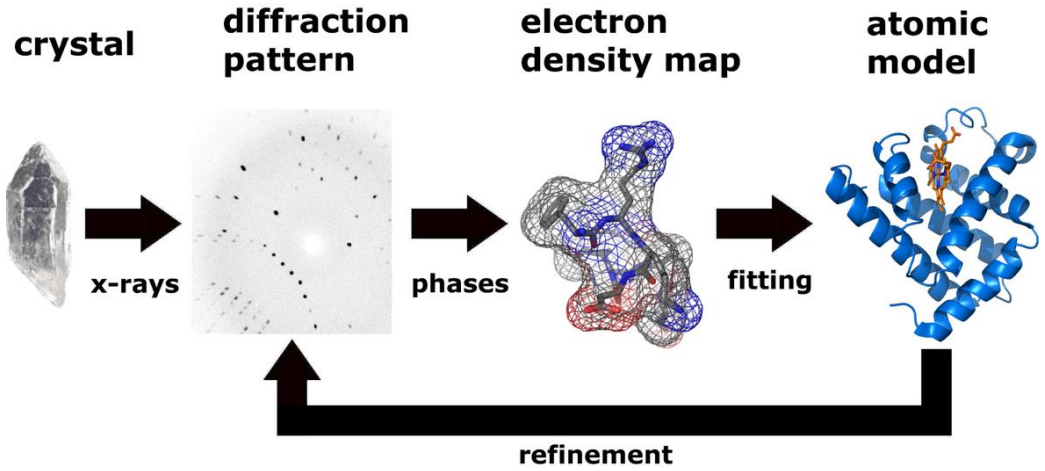
• Cooperativity and Allostery



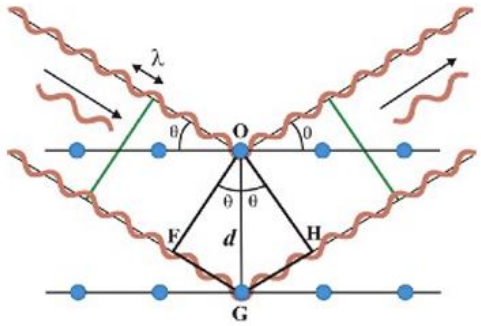


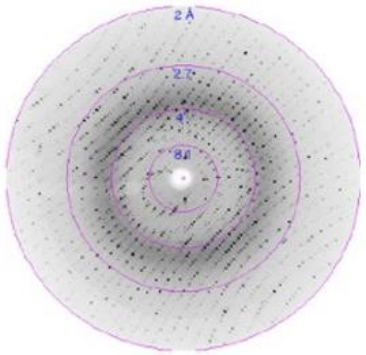
Lecture 11 – Structural Biology

• X-ray crystallography

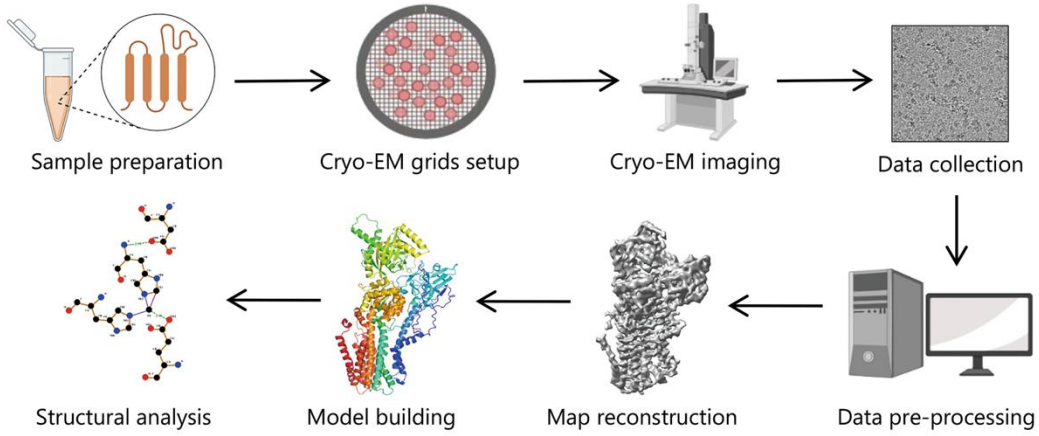


Bragg's law $n\lambda = 2d \sin\theta$

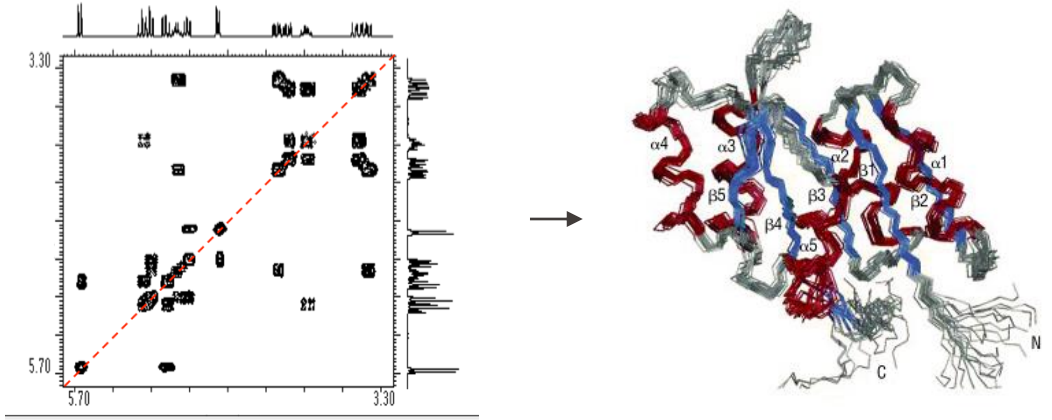




• Cryo-electron microscopy (CryoEM)

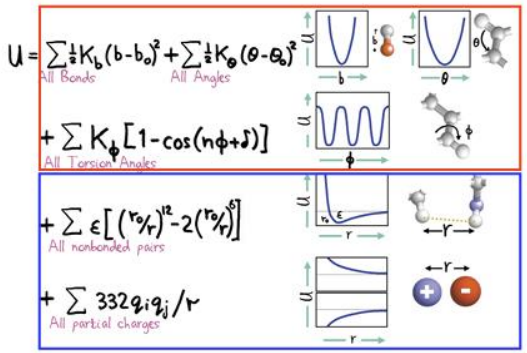


• Nuclear Magnetic Resonance (NMR)



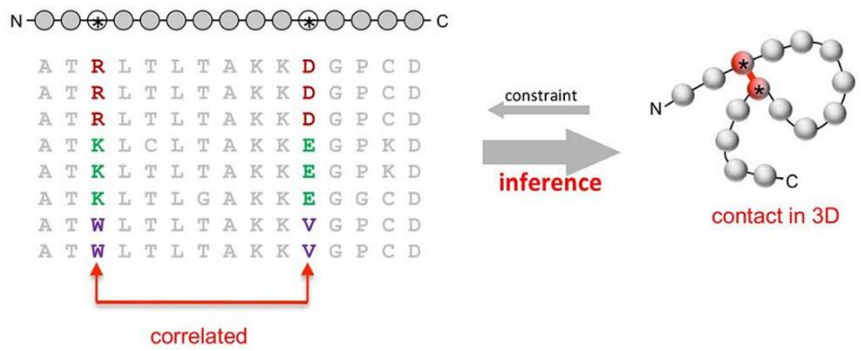
Lecture 12 – Computational Structural Biology

• Molecular simulations



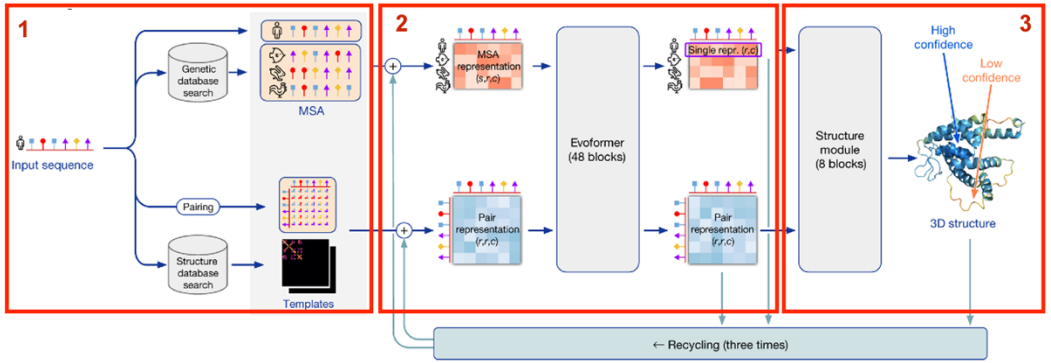
- Modeling biomolecular behavior using physical potentials

• Evolutionary couplings



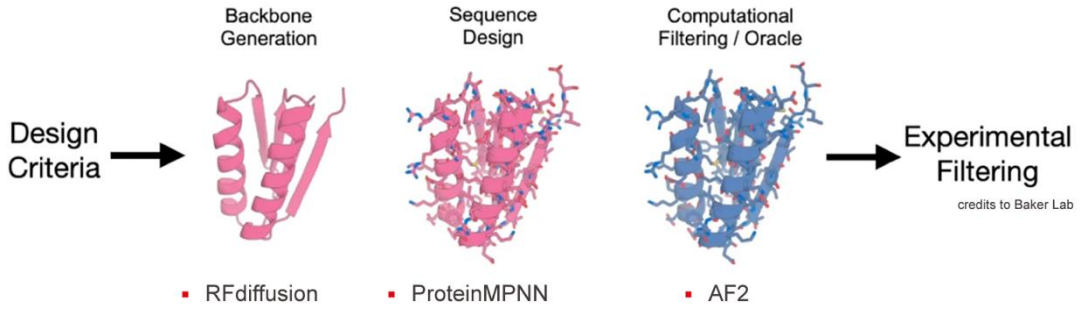
- Extracting structural information from sequence data

• Structure prediction using Alphafold 2



- Machine learning for predicting biomolecule assembly

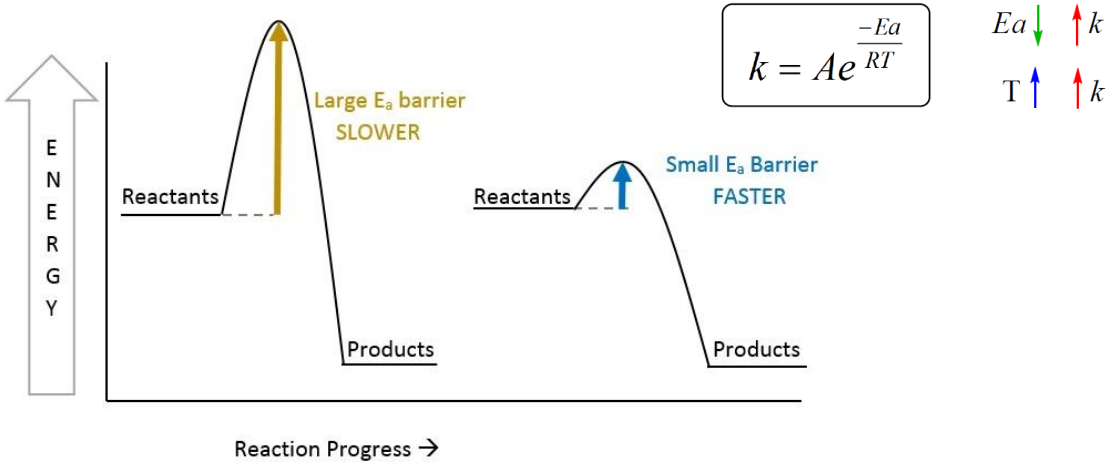
• Protein design



- Machine-learning-based methods for molecule engineering

Lecture 13 - Kinetics and Catalysis

• Reaction rates and Activation Energies

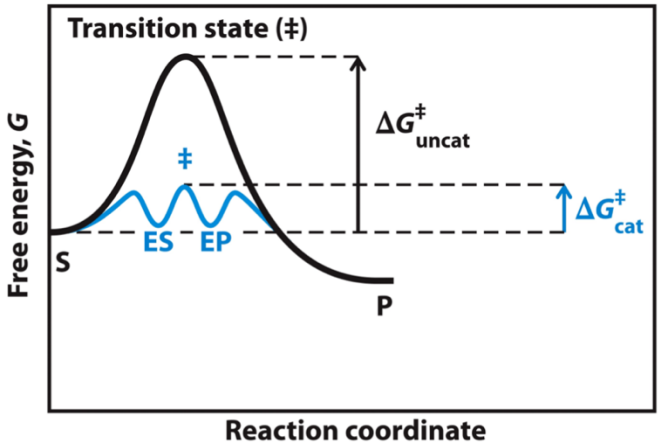


$$k = Ae^{\frac{-Ea}{RT}}$$

$Ea \downarrow \quad k \uparrow$

$T \uparrow \quad k \uparrow$

• Catalysis and enzymes



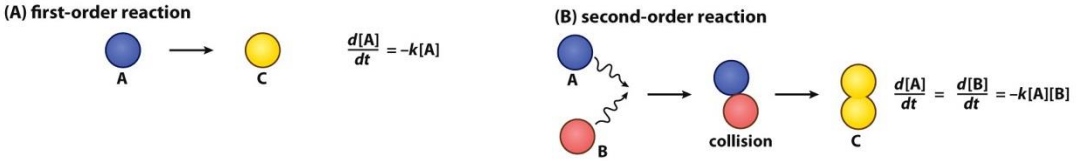
$$E + S \rightleftarrows ES \rightleftarrows EP \rightleftarrows E + P$$

$$V_0 = \frac{V_{max}[S]}{[S] + K_m}$$

- Michaelis-Menten equation

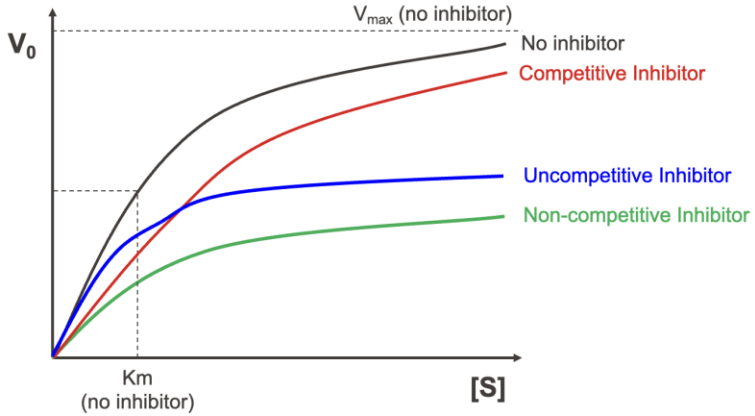
• Reaction order

- Order of the reaction depends on the number of molecules whose quantities impact the reaction rate



- Rate constant units depend on the order

• Enzyme inhibition mechanisms



- Inhibition depends on the K_I and inhibitor conc.

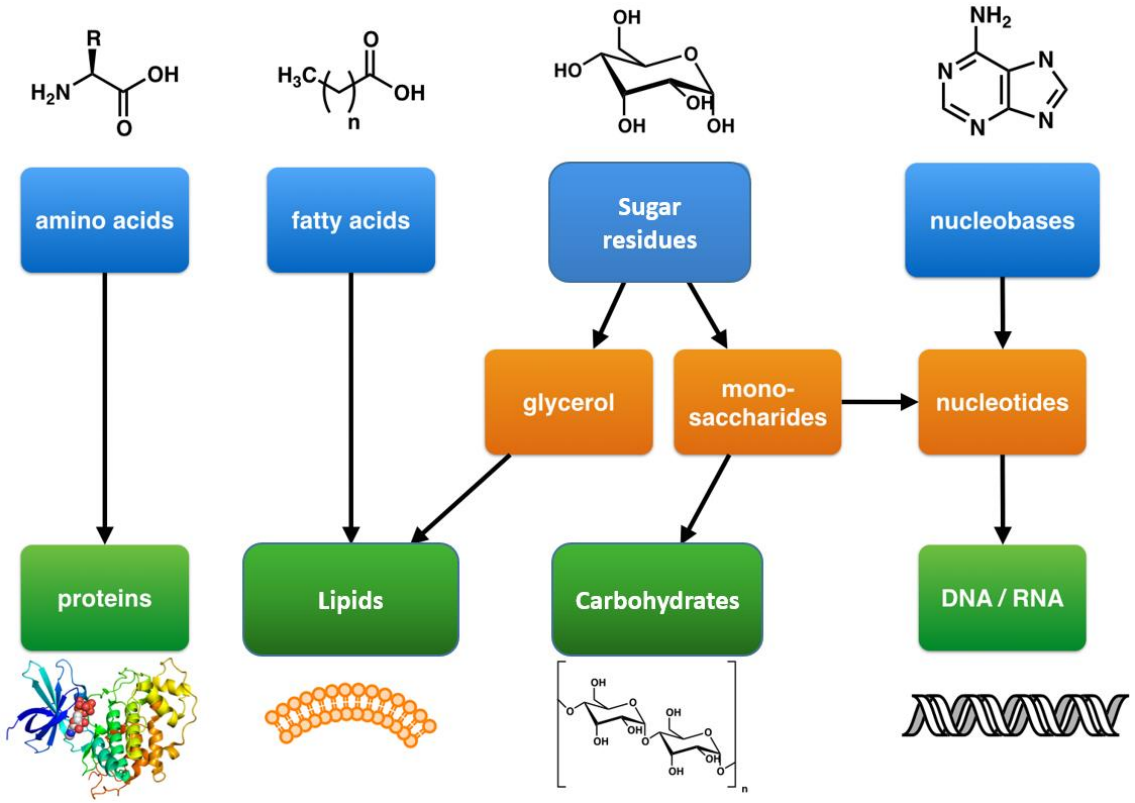
- Often expressed as **α**

$$\alpha = 1 + \frac{[I]}{k_I}$$

Essential content

- The **theory** from all lectures (fundamental concepts, mechanisms, properties of biomolecules, correlations…).
- Biomolecule **assembly** and their **properties** (chemical bonds and their properties, relevant functional groups, non-covalent interactions…)
- Biomolecule **production** and **purification** (principles, systems for production, chromatographic methods…)
- **Thermodynamic** principles, **biophysical** methods and **computational** approaches applied in biochemistry
- **Equations** for calculating constants, energies, reaction rates etc.
- **Exercises** (questions, problems, calculations…)

How to approach learning about biomolecules?



What are the building blocks?

What are the most important covalent bonds?

What are the most important non-covalent interactions?

How do they assemble in 3D space?

What function do they serve in cells?

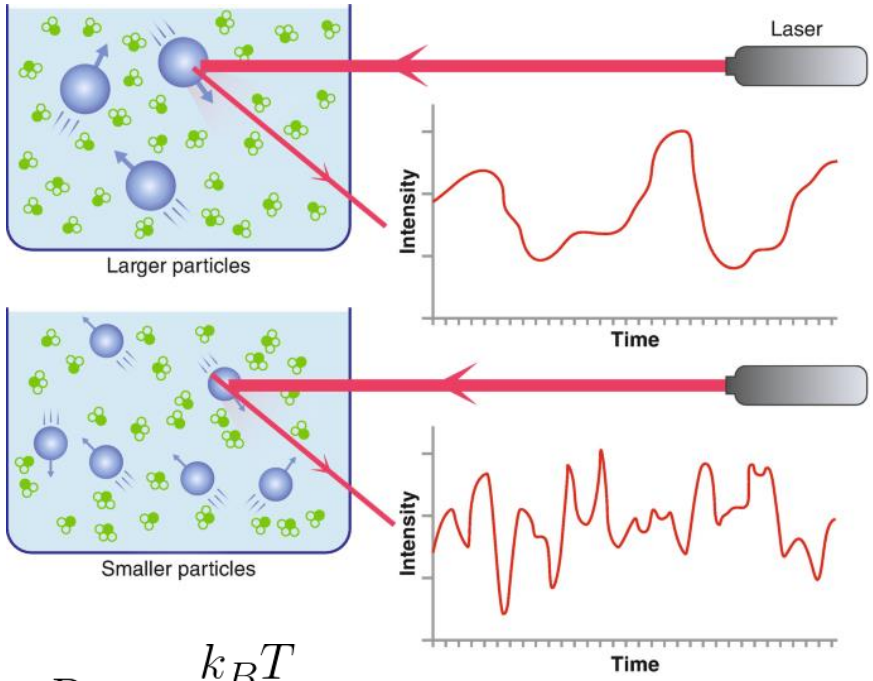
What are some important examples?

Are there subtypes? How do they differ?

Molecular structures of the essential building blocks of **proteins**, **carbohydrates** and **nucleic acids** need to be learned!

How to approach learning about experimental methods?

Example: Dynamic Light Scattering



$$R_H = \frac{k_B T}{6\pi\eta D}$$

How do different experimental methods work?

What are the quantities they measure?

What are their target biomolecule applications?

What is the minimal requirement for the method to work?

What are the limitations in their applicability?

Are there alternatives that cover the gap in applicability?

All relevant equations used for calculations of molecular properties need to be learned for the exam!

Exam Details

When?

January 15th, 2026
Start time: 15:15

* Please be there by 14:45 PM

Where?

SwissTech Conv. Center
Main hall: Zones I, J, and M

Seating will be assigned

How long?

3 hours total
End time: 18:15

Students that requested special accommodations will have 1 extra hour (End time: 19:15)

What to bring?

1) **Camipro card** (VERY IMPORTANT)
2) **Writing supplies** (pens, pencils etc.)
3) **Simple calculator** (no smartphone)

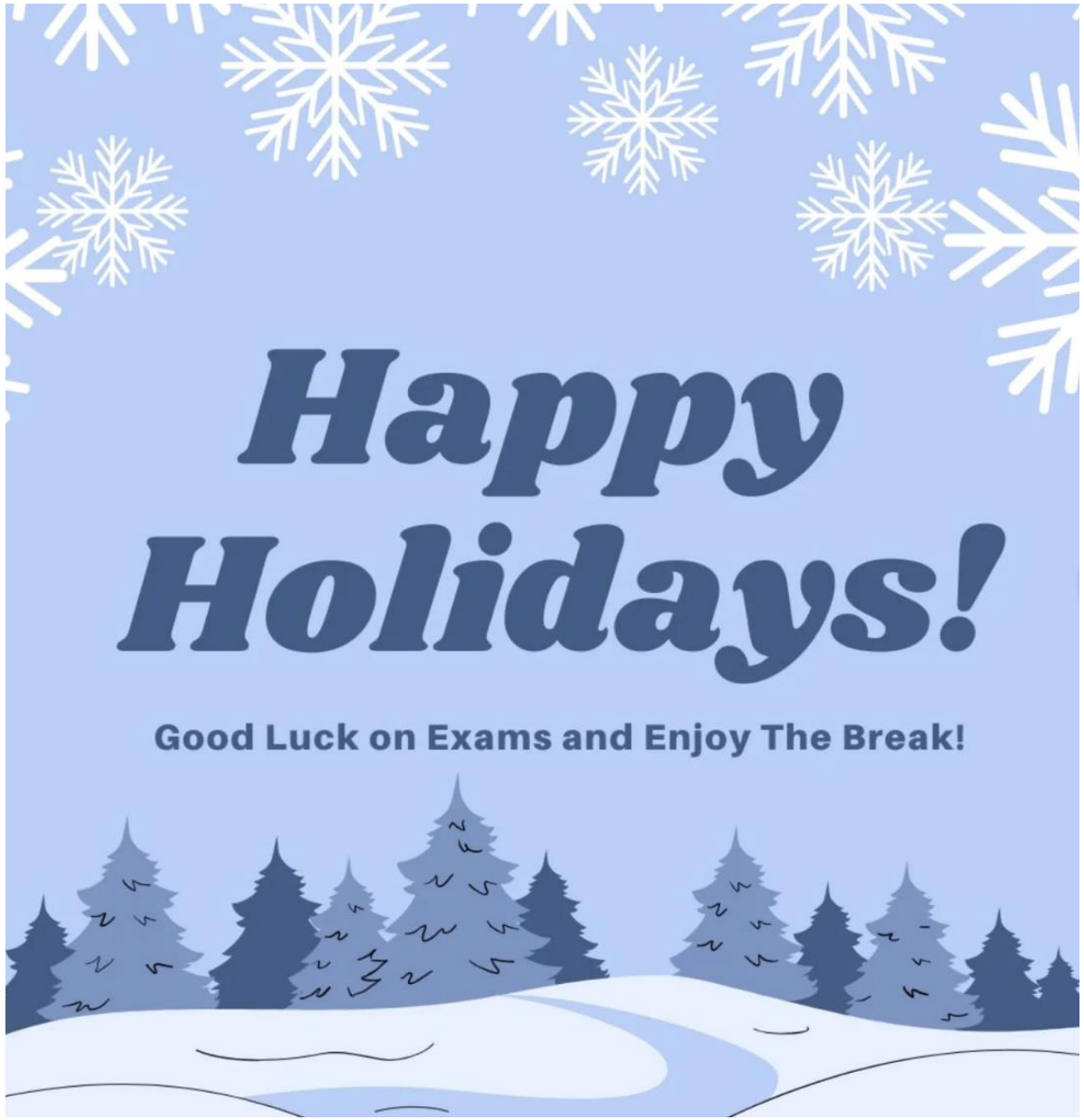
All paper supplies will be provided by the staff

Exam contents

1) **Multiple choice questions**
2) **Short questions/problems**
3) **Longer multistep problems**

The exam will be in French and English and you can answer in any language

Books, printouts, cheat-sheets, calculators with memory and fitting capability are not allowed


Happy Holidays!
Good Luck on Exams and Enjoy The Break!