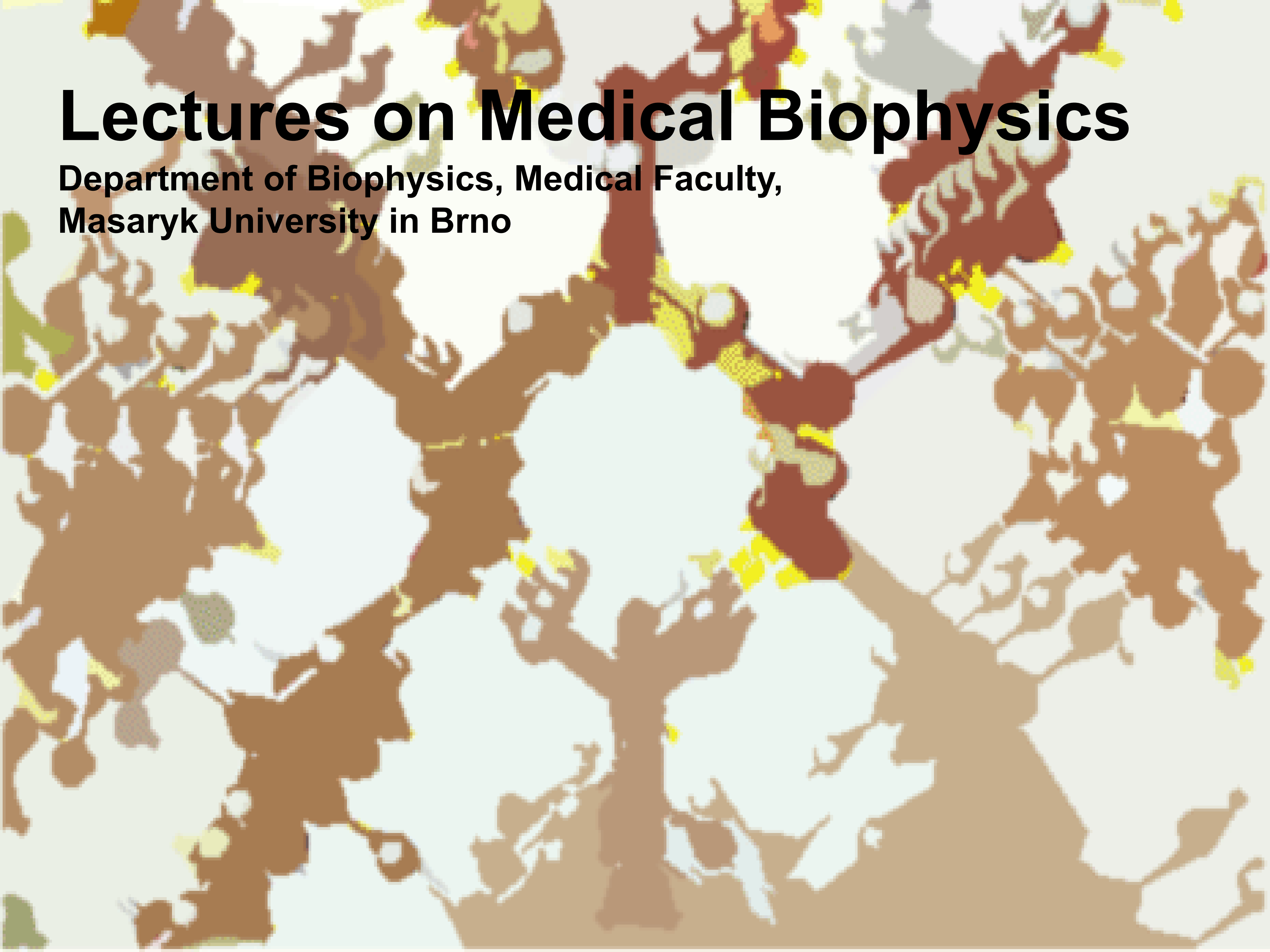
Lectures on Medical Biophysics

Department of Biophysics, Medical Faculty,
Masaryk University in Brno



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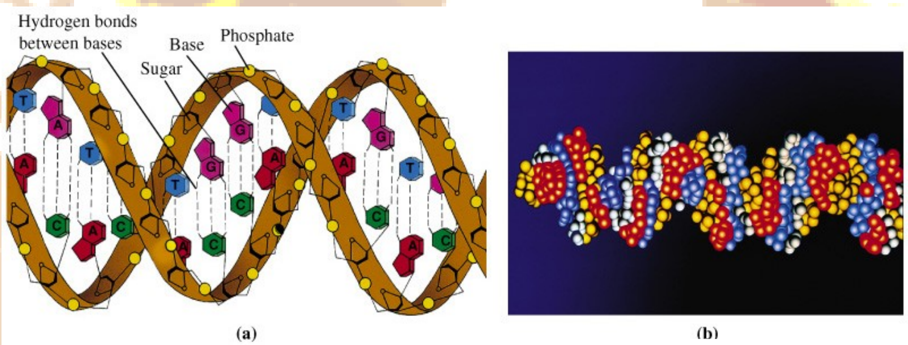
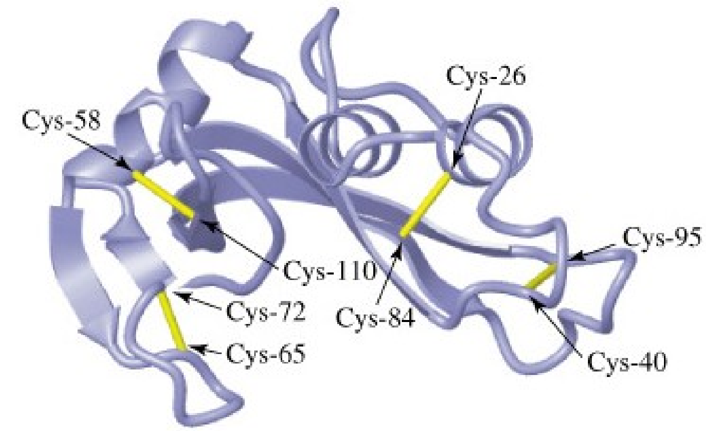
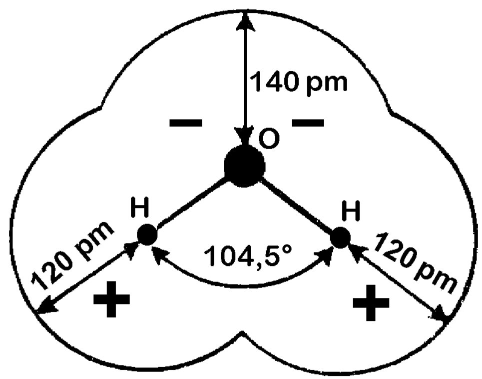






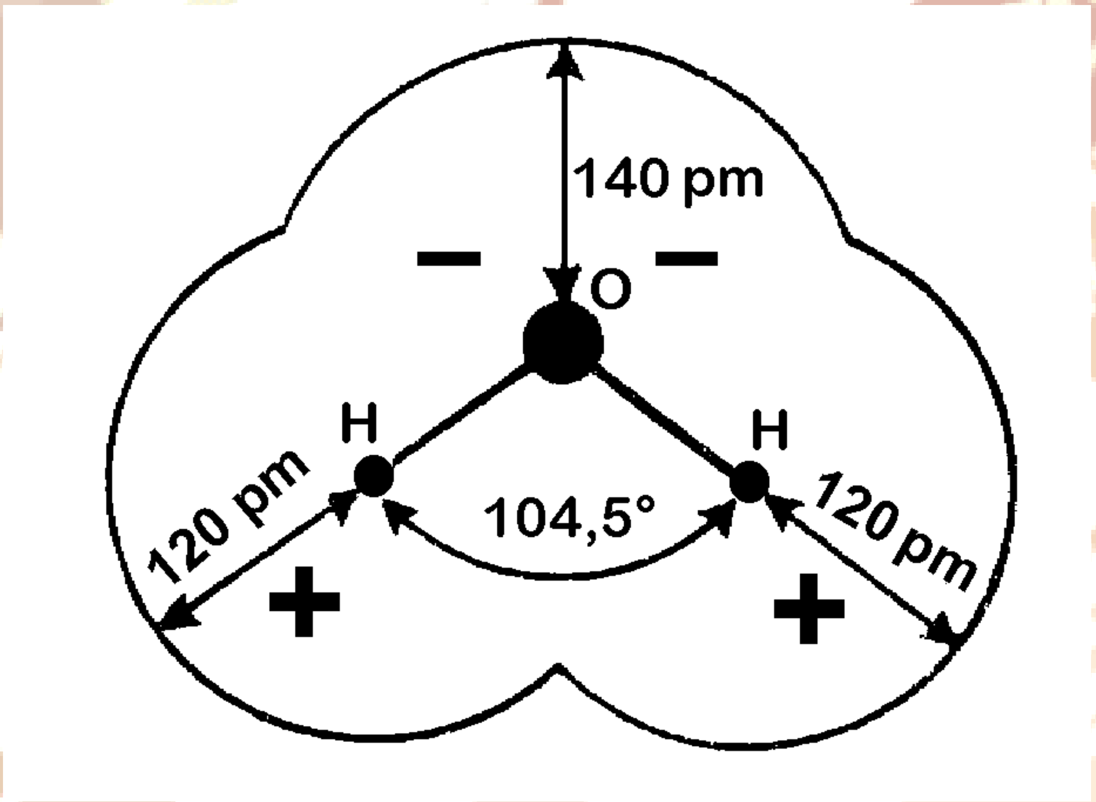
Structure of living matter

Lecture outline

Water
Properties of colloids
Structure of proteins
Structure of nucleic acids

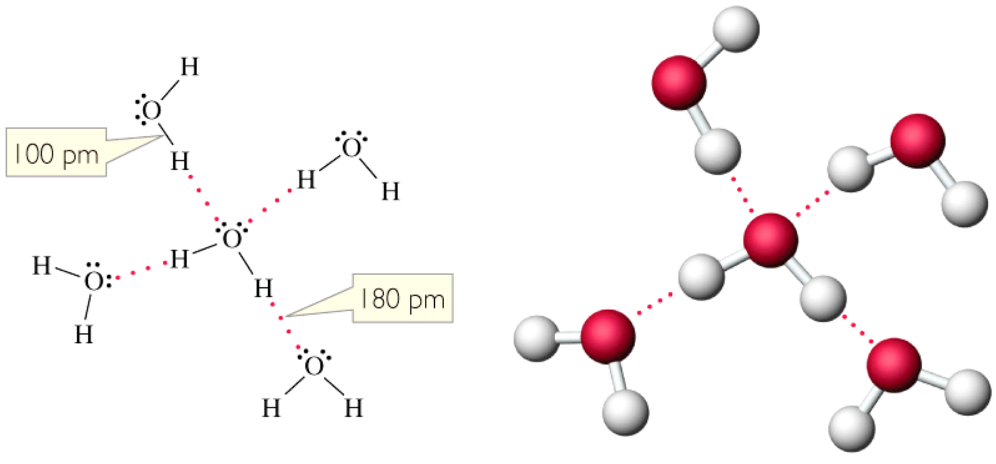
This lecture deals only with selected components of living matter with distinct biophysical properties. Importance of some electrolytes will be shown in the lecture on bioelectric phenomena. Check on further information in textbooks of biology and biochemistry.

Water



Molecules of water are strongly polar. Between the oxygen and hydrogen atoms of neighbouring molecules, **hydrogen bonds** are formed. They join water molecules in aggregates – clusters.

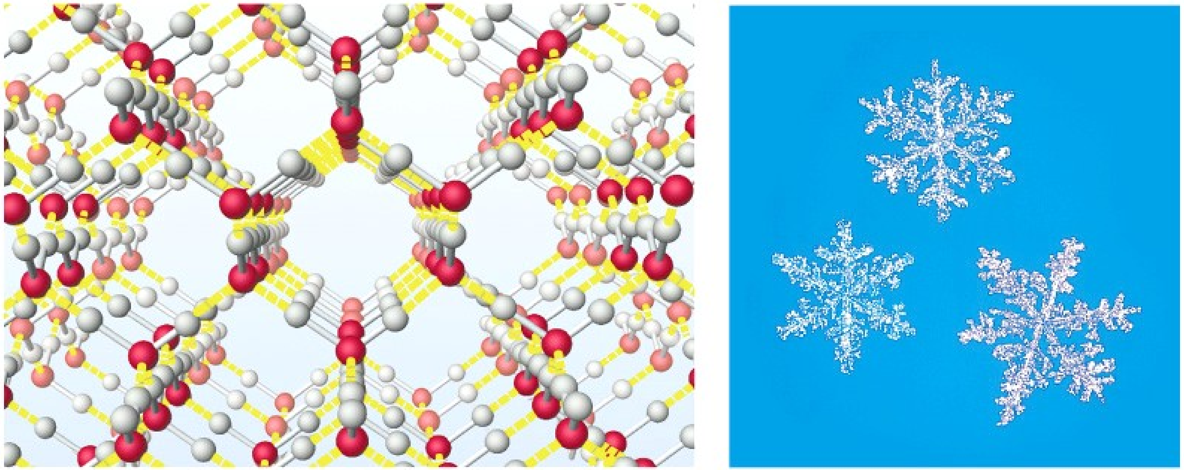
Hydrogen bonds between water molecules



(a) (b)

Liquid water

Ice


(a) (b)

Pictures: http://cwx.prenhall.com/bookbind/pubbooks/hillchem3/medialib/media_portfolio/11.html

Colloids

Colloids – also known as non-true solutions – the solution consists of solute particles of diameter about 10 – 1000 nm dispersed in the solvent.

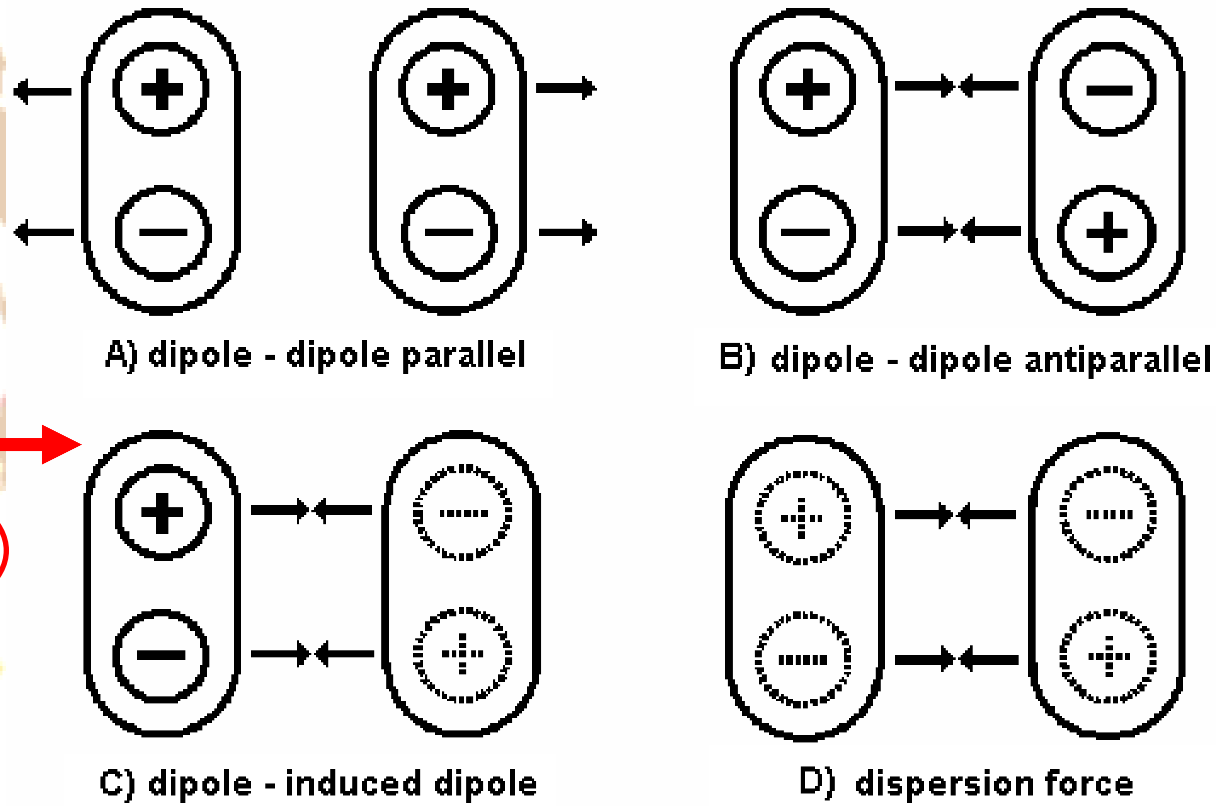
We can distinguish two types of colloids according to the type of binding forces:

- Micellar colloids (also associative, small particles are bound together by *van der Waals bonds*)

- Molecular colloids (particles are macromolecules which subunits are bound together by *covalent bonds*)

Weak chemical bonds

- Hydrogen bonds
- Hydrophobic interaction
- van der Waals bonds



Properties of colloids

Mechanical: rigidity, elasticity, viscosity – caused by covalent and weak chemical bonds

These properties depend on the form of colloid:

sol (liquid) or gel (solid). Gel formation = gelatinisation

Optical:

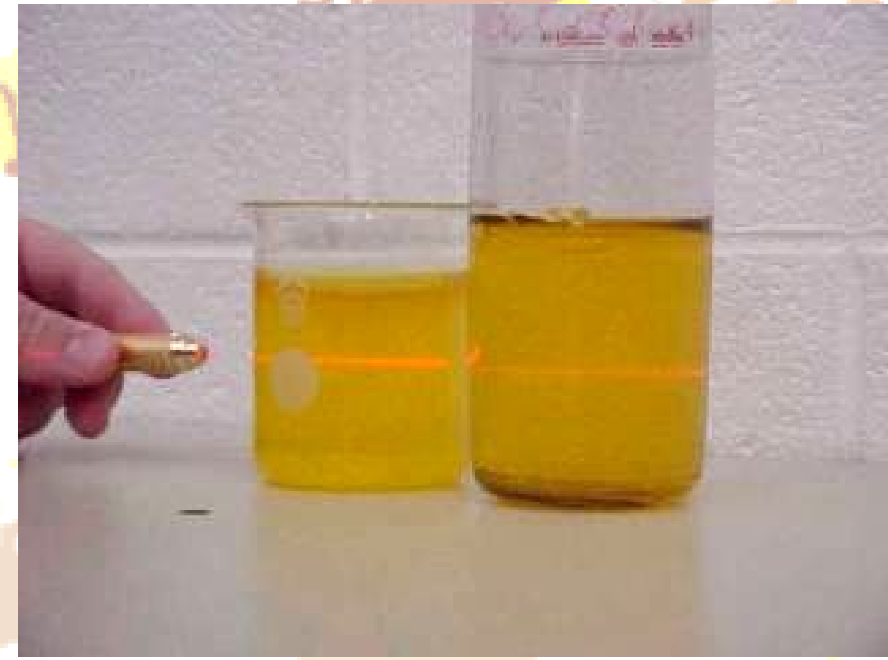
- Light scatter: Tyndall effect (opalescence). Light can be scattered off the colloid particles.
  - Track of a light beam passing through a colloid is made visible by the light scattered by the colloidal particles.
  - Ultramicroscopy – before electron microscopy it was possible to observe colloidal particles in a light microscope as points of light on a dark background (observation in dark field).
- Optical activity: Colloidal particles can rotate the plane of polarization of plane-polarised light passing through the colloid

Electrical: see lecture on instrumental methods in molecular biophysics

Tyndall effect in micellar and molecular colloids

- In solution of colloidal gold

http://mrsec.wisc.edu/edetc/cineplex/gold/



- In solution of gelatin (a protein)

http://link.springer-ny.com/link/service/journals/00897/papers/0006002/620095mb.htm

Types of Colloids - Biopolymers

- According to the affinity of the biopolymer to solvent (water)
  - Lyophilic (hydrophilic) - form stable solutions
  - Lyophobic (hydrophobic) - form unstable solutions
- According to the shape of the biopolymer (the shape is also influenced by the solvent!)
  - Linear (fibrillar – DNA, myosin, synthetic polymers…..also scleroproteins, mostly insoluble in pure water)
  - Spherical (globular – haemoglobin, glycogen … also spheroproteins, mostly soluble in pure water)

Chemical composition of proteins

According to the products of hydrolysis:

- simple (only amino acids in hydrolysate)
- conjugated (not only amino acids in hydrolysate)
    - Nucleoproteins
    - Haemoproteins
    - Flavoproteins
    - Metalloproteins
    - Lipoproteins

Structure of proteins

- Structural units of proteins are amino acids (AA), connected by peptide bond:

$$-RCH-NH-CO-RCH-,$$

which can hydrolyse:

$$-RCH-NH-CO-RCH- + H_2O \longleftrightarrow -RCH-NH_2 + HOOC-RCH-$$

- The carboxylic and amino groups can dissociate or protonise. E.g. the glutamic and asparagic acids have one free carboxylic group:

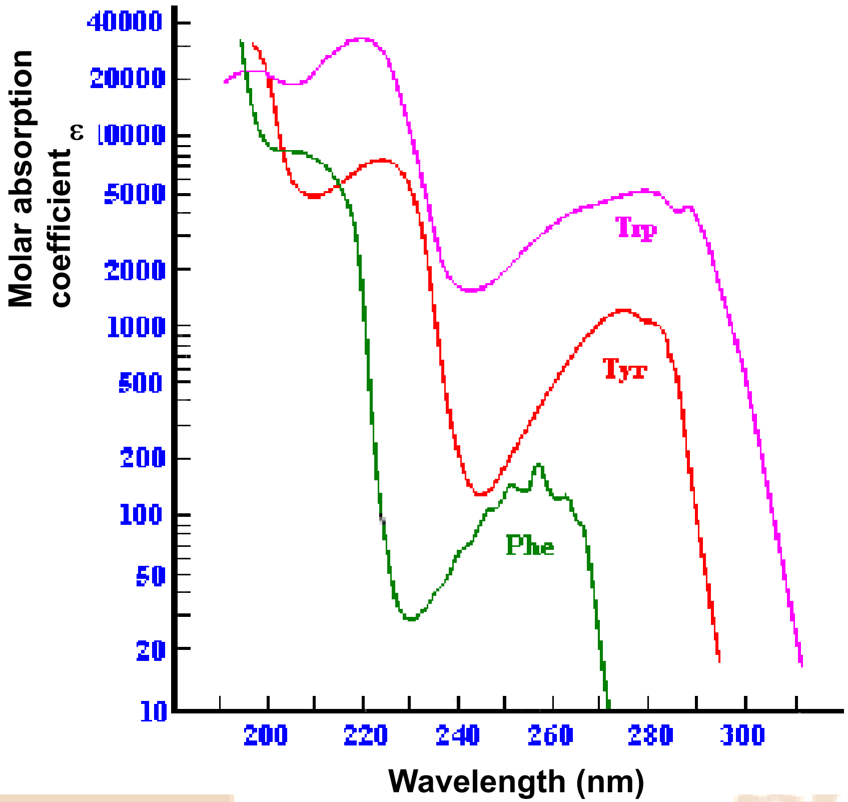
$$-COOH \longleftrightarrow -COO^- + H^+$$

- AA lysine and arginine have one free amino group, which can protonise:

$$-NH_2 + H^+ \longleftrightarrow -NH_3^+$$

- In proteins, 20 different AA can be found which can be divided into AA with polar and non-polar side chain.
- AA with aromatic ring or heterocycle (phenylalanine, tyrosine, tryptophan) strongly absorb UV light around 280 nm.
- AA cysteine contains sulphhydryl group (-SH), which is oxidised by dehydrogenation and connected with dehydrogenated group of another cysteine residue by covalent disulphidic bridge (bond -S-S-).

Structure of proteins

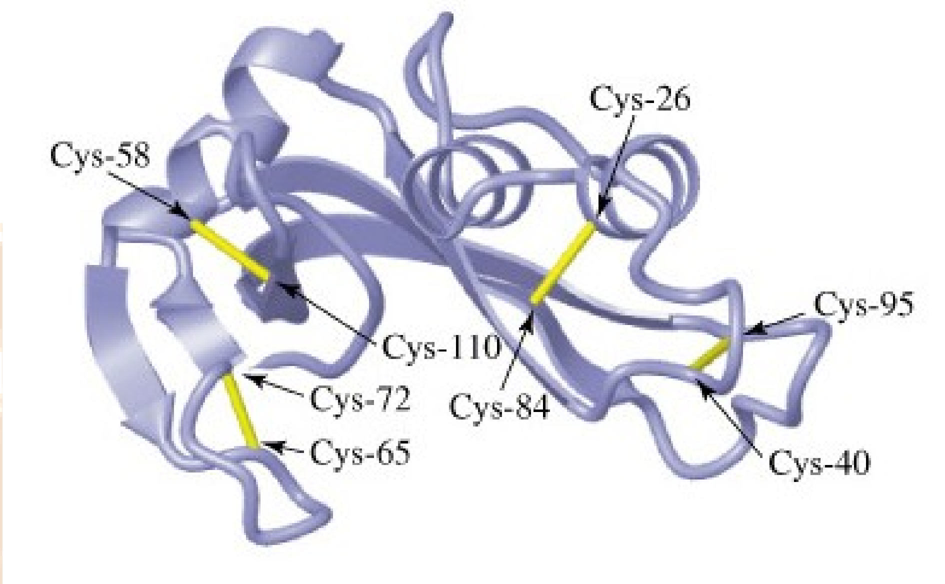


Absorption spectrum of free phenylalanine, tyrosine and tryptophan in UV range

- According:http://www.fst.rdg.ac.uk/courses/fs460/lecture6/lecture6.htm

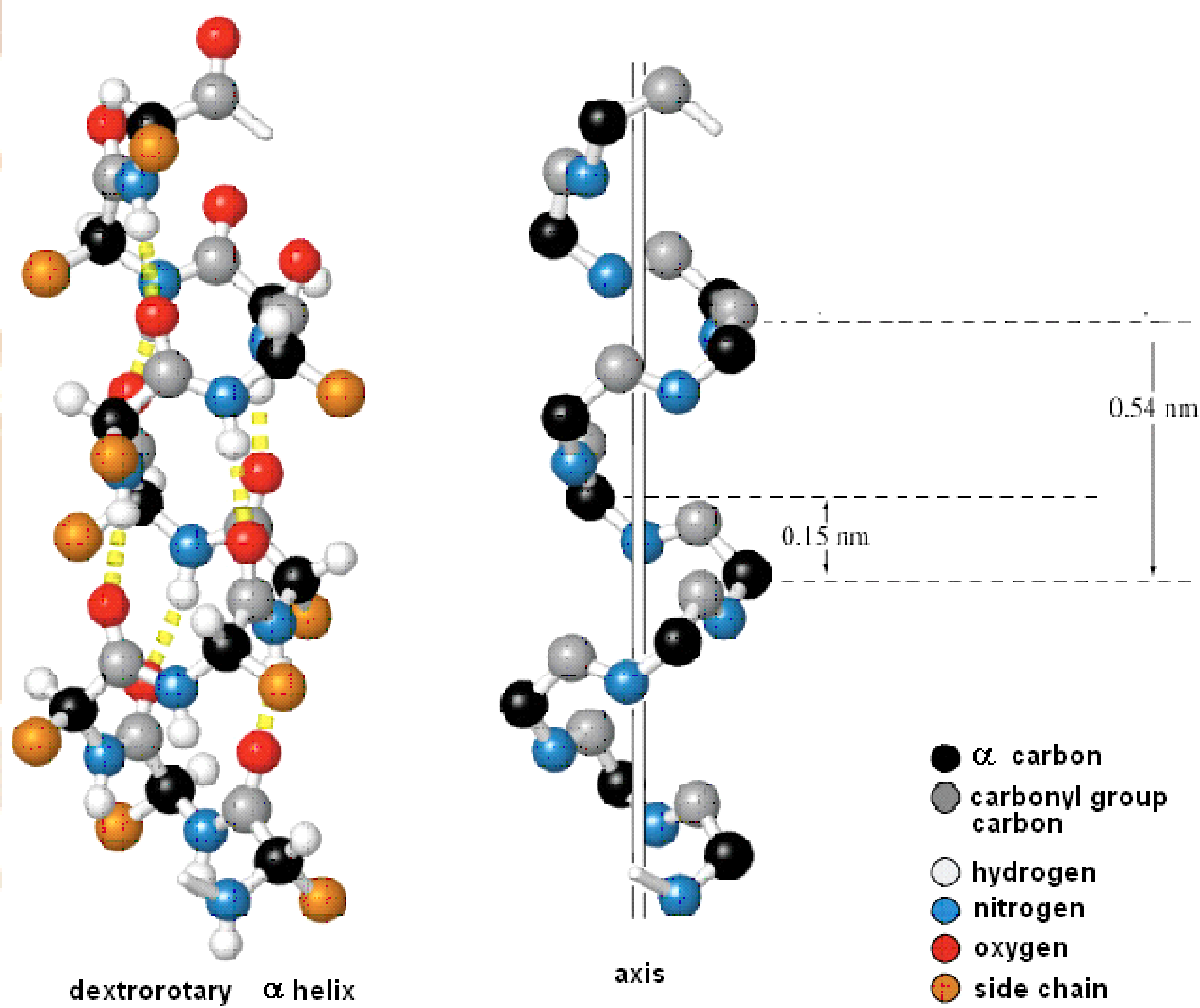
Disulphidic bridges stabilise the protein structure (bovine ribonuclease A)

- http://cwx.prenhall.com/horton/medialib/media_portfolio/text_images/FG04_28a-b.JPG



Structure of proteins

- **Primary** (sequence of covalently bound AA residues)
- **Secondary** (mutual spatial arrangement of neighbouring links of the polypeptide chain – given mainly by hydrogen bonds)
  - α-helix
  - β-structure (pleated sheet)
  - other
- **Tertiary** (spatial arrangement of the polypeptide chain as a whole – given by hydrophobic and hydrogen bonds, stabilised by -S-S- bridges)
- **Quaternary** (a way of non-covalent association of individual polypeptide chains (subunits) in whole of higher order)
  - Homogeneous – all subunits are identical
  - Heterogeneous – subunits of two or more kinds



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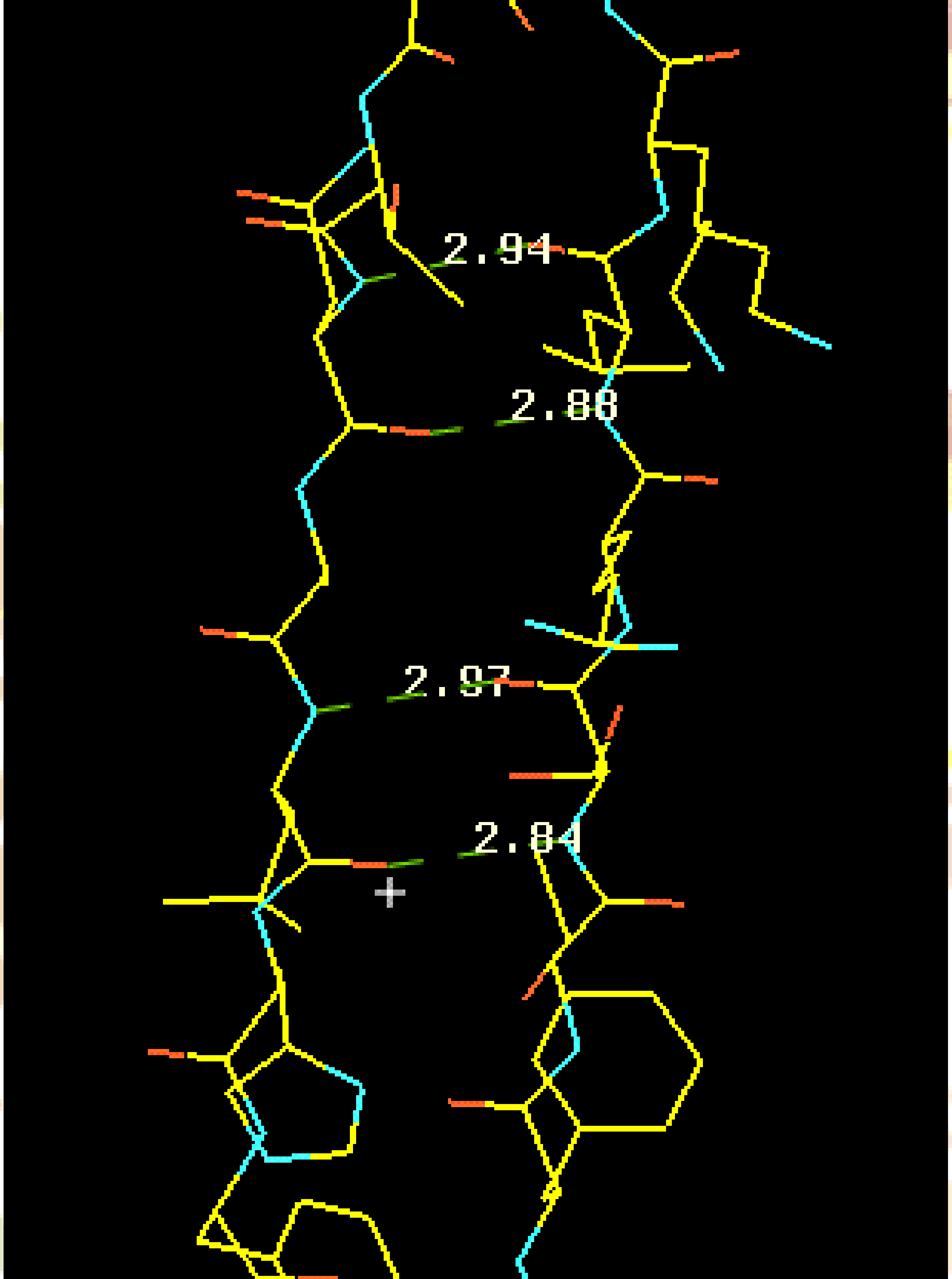
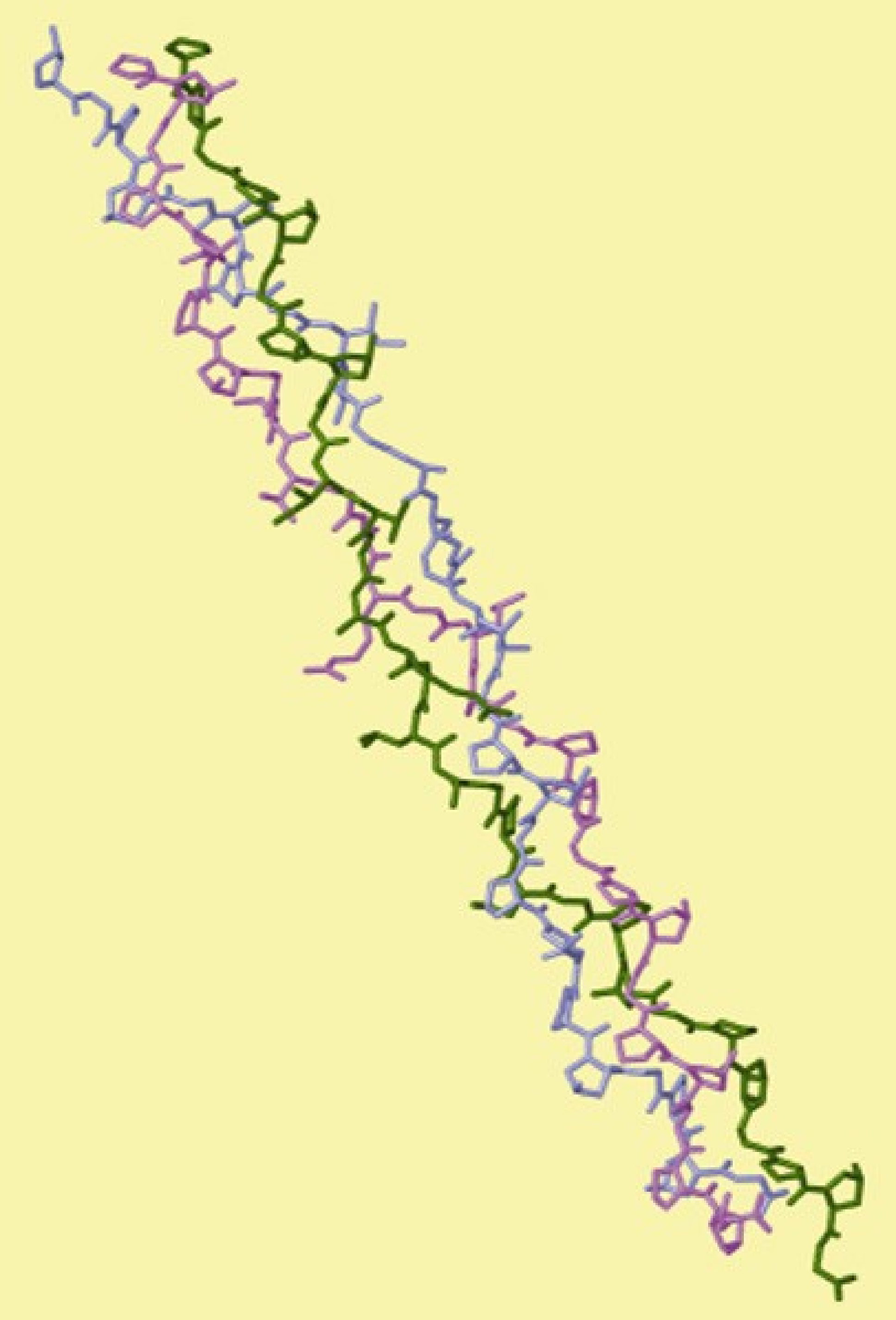


β-structure (pleated sheet – antiparallel model)

http://www-structure.llnl.gov/Xray/tutorial/protein_structure.htm



Triple helix of collagen

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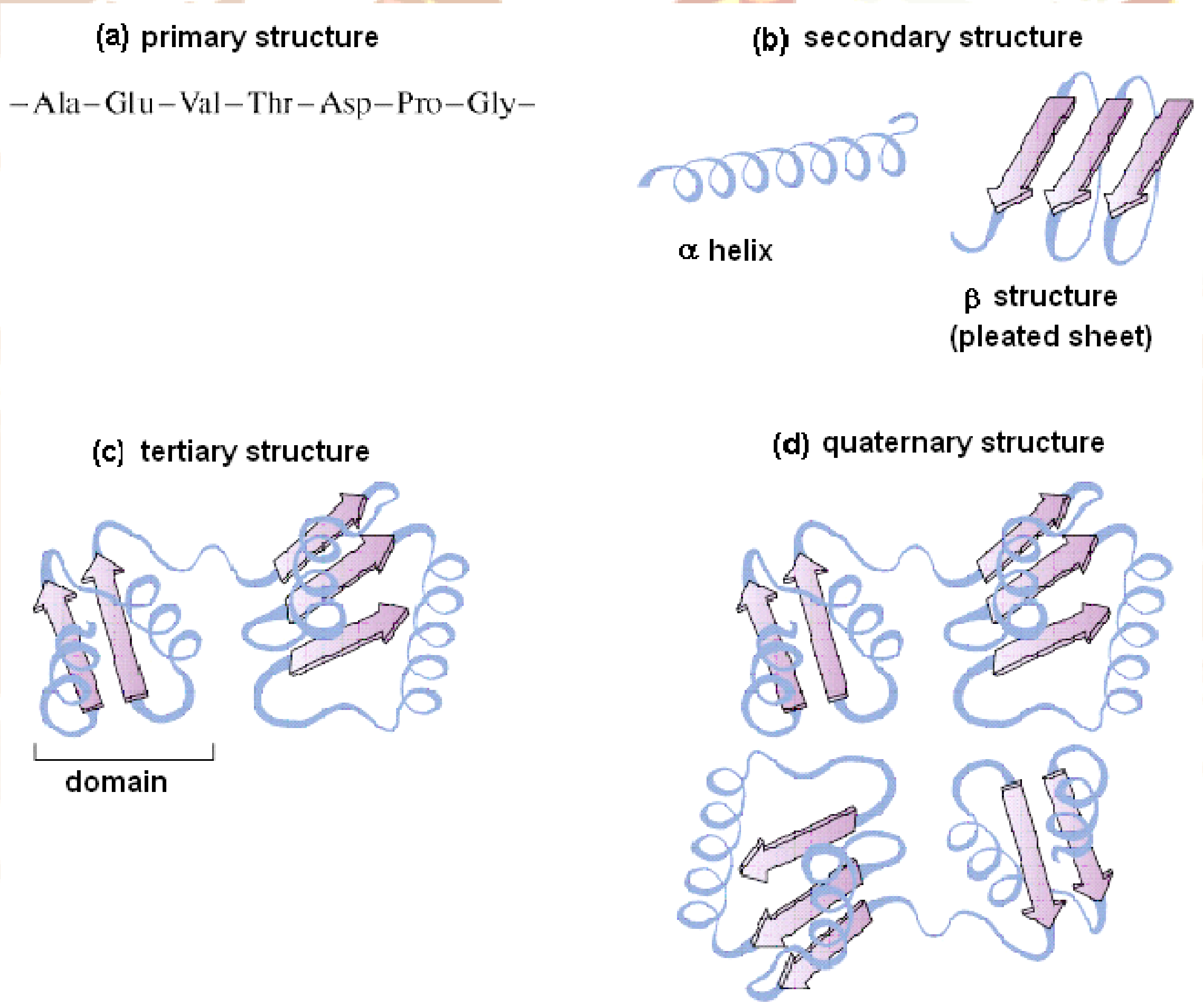
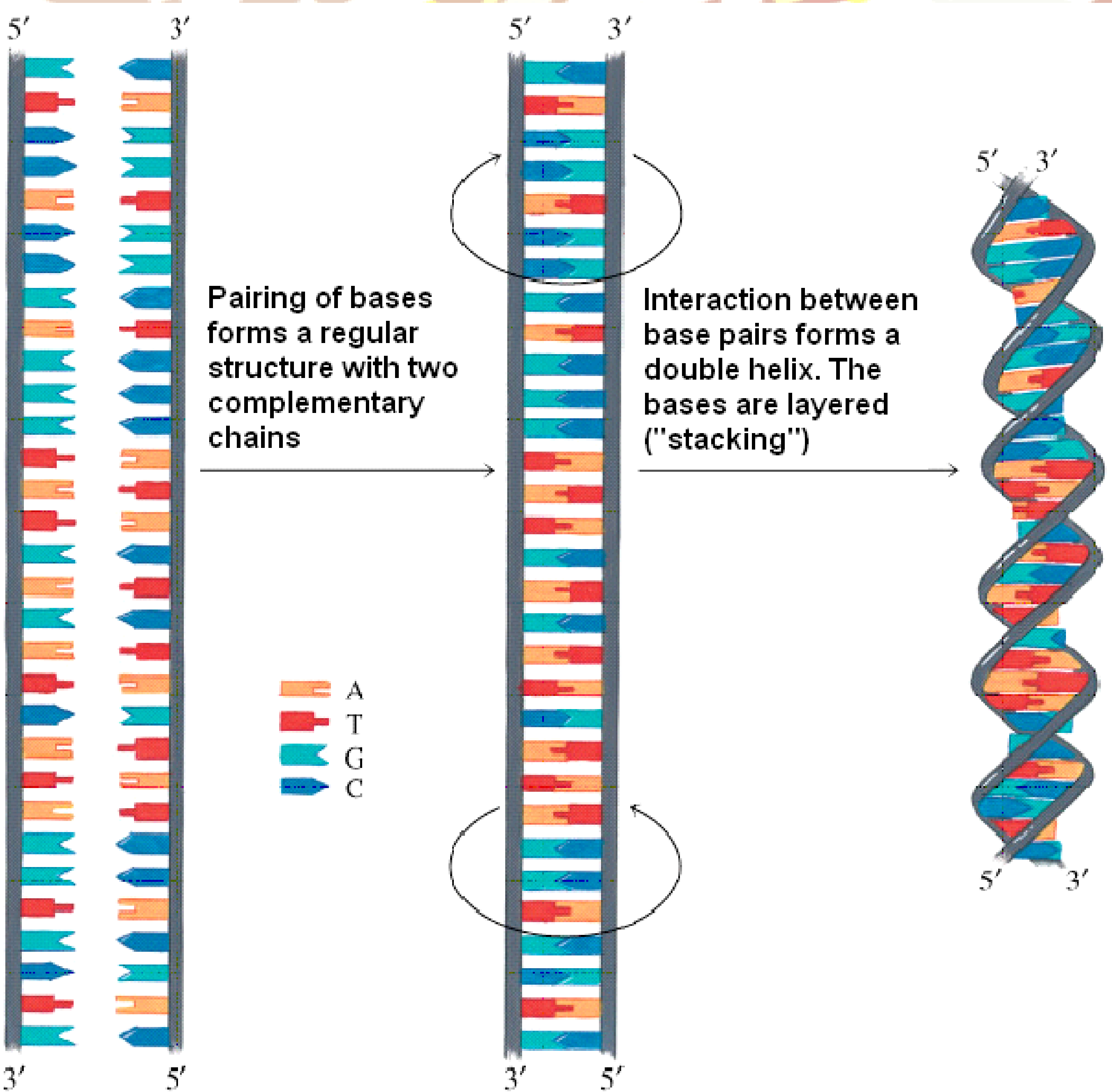


•Podle: http://cwx.prenhall.com/horton/medialib/media_portfolio/text_images/FG04_01.JPG

Structure of nucleic acids (NA)

- Mononucleotide (the structural subunit of NA) is formed by:
  - Pyrimidine (C, U, T) or purine (A, G) nitrogen base
  - Sugar (ribose or deoxyribose)
  - Phosphoric acid residue

- DNA: up to hundreds thousands of subunits. M.w. 10^7 – 10^{12}. Two chains (strands) form antiparallel double helix.
- RNA:
  - m-RNA (mediator, messenger)
  - t-RNA (transfer)
  - r-RNA (ribosomal)
  - (viral RNA)



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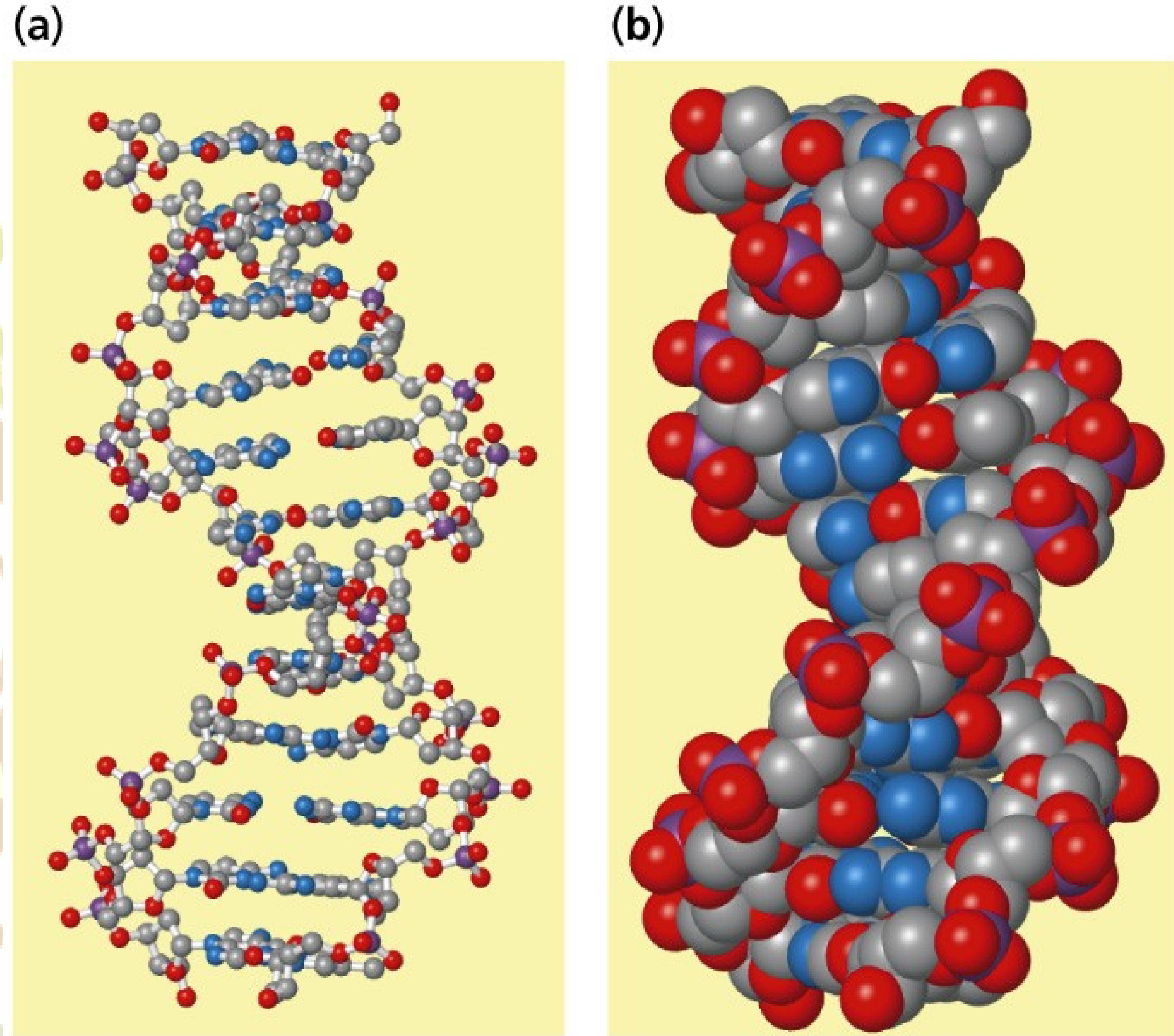

B-DNA

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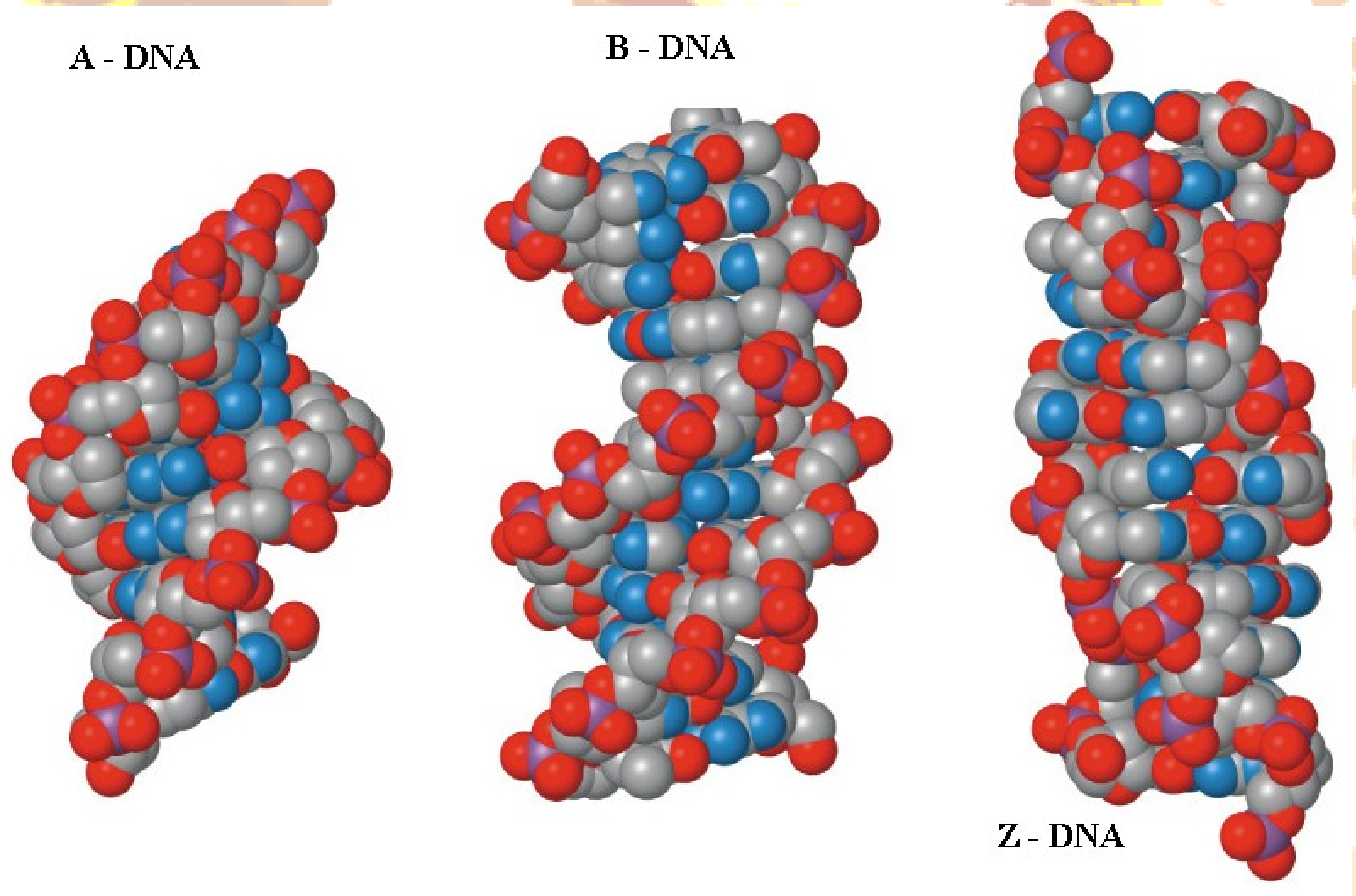
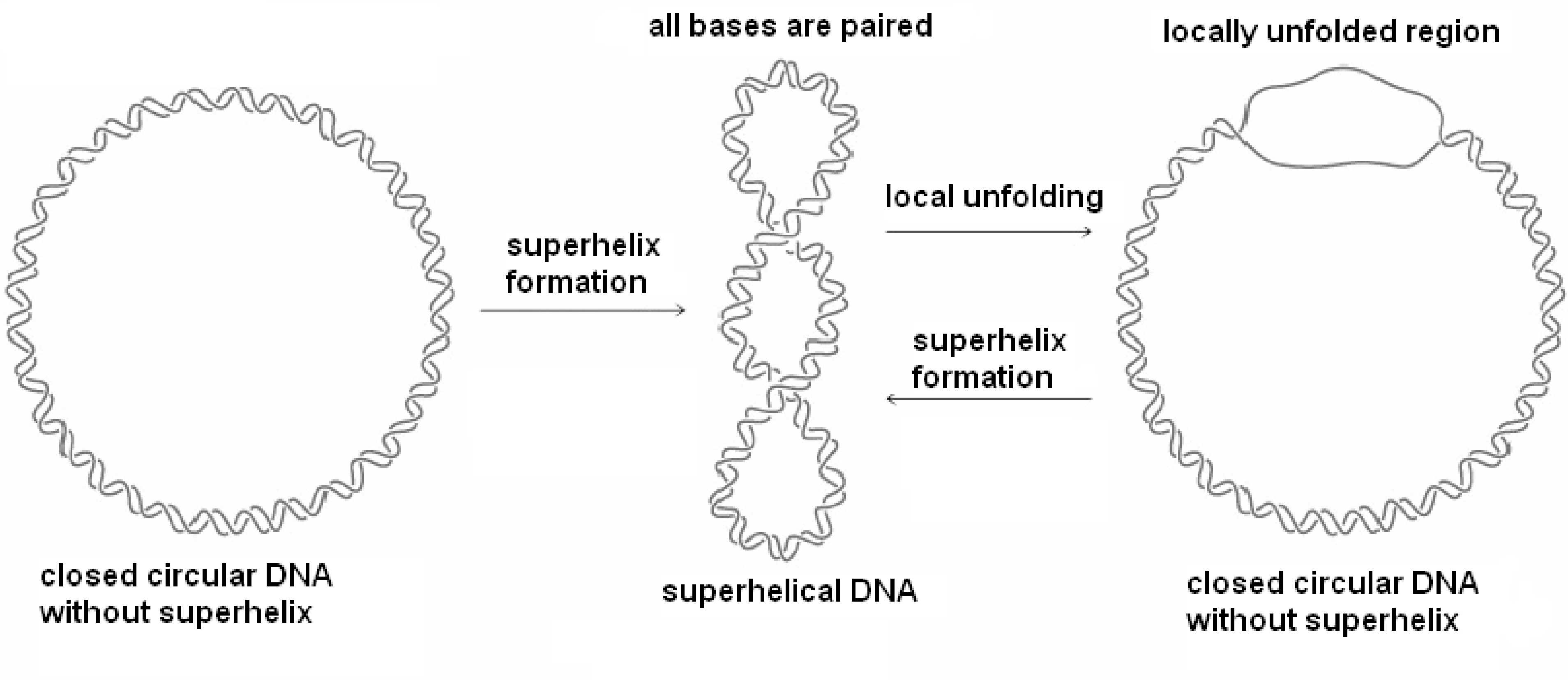
A-DNA – dehydrated, B-DNA – commonly present under physiological conditions, Z-DNA – in sequences rich on CG pairs



Superhelical structure of circular DNA



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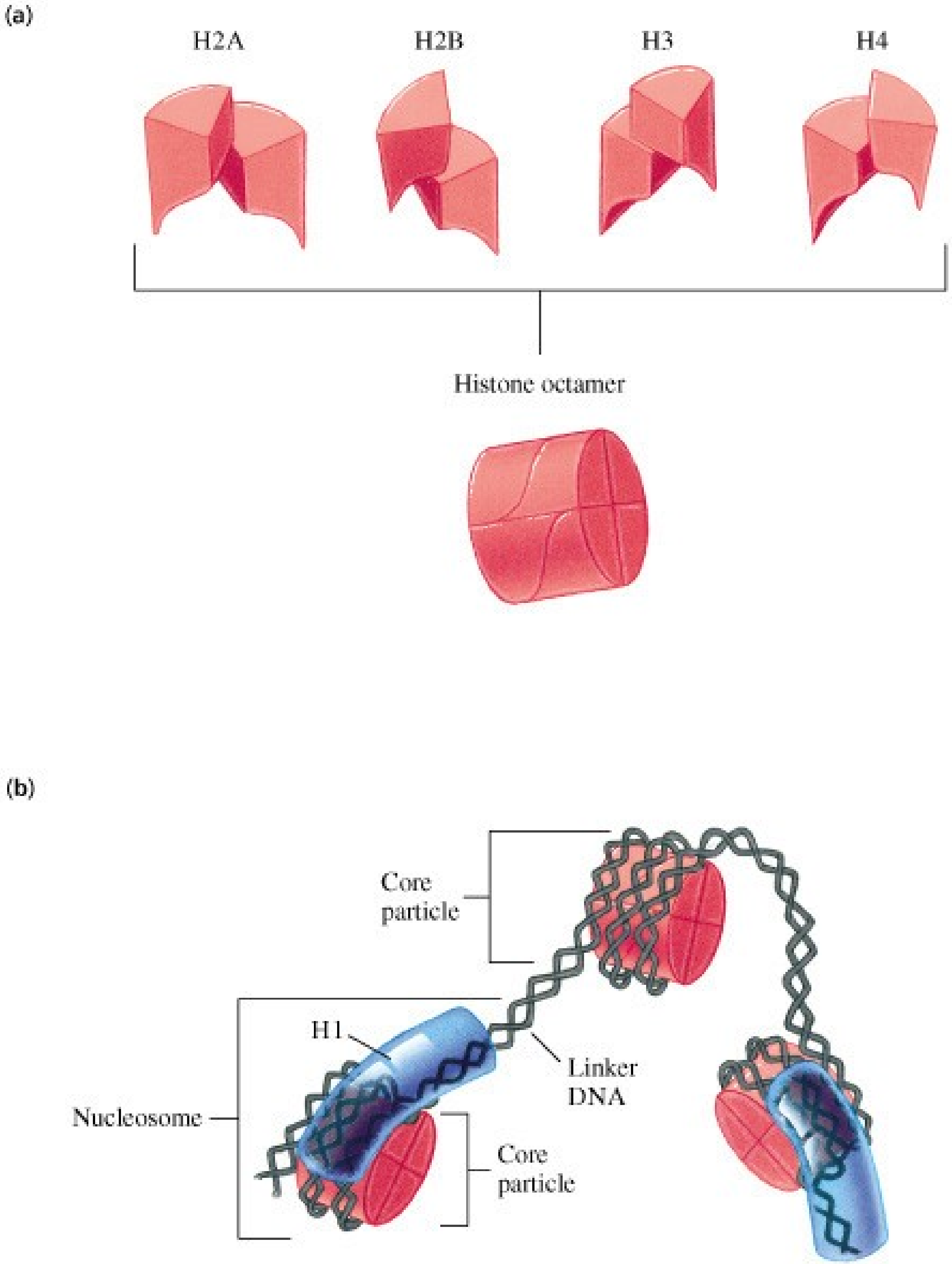

Structure of chromatin

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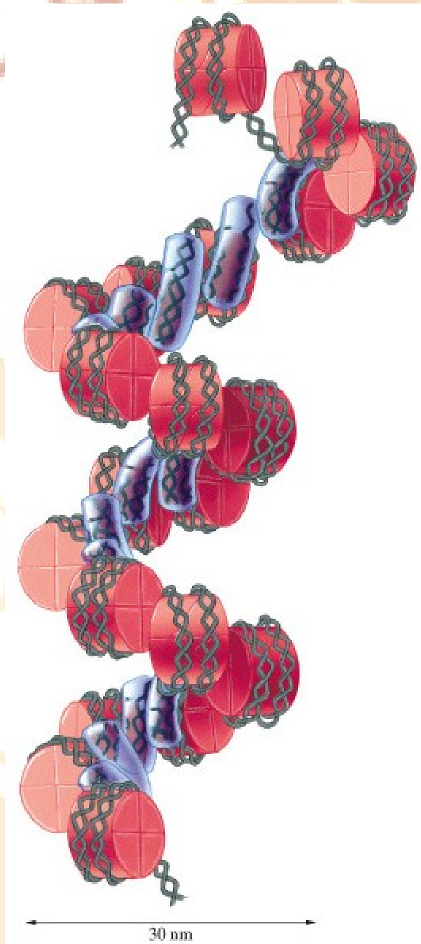
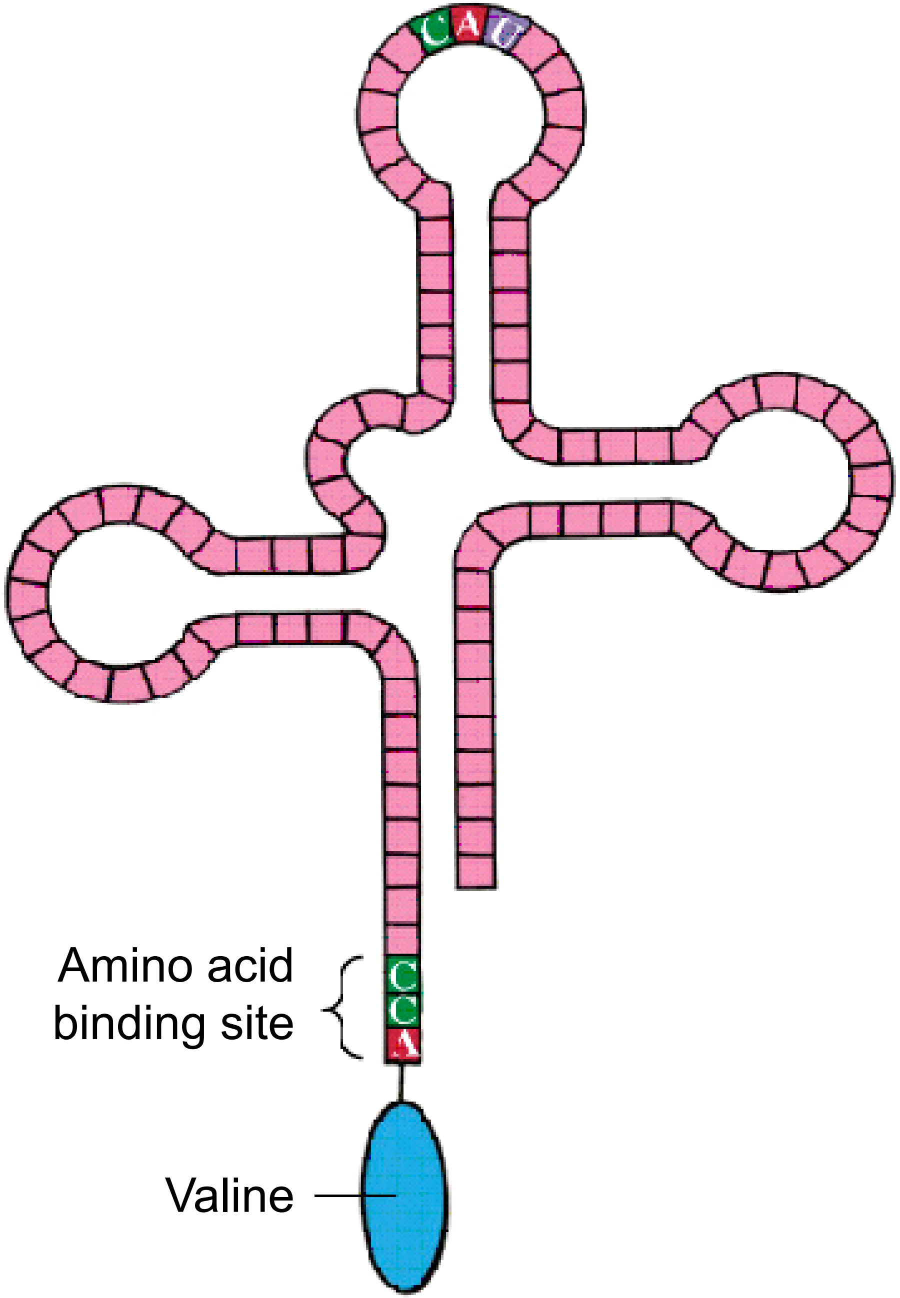
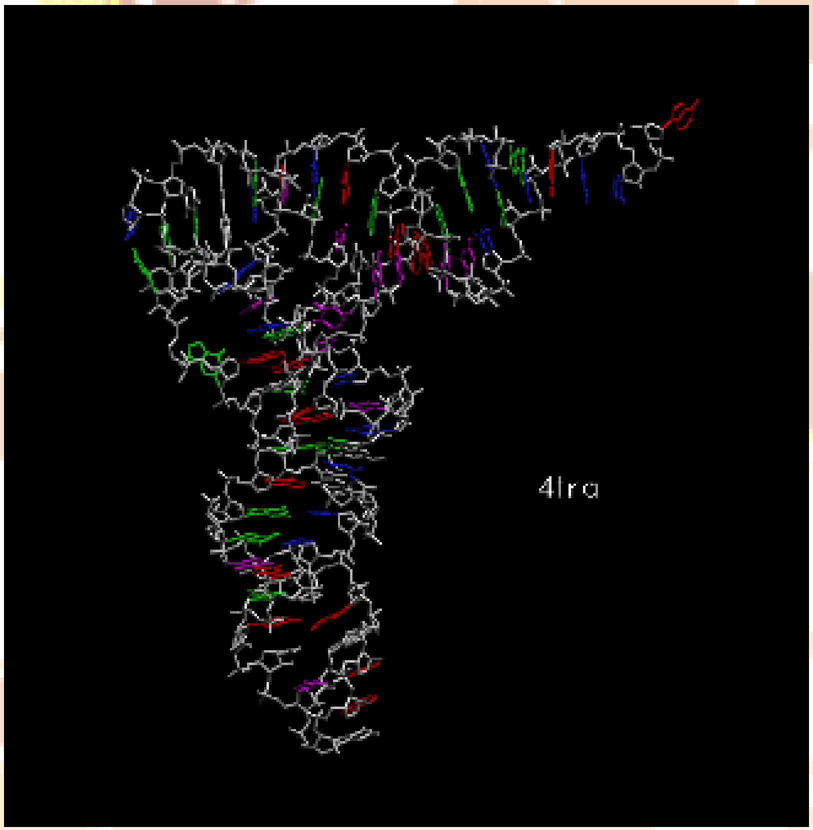
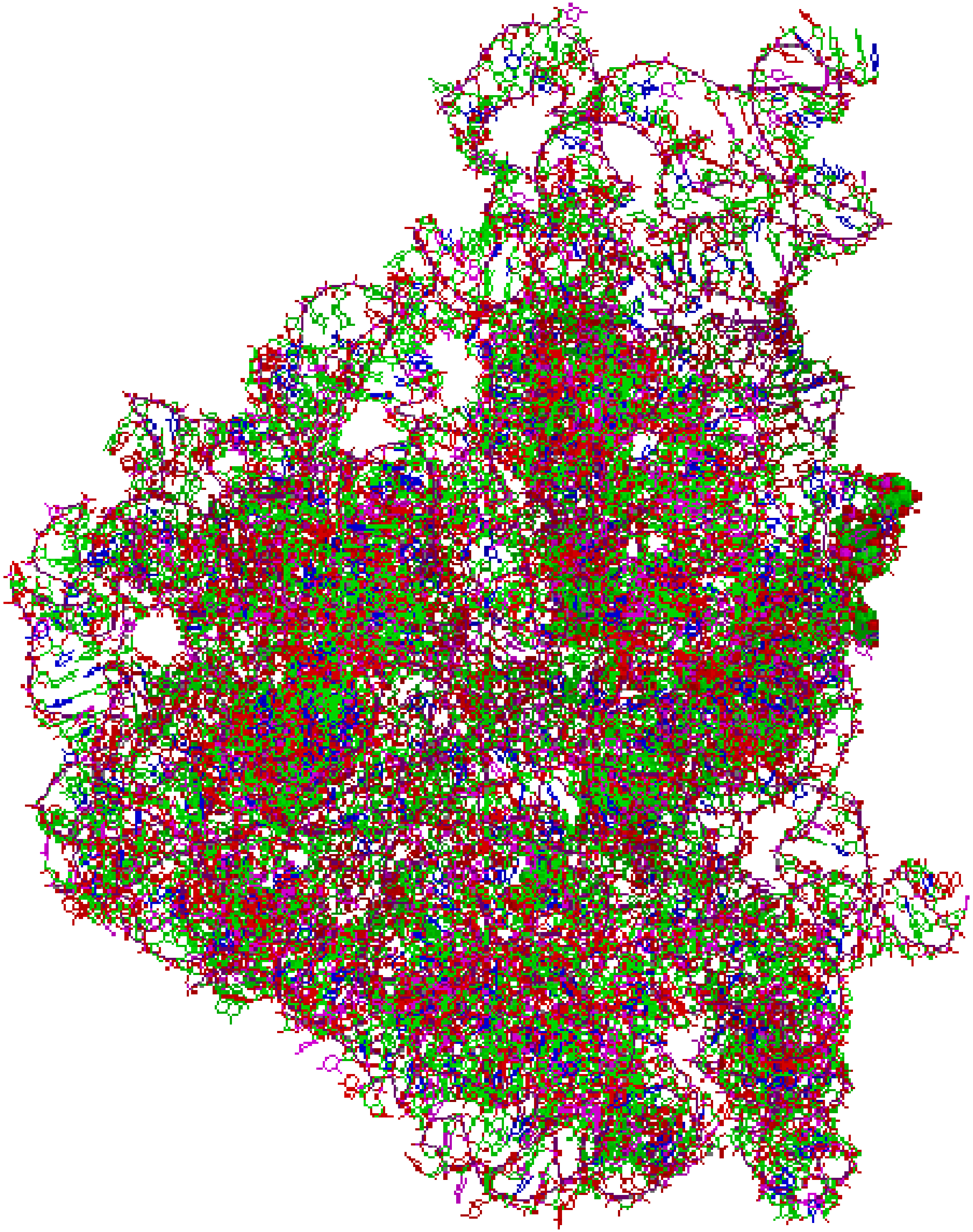




- Transfer RNA for valine – schematic
- t-RNA from yeasts ↓
- http://cwx.prenhall.com/bookbind/pubbooks/hillchem3/medialib/media_portfolio/text_images/CH23/FG23_14.JPG, http://www.imb-jena.de/cgi-bin/ImgLib.pl?CODE=4tra





Ribosomal RNA

http://www.imb-jena.de/cgi-bin/htmlit.pl?color=ffffff&id=GIF&src=1c2w.gif&name=Image%20Library%20Thumb%20Nail%201C2W

Conformation changes and denaturation of biopolymers

- Changes in secondary, tertiary and quaternary structure of biopolymers are denoted as **conformation changes**.
- They can be both reversible and irreversible.
- ‘native’ state of a biopolymer: the functional state of the biopolymers. Otherwise the biopolymer has been ‘denatured’.

Denaturation factors

- Physical:
  - Increased temperature
  - Ionising radiation
  - Ultrasound
  - …..
- Chemical:
  - Changes of pH
  - Changes in electrolyte concentration
  - Heavy metals
  - Denaturation agents destroying hydrogen bonds – urea
  - …..
- Combination of above factors: ionising radiation or ultrasound act directly and/or indirectly (chemically via free radicals)

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