



EDMI Microsystems and Microelectronics

MICRO-614: Electrochemical Nano-Bio-Sensing
and Bio/CMOS interfaces

Lecture #2 – Targets & Probes

Building Blocks of Metabolites,
Proteins, DNA and RNA

Lecture Outline

(Book Bio/CMOS: Chapter' paragraphs § 3.3-3.8)

- Metabolites
- Linkers
- Peptides
- Poly-peptides
- Proteins
- DNA

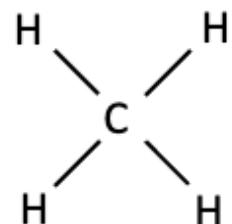


Q1

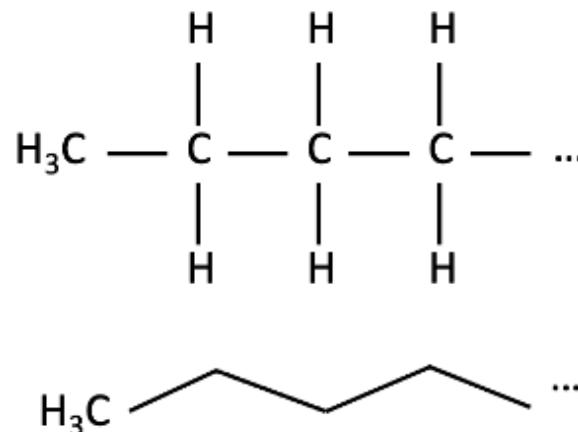
What are the Organic Molecules?

- A. I don't know
- B. All molecules related to metabolism
- C.** All molecules based on carbon
- D. All molecules based on hydrogen and oxygen
- E. Any molecular product of a biological processes

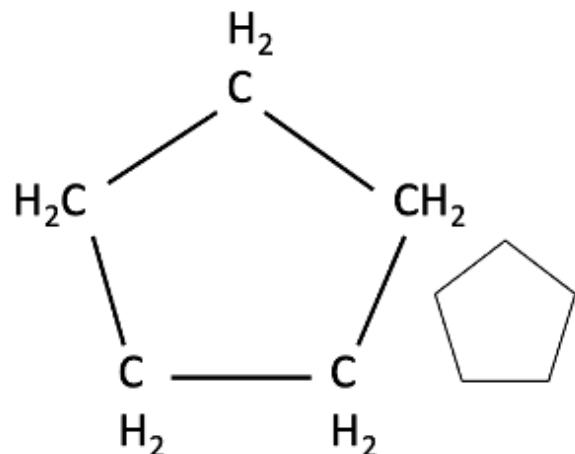
Very Simple Organic Molecules



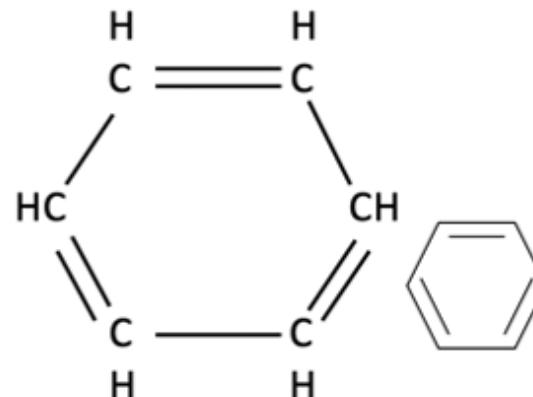
Methane: CH_4



Alkyl Chain: $(\text{CH}_2)_n$

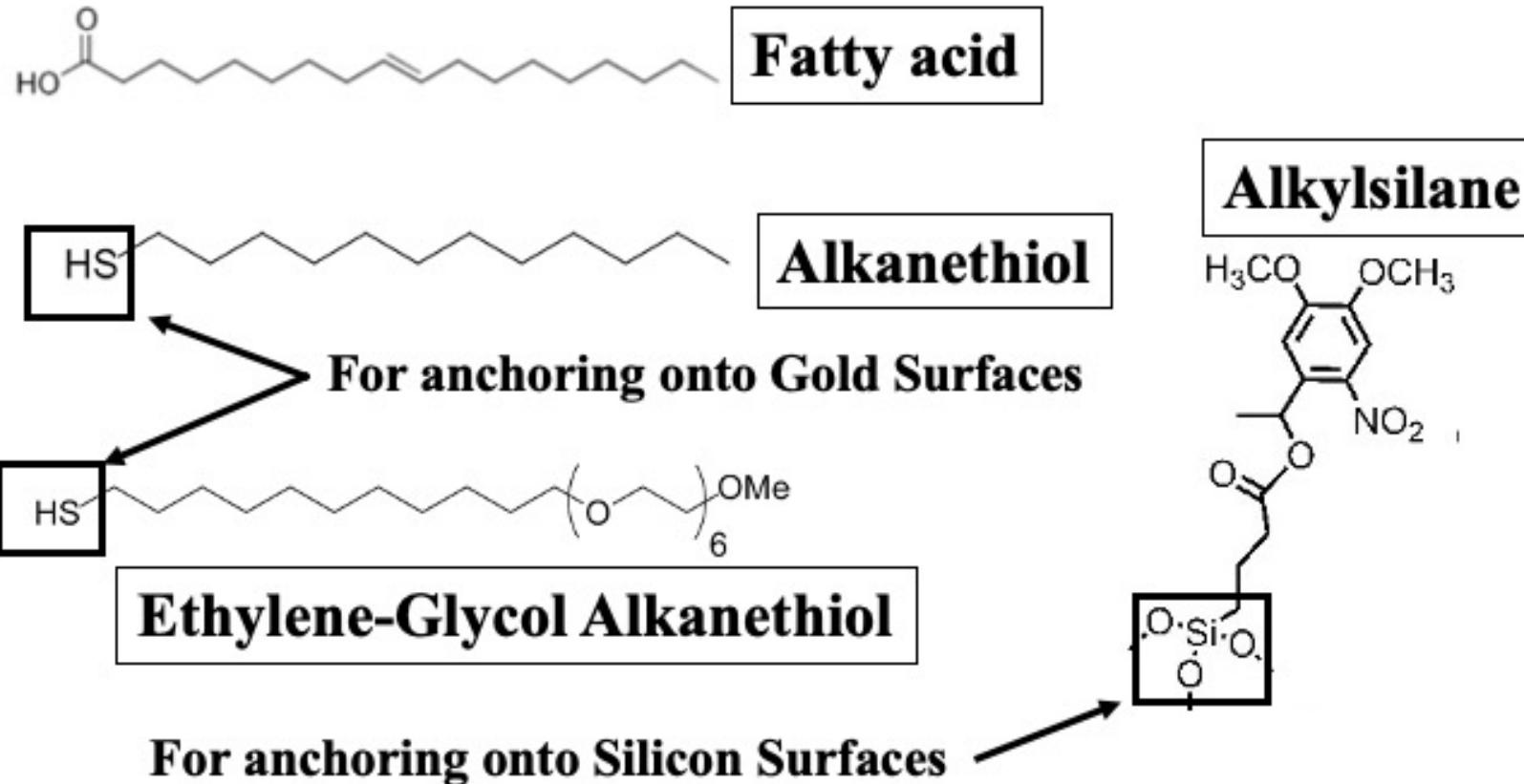


Cyclopentane: $(\text{CH}_2)_5$



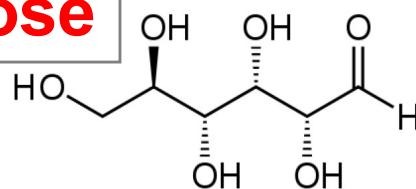
Benzene: $(\text{CH})_6$

Quite important Linkers

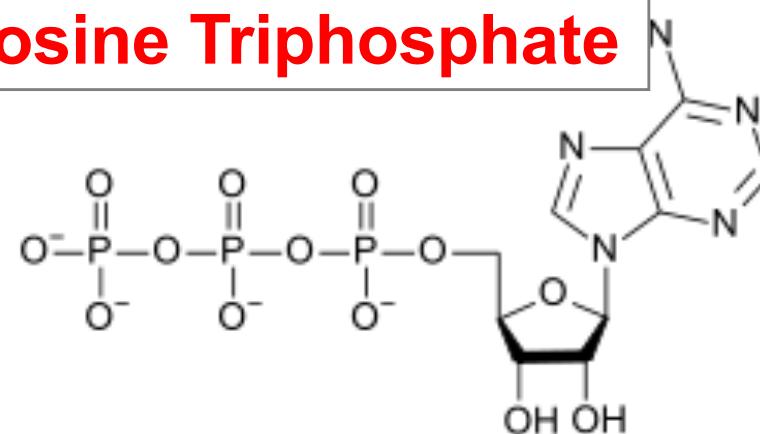


Human metabolites

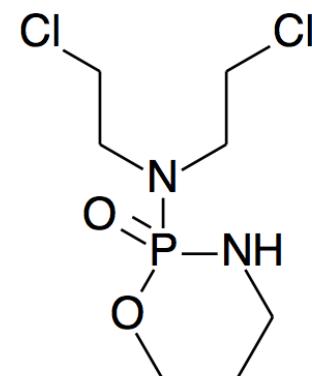
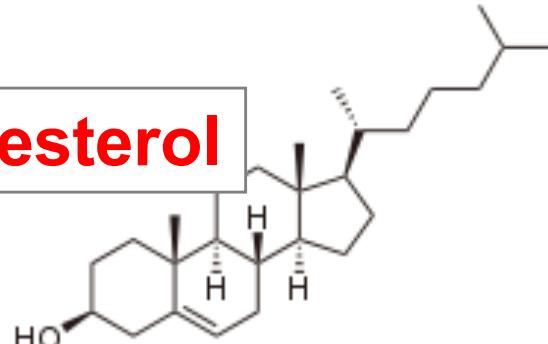
D-glucose



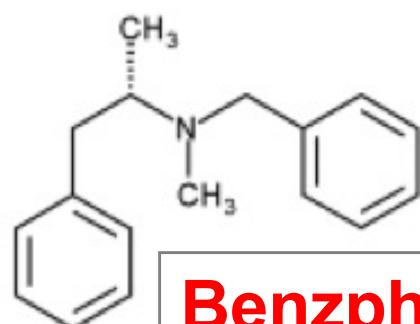
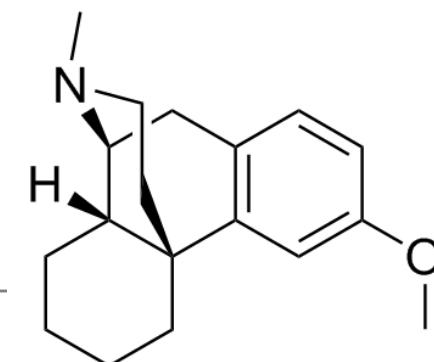
Adenosine Triphosphate



Cholesterol

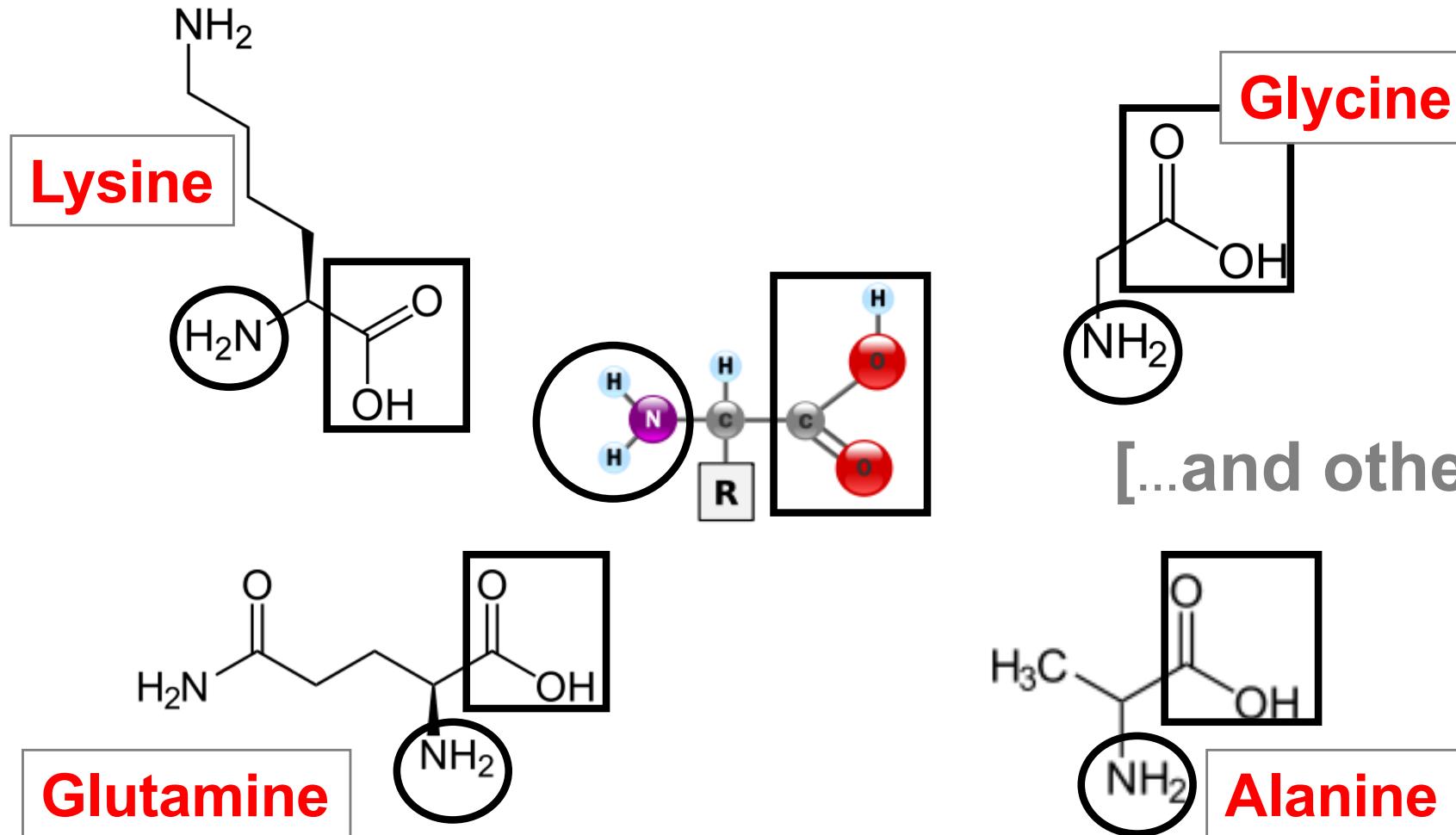


Dextromethorphan



Benzphetamine

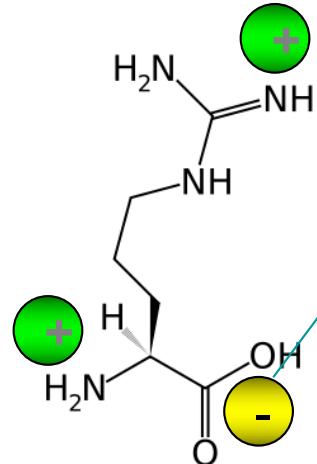
Amino Acids



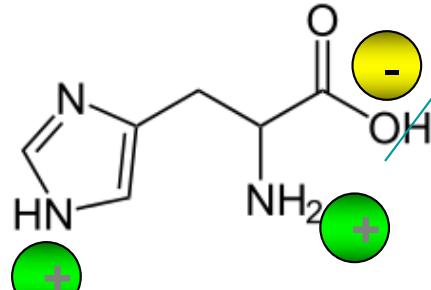
Amino acids are molecules containing an amine group (NH₂), a carboxylic acid group (COOH) and a side chain that varies between different amino acids

Charged AA

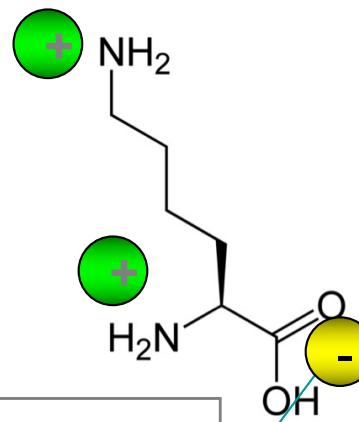
Positively Charged



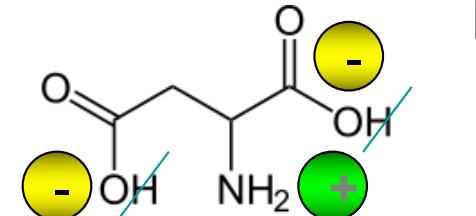
Arginine



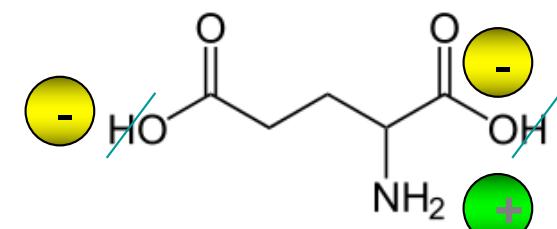
Histidine



Lysine

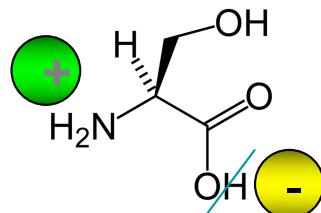


Aspartic Acid

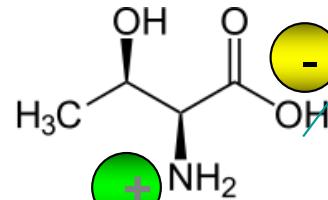


Glutamic Acid

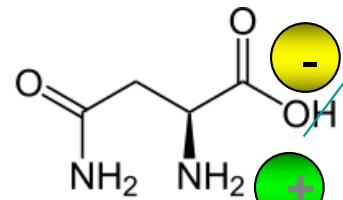
Polar Uncharged



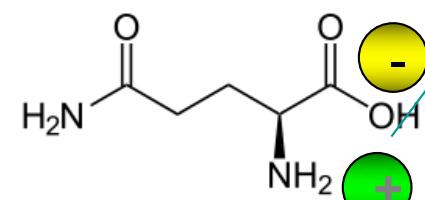
Serine



Threonine



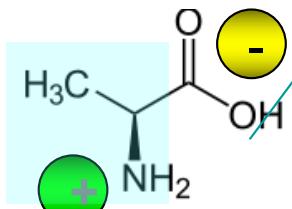
Asparagine



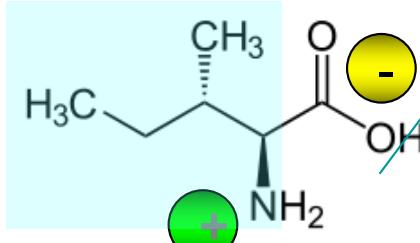
Glutamine

Hydrophobic AA

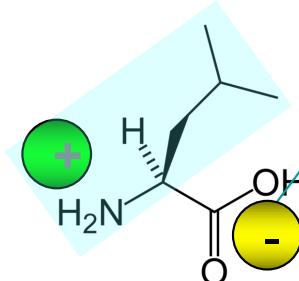
Hydrophobic Side Chains



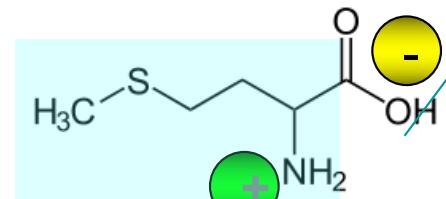
Alanine



Isoleucine



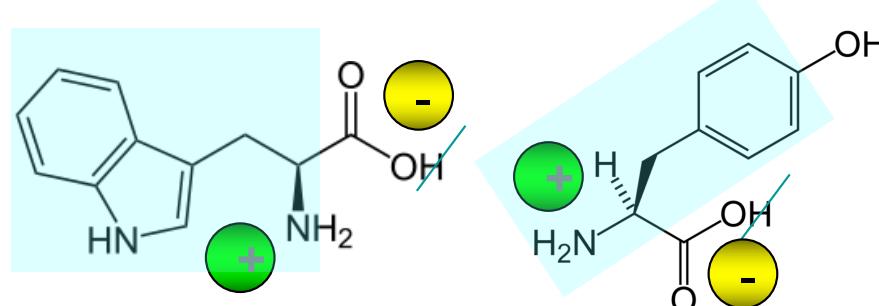
Leucine



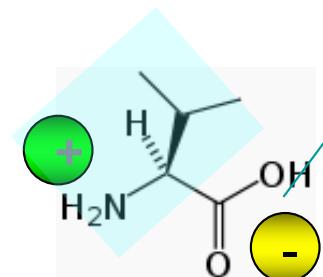
Methionine



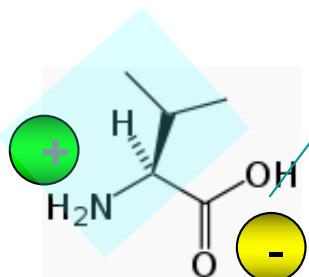
Phenylalanine



Tryptophan



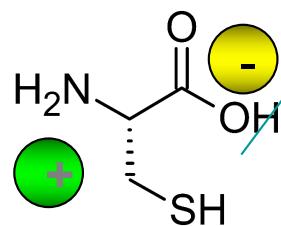
Tyrosine



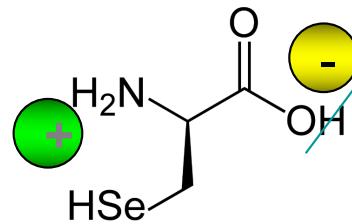
Valine

Neutral AA

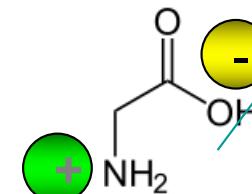
Special Cases



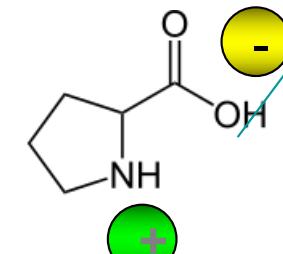
Cysteine



Selenocysteine

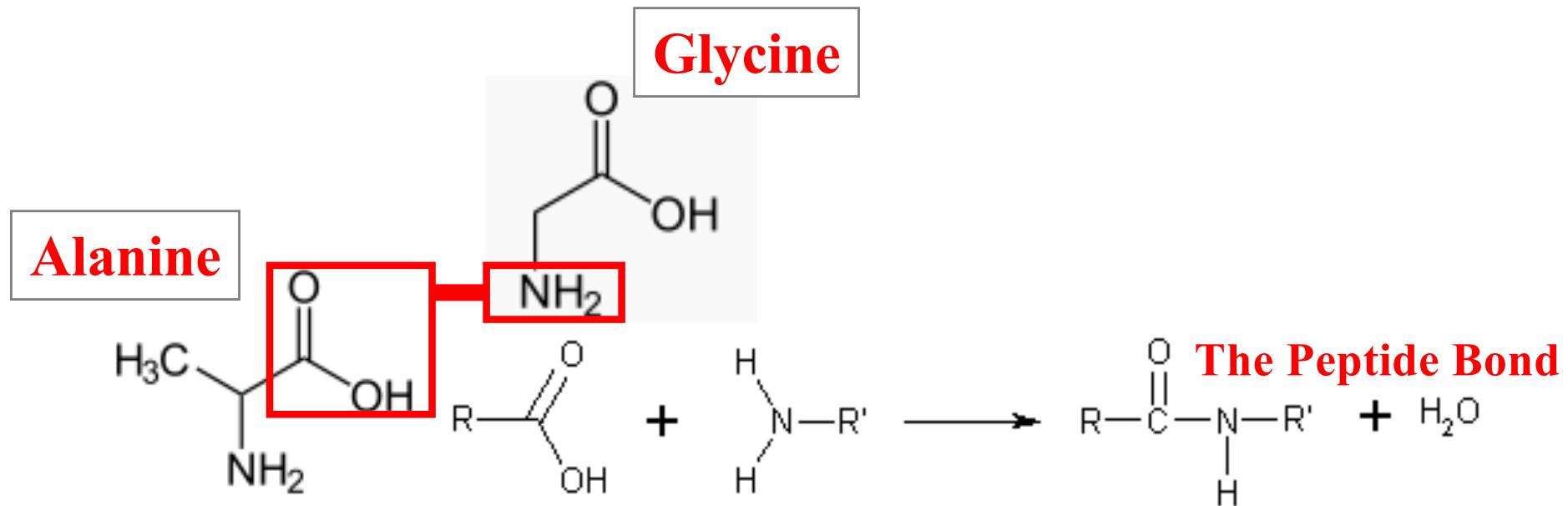


Glycine



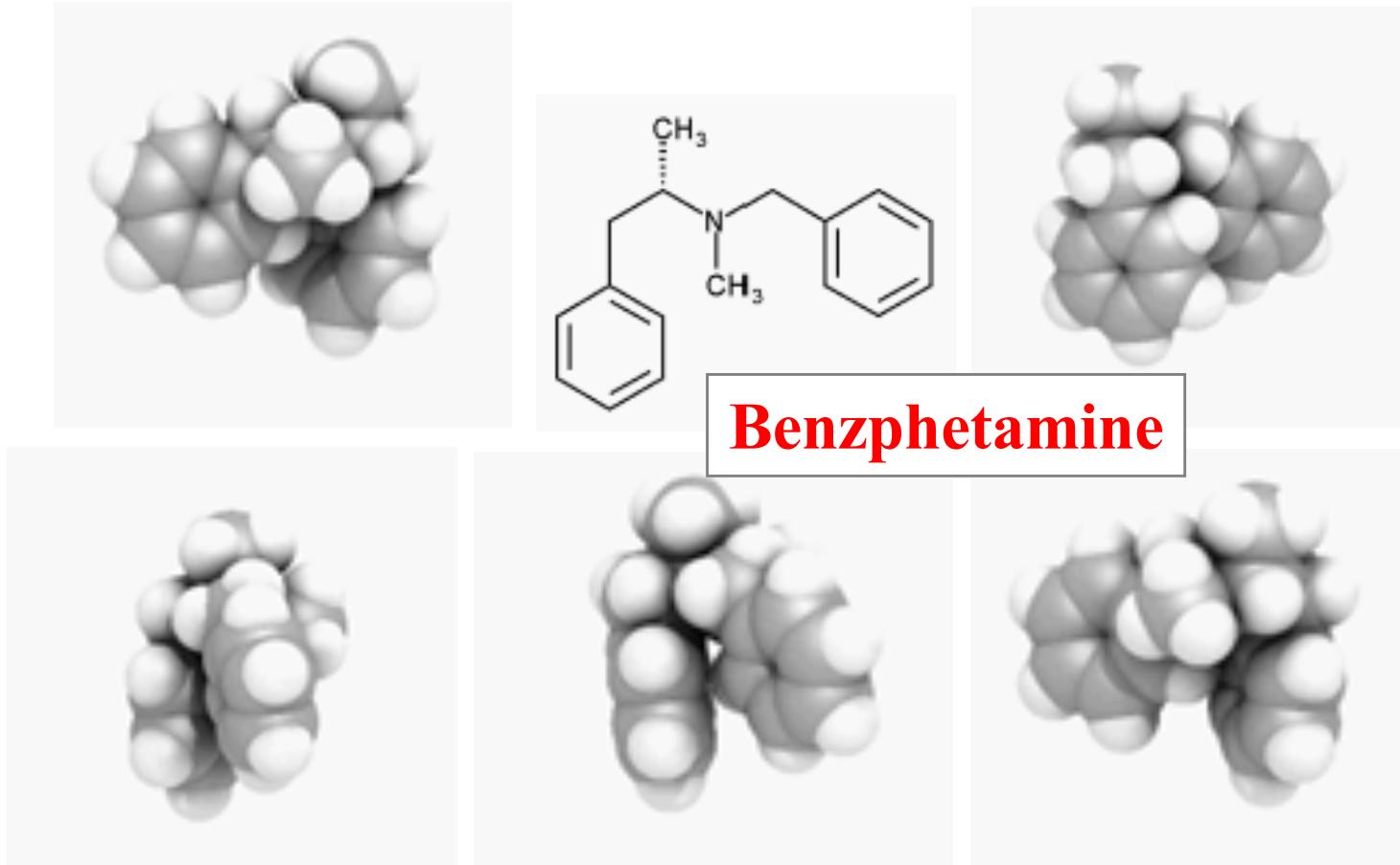
Proline

The Peptides



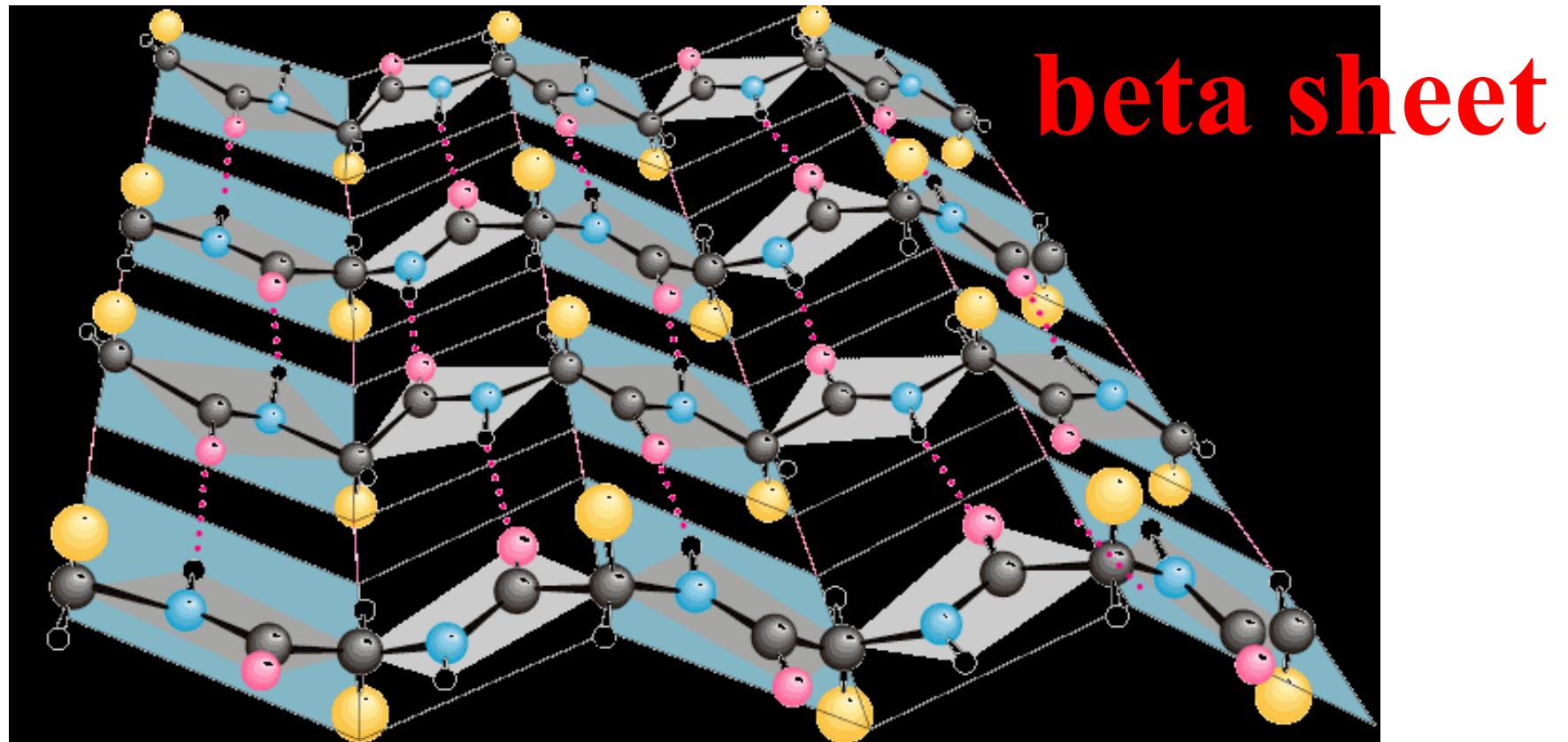
Peptides are short polymers formed by linking amino acids in a defined order

The importance of 3D Conformation



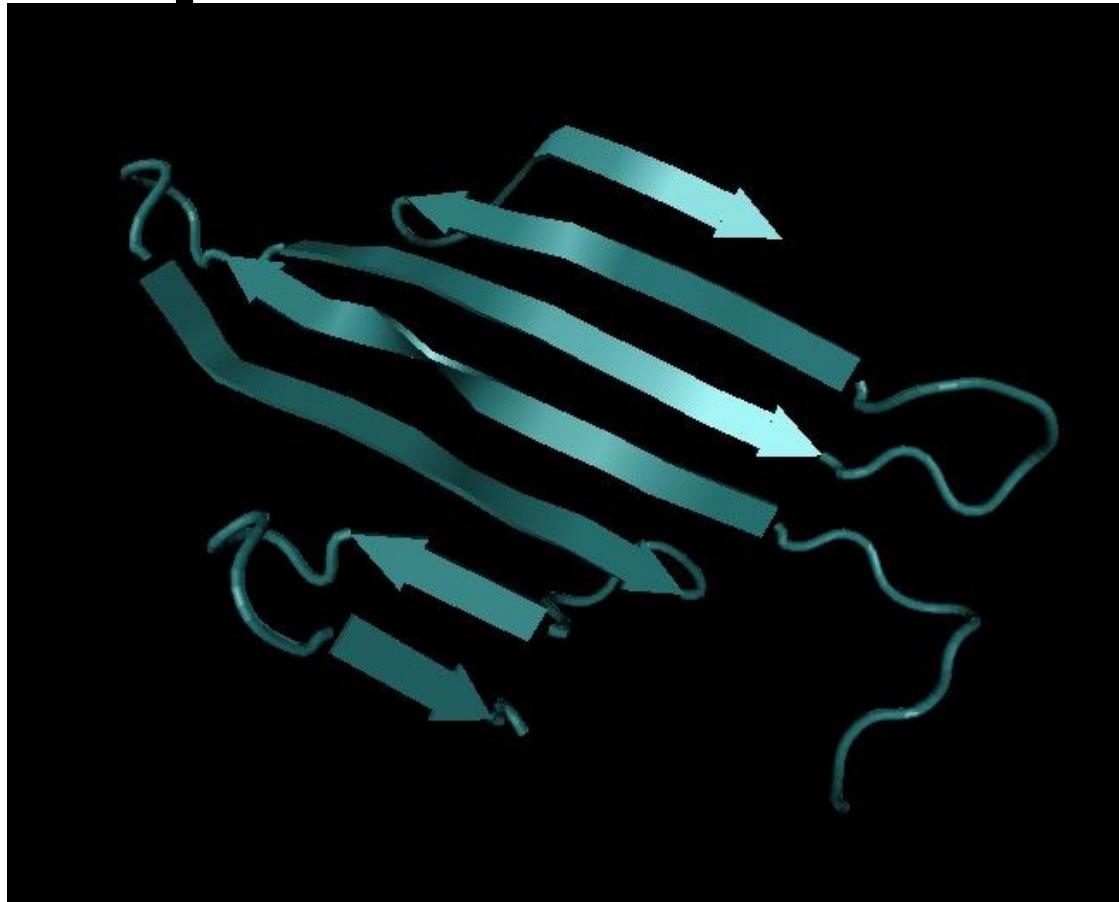
The 3D shape of a molecule may be so important for its biological function

Poly-Peptides 3D structure



Peptides are short polymers that assume particular 3D structure: e.g. the beta-sheet

Poly-Peptides 3D structure



The Beta-sheets are usually visualized as a string with a terminal arrow

Poly-Peptides 3D structure

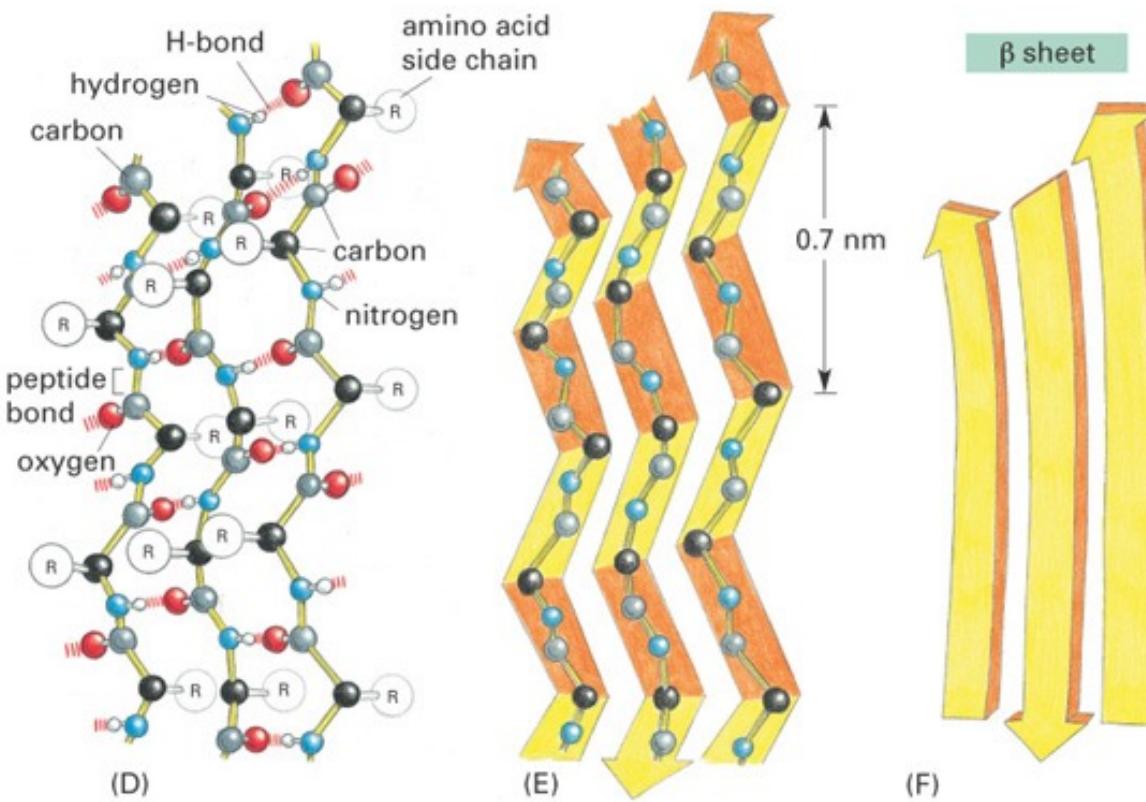
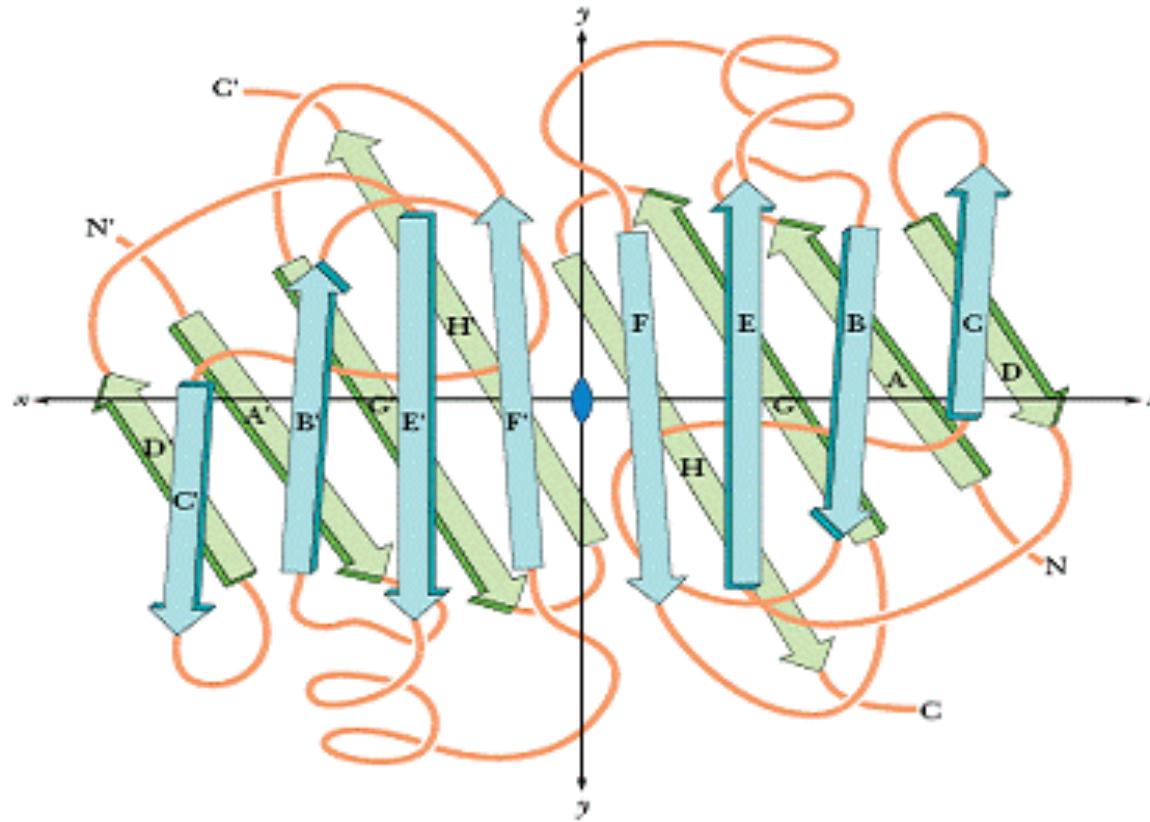


Figure 4-10 part 2 of 2 Essential Cell Biology, 2/e. (© 2004 Garland Science)

The arrows of the beta-sheets are pointing to the carboxylic groups

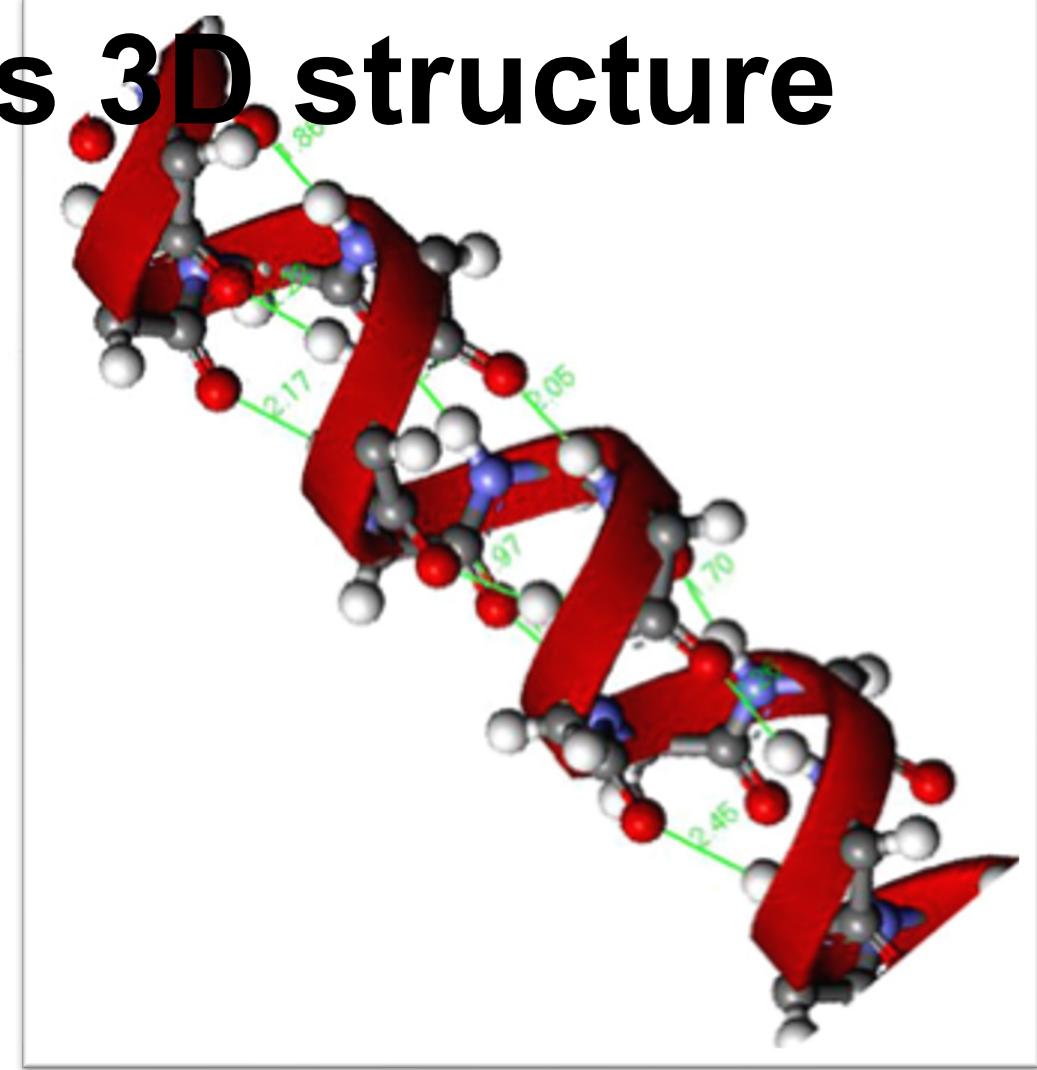
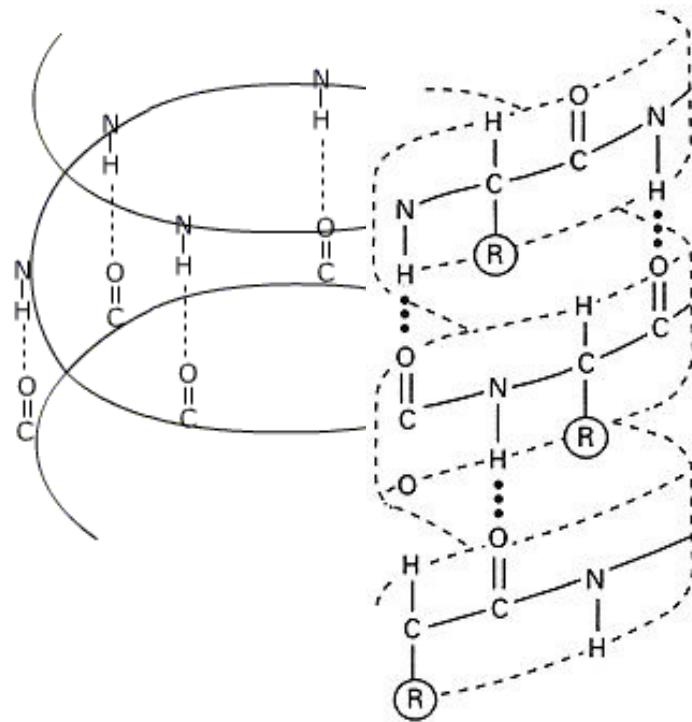
Poly-Peptides 3D structure



Different beta-sheet chains may be organized in more complex 3D super-structures

Poly-Peptides 3D structure

H - bonds in α - helix

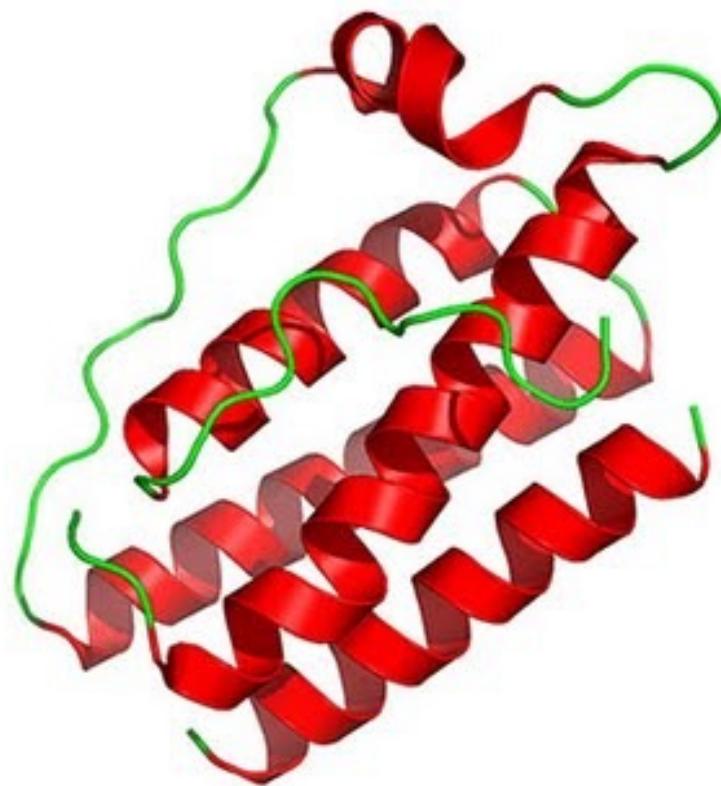


The weak hydrogen bonds may create helix structures in poly-peptides

Hydrophobicity of the α -helix

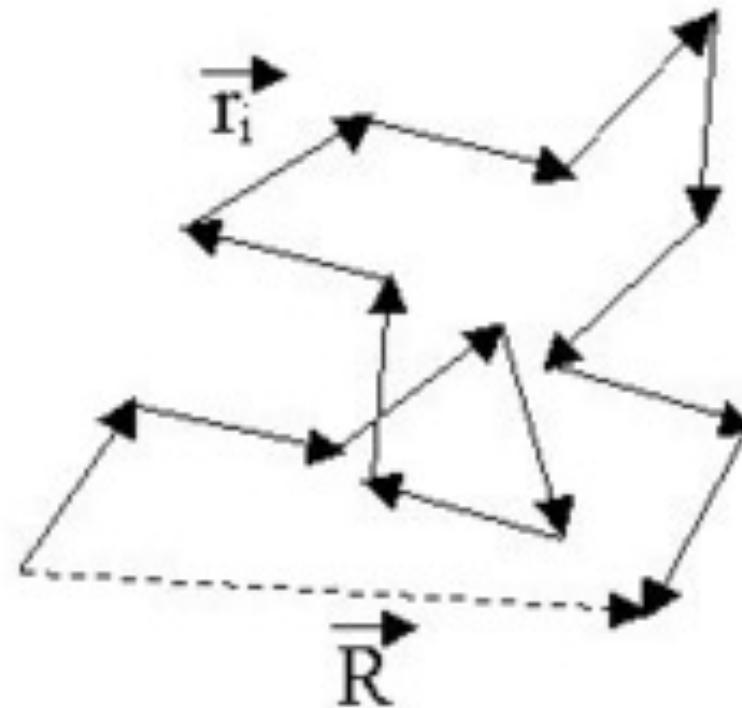
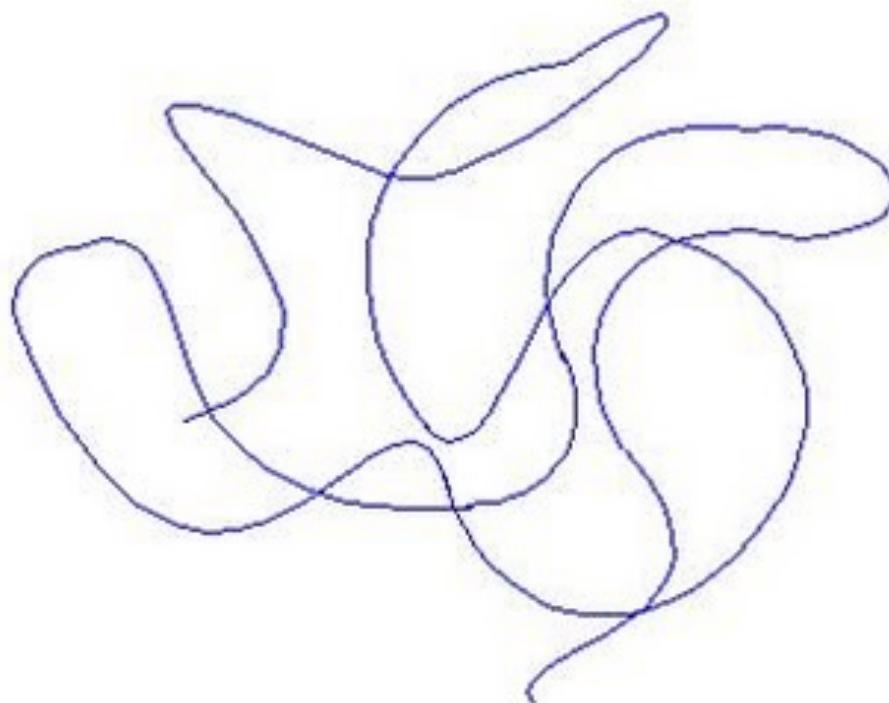


Poly-Peptides 3D structure



Different alpha-helix chains may be organized in more complex 3D super-structures

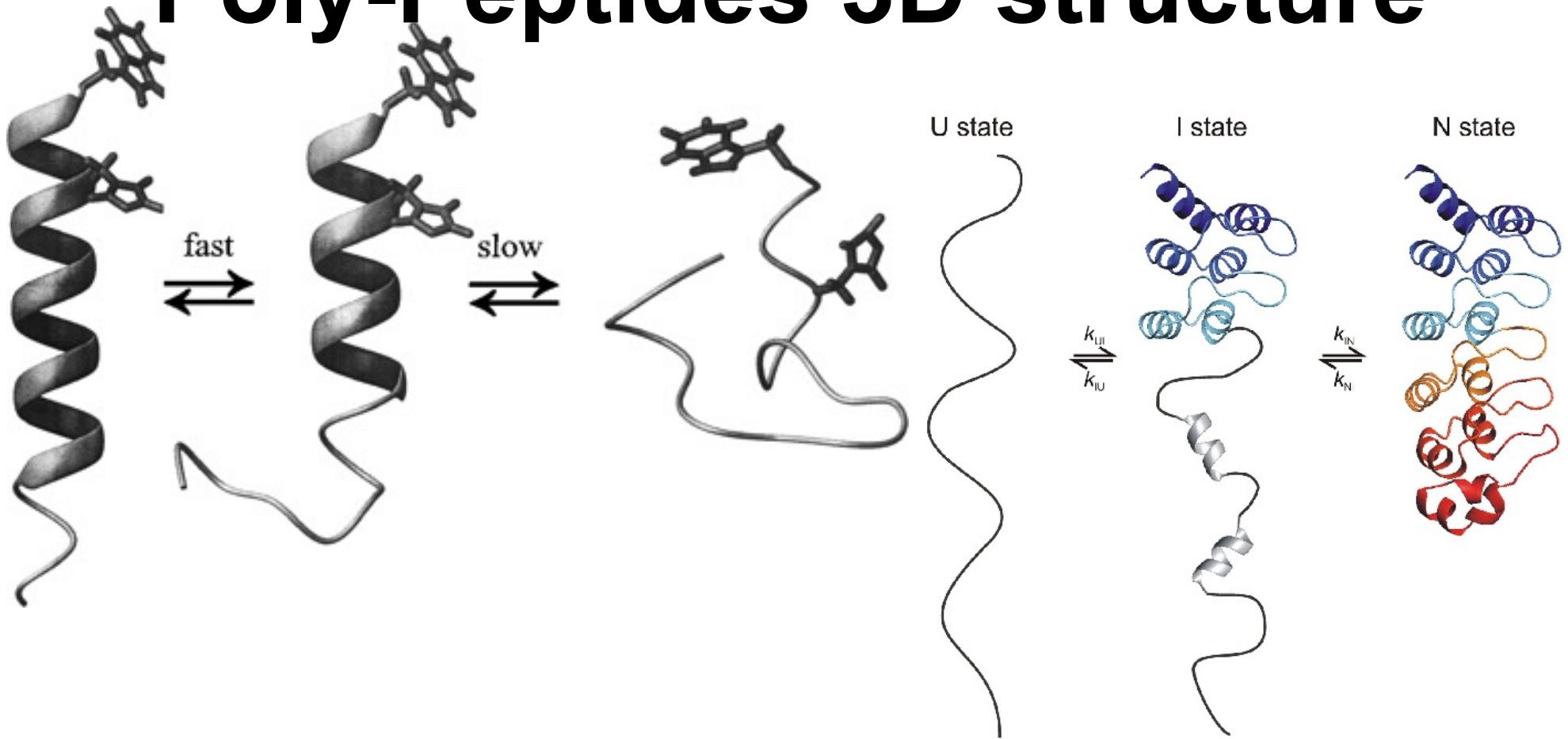
Poly-Peptides 3D structure



A polymer molecule tangled in a random coil.

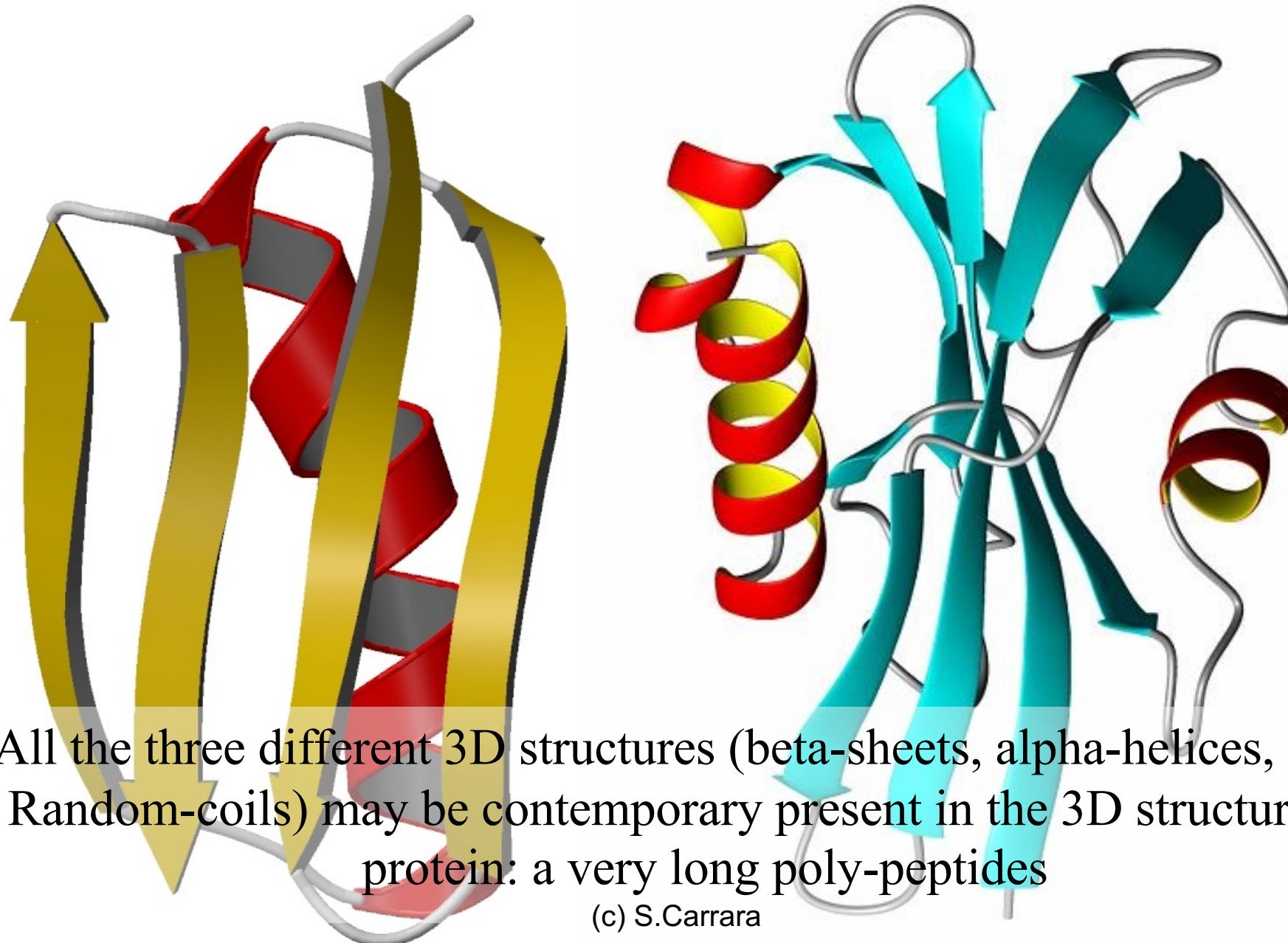
Peptides are short polymers that assume particular 3D structure: e.g. random-coil

Poly-Peptides 3D structure



Poly-Peptides may be organized in different 3D structures by molecular states-transition

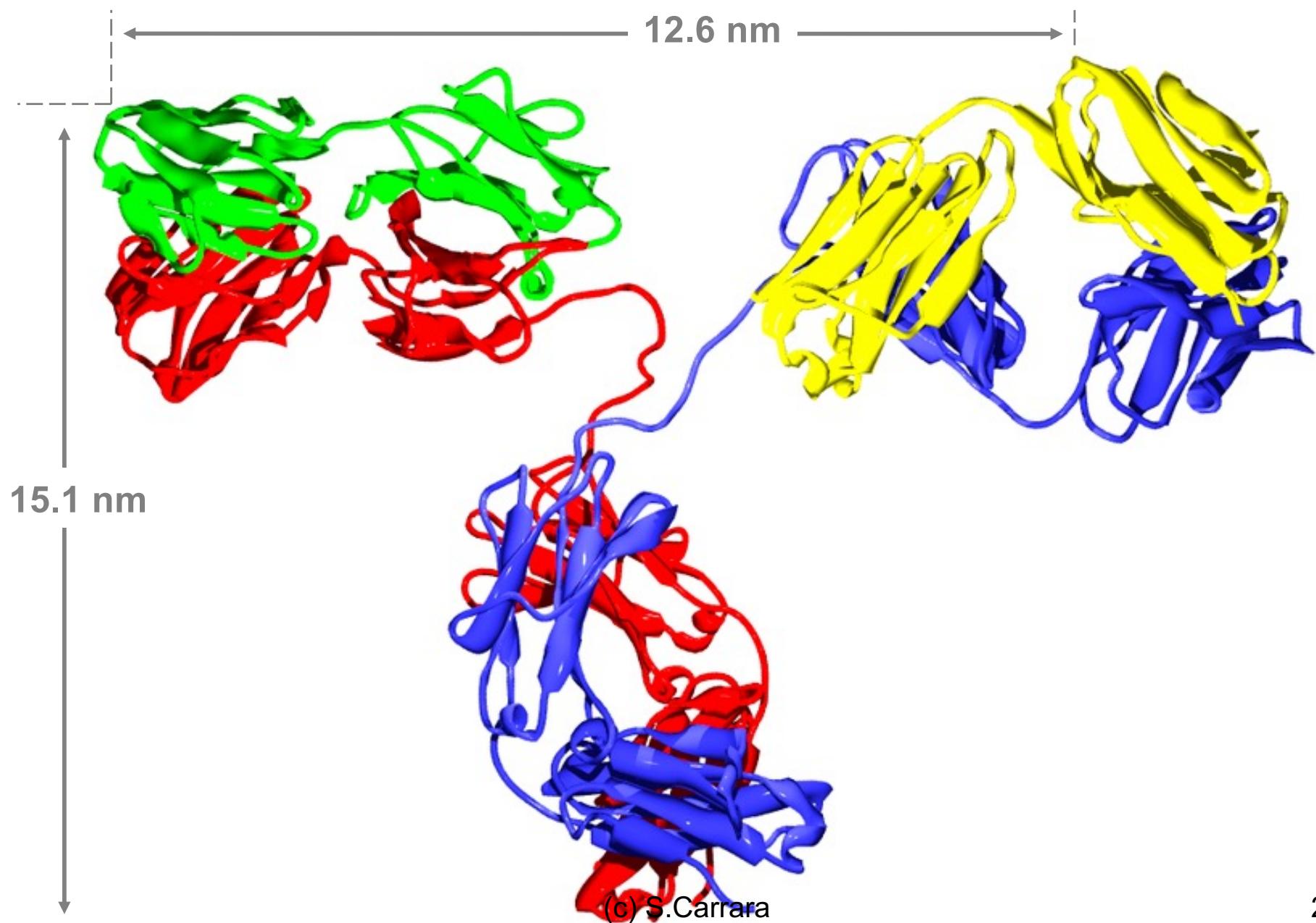
Poly-Peptides 3D structure



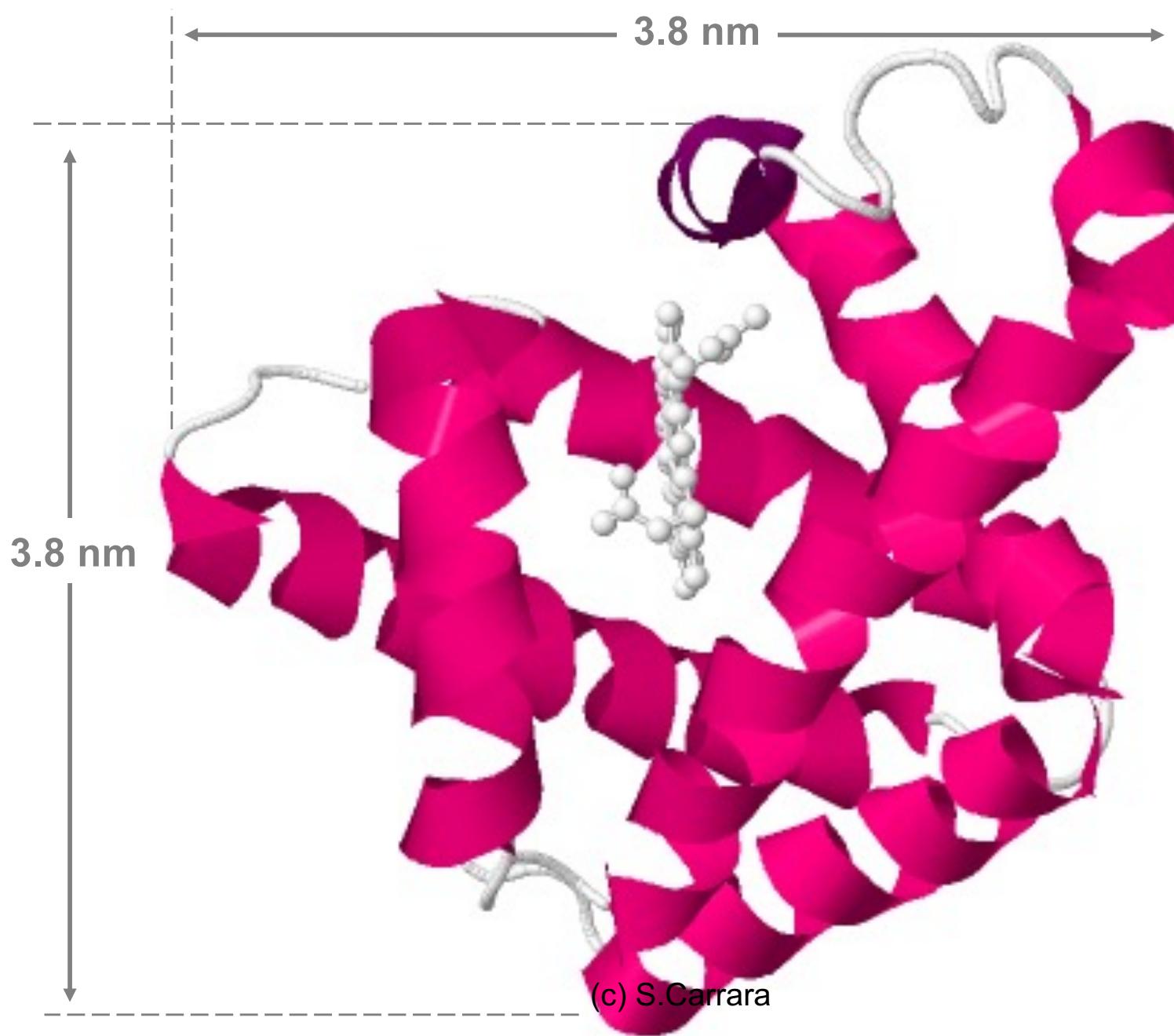
Proteins

More complex bio-molecules are called **Proteins**, which are **polypeptides**, organic compounds made of amino acids arranged in a linear long chain and folded into a 3D usually complex form organized in beta-sheets, alpha-helices, and random-coils conformations

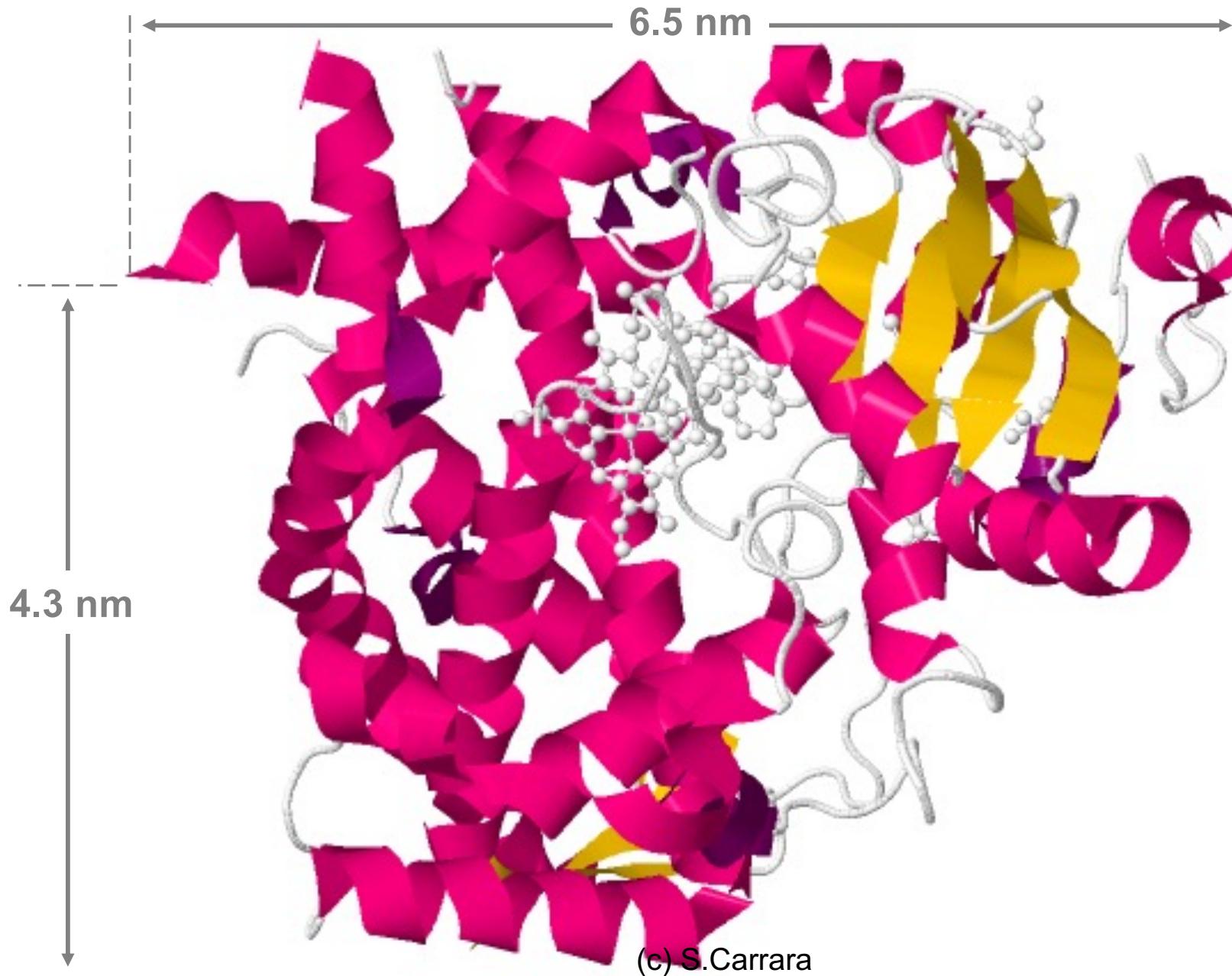
Antibody



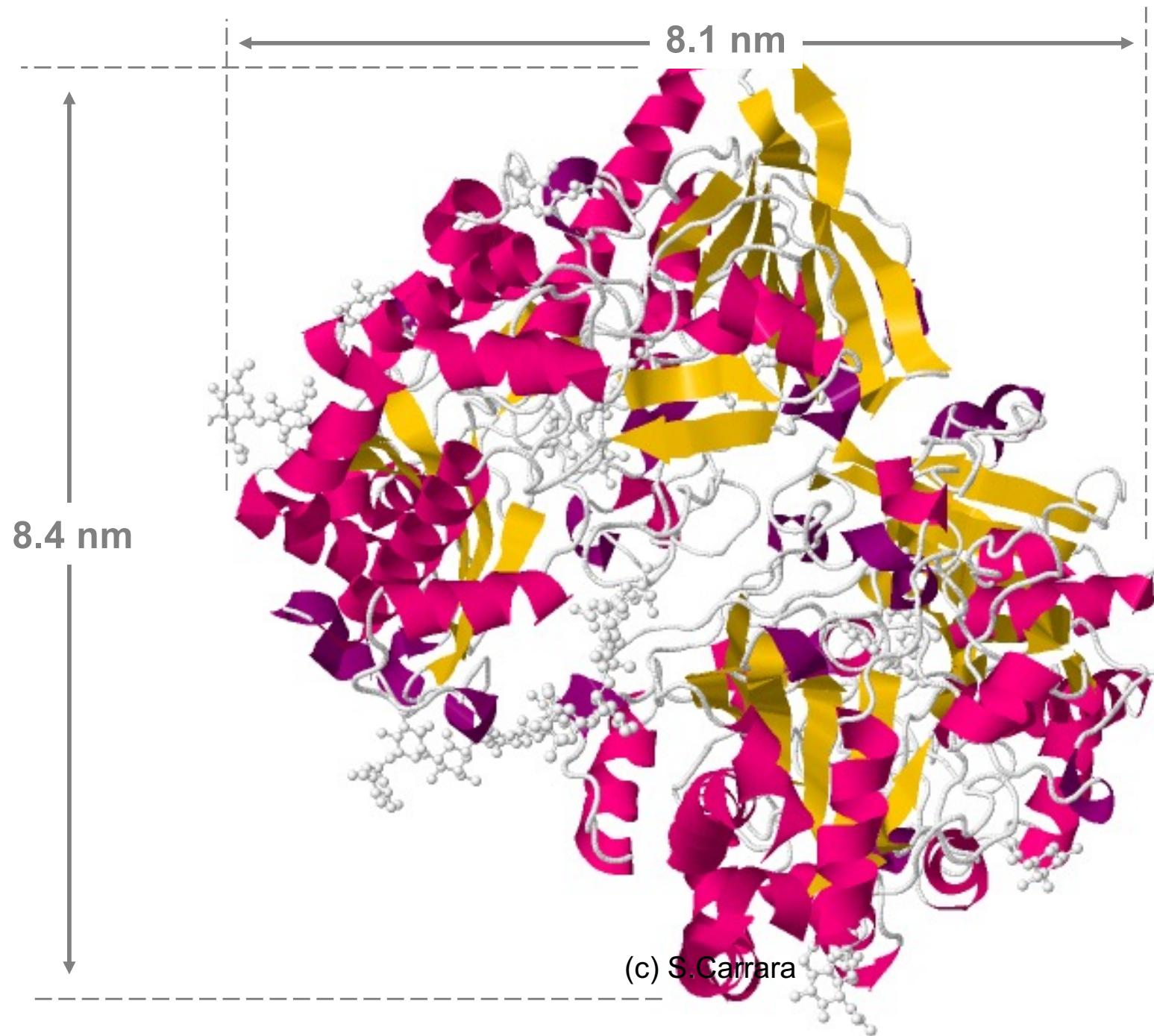
Myoglobin

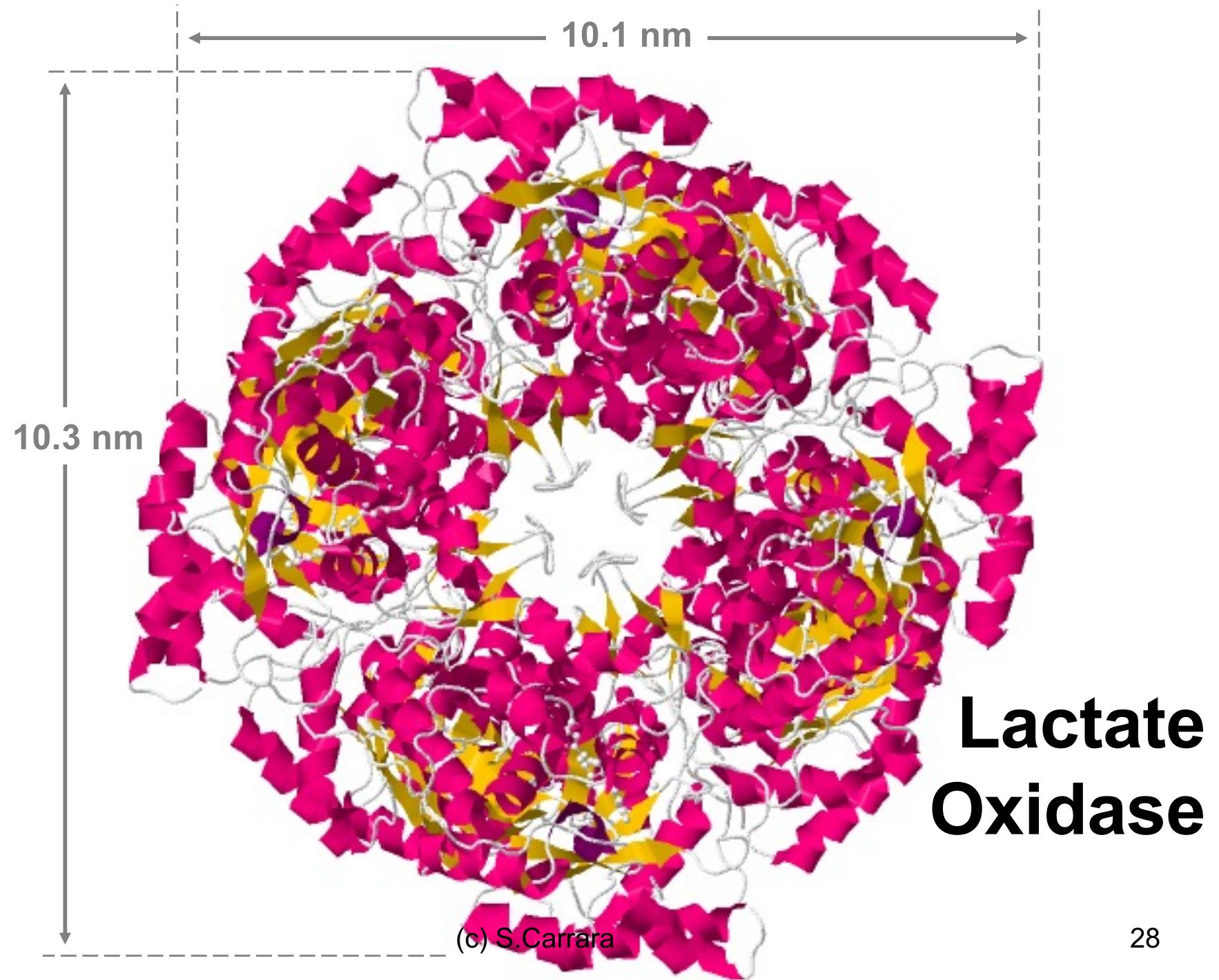


Cytochromes P450



Glucose Oxidase





Structure-TO-Function in Proteins

Enzymes	catalytic activity A -----> B
Transport Proteins	bind & carry ligand molecules (hemoglobins)
Storage Proteins	ovalbumin (egg), ferretin (iron), casein (milk)
Contractile Proteins	can contract, change shape (actin & myosins) and make up elements of cytoskeleton & muscles
Structural Proteins	provide support... collagen fibers of tendons (wounds), elastin of ligaments, keratin of hair & feathers, fibroin of silk & spider webs
Defensive Proteins	provide protection: antibodies (IgG), fibrinogen , thrombin , and snake venoms (digestive enzymes)
Regulatory Proteins	regulate metabolic processes: includes hormones , transcription factors & enhancers

Different 3D structures lead to different protein functions

Outline on DNA

(Book Bio/CMOS: Chapter' paragraphs § 3.9 and § 4.1-3)

- Nuclear bases
- DNA
- RNA
- DNA hybridization
- DNA/RNA role in biological cells

DNA



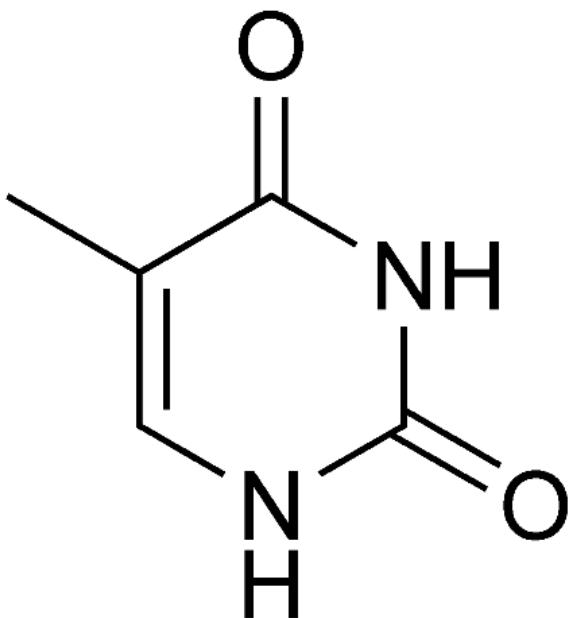
Another fundamental molecules in
Biochemistry is the DNA

DNA

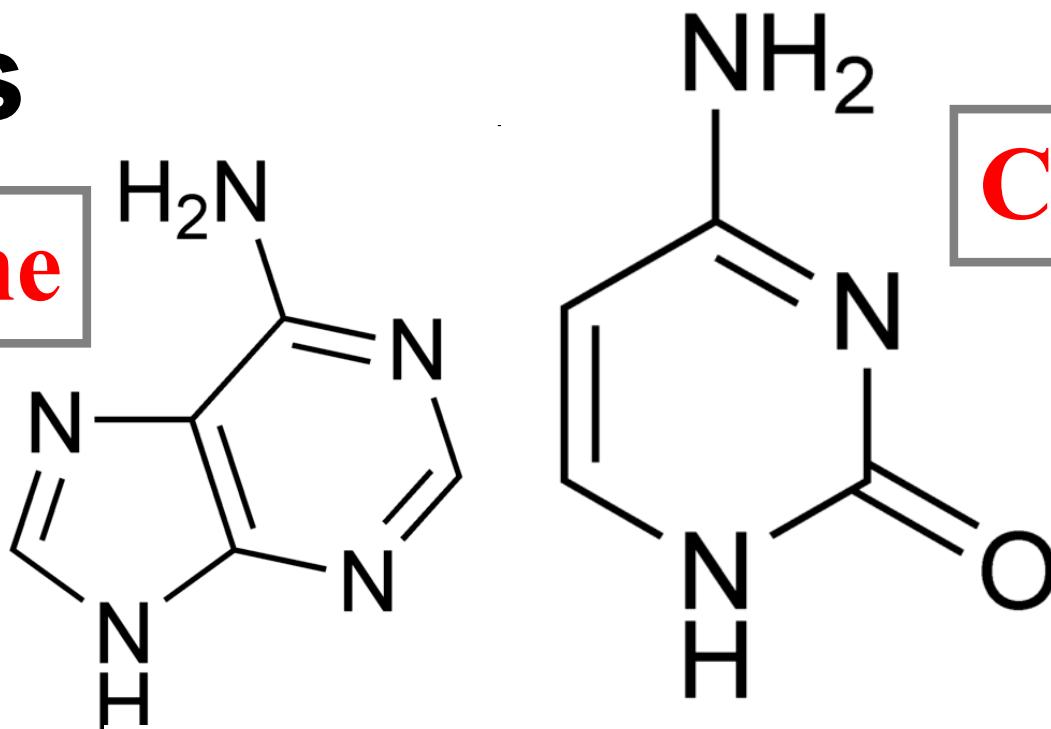
Definition

is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses.

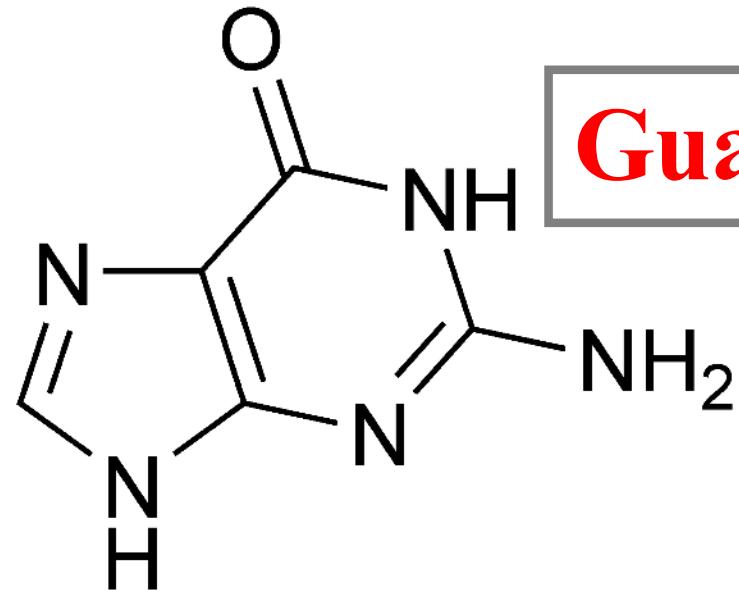
DNA Bases



Thymine

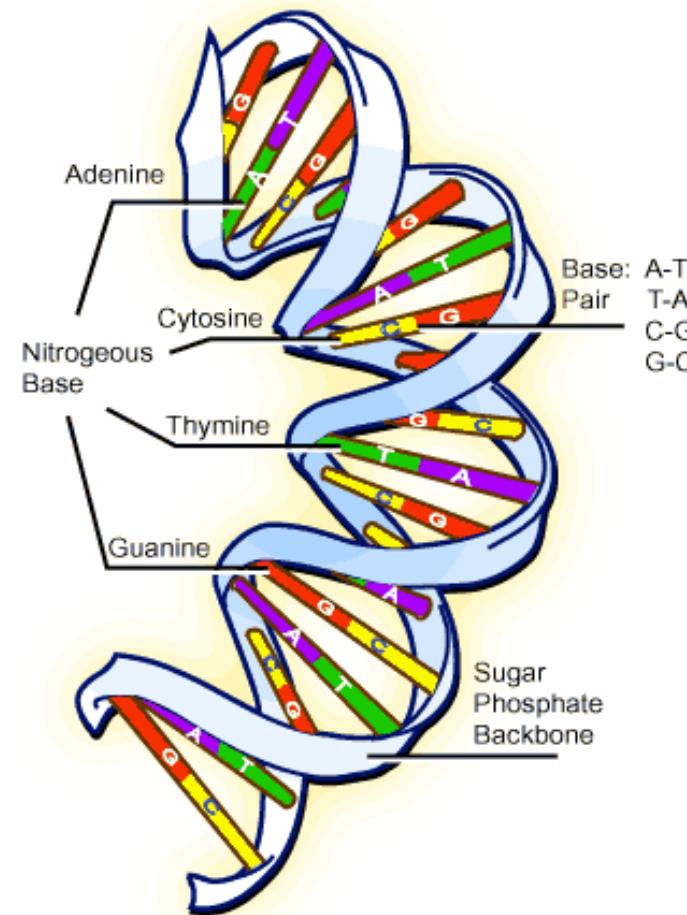


Cytosine



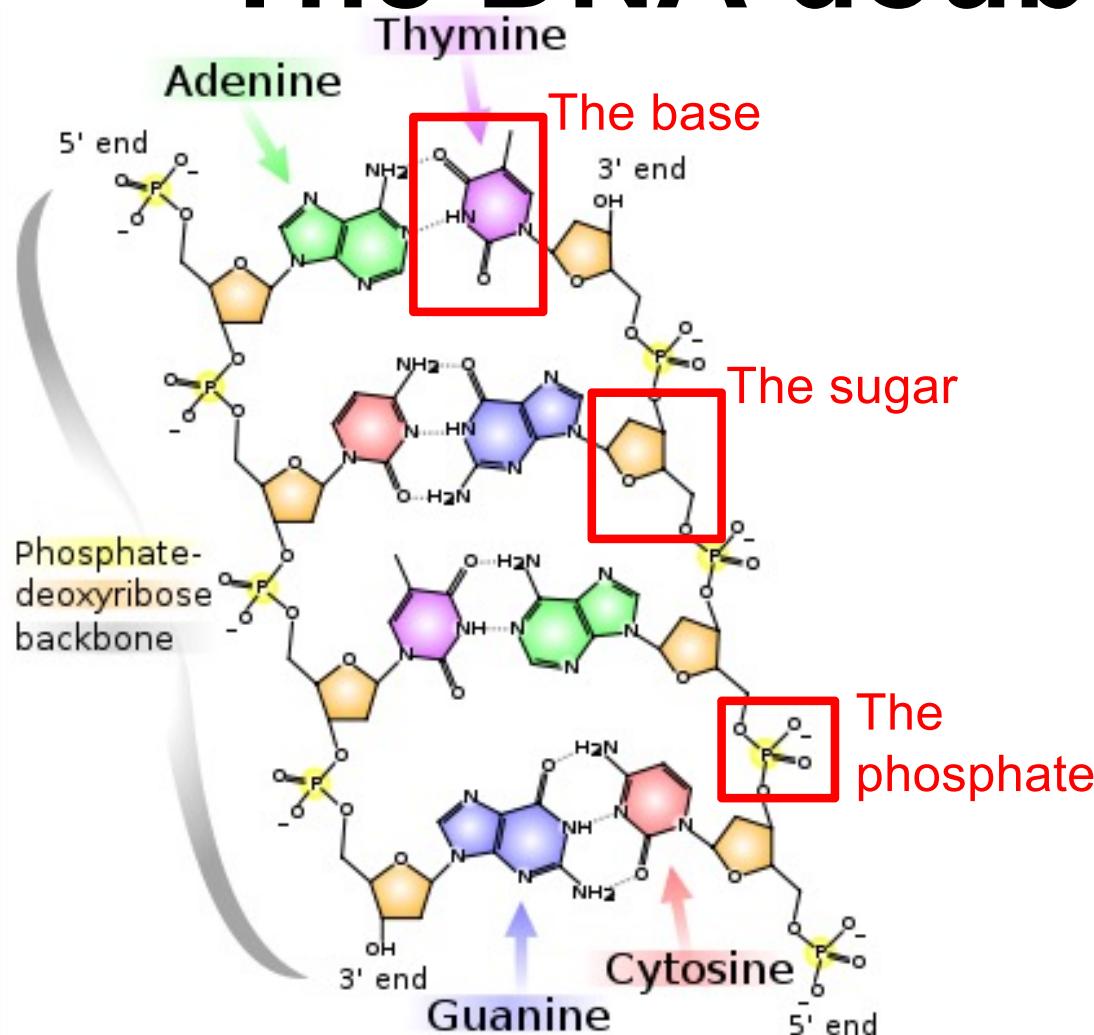
Guanine

DNA



DNA is constitutes by a Sugar Phosphate backbone and by four Nitrogenous Bases

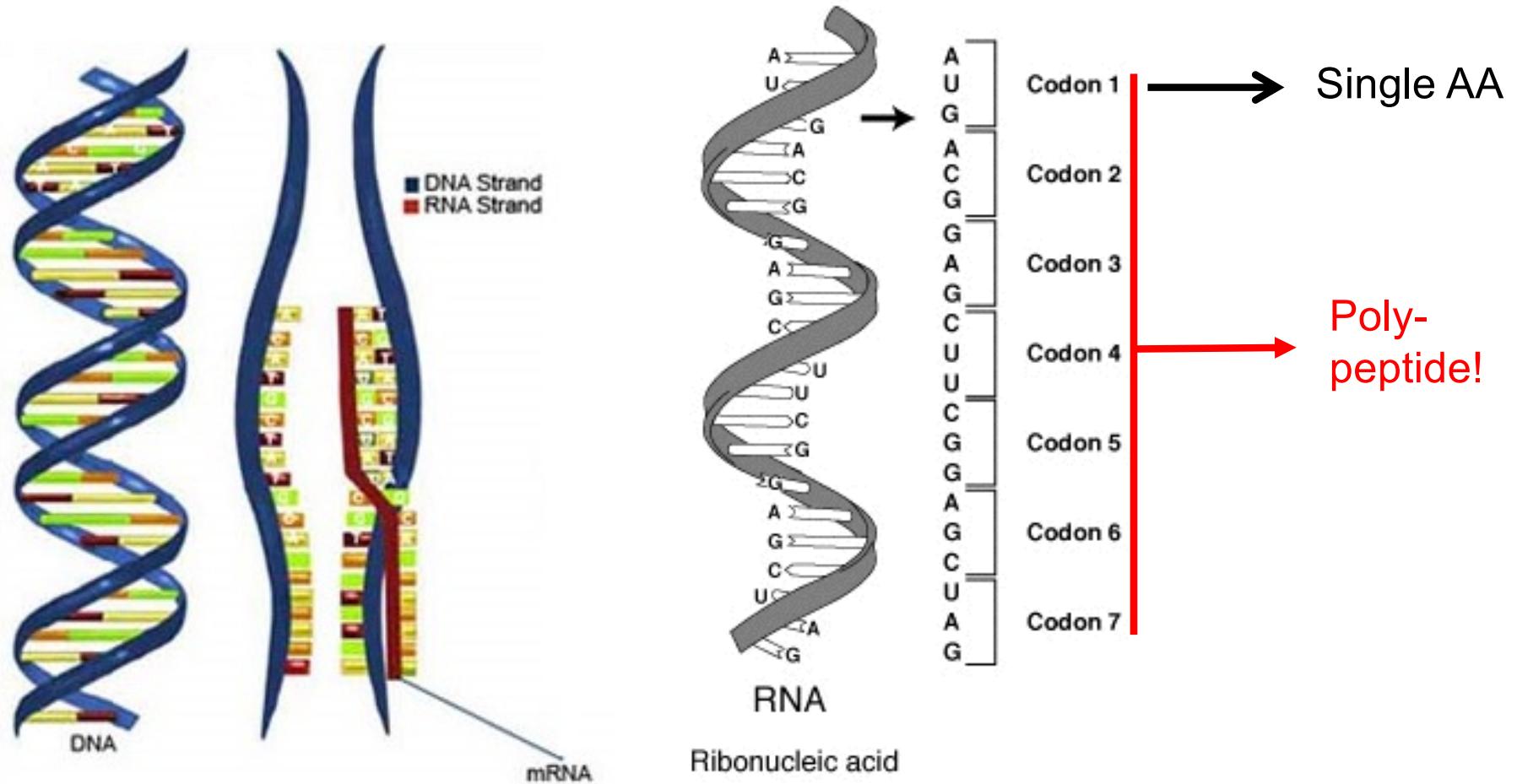
The DNA double helix



The two DNA strands are also called « polynucleotides » since they are composed of simpler units called nucleotides. The nucleotide is composed of a nitrogen-containing base as well as a monosaccharide sugar, called deoxyribose, and a phosphate group.

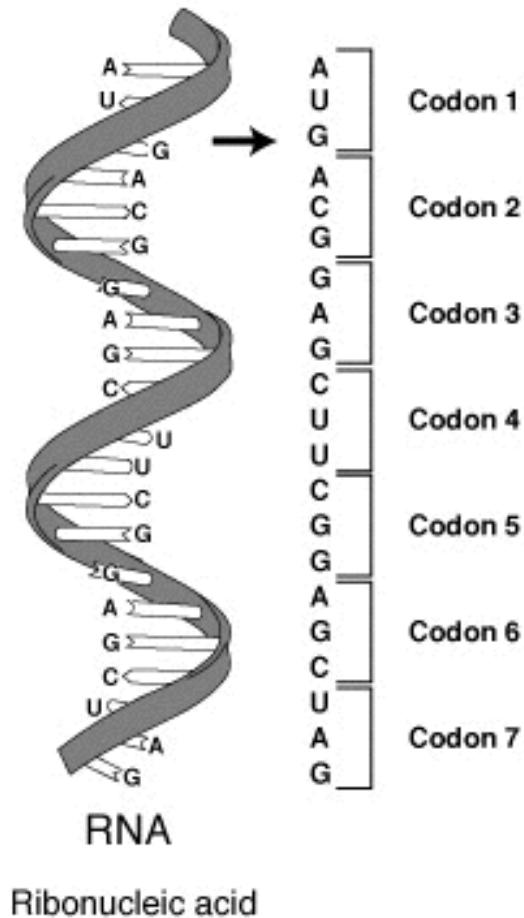
The base pairing forms very long double strength DNA chains

RNA decodes the genes



The RNA is another similar molecule useful to decode the genetic code

DNA/RNA differences



RNA and DNA are both nucleic acids. They differ in four main ways:

- RNA is mainly a single-stranded molecule (DNA is double-stranded)
- RNA usually has a much shorter chain of nucleotides
- RNA is less stable than DNA because it is more prone to hydrolysis because it contains *ribose* while DNA contains *deoxyribose*
- RNA has as fourth base the Uracil, an unmethylated form of thymine (while DNA has thymine)