



**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

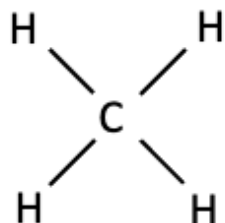


Q1

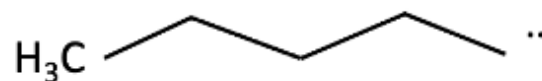
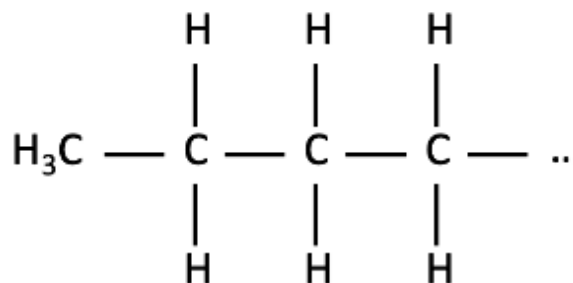
# What are the Organic Molecules?

- 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

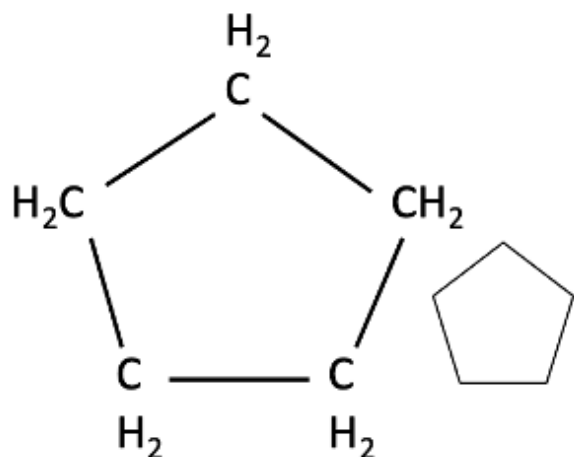
# Very Simple Organic Molecules



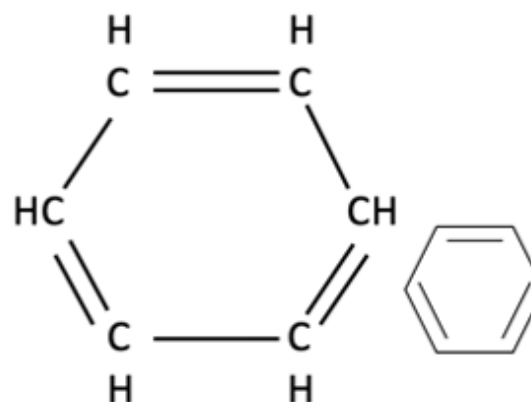
**Methane: CH<sub>4</sub>**



**Alkyl Chain: (CH<sub>2</sub>)<sub>n</sub>**

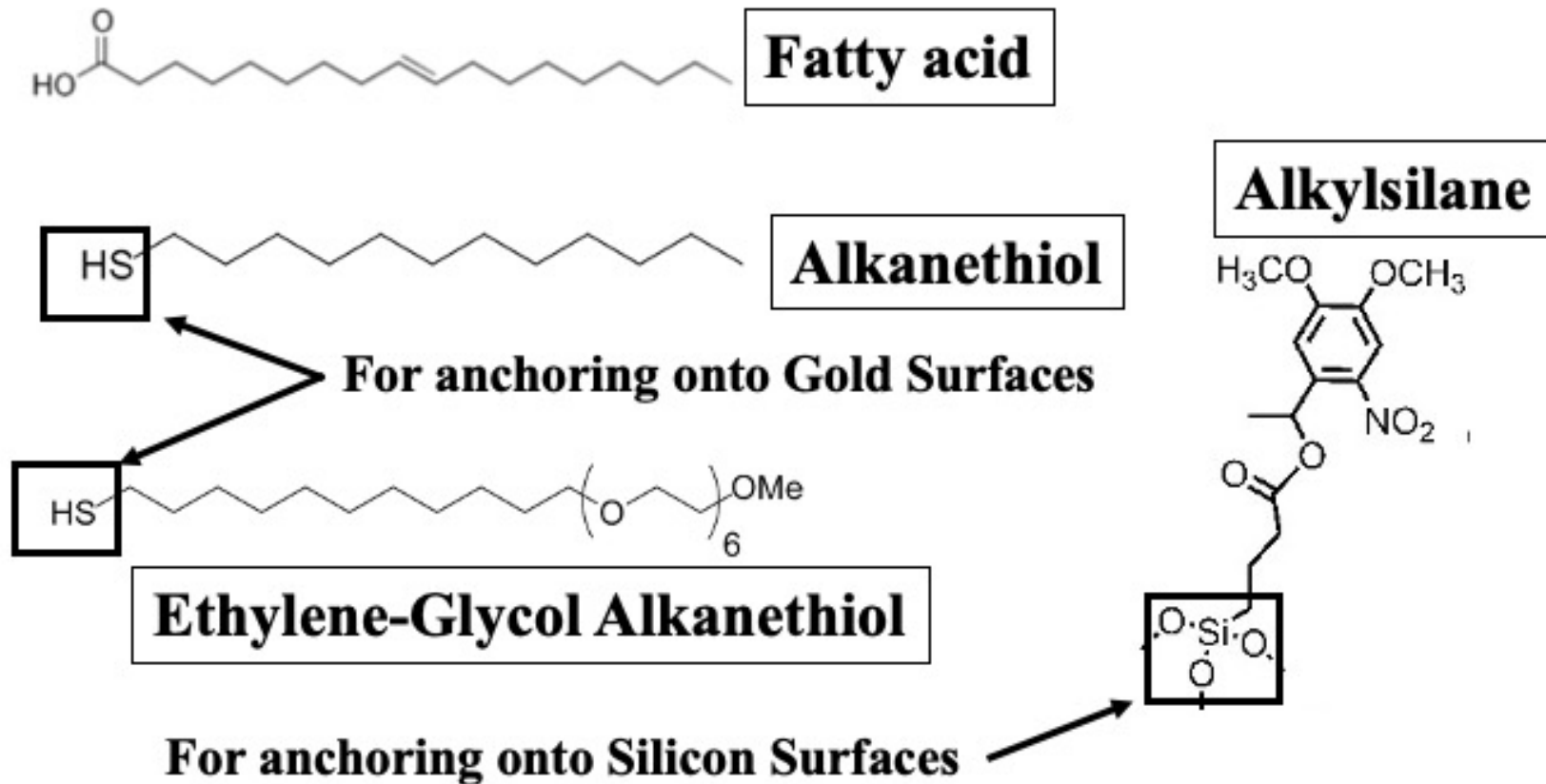


**Cyclopentane: (CH<sub>2</sub>)<sub>5</sub>**



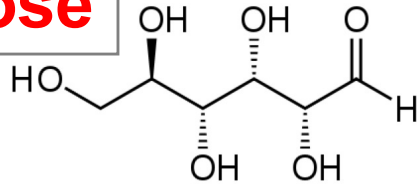
**Benzene: (CH)<sub>6</sub>**

# Quite important Linkers

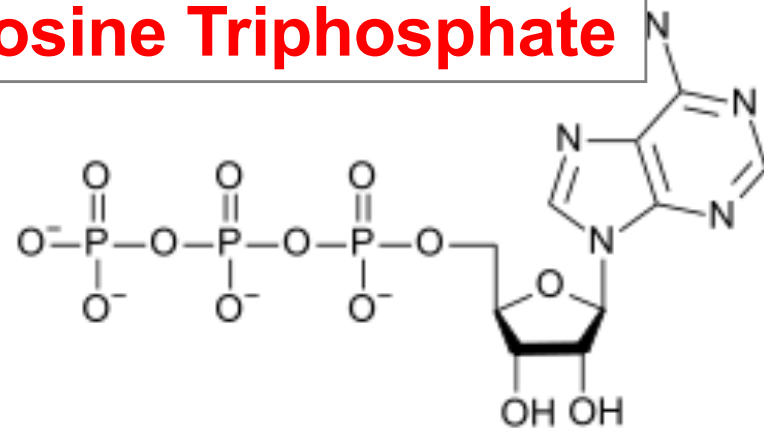


# Human metabolites

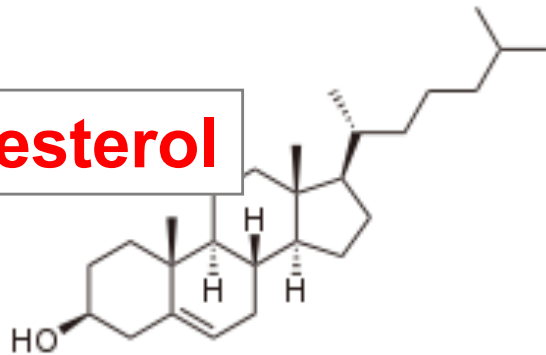
**D-glucose**



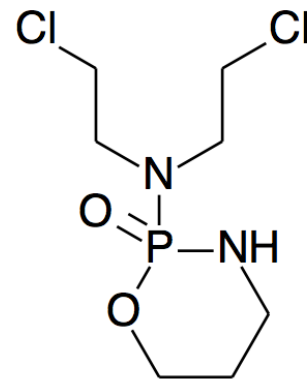
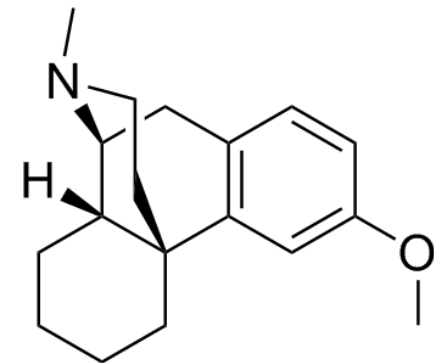
**Adenosine Triphosphate**



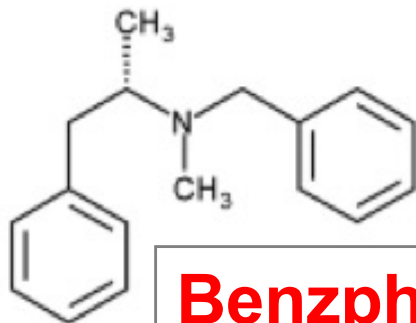
**Cholesterol**



**Dextromethorphan**

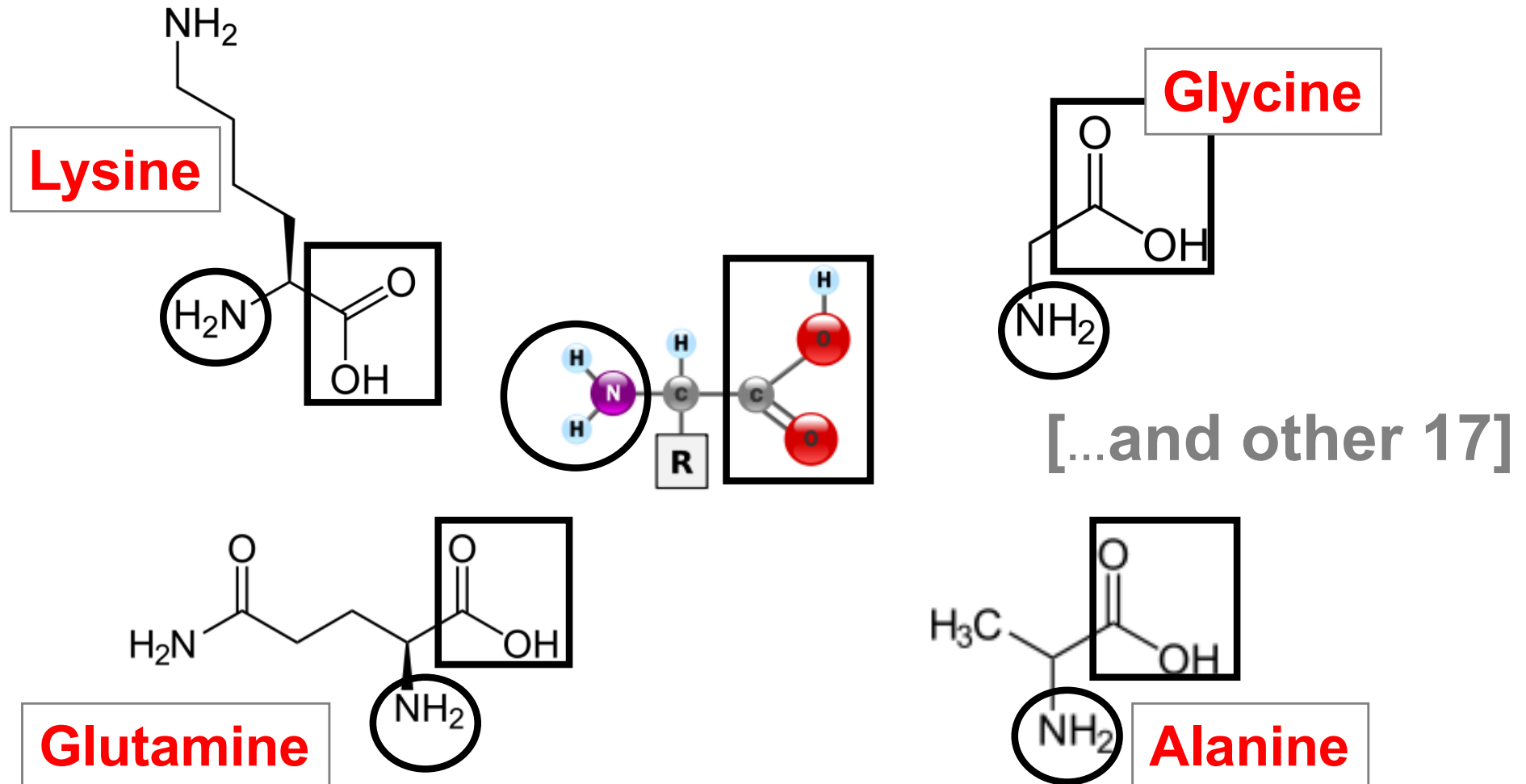


**Cyclophosphamide**



**Benzphetamine**

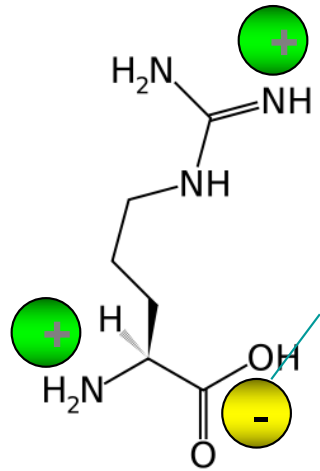
# Amino Acids



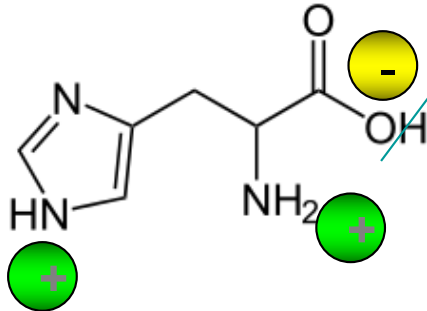
Amino acids are molecules containing an amine group (NH<sub>2</sub>), a carboxylic acid group (COOH) and a side chain that varies between different amino acids

# Charged AA

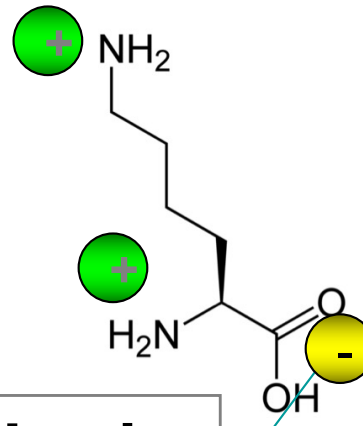
## Positively Charged



**Arginine**

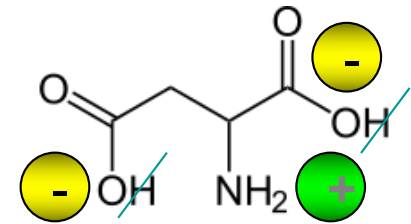


**Histidine**

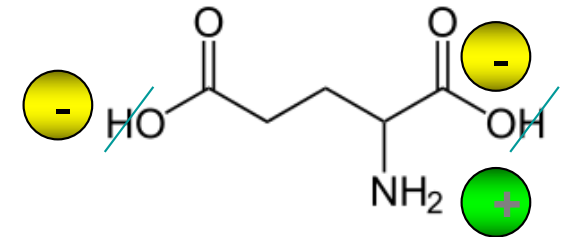


**Lysine**

## Neg. Charged

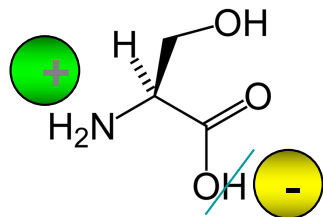


**Aspartic Acid**

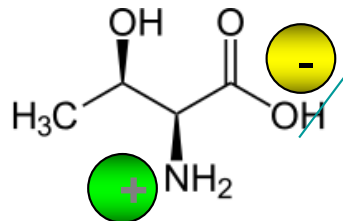


**Glutamic Acid**

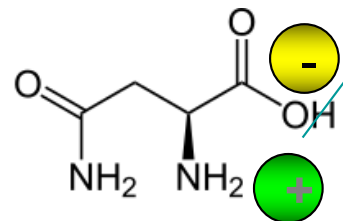
## Polar Uncharged



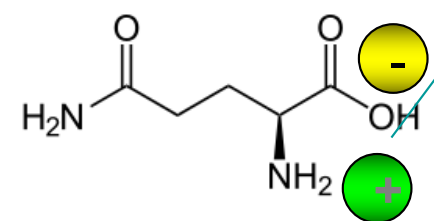
**Serine**



**Threonine**



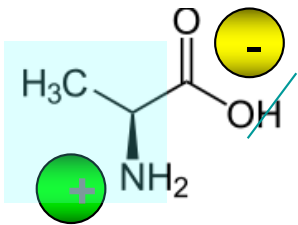
**Asparagine**



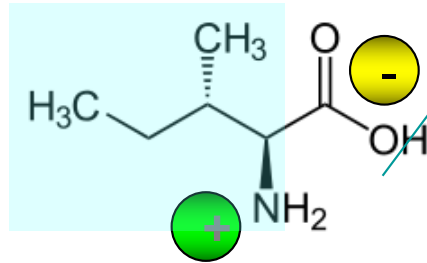
**Glutamine**

# Hydrophobic AA

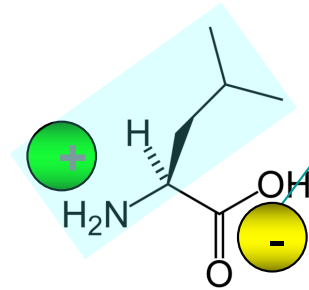
## Hydrophobic Side Chains



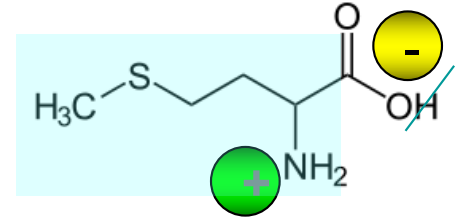
**Alanine**



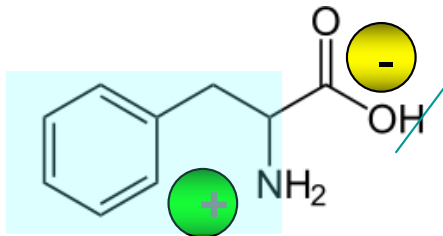
**Isoleucine**



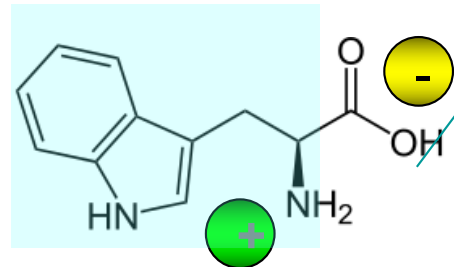
**Leucine**



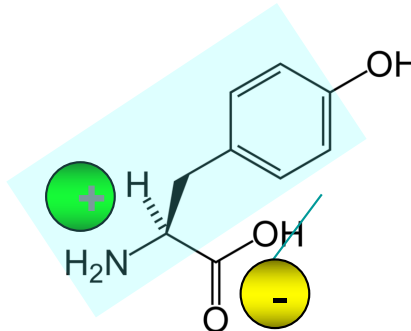
**Methionine**



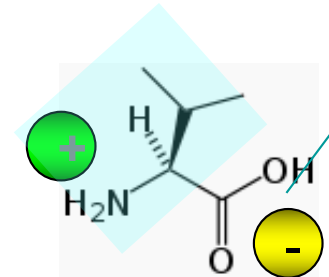
**Phenylalanine**



**Tryptophan**



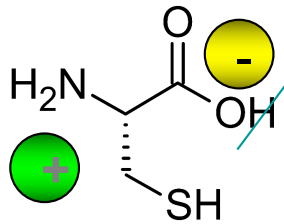
**Tyrosine**



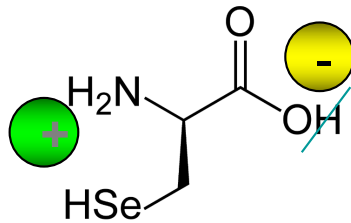
**Valine**

# Neutral AA

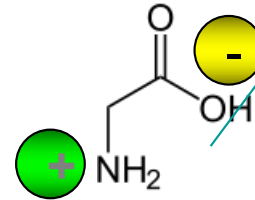
## Special Cases



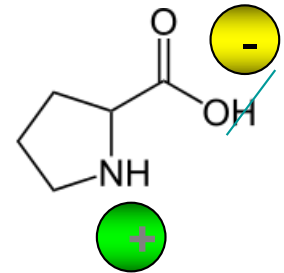
**Cysteine**



**Selenocysteine**

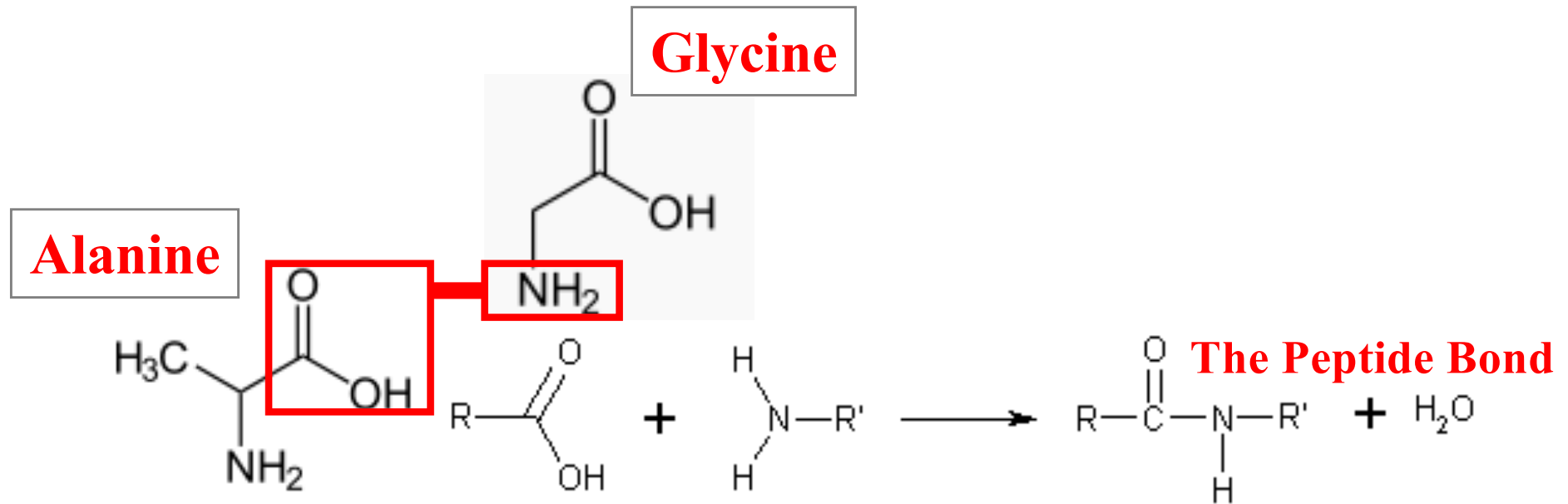


**Glycine**



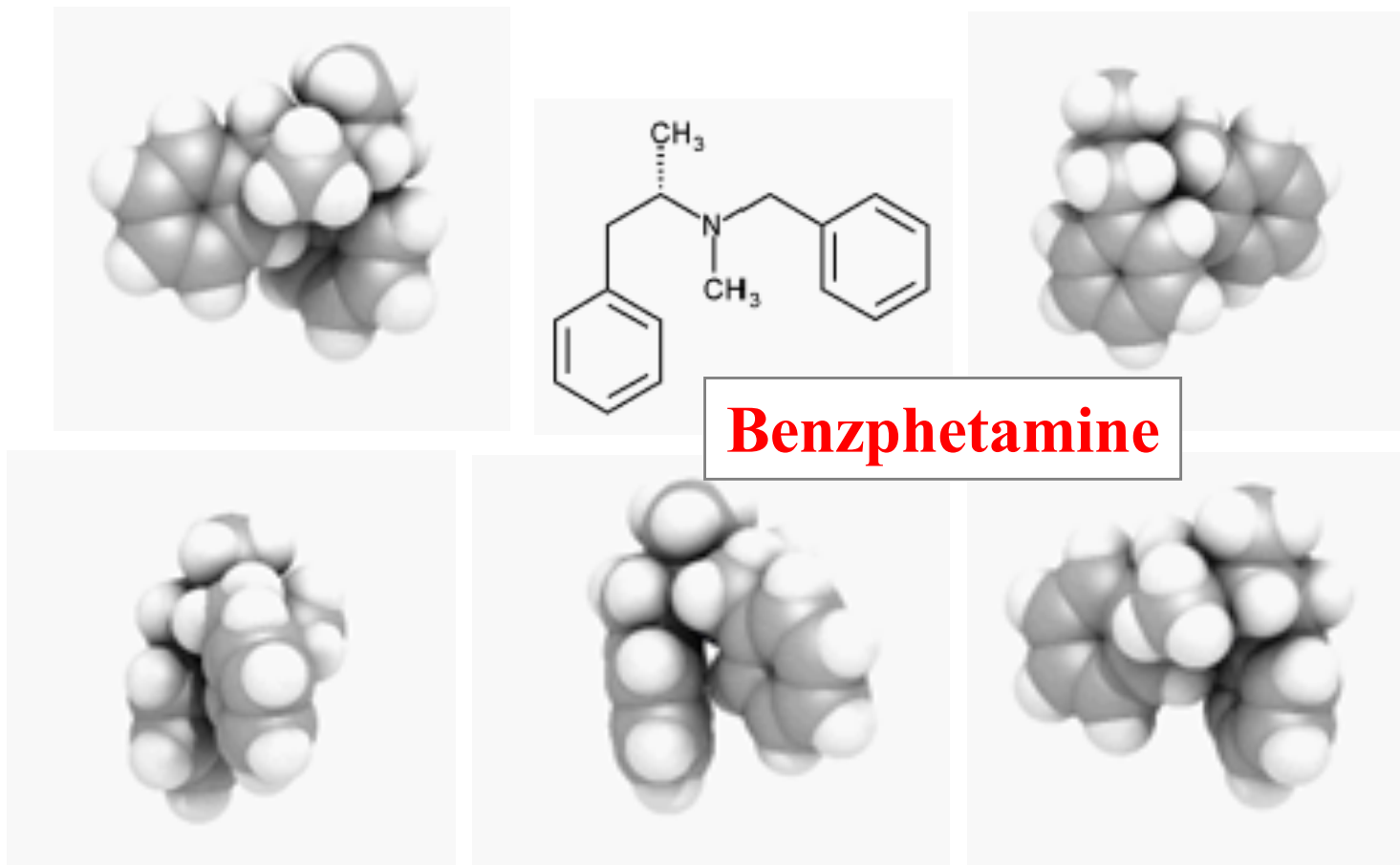
**Proline**

# The Peptides



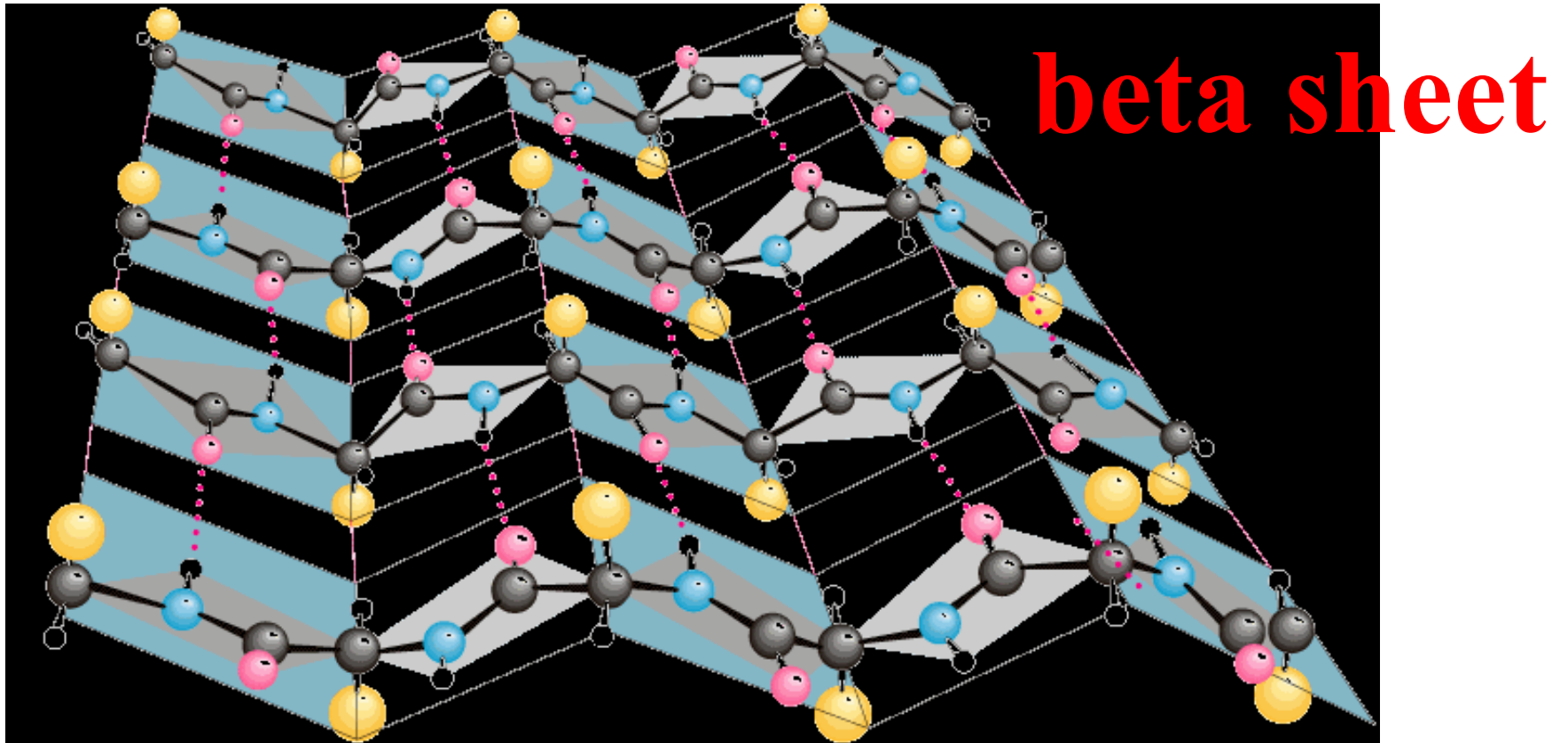
Peptides are short polymers formed by linking amino acids in a defined order

# 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

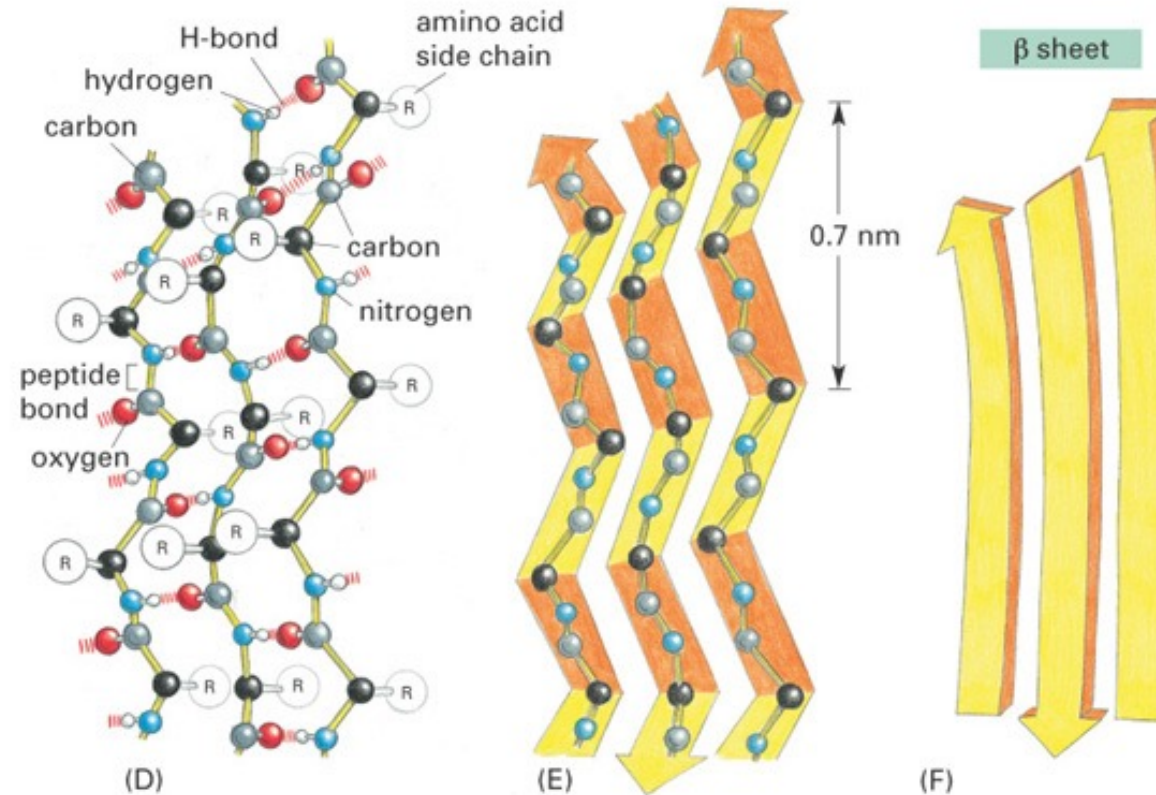
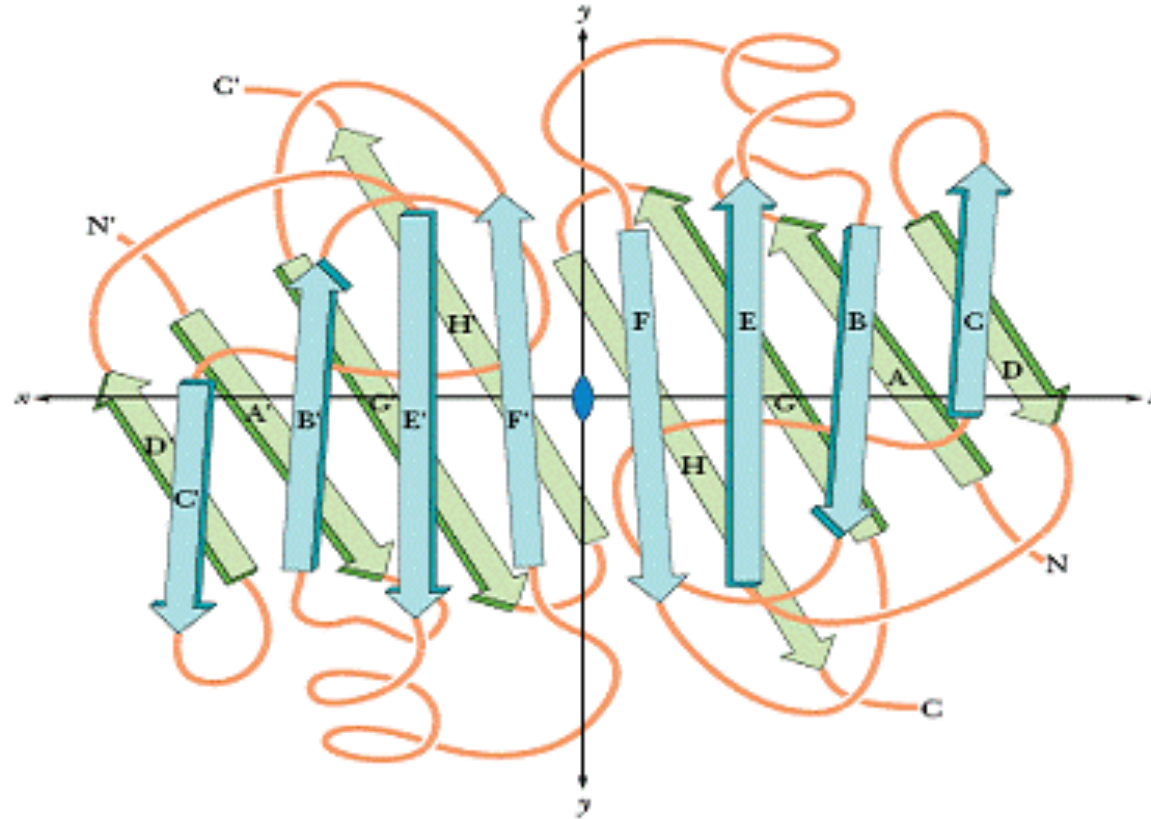


Figure 4-10 part 2 of 2 Essential Cell Biology, 2/e. (© 2004 Garland Science)

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

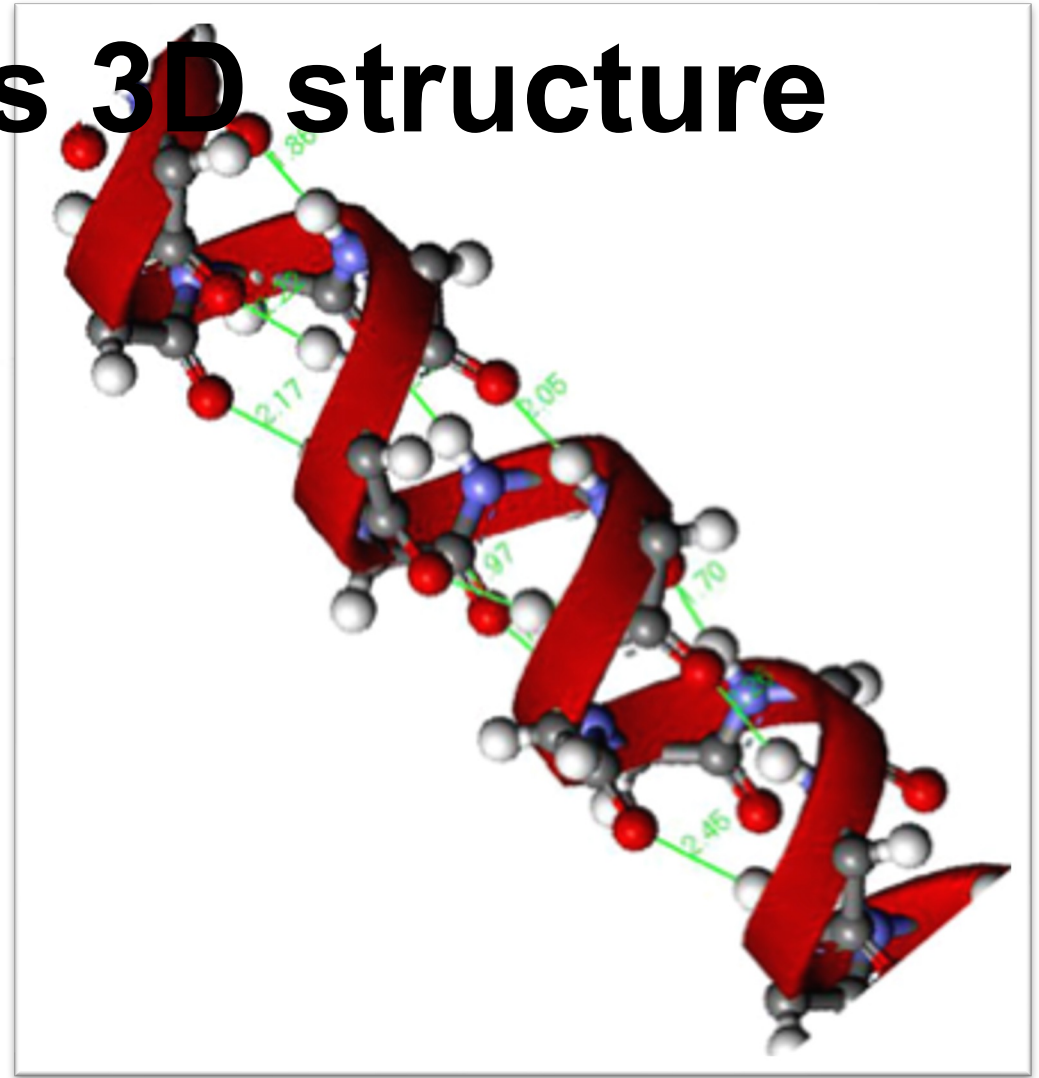
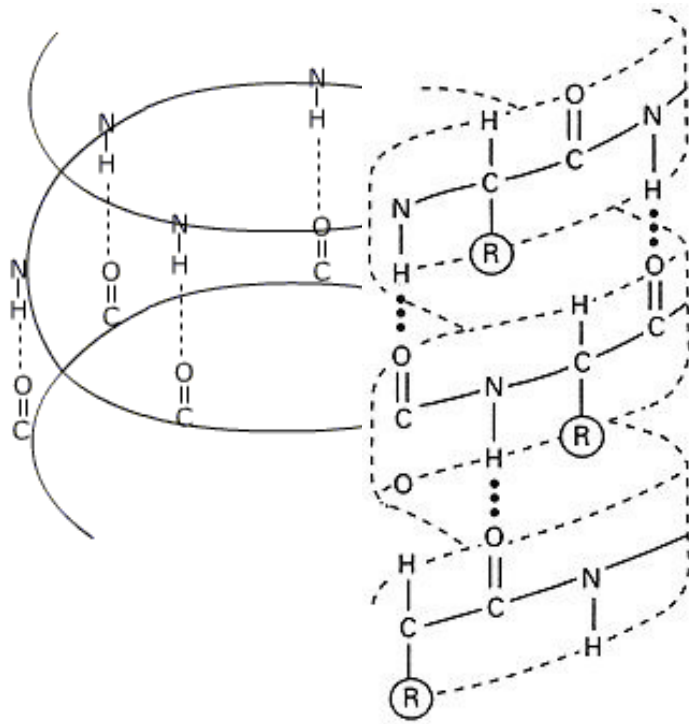
# Poly-Peptides 3D structure



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

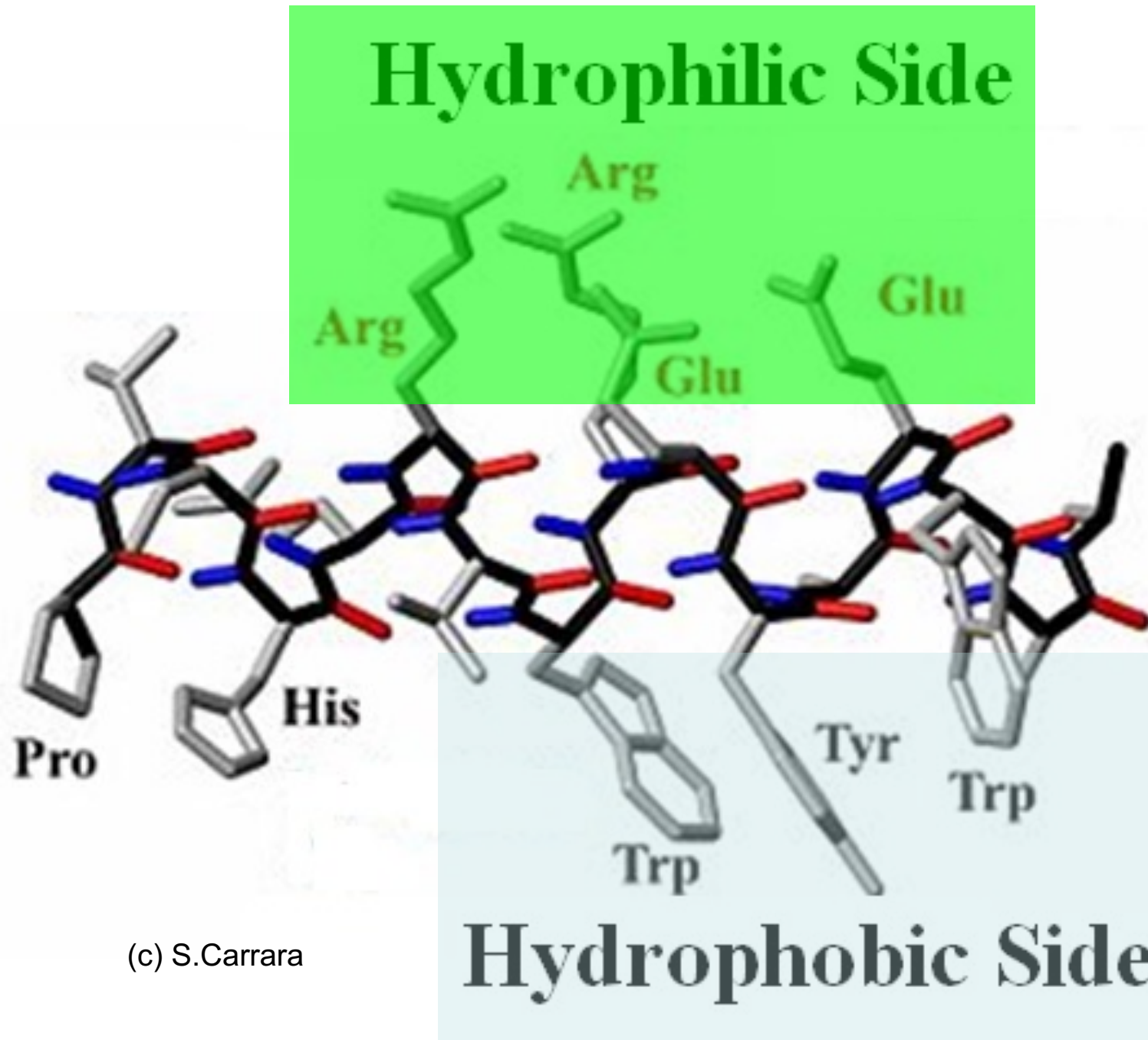
# Poly-Peptides 3D structure

H - bonds in  $\alpha$  - helix



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

# Hydrophobicity of the $\alpha$ -helix

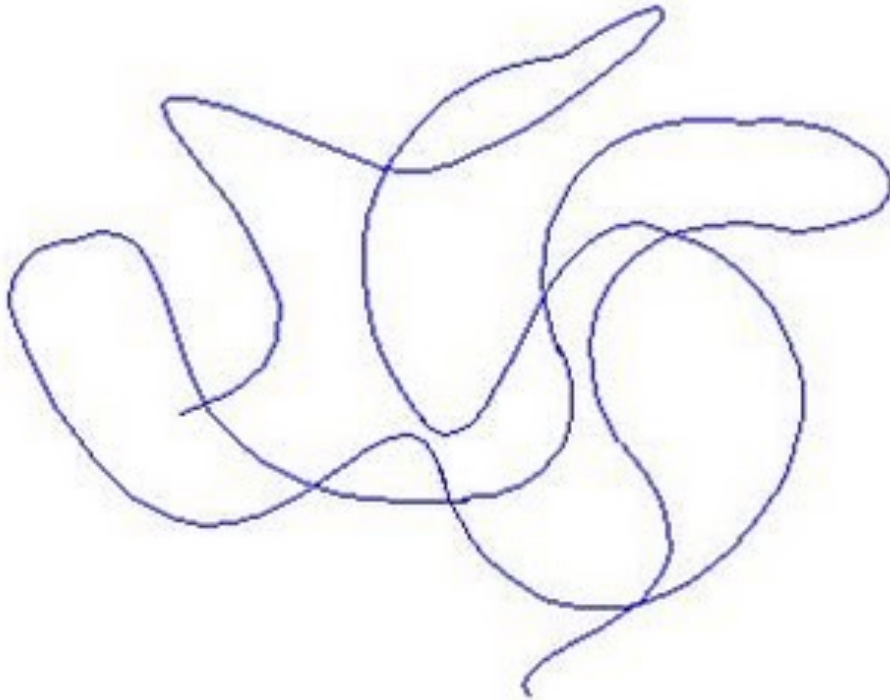


# Poly-Peptides 3D structure

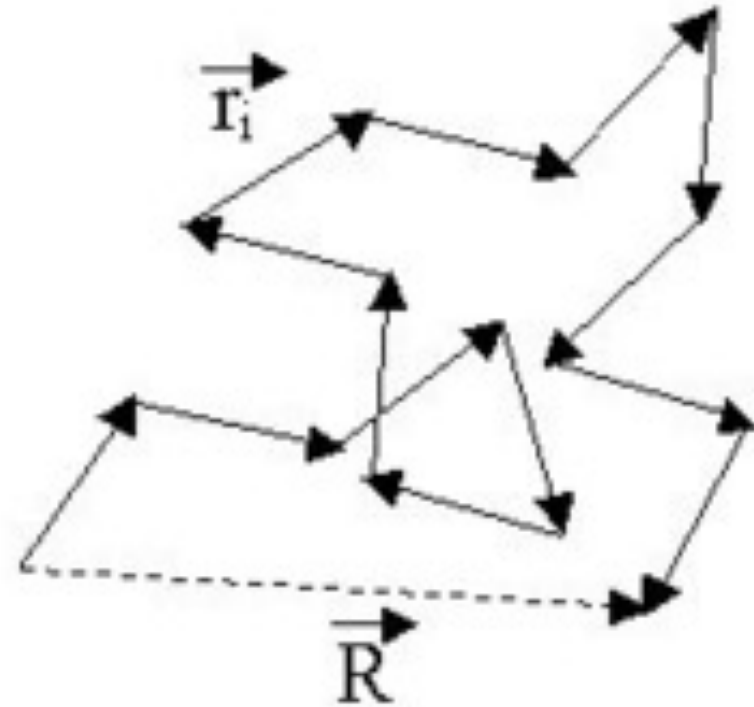


Different alpha-helix chains may be organized in more complex 3D super-structures

# Poly-Peptides 3D structure

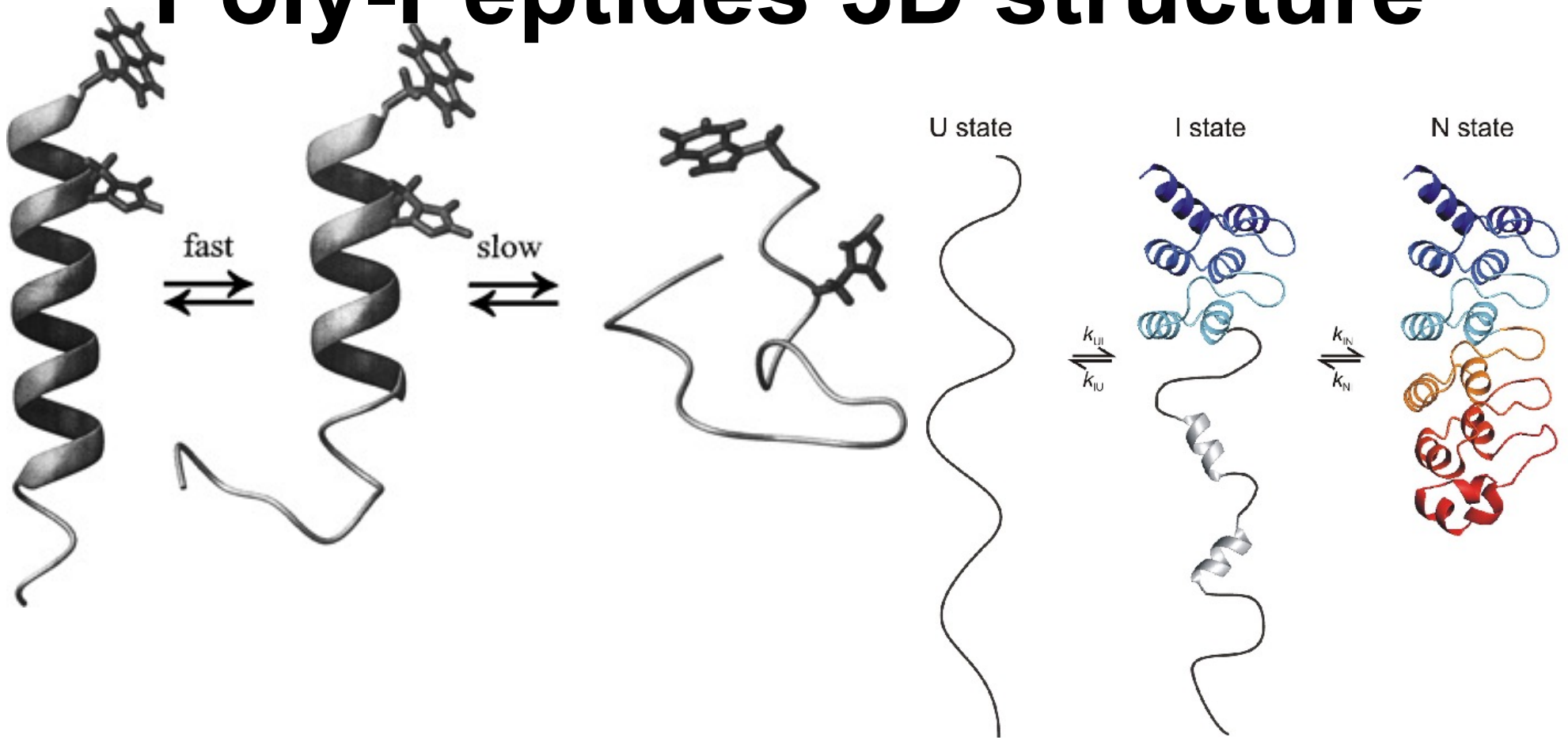


A polymer molecule tangled in a random coil.



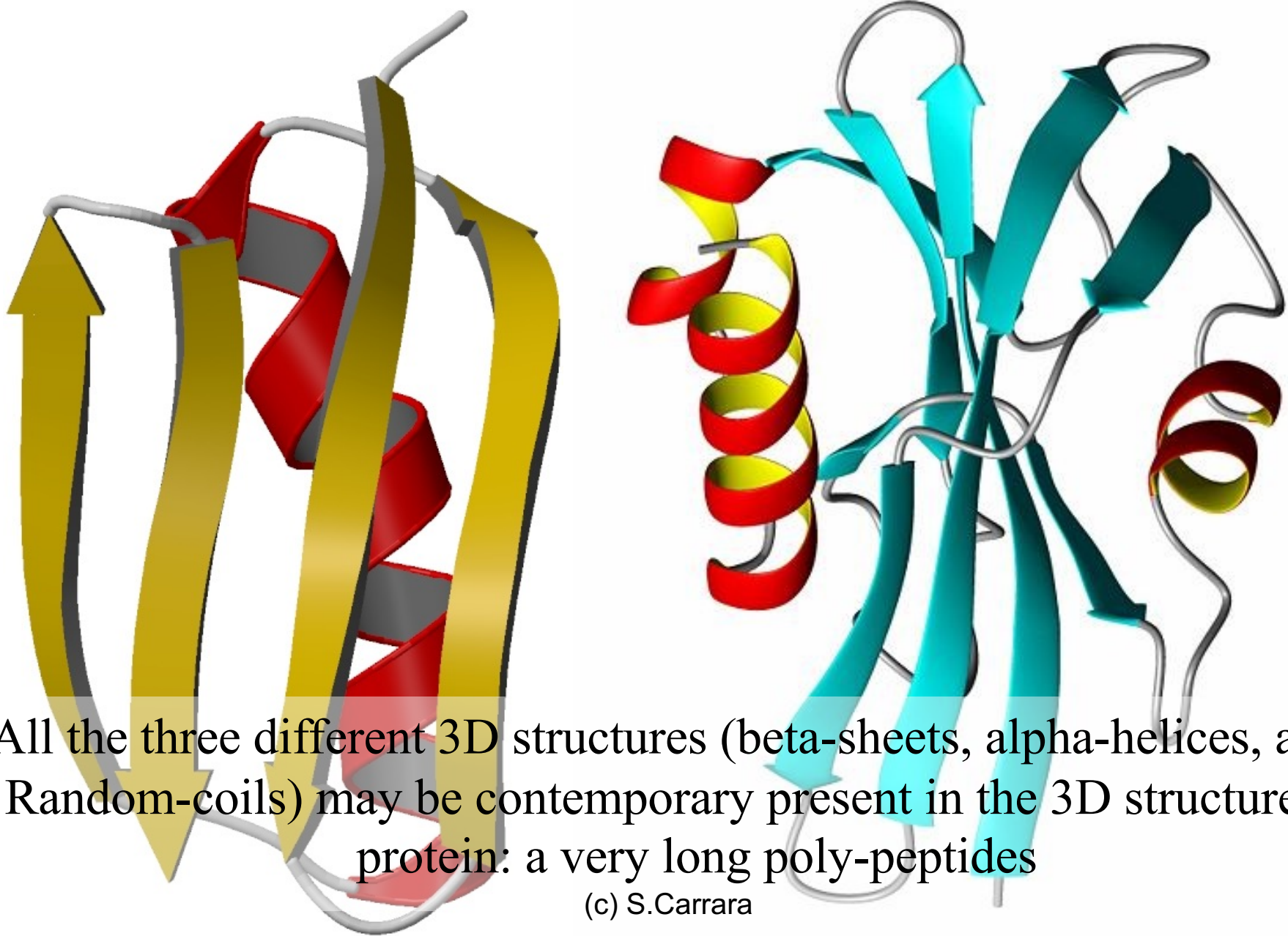
Peptides are short polymers that assume particular 3D structure: e.g. random-coil

# Poly-Peptides 3D structure



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

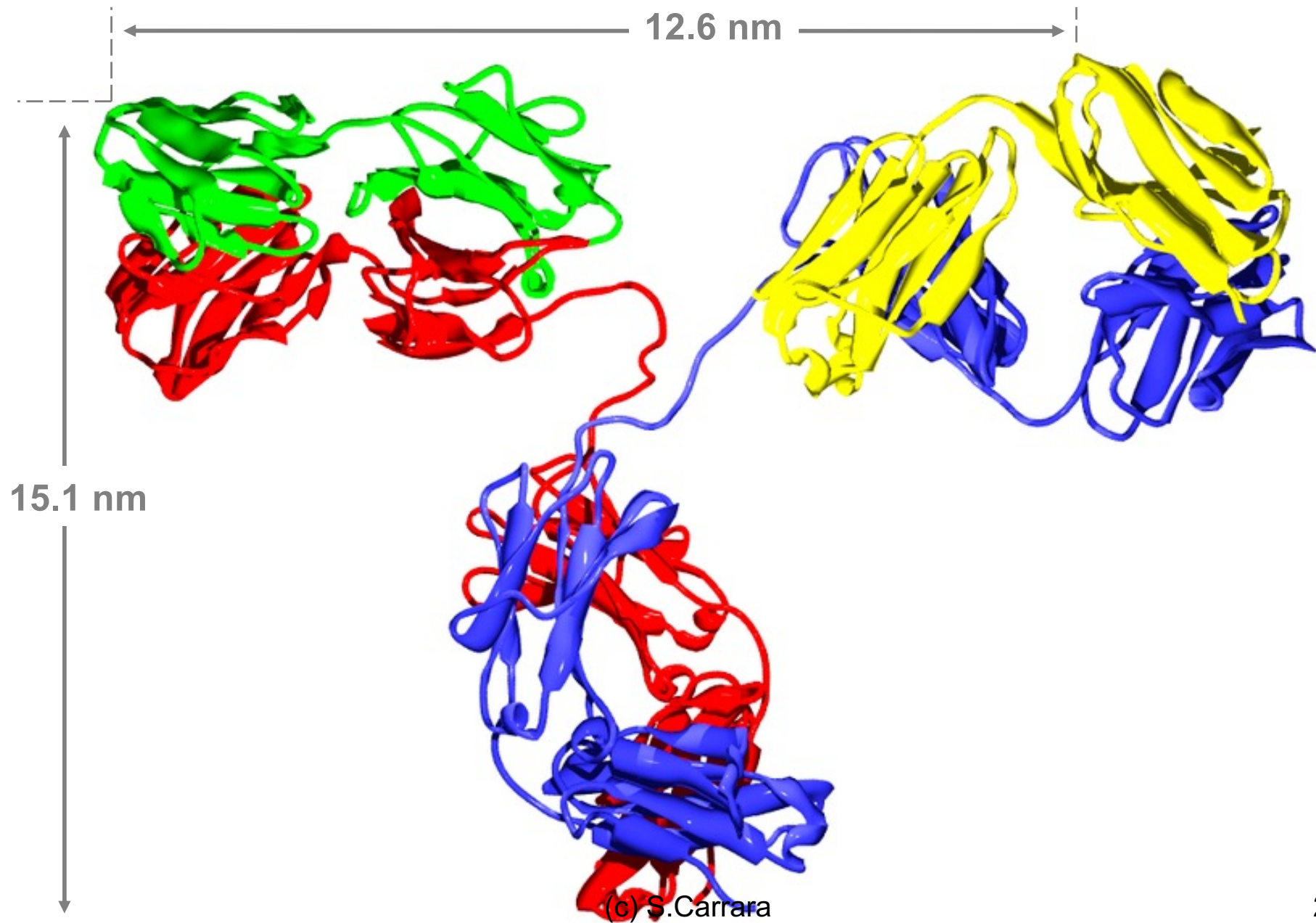
# Poly-Peptides 3D structure



# 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

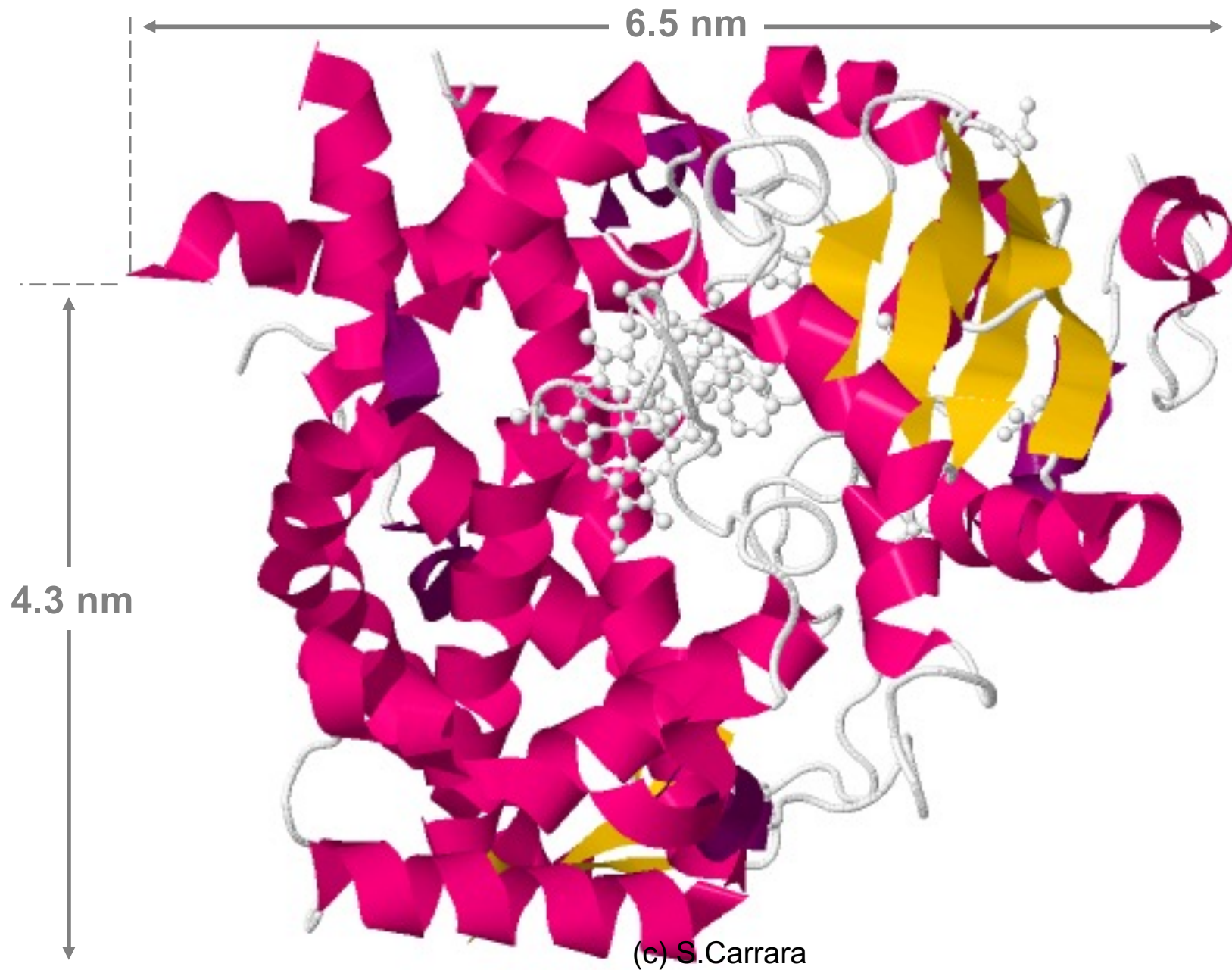


# Myoglobin

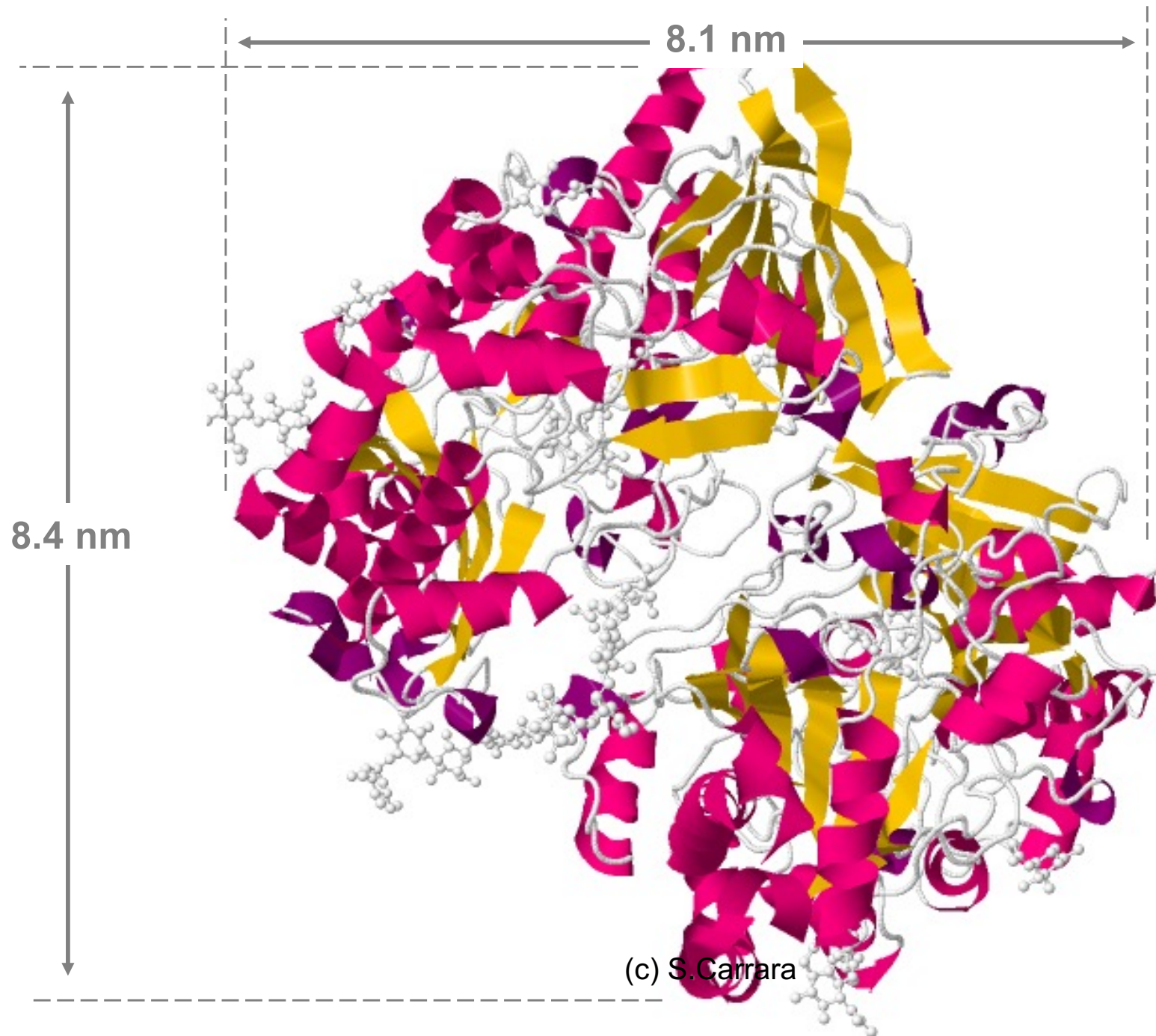


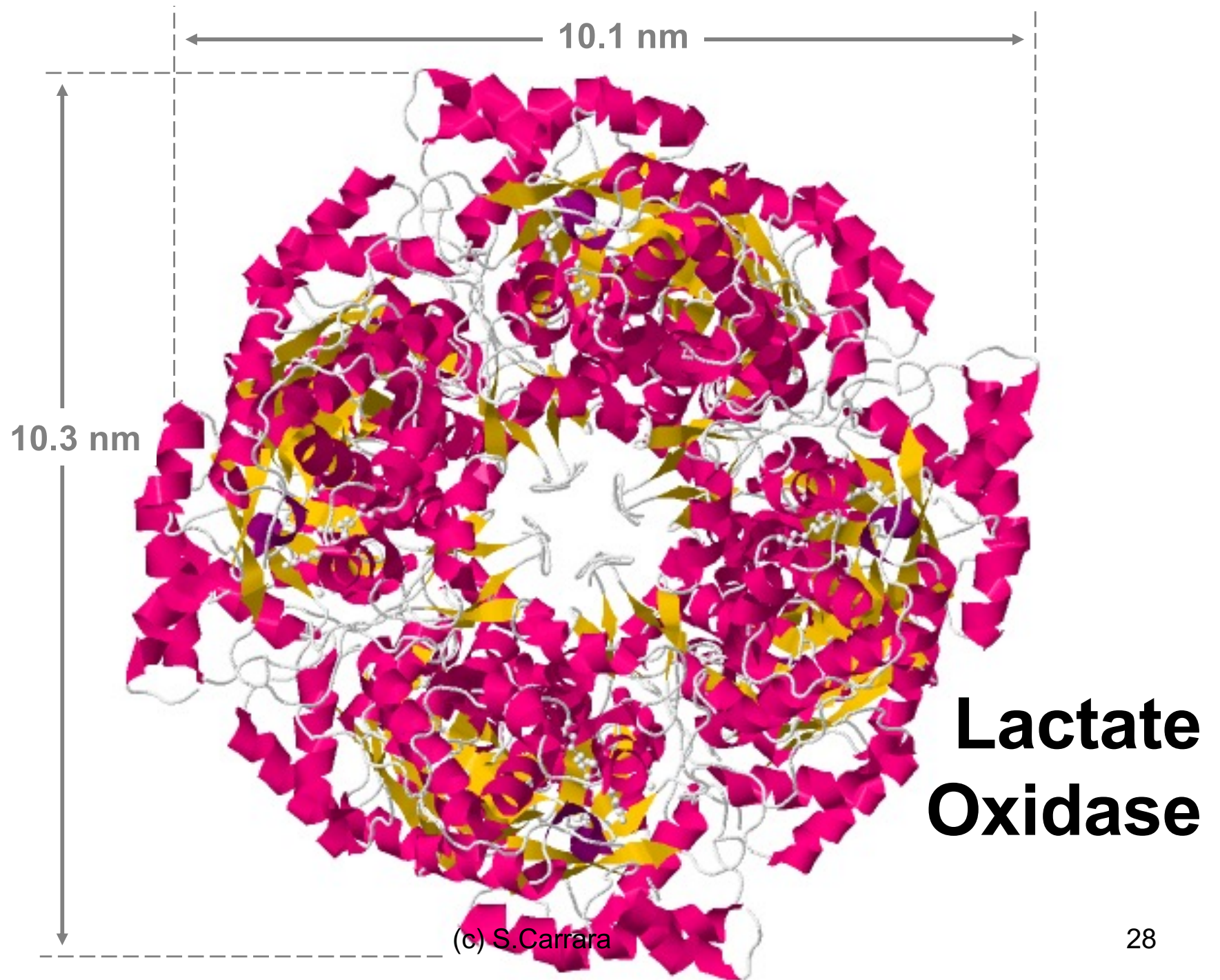
(c) S.Carrara

# Cytochromes P450



# Glucose Oxidase





# Structure-TO-Function in Proteins

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

Different 3D structures lead to  
different protein functions

# Outline on DNA

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(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

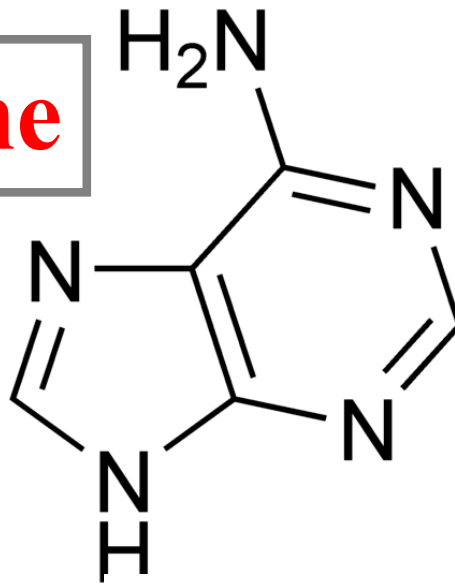
# DNA

## Definition

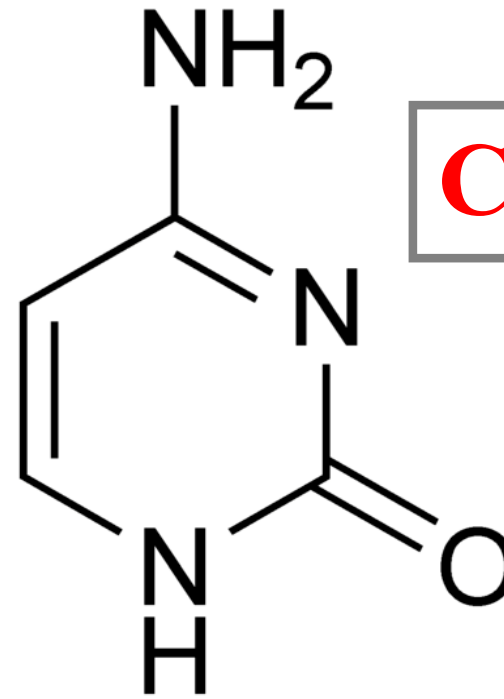
is a **nucleic acid** that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses.

# DNA Bases

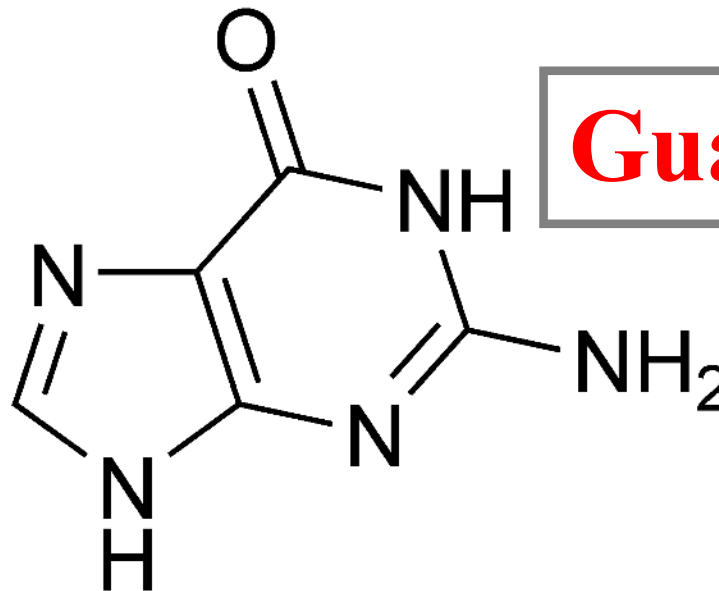
**Adenine**



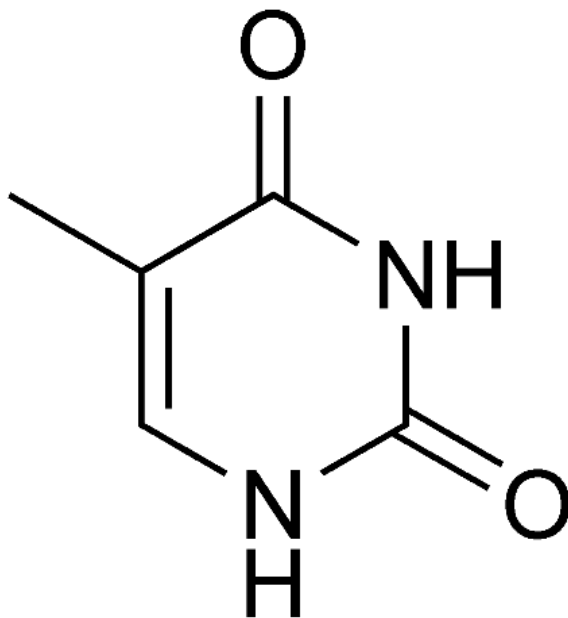
**Cytosine**



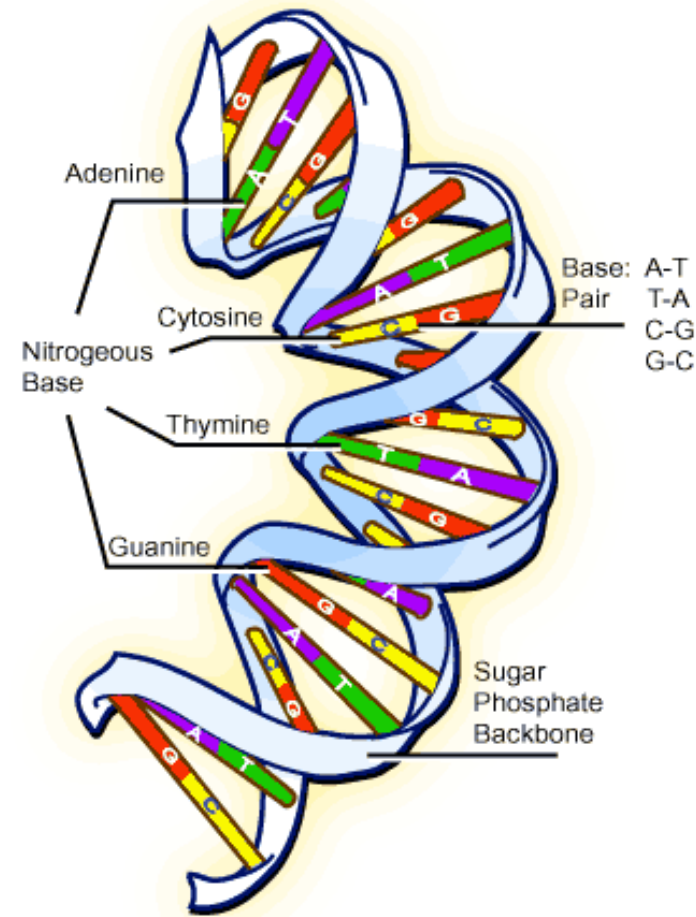
**Guanine**



**Thymine**

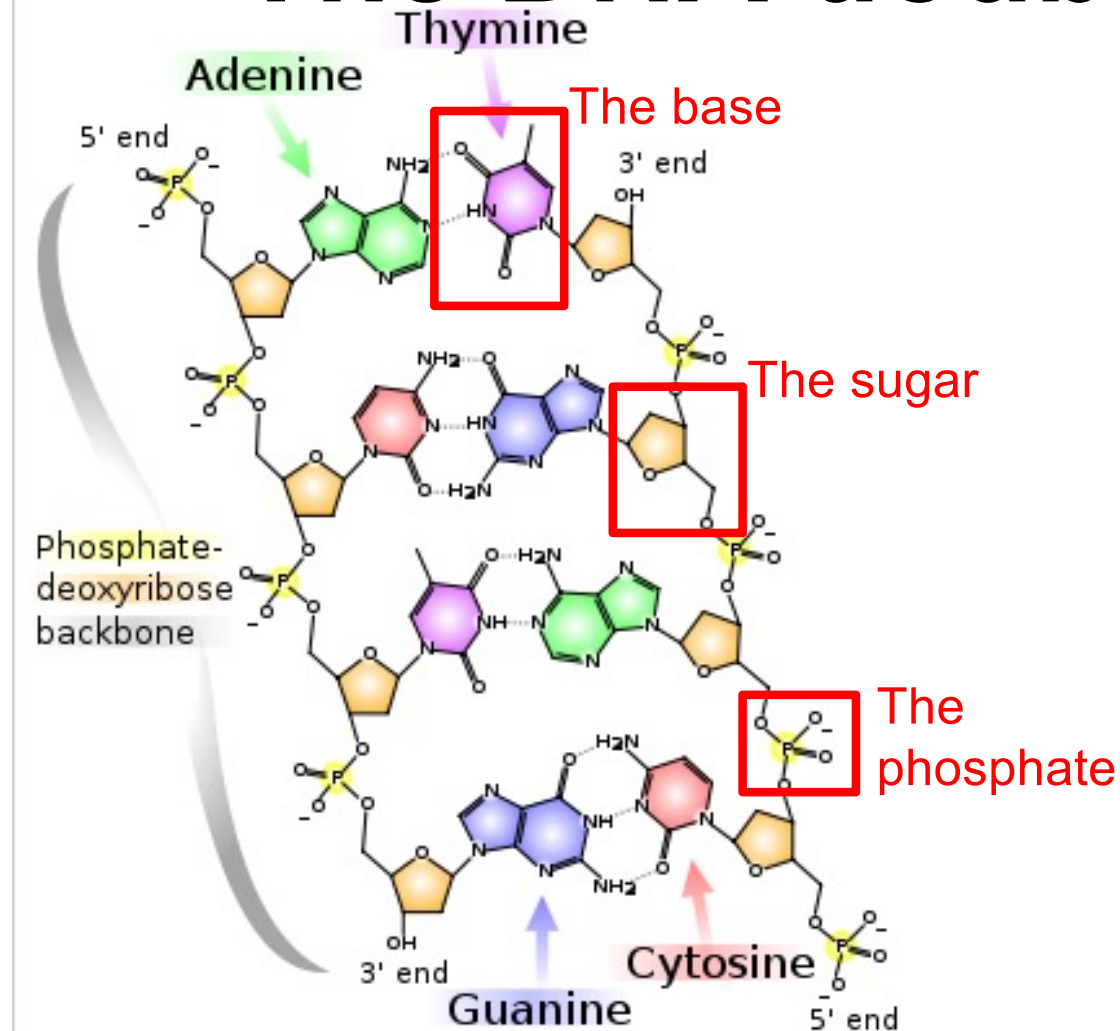


# DNA



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

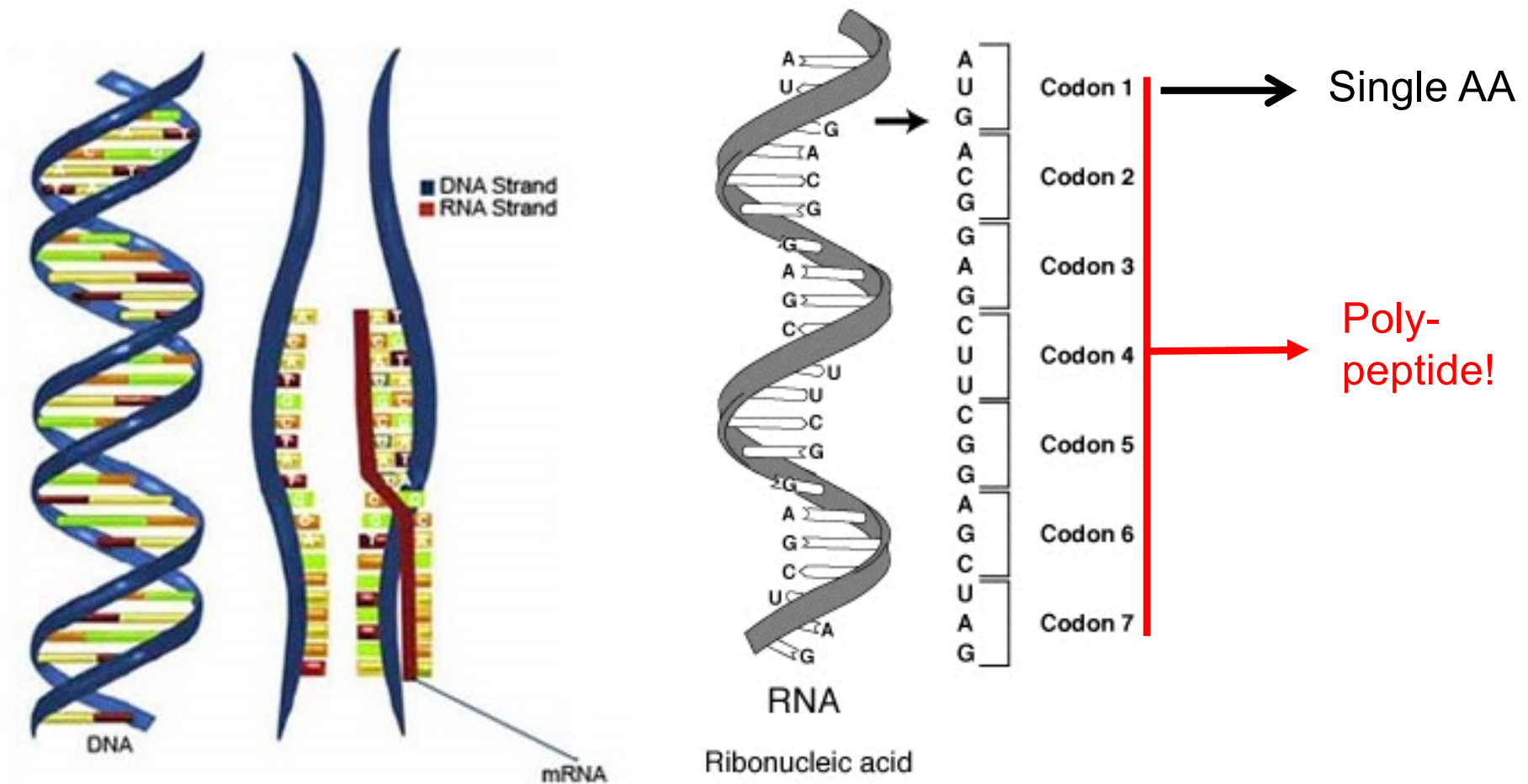
# The DNA double helix



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.

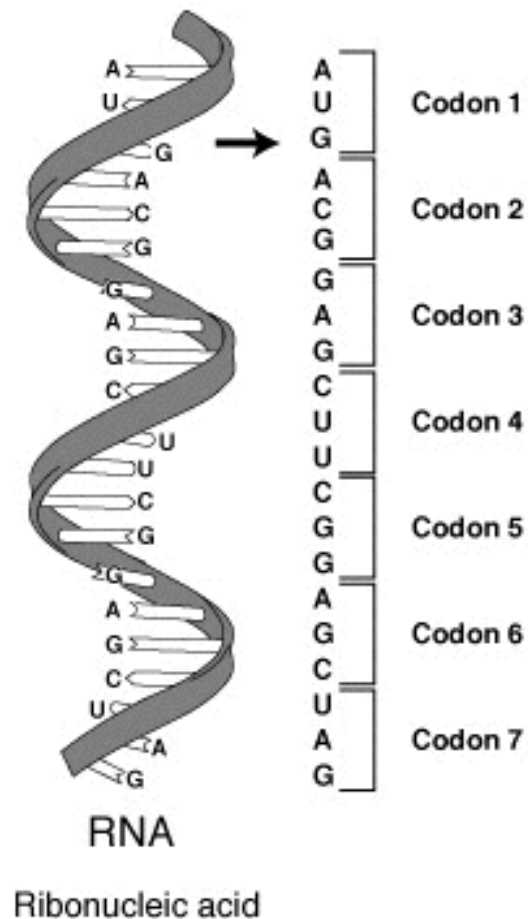
The base pairing forms very long double strength DNA chains

# 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 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)