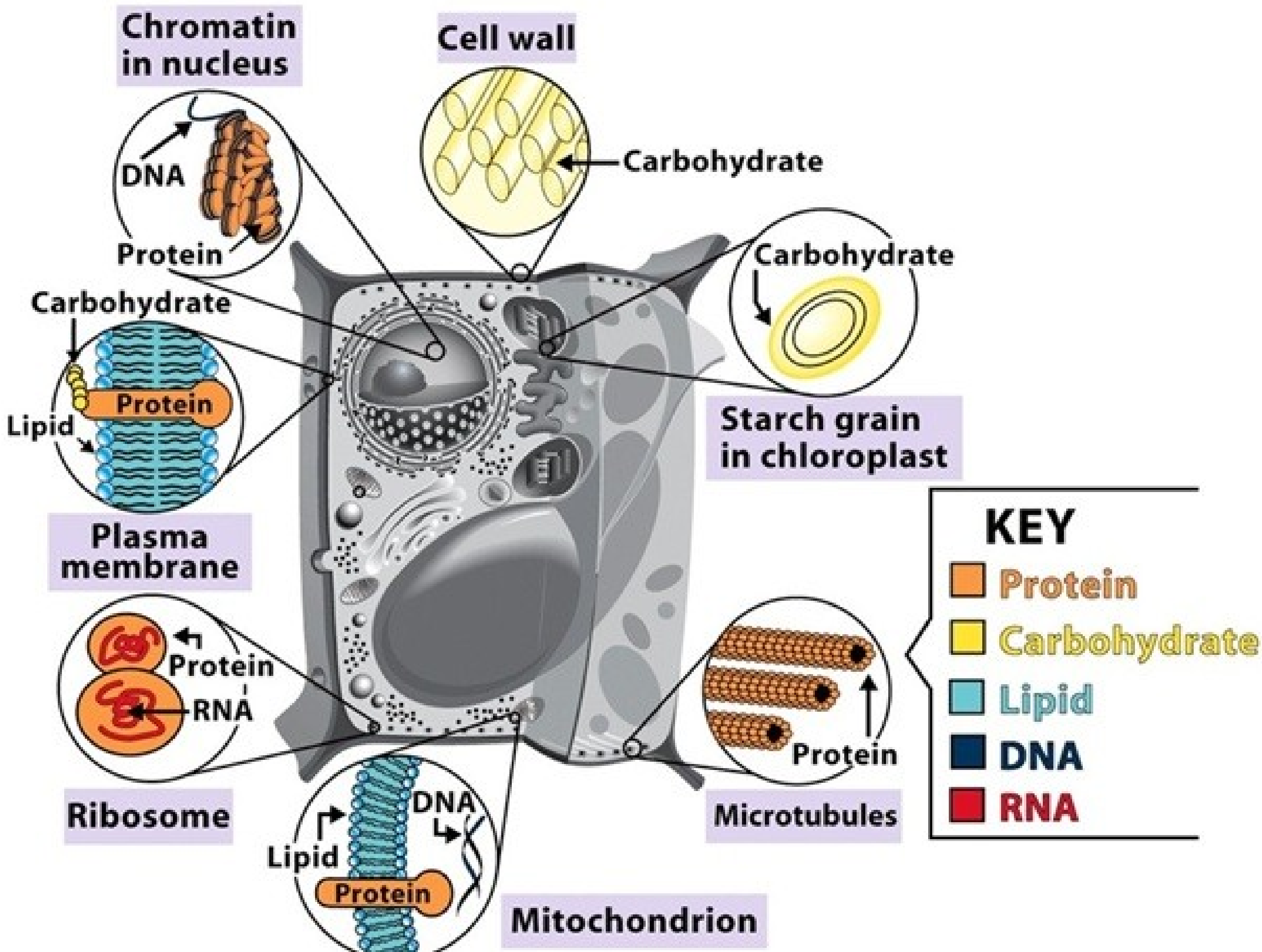
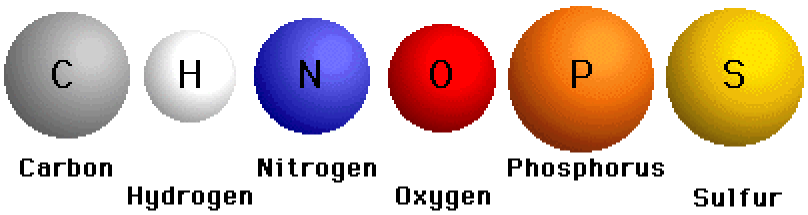
# Biological molecules



- Most biological molecules are made from covalent combinations of six important elements, whose chemical symbols are CHNOPS. the letters stand for the chemical abbreviations of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur..
- The four most important elements, which account for more than 99% of the atoms found in living things, are:
  **Carbon**
  **Hydrogen**
  **Oxygen**
  **Nitrogen**
- Biological molecules, or biomolecules, are built by joining atoms through covalent bonds.



# Why is carbon so special?

- Carbon has 4 valence electrons.
- Carbon can form up to four bonds with other atoms.
- This allows carbon (C) to form lots of different types of structures and molecules, all with different functions.
- Carbon can form long chains or ring structures, which can be thought as the ´basic skeletons´ of organic molecules to which groups of other atoms attach.

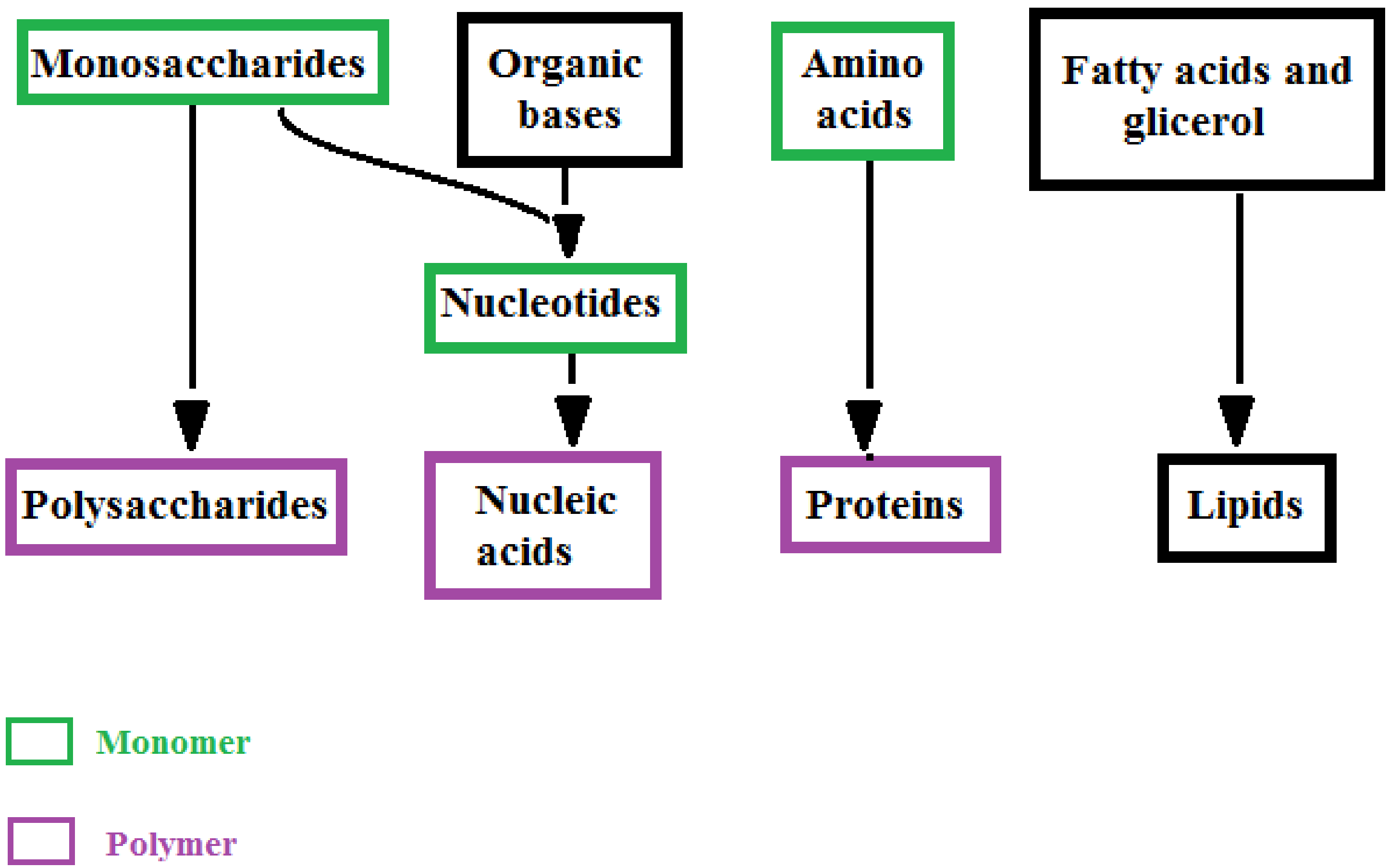
# What is a biomolecule or biological molecule?

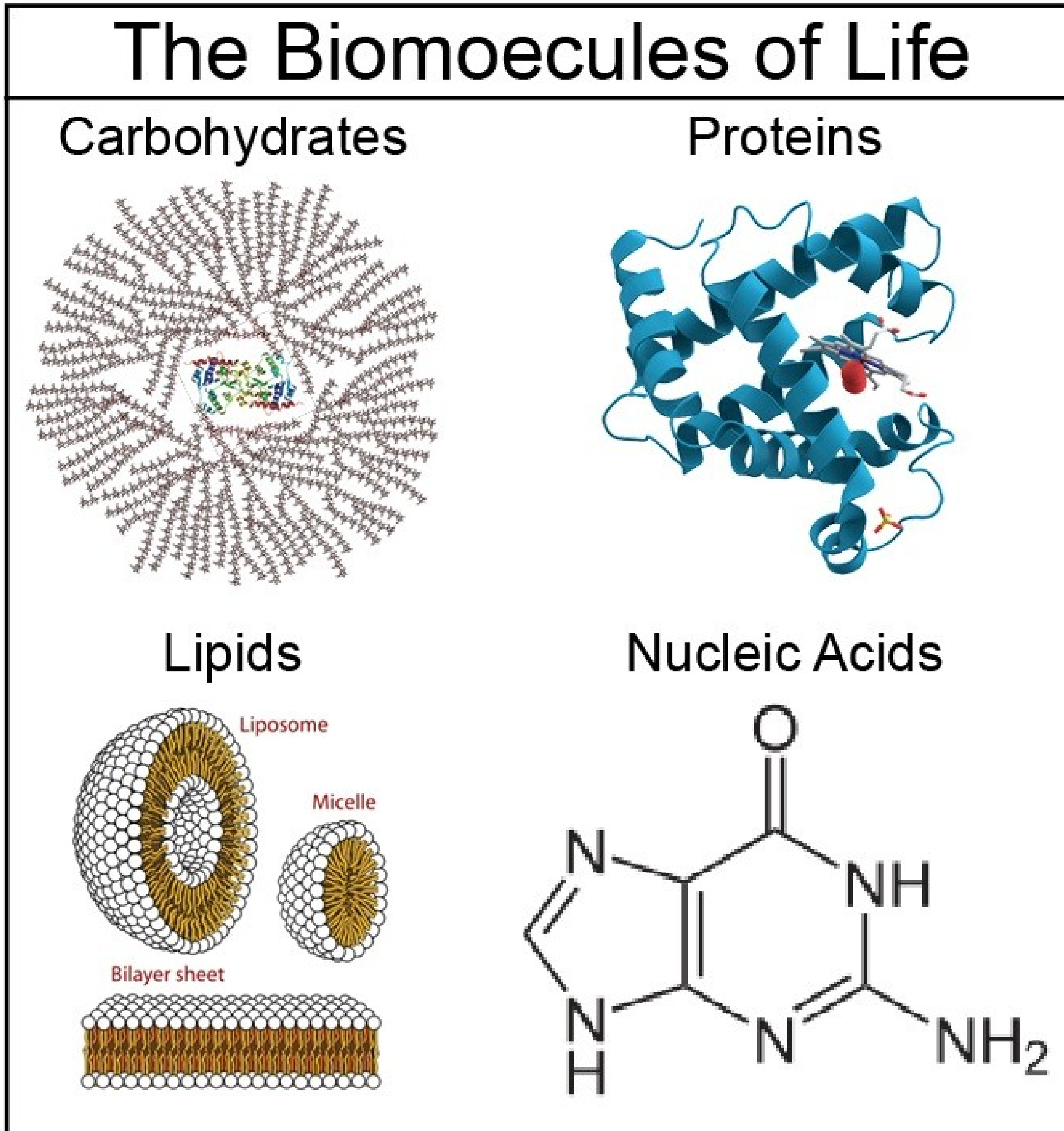
- Biomolecules are **organic molecules** especially **macromolecules** like carbohydrates, proteins in living organisms.  All living forms of life are made of similar macromolecules that are responsible for life.
  All forms of life are composed of biomolecules only.
- Biomolecules are molecules that occur naturally in living organisms.
- Biomolecules consists mainly of carbon and hydrogen with nitrogen, oxygen, sulphur, and phosphorus.
- Biomolecules include macromolecules like proteins, carbohydrates, lipids and nucleic acids. But, it also includes small molecules like primary and secondary metabolites and natural products.
- Biomolecules are very large molecules of many atoms, that are covalently bound together.

# Some definitions to keep in mind…

- Organic molecule: contains at least C (carbon) and H (hydrogen)
- Macromolecule (“giant molecule”): large biological molecule, such as a protein or nucleic acid
- Monomer: a relatively simple molecule which is used as a basic building block for thr synthesis of a polymer. Many monomers join together make a polymer.
- Polymer: a giant molecule made from many similar repeating subunits joined together in a chain.

# Monomers and polymers

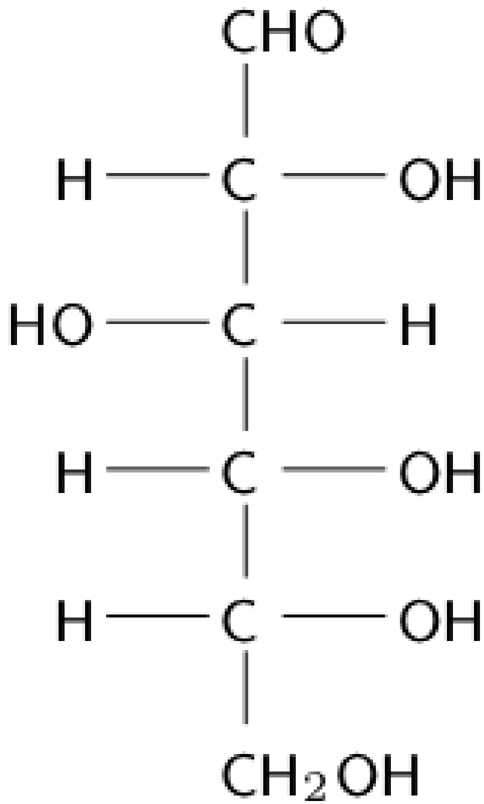


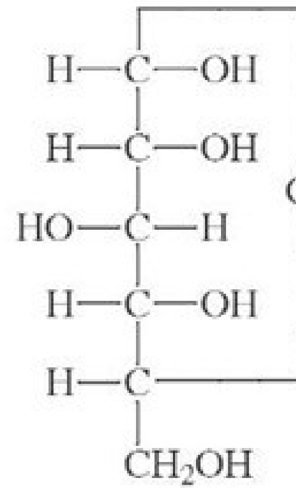


The Biomoecules of Life
Carbohydrates
Proteins
Lipids
Liposome
Micelle
Bilayer sheet
Nucleic Acids
O
N
NH
N
H
N
NH2

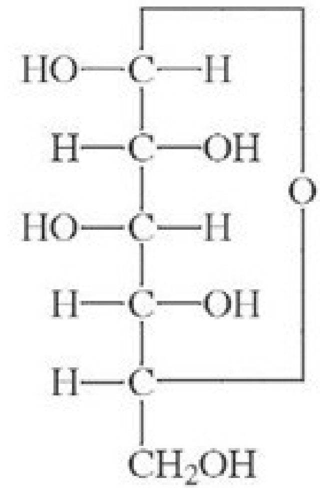
# Carbohydrates

- Molecular formula: shows the atoms an its amount
- Structural formula: shows the arrangements of the atoms using a diagram.
- Ring structure: When the chain ´closes´

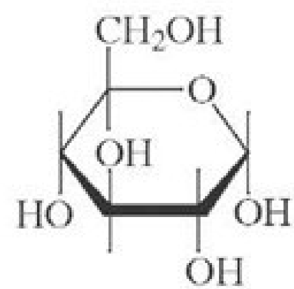




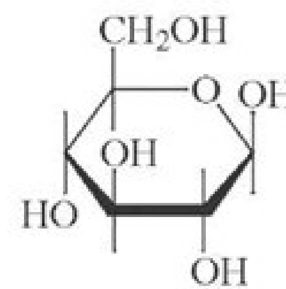
**α-D-Glucose**
**(Fischer projection)**



**β-D-Glucose**
**(Fischer projection)**



**α-D-Glucose**
**(Haworth projection)**

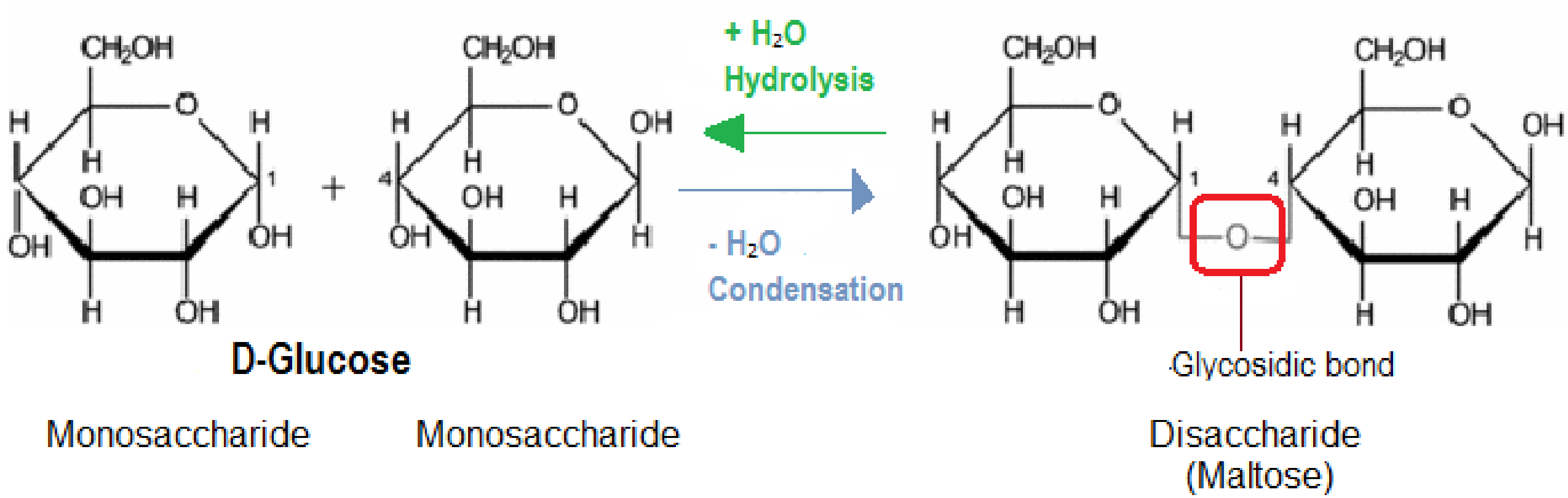


**β-D-Glucose**
**(Haworth projection)**

# Formation of the glycosidic bond: Condensation

Monosaccharides have to major functions:

- Commonly used as a source of energy
- Are important as building blocks for larger molecules
- Monosaccharides and disaccharides are sugars.



# Polysaccharides.

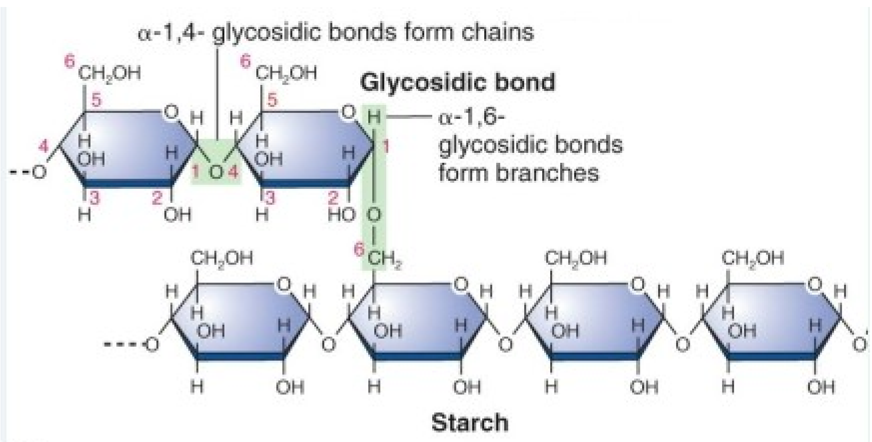
- Polysaccharides are polymers of monosaccharides. They are unsweet, and complex carbohydrates. They are insoluble in water and are not in crystalline form. Examples:starch, glycogen,cellulose.
- Starch and glycogen
- Cellulose
- Structure and function

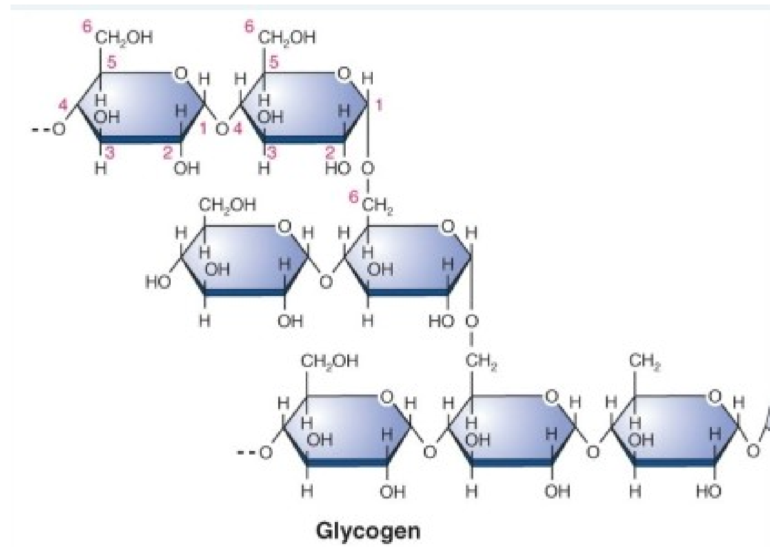
# Storage of glucose

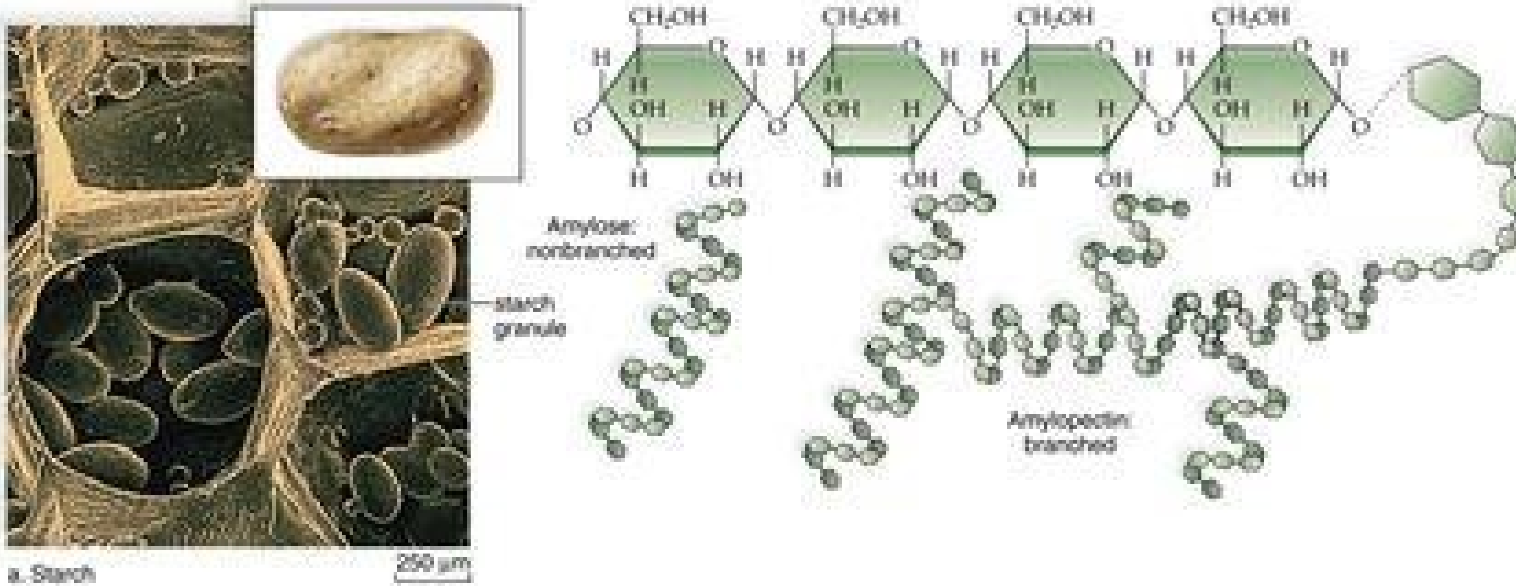
- Glucose is the main form of energy for cells, which is why it is important for livinf organisms to store it.
- If glucose was accummulated in cells:
  1. It would affect osmotic properties
  2. It would interfere with the cell chemistry
- How to solve the problem? Glucose is converted to a storage polysaccharide form:
  Starch in plants
  Glycogen in animals
- Glucose can become quickly available again for the organism, by a quick enzyme-controlled reaction

# Starch and glycogen

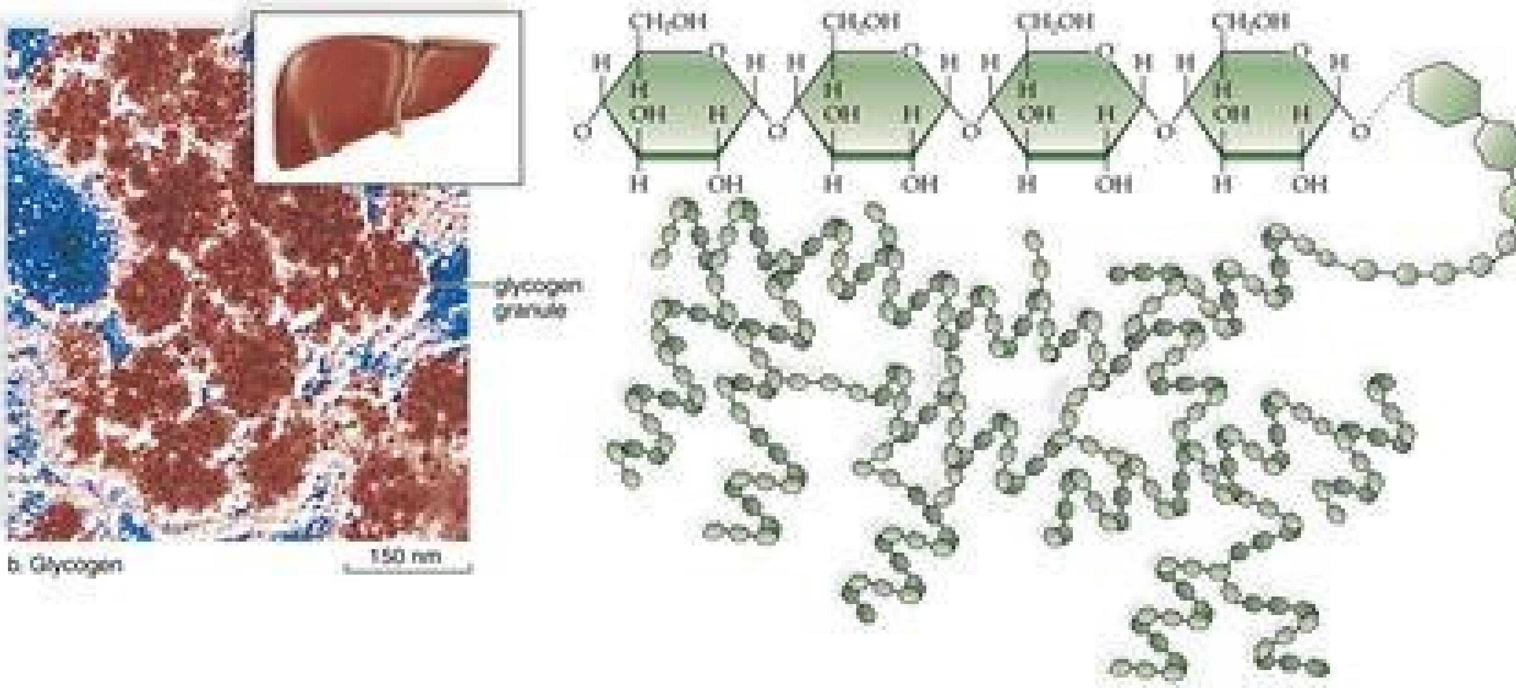
- **Starch:**
- Mixture of two substances: amylose and amylopectin
- Amylose: 1,4 linked molecules of glucose --- Unbranched
- Amylopectin: 1,4 linked glucose, but with branvhes (1,6 linkages)
- **Glycogen**:
- Only one type of molecule, similar to amilopectin, but more branched





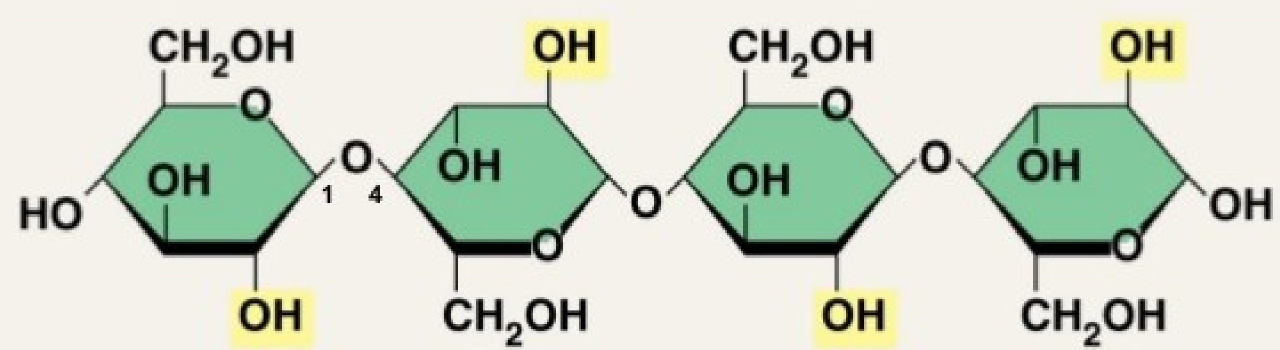
$CH_2OH$
H
O
OH
Amylose: nonbranched
starch granule
Amylopectin: branched
a. Starch
250 µm

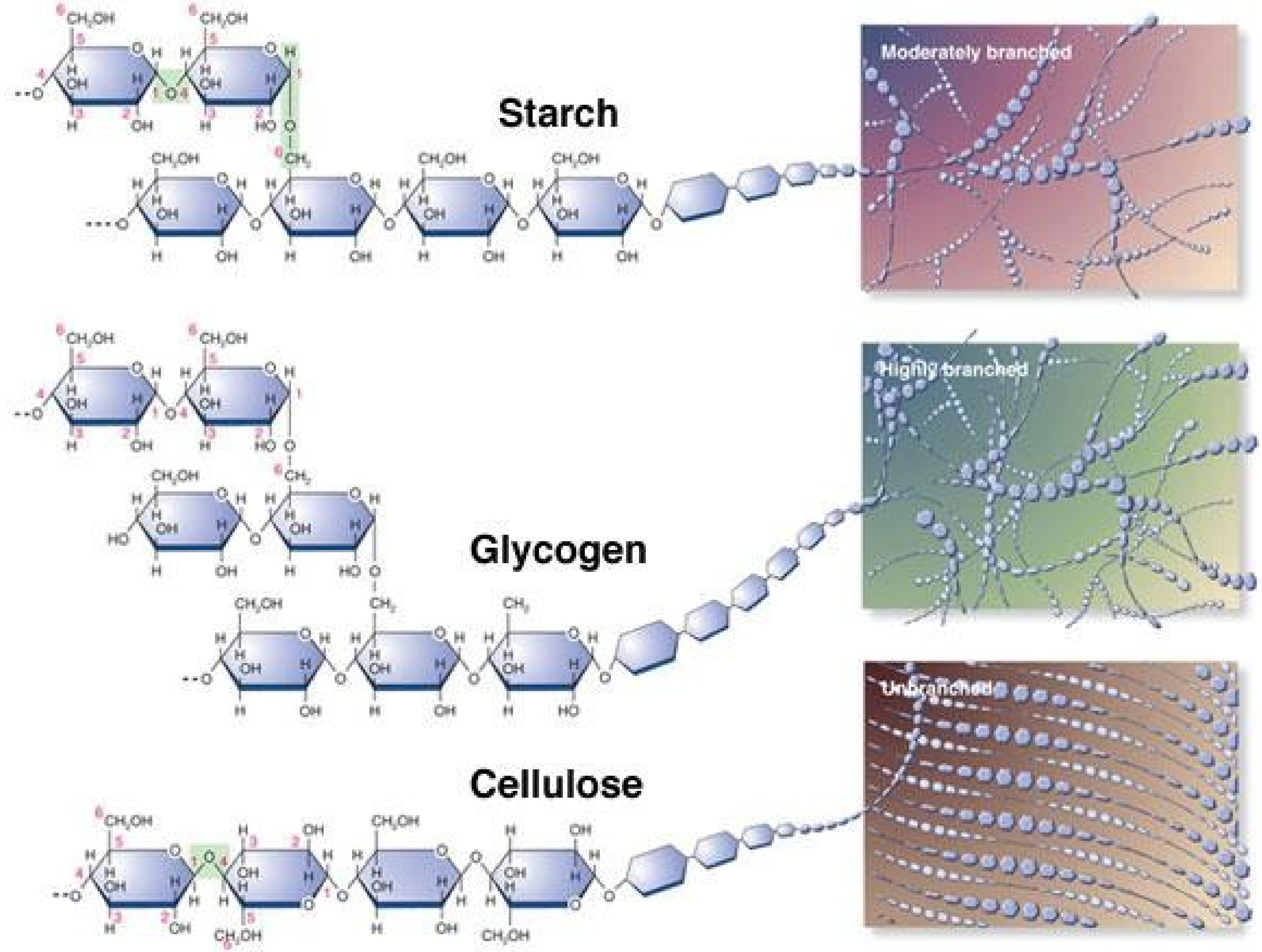
$CH_2OH$
H
O
OH
glycogen granule
b. Glycogen
150 nm

# Cellulose

- Most abundant molecule on the planet (due its presence in plant cell walls and slow rate of breakdown)
- Mechanically strong molecule – form cell walls
- Differs from starch and glycogen, because cellulose is formed by β-glucose.
- This arrangement  allows formation og hydrogen bonds – STRONG!!!!!




(c) Cellulose: 1–4 linkage of β glucose monomers

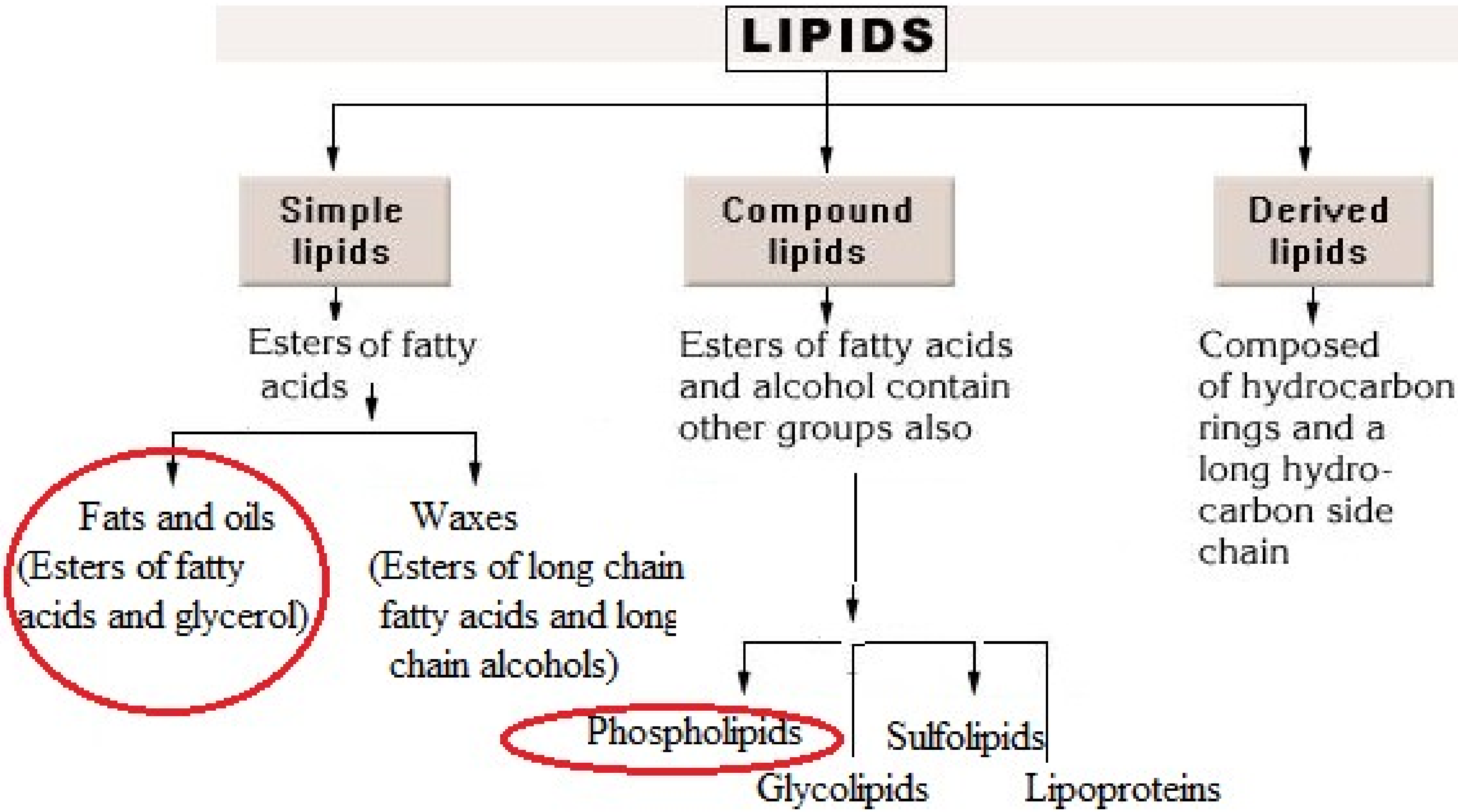


Starch
Moderately branched
Glycogen
Highly branched
Cellulose
Unbranched

# Lipids

- The lipids are a heterogeneous group of naturally occuring compounds (organic), that are related more by their physycal than by their chemical properties.
- They have in common the property of being relatively **insoluble in water** and **soluble in nonpolar solvents** such as ether and chloroform.
- ´True lipids´ are esters formed by fatty acids combinig with an alcohol.

# Classification of lipids

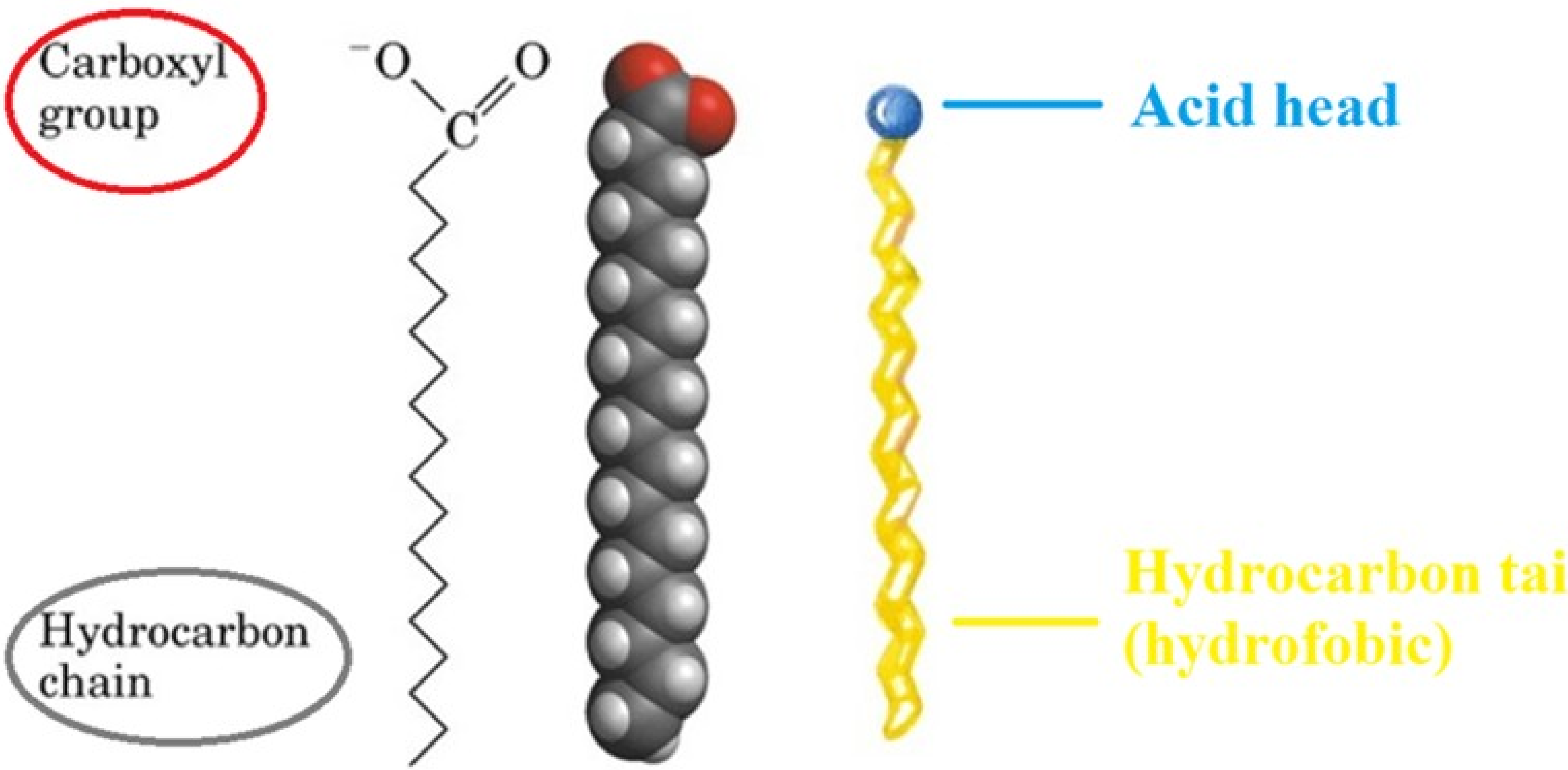


# Fatty acids

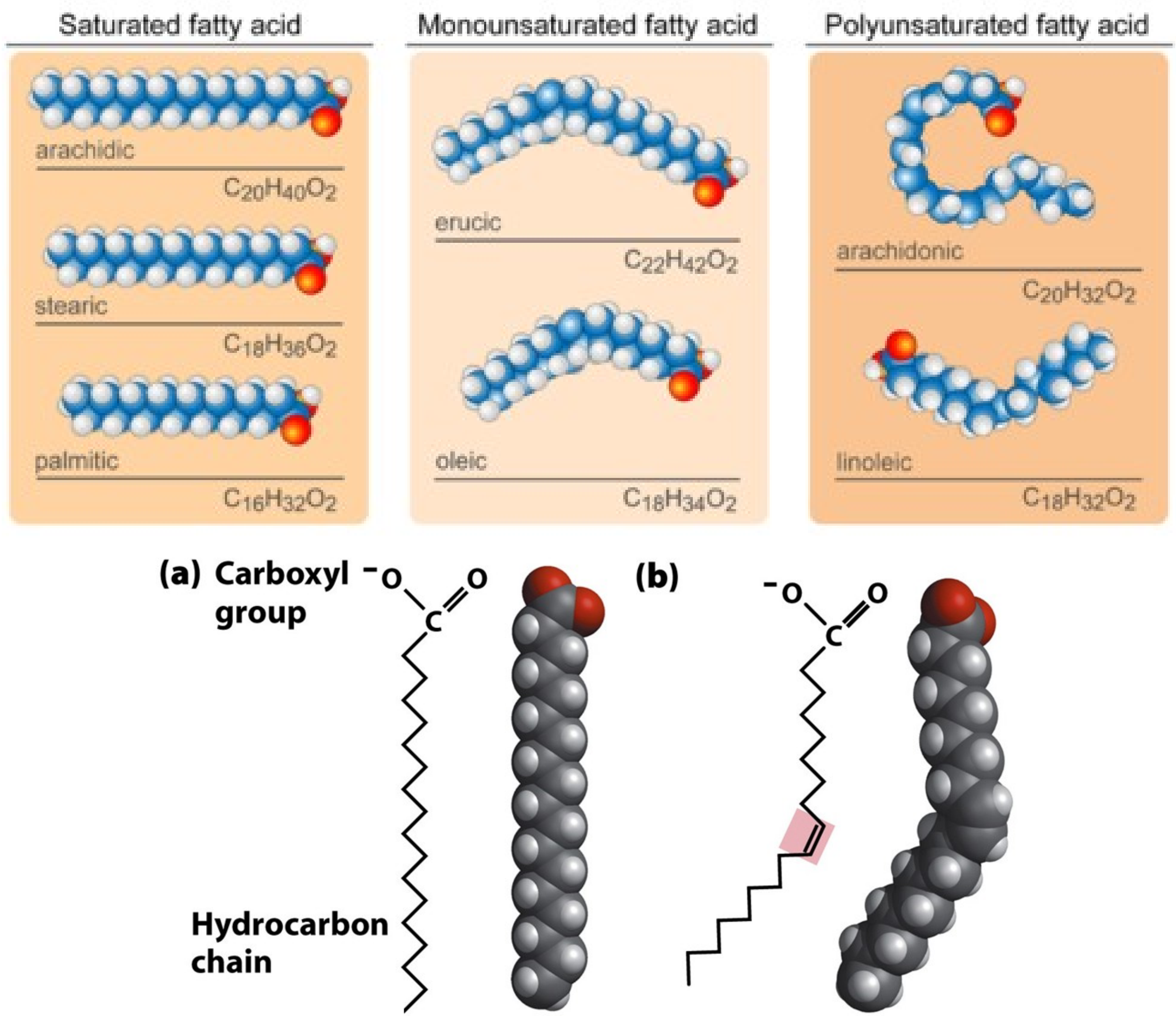
- Fatty acids are important component of lipids in plants, animals, and microorganisms.
- A fatty acid consists of a straight chain of carbon atoms, with hydrogen atoms along the length of the chain and at one end of the chain, and a carboxyl group (−COOH) at the other end. It is that carboxyl group that makes it an acid (carboxylic acid).
- Fatty acids are included in the group of derived lipids

- If the carbon-to-carbon bonds are all single, the acid is saturated; if any of the bonds is double or triple, the acid is unsaturated and is more reactive.

# Fatty acid structure

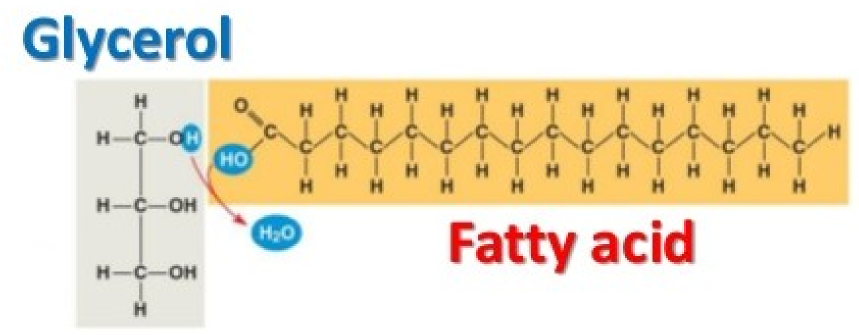


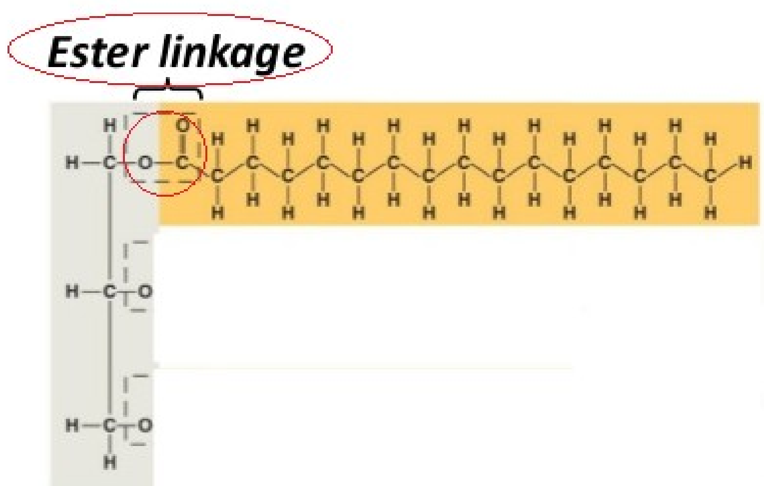
# Saturated and unsaturated fatty acids

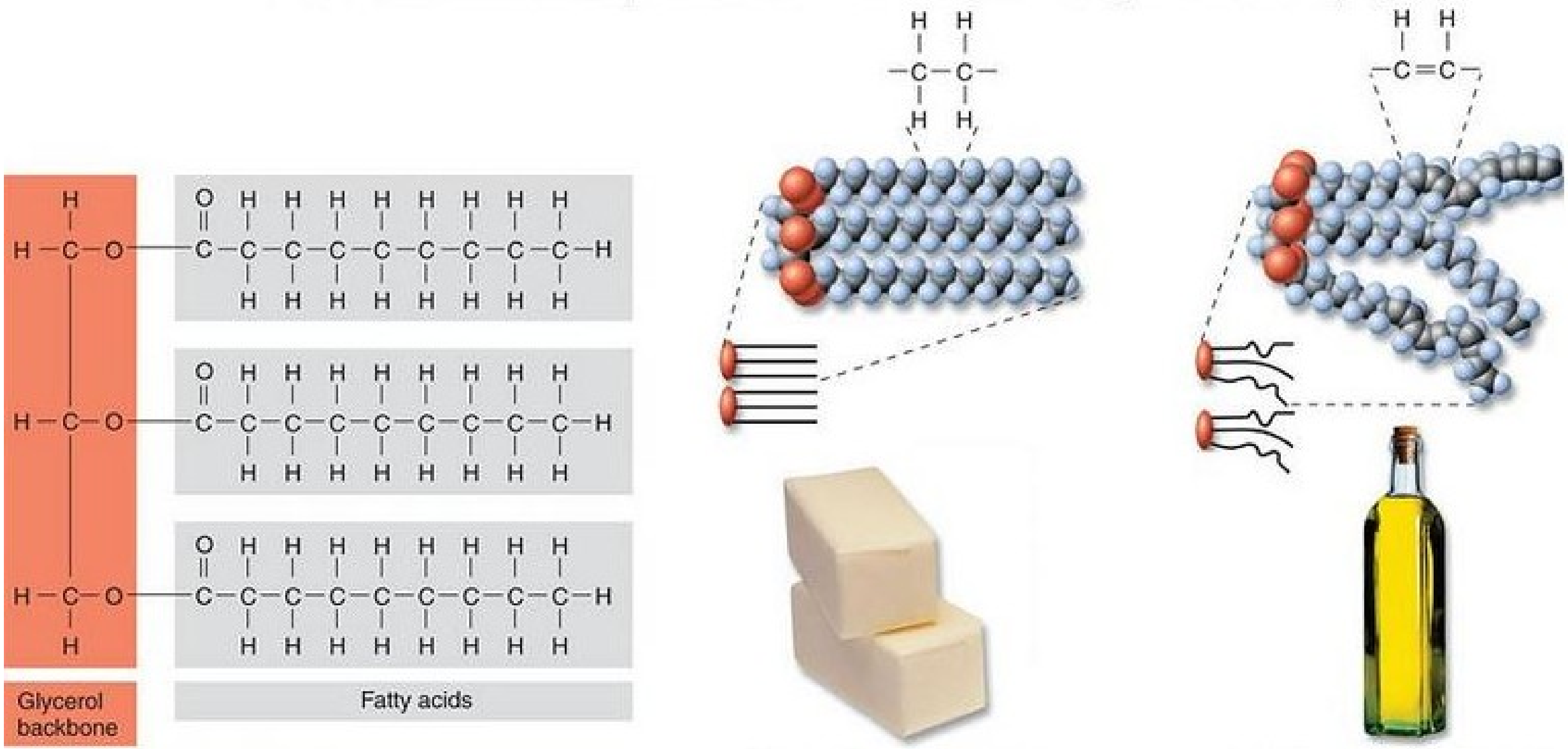


- Fatty acids are not found in a free state in nature; commonly they exist combined with glycerol forming triglycerides.
- Alcohols are a series of organic molecules wich contain a hydroxil group (-OH) attached to a carbon atom.
- **Glycerol** is an alcohol with three carbons and three hydroxyl groups.
- The reaction between an acid and an alcohol, called **condensation**, produces a chemical known as **ester**. The chemical link established between an alcohol and an acid is called **ester bond**. In every condensation reaction water is formed.
- **Tryglicerides** are esters formed by one molecule of glycerol combined with three fatty acids.

# Condensation reaction





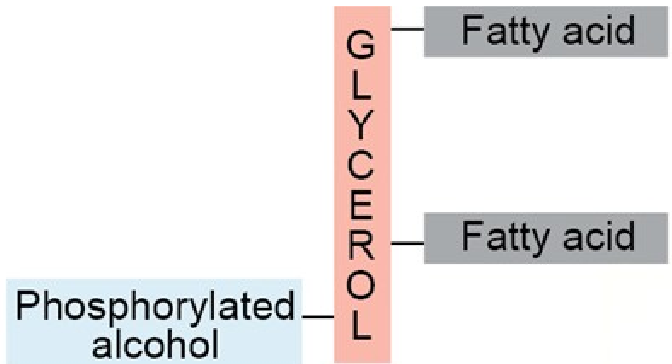

(a) Fat molecule (triacylglycerol)

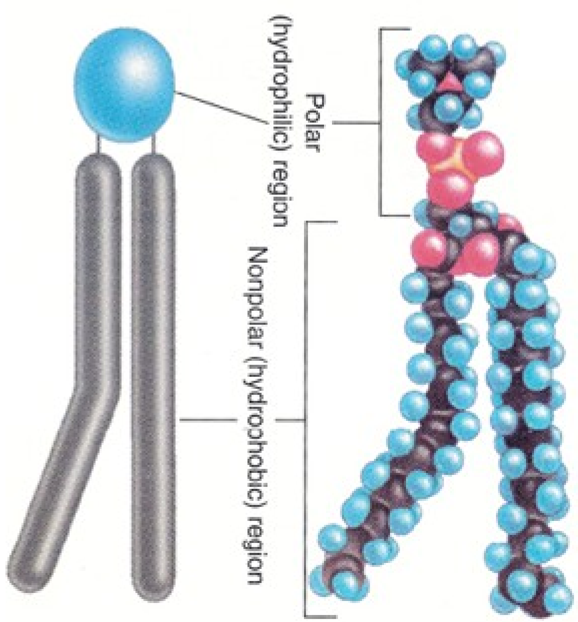
(b) Hard fat (saturated): Fatty acids with single bonds between all carbon pairs

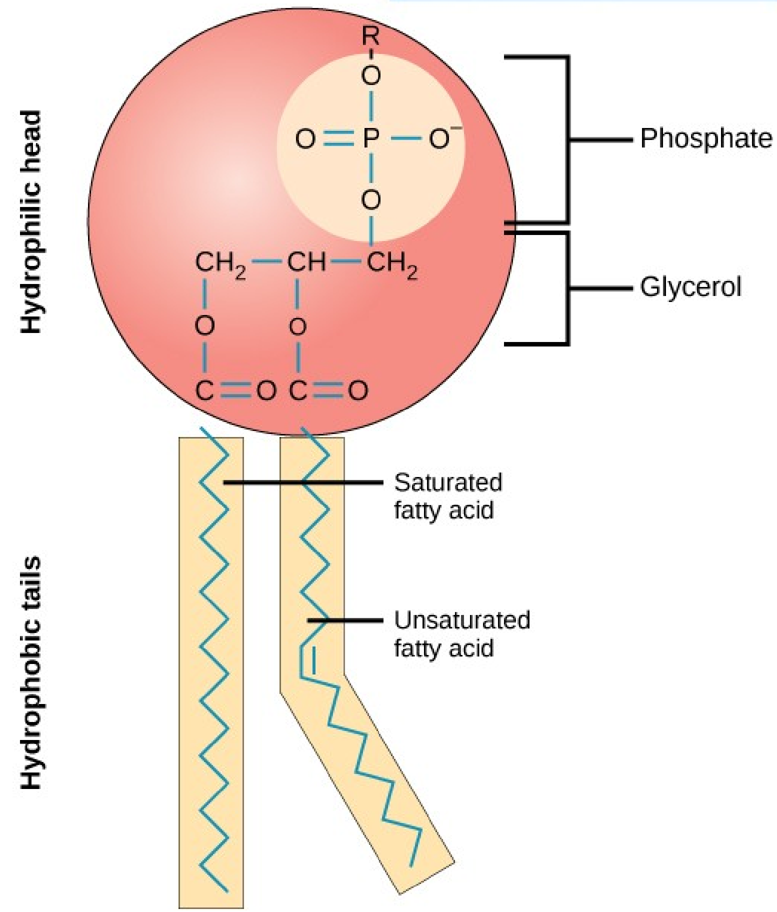
(c) Oil (unsaturated): Fatty acids that contain double bonds between one or more pairs of carbon atoms

# Phospholipids: a special type of lipid

**Phospholipids are amphipathic – have both polar & nonpolar portions**



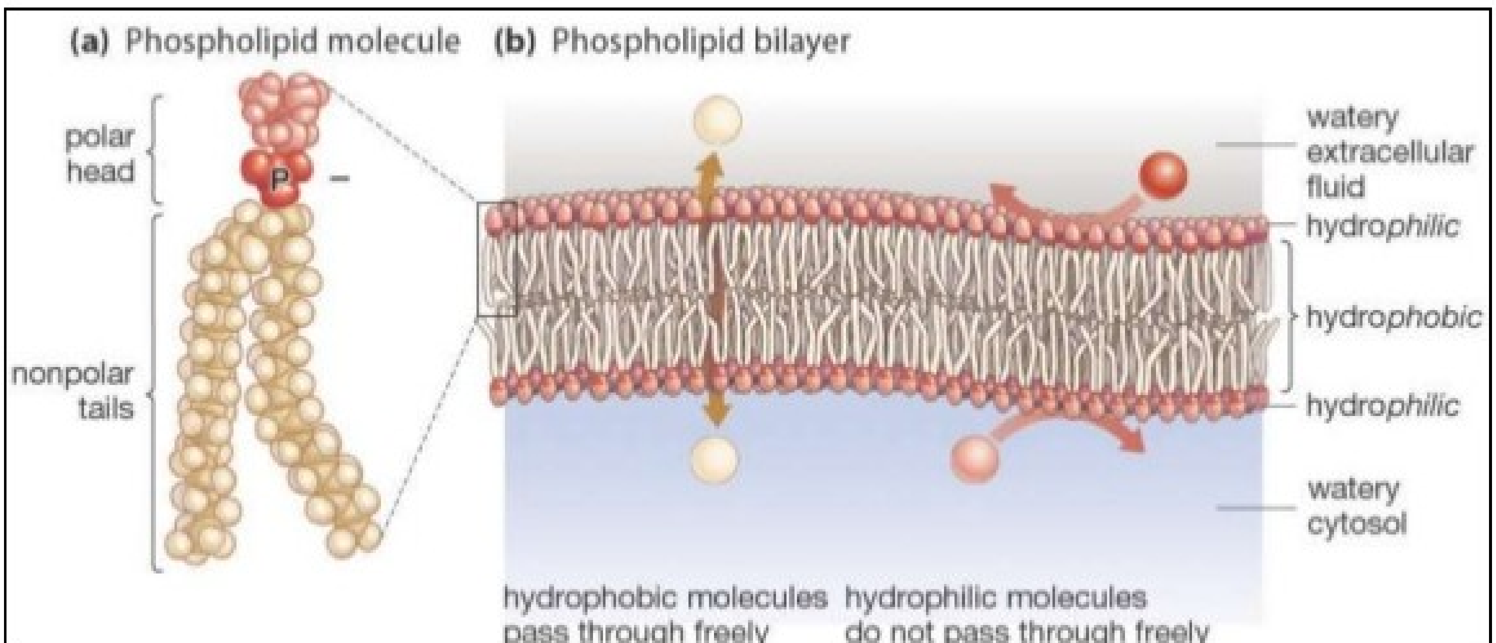
# Roles of lipids

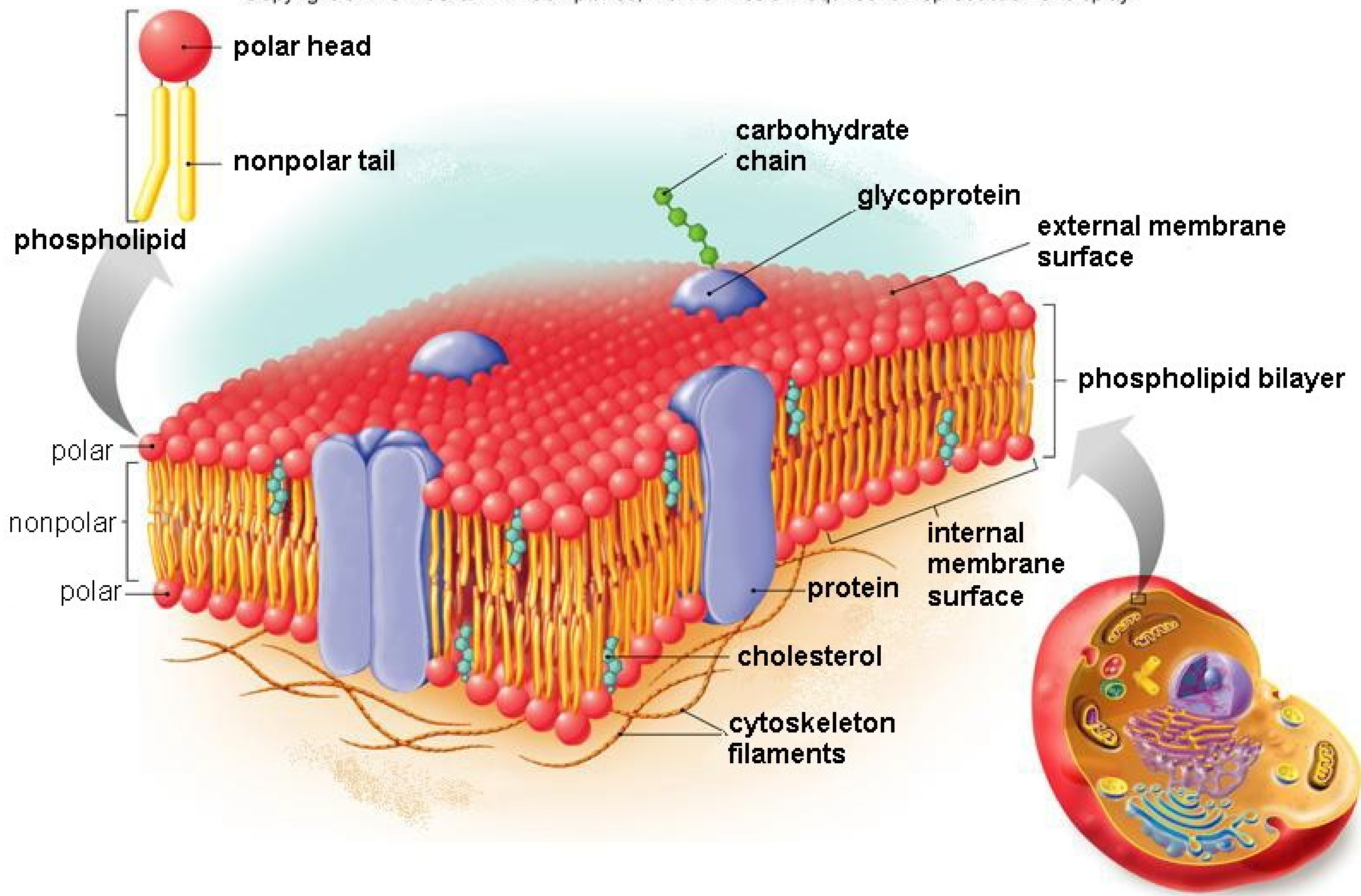
- **Triglycerides**
- Energy source
- Energy reserves (storage form of energy – adipose tissue)
- Body insulation and protection around organs
- Sensory qualities (adds flavor and texture to food)
- Contribute to satiety

- **Phospholipids**
- Form structure of membranes, matrix of cell wall, mielin sheath, among others
- Carriers of ions across membranes
- Perform many vital functions within the body

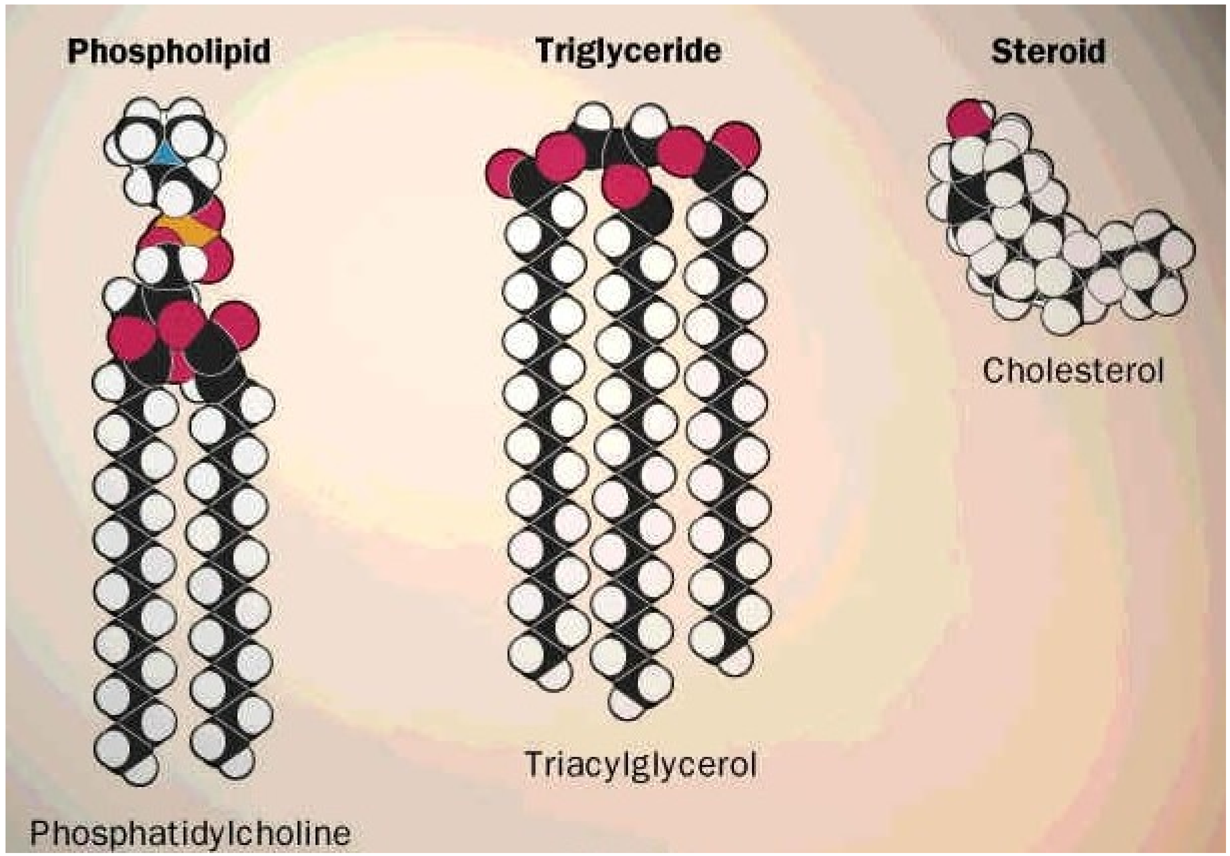
# Phospholipids are constituents of membranes

- Phospholipids are composed of a hydrophilic head, which is attracted to water, and two hydrophobic tails, which repel water. Because these cells contain molecules that simultaneously attract and resist water, they are considered **amphipathic** (both water-soluble and non-water-soluble).




polar head
nonpolar tail
phospholipid
carbohydrate chain
glycoprotein
external membrane surface
phospholipid bilayer
polar
nonpolar
polar
internal membrane surface
protein
cholesterol
cytoskeleton filaments

# Different lipids: how do they look?

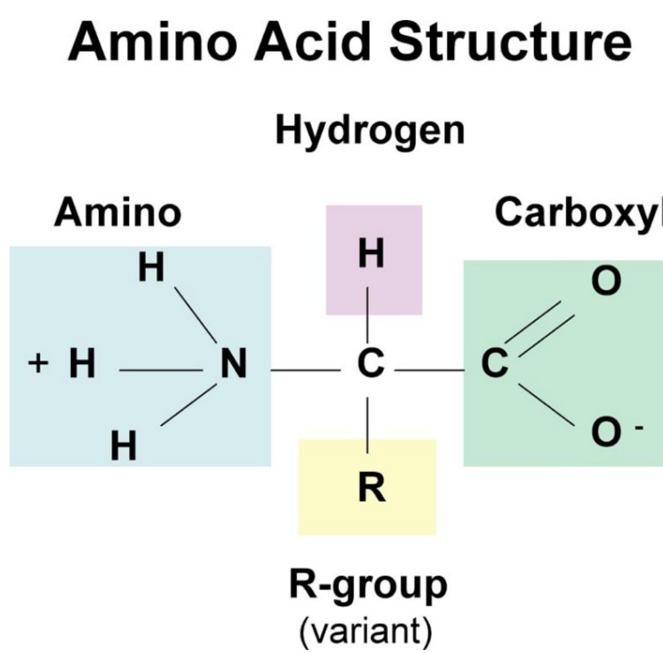


# Proteins

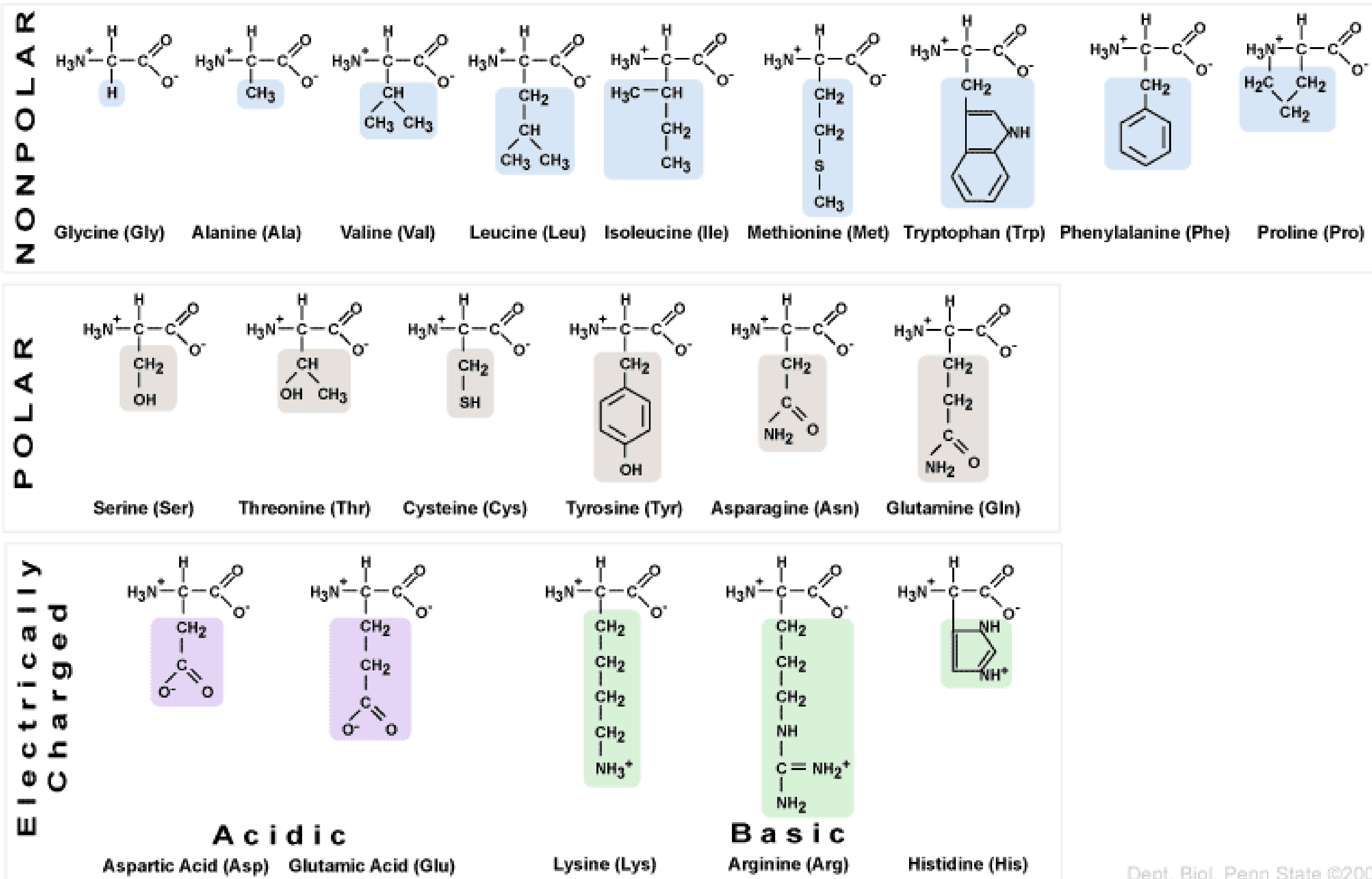
- Amino acids
- Peptide bond
- Primary, secondary, third and cuaternary structure

# Proteins

- Extremely important group of biological molecules. WHY?
- Huge variety, but common basic monomers: amino acids

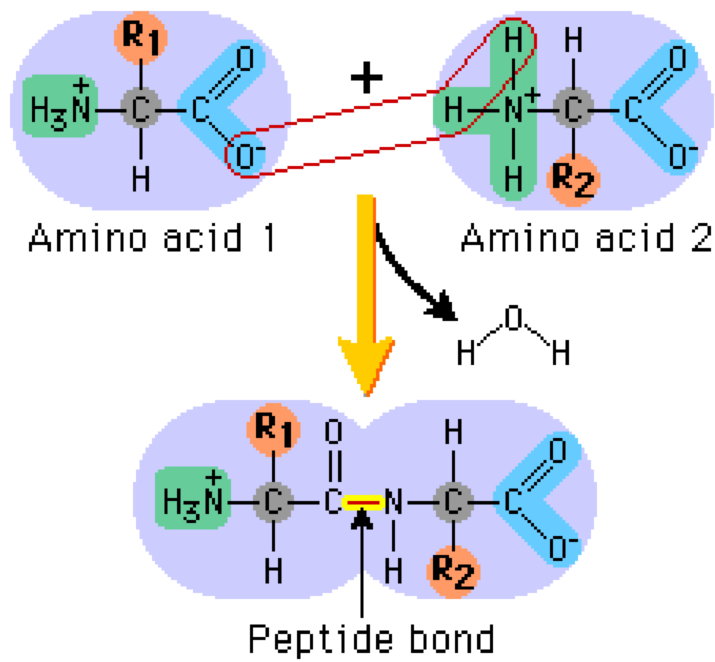


# Amino acid table

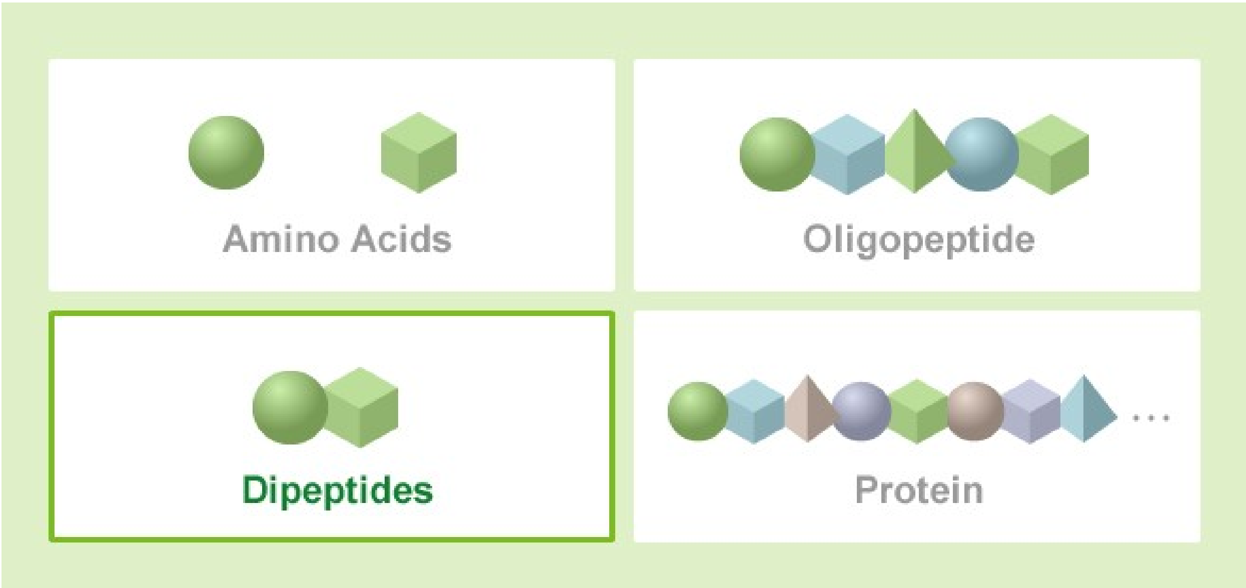


# Peptide bond

- Two amino acids can join together by a peptide bond
- In this reaction one molecule of water is formed
- Dipeptide: molecule formed by two amino acids
- Polypeptide: molecule formed by many amino acids linked
  Polypetides are another example of polymers and macromolecules



- Protein molecule may have just one polypeptide chain, or two or more chains interacting with each other



# Structure of proteins

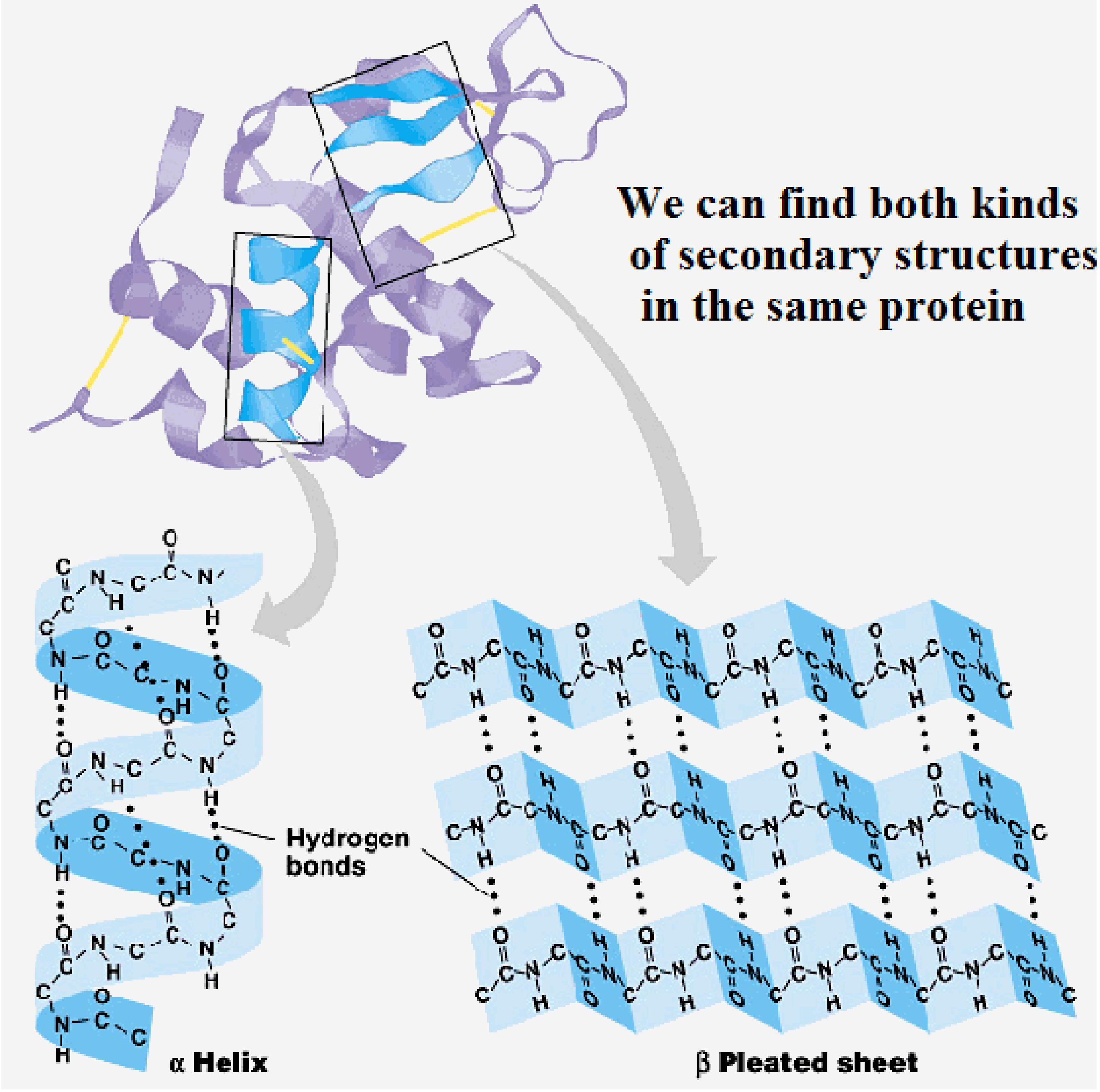
- **Primary structure**: is the sequence of amino acids in a polypeptide or protein.

- **Secondary structure**: is the structure of a protein molecule resulting from the regular coiling or folding of the chain of amino acids. E.g. β-pleated sheet α-helix.

- **Tertiary structure**: is the compact structure of a proteinmolecule resulting from the three-dimensional coiling of the already-folded chain of amino acids.
  IMPORTANT: different kind of bonds (SEE BOOKLET)

- **Quaternary structure**: is the three-dimensional arrangement of two or more polypeptides, or of a polypeptide and a non-protein component such as haem, in a protein molecule.

We can find both kinds of secondary structures in the same protein



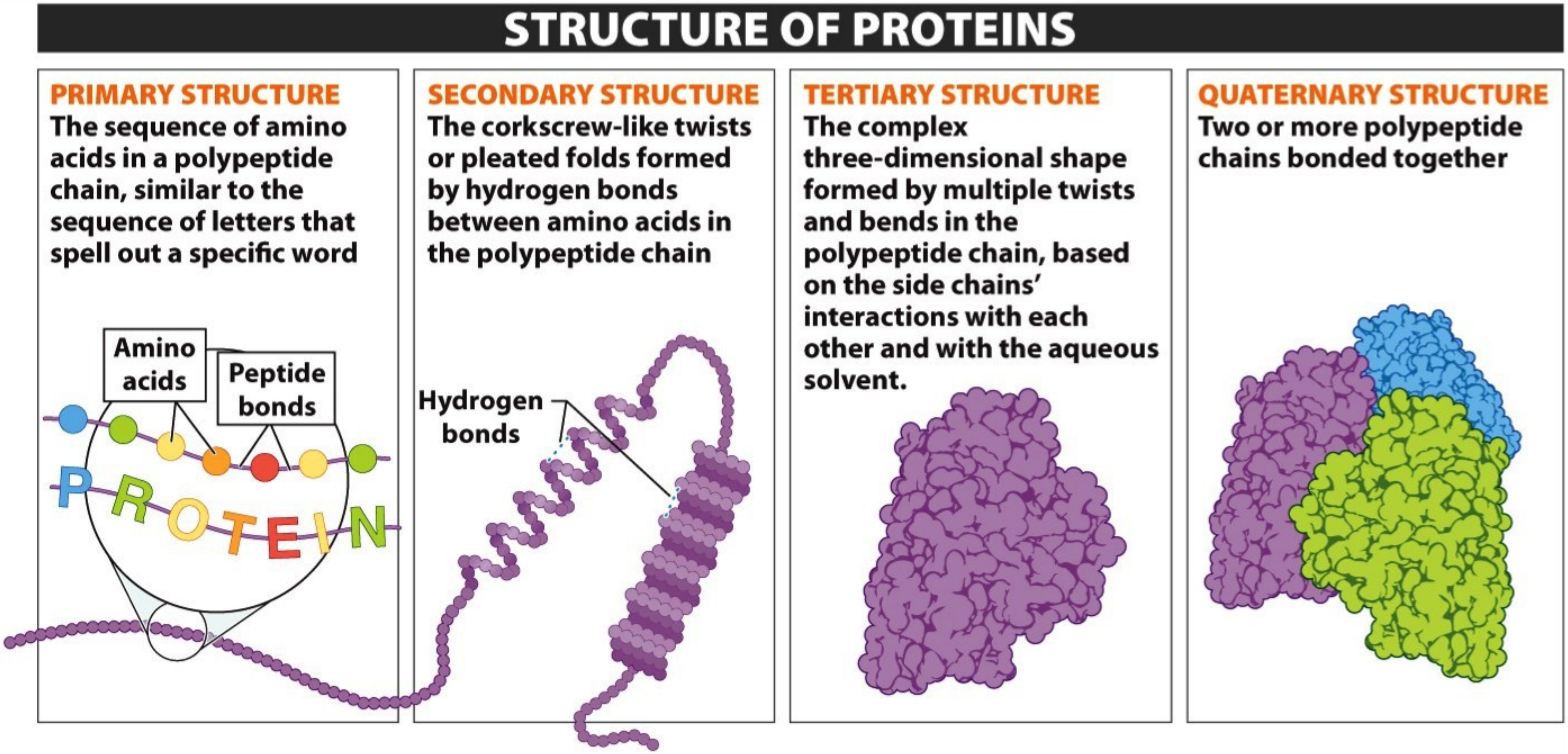
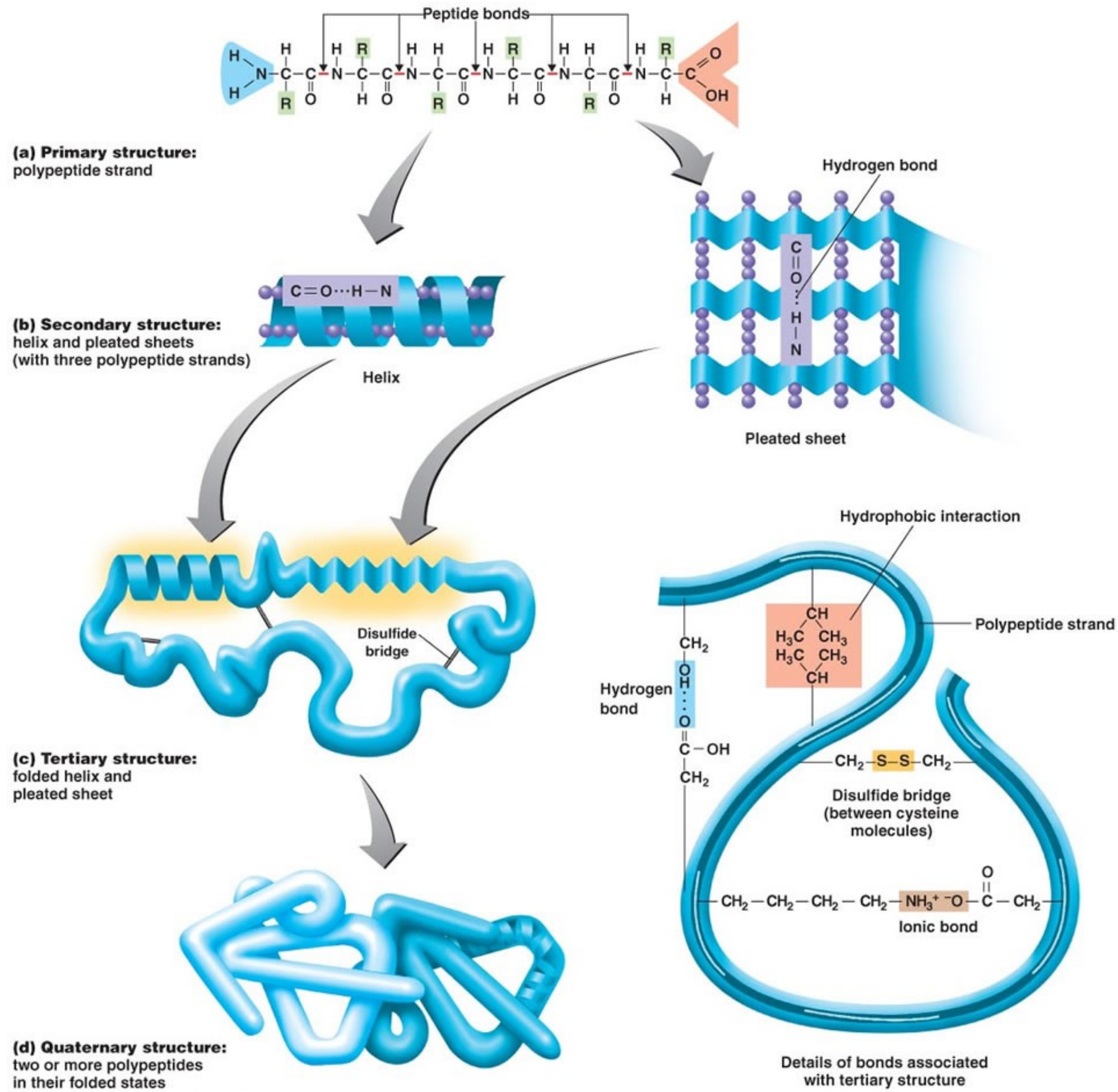



**Figure 2-39**

***What Is Life? A Guide To Biology*, Second Edition**

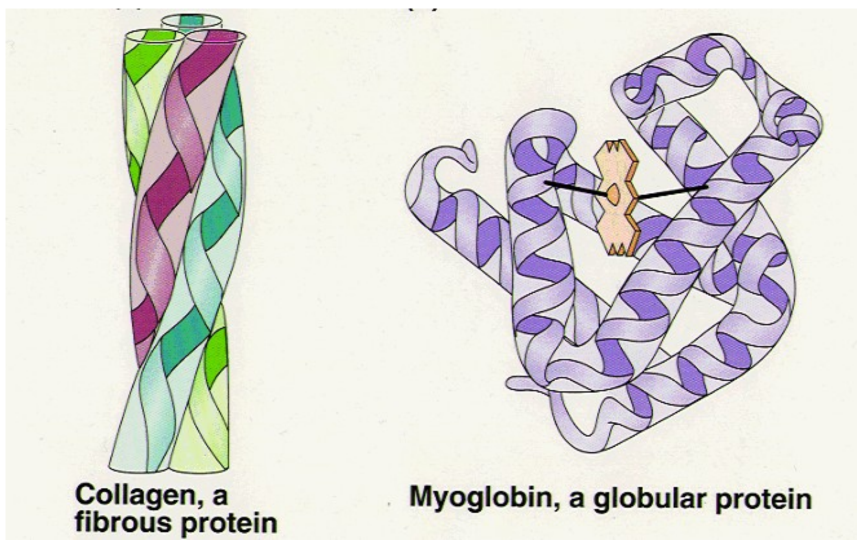


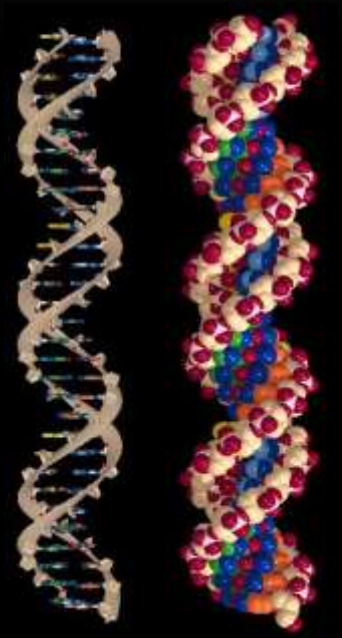
Peptide bonds
(a) Primary structure:
polypeptide strand
Hydrogen bond
(b) Secondary structure:
helix and pleated sheets
(with three polypeptide strands)
C=O···H—N
Helix
Pleated sheet
Hydrophobic interaction
Polypeptide strand
Disulfide
bridge
Hydrogen
bond
Disulfide bridge
(between cysteine
molecules)
Ionic bond
(c) Tertiary structure:
folded helix and
pleated sheet
(d) Quaternary structure:
two or more polypeptides
in their folded states
Details of bonds associated
with tertiary structure

# Globular and fibrous proteins

- **Globular proteins**: folded and ´curled´. Usually soluble in water (because hydrophilic groups remain on the outside).
  Many globular proteins have roles in metabolic reactions. For example: enzymes and myoglobin

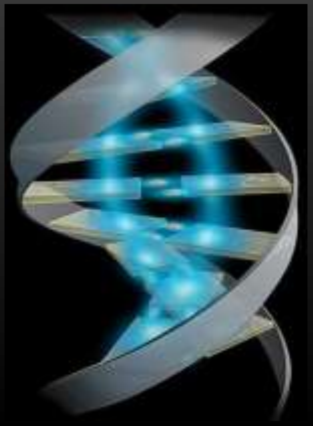
- **Fibrous proteins**: Do not curl-up, but form long strands. Usually not soluble in water, and have structural roles. For example: collagen and keartin.



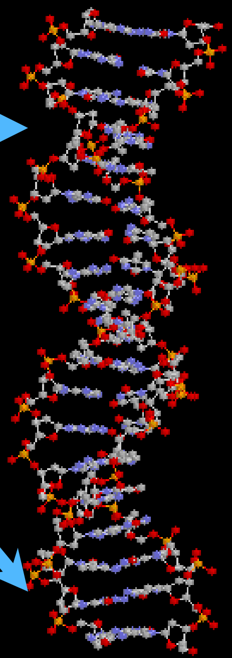


# WHAT IS DNA?

# DNA (DEOXYRIBONUCLEIC ACID)



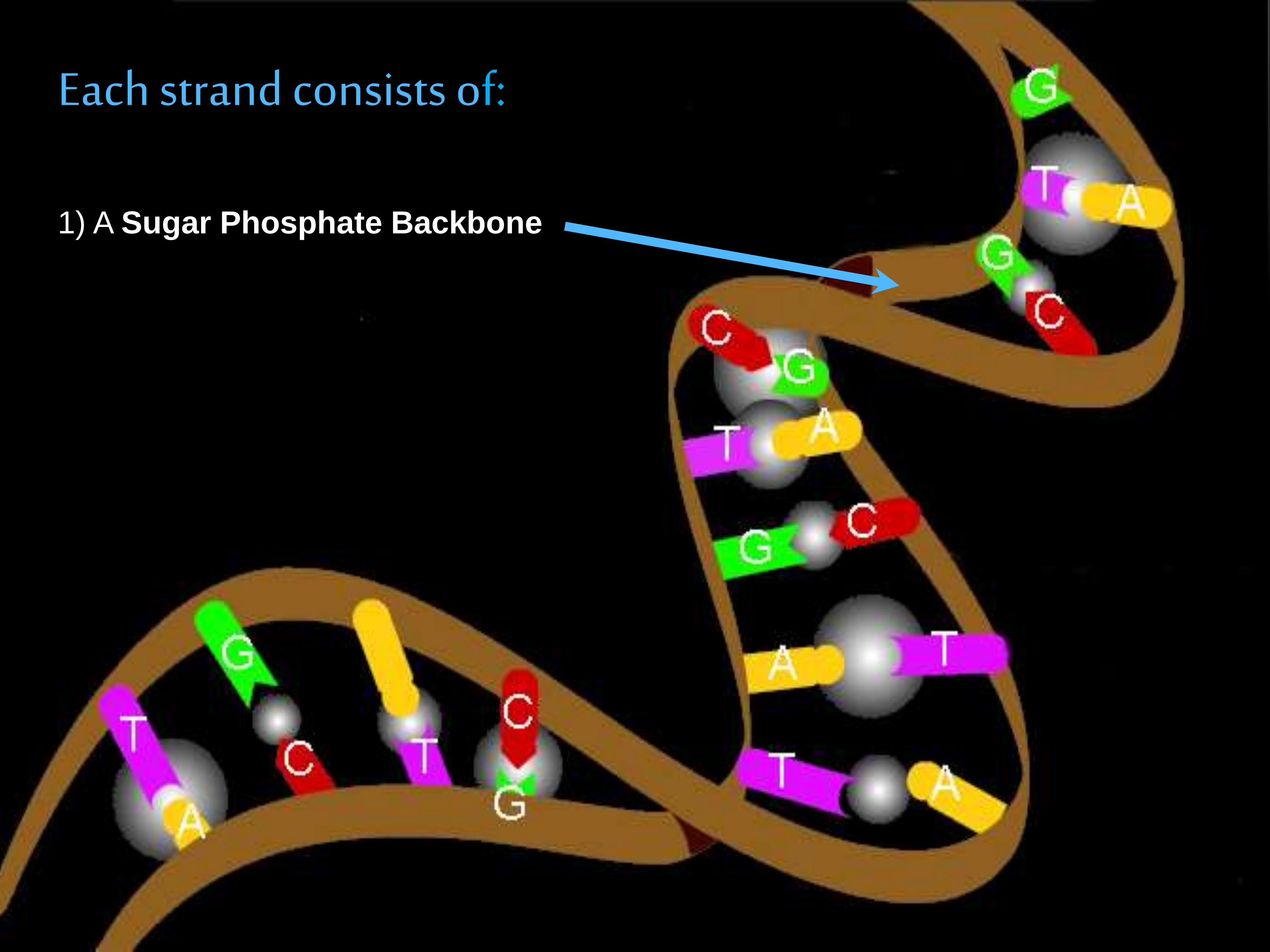
**DNA** is a double stranded molecule that is twisted into a **Helix** (Spiraling Staircase)



**DNA Double Helix**

# Each strand consists of:

1) A **Sugar Phosphate Backbone**



# Each strand consists of:

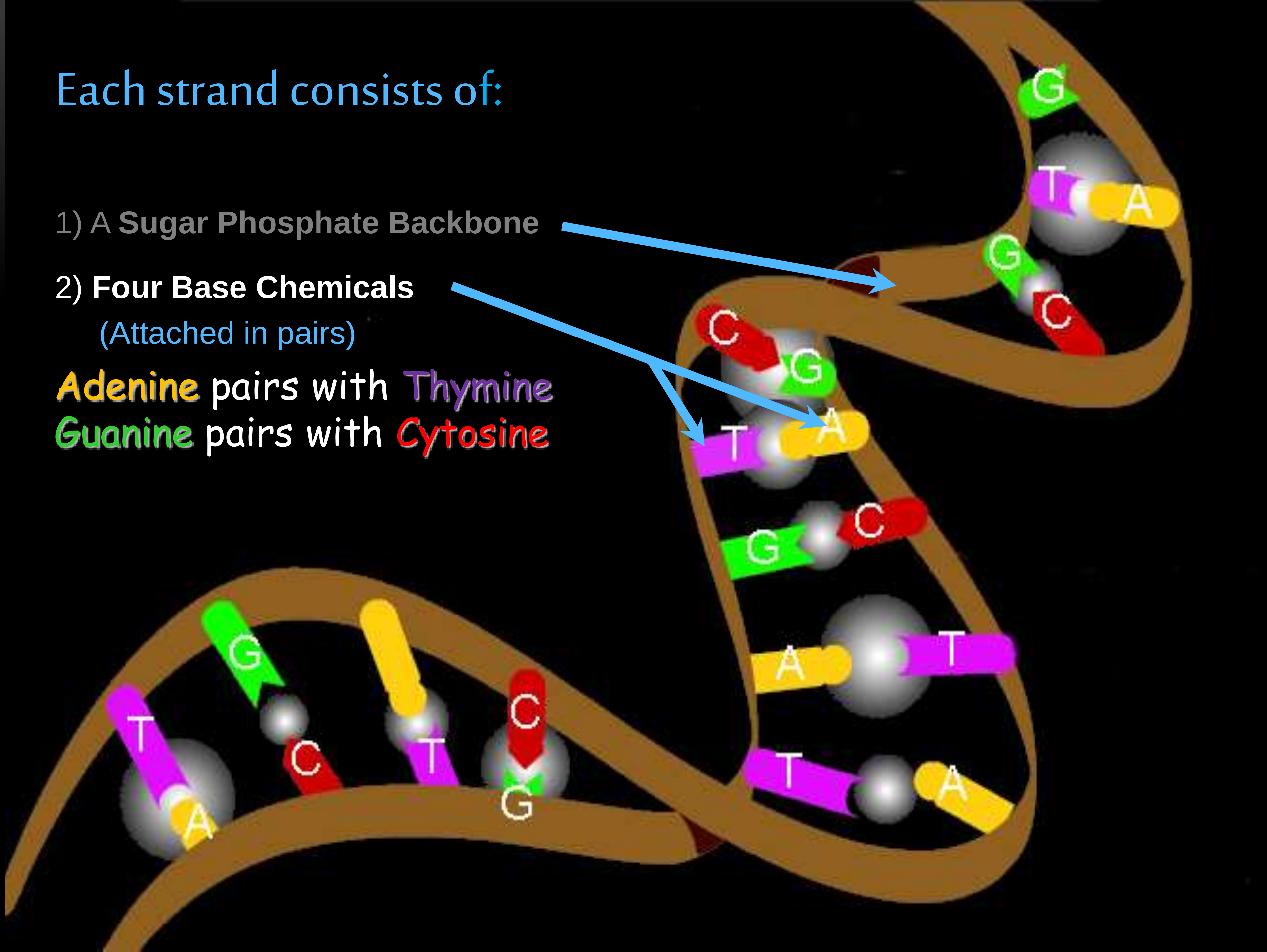
1) A **Sugar Phosphate Backbone**

2) **Four Base Chemicals**

(Attached in pairs)

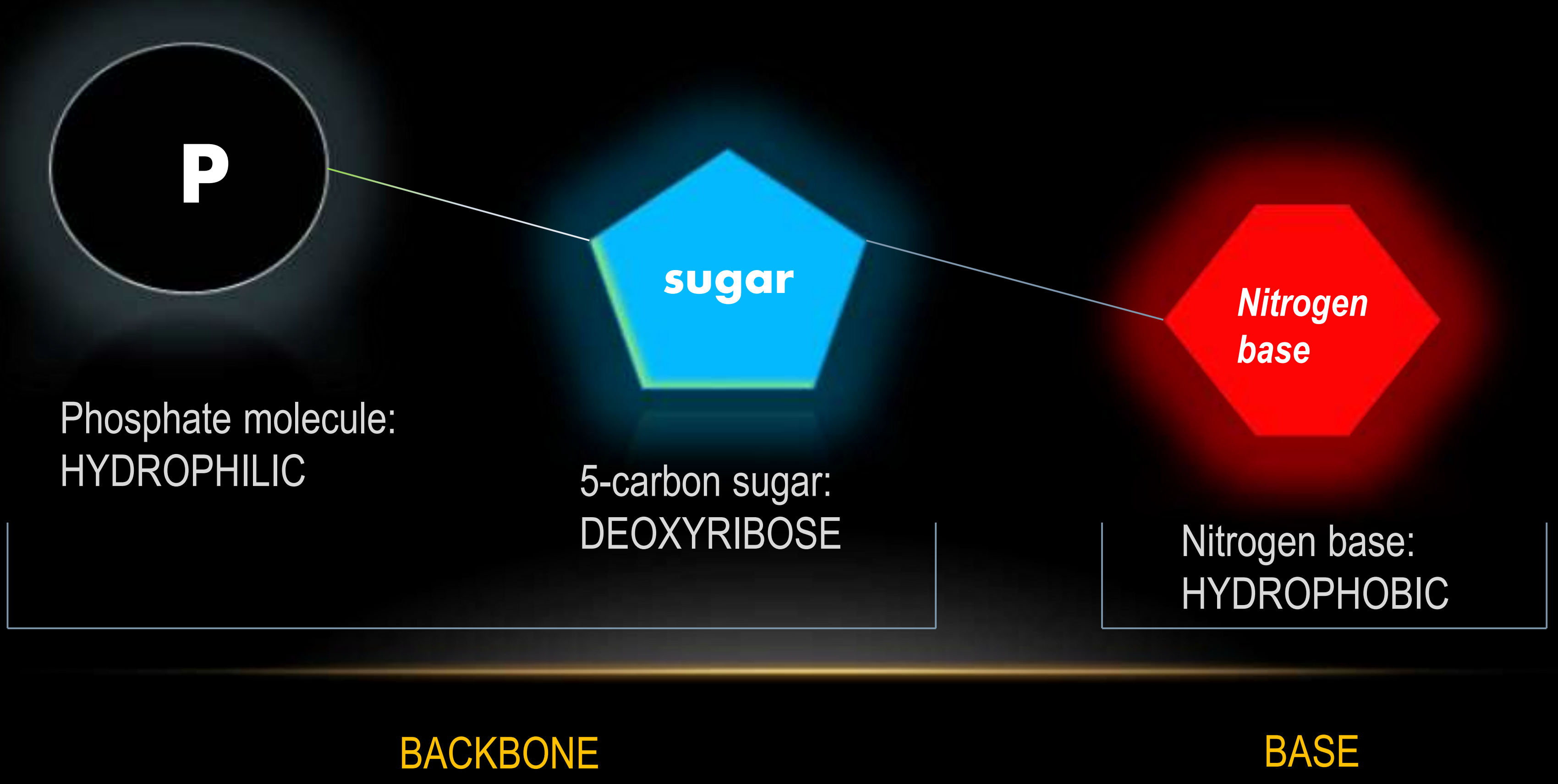
Adenine pairs with Thymine

Guanine pairs with Cytosine



# STRUCTURE

Basic structure of DNA is a sugar-phosphate backbone with 4 variable nitrogenous bases. This structure is called a nucleotide.



# NUCLEIC ACIDS

- Nucleic acids are polymers
- Nucleotides are monomer
  - Nitrogenous bases
    - Purines
    - Pyrimidine
  - Sugar
    - Ribose
    - Deoxyribose

  Nucleosides

  - Phosphates + nucleoside = nucleotide

# Structure

## Does DNA fit the requirements of a hereditary material?

| REQUIREMENT | DNA Component |
| --- | --- |
| Has biologically useful information to make protein | Genetic code: 3 bases code for 1 amino acid(protein) |
| Must reproduce faithfully and transmit to offspring | Complementary bases are faithful: found in germ cells |
| Must be stable within a living organism | Backbone is strong covalent : hydrogen bonds |
| Must be capable of incorporating stable changes | Bases can change through known mechanisms |

# THE EARLY EFFORTS

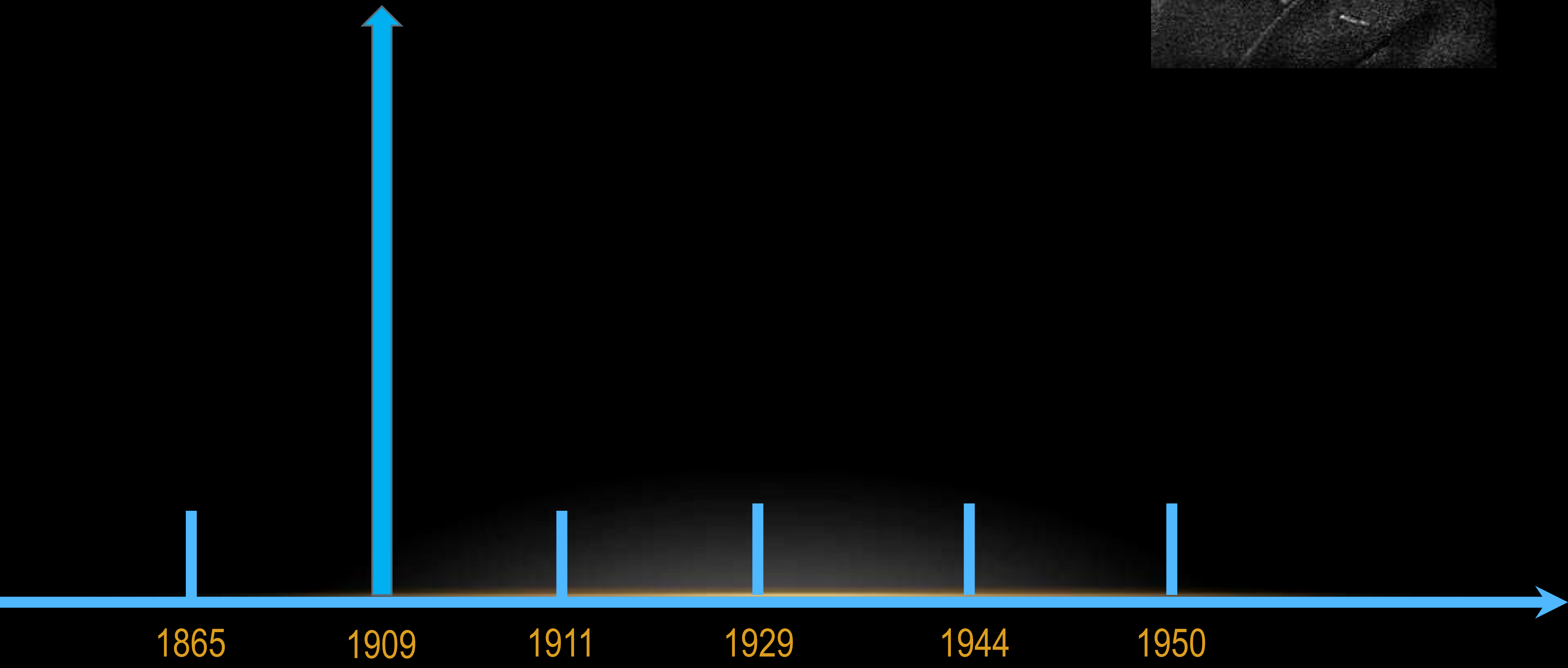
- By the early 1900's it was known that the chromosomes carry the genetic (hereditary) information

- Chromosomes consist of DNA (deoxyribonucleic acid)

**Gregor Mendel:**
Introduces the concept of heredity

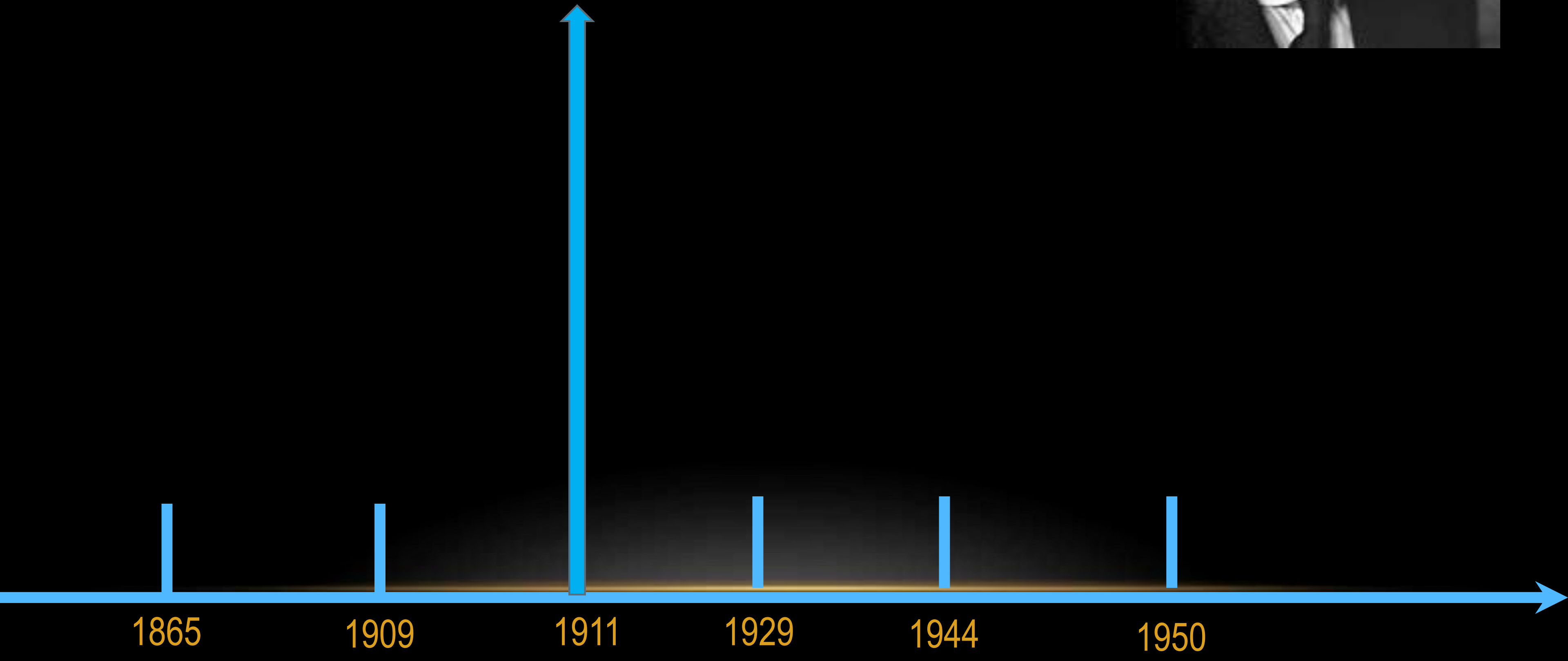
1865 1909 1911 1929 1944 1950

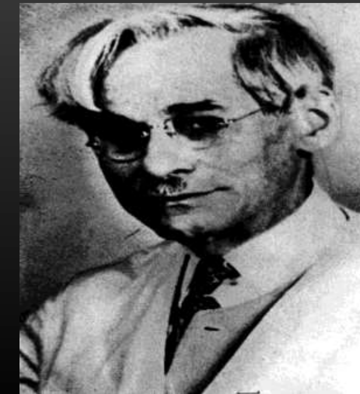
**Wilhelm Johannsen:**
Coins the term “Gene



**Thomas Hunt Morgan:**

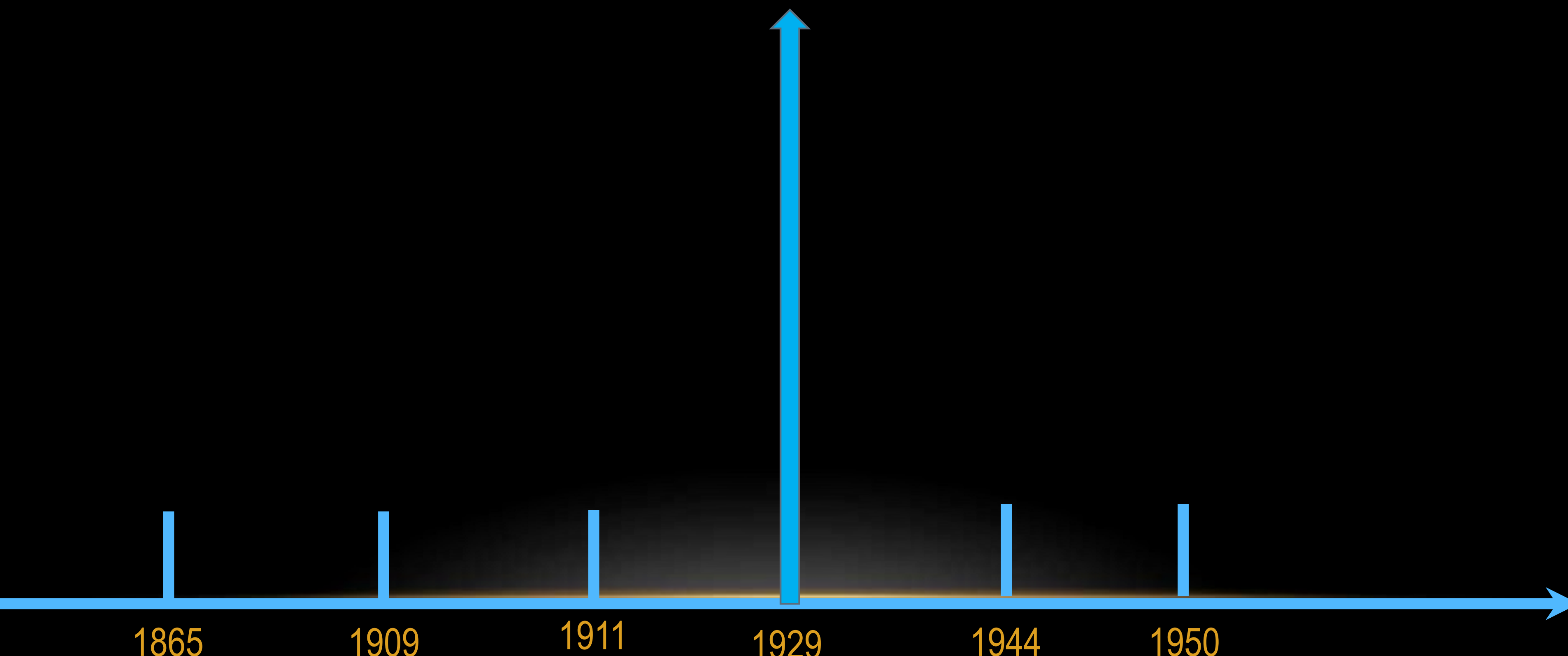
Discovers that genes are responsible for inheritance





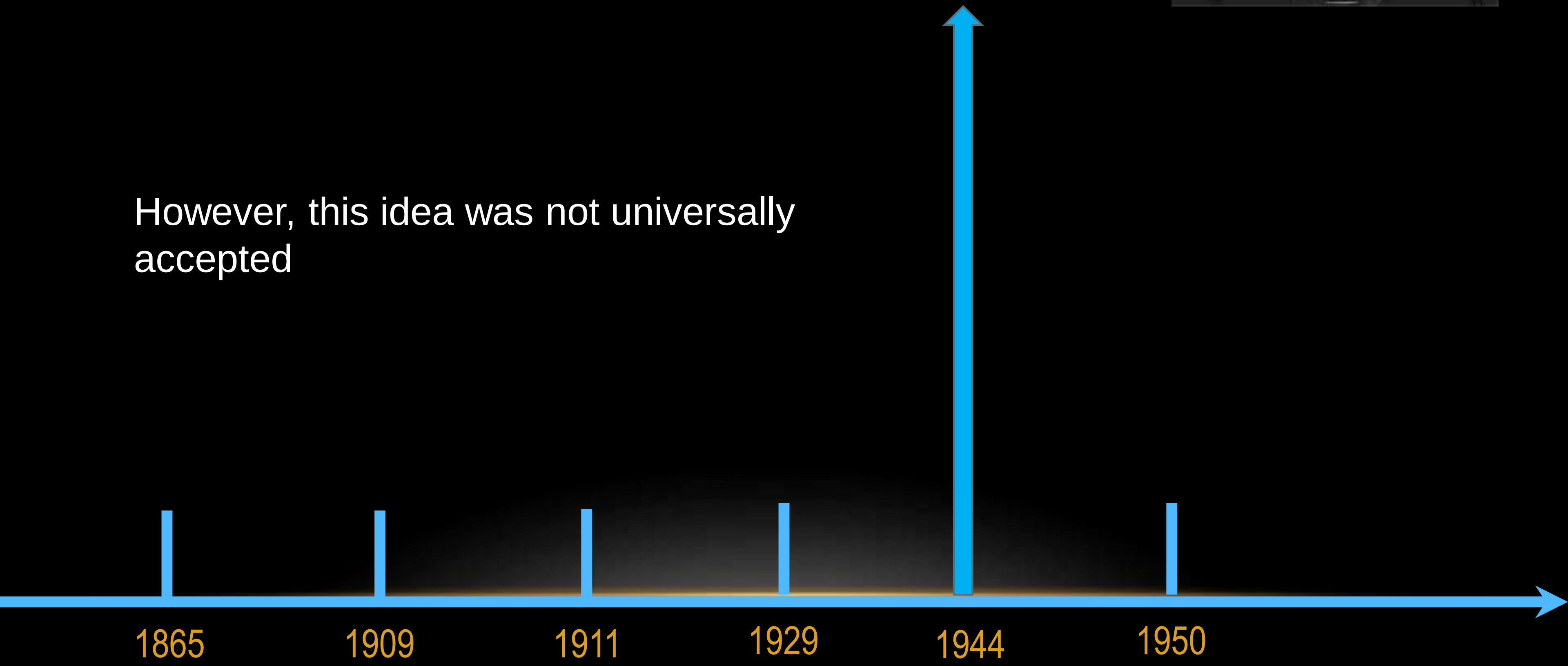
**Phoebus Levene:**

Discovers that DNA is made up of nucleotides, phosphates, sugars and 4 bases



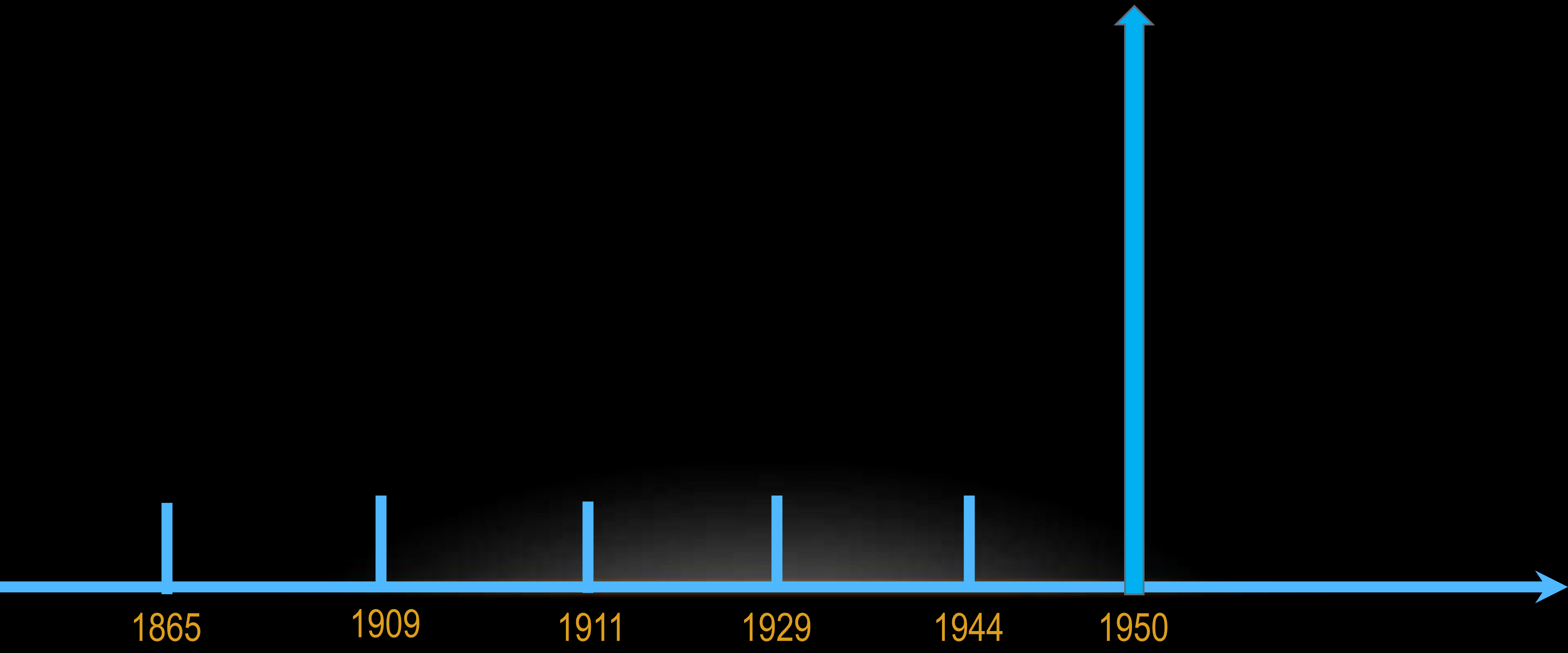
**Oswald Avery:**
Shows that DNA can transform the property of cells

However, this idea was not universally accepted



**Erwin Chargaff:**

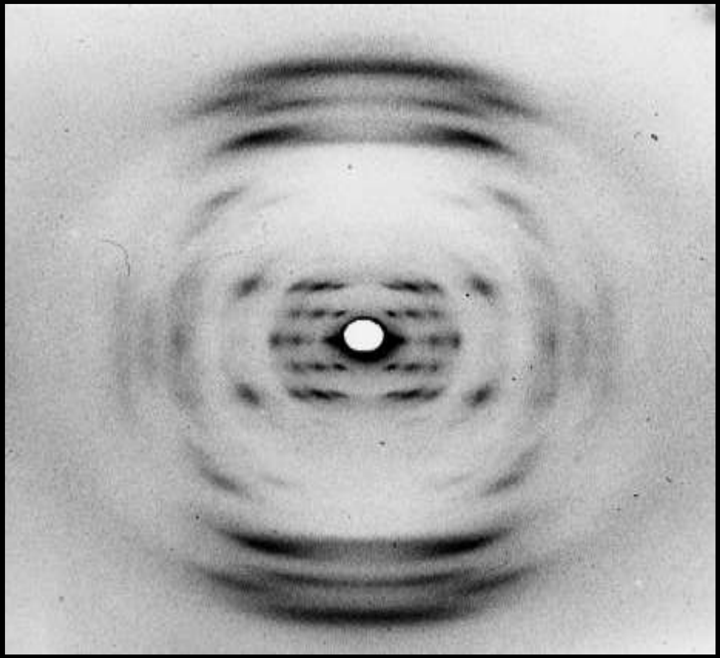
Shows that: A + G = T + C = 50%



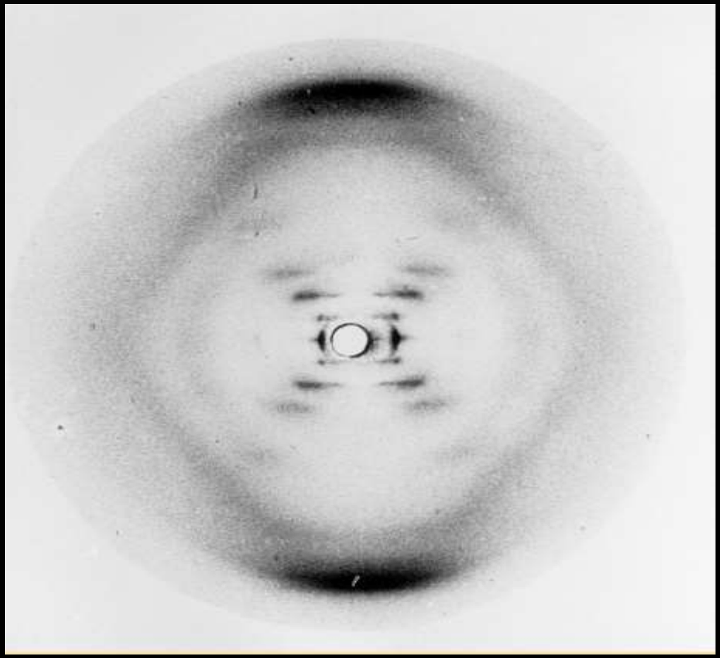
# Franklin's Work

## TWO FORMS OF DNA

In 1951 Rosalind Franklin discovers the **Two Forms of DNA** through her X-ray diffraction images.

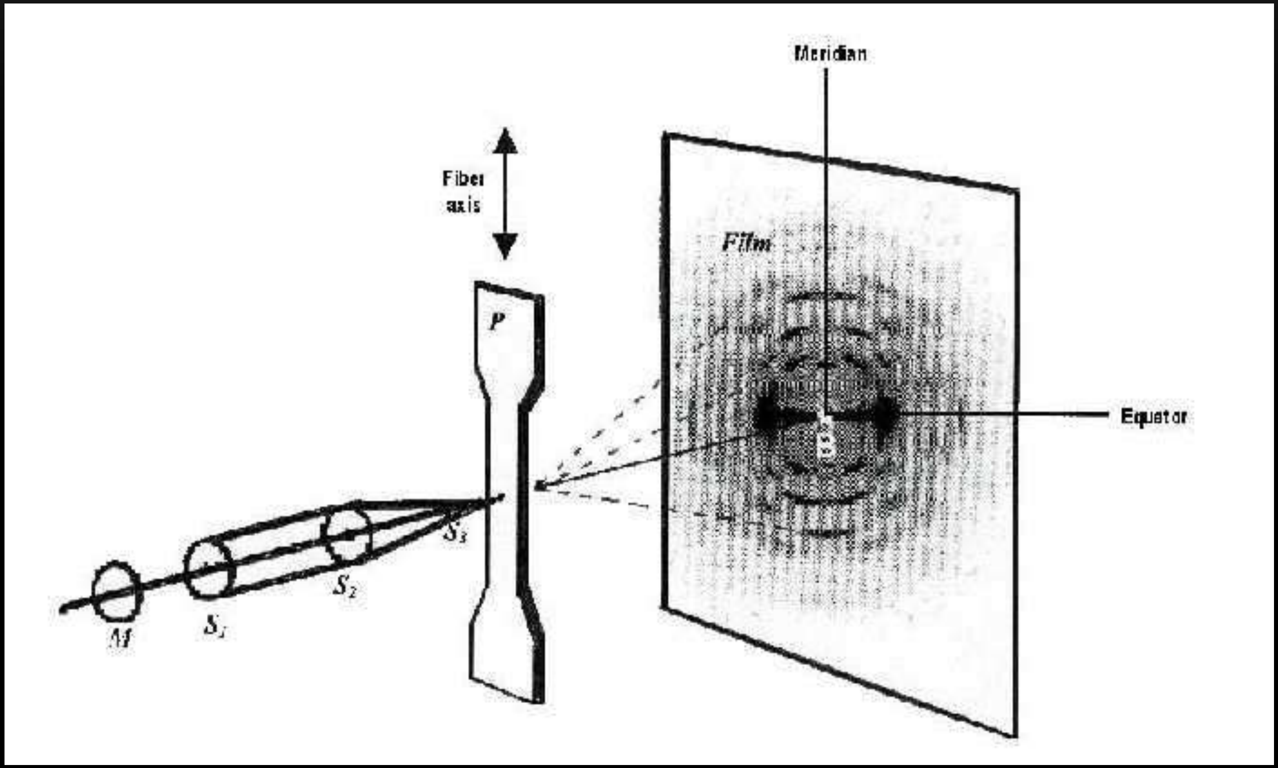


A – Dry Form



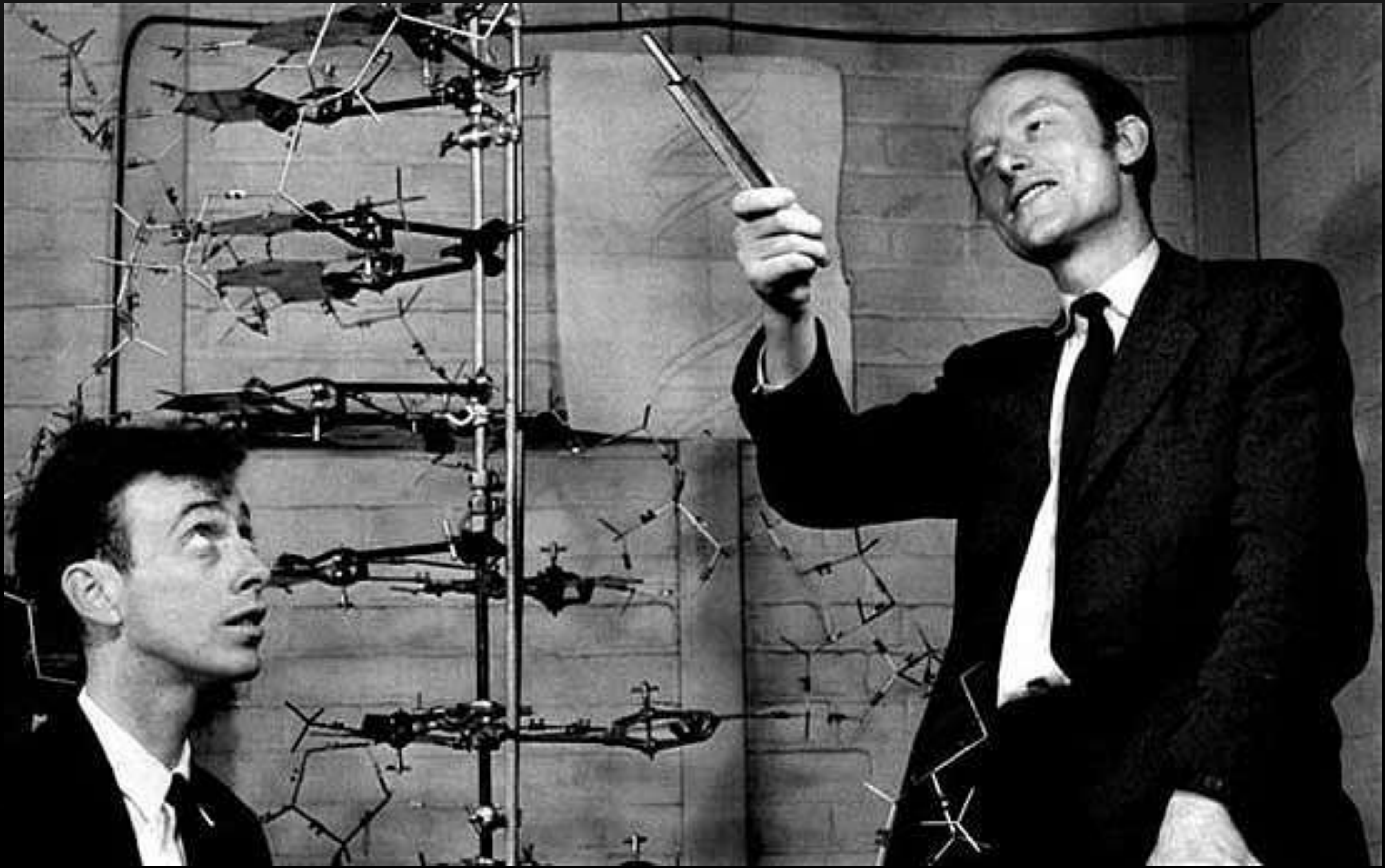
B – Wet Form

# X-Ray Crystallography



SOON AFTER **WWII** THE RACE TO DISCOVER THE “SECRET OF LIFE” WAS ON.  SCIENTISTS KNEW THIS WOULD BE THE DISCOVERY OF THE CENTURY AND WOULD GUARANTEE A NOBEL PRIZE

# The Watson-Crick Model of the Structure of DNA



On Feb. 28, 1953, Francis Crick walked into the Eagle pub in Cambridge, England, and, as James Watson later recalled, announced that "we had found the secret of life." Actually, they had. That morning, Watson and Crick had figured out the structure of deoxyribonucleic acid, DNA. And that structure — a "double helix" that can "unzip" to make copies of itself — confirmed suspicions that DNA carries life's hereditary information.

# Watson and Crick's Work

- In 1951 James Watson traveled from the United States to work with Francis Crick at Cambridge University.
- Watson and Crick used the "Model Building" approach.
- They physically built models out of wire, sheet metal, nuts and bolts to come up with the structure of DNA.

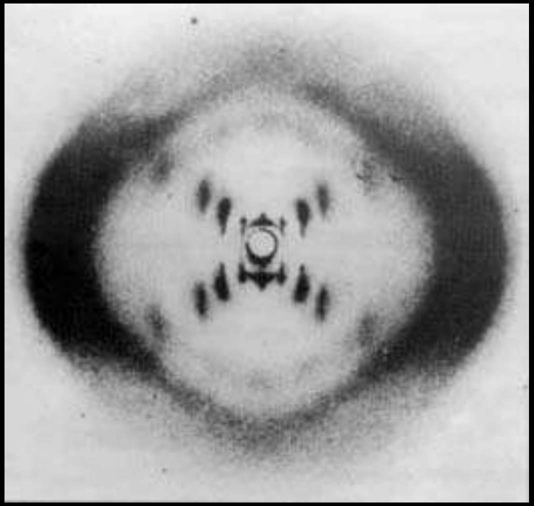
**Why did they build models?**
"*Sometimes the fingers can grasp what the mind cannot*"
(Biology the Science of Life)

- DNA consists of two chains of nucleotides in a ladder-like structure which is twisted (Double Helix)

- Used data of *M.H.F. Wilkins and Rosalind Franklin*, ***early 50's***

- Wilkins and Franklin studied the structure of DNA crystals using X-rays.

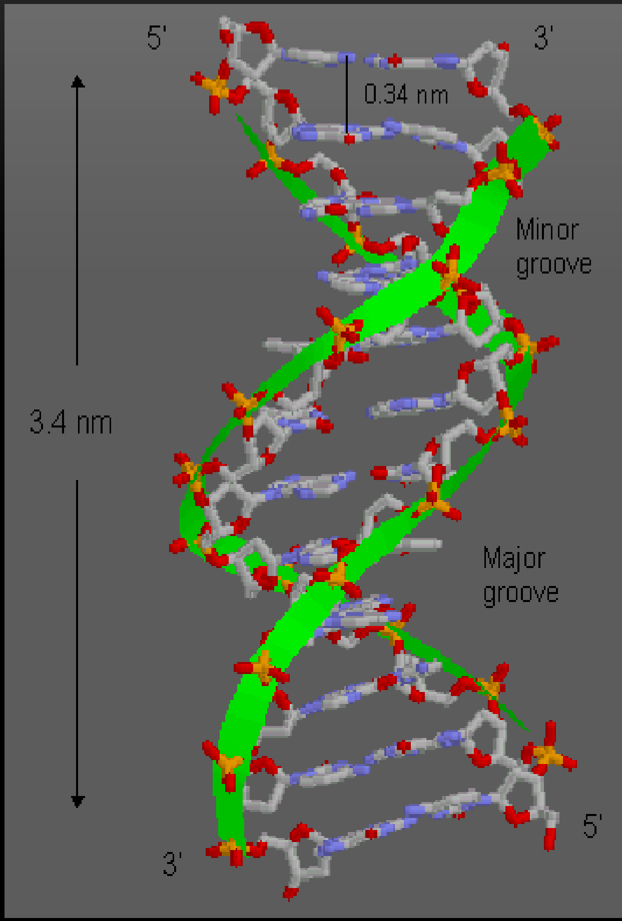
- The X pattern suggested the structure of DNA was a helix.



- Used data of ***Erwin Chargaff, 1940's and early 50's***

- Chargaff's Rule: His data showed that in each species, the percent of A equals the percent of T, and the percent of G equals the percent of C.

- Watson was shown this picture by Wilkins in early 1953.
  From the picture it was possible to calculate:
  1) the distance between bases (3.4A)
  2) the length of the period (34A)
  3) the rise of the helix (36 degrees)



- Francis Crick and James Watson with Maurice Wilkins received the 1962 Nobel Prize for discovering the molecular structure of deoxyribonucleic acid (DNA).

- Widely regarded as one of the most important discoveries of the 20th century it has led the way to the mapping and deciphering of all the genes in the human chromosomes

# Watson and Crick Model:

- The sides of the ladder are made up of alternating molecules of phosphate and deoxyribose.
- The bases make up the rungs of the ladder are attracted by a weak chemical bonds called hydrogen bonds.
- The DNA double helix is anti-parallel, which means that the 5' end of one strand is paired with the 3' end of its complementary strand (and vice versa).
- 5'---------------->3'
  3'<----------------5'
- Two hydrogen bonds connect T to A; three hydrogen bonds connect G to C.

# Watson and Crick's Double Helix Model explained:

1. How replication of DNA during mitosis produces exact copies for the daughter cells.

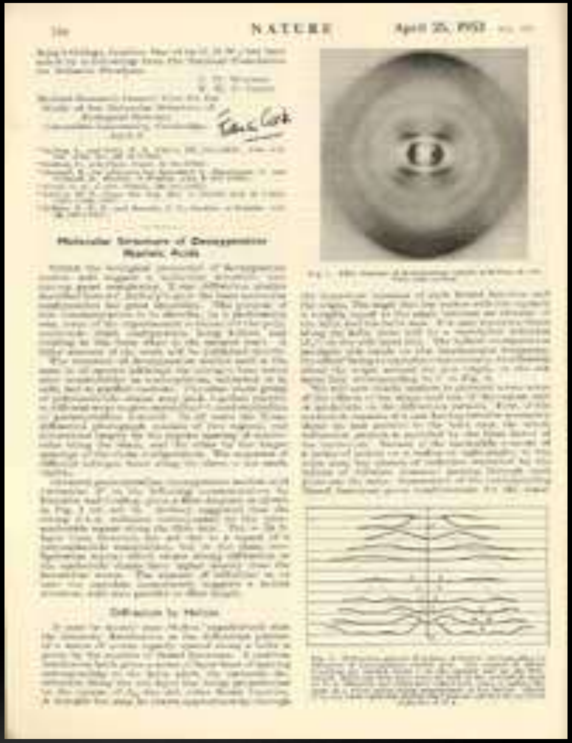
2. How DNA acts as a code, specifying how proteins are made by the cell.

# “Nature”

Watson & Crick quickly published their Scientific Journal called **“Nature”** on April 25th 1953


April 25, 1953 NATURE

MOLECULAR STRUCTURE OF NUCLEIC ACIDS


NATURE April 25, 1953

# The Nobel Prize

- In 1962 Watson, Crick & Wilkins won the **Nobel Prize** for their discovery of the structure of **DNA.**

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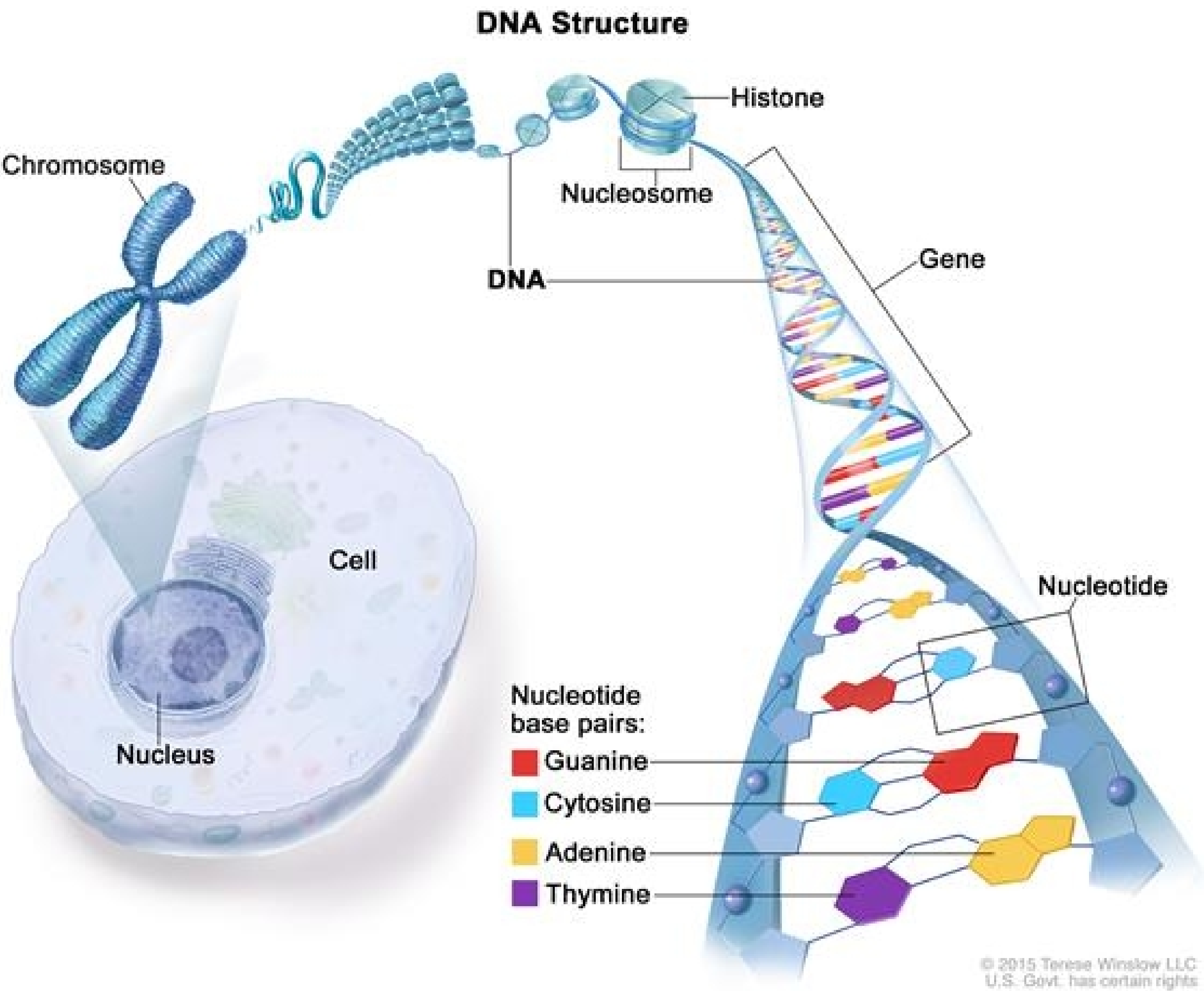
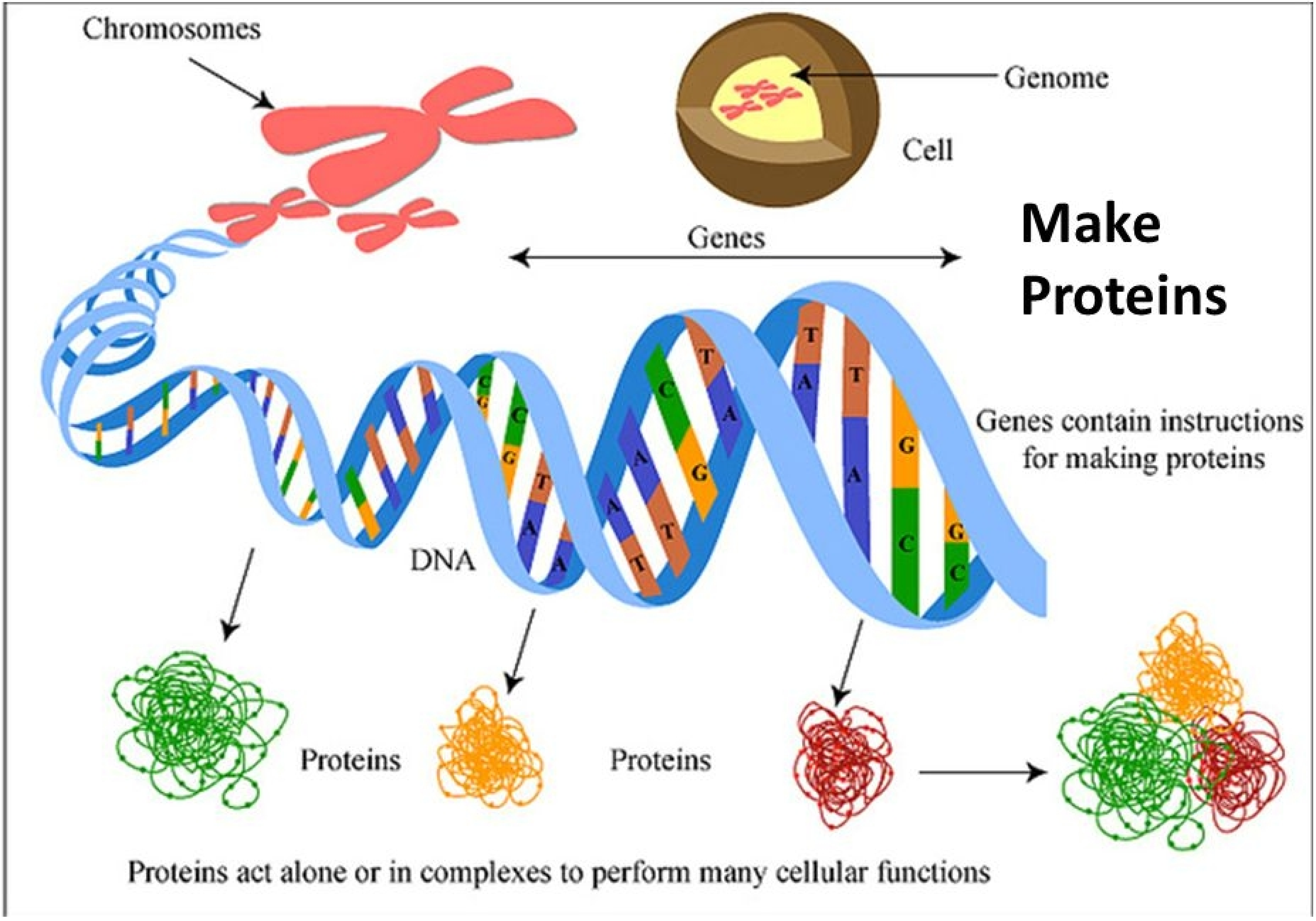
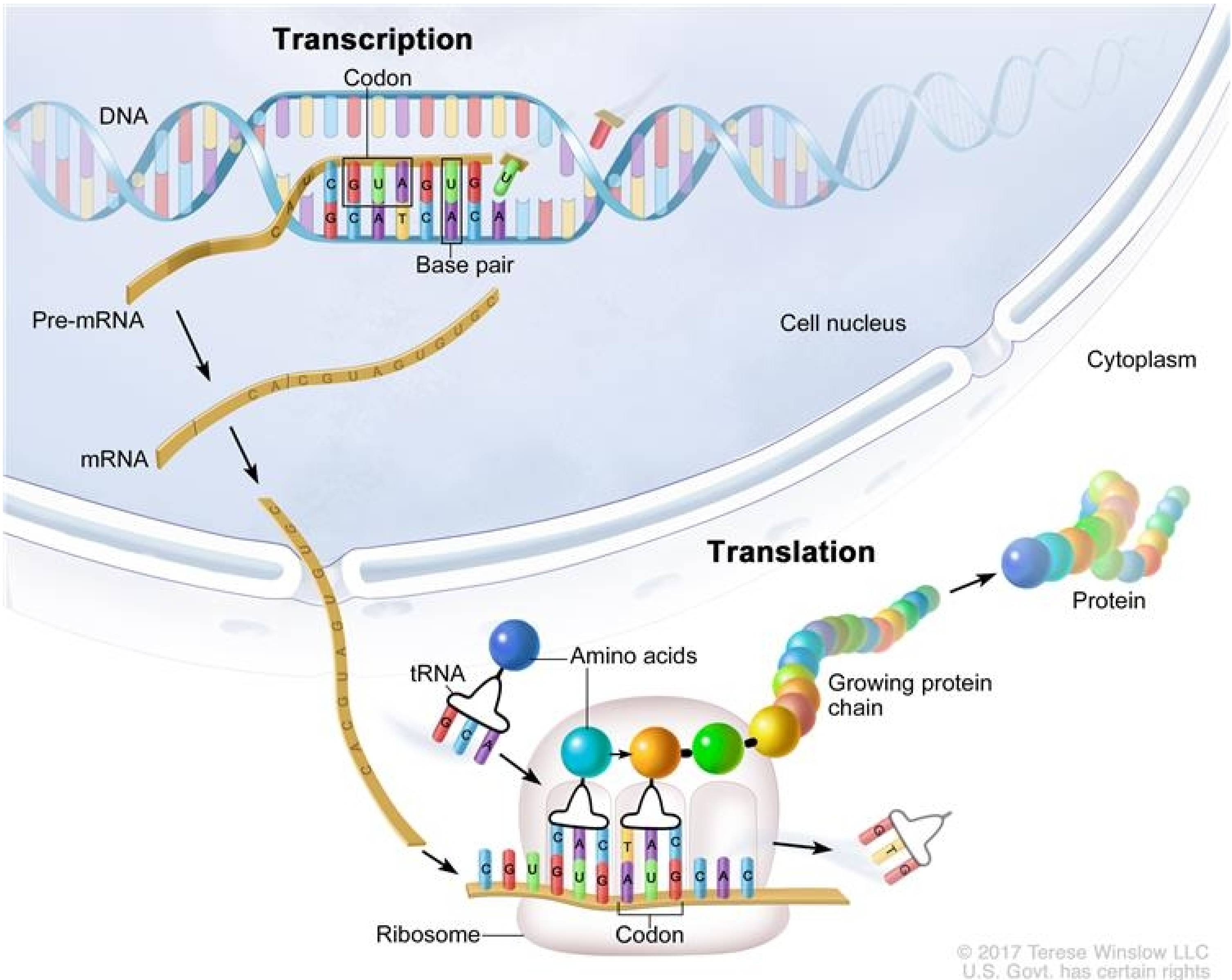
# DNA, genes, histone & chromosome



# Brief summary of Protein synthesis



# Transcription & Translation



# Translation: the genetic code