



# CLS 232 - Lecture 1

## An Introduction to Biochemistry

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# What is Biochemistry ?

- Biochemistry is the application of chemistry to the study of biological processes at the cellular and molecular level.
- It emerged as a distinct discipline around the beginning of the 20th century when scientists combined chemistry, physiology and biology to investigate the chemistry of living systems by:
  - A. Studying the structure and behavior of the complex molecules found in biological material and
  - B. How these molecules interact to form cells, tissues and whole organism

# What is Biochemistry ?

- Biochemistry = chemistry of life.
- Biochemists use physical and chemical principles to explain biology at the molecular level.
- Basic principles of biochemistry are common to all living organism
- Aim: to describe and explain, *in molecular terms*, all chemical processes of living cells
  - Structure-function
  - Metabolism and Regulation
  - How life began?

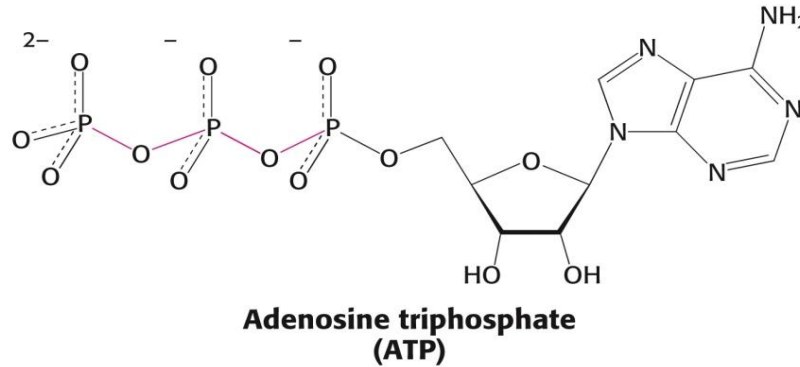
# What is Biochemistry ?

- Significance: be essential to all life sciences as the common knowledge
  - Genetics; Cell biology; Molecular biology
  - Physiology and Immunology
  - Pharmacology and Pharmacy
  - Toxicology; Pathology; Microbiology
  - Zoology and Botany
  - Agriculture
  - Industrial applications
  - Environmental implications

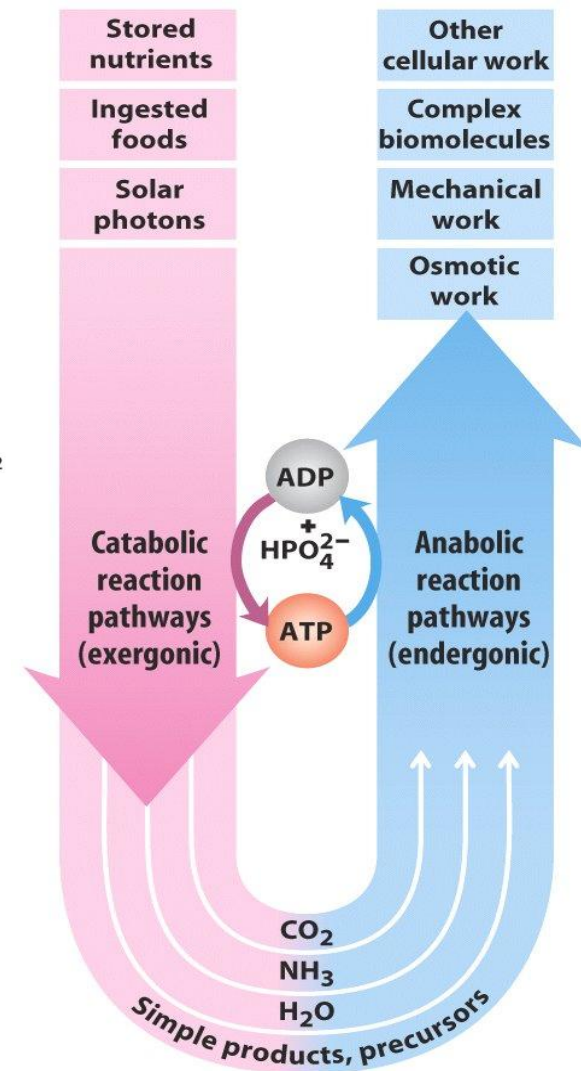
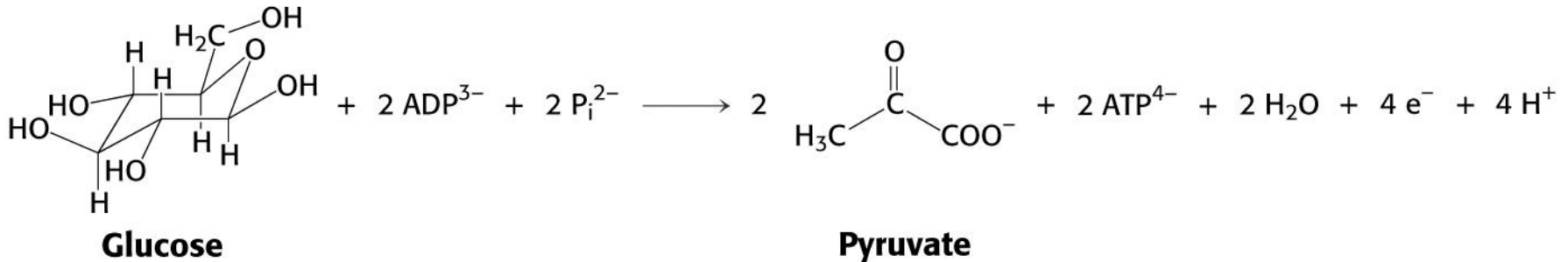
# Life has 3 requirements:

**(1) ENERGY:** which it must know how to:

- Extract
- Transform
- Utilize



**Glycolysis** is the preferred pathway for the formation of **ATP**



**(2) *SIMPLE MOLECULES***, which it must know how to:

- Convert
- Polymerize
- Degrade

**(3) *CHEMICAL MECHANISMS***, to:

- Harness energy
- Drive sequential chemical reactions
- Synthesize & degrade macromolecules
- Maintain a dynamic steady state
- Self-assemble complex structures
- Replicate accurately & efficiently
- Maintain biochemical “order” vs outside

# Organization of Life

- elements
- simple organic compounds (monomers)
- macromolecules (polymers)
- supramolecular structures
- organelles
- cells
- tissues
- organisms

# Elements

- Make up all matter.
- 92 occur in nature.
- Identified by names or chemical symbols (abbreviations of modern or Latin names).
- Identified by number (based on structure of subunits or atoms).
- Described and organized in periodic table.

hydrogen 1 <b>H</b> 1.0079												helium 2 <b>He</b> 4.0026																							
lithium 3 <b>Li</b> 6.941	beryllium 4 <b>Be</b> 9.0122											boron 5 <b>B</b> 10.811	carbon 6 <b>C</b> 12.011	nitrogen 7 <b>N</b> 14.007	oxygen 8 <b>O</b> 15.999	fluorine 9 <b>F</b> 18.998	neon 10 <b>Ne</b> 20.180																		
sodium 11 <b>Na</b> 22.990	magnesium 12 <b>Mg</b> 24.305											aluminum 13 <b>Al</b> 26.982	silicon 14 <b>Si</b> 28.086	phosphorus 15 <b>P</b> 30.974	sulfur 16 <b>S</b> 32.065	chlorine 17 <b>Cl</b> 35.453	argon 18 <b>Ar</b> 39.948																		
potassium 19 <b>K</b> 39.098		calcium 20 <b>Ca</b> 40.078		scandium 21 <b>Sc</b> 44.956		titanium 22 <b>Ti</b> 47.887		vanadium 23 <b>V</b> 50.942		chromium 24 <b>Cr</b> 51.996		manganese 25 <b>Mn</b> 54.938		iron 26 <b>Fe</b> 55.845		cobalt 27 <b>Co</b> 58.933		nickel 28 <b>Ni</b> 58.693		copper 29 <b>Cu</b> 63.546		zinc 30 <b>Zn</b> 65.39		gallium 31 <b>Ga</b> 69.723		germanium 32 <b>Ge</b> 72.61		arsenic 33 <b>As</b> 74.922		selenium 34 <b>Se</b> 78.96		bromine 35 <b>Br</b> 79.904		krypton 36 <b>Kr</b> 83.80	
rubidium 37 <b>Rb</b> 85.468		strontium 38 <b>Sr</b> 87.62		yttrium 39 <b>Y</b> 88.906		zirconium 40 <b>Zr</b> 91.224		niobium 41 <b>Nb</b> 92.906		molybdenum 42 <b>Mo</b> 95.94		technetium 43 <b>Tc</b> [98]		ruthenium 44 <b>Ru</b> 101.07		rhodium 45 <b>Rh</b> 102.91		palladium 46 <b>Pd</b> 106.42		silver 47 <b>Ag</b> 107.87		cadmium 48 <b>Cd</b> 112.41		indium 49 <b>In</b> 114.82		tin 50 <b>Sn</b> 118.71		antimony 51 <b>Sb</b> 121.76		tellurium 52 <b>Te</b> 127.60		iodine 53 <b>I</b> 126.90		xenon 54 <b>Xe</b> 131.29	
cesium 55 <b>Cs</b> 132.91		barium 56 <b>Ba</b> 137.33		lanthanum 57 <b>La</b> 174.97		hafnium 72 <b>Hf</b> 178.49		tantalum 73 <b>Ta</b> 180.95		tungsten 74 <b>W</b> 183.84		rhenium 75 <b>Re</b> 186.21		osmium 76 <b>Os</b> 190.23		iridium 77 <b>Ir</b> 192.22		platinum 78 <b>Pt</b> 195.08		gold 79 <b>Au</b> 196.97		mercury 80 <b>Hg</b> 200.59		thallium 81 <b>Tl</b> 204.38		lead 82 <b>Pb</b> 207.2		bismuth 83 <b>Bi</b> 208.98		polonium 84 <b>Po</b> [209]		astatine 85 <b>At</b> [210]		radon 86 <b>Rn</b> [222]	
francium 87 <b>Fr</b> [223]		radium 88 <b>Ra</b> [226]		actinoids 89-102 <b>Ac</b> [227]		lawrencium 103 <b>Lr</b> [262]		rutherfordium 104 <b>Rf</b> [261]		dubnium 105 <b>Db</b> [262]		seaborgium 106 <b>Sg</b> [266]		bohrium 107 <b>Bh</b> [264]		hassium 108 <b>Hs</b> [269]		meitnerium 109 <b>Mt</b> [268]		darmstadtium 110 <b>Ds</b> [271]		roentgenium 111 <b>Rg</b> [272]		copernicium 112 <b>Cn</b> [277]		unquadrium 114 <b>Uuq</b> [289]									
				lanthanoids lanthanum 57 <b>La</b> 138.91		cerium 58 <b>Ce</b> 140.12		praseodymium 59 <b>Pr</b> 140.91		neodymium 60 <b>Nd</b> 144.24		promethium 61 <b>Pm</b> [145]		samarium 62 <b>Sm</b> 150.36		europium 63 <b>Eu</b> 151.96		gadolinium 64 <b>Gd</b> 157.25		terbium 65 <b>Tb</b> 158.93		dysprosium 66 <b>Dy</b> 162.50		holmium 67 <b>Ho</b> 164.93		erbium 68 <b>Er</b> 167.26		thulium 69 <b>Tm</b> 168.93		ytterbium 70 <b>Yb</b> 173.04					
				actinium 89 <b>Ac</b> [227]		thorium 90 <b>Th</b> 232.04		protactinium 91 <b>Pa</b> 231.04		uranium 92 <b>U</b> 238.03		neptunium 93 <b>Np</b> [237]		plutonium 94 <b>Pu</b> [244]		americium 95 <b>Am</b> [243]		curium 96 <b>Cm</b> [247]		berkelium 97 <b>Bk</b> [247]		californium 98 <b>Cf</b> [251]		einsteinium 99 <b>Es</b> [252]		fermium 100 <b>Fm</b> [257]		mendelevium 101 <b>Md</b> [258]		nobelium 102 <b>No</b> [259]					

Key:  
 element name  
 atomic number  
 symbol  
 atomic weight (mean relative mass)

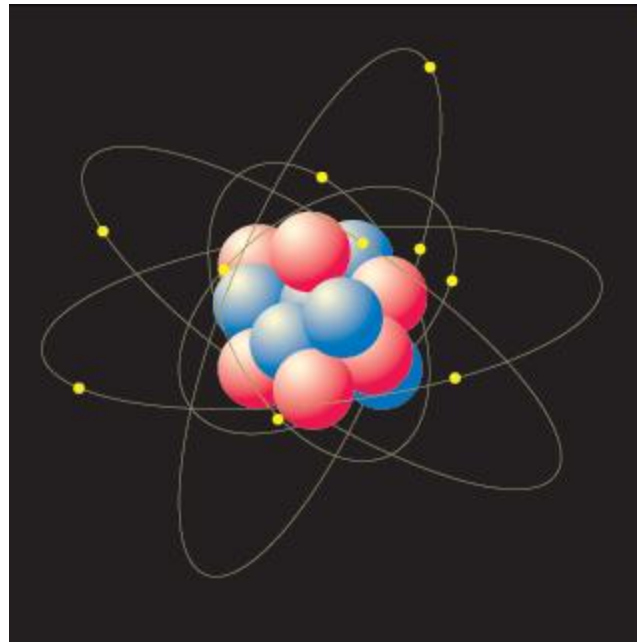
\*lanthanoids

\*\*actinoids



# Atoms

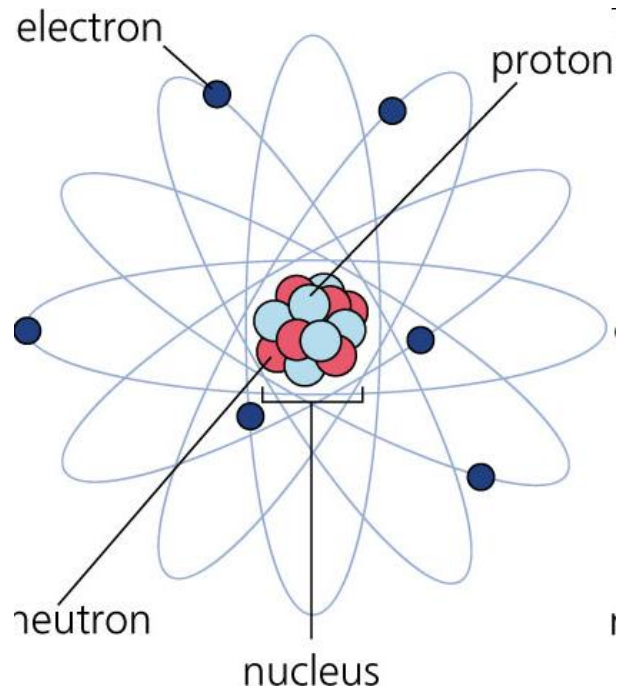
- Subunits of elements.
- Smallest complete units of matter.
- Cannot be broken down or changed by ordinary chemical and physical means.



# Atomic Structure

- **Nucleus**

- Positively charged **protons**.
- Neutrally charged **neutrons**.
- Surrounded by negatively charged **electrons**.



# Molecules and Compounds

## Molecules

- Formed when two or more atoms unite on the basis of their electron structures
- Can be made of like atoms or atoms of different elements

## Compounds

- Composed of two or more elements
- Chemical bonds hold the atoms together in a molecule.
- There are 2 types of chemical bonds **IONIC** and **COVALENT**

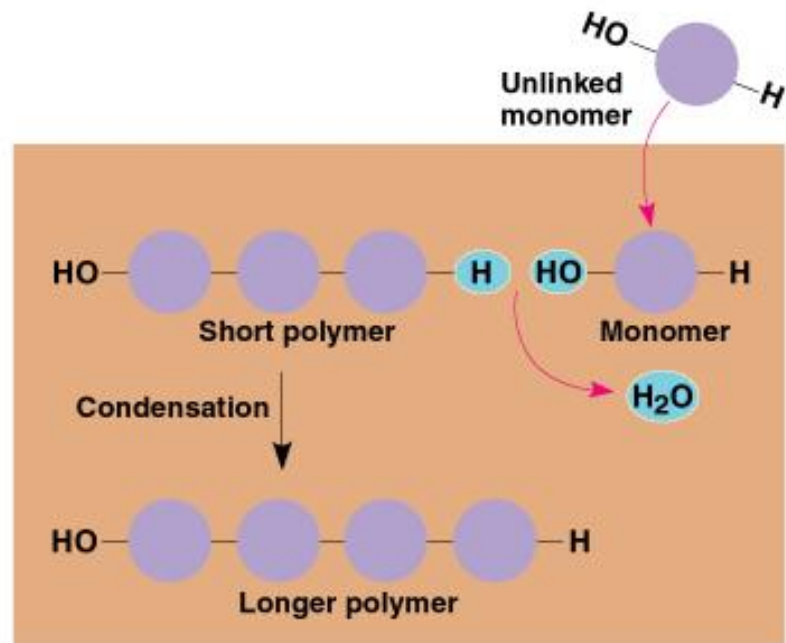
# Biomolecules as polymers

- Carbohydrates
  - Proteins
  - Lipids
  - Nucleic acid
- 
- Each of these types of molecules are **polymers** that are assembled from single units called **monomers**.
  - Each type of macromolecule is an assemblage of a different type of monomer

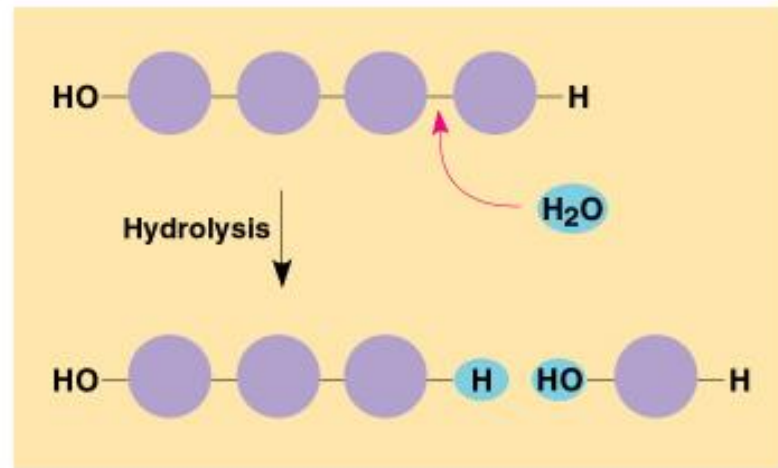
Common theme:

**Monomers** form  
polymers through  
condensations

**Polymers** are broken  
down through hydrolysis.



(a) Condensation (dehydration) synthesis of a polymer



(b) Hydrolysis of a polymer

# Carbohydrates

monomer

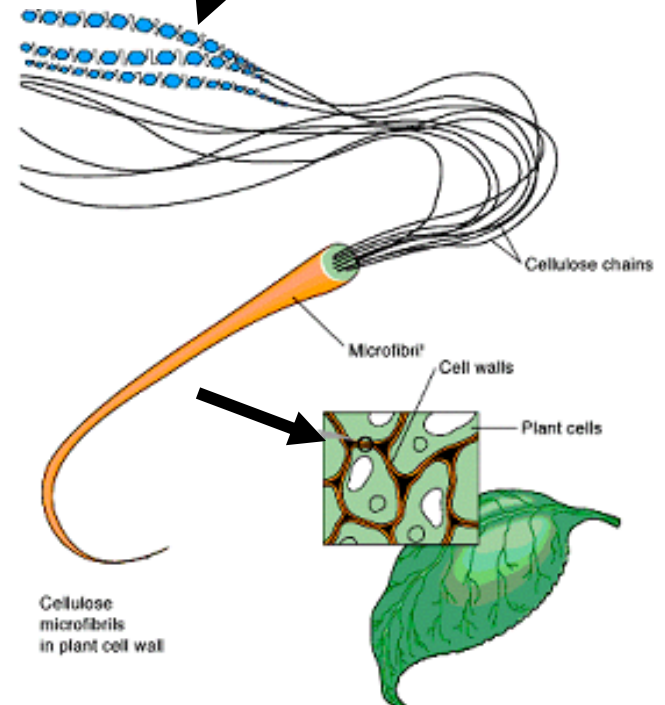
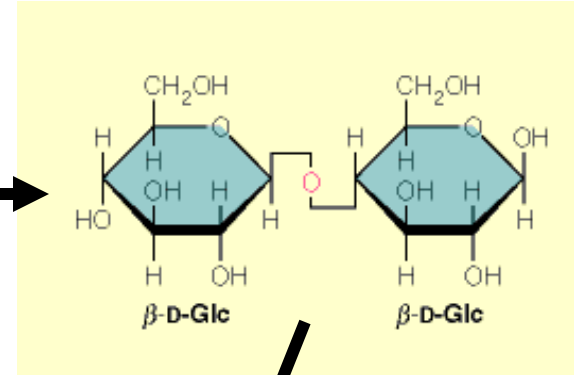
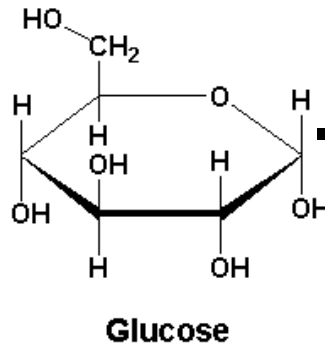
glucose

polymer

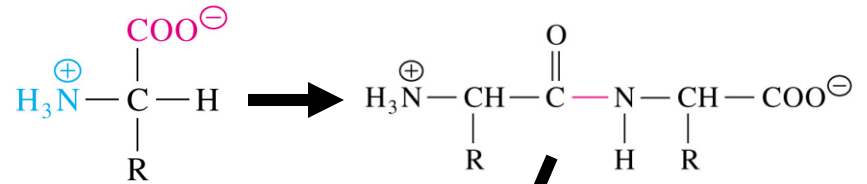
cellulose

supramolecular  
structure

cell wall



# Proteins



monomer

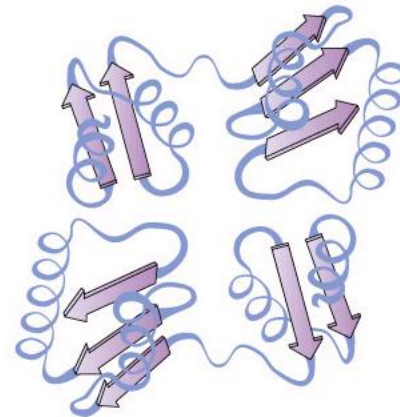
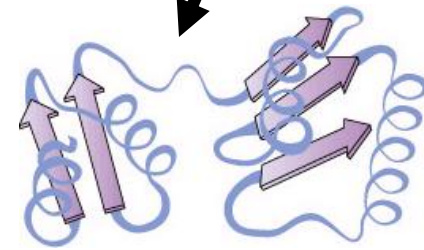
amino acid

polymer

protein subunit

supramolecular  
structure

Enzyme complex

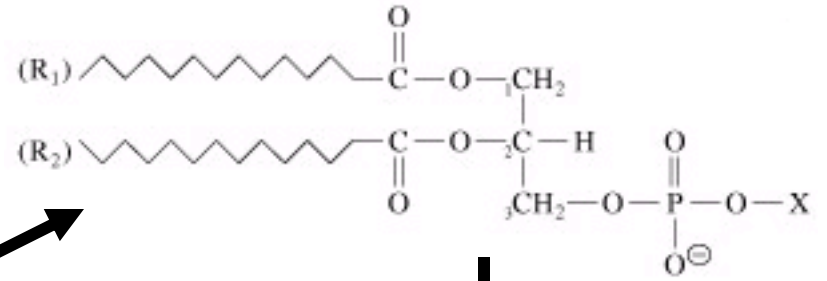
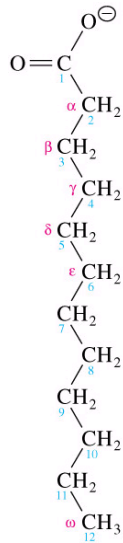


# Lipids

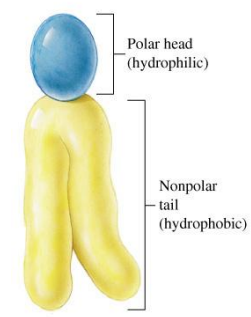
monomer fatty acid

polymer phospholipid

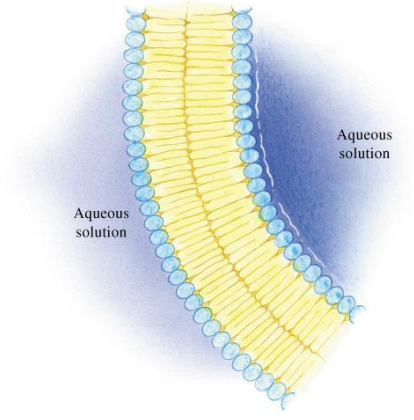
supramolecular structure membrane



(a)

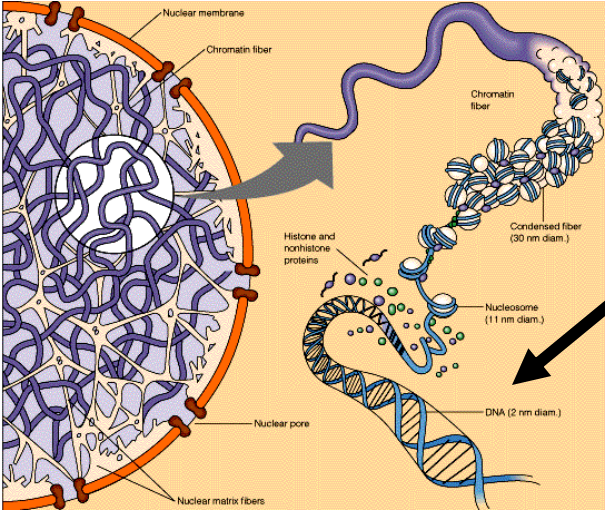
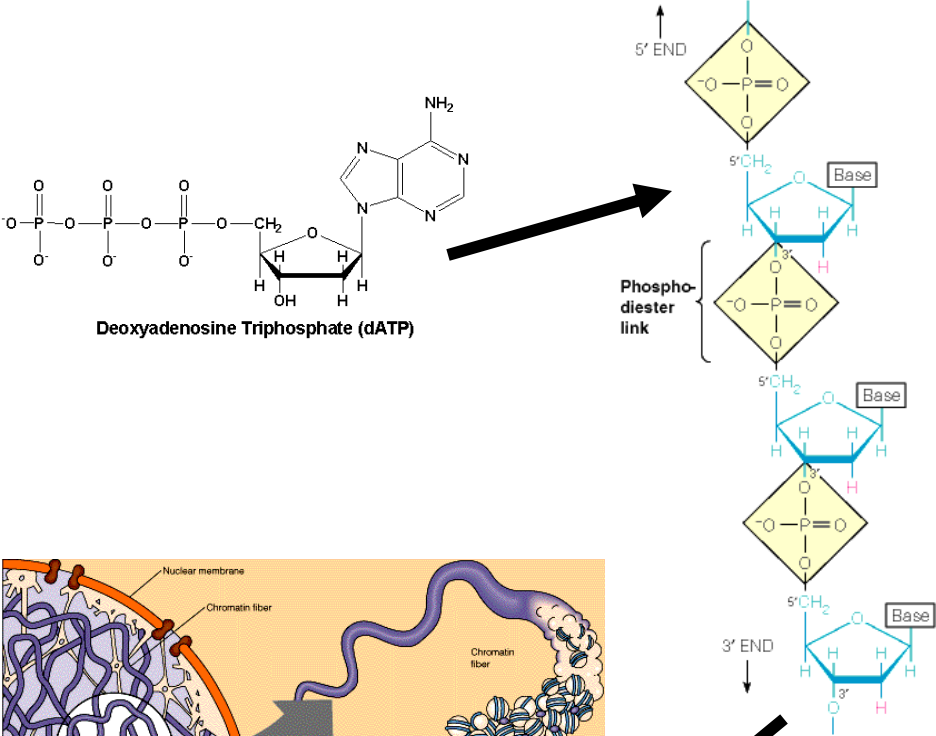
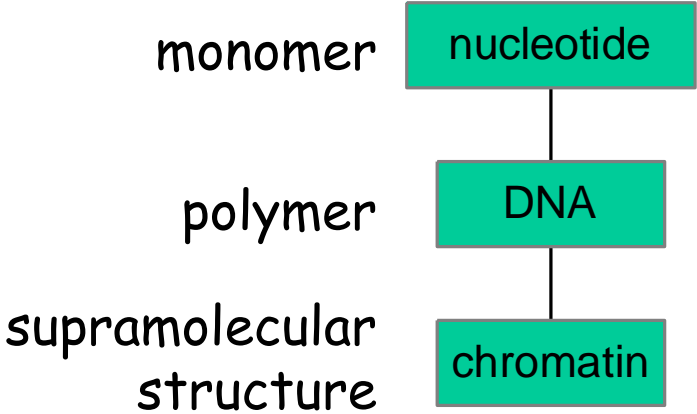


(b)

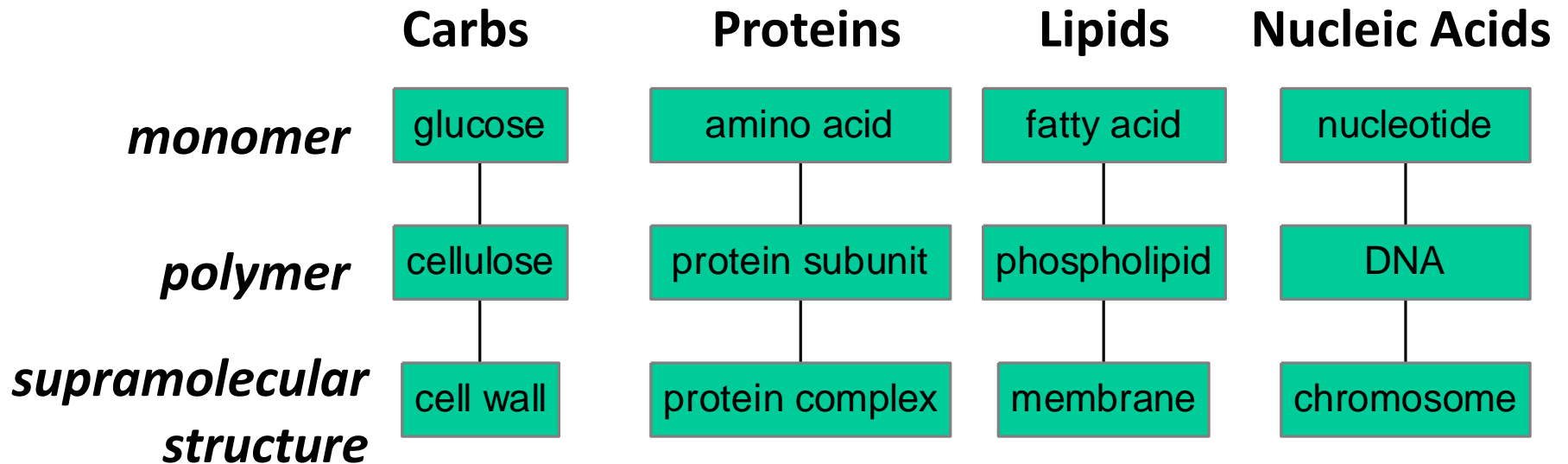




# Nucleic Acids



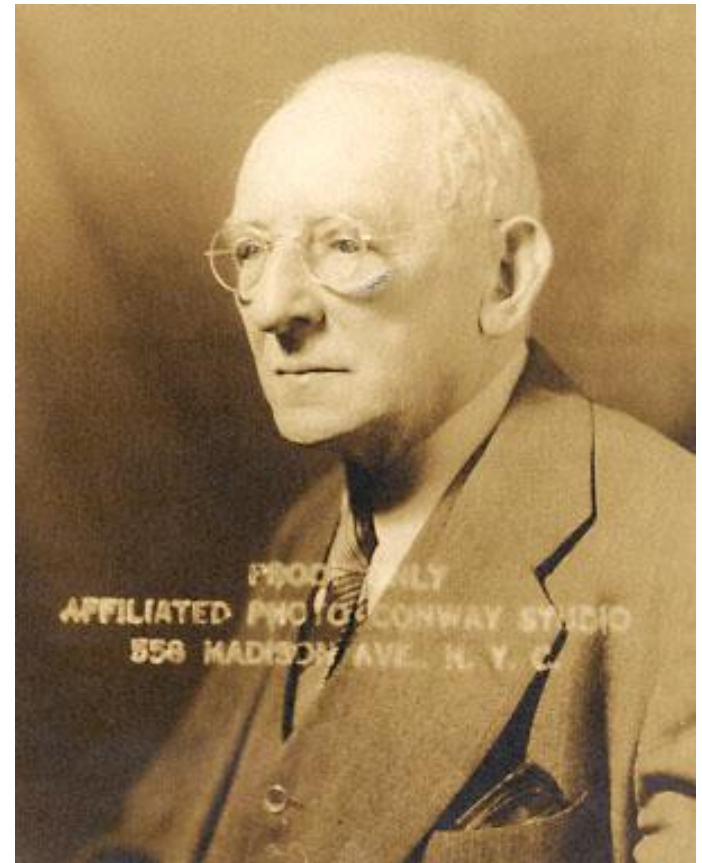
# Many Important Biomolecules are Polymers



# History and development of Biochemistry

**1903, Neuberg (German):  
“Biochemistry”**

**“Chemistry of Life”**



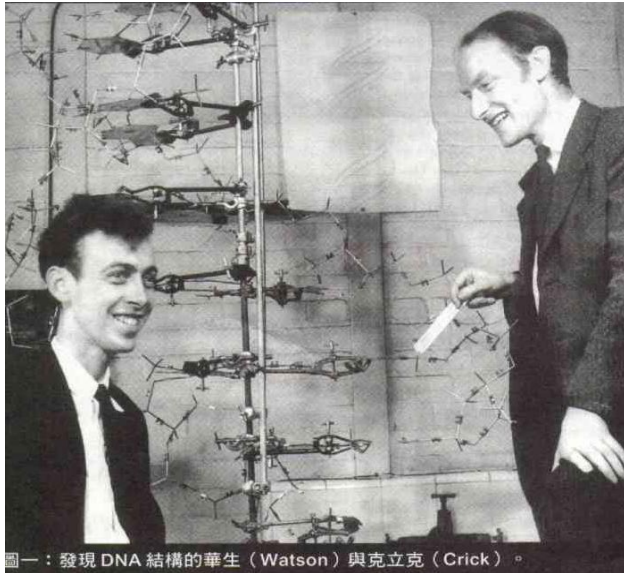
## Two notable breakthroughs

- (1) Discovery of the role of **enzymes** as catalysts
- (2) Identification of **nucleic acids** as information molecules

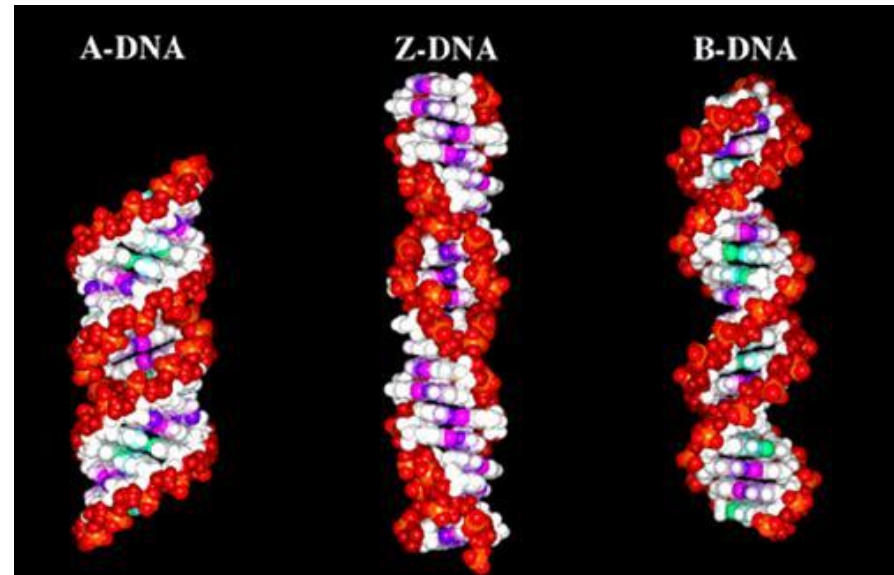
**Flow of information:** from nucleic acids to proteins

**DNA** → **RNA** → **Protein**

- **1937:** *Krebs* won the Nobel Prize in Physiology or Medicine in 1953 for the discovery of the **Citric Acid Cycle**
- **1953:** *Watson & Crick* won the Nobel Prize in Physiology or Medicine in 1962 for the discovery of the **DNA Double Helix**

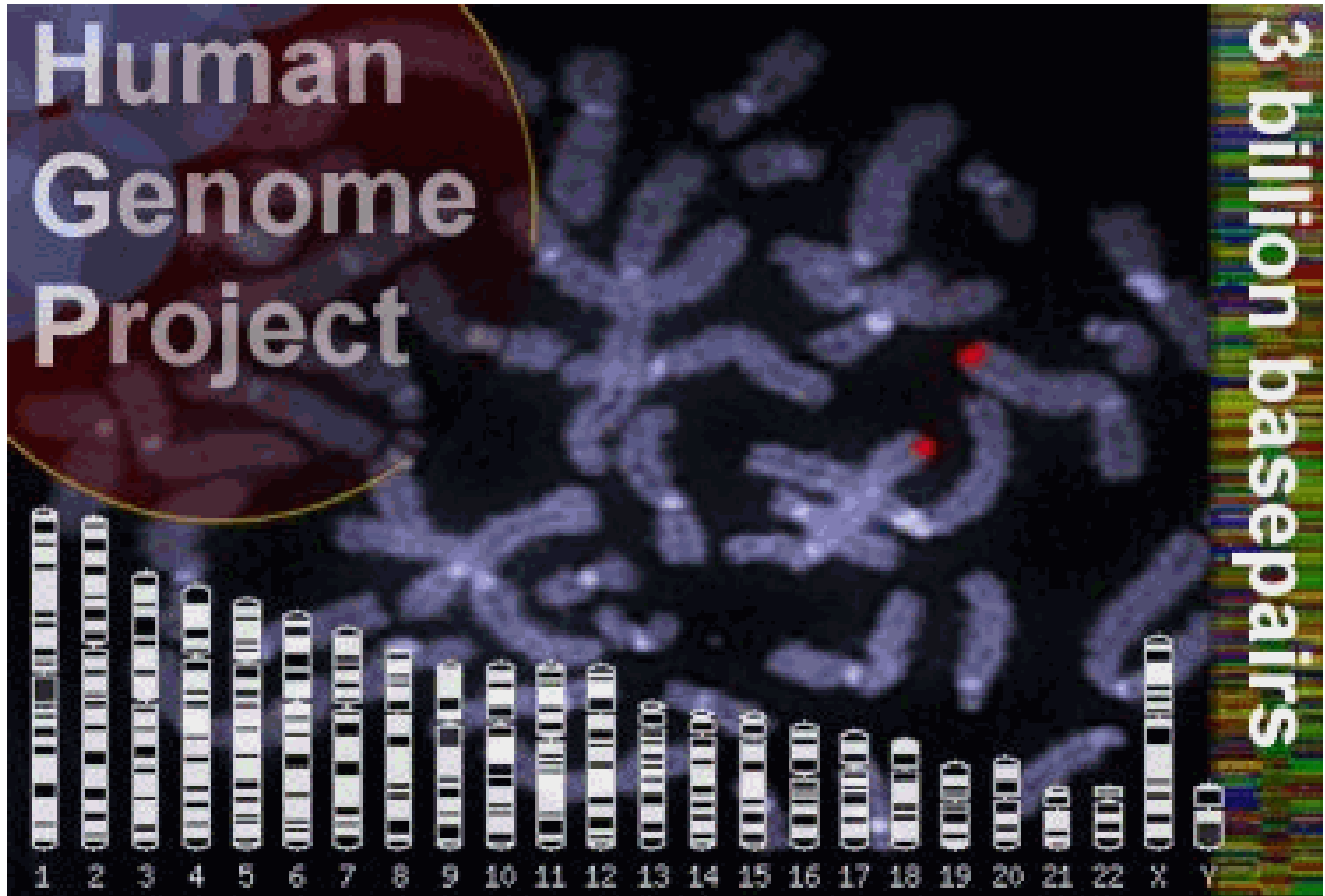


圖一：發現 DNA 結構的華生（Watson）與克立克（Crick）。



- In **1955**, *Sanger* for the determination of insulin sequence- won the Nobel Prize in Physiology or Medicine in 1956
- In **1980**, *Sanger & Gilbert* for first sequencing DNA- won the Nobel Prize in Chemistry in 1980
- In **1993**, *Kary B. Mullis* for the invention of the PCR method -won the Nobel Prize in Chemistry in 1993

# HGP from 1990, completed in 2003



# Principle areas of Biochemistry

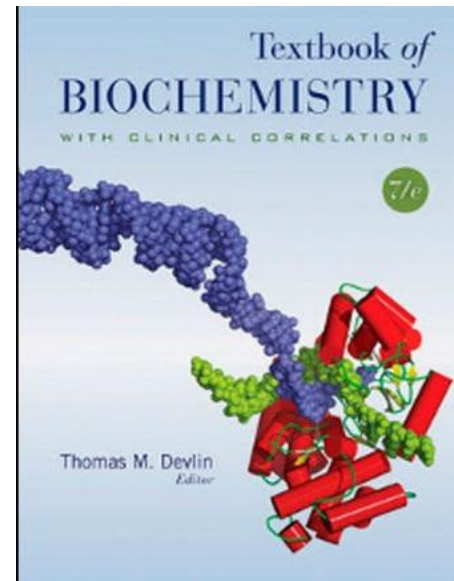
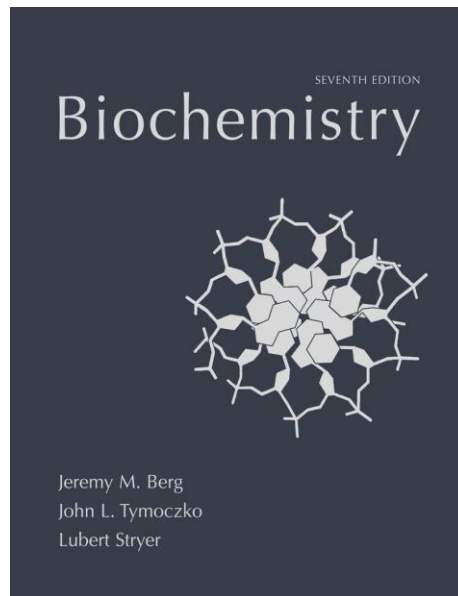
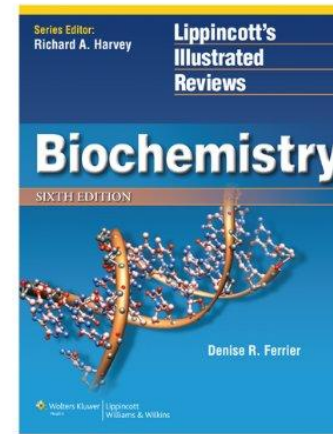
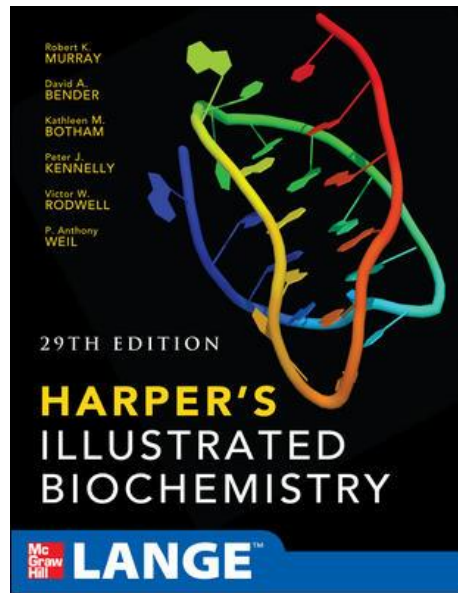
- Structure and function of cellular components  
**(i.e.) proteins, carbohydrates, lipids, nucleic acids** and other biomolecules
- Metabolism (catabolic and anabolic processes) and its regulation
- Molecular Genetics:
  - Gene expression and modulation
  - Regulation of protein synthesis
  - How life is replicated

**DNA**      **RNA**      **Protein**



## Topics of this course

- 1 Acids, Bases, pH scale and buffers
- 2 Chemical bonds
- 3 Amino acids: structure and properties
- 4 Peptide bonds, proteins: types, structure, function
- 5 Enzymes
- 6 Vitamins and coenzymes
- 7 Carbohydrates: structure and properties
- 8 Nucleotides and nucleic acids
- 9 Fatty acids and lipids
- 10 Hormones



**Material for this introductory lecture were derived from presentations by:**

- **David Shintani**

Department Chair and Full Professor in the Department of Biochemistry, University of Nevada, Reno

- **Zhihong Li**

Associate Prof. & Director, Department of Biochemistry, China Three Gorges University