THE MOLECULE THAT SUPPORTS ALL OF LIFE

- Water is the biological medium on Earth
- All living organisms require water more than any other substance
- Most cells are surrounded by water, and cells themselves are about 70–95% water
- The abundance of water is the main reason the Earth is habitable

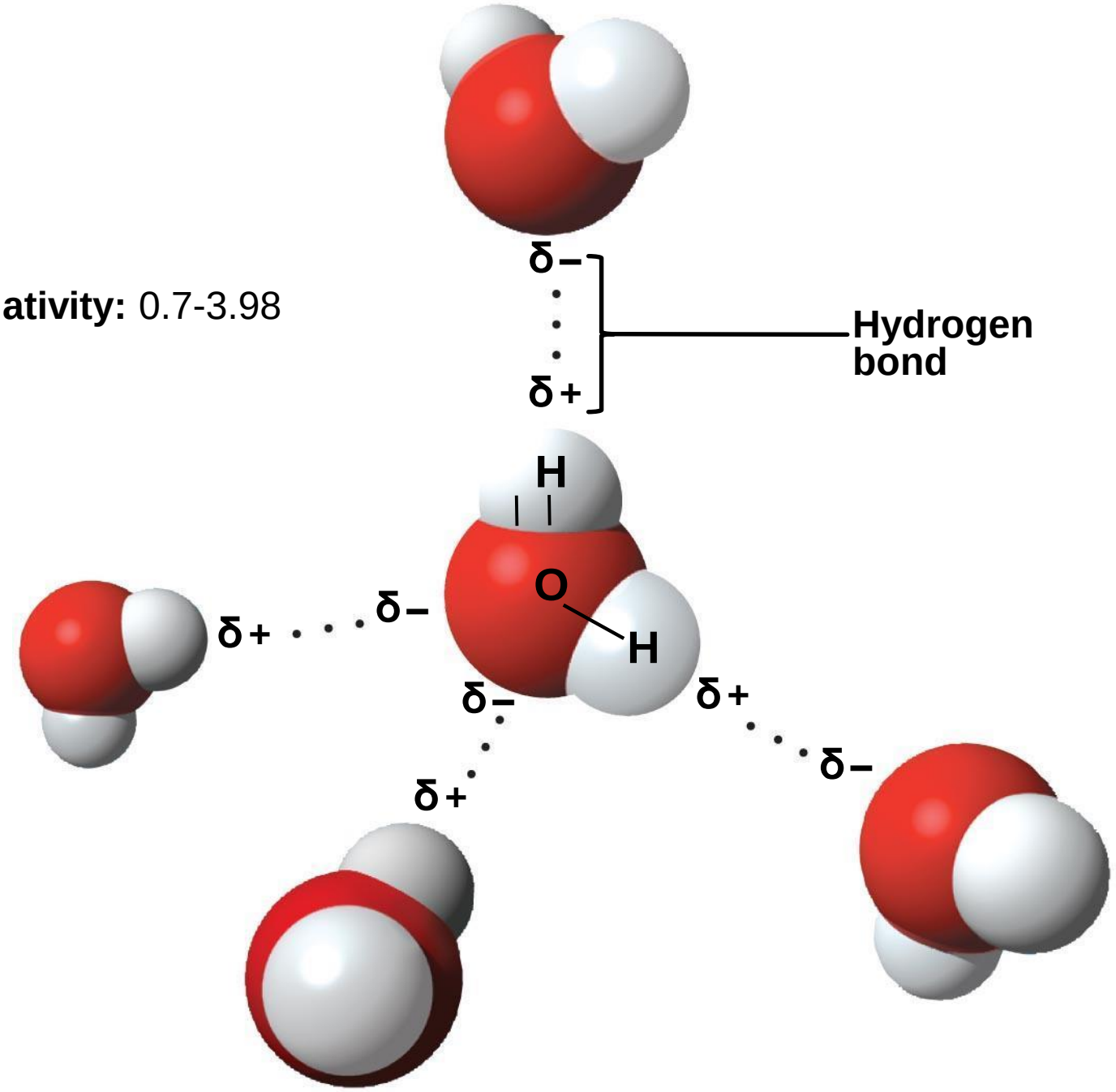
THE POLARITY OF WATER MOLECULES RESULTS IN HYDROGEN BONDING

- The water molecule is a **polar molecule**: The opposite ends have opposite charges
- Polarity allows water molecules to form hydrogen bonds with each other

How many hydrogen bonds each water can have?

Fig. 3-2

Electronegativity: 0.7-3.98



FOUR EMERGENT PROPERTIES OF WATER CONTRIBUTE TO EARTH'S FITNESS FOR LIFE

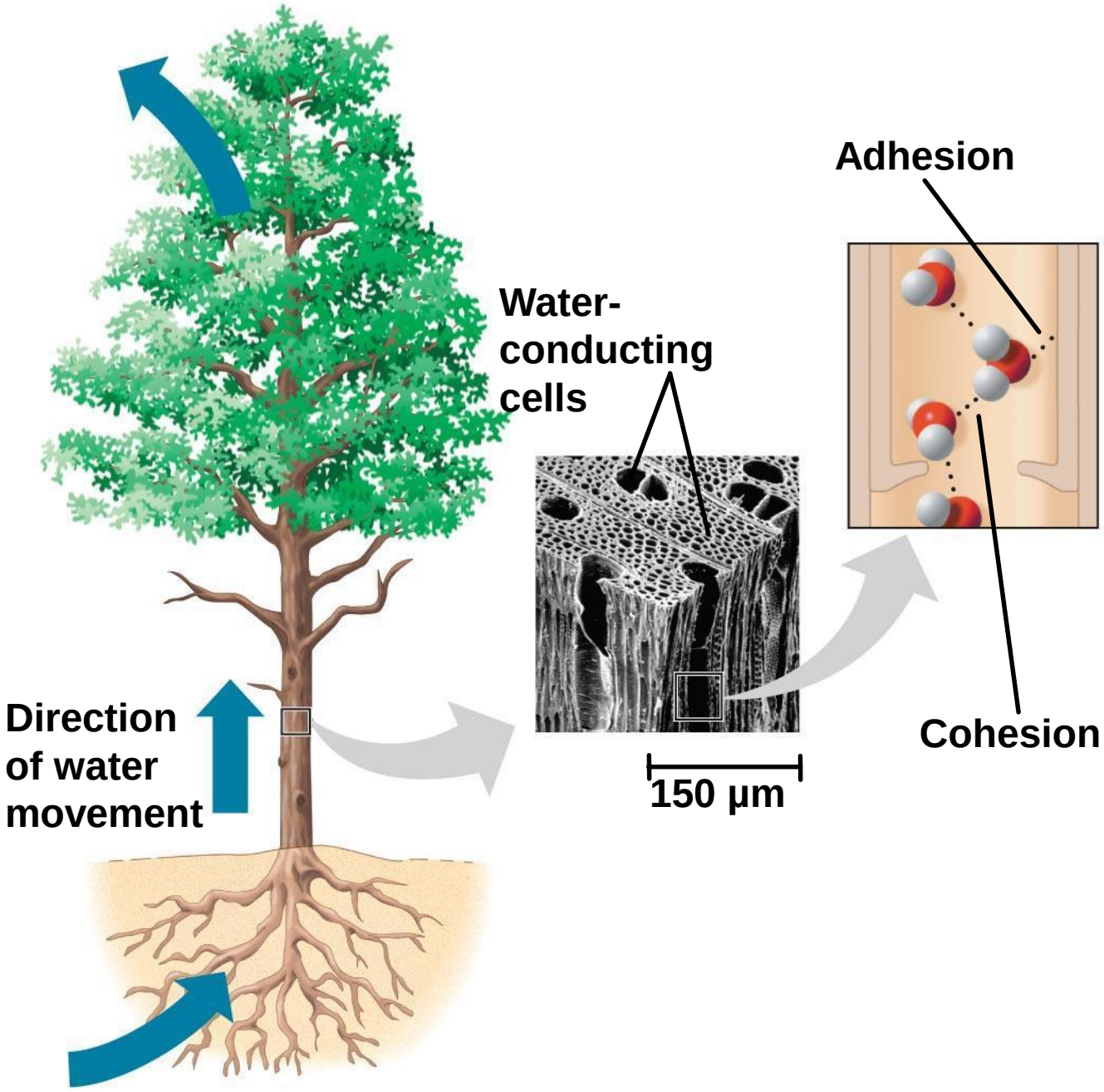
Four of water's properties that facilitate an environment for life are:

- Cohesive behavior
- Ability to moderate temperature
- Expansion upon freezing
- Versatility as a solvent

COHESION AND ADHESION

- Collectively, hydrogen bonds hold water molecules together, a phenomenon called **cohesion**

How these properties of water support the life on earth?



- **Surface tension** is a measure of how hard it is to break the surface of a liquid
- Surface tension is related to cohesion

The high surface tension of water is also essential for processes such as water and blood transport in plants and animals respectively.

Allows the cytoplasm to hold-up the cell membrane

Highly essential for maintaining structure of the cell and organelle.

MODERATION OF TEMPERATURE

- Water absorbs heat from warmer air and releases stored heat to cooler air
- Water can absorb or release a large amount of heat with only a slight change in its own temperature
- The **specific heat** of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1ºC
- The water has very high specific heat
- Water resists changing its temperature because of its high specific heat

Water: 4.184 Joules /g ^{O}C
Ethanol: 2.46
Iron: 0.450 : 9 times lesser
Gold: 0-129: 30 times
Copper: 0.385: 11 times

Body temperature of human: 37^{O}C $\pm$ 0.6
High fever: 39.4 to 41.1 ^{O}C

Why water has high specific heat?
How it's relevant for supporting the life on earth?

The high specific heat of **water minimizes temperature fluctuations to within limits that permit life**

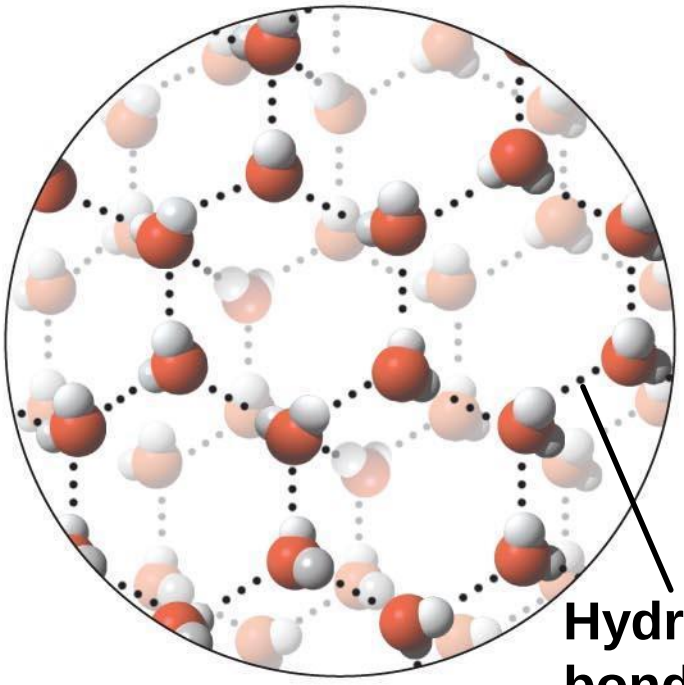
Expansion upon freezing
INSULATION OF BODIES OF WATER BY FLOATING ICE

- Ice floats in liquid water because hydrogen bonds in ice are more "ordered," making ice less dense

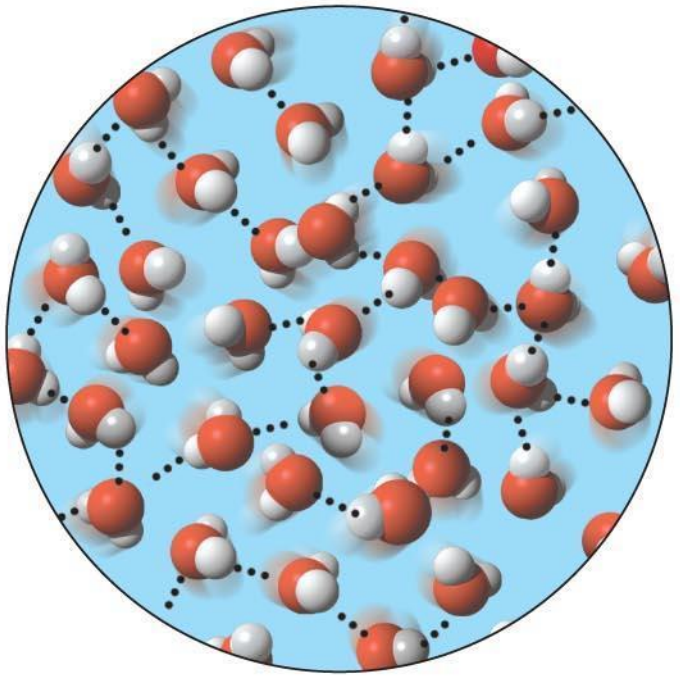
- Water reaches its greatest density at 4°C

How this property of water supports the life on earth?

Fig. 3-6a



Ice
Hydrogen bonds are stable



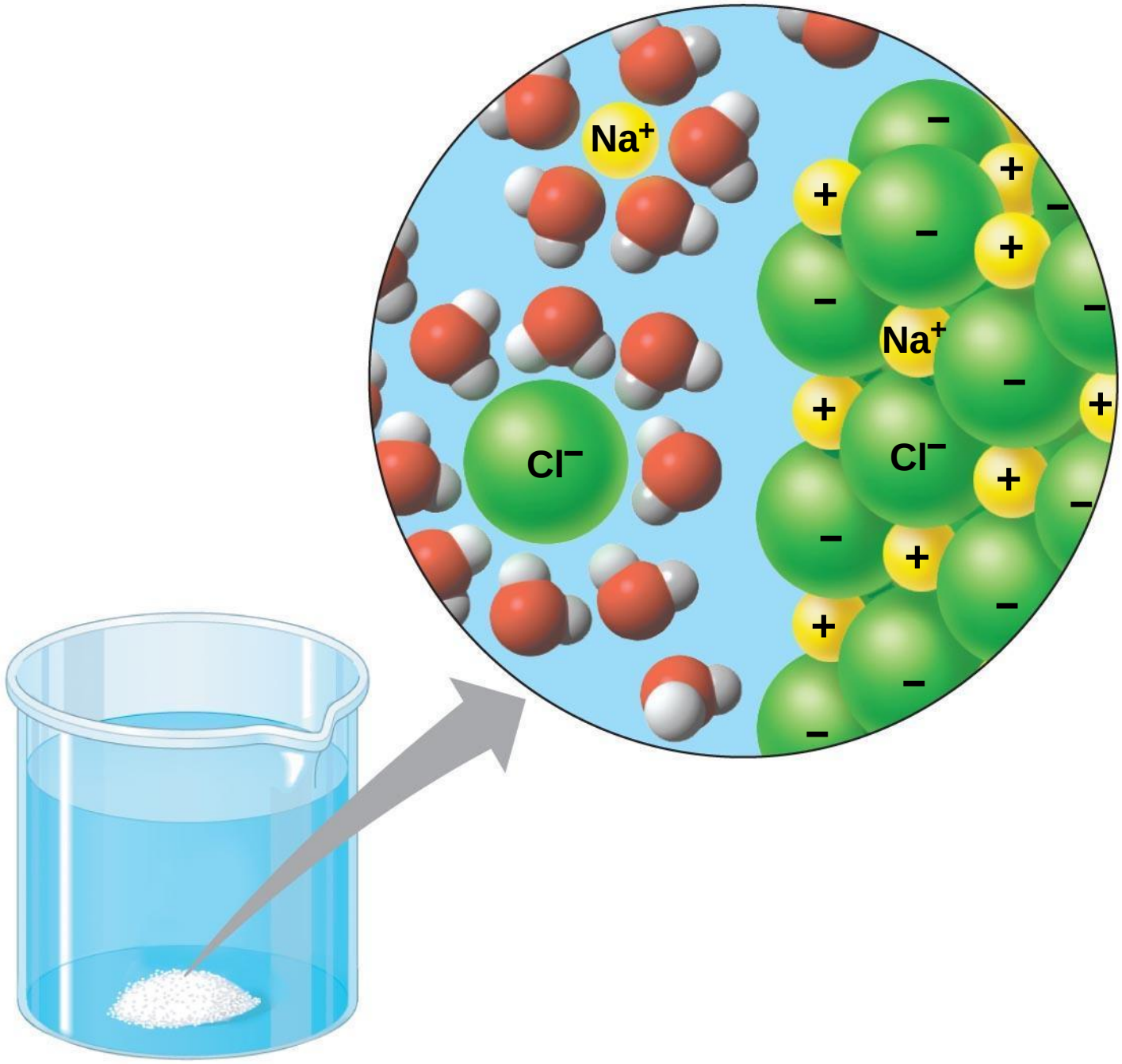
Liquid water
Hydrogen bonds break and re-form

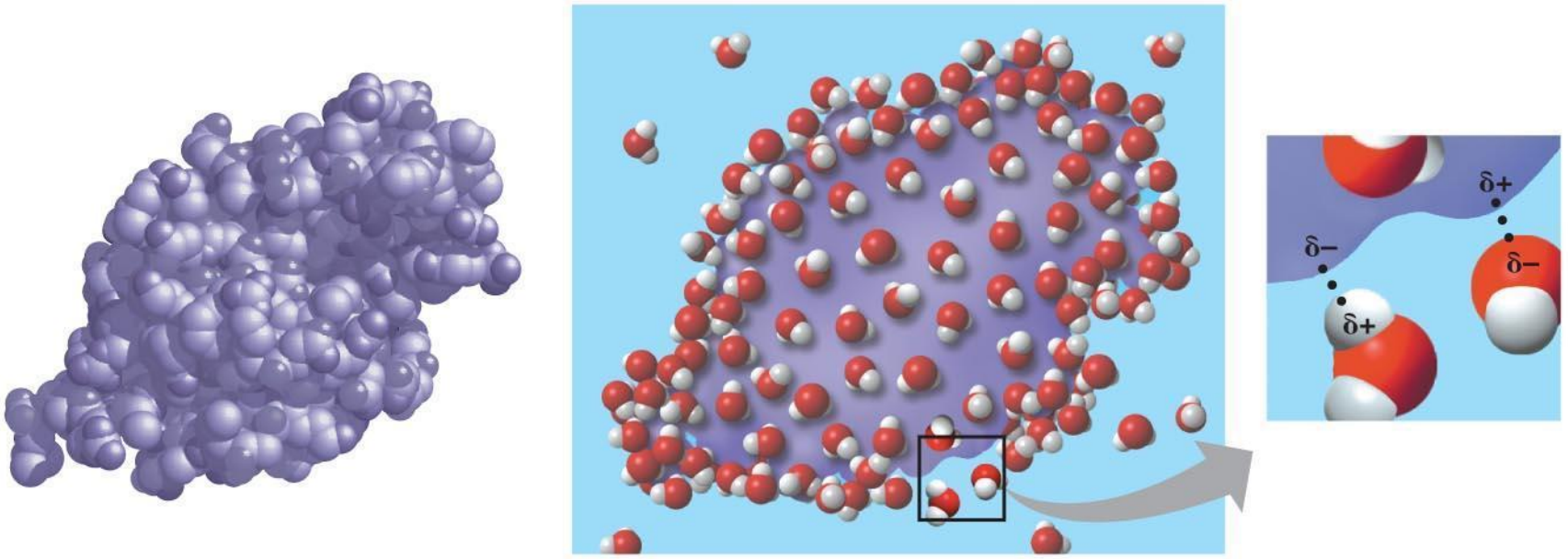
Ice: crystalline structure and floating barrier

THE SOLVENT OF LIFE

- **solution**
- **solvent**
- **solute**
- An **aqueous solution** is one in which water is the solvent

- Water is a versatile solvent due **to its polarity**, which **allows it to form hydrogen bonds easily**
- When an ionic compound is dissolved in water, **each ion is surrounded** by a sphere of water molecules called a **hydration shell**





(a) Lysozyme molecule in a nonaqueous environment

(b) Lysozyme molecule (purple) in an aqueous environment

(c) Ionic and polar regions on the protein's surface attract water molecules.

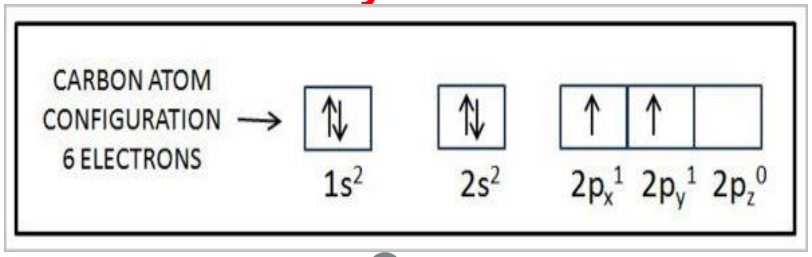
- Water can also dissolve compounds made of ionic polar molecule
- Even large polar molecules such as proteins can dissolve in water if they have ionic and polar regions
- Proteins are active/alive in our body because of cell contains >80% of water

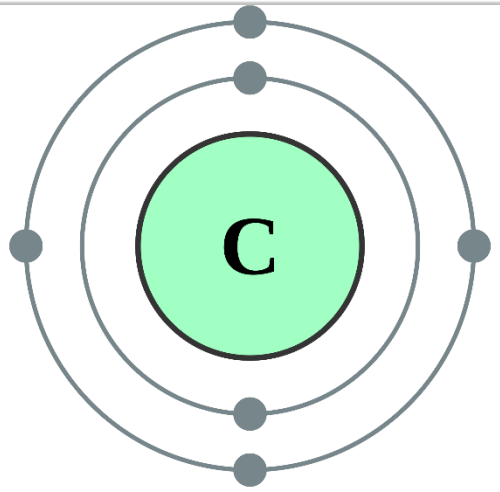
Carbon: The Backbone of Life

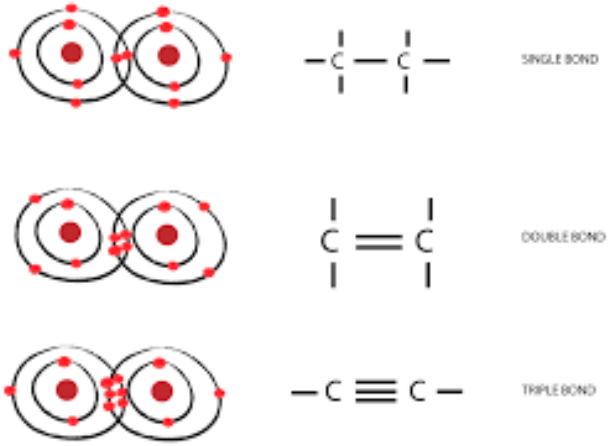
- Cells are 70–95% water, the rest is mostly carbon-based compounds
- Carbon can form large, complex, and diverse molecules with ease.
- Proteins, DNA, carbohydrates, and other molecules found only in living matter are all composed of carbon compounds

- **Organic chemistry** is the study of compounds containing carbon
- Organic compounds range from simple molecules to colossal ones
- Most organic compounds contain hydrogen atoms as well as carbon atoms

Why carbon atoms can form diverse molecules ?

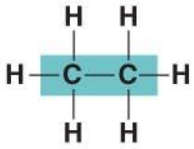




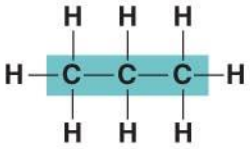


How vast molecular diversity arise from the carbon molecules?

- Carbon chains form the skeletons of most organic molecules
- Carbon chains vary in length and shape

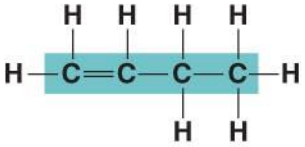


Ethane

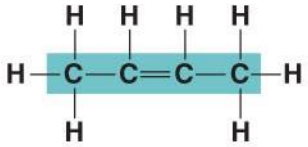


Propane

(a) Length

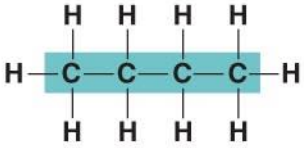


1-Butene

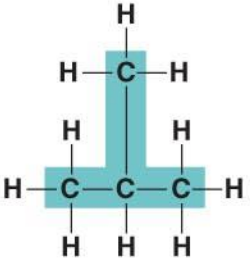


2-Butene

(c) Double bonds

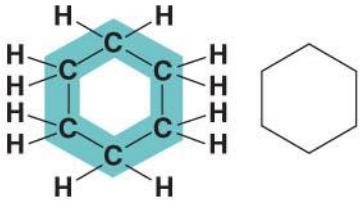


Butane

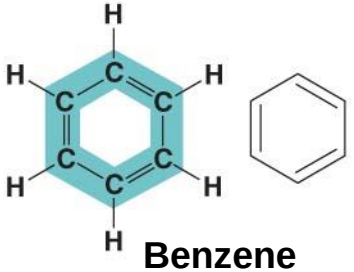


2-Methylpropane
(commonly called isobutane)

(b) Branching



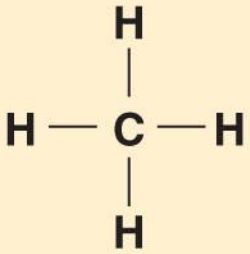
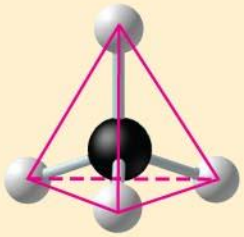
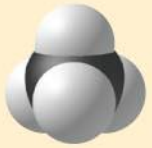
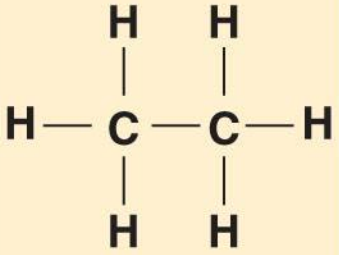
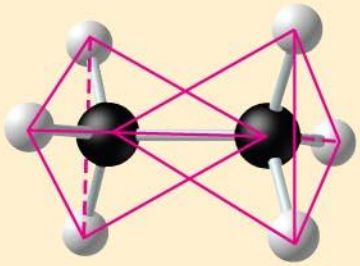
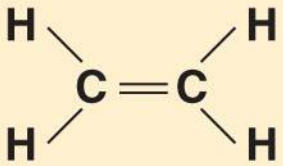
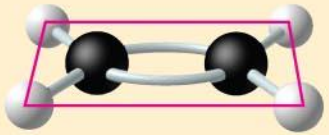
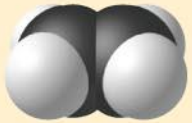
Cyclohexane



Benzene

(d) Rings

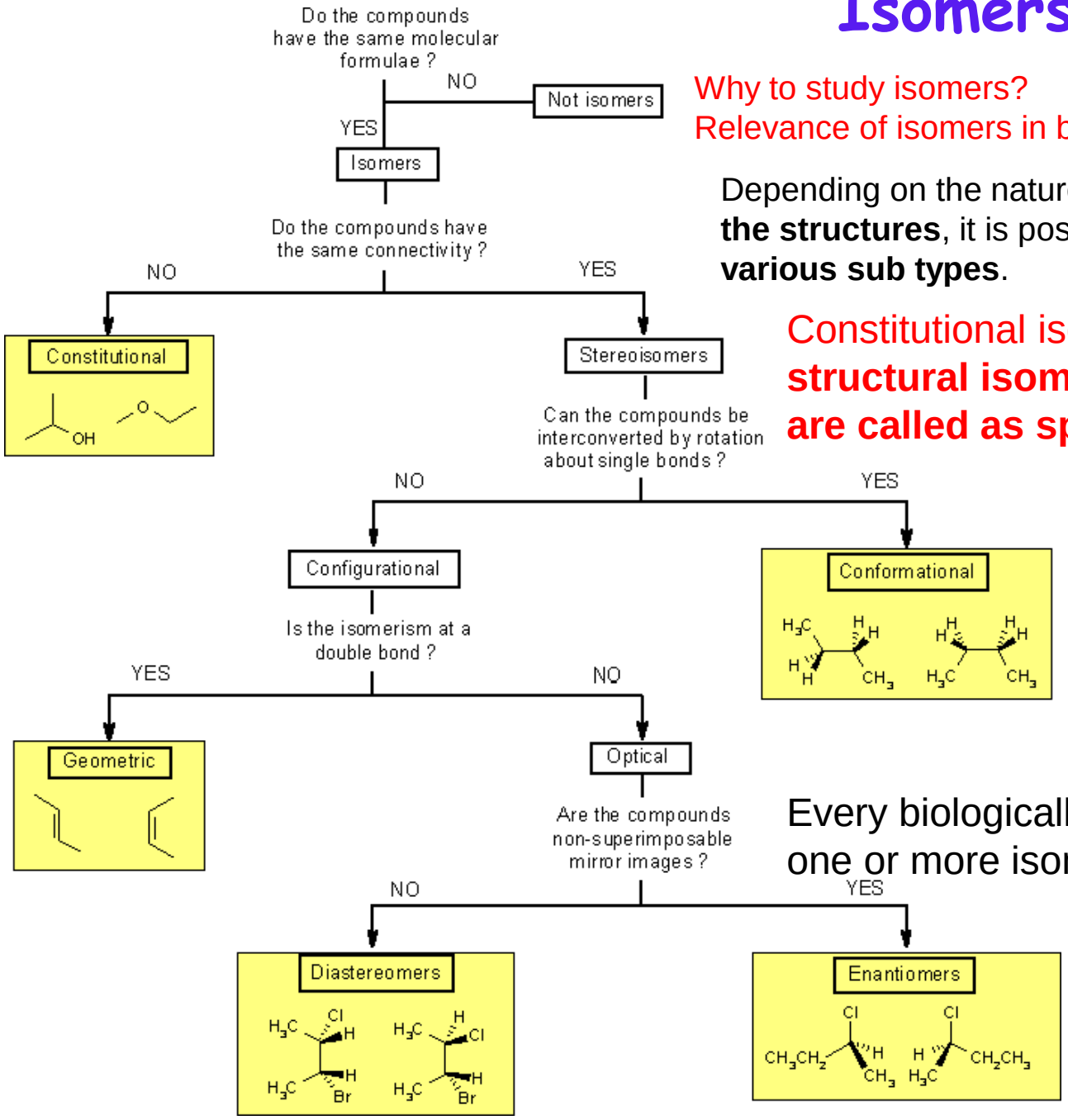
Fig. 4-5

Name	Molecular Formula	Structural Formula	Ball-and-Stick Model	Space-Filling Model
(a) Methane	CH_4			
(b) Ethane	C_2H_6			
(c) Ethene (ethylene)	C_2H_4			

What is the difference between molecular and structural formula?

Single molecule may have different structural compounds?

Isomers



Why to study isomers?
Relevance of isomers in biology or pharmaceutical industry?

Depending on the nature of the **difference between the structures**, it is possible to classify isomers into **various sub types**.

Constitutional isomers are also called **structural isomers ,**where **stereoisomer are called as spatial isomers?**

Functioning (dynamic) of proteins is depends on conformational isomers

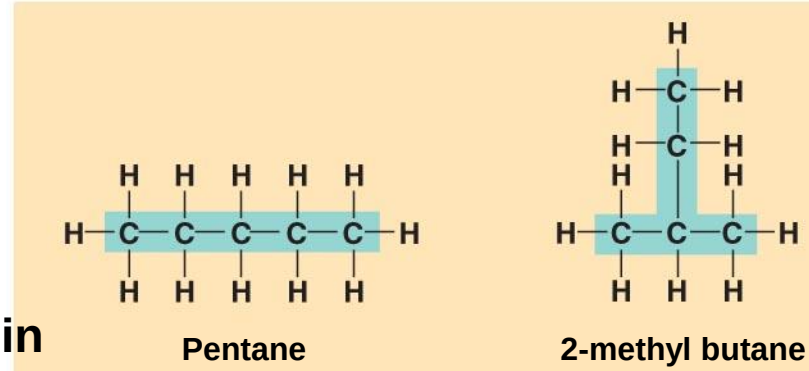
Every biologically important molecule has one or more isomers

University of Calgary
Chemistry Department

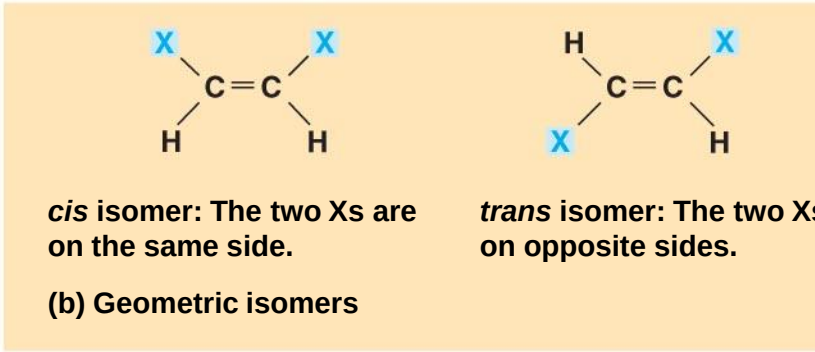
Isomers

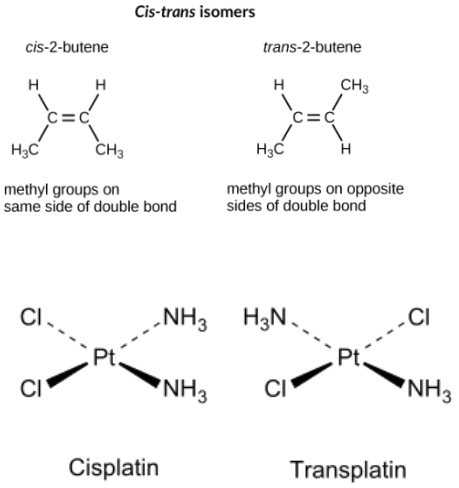
Structural isomers(constitutional isomers) have different covalent arrangements of their atoms

3,66,319 possible structural isomers in C20H42

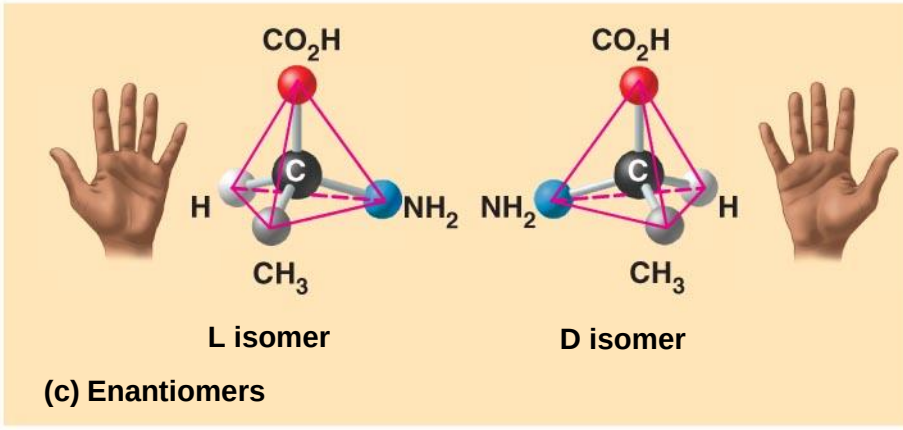


Geometric isomers (cis-trans isomers) have the same covalent arrangements but differ in spatial arrangements

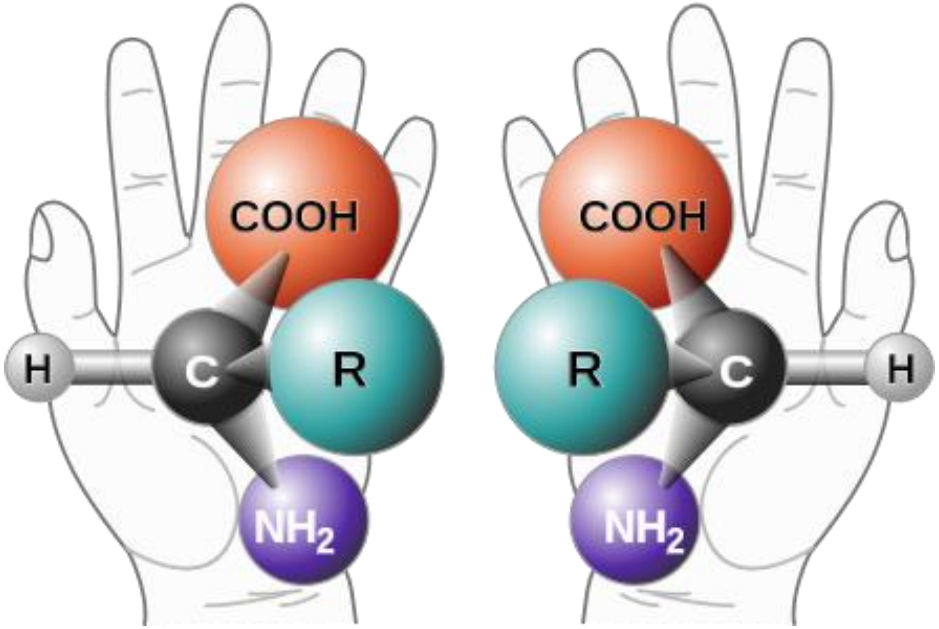


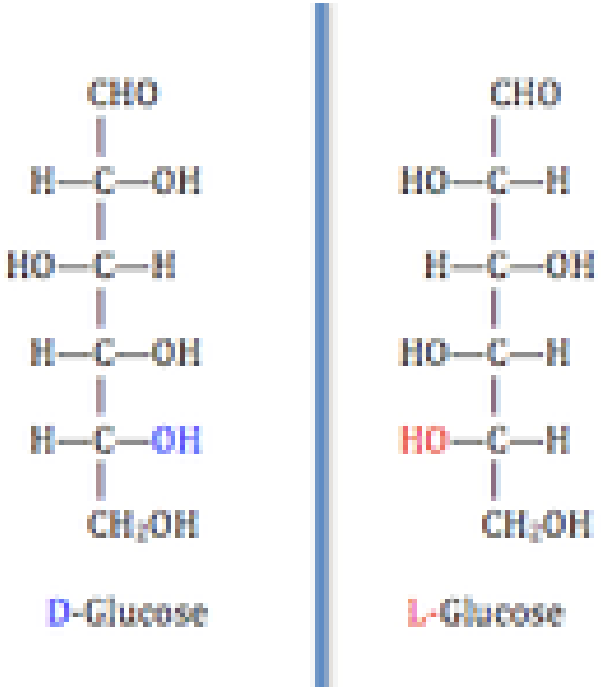


Enantiomers are isomers that are mirror images of each other.



L and D-amino acids (enantiomer)
D- and L- Sugars

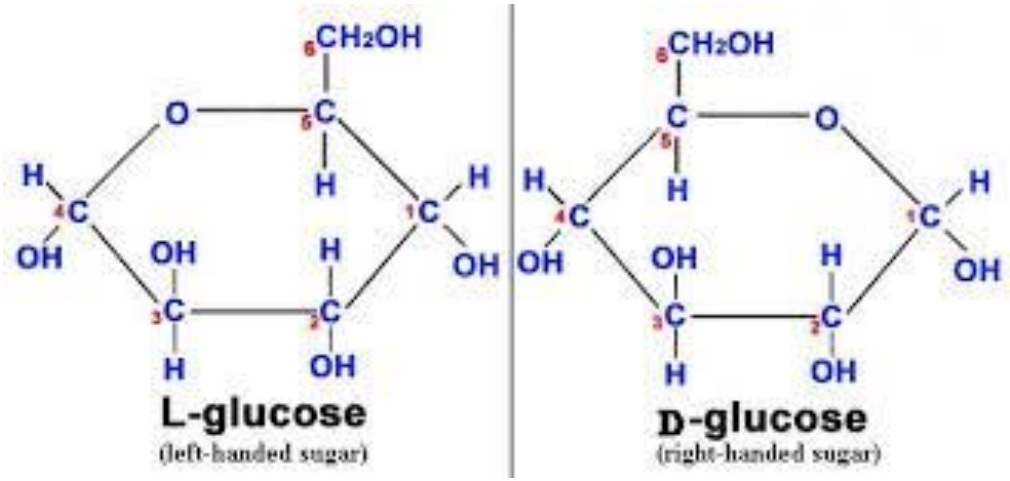




If n is the number of asymmetric carbon atoms then the maximum number of stereoisomers = 2^n

Why to study the enantiomers?

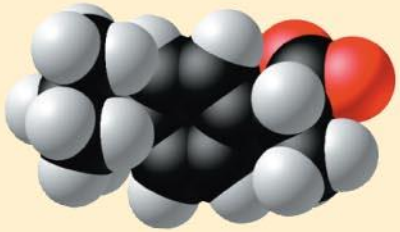
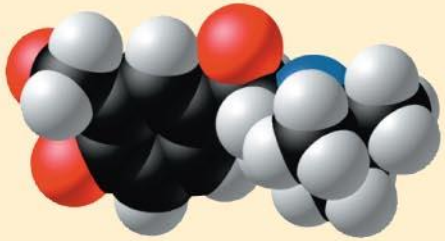
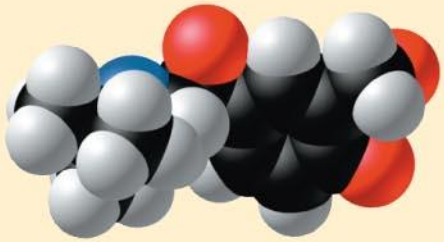
- **Usually only one form is active in biological systems**
- **Most of the large biological macromolecules made of one type of enantiomers**
  - **Proteins are made of L-amino acids**
  - **Polysaccharides (carbohydrates) are made of D-sugars**



Why to study the Enantiomers?

- Usually only one form is active in biological systems
- Most of the large biological macromolecules made of one type of Enantiomers

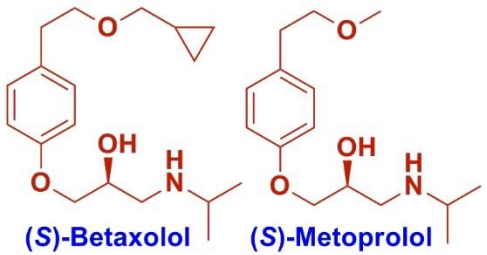
Pharmacological importance of enantiomers

Drug	Condition	Effective Enantiomer	Ineffective Enantiomer
Ibuprofen	Pain; inflammation	 *S*-Ibuprofen	 *R*-Ibuprofen
Albuterol	Asthma	 *R*-Albuterol	 *S*-Albuterol

Molecule properties are depends on arrangement of their atoms.

Thalidomide?

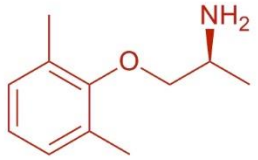
Chiral Drugs



(*S*)-Betaxolol **(*S*)-Metoprolol**

(Antihypertensive drugs)

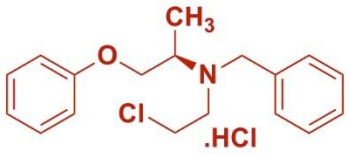
Tetrahedron, 2007, 63, 1872



(*R*)- Mexiletine

(Antiarrhythmic agent)

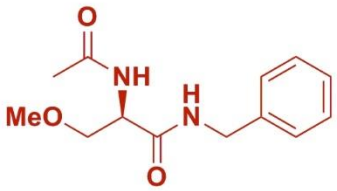
Tetrahedron:Asymmetry, 2009, 20, 2814



(*R*)- Phenoxybenzamine

(Antihypertensive drug)

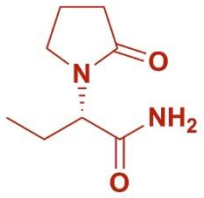
Tetrahedron: Asymmetry, 2010, 21, 2825



Lacosamide

(Antiepileptic drug)

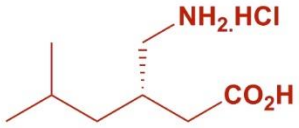
Tetrahedron: Asymmetry, 2011, 22, 1353



Levetiracetam

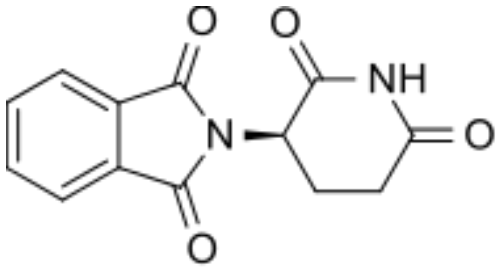
(Antiepileptic drug)

Tetrahedron: Asymmetry, 2012 (in press)

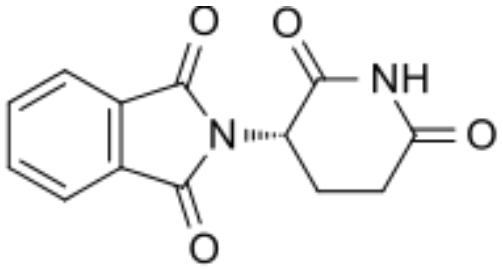


Pregabalin

(Antiepileptic drug)



(R)-thalidomide

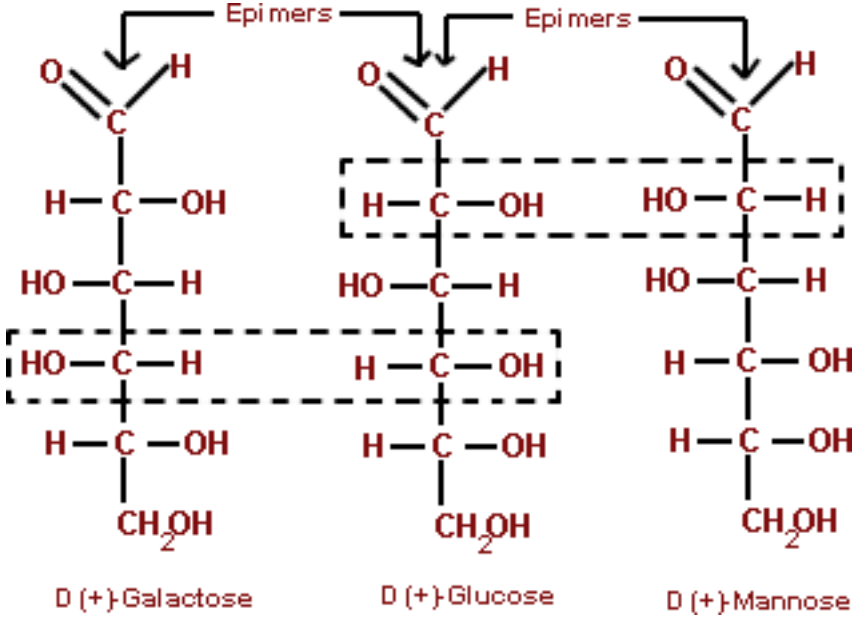


(S)-thalidomide

Racemic mixture?

Diastereomers

When two or more stereoisomers of a compound have different configurations at one or more of the equivalent chiral centers and are not mirror images of each other.
Epimers: When two diastereoisomers differ from each other at only one stereocenter (chiral center) they are **epimers**.



Epimers

Epimerase: UDP-galactose 4-epimerase

Galactosemia III?

Without treatment, mortality in infants with galactosemia is about 75%.

A small number of chemical groups are key to the functioning of biological molecules

- Distinctive properties of organic molecules depend also on the molecular components attached to the carbon skeleton
- A number of characteristic groups may be attached to skeletons of organic molecules
- These are called **functional groups**

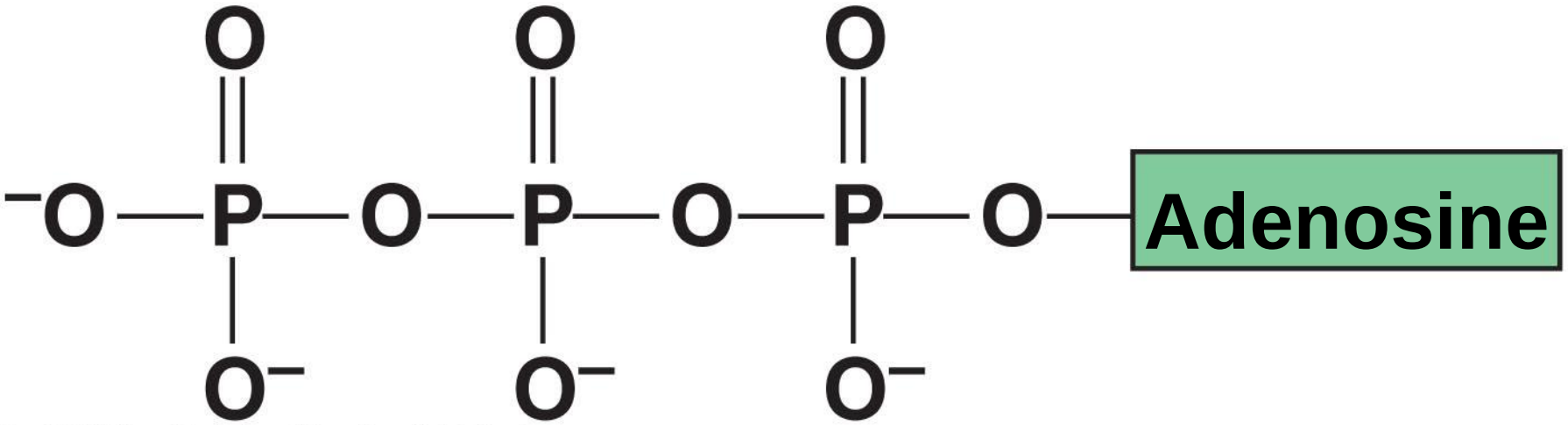
The Chemical Groups Most Important in the Processes of Life

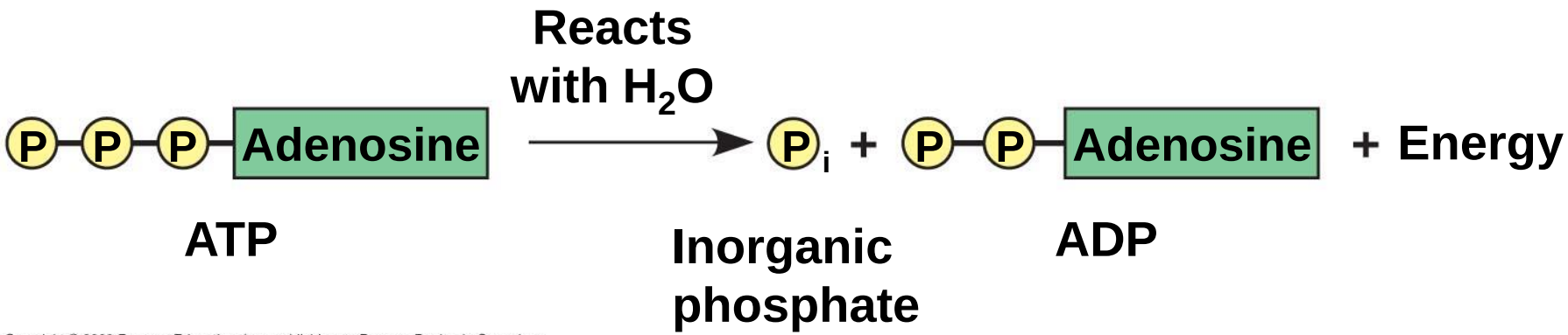
The seven functional groups that are most important in the chemistry of life:

Hydroxyl group
Carbonyl group
Carboxyl group
Amino group
Sulfhydryl group
Phosphate group
Methyl group

ATP: An Important Source of Energy for Cellular Processes

- **Adenosine triphosphate** (**ATP**), is the primary energy-transferring molecule in the cell
- ATP consists of an organic molecule called adenosine attached to a string of three phosphate groups





Chemical group determines sex hormone in mammals