Universidad de Chile

Programa Académico de Bachillerato

Introducción a la Biología Celular

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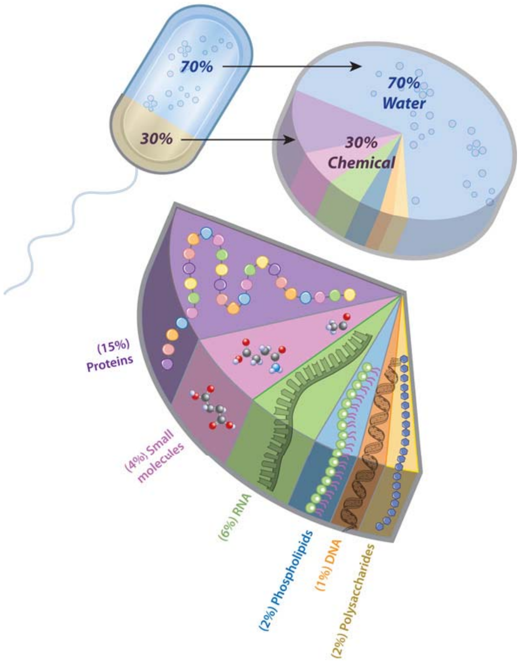
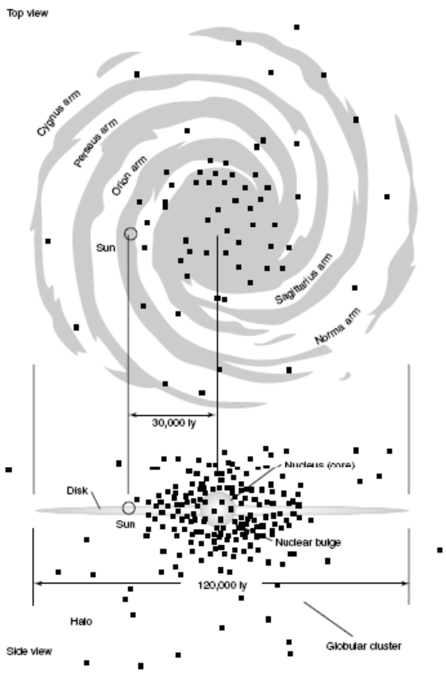
Átomos y Agua

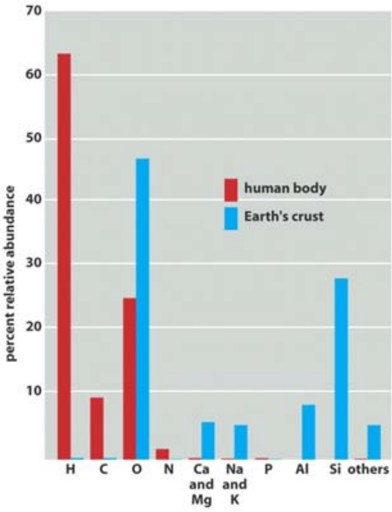




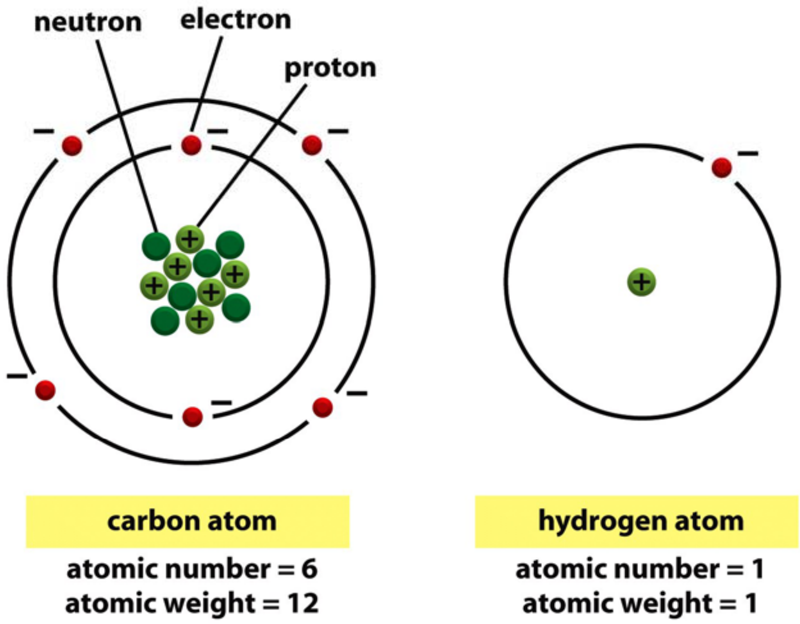
The Milky Way. (Reproduced from ‘‘Astronomy, the Evolving Universe’’ 9th Edition, 2002, by permission of Boris Starosta and Michael Zeilik)

RELATIVE COSMIC ABUNDANCES OF THE ELEMENTS

Element	Relative abundance
H	**1**
He	0,085
Li	$1,5 \times 10^{-9}$
C	**$3,7 \times 10^{-3}$**
N	**$1,2 \times 10^{-3}$**
O	**$6,7 \times 10^{-3}$**
S	**$1,6 \times 10^{-5}$**
P	**$3,2 \times 10^{-7}$**
Mg	$3,5 \times 10^{-5}$
Na	$1,7 \times 10^{-6}$
K	$1,1 \times 10^{-7}$
Si	$3,6 \times 10^{-6}$

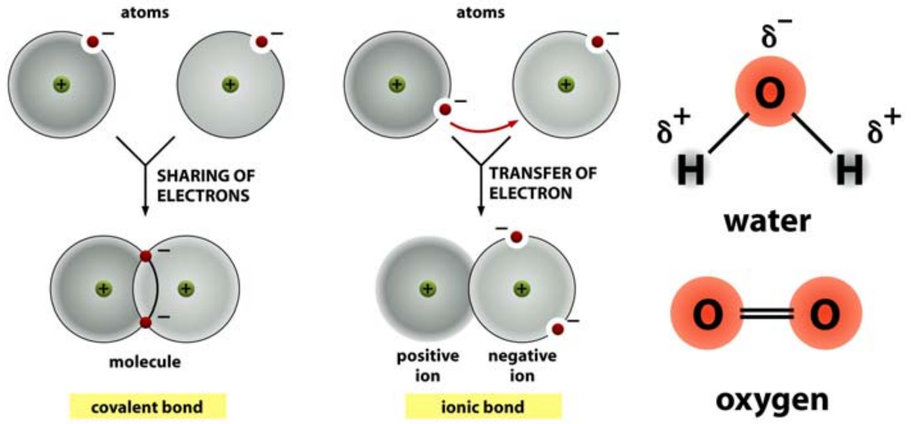


Abundancia relativa de los elementos químicos presentes en la corteza terrestre (el mundo no vivo) comparada con la determinada en los tejidos blandos de los organismos vivos. La abundancia relativa se expresa como porcentaje del total de átomos presente. Así, cerca del 60% de los átomos presentes en un organismo vivo son átomos de hidrógeno

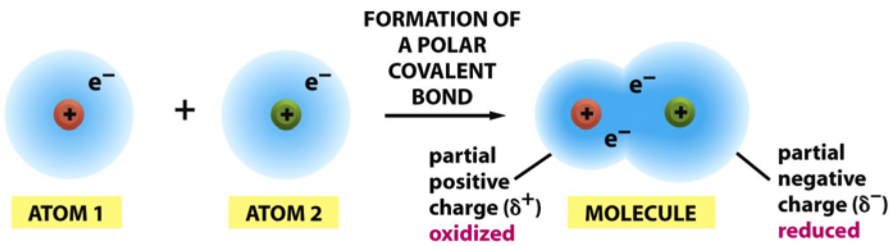


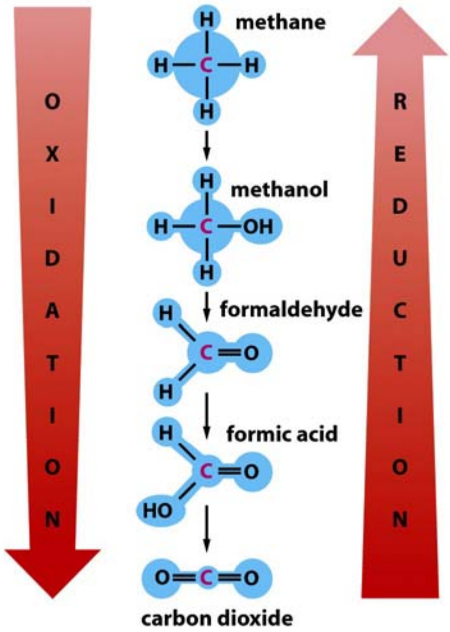
atomic number

		electron shell			
	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

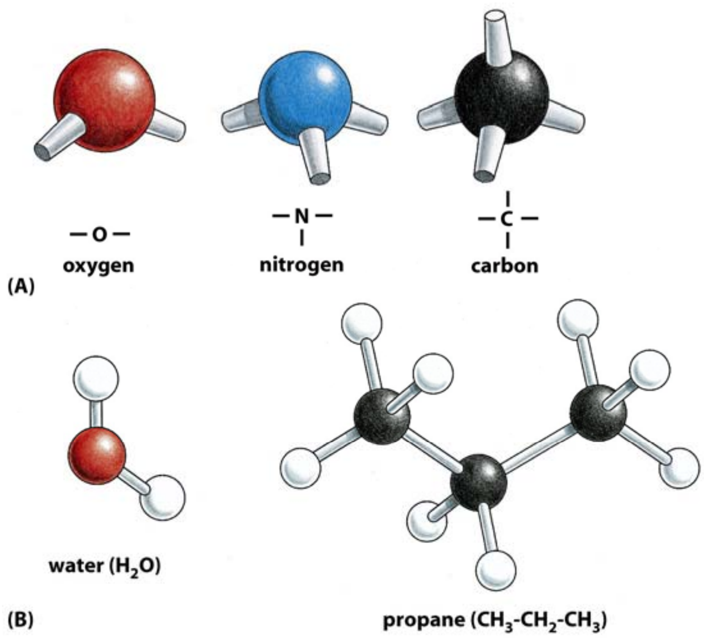


La interacción entre átomos resulta en la estabilización de los electrones de las capas más externas. Un enlace iónico se forma cuando los electrones se transfieren de un átomo a otro. Un enlace covalente se forma cuando los electrones se comparten entre los átomos. Los dos casos representan situaciones extremas. Frecuentemente, como en el caso del agua, los enlaces covalentes son polares

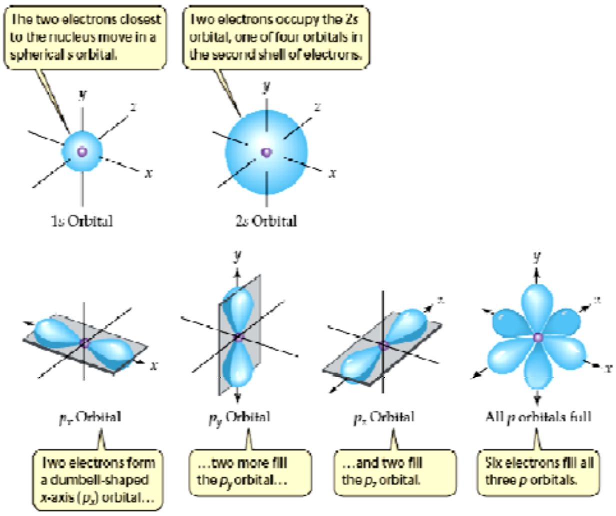




OXIDATION
REDUCTION
methane
methanol
formaldehyde
formic acid
carbon dioxide



oxygen
nitrogen
carbon
(A)
water (H_2O)
(B)
propane (CH_3-CH_2-CH_3)



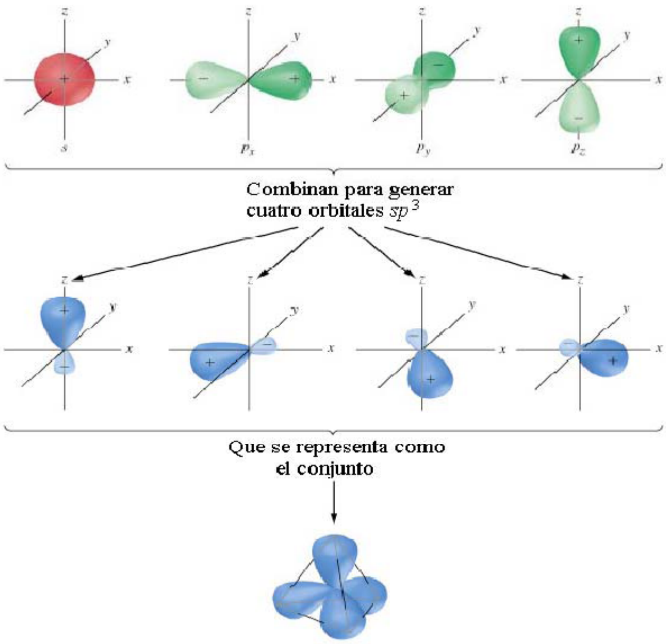
$1s^2\ 2s^2\ 2px^1\ 2py^1\ 2pz$ (estado basal)

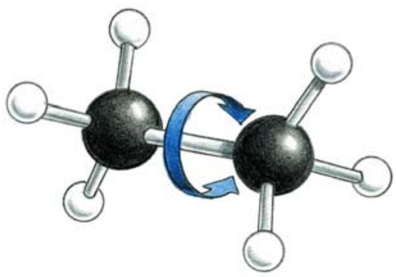
$1s^2\ 2s^1\ 2px^1\ 2py^1\ 2pz^1$ (estado excitado)

$1s^2\ (2sp^3)^1\ (2sp^3)^1\ (2sp^3)^1\ (2sp^3)^1$

$1s^2\ (2sp^2)^1\ (2sp^2)^1\ (2sp^2)^1\ 2pz^1$

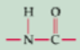
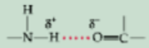
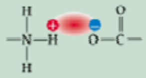
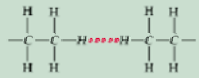
$1s^2\ 2(sp)^1\ 2(sp)^1\ 2py^1\ 2pz^1$





(A) ethane

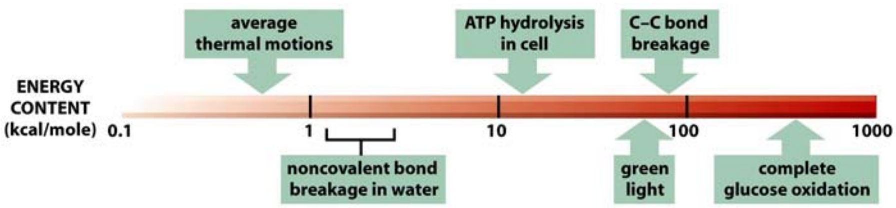
(B) ethene

NAME	BASIS OF INTERACTION	STRUCTURE	BOND ENERGY[a] (KCAL/MOL)
Covalent bond	Sharing of electron pairs		50–110
Hydrogen bond	Sharing of H atom		3–7
Ionic bond	Attraction of opposite charges		3–7
Hydrophobic interaction	Interaction of nonpolar substances in the presence of polar substances		1–2
van der Waals interaction	Interaction of electrons of nonpolar substances		1

[a]*Bond energy* is the amount of energy needed to separate two bonded or interacting atoms under physiological conditions.

Enlaces químicos covalentes y no covalentes			
		Fuerza (kcal/mol)	
Tipo de enlace	Longitud (pm)	En el vacío	En agua
Covalente	150	90	90
Iónico	250	80	3
Hidrógeno	300	4	1
Van der Waals (por átomo)	350	0,1	0,1

Enlaces	Distancia C	Energía Kj/mol
C – C	1'54	347
C = C	1'34	598
C ≡ C	1'20	811



Composición química aproximada de una bacteria y una célula de mamífero típicas		
	% del peso total celular	
Componente	***E. coli***	Célula de mamífero
H_2O	70	70
Iones inorgánicos (Na^+, K^+, $Mg2^+$, Ca^{2+}, Cl^-, etc.	1	1
Metabolitos pequeños varios	3	3
Proteínas	15	18
RNA	6	1,1
DNA	1	0,25
Fosfolípidos	2	3
Otros lípidos	-	2
Polisacáridos	2	2
Volumen celular (ml)	2×10^{-12}	4×10^{-4}
Volumen celular relativo	1	2000

	ΔH_{vap} de algunos líquidos en sus puntos de ebullición (cal/g)	**Constantes dieléctricas de algunos líquidos (20ºC)**
Agua	540	80
Metanol	263	33
Etanol	204	24
n-propanol	164	-
Acetona	125	21,4
Benceno	94	2,3
Cloroformo	59	-
Hexano	-	1,9

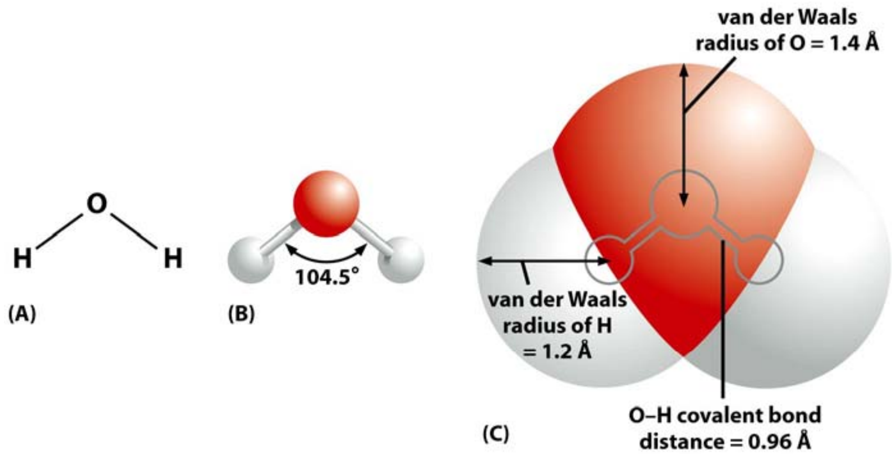
Puntos de fusión, ebullición y calor de vaporización de algunos solventes			
	Punto de fusión (ºC)	**Punto de ebullición (ºC)**	**Calor de vaporización (J/g)***
Agua	**0**	**100**	**2260**
Metanol (CH_3OH)	**-98**	**65**	**1100**
Etanol (CH_3CH_2OH)	**-117**	**78**	**854**
Propanol ($CH_3CH_2CH_2OH$)	**-127**	**97**	**687**
Butanol ($CH_3(CH_2)_2CH_2OH$)	**-90**	**117**	**590**
Acetona (CH_3COCH_3)	**-95**	**56**	**523**
Hexano ($CH_3(CH_2)_4CH_3$)	**-98**	**69**	**423**
Benceno (C_6H_6)	**6**	**80**	**394**
Butano ($CH_3(CH_2)_2CH_3$)	**-135**	**-0,5**	**381**
Cloroformo ($CHCl_3$)	**-63**	**61**	**247**

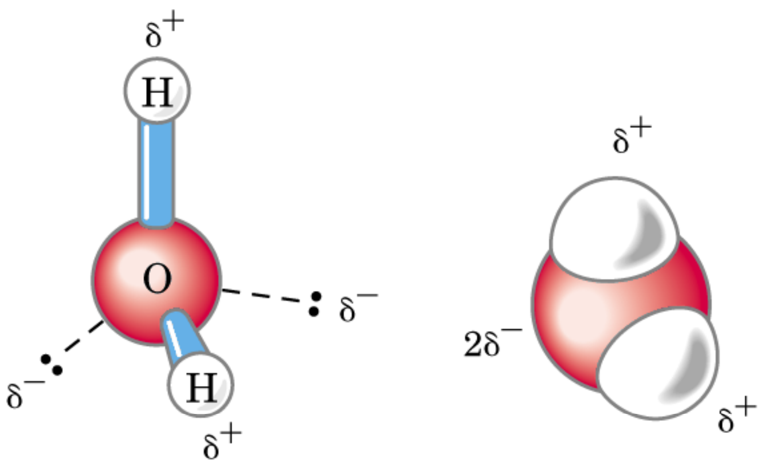
* La energía que se necesita para convertir 1 g de un líquido, en su temperatura de ebullición, a presión atmosférica, al estado gaseoso a la misma temperatura. Es una medida directa de la energía que se requiere para sobrepasar las fuerzas de atracción entre las moléculas en la fase líquida

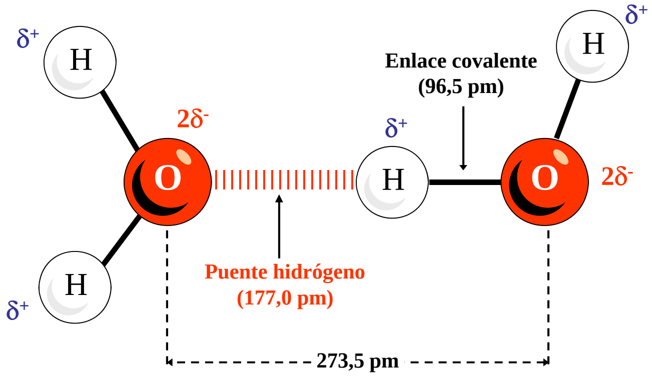
Electronegatividad de algunos elementos

Elemento	Electronegatividad
F	4.0
O	3.5
Cl	3.0
N	3.0
Br	2.8
S	2.5
C	2.5
I	2.5
Se	2.4
P	2.1
H	2.1
Cu	1.9
Fe	1.8
Co	1.8
Ni	1.8
Mo	1.8
Zn	1.6
Mn	1.5
Mg	1.2
Ca	1.0
Li	1.0
Na	0.9
K	0.8

Electronegatividad: capacidad de un átomo para atraer electrones hacia él en un enlace químico (alta afinidad electrónica, alta energía de ionización)


H
O
H
(A)
104.5°
(B)
van der Waals
radius of O = 1.4 Å
van der Waals
radius of H
= 1.2 Å
O–H covalent bond
distance = 0.96 Å
(C)


δ+
H
O
δ−
δ−
H
δ+
δ+
2δ−
δ+



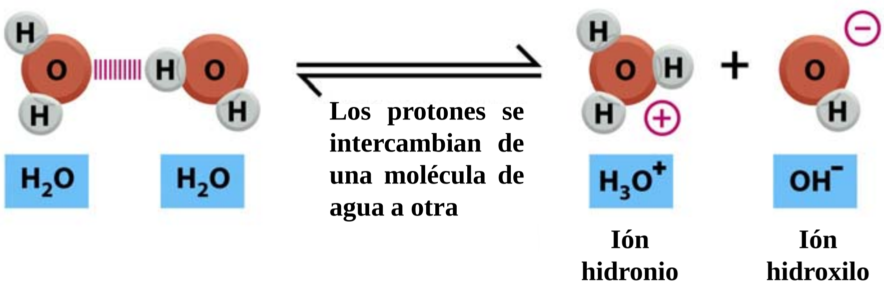
Las moléculas de agua tienen **carga neta igual a cero** pero, debido a la ***diferencia de electronegatividad*** que existe entre los átomos de oxígeno e hidrógeno, son **moléculas polares** y pueden establecer entre si un tipo de unión no covalente que se conoce con el nombre de **puente hidrógeno**. Un puente hidrógeno se forma siempre que un átomo de hidrógeno queda compartido, a una distancia apropiada, entre dos centros electronegativos. La unión puente hidrógeno tiene usualmente 1/20 de la fuerza de un enlace covalente.

Cohesion. Some insects, such as this water strider, literally walk on water. In this photograph you can see the dimpling the insect's feet make on the water as its weight bears down on the surface. Because the surface tension of the water is greater than the force that one foot brings to bear, the strider glides atop the surface of the water rather than sinking.

Capillary action. Capillary action causes the water within a narrow tube to rise above the surrounding water; the adhesion of the water to the glass surface, which draws water upward, is stronger than the force of gravity, which tends to draw it down. The narrower the tube, the greater the surface area available for adhesion for a given volume of water, and the higher the water rises in the tube.

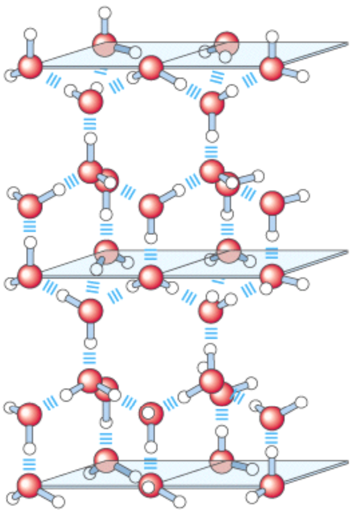
The Properties of water

Property	Explanation	Example of Benefit to Life
Cohesion	Hydrogen bonds hold water molecules together	Leaves pull water upward from the roots; seeds swell and germinate
High specific heat	Hydrogen bonds absorb heat when they break, and release heat when they form, minimizing temperature changes	Water stabilizes the temperature of organisms and the environment
High heat of vaporization	Many hydrogen bonds must be broken for water to evaporate	Evaporation of water cools body surfaces
Lower density of ice	Water molecules in an ice crystal are spaced relatively far apart because of hydrogen bonding	Because ice is less dense than water, lakes do not freeze solid
High polarity	Polar water molecules are attracted to ions and polar compounds, making them soluble	Many kinds of molecules can move freely in cells, permitting a diverse array of chemical reactions

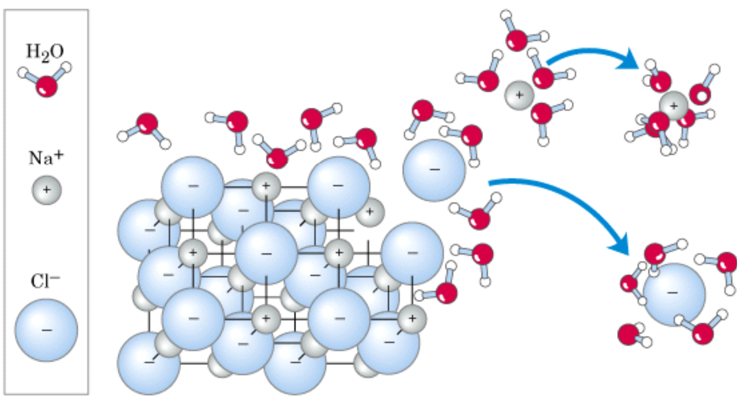


Las moléculas de agua intercambian protones de manera continua entre si; esto resulta en la formación de iones hidronio e hidroxilo. Ambos iones se recombinan rápidamente formando moléculas de agua

$$K_w = [H^+] \times [OH^-] = 10^{-14}$$

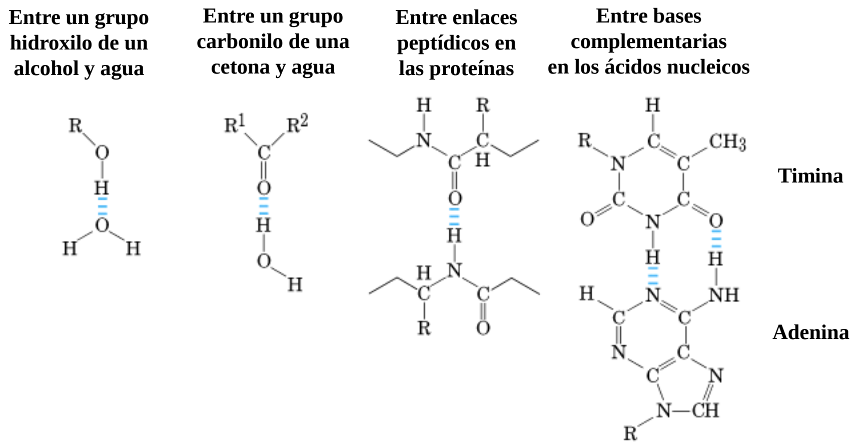


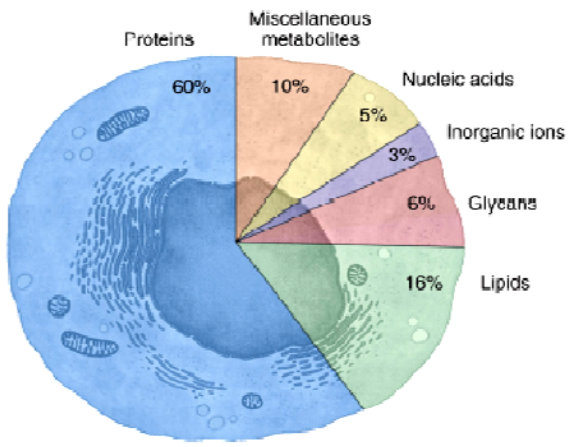
Puentes hidrógeno en el hielo. Cada molécula de agua forma un máximo de cuatro puentes hidrógeno de manera que se forma una red cristalina regular. En el agua líquida, a temperatura ambiente, cada molécula de agua se une, vía puente hidrógeno, con un promedio de 3,4 moléculas de agua. La red cristalina de hielo ocupa más espacio que el ocupado por el mismo número de moléculas de agua en estado líquido; de este modo, el hielo es menos denso y flota sobre el agua líquida.



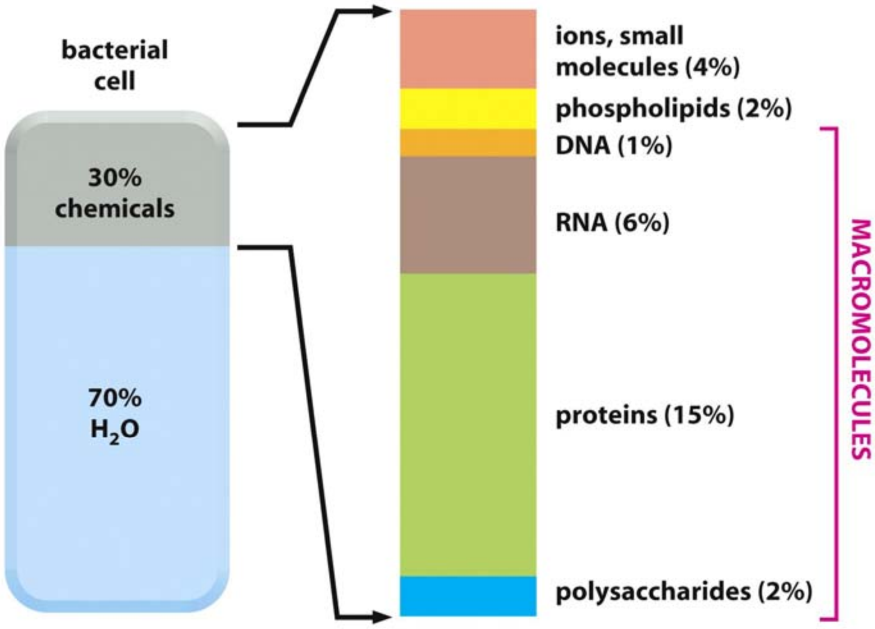
El agua disuelve muchas sales cristalinas hidratando sus componentes iónicos. La red cristalina de cloruro de sodio es rota por moléculas de agua que rodean a los iones Na^+ y Cl^-. Las cargas iónicas se neutralizan parcialmente, y las interacciones electrostáticas necesarias para la formación de la red se debilitan..

Interacciones de importancia biológica estabilizadas por puentes hidrógeno





Composición de una célula de mámifero típica. Aunque las proteínas representan la fracción más importante del peso seco de una célula, se estima que más de la mitad se encuentra modificada con oligosacáridos, lípidos y otros metabolitos. (*Prescher J. A. & C.R. Bertozzi 2005 Nature Chem. Biol (1): 14-21.2005*)


bacterial cell
30% chemicals
70% H_2O
ions, small molecules (4%)
phospholipids (2%)
DNA (1%)
RNA (6%)
proteins (15%)
polysaccharides (2%)
MACROMOLECULES

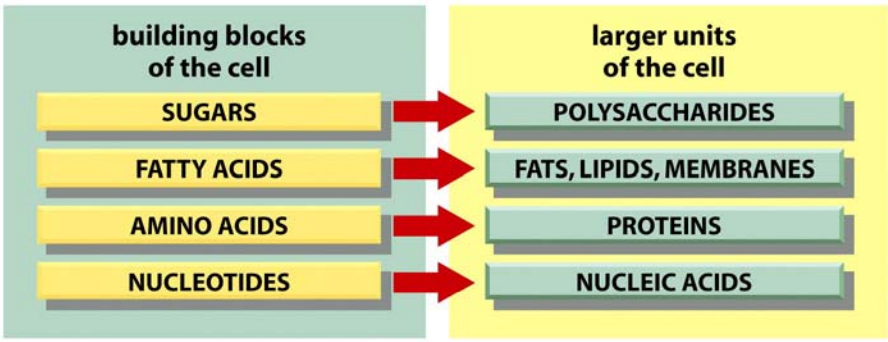
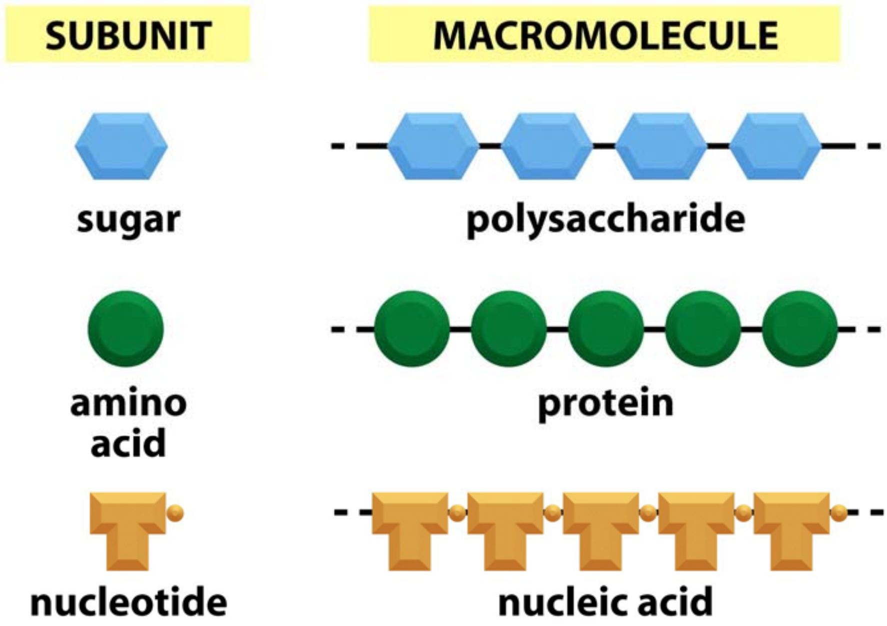

building blocks of the cell
larger units of the cell
SUGARS
POLYSACCHARIDES
FATTY ACIDS
FATS, LIPIDS, MEMBRANES
AMINO ACIDS
PROTEINS
NUCLEOTIDES
NUCLEIC ACIDS

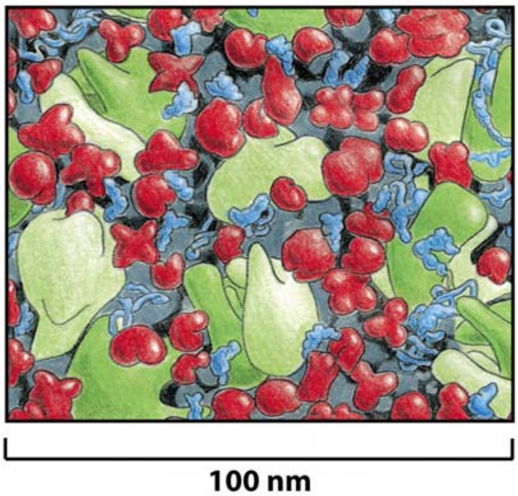
Table 3.1 Macromolecules

Macromolecule	Subunit	Function	Example
PROTEINS			
Globular	Amino acids	Modified glucose	Hemoglobin
Structural	Amino acids	Catalysis; transport	Hair; silk
		Support	
NUCLEIC ACIDS			
DNA	Nucleotides	Encodes genes	Chromosomes
RNA	Nucleotides	Needed for gene expression	Messenger RNA
LIPIDS			
Fats	Glycerol and three fatty acids	Energy storage	Butter; corn oil; soap
Phospholipids	Glycerol, two fatty acids, phosphate, and polar R groups	Cell membranes	Lecithin
Prostaglandins	Five-carbon rings with two nonpolar tails	Chemical messengers	Prostaglandin E (PGE)
Steroids	Four fused carbon rings	Membranes; hormones	Cholesterol; estrogen
Terpenes	Long carbon chains	Pigments; structural	Carotene; rubber
CARBOHYDRATES			
Starch, glycogen	Glucose	Energy storage	Potatoes
Cellulose	Glucose	Cell walls	Paper; strings of celery
Chitin		Structural support	Crab shells

Table 3.2 The Many Functions of Proteins

Function	Class of Protein	Examples	Use
Metabolism (Catalysis)	Enzymes	Hydrolytic enzymes	Cleave polysaccharides
		Proteases	Break down proteins
		Polymerases	Produce nucleic acids
		Kinases	Phosphorylate sugars and proteins
Defense	Immunoglobulins	Antibodies	Mark foreign proteins for elimination
Cell recognition	Toxins	Snake venom	Block nerve function
Transport throughout body	Cell surface antigens	MHC proteins	"Self" recognition
	Globins	Hemoglobin	Carries O_2 and CO_2 in blood
		Myoglobin	Carries O_2 and CO_2 in muscle
		Cytochromes	Electron transport
Membrane transport	Transporters	Sodium-potassium pump	Excitable membranes
		Proton pump	Chemiosmosis
		Anion channels	Transport Cl^- ions
Structure/Support	Fibers	Collagen	Cartilage
		Keratin	Hair, nails
		Fibrin	Blood clot
Motion	Muscle	Actin	Contraction of muscle fibers
		Myosin	Contraction of muscle fibers
Osmotic regulation	Albumin	Serum albumin	Maintains osmotic concentration of blood
Regulation of gene action	Repressors	lac repressor	Regulates transcription
Regulation of body functions	Hormones	Insulin	Controls blood glucose levels
		Vasopressin	Increases water retention by kidneys
		Oxytocin	Regulates uterine contractions and milk production
Storage	Ion binding	Ferritin	Stores iron, especially in spleen
		Casein	Stores ions in milk
		Calmodulin	Binds calcium ions

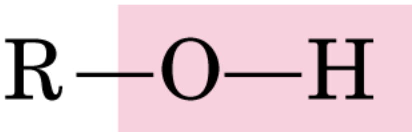




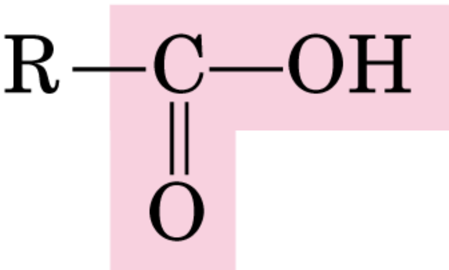
La estructura del citoplasma. El esquema (aproximadamente a escala) resalta el enorme volumen ocupado por las macromoléculas. **Los RNAs se muestran en *azul*, los ribosomas en *verde*** y **las proteínas en *rojo***. Las enzimas y otras macromoléculas difunden lentamente en el citoplasma lo que se debe, en parte, a sus interacciones con otras macromoléculas; los metabolitos pequeños en cambio difunden a una velocidad cercana a su velocidad de difusión en agua

Grupos funcionales presentes en las moléculas del mundo vivo

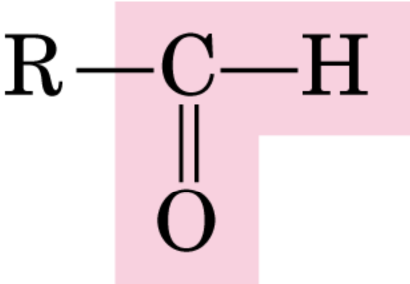
Hidroxil



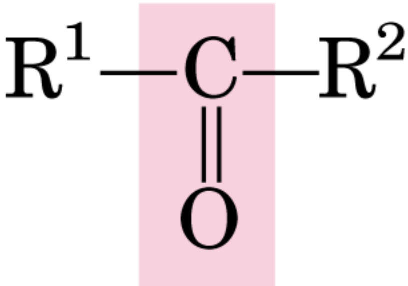
Carboxil



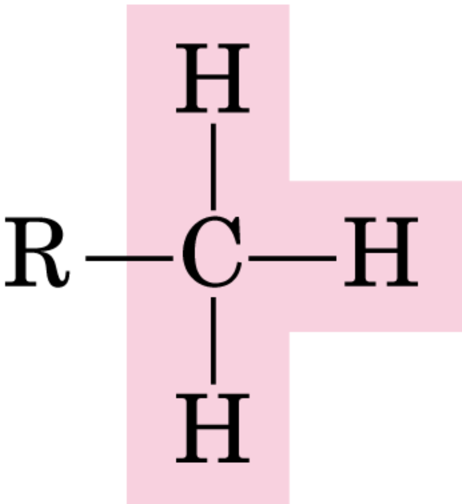
Carbonil (aldehído)



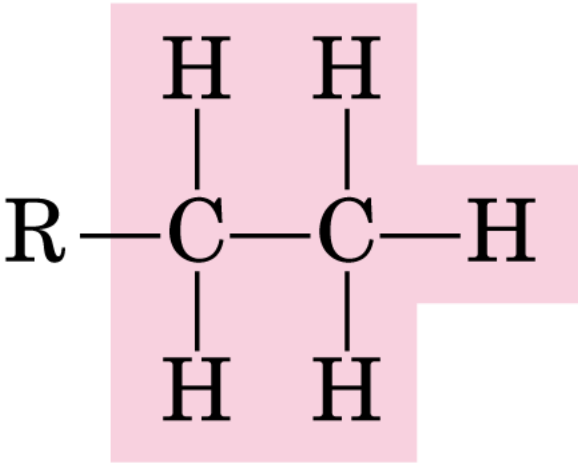
Carbonil (cetona)



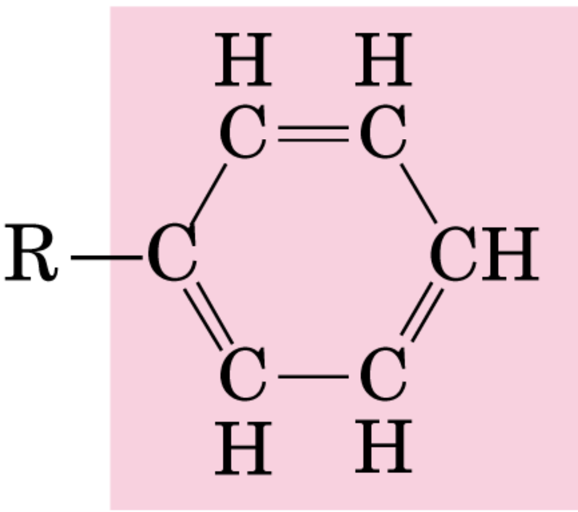
Metil



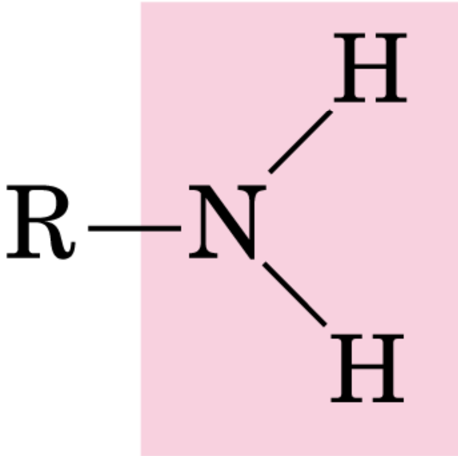
Etil



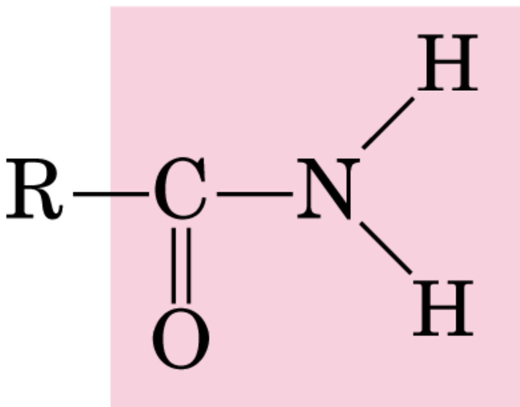
Fenil



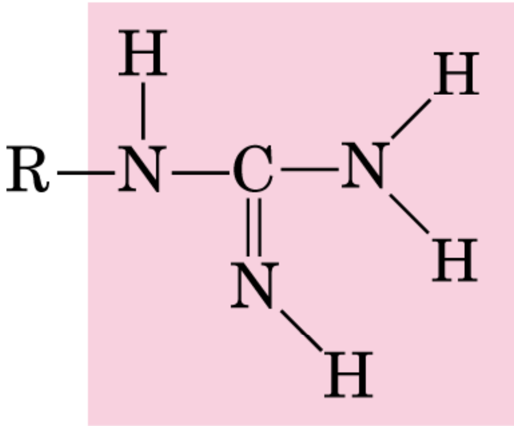
Amino



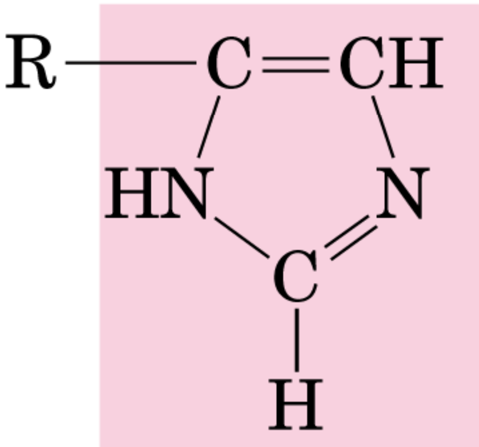
Amido



Guanidino



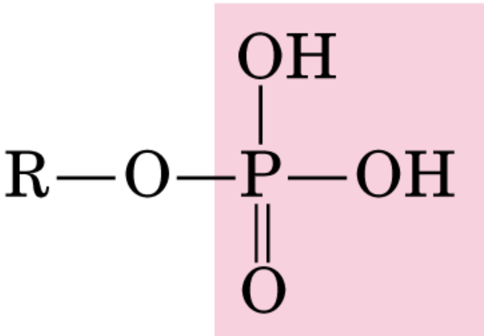
Imidazol



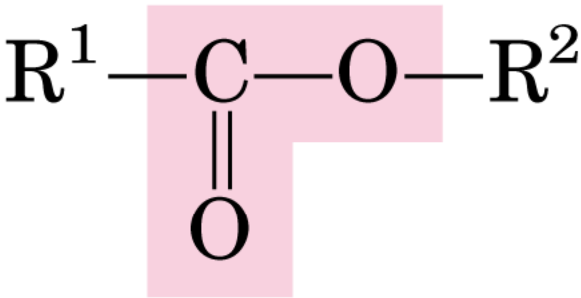
Sulfidril $R{-}S{-}H$

Disulfuro $R^1{-}S{-}S{-}R^2$

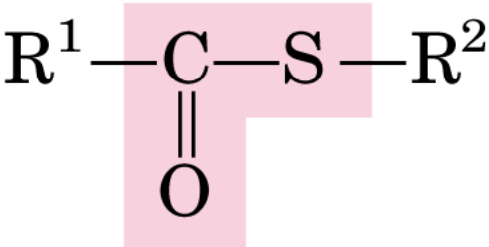
Fosforil



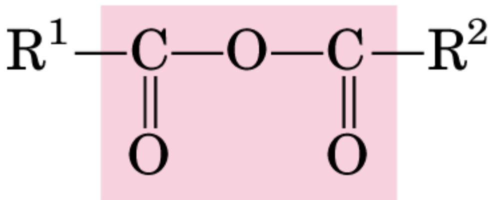
Éster



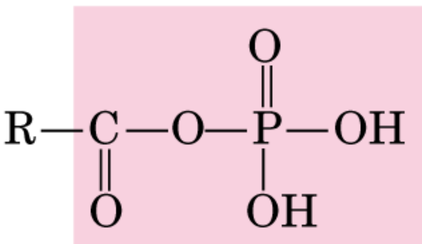
Tioéster



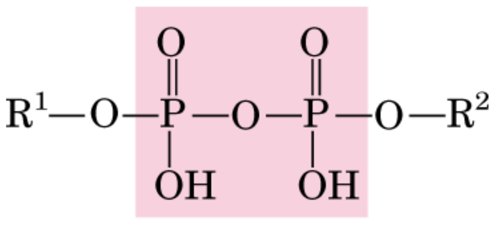
Anhidrido

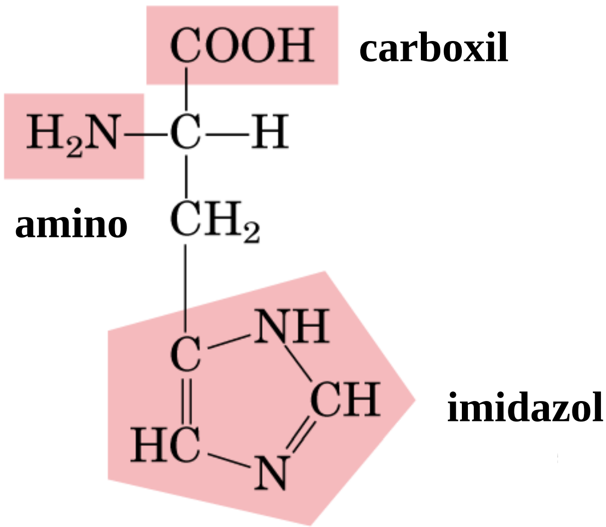


Anhidrido mixto (acil fosfato)

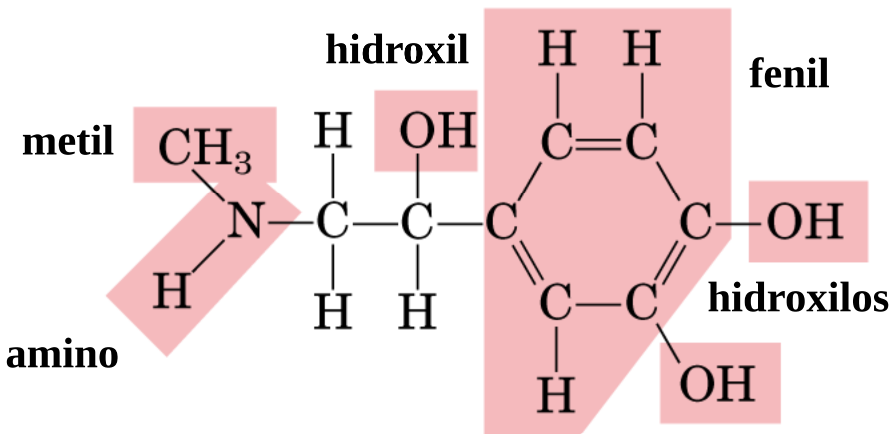


Fosfoanhidrido

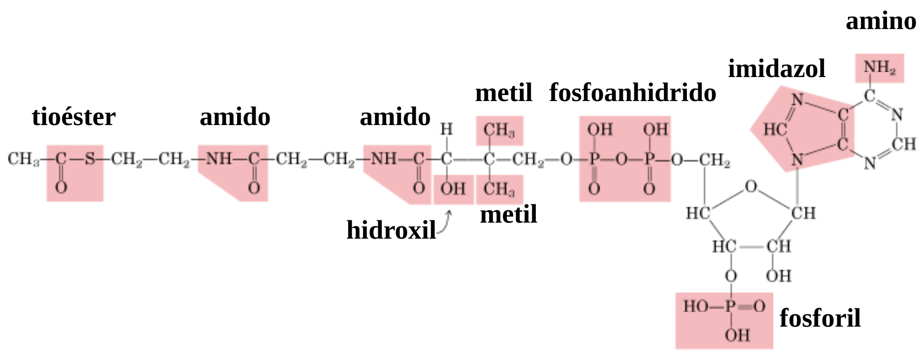




Histidina (un aminoácido)



Epinefrina



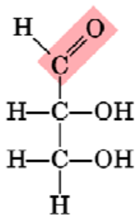
Acetil-coenzima A

Hidratos de carbono

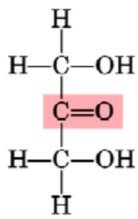
Hidratos de carbono

Según su naturaleza

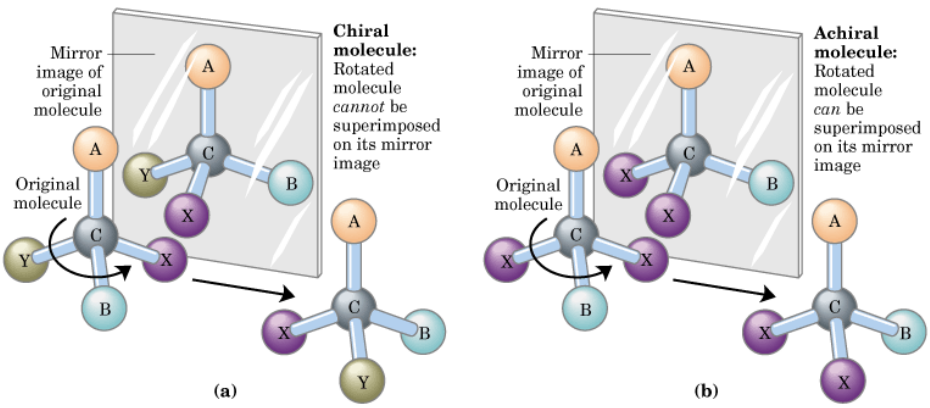
Aldosas **Cetosas**

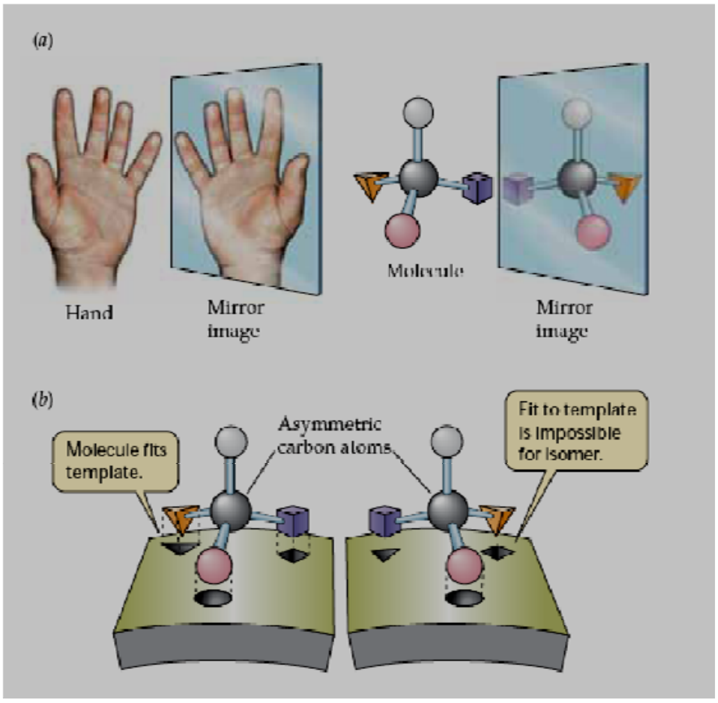


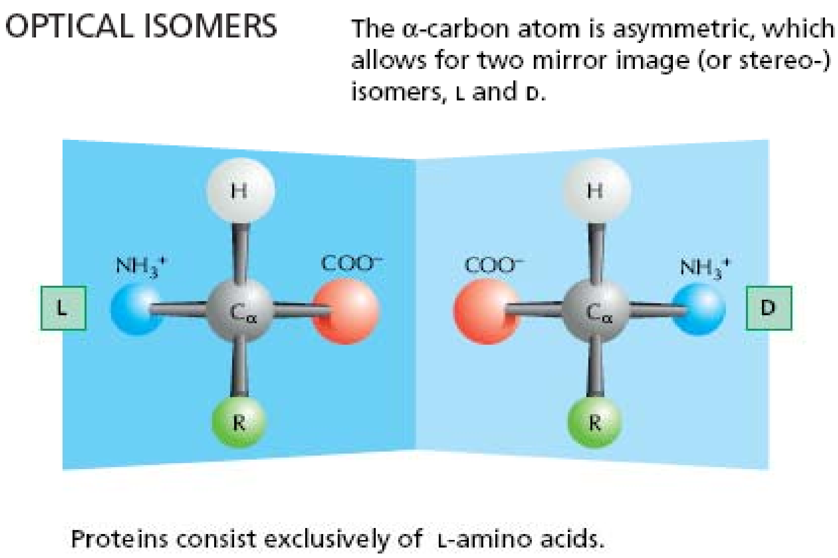
Gliceraldehído



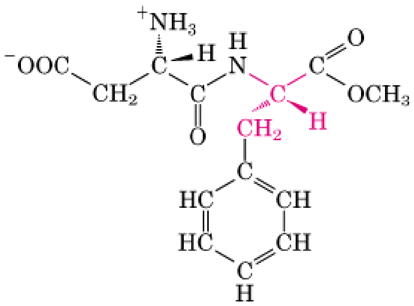
Dihidroxiacetona

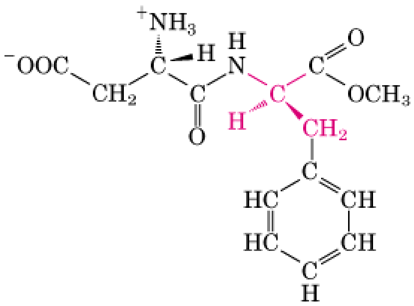



(a)
Hand
Mirror image
Molecule
Mirror image
(b)
Molecule fits template.
Asymmetric carbon atoms
Fit to template is impossible for isomer.


OPTICAL ISOMERS
The α-carbon atom is asymmetric, which allows for two mirror image (or stereo-) isomers, L and D.
H
NH_3^+
COO^-
L
C_α
R
H
COO^-
NH_3^+
D
C_α
R
Proteins consist exclusively of L-amino acids.

L-aspartil-L-fenilalanil metil éster
(aspartame) (dulce)

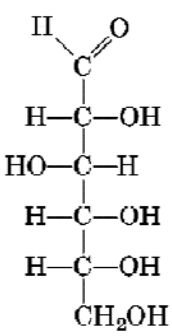




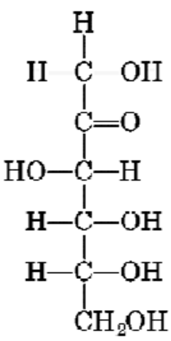
L-aspartil-D-fenilalanil metil éster
(amargo)

Según número de átomos de carbono

Triosas (Gliceraldehído, Dihidroxiacetona)
Tetrosas (Eritrosa)
Pentosas (Ribosa)
Hexosas (Glucosa, Fructosa, Galactosa, Manosa

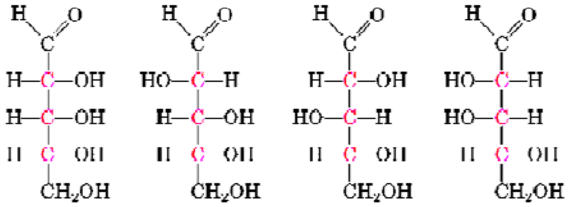


D-Glucosa
(aldohexosa)



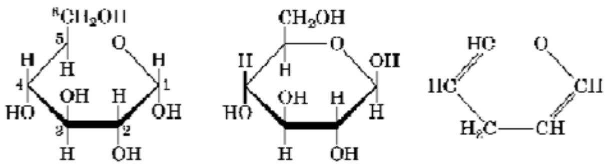
D-Fructosa
(cetohexosa)

Aldopentosas

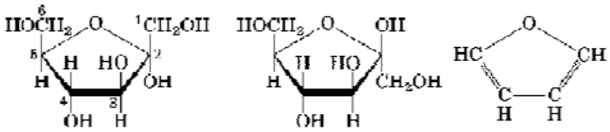


D-Ribosa D-Arabinosa D-Xilosa D-Lixosa

Formas cíclicas de las hexosas



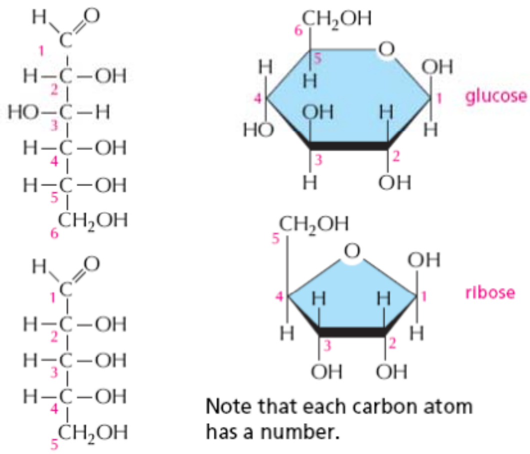
α-D-glucopiranosa **β-D-glucopiranosa** **Pirano**



α-D-fructofuranosa **β-D-fructofuranosa** **Furano**

RING FORMATION

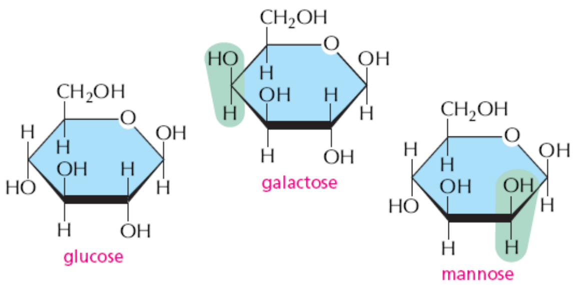
In aqueous solution, the aldehyde or ketone group of a sugar molecule tends to react with a hydroxyl group of the same molecule, thereby closing the molecule into a ring.



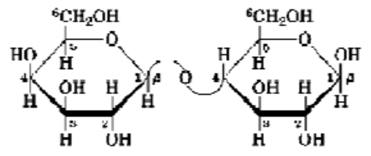
Note that each carbon atom has a number.

ISOMERS

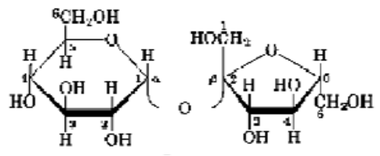
Many monosaccharides differ only in the spatial arrangement of atoms—that is, they are isomers. For example, glucose, galactose, and mannose have the same formula ($C_6H_{12}O_6$) but differ in the arrangement of groups around one or two carbon atoms.



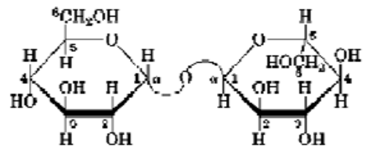
These small differences make only minor changes in the chemical properties of the sugars. But they are recognized by enzymes and other proteins and therefore can have important biological effects.



Lactosa



Sacarosa

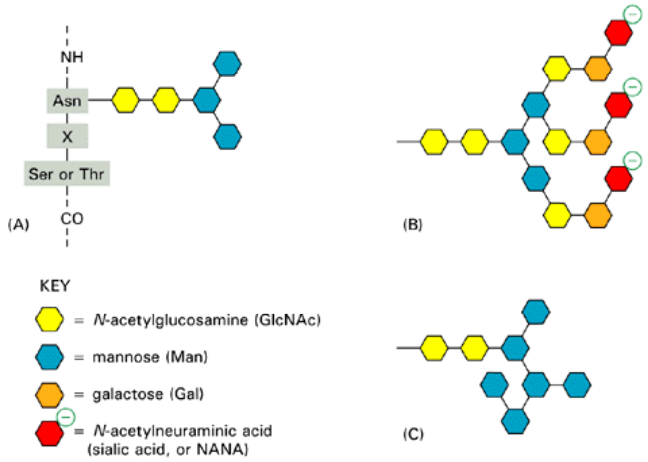


Trehalosa

Según número de unidades constituyentes

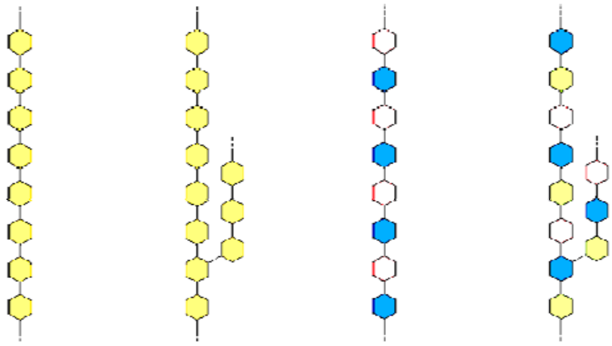
discáridos

Oligosacáridos conjugados con proteínas

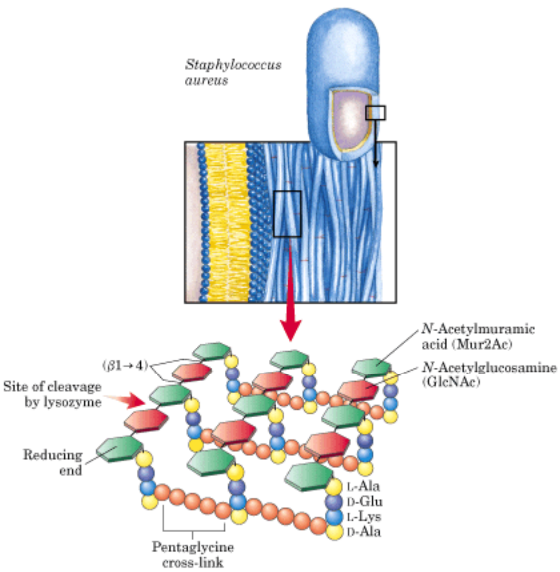


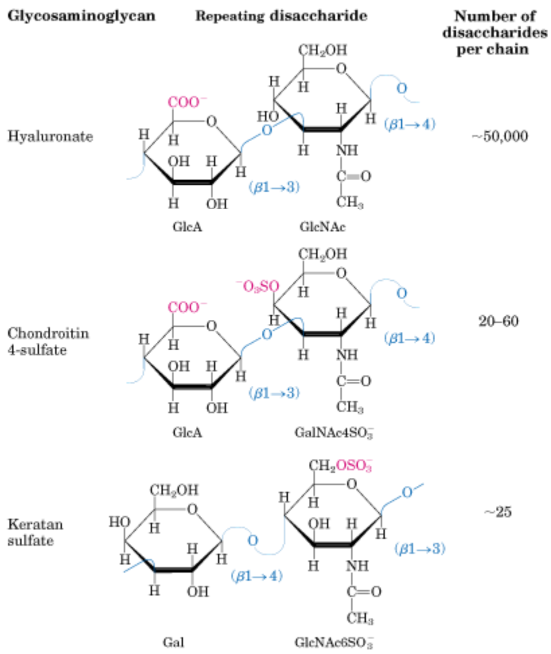
Polisacáridos

Homopolisacáridos		Heteropolisacáridos	
No ramificados	Ramificados	Dos monómeros, no ramificados	Múltiples monómeros, ramificados

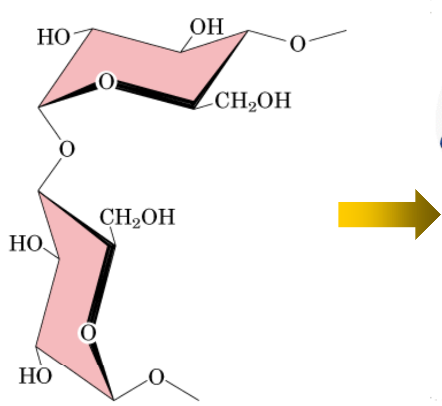


Péptidoglicano (pared celular de bacterias)

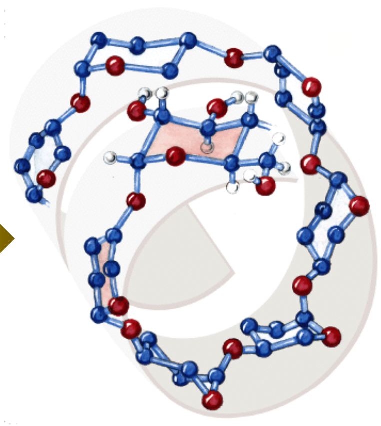




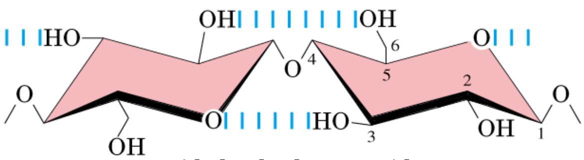
Glicosaminoglicanos (matriz extracelular)



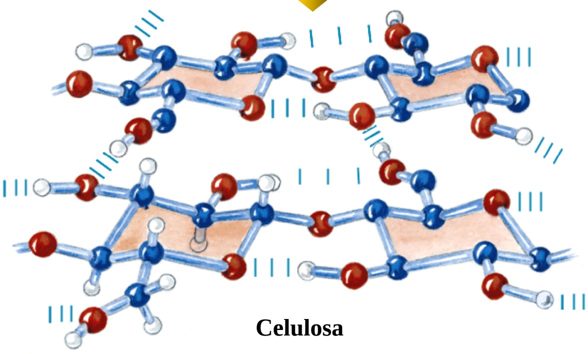
Unidades de glucosa unidas por enlace (α 1→4) glicosídico



Almidón



Unidades de glucosa unidas por enlace (β 1→4) glicosídico



Celulosa

table 9–2

Structures and Roles of Some Polysaccharides

Polymer	Type*	Repeating unit†	Size (number of monosaccharide units)	Roles
Starch				Energy storage: in plants
Amylose	Homo-	(α1→4)Glc, linear	50–5,000	
Amylopectin	Homo-	(α1→4)Glc, with (α1→6)Glc branches every 24 to 30 residues	Up to 10^6	
Glycogen	Homo-	(α1→4)Glc, with (α1→6)Glc branches every 8 to 12 residues	Up to 50,000	Energy storage: in bacteria and animal cells
Cellulose	Homo-	(β1→4)Glc	Up to 15,000	Structural: in plants, gives rigidity and strength to cell walls
Chitin	Homo-	(β1→4)GlcNAc	Very large	Structural: in insects, spiders, crustaceans, gives rigidity and strength to exoskeletons
Peptidoglycan	Hetero-; peptides attached	4)Mur2Ac(β1→4) GlcNAc(β1	Very large	Structural: in bacteria, gives rigidity and strength to cell envelope
Hyaluronate (a glycosamino-glycan)	Hetero-; acidic	4)GlcA(β1→3) GlcNAc(β1	Up to 100,000	Structural: in vertebrates, extracellular matrix of skin and connective tissue; viscosity and lubrication in joints

Lípidos

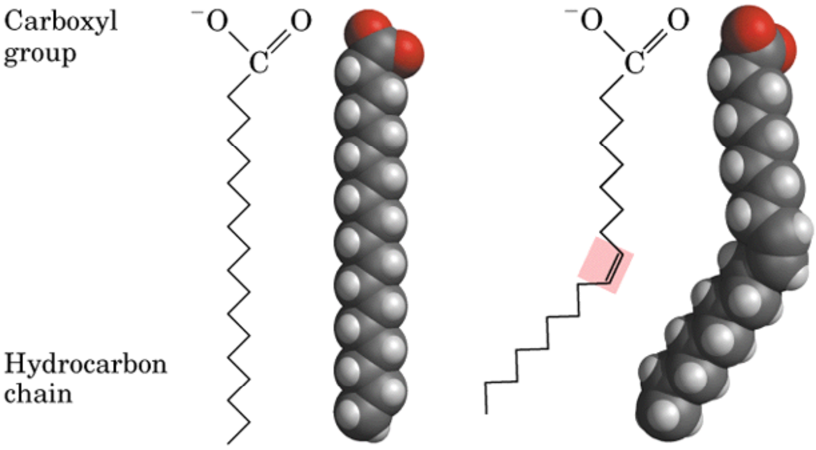
table 11–1

Some Naturally Occurring Fatty Acids

Carbon skeleton	Structure*	Systematic name†	Common name (derivation)	Melting point (°C)	Solubility at 30 °C (mg/g solvent) Water	Benzene
12:0	$CH_3(CH_2)_{10}COOH$	*n*-Dodecanoic acid	Lauric acid (Latin *laurus*, "laurel plant")	44.2	0.063	2,600
14:0	$CH_3(CH_2)_{12}COOH$	*n*-Tetradecanoic acid	Myristic acid (Latin *Myristica*, nutmeg genus)	53.9	0.024	874
16:0	$CH_3(CH_2)_{14}COOH$	*n*-Hexadecanoic acid	Palmitic acid (Latin *palma*, "palm tree")	63.1	0.0083	348
18:0	$CH_3(CH_2)_{16}COOH$	*n*-Octadecanoic acid	Stearic acid (Greek *stear*, "hard fat")	69.6	0.0034	124
20:0	$CH_3(CH_2)_{18}COOH$	*n*-Eicosanoic acid	Arachidic acid (Latin *Arachis*, legume genus)	76.5		
24:0	$CH_3(CH_2)_{22}COOH$	*n*-Tetracosanoic acid	Lignoceric acid (Latin *lignum*, "wood" + *cera*, "wax")	86.0		
16:1(Δ^9)	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	*cis*-9-Hexadecenoic acid	Palmitoleic acid	−0.5		
18:1(Δ^9)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	*cis*-9-Octadecenoic acid	Oleic acid (Latin *oleum*, "oil")	13.4		
18:2($\Delta^{9,12}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-9,12-Octadecadienoic acid	Linoleic acid (Greek *linon*, "flax")	−5		
18:3($\Delta^{9,12,15}$)	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-,*cis*-9,12,15-Octadecatrienoic acid	α-Linolenic acid	−11		
20:4($\Delta^{5,8,11,14}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$	*cis*-,*cis*-,*cis*-,*cis*-5,8,11,14-Icosatetraenoic acid	Arachidonic acid	−49.5		

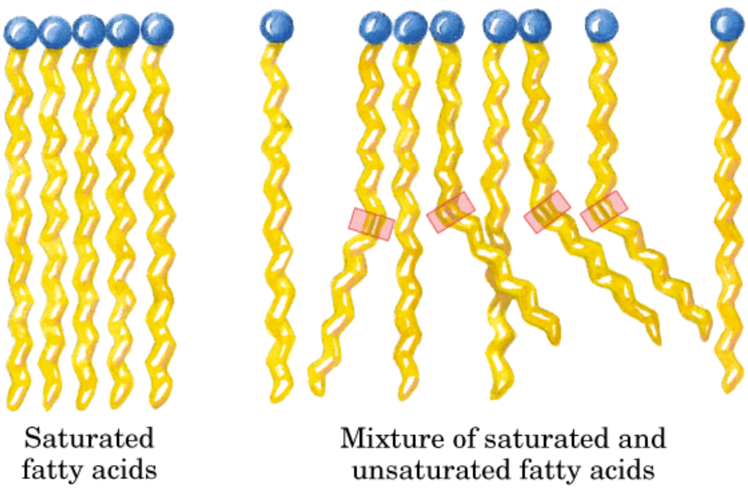
*All acids are shown in their nonionized form. At pH 7, all free fatty acids have an ionized carboxylate. Note that numbering of carbon atoms begins at the carboxyl carbon.

†The prefix *n*- indicates the "normal" unbranched structure. For instance, "dodecanoic" simply indicates 12 carbon atoms, which could be arranged in a variety of branched forms; "*n*-dodecanoic" specifies the linear, unbranched form. For unsaturated fatty acids, the configuration of each double bond is indicated; in biological fatty acids the configuration is almost always cis.



Carboxyl group
Hydrocarbon chain

(a) (b)



Saturated fatty acids
Mixture of saturated and unsaturated fatty acids

(c) (d)

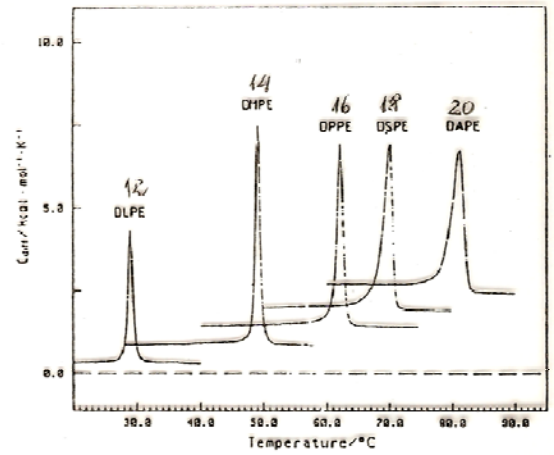
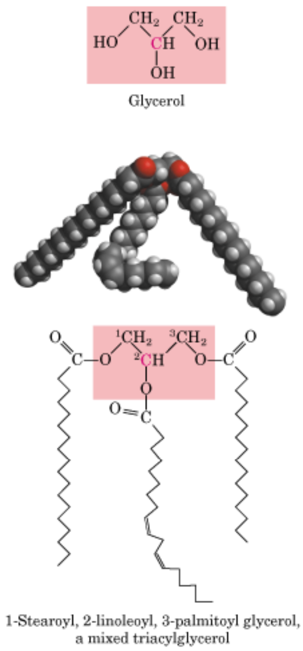
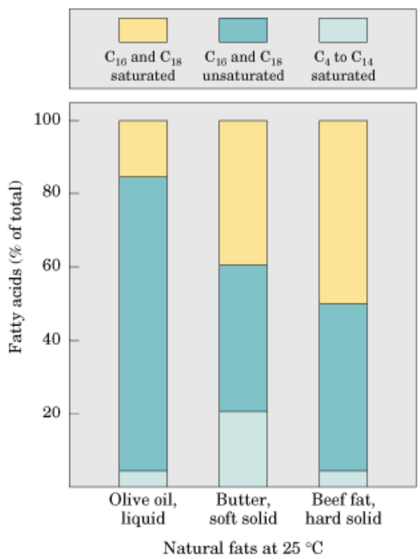
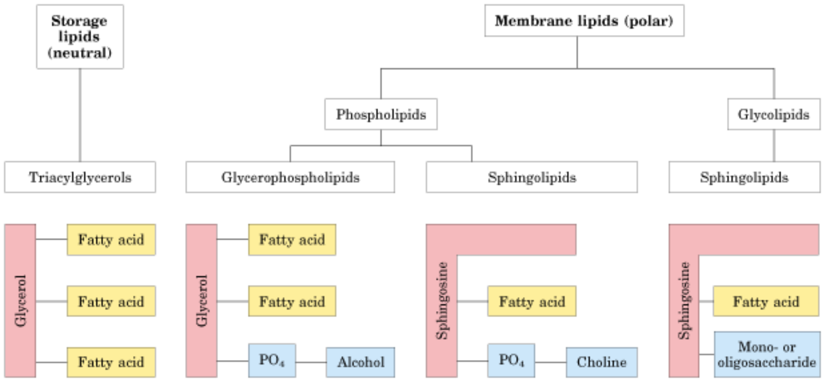
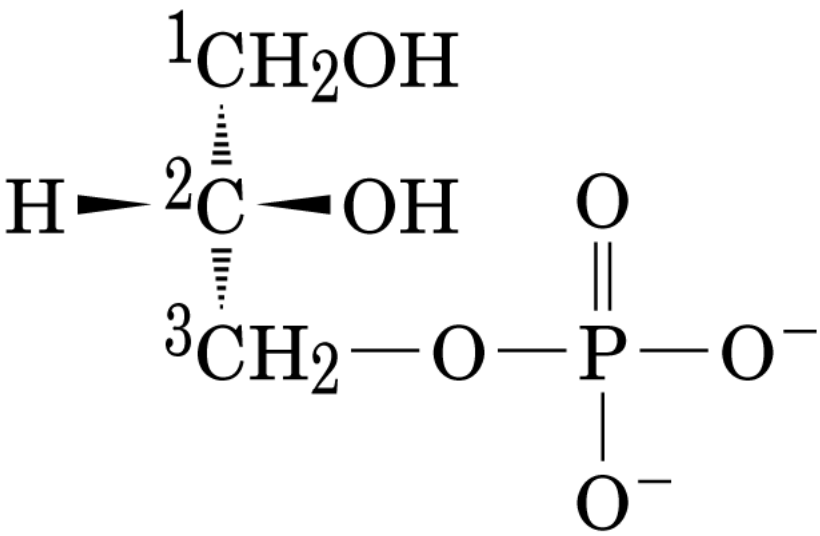


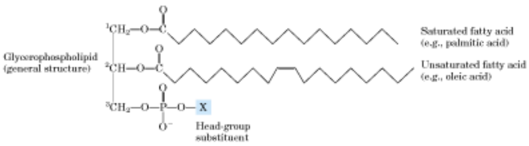
Figure 4. Calorimetric scans of phosphatidylethanolamines (PEs) with different chain lengths (c = 1 mg/ml).

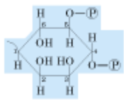
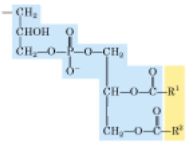


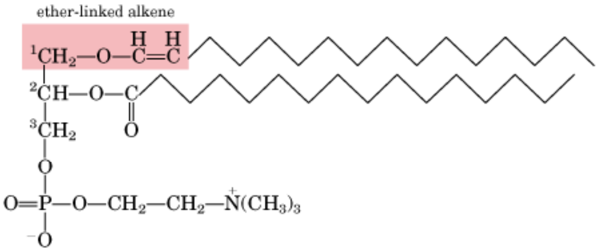



Storage lipids (neutral)
Membrane lipids (polar)
Phospholipids
Glycolipids
Triacylglycerols
Glycerophospholipids
Sphingolipids
Sphingolipids
Glycerol
Fatty acid
Fatty acid
Fatty acid
Glycerol
Fatty acid
Fatty acid
PO4
Alcohol
Sphingosine
Fatty acid
PO4
Choline
Sphingosine
Fatty acid
Mono- or oligosaccharide

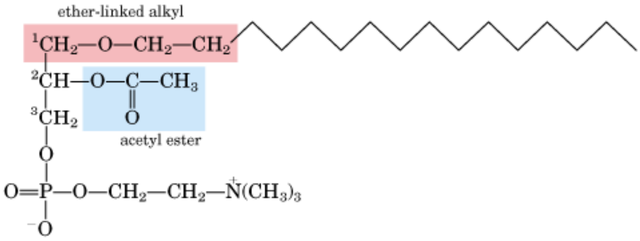




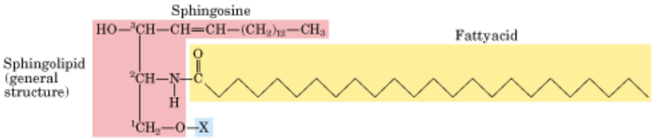
Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	—H	−1
Phosphatidylethanolamine	Ethanolamine	$—CH_2—CH_2—\overset{+}{N}H_3$	0
Phosphatidylcholine	Choline	$—CH_2—CH_2—\overset{+}{N}(CH_3)_3$	0
Phosphatidylserine	Serine	$—CH_2—CH(COO^-)—\overset{+}{N}H_3$	−1
Phosphatidylglycerol	Glycerol	$—CH_2—CH(OH)—CH_2—OH$	−1
Phosphatidylinositol 4,5-bisphosphate	*myo*-Inositol 4,5-bisphosphate		−4
Cardiolipin	Phosphatidyl-glycerol		−2

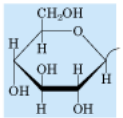
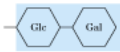
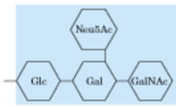


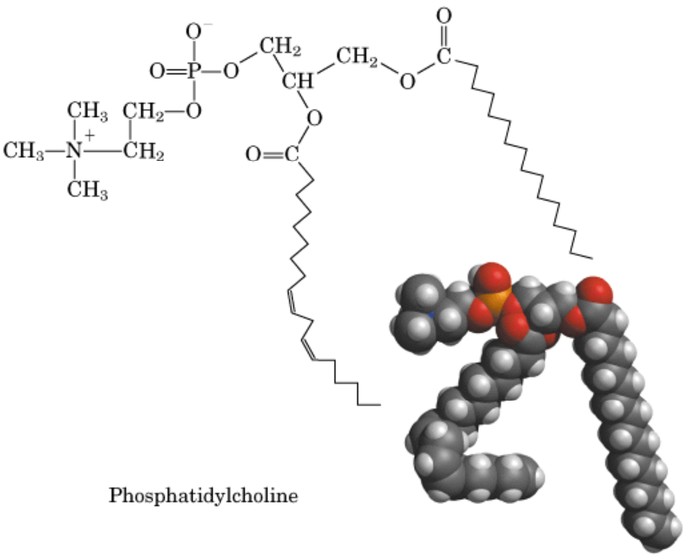
Plasmalogen



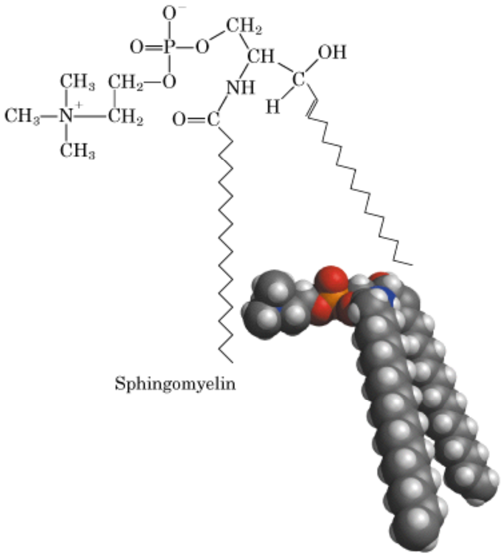
Platelet-activating factor

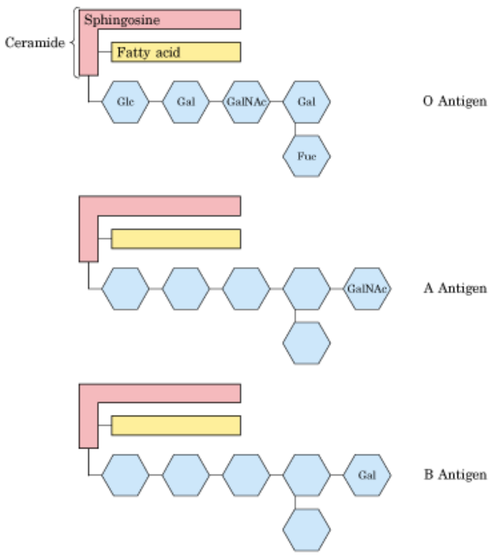


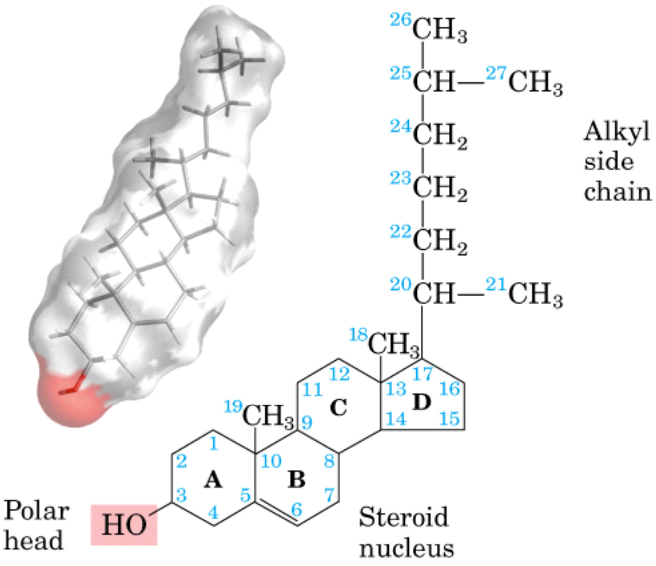
Name of sphingolipid	Name of X	Formula of X
Ceramide	—	$-H$
Sphingomyelin	Phosphocholine	$-\overset{O}{\underset{O^-}{P}}-O-CH_2-CH_2-\overset{+}{N}(CH_3)_3$
Neutral glycolipids Glucosylcerebroside	Glucose	
Lactosylceramide (a globoside)	Di-, tri-, or tetrasaccharide	
Ganglioside GM2	Complex oligosaccharide	

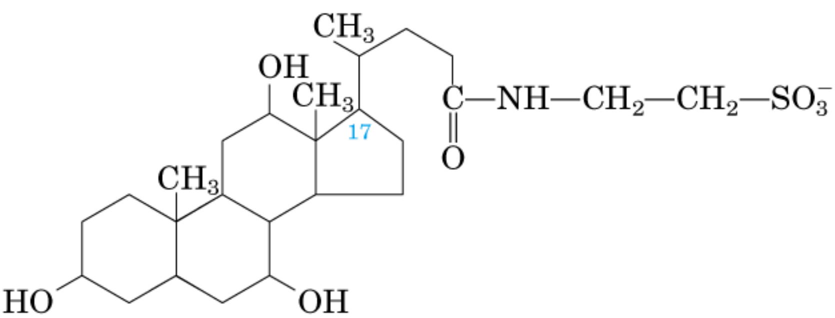


Phosphatidylcholine

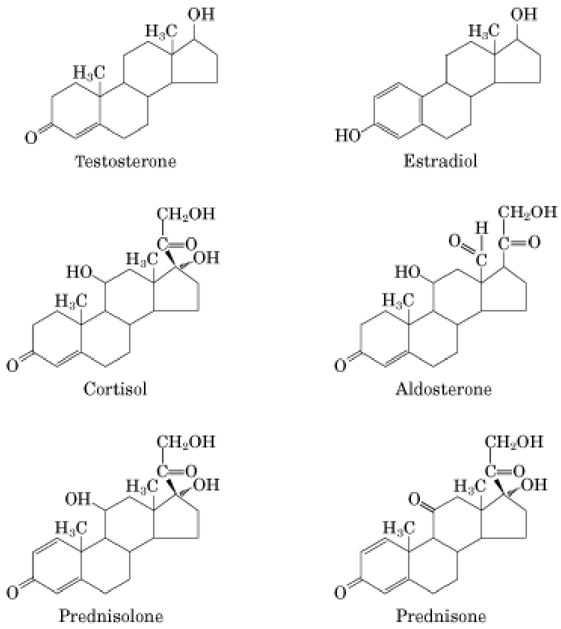

Sphingomyelin


Ceramide
Sphingosine
Fatty acid
Glc
Gal
GalNAc
Gal
Fuc
O Antigen
GalNAc
A Antigen
Gal
B Antigen

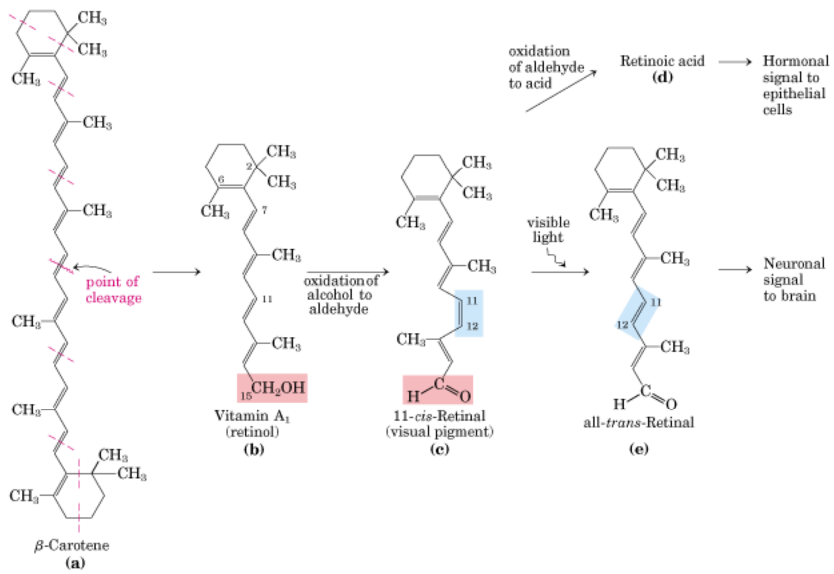




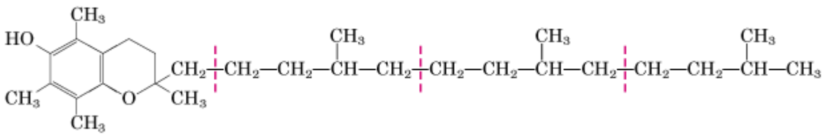
Taurocholic acid
(a bile acid)



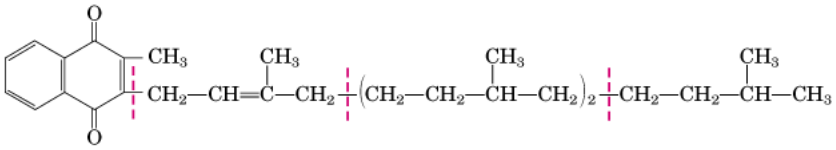
Testosterone
Estradiol
Cortisol
Aldosterone
Prednisolone
Prednisone



point of cleavage
β-Carotene
(a)
Vitamin A₁
(retinol)
(b)
oxidation of alcohol to aldehyde
11-cis-Retinal
(visual pigment)
(c)
oxidation of aldehyde to acid
Retinoic acid
(d)
Hormonal signal to epithelial cells
visible light
all-trans-Retinal
(e)
Neuronal signal to brain

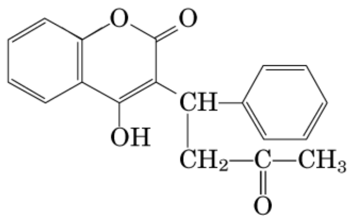


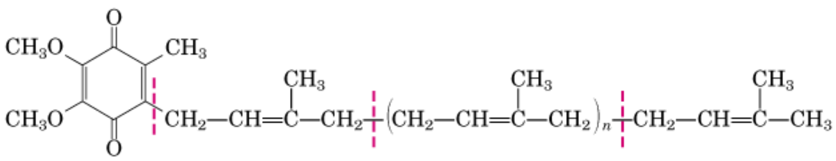
(a)
Vitamin E: an antioxidant



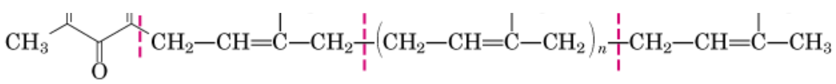
(b)
Vitamin K_1: a blood-clotting cofactor (phylloquinone)

(c)
Warfarin: a blood anticoagulant

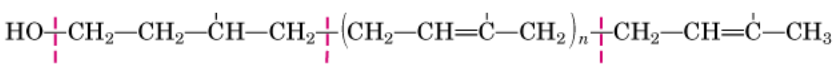




(d)
Ubiquinone: a mitochondrial electron carrier (coenzyme Q)
(n = 4–8)



(e)
Plastoquinone: a chloroplast electron carrier (n = 4–8)



(f)
Dolichol: a sugar carrier
(n = 9–22)