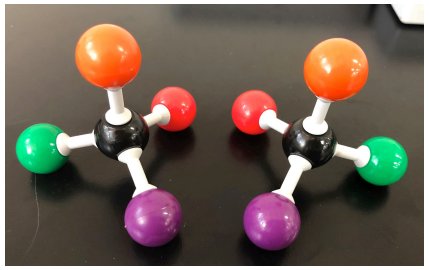
Curso propedéutico de Química Orgánica

Maestría en Ciencias: Productos Naturales y Alimentos

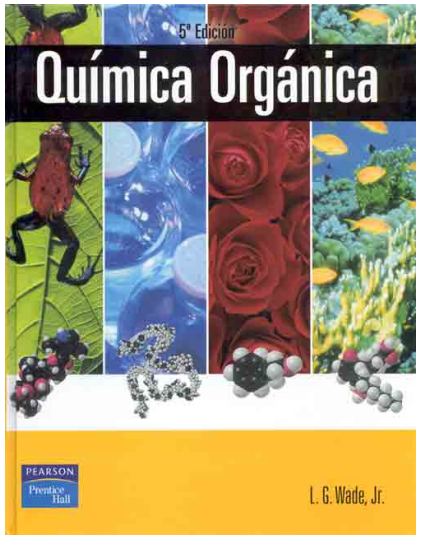


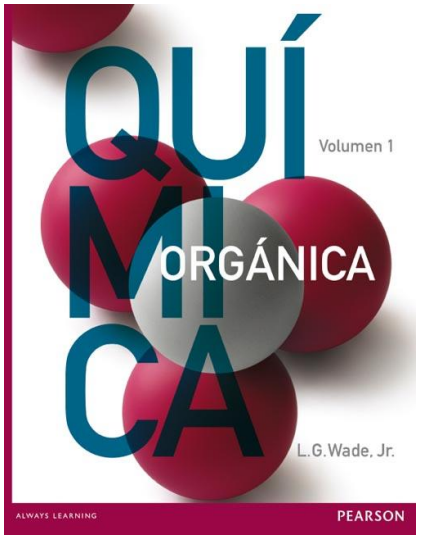
2ª Parte: Estereoquímica

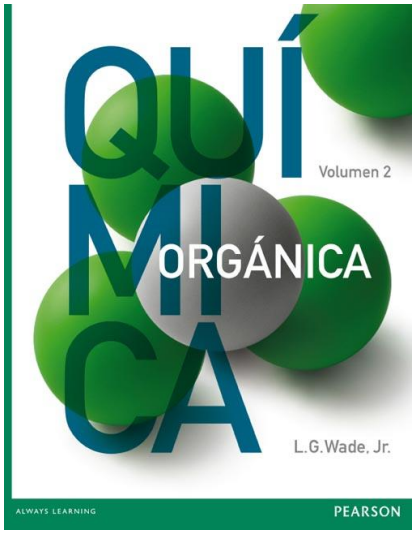
- Conformaciones de alcanos: Rotación de enlaces carbono-carbono
- Cicloalcanos: Tensión del anillo
- Conformación de ciclohexano
- Conformación de ciclohexanos mono- y disustituidos
- Isómeros *cis-trans*
- Quiralidad
- Centros de quiralidad, estereocentros
- Enantiómeros
- Actividad óptica
- Isómeros con uno y más centros estereogénicos
- Sistema *R,S* de nomenclatura
- Estereoquímica de las reacciones catalizadas por enzimas

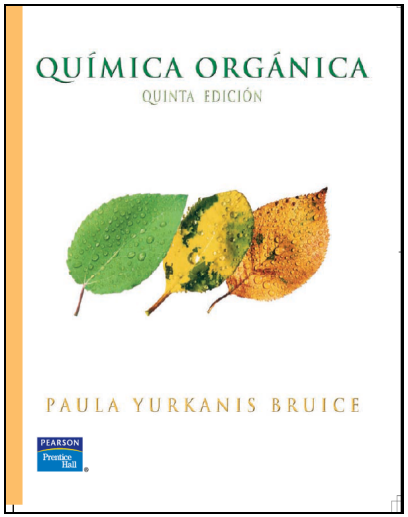
Dra. Norma Francenia Santos Sánchez
nsantos@mixteco.utm.mx
nfrancenia@msn.com

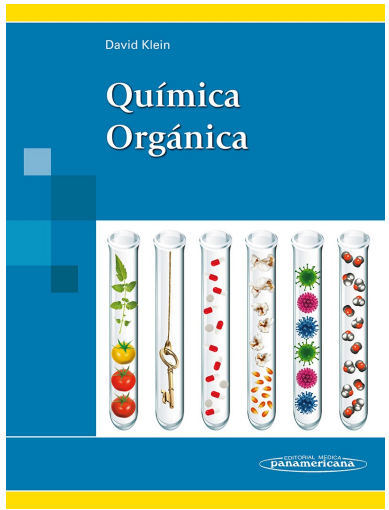
Huajuapan de León, Oaxaca, México


5ª Edición
Química Orgánica
PEARSON
Prentice Hall
L. G. Wade, Jr.

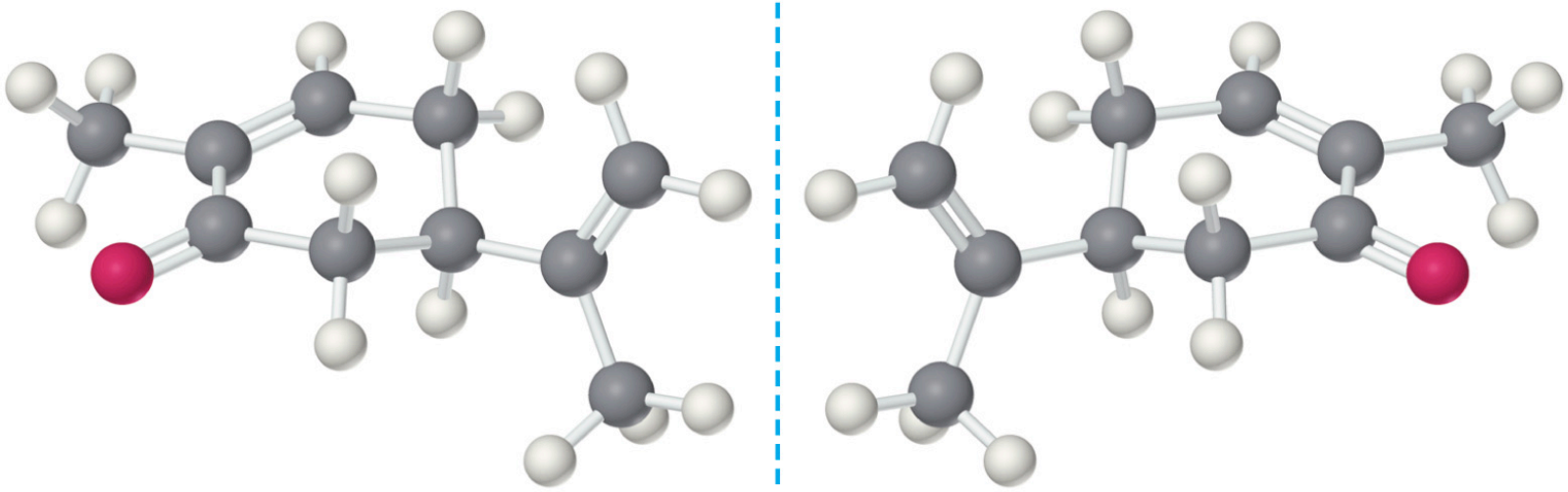

QUÍMICA
Volumen 1
ORGÁNICA
L.G.Wade, Jr.
ALWAYS LEARNING
PEARSON


QUÍMICA
Volumen 2
ORGÁNICA
L.G.Wade, Jr.
ALWAYS LEARNING
PEARSON


QUÍMICA ORGÁNICA
QUINTA EDICIÓN
PAULA YURKANIS BRUICE
PEARSON
Prentice Hall


David Klein
Química
Orgánica
panamericana

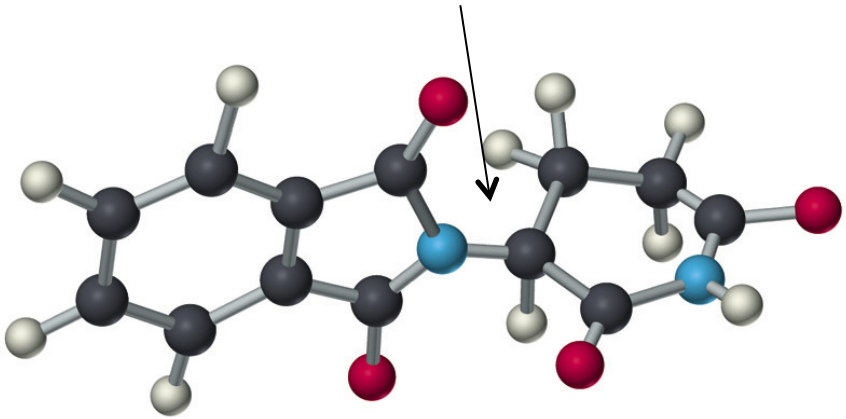
Importancia

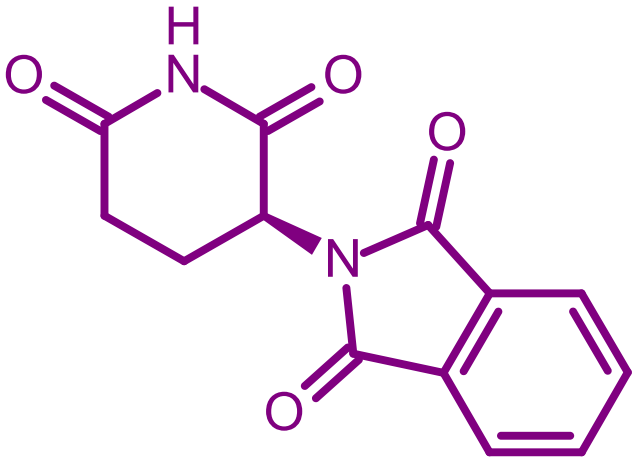


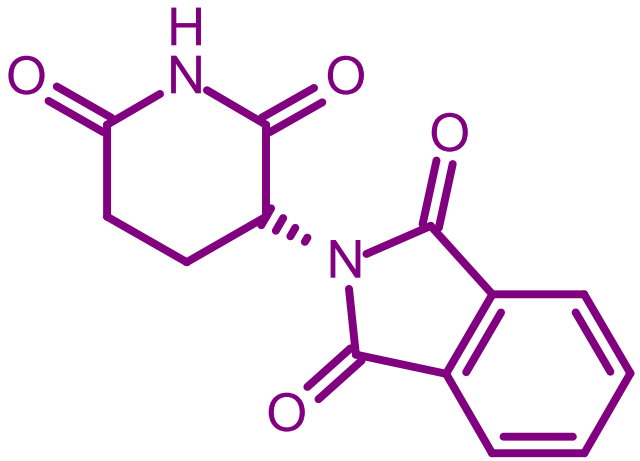
"Left-handed" carvone
(odor of spearmint)

"Right-handed" carvone
(odor of caraway)

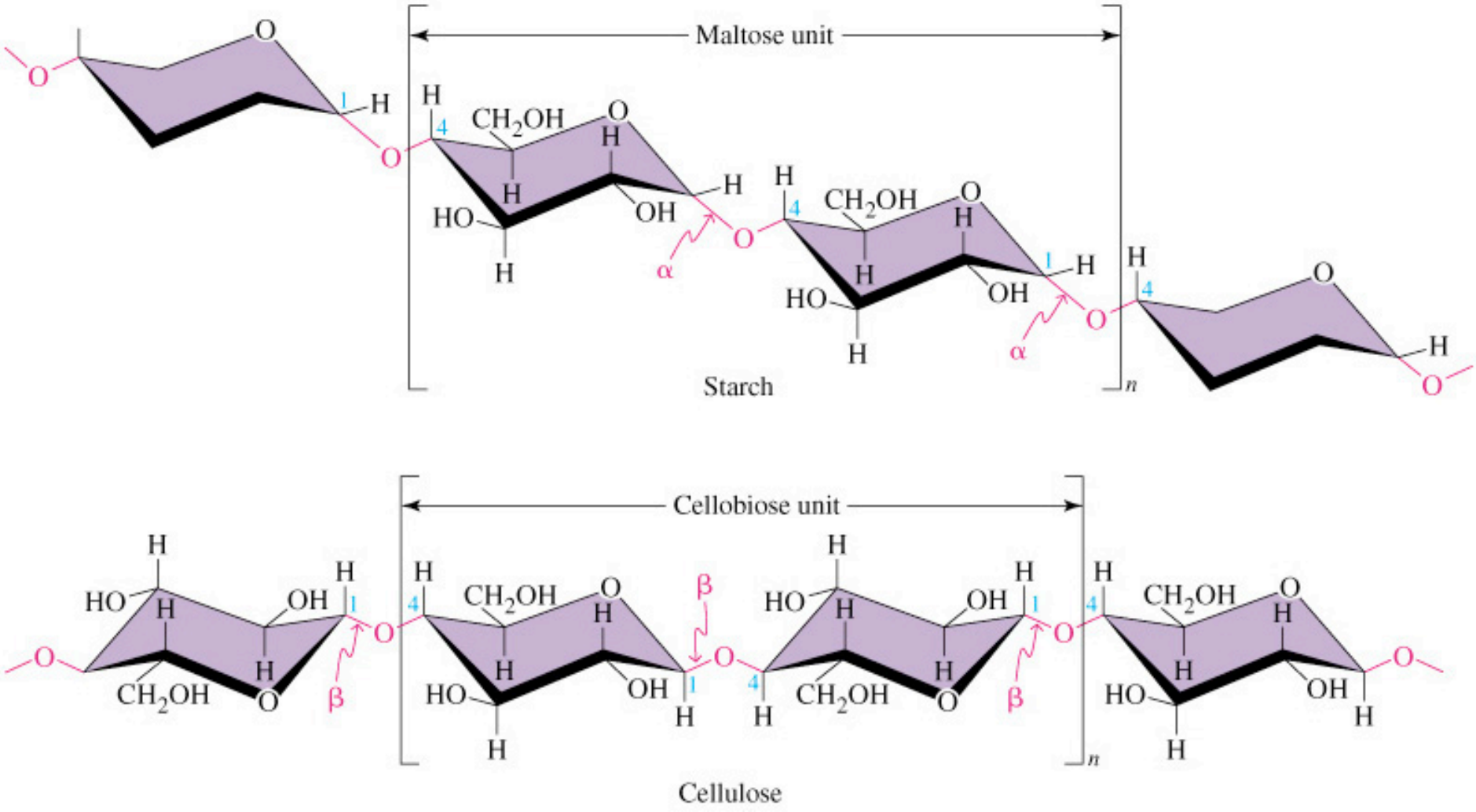
Thalidomide



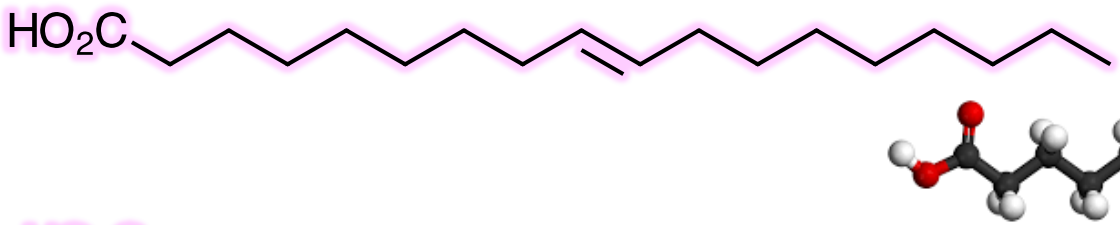


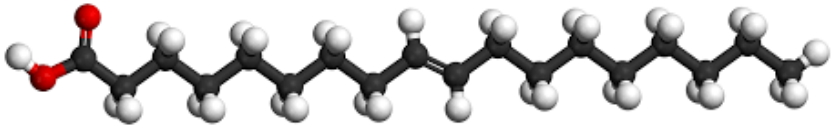


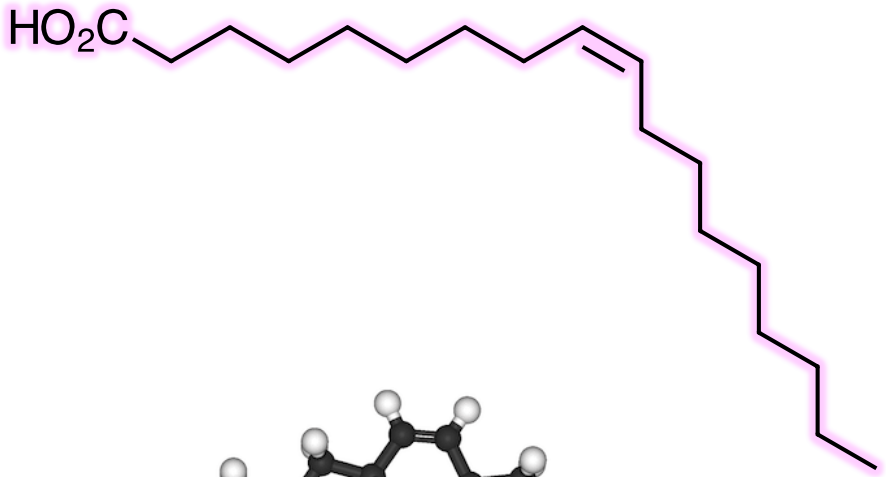
Enzimas glucosidasas α- y β-

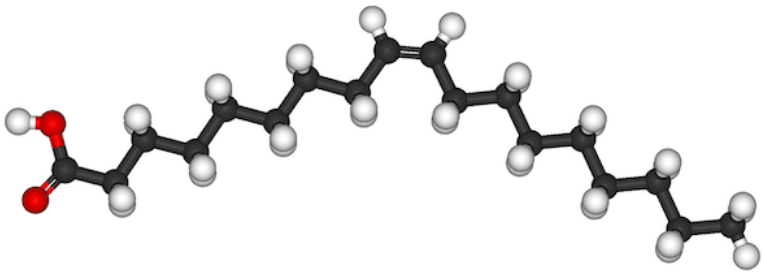


Diet and Heart Disease

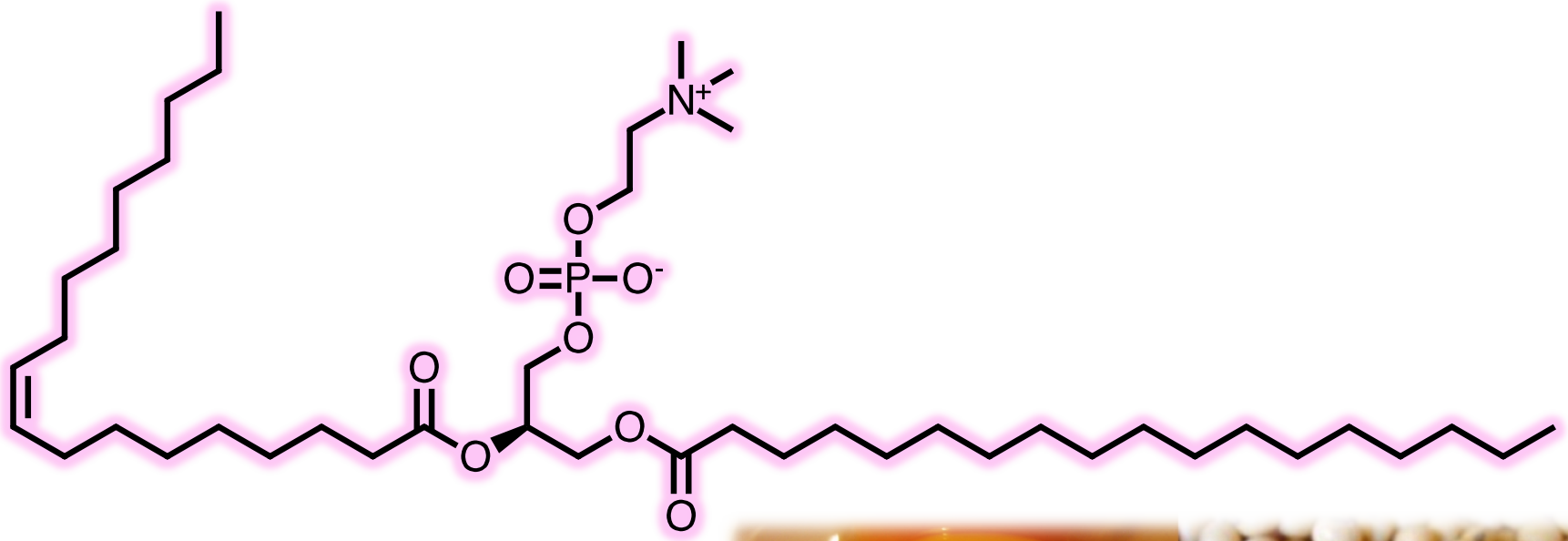






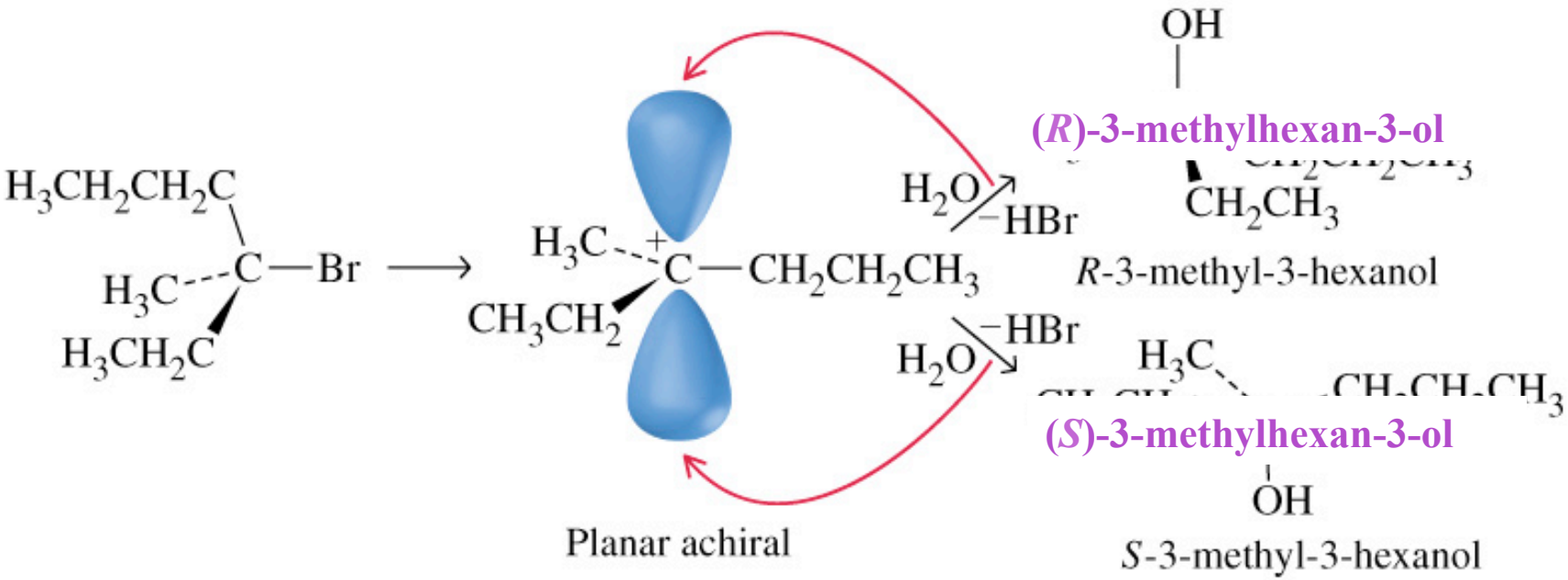


Functional Foods



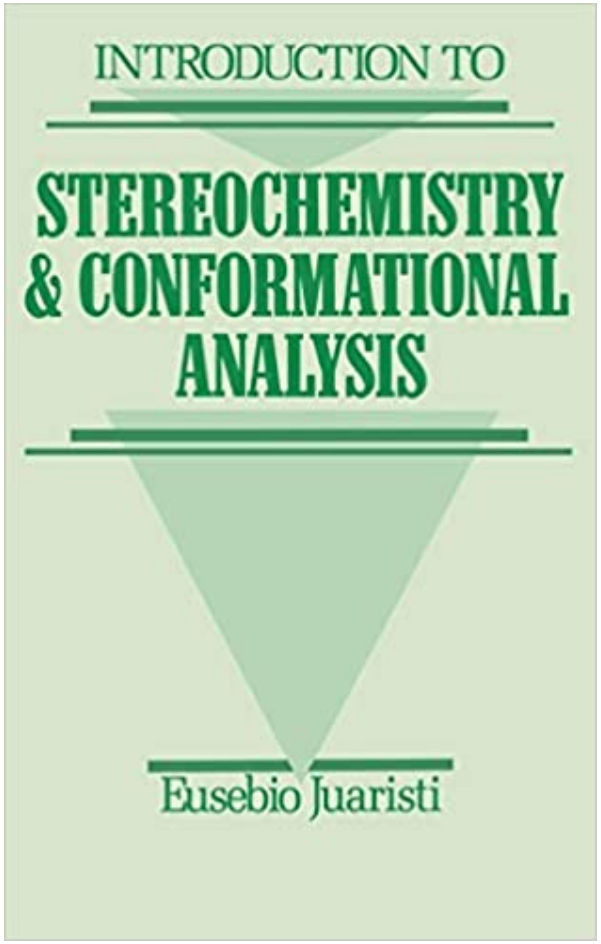
Lecithin
(Phosphatidylcholine)

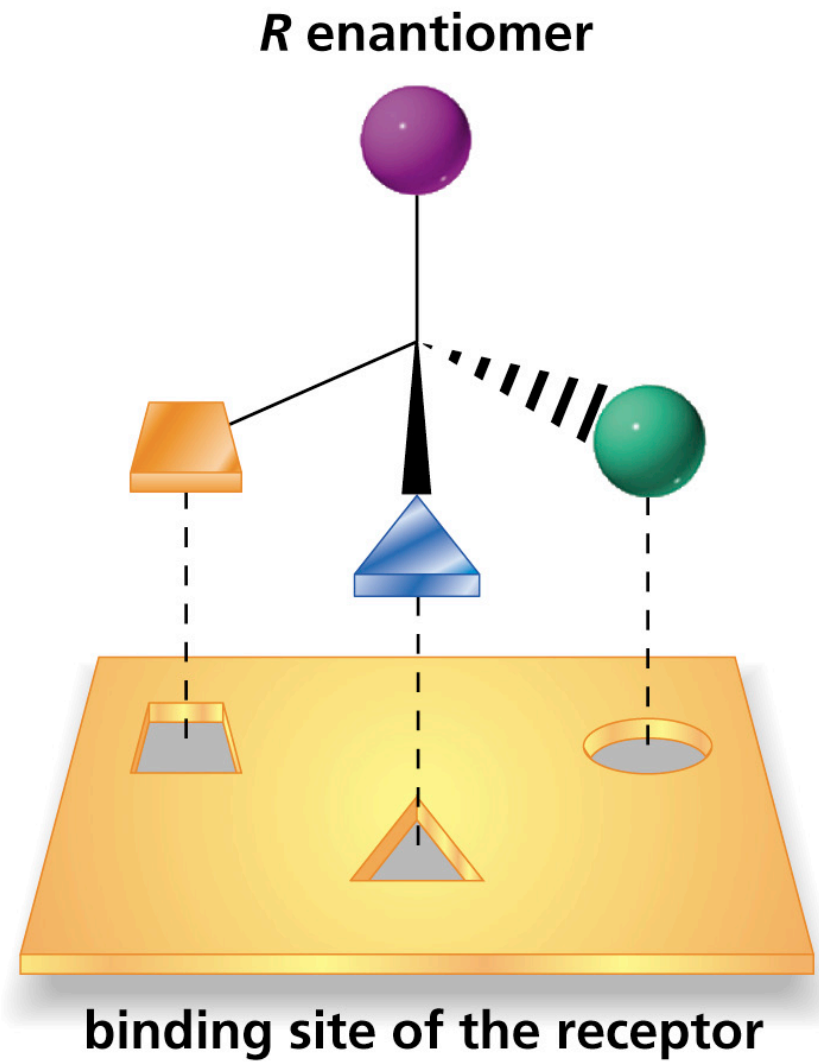
Estereoquímica de una reacción

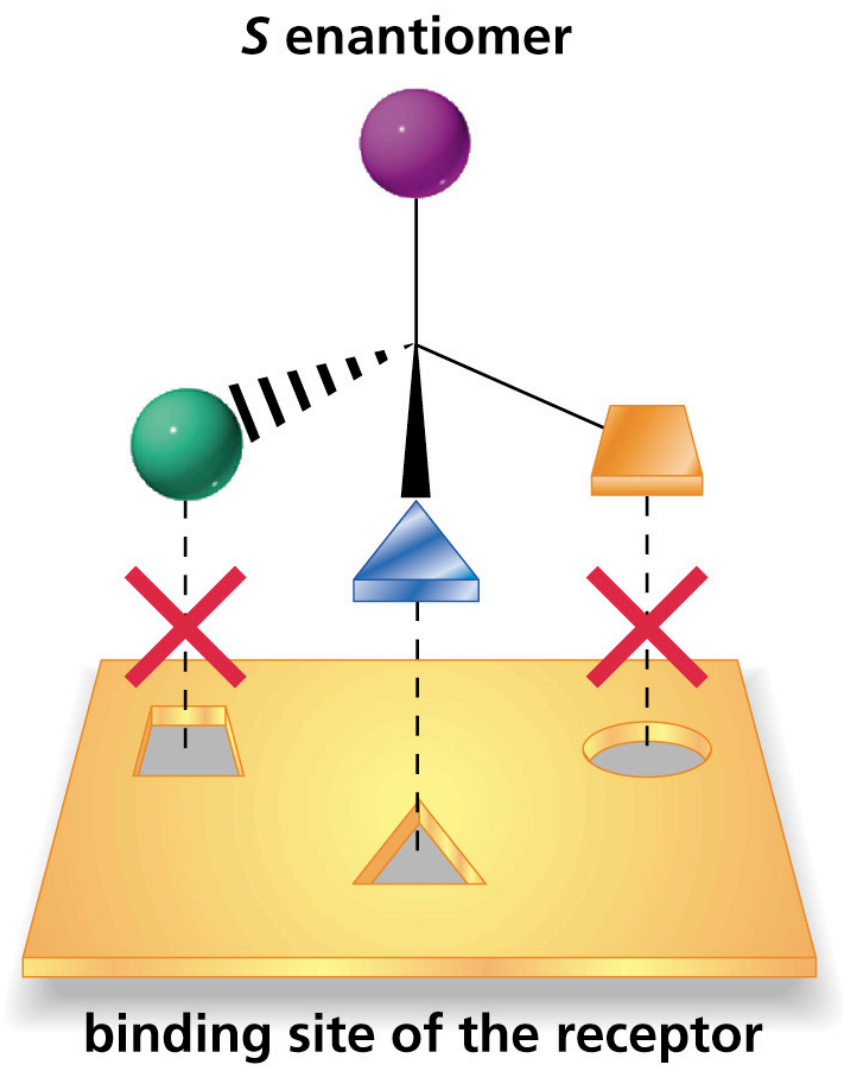


Estereoquímica en México

Dr. Eusebio Juaristi Cosío. Departamento de Química, Cinvestav.

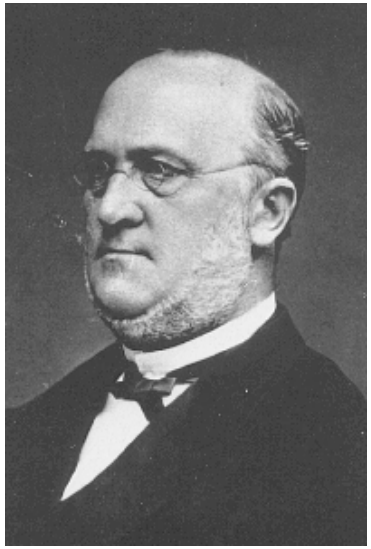



R enantiomer
binding site of the receptor

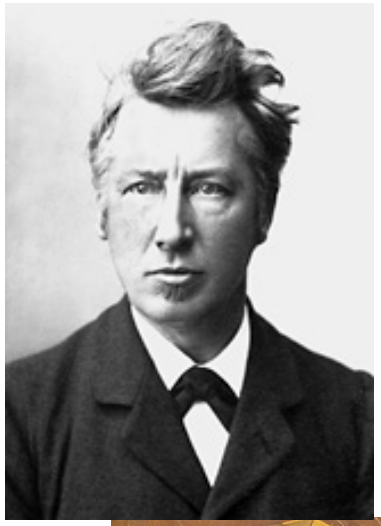

S enantiomer
binding site of the receptor

"No hace mucho tiempo, expresé mi opinión que la falta de educación en general, y de una capacitación profunda en química, eran una de las causas del deterioro de la investigación química en Alemania... Si alguien pensó que mi preocupación parecía exagerada, lea si le es posible, un ensayo reciente de un señor van't Hoff sobre la "Distribución de los átomos en el espacio", un documento que desborda con la sobreabundancia de una fantasía infantil... Este Dr. J. H. van't Hoff que trabaja en el Colegio Veterinario en Utrecht, no tiene al parecer ningún gusto por la investigación química exacta. Encuentra más conveniente cabalgar sobre su Pegaso (sacado evidentemente de los establos del Colegio Veterinario) y anunciar como, en su aventurado vuelo al Monte Parnaso, vió a los átomos distribuidos en el espacio."

A. W. Hermann Kolbe



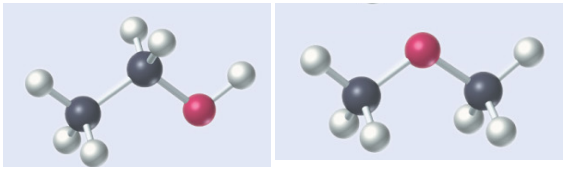
Adolf Wilhelm Hermann Kolbe (1818-1884)



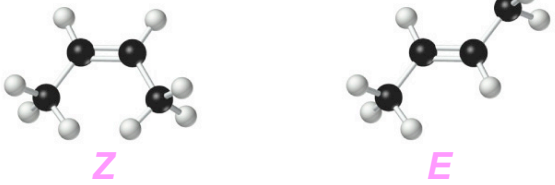
Jacobus Henricus van't Hoff (1852-1911) Nobel en Química 1901

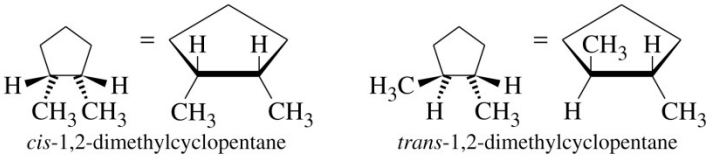
Isómeros

- Constitucionales



- Estereoisómeros
  - Configuracionales
    - Geométricos

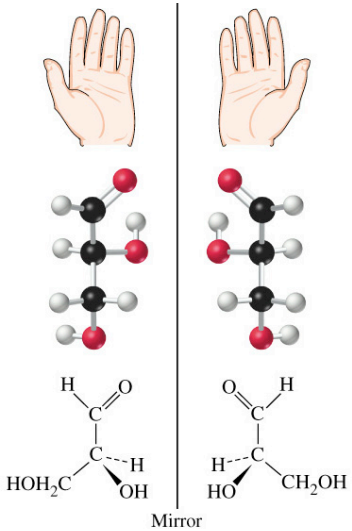




cis-1,2-dimethylcyclopentane

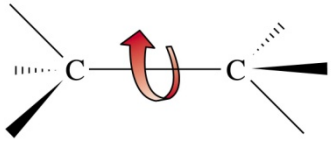
trans-1,2-dimethylcyclopentane

    - Ópticos
      - Enantiómeros

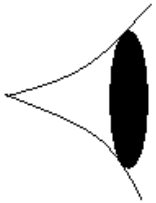


      - Diastereoisómeros

  - Conformacionales

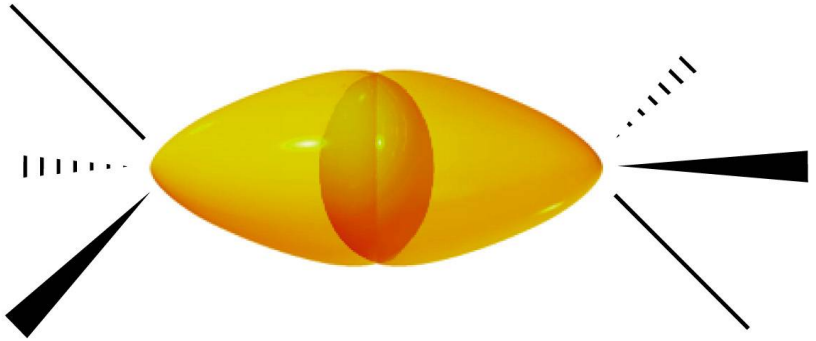


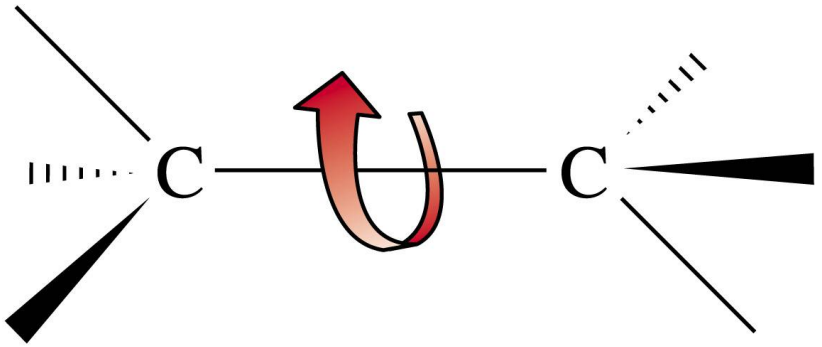
Conformaciones de alcanos: Rotación de enlaces carbono-carbono



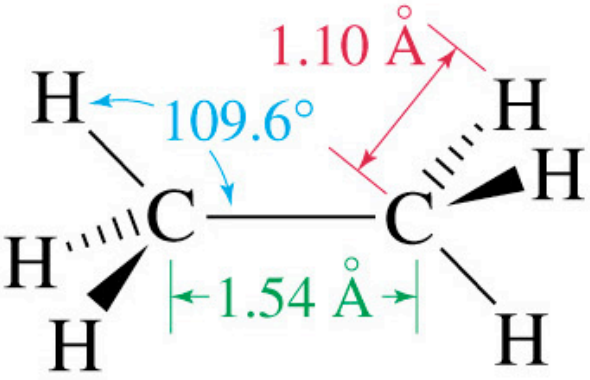
CH_3-CH_3

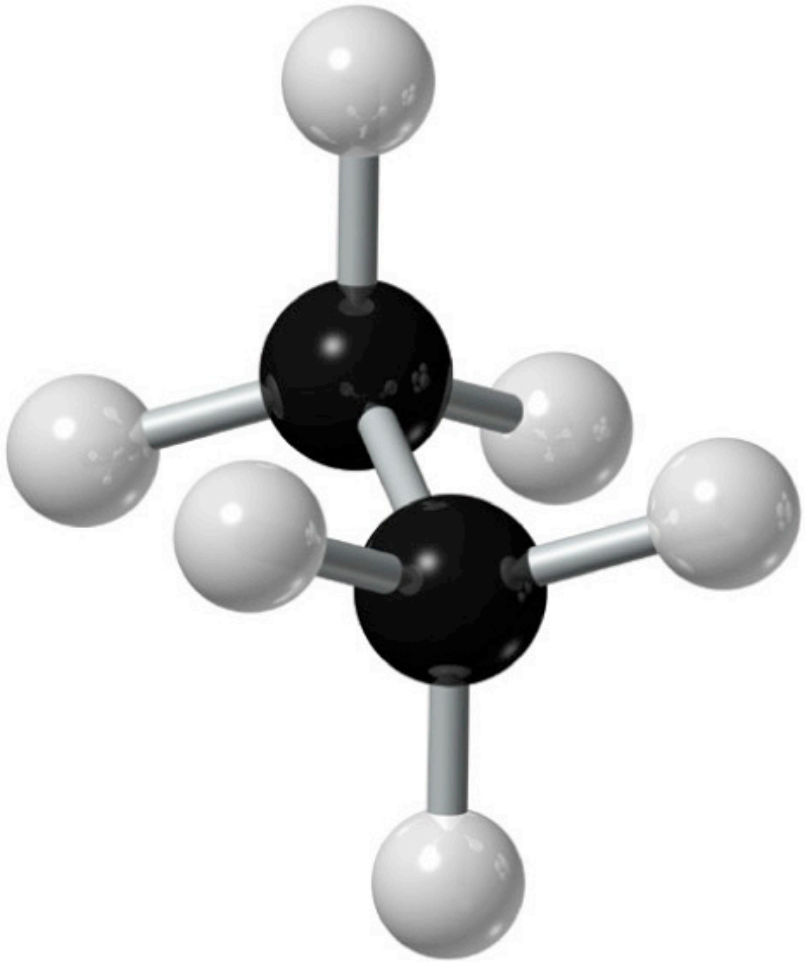
Etano

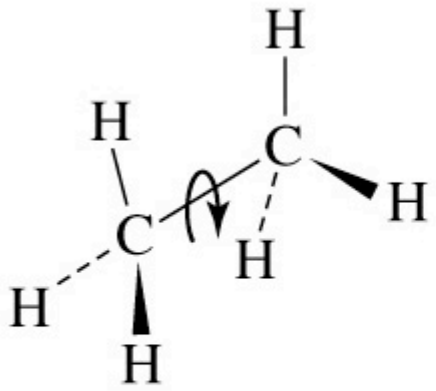


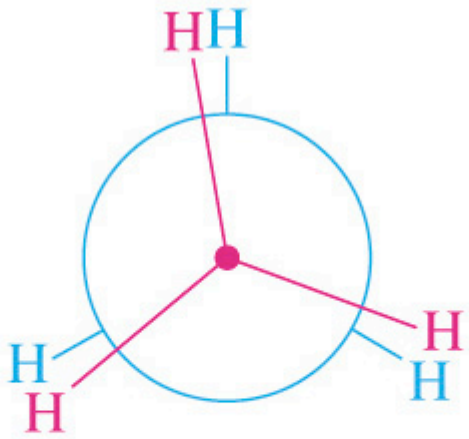


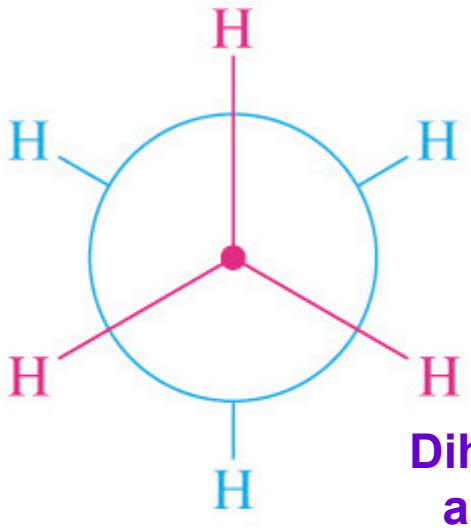
Una molécula de cadena abierta puede adoptar una variedad casi infinita de posiciones relativas en el espacio: **conformaciones**


1.10 Å
H
109.6°
H
H
C
C
H
H
1.54 Å
H









Dihedral angle

Eclipsed

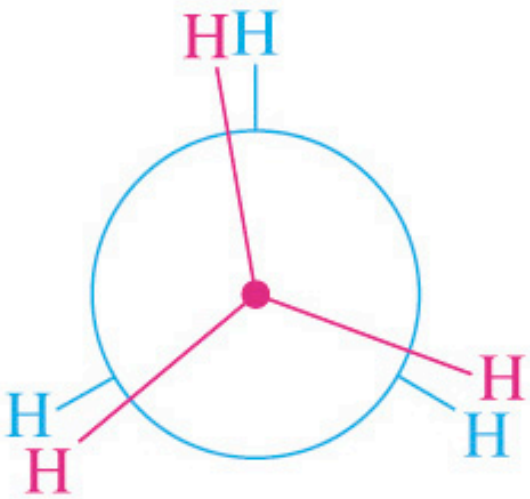
Staggered

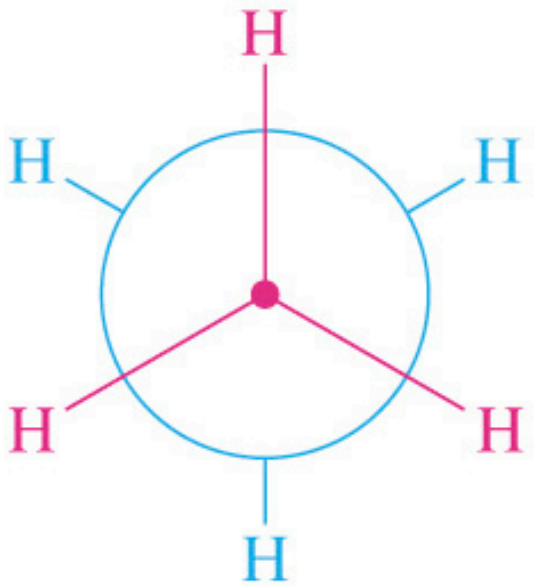
(a) **(b)**

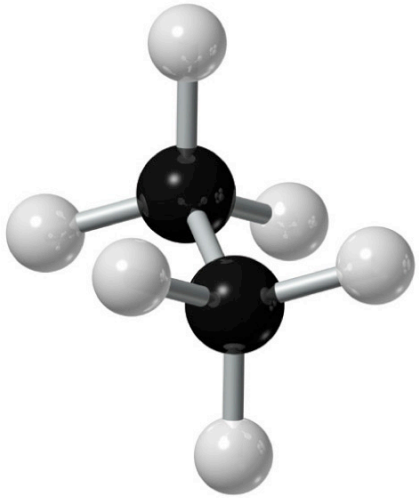
(a) Fórmula dimensional
(b) Proyecciones de Newman

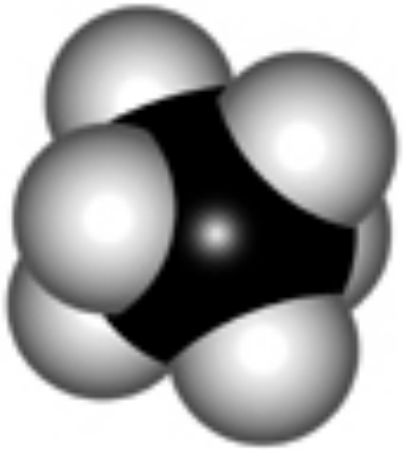
Proyecciones de Newman

Melvin Spencer Newman
1908-1993

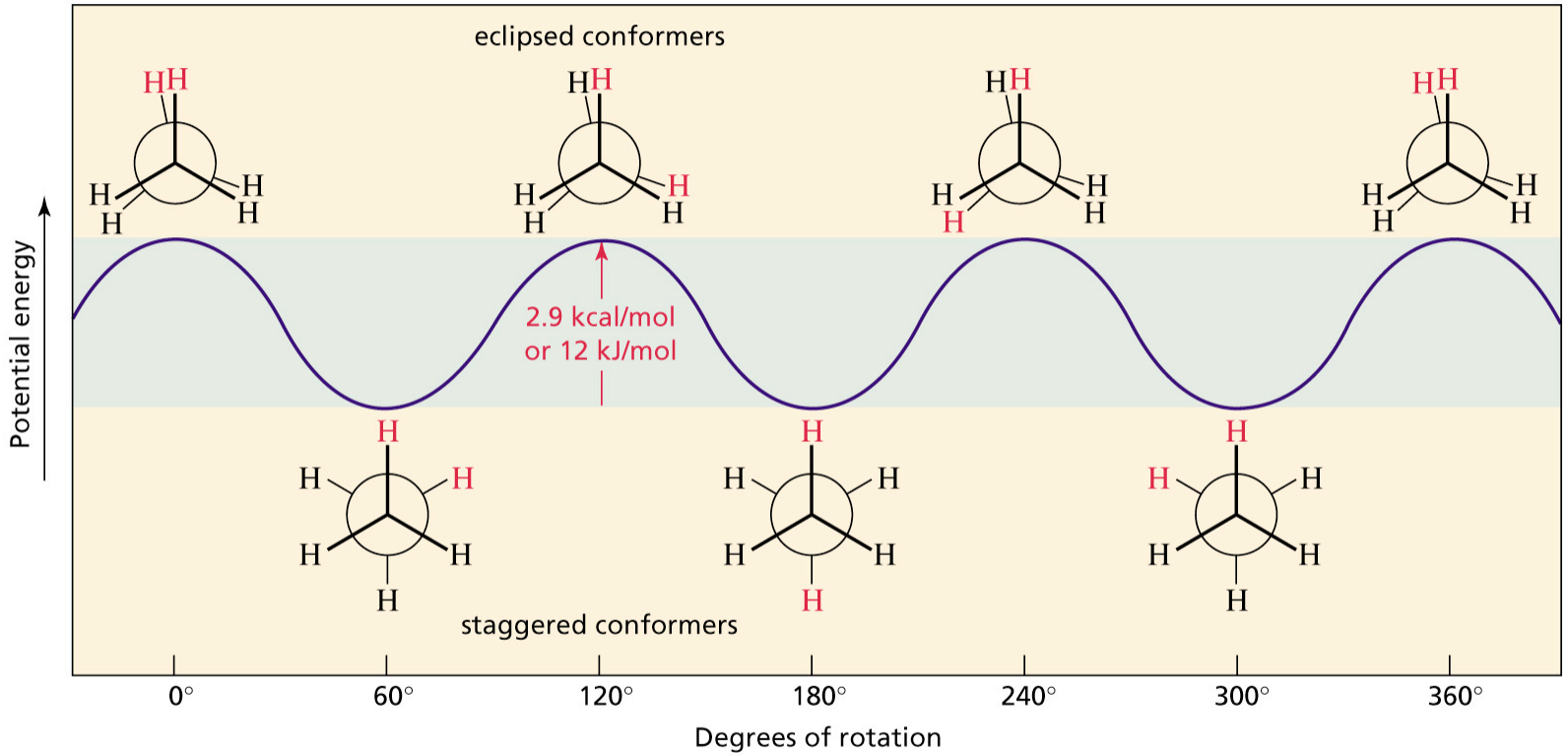






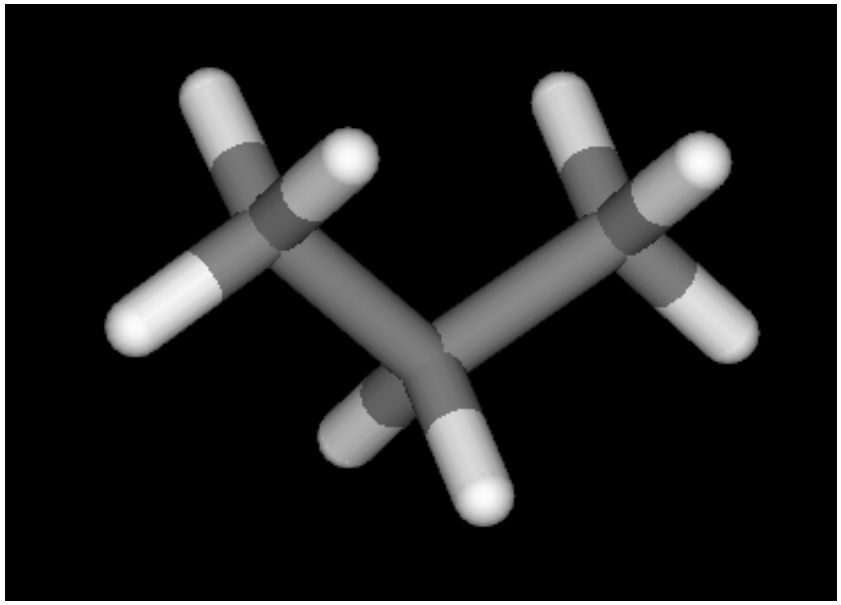


Different Conformations of Ethane



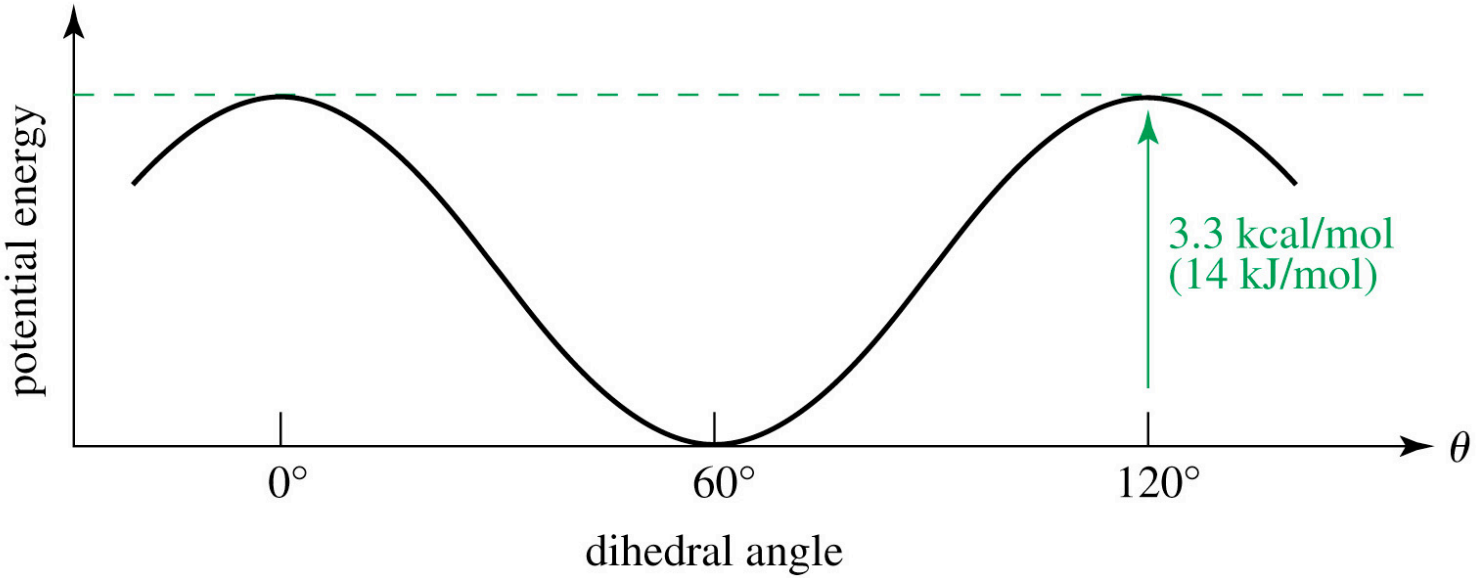
- A staggered conformer is more stable than an eclipsed conformer
- Torsional strain: repulsion between pairs of bonding electrons

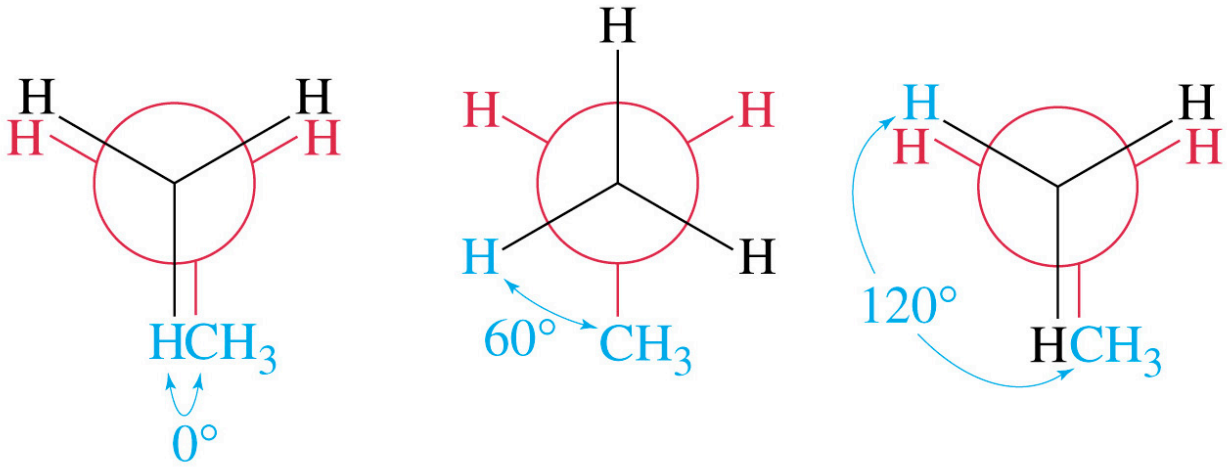
¿Cómo sería el perfil de energía frente al grado de rotación de un enlace C-C en el propano?



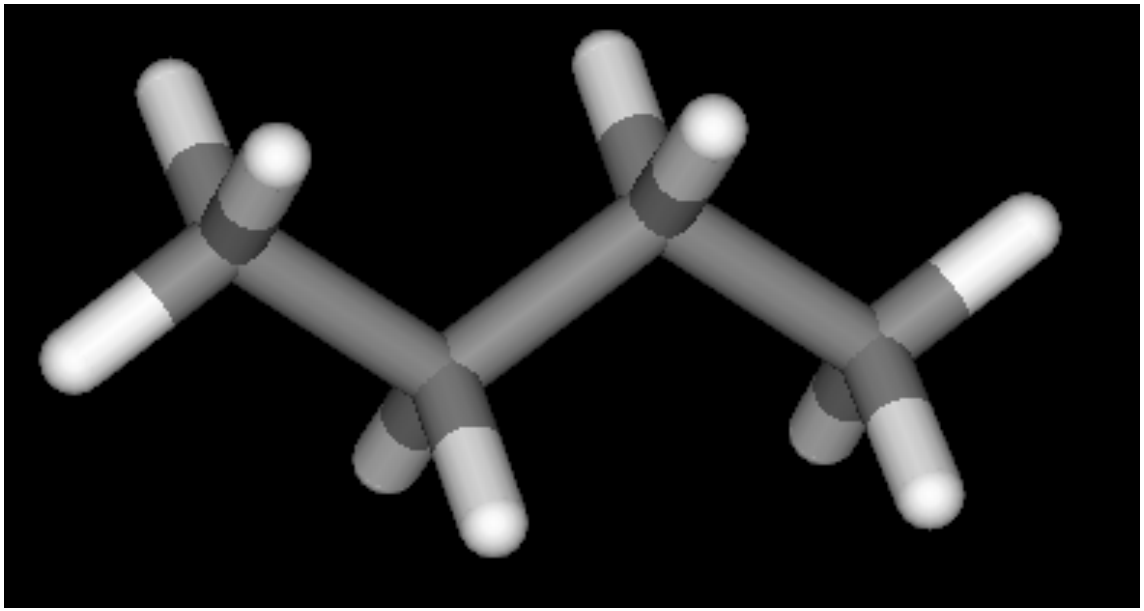
Dibuje una gráfica que muestre los ángulos diedros o de torsión C1-C2 contra la energía del 2-metilpropano. Dibuje las proyecciones de Newman para cada conformación alternada y eclipsada.

Cambios energéticos implicados en la rotación alrededor del enlace sigma C-C del propano

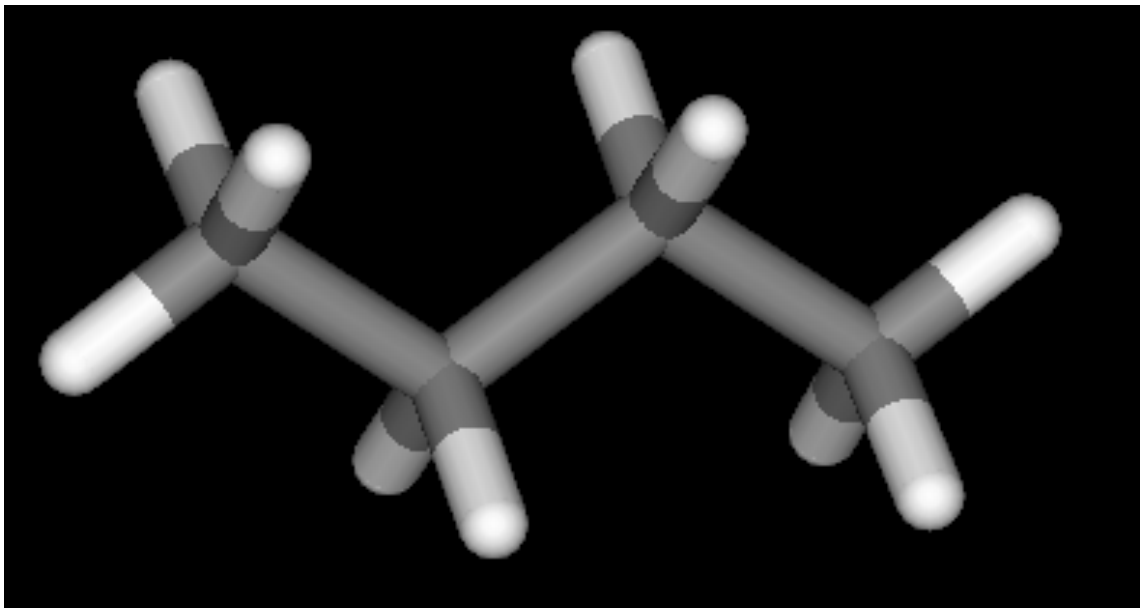


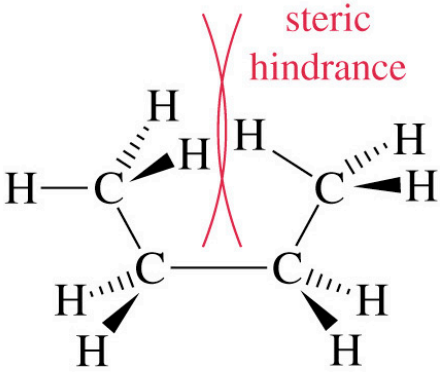


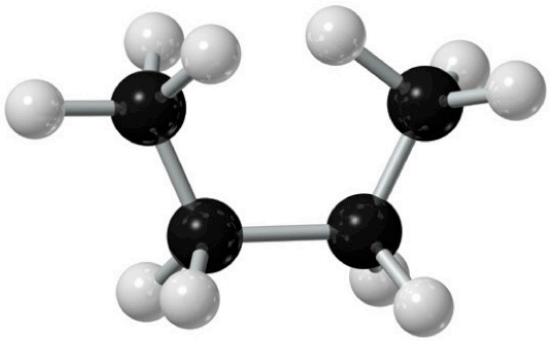
¿Cómo sería el perfil de energía frente al grado de rotación del enlace C-C central del butano?

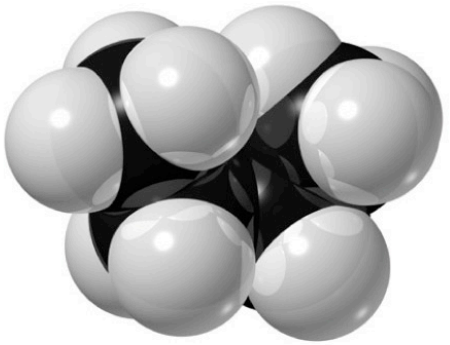


¿Cómo sería el perfil de energía frente al grado de rotación del enlace C-C central del butano?



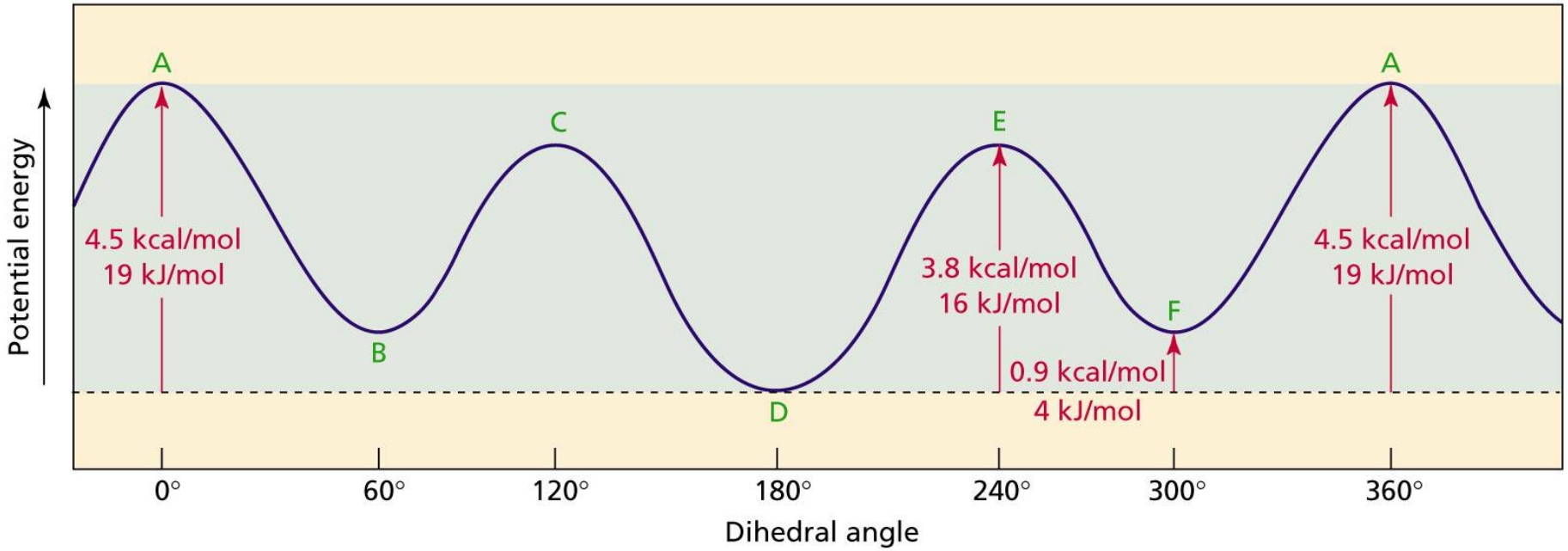




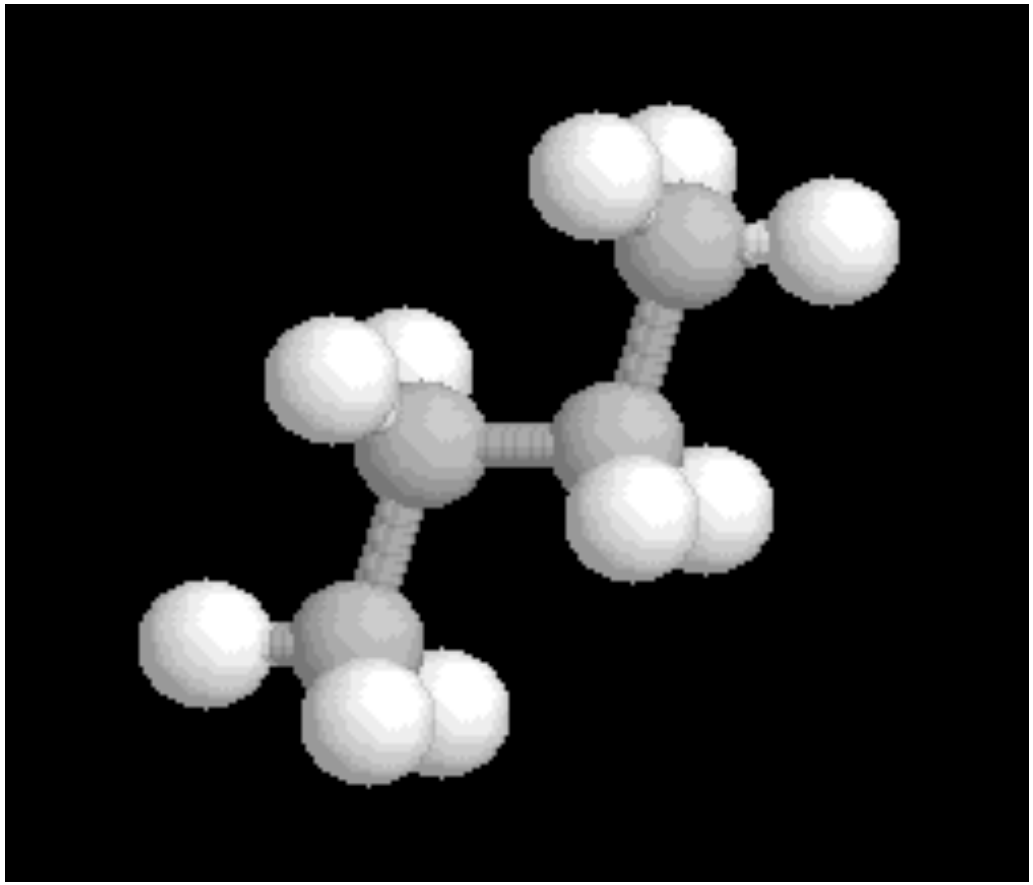


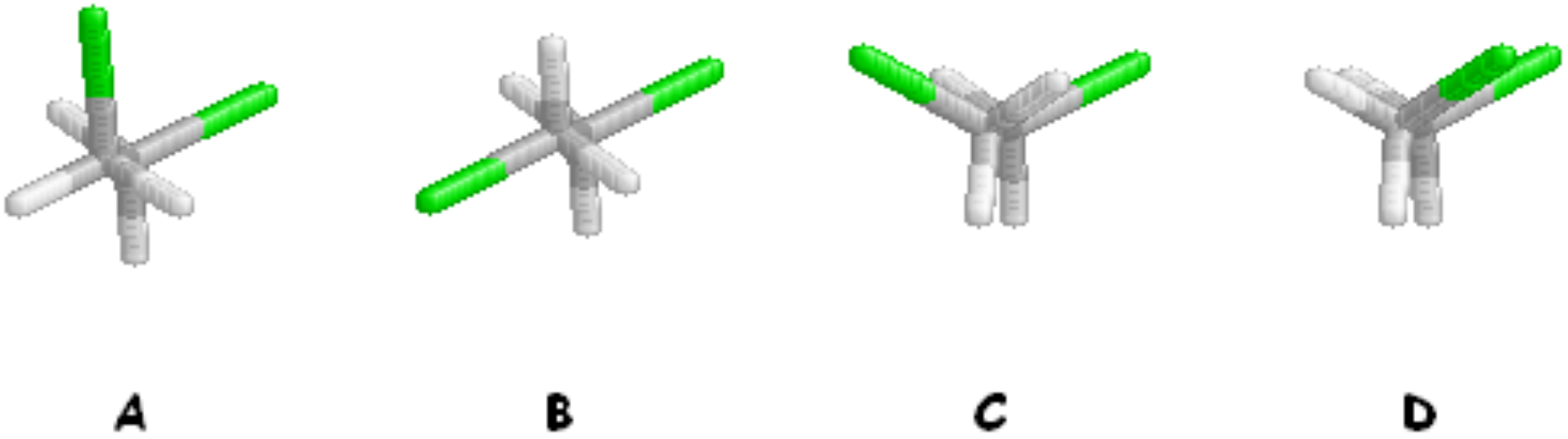
Totally eclipsed conformation of butane

Potential energy of butane as a function of the degree of rotation about the C-2–C-3 bond.



The number of molecules in a particular conformation at any one time depends on the stability of the conformation; the more stable the conformation, the greater the number of molecules that will be in that conformation.

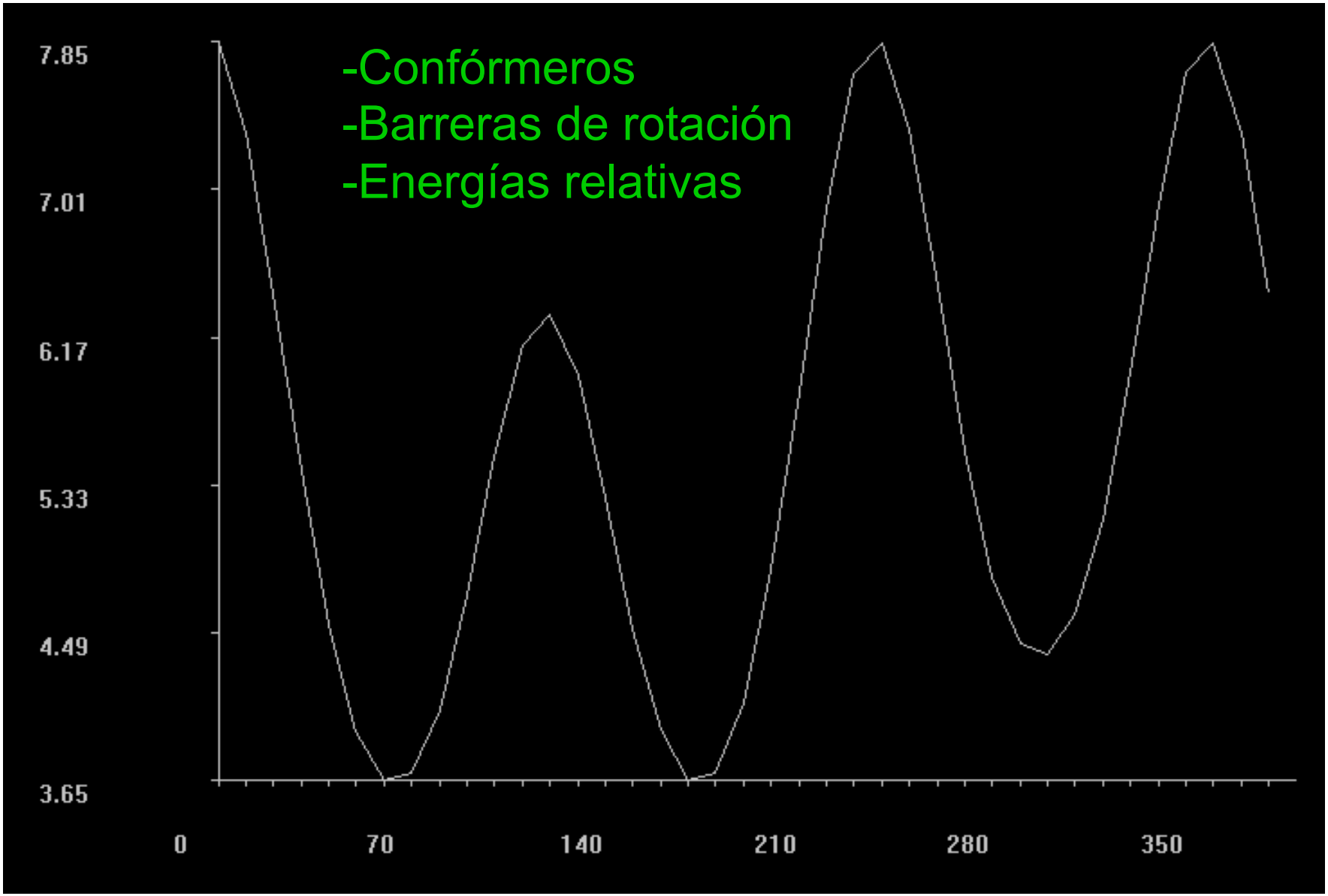




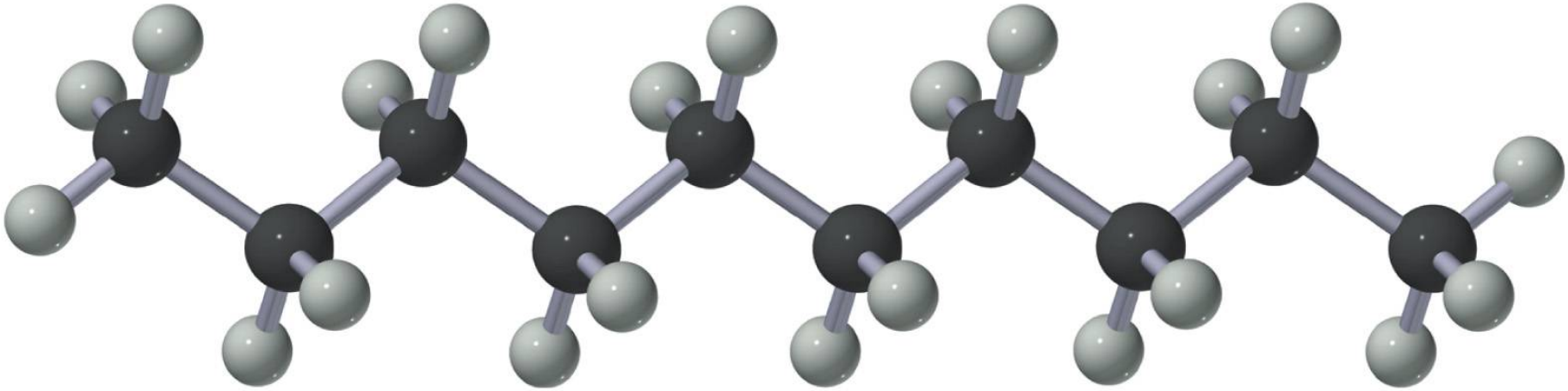
Above are four models of 1,2-dichloroethane. Which of the lines below lists the conformations in order of **decreasing** energy?

1. D - A - C - B
2. D - C - B - A
3. A - D - C - B
4. A - C - B - D
5. D - C - A - B
6. B - A - C - D

Dibuje una gráfica de energía torsional del 2-metilbutano cuando rota el enlace C2-C3.



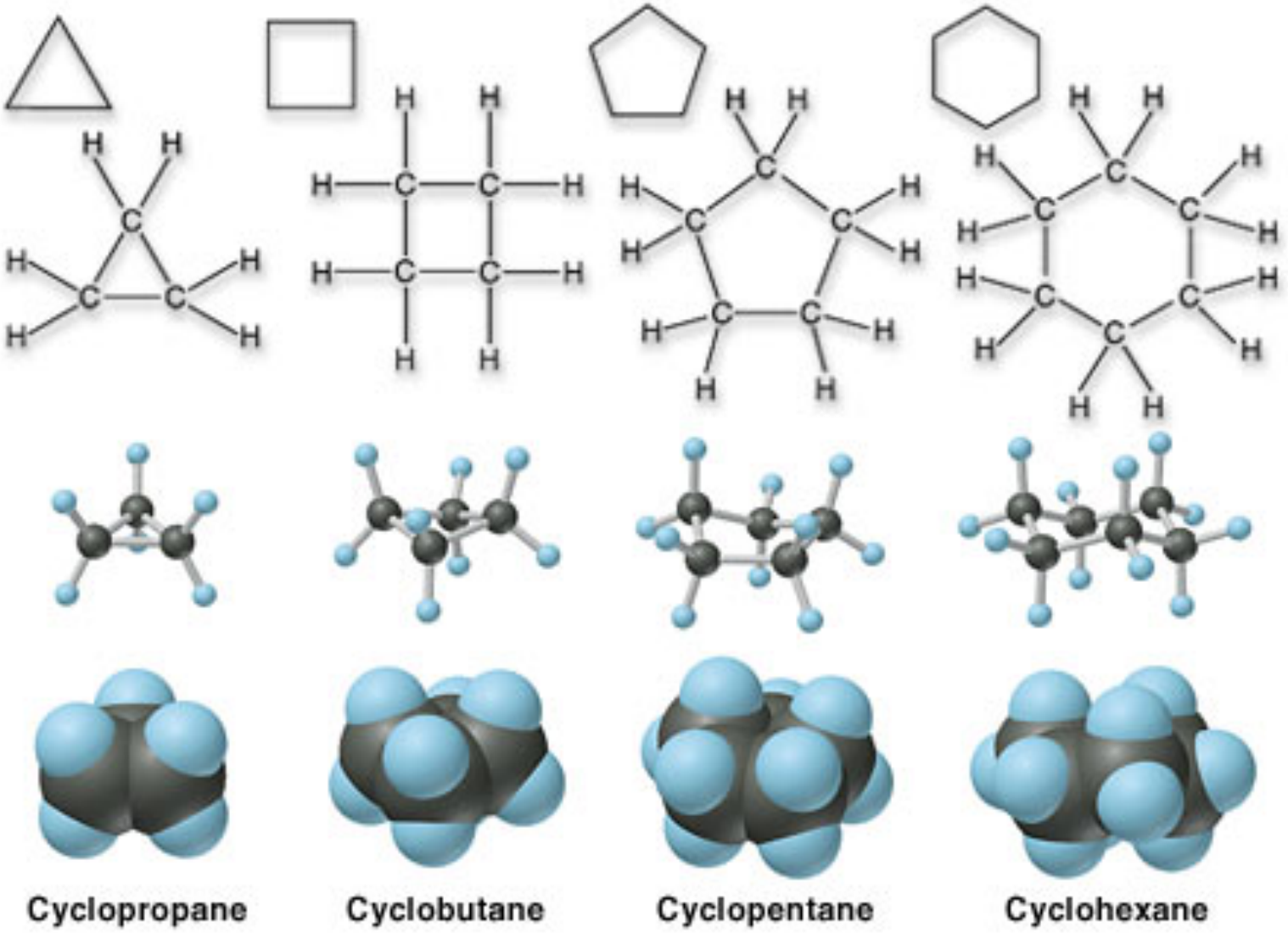
Conformaciones de alcanos más grandes



ball-and-stick model of decane

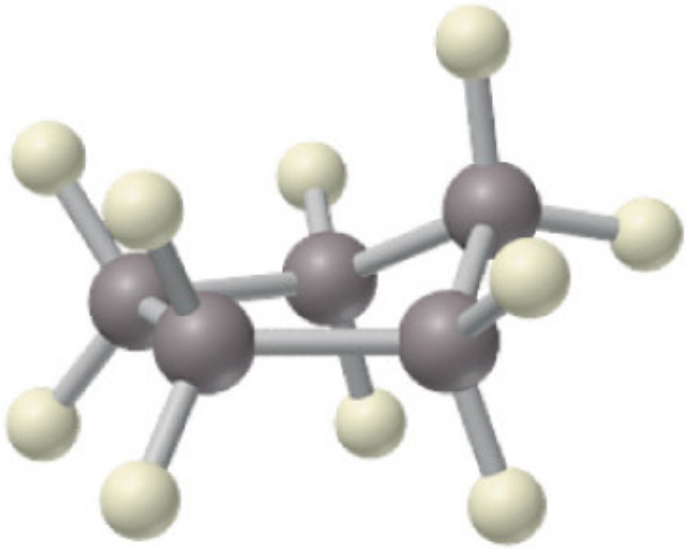
Dibuje una representación en perspectiva de la conformación más estable de 3-metilhexano

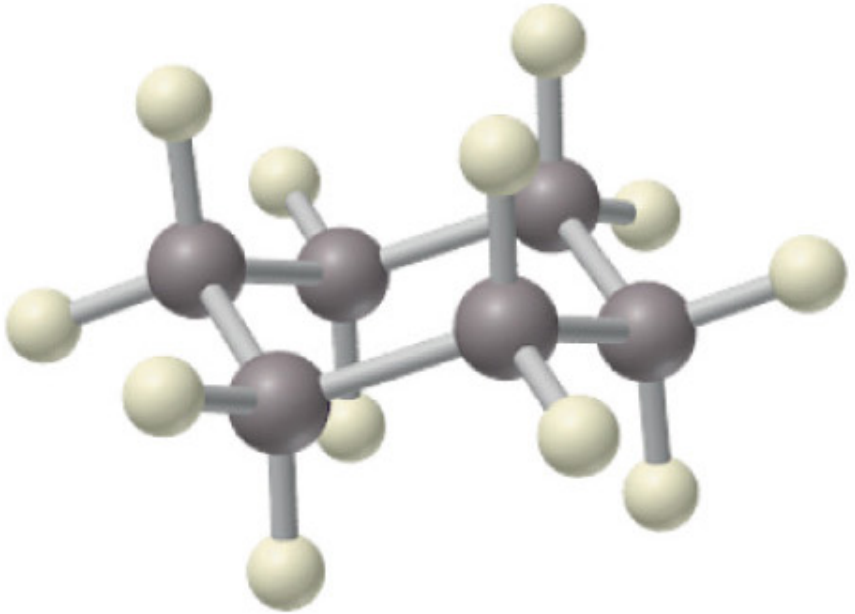
Cicloalcanos: Tensión del anillo

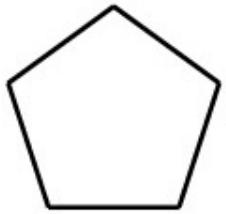


Cicloalcanos: **Serie homóloga**, cada miembro de la serie difiere del inmediato anterior en un grupo -CH_2-

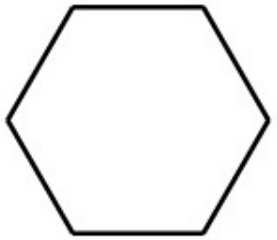
Although all the simple cycloalkanes (up to about C_{20}) have been synthesized, the most common rings contain five or six carbon atoms. Why are five-membered and six-membered rings more common than the other sizes?



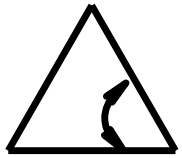


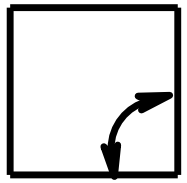


Cyclopentane



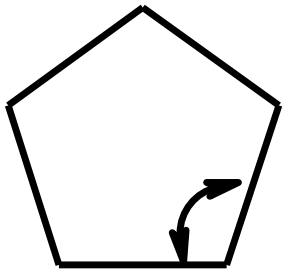
Cyclohexane

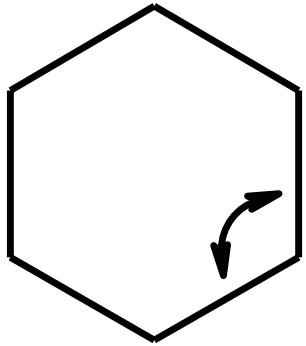




Johann Friedrich Wilhelm Adolf von Baeyer (German) 1835-1917
The Nobel Prize in Chemistry 1905

He came from a family distinguished both in literature and the natural sciences. Even as a child Baeyer was interested in chemical experiments and at the age of twelve found a new double salt of copper.

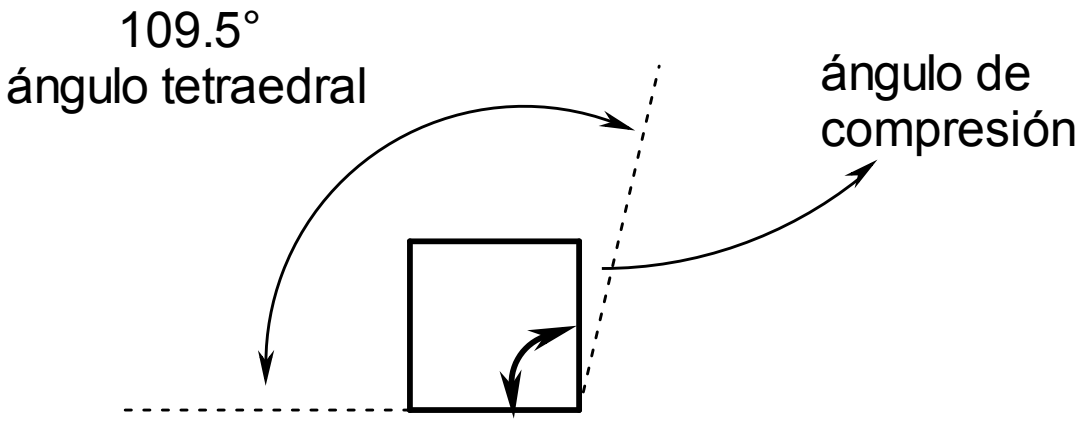




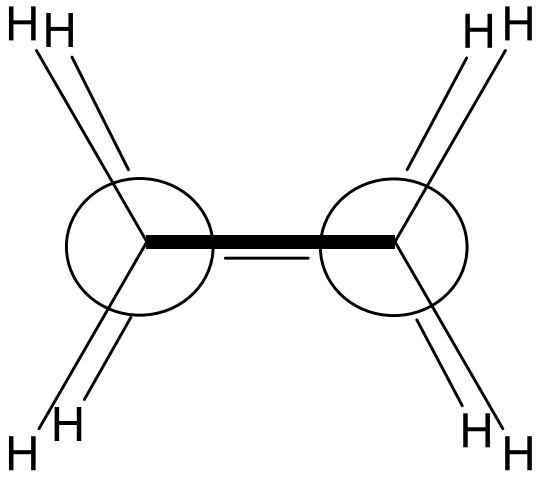
$$\text{ángulo interno} = \frac{(n-2) \times 180°}{n}$$

Tensión anular (Tensión de Baeyer)

La tensión anular para el ciclobutano planar resulta de dos factores: La compresión del ángulo de enlace a 90° y la tensión torsional resultado del eclipsamiento de los enlaces.



Dibuje la proyección de Newman para el ciclobutano plano

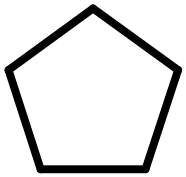


Proyección de Newman para el cilcobutano planar

Heats of Combustion of Cycloalkanes

cycloalkane $(CH_2)_n$	n	ΔH_{comb} (kcal/mol)	heat evolved per CH_2 group (kcal/mol)
cyclopropane	3	499.8	166.6
cyclobutane	4	655.9	164.0
cyclopentane	5	793.5	158.7
cyclohexane	6	944.5	157.4
cycloheptane	7	1108.2	158.3
cyclooctane	8	1269.2	158.6
cyclononane	9	1429.5	158.8
cyclodecane	10	1586.0	158.6
unbranched alkanes			(157.4)

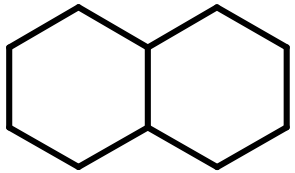
Calcular la tensión anular por cada grupo CH_2 y la tensión total del anillo



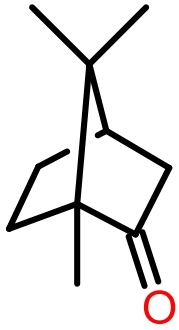
+ H_2 $\xrightarrow{\text{catalizador}}$ no reacciona

+ H_2 $\xrightarrow{\text{catalizador}}$ 

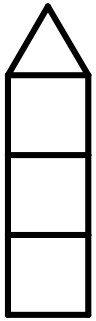
Considerando el tamaño de los anillos, ¿cuáles de los siguientes compuestos se esperaría que presentaran cantidades sustanciales de tensión anular?

(a) 

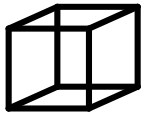
decalina

(b) 

alcanfor

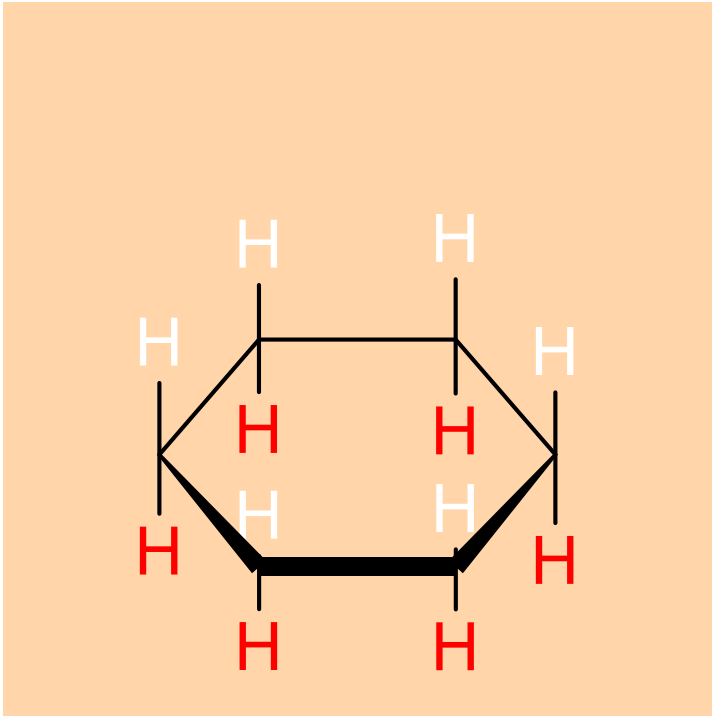
(c) 

aparmentosano

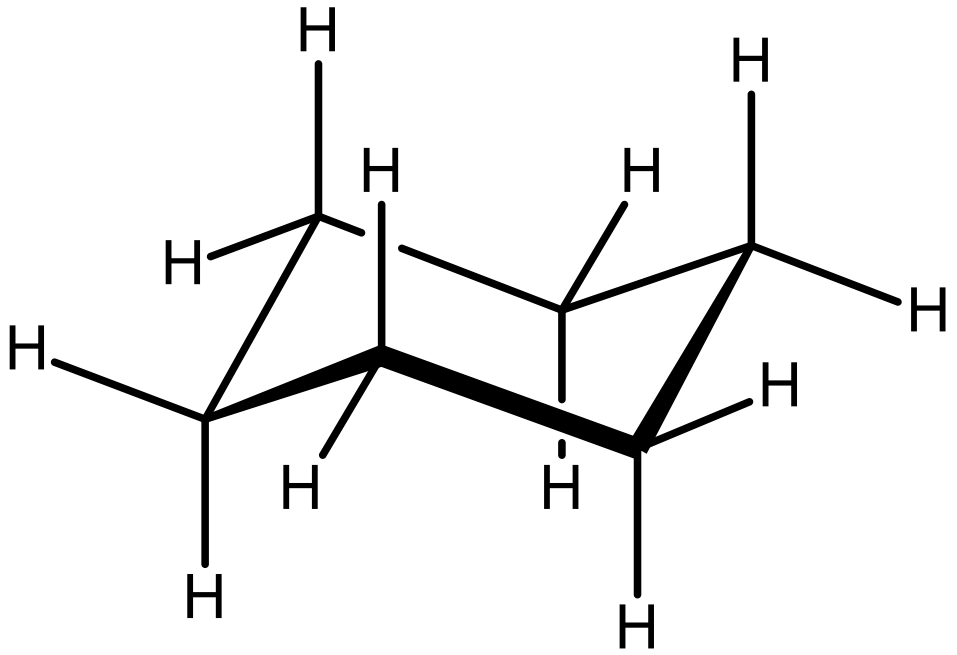
(d) 

cubano

Conformación de ciclohexano

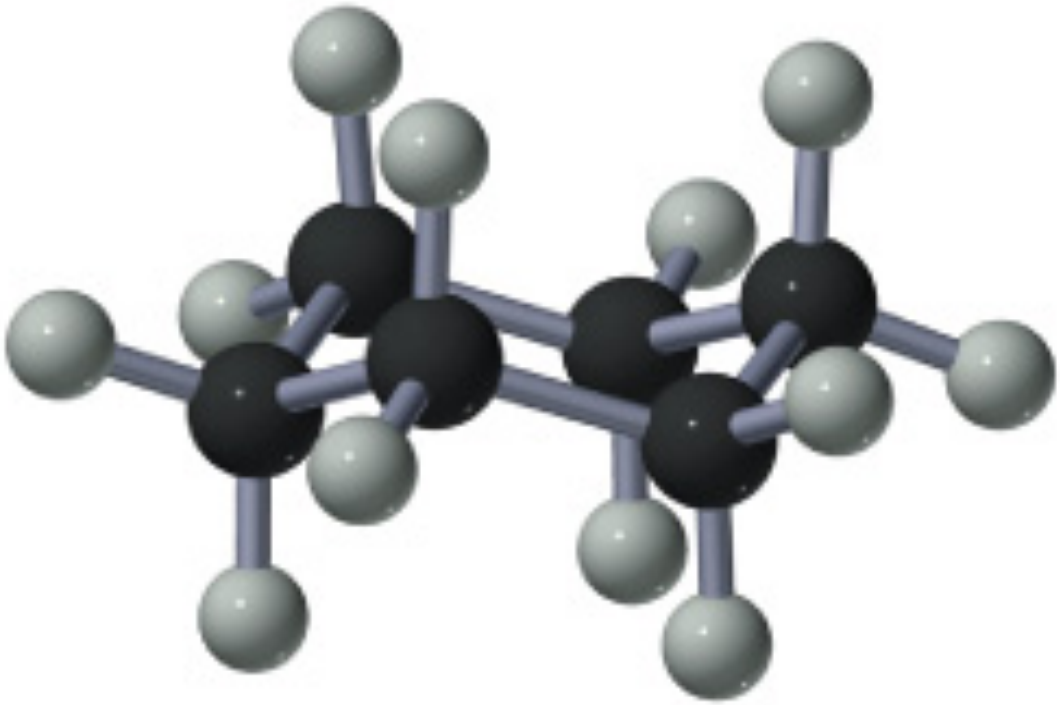


Todos los hidrógenos eclipsados

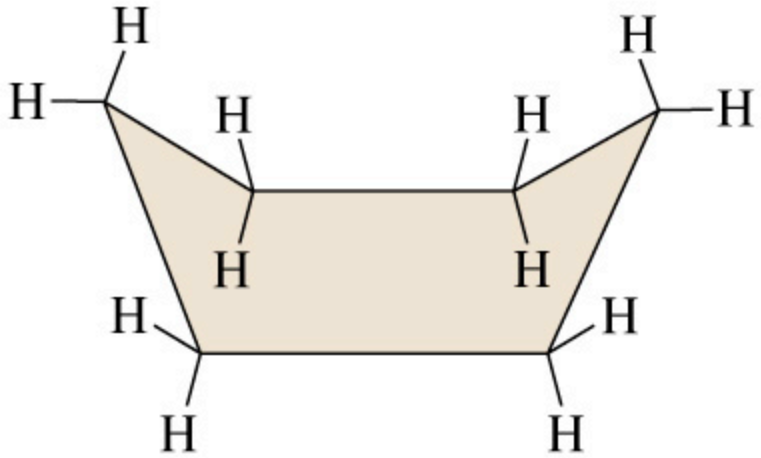


Todos los hidrógenos alternados (menores repulsiones)

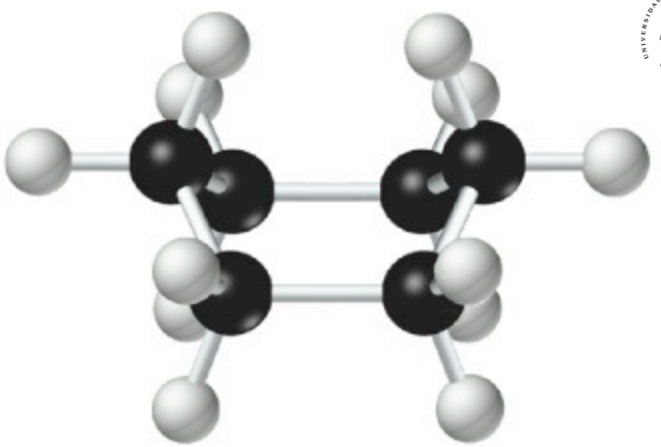
plegamiento



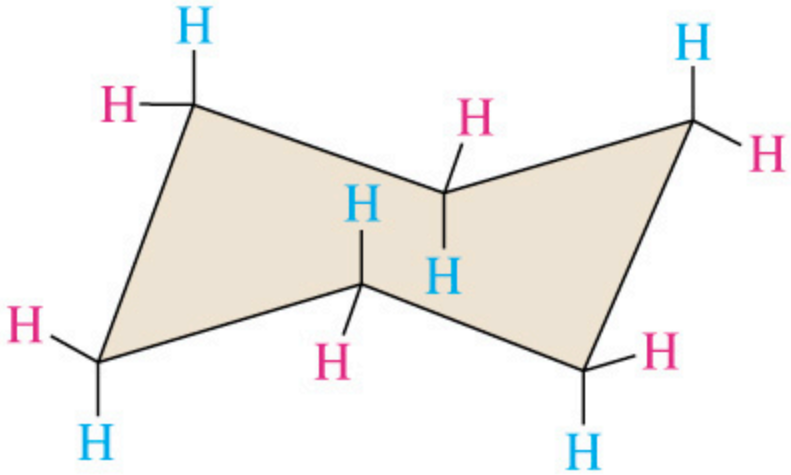
ball-and-stick model of the
chair conformer of cyclohexane



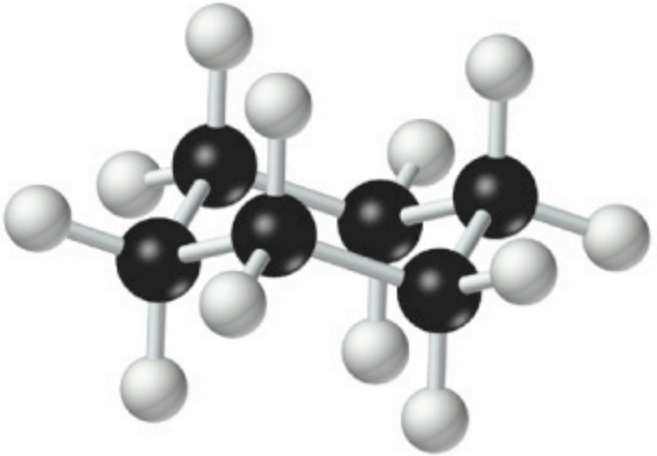
(a)



plegamiento

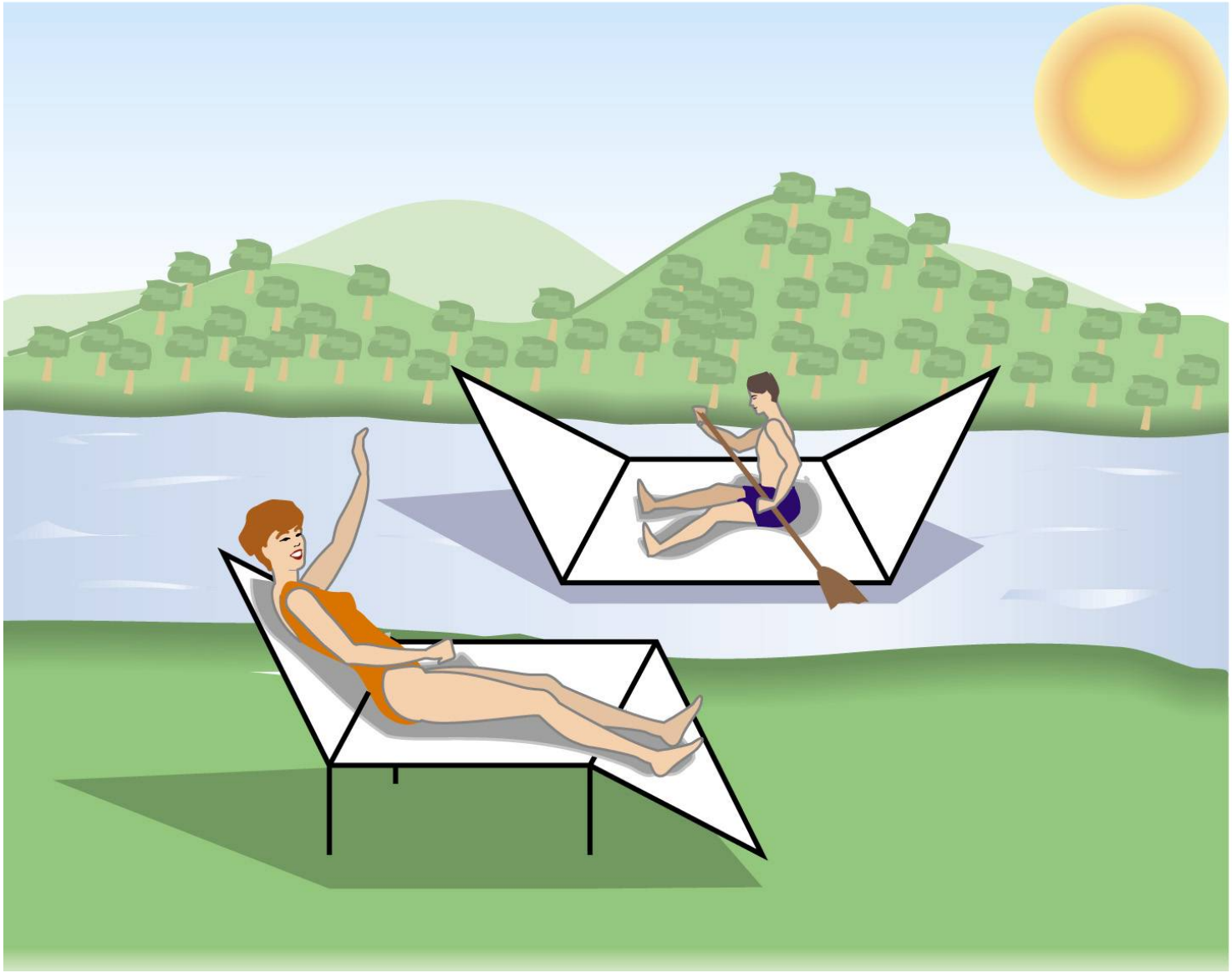


(b)

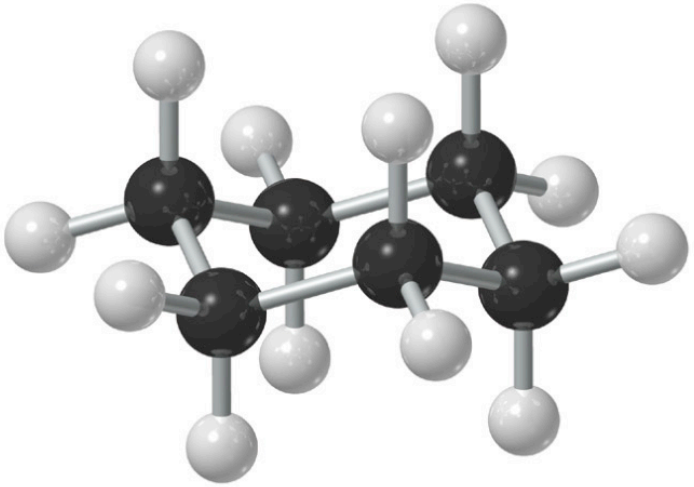


Libres de tensión angular

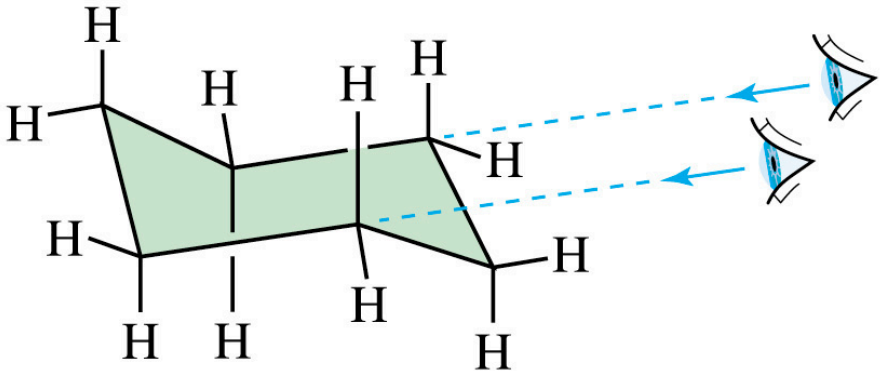
Recreación de las conformaciones bote y silla del ciclohexano



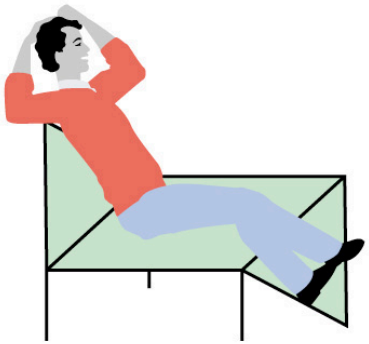
Dibuje la proyección de Newman de una forma silla del ciclohexano

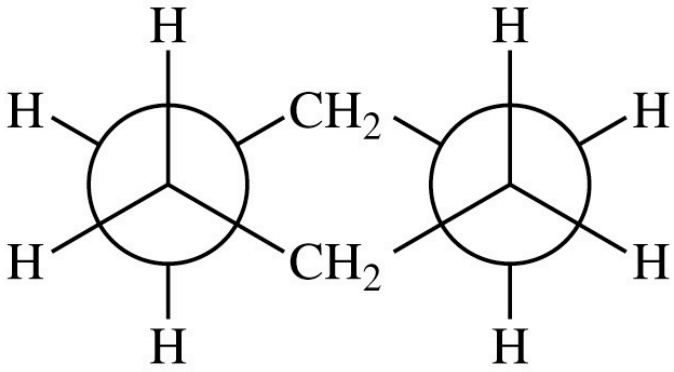


chair conformation

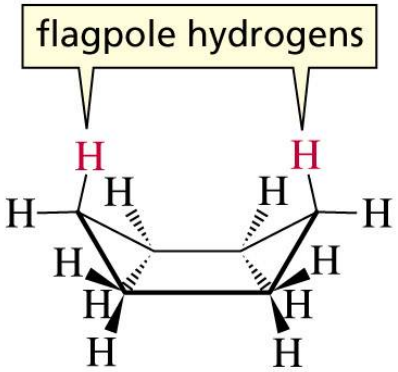


viewed along the “seat” bonds

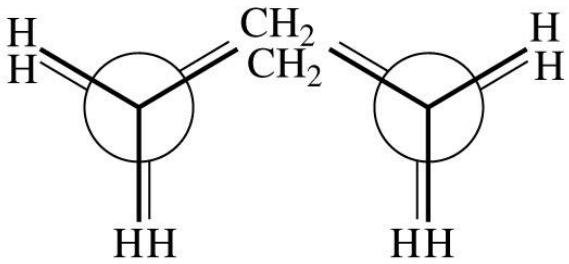




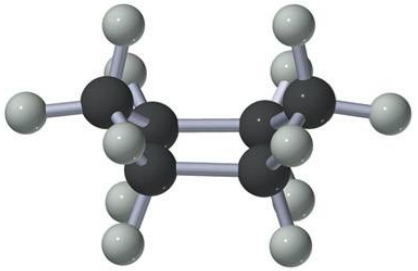
Newman projection



boat conformer of cyclohexane

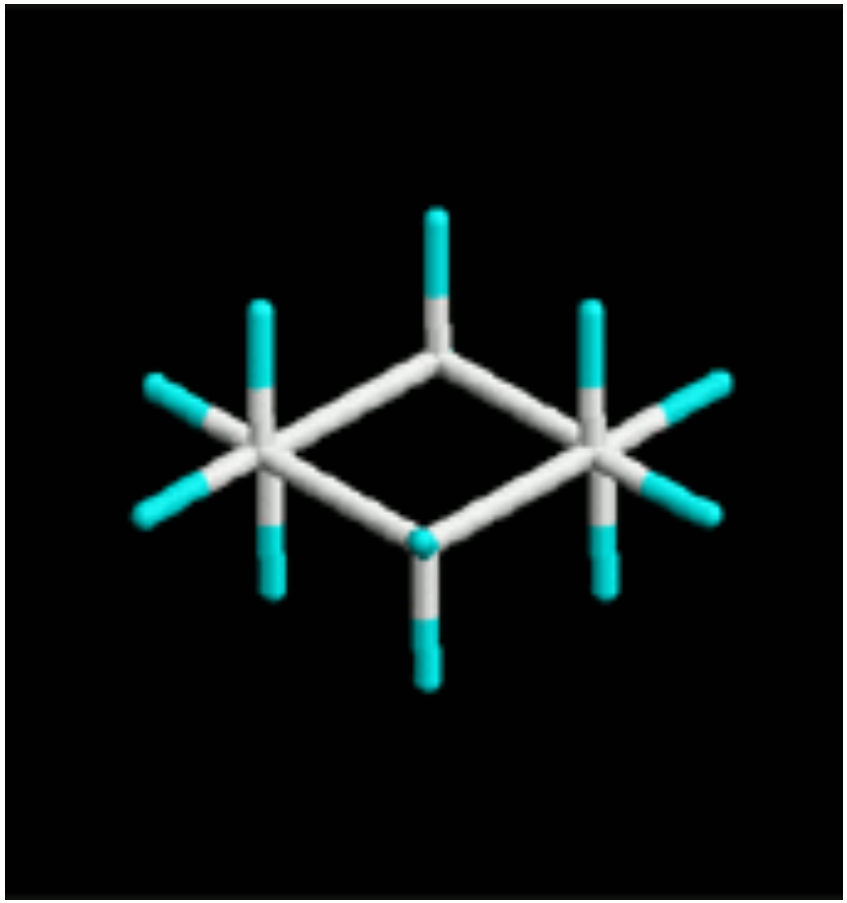


Newman projection of the boat conformer

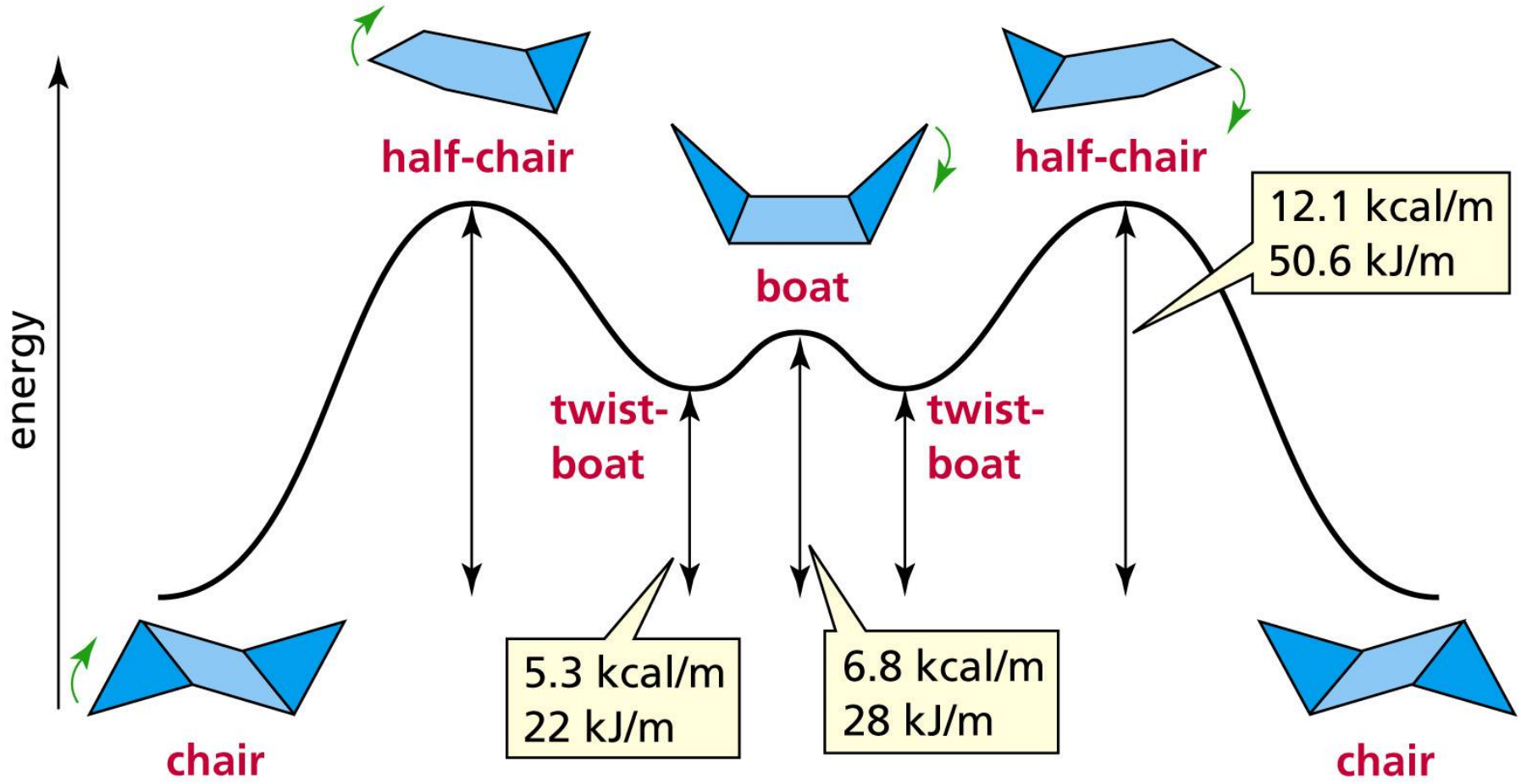


ball-and-stick model of the boat conformer of cyclohexane

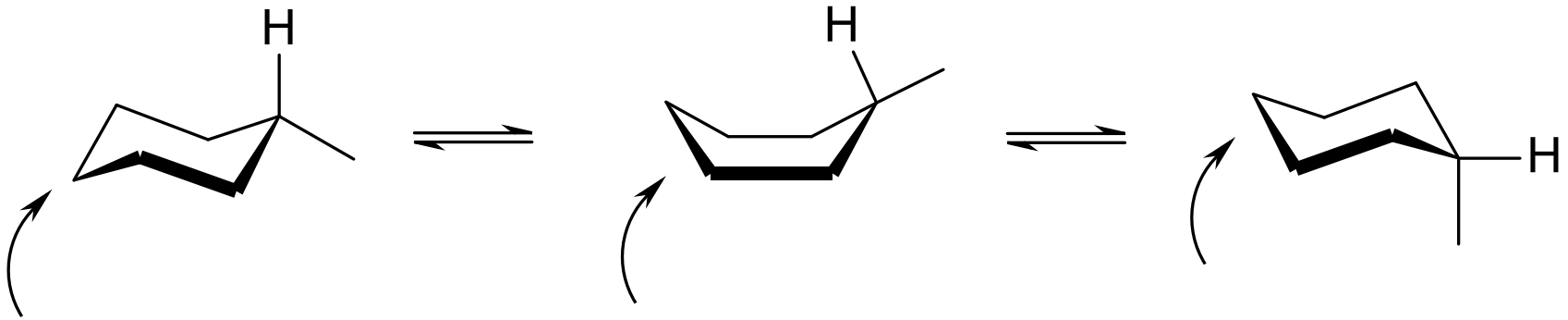
Tensión torsional

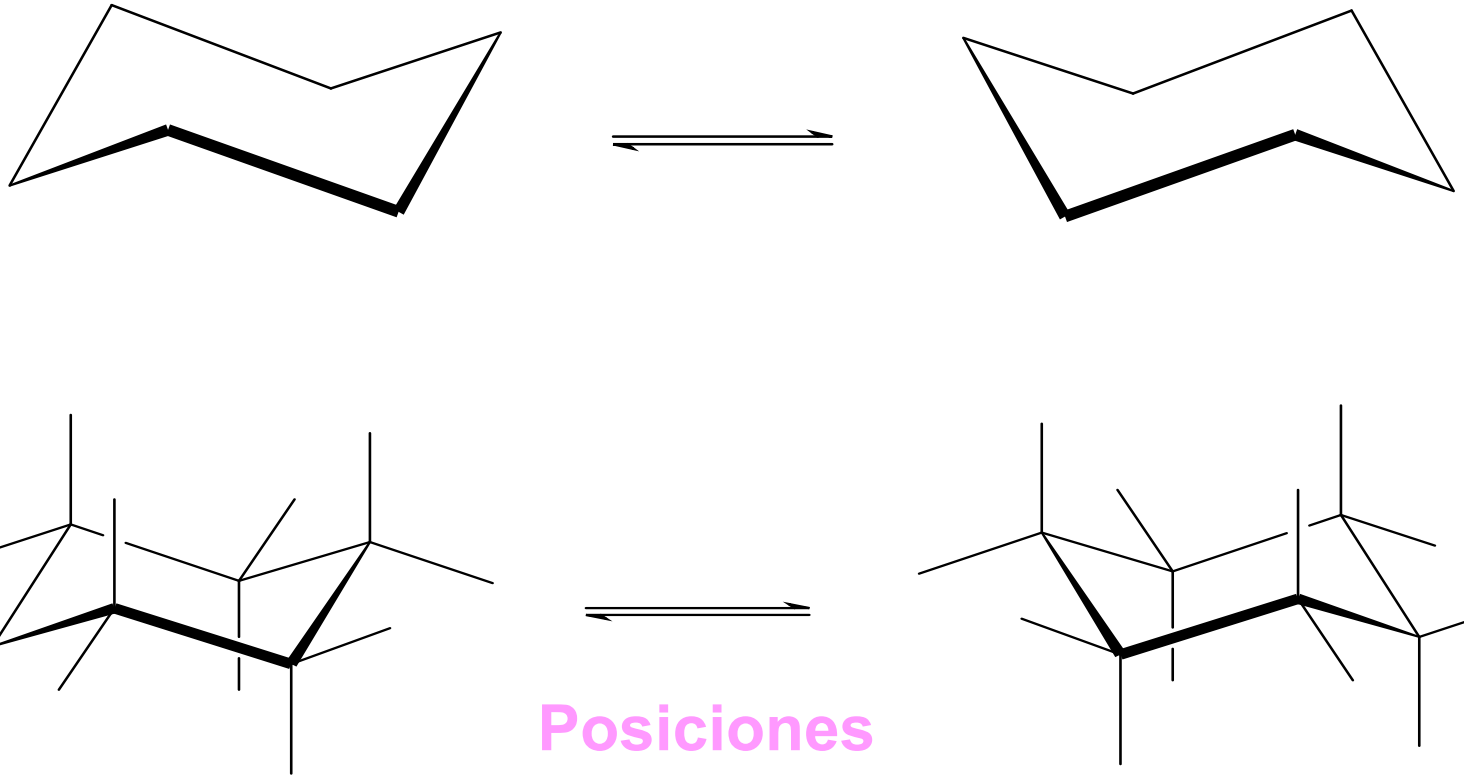


Energía conformacional del ciclohexano



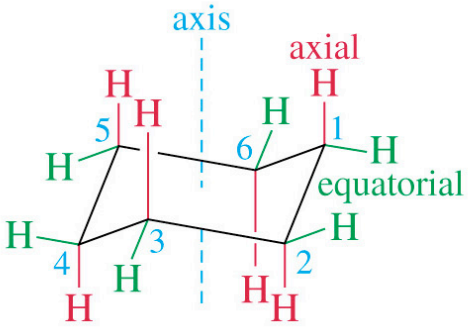
Interconversión de los hidrógenos en el ciclohexano
(sustituyentes ecuatoriales y axiales)

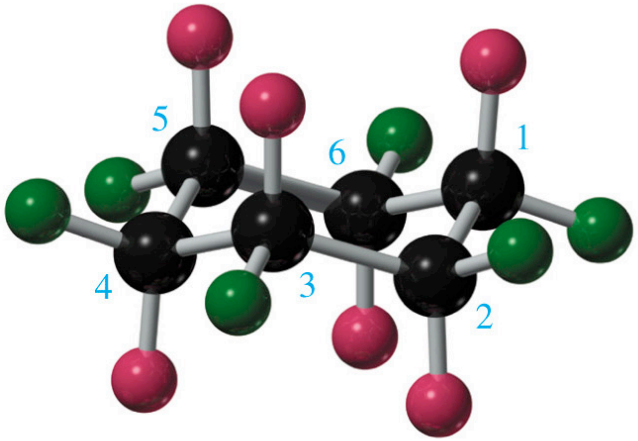


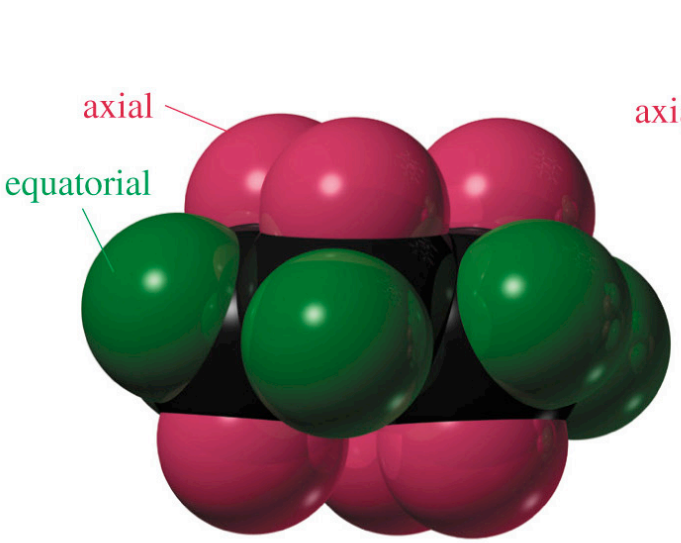


Posiciones axiales y ecuatoriales

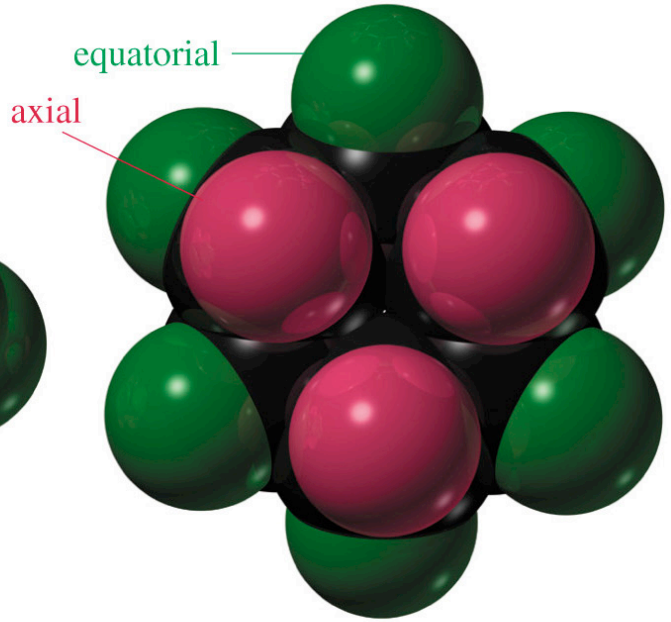
Axial and Equatorial Positions



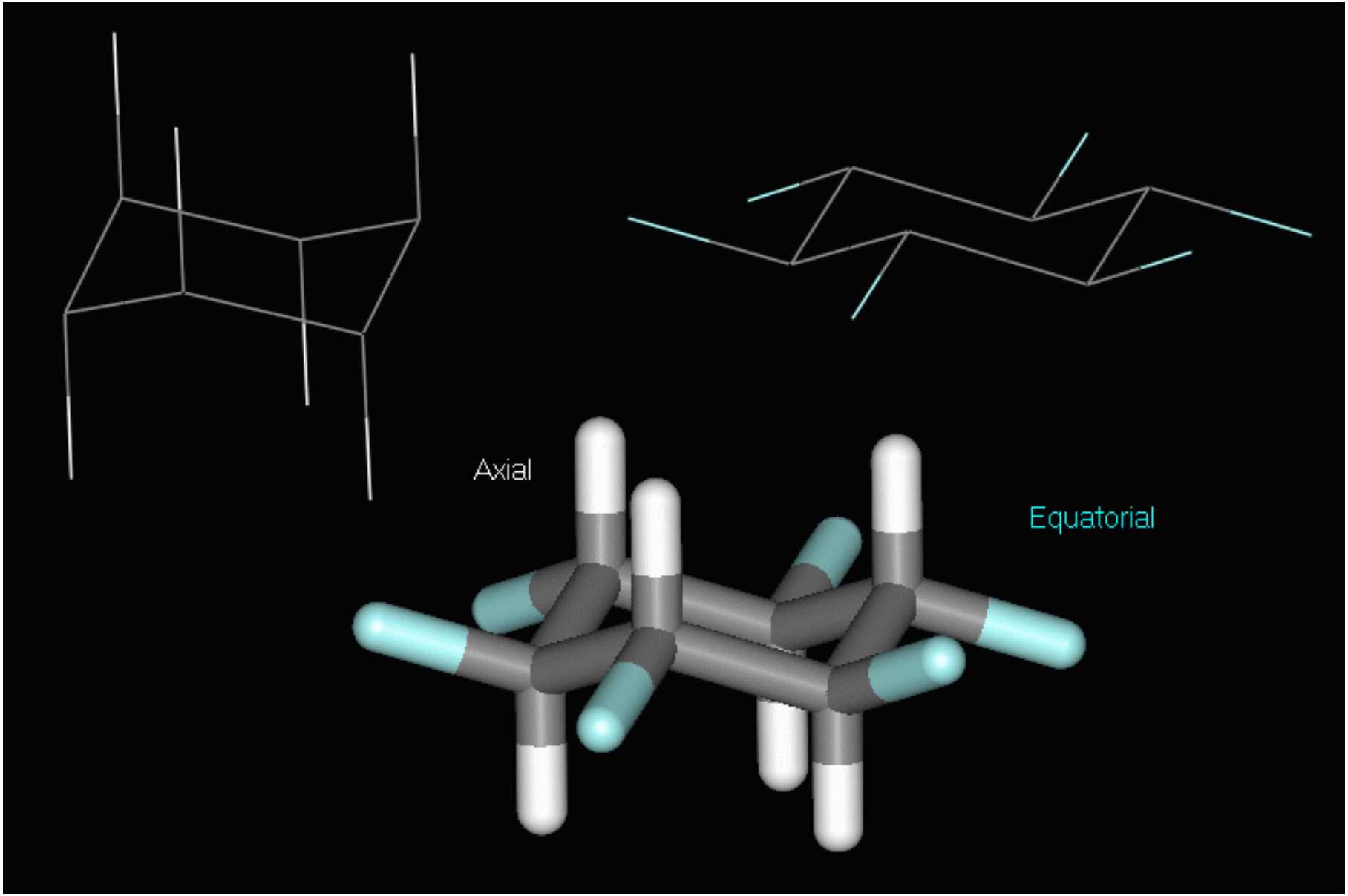




seen from the side



seen from above


Axial
Equatorial

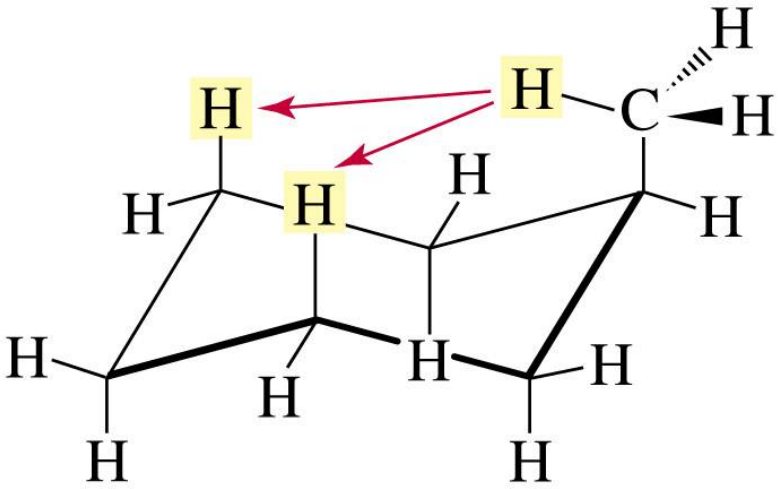
Dibuje el 1,2,3,4,5,6-hexametilciclohexano con todos los grupos metilo

(a) En posiciones axiales

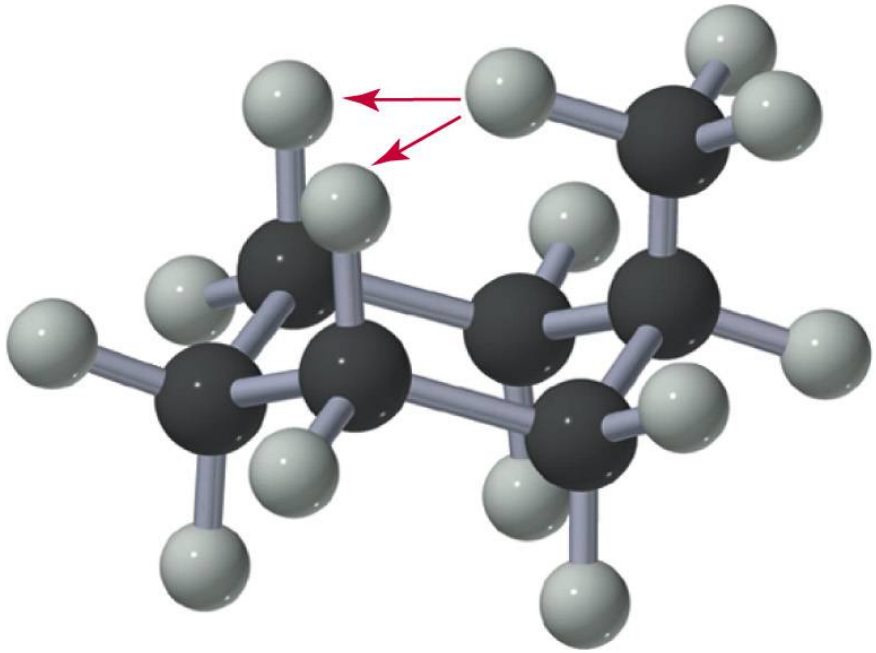
(b) En posiciones ecuatoriales

Conformación de ciclohexanos mono- y disustituidos

Metilciclohexano

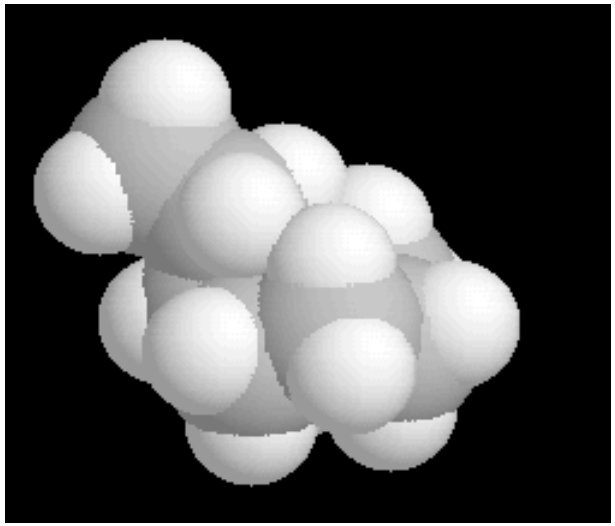


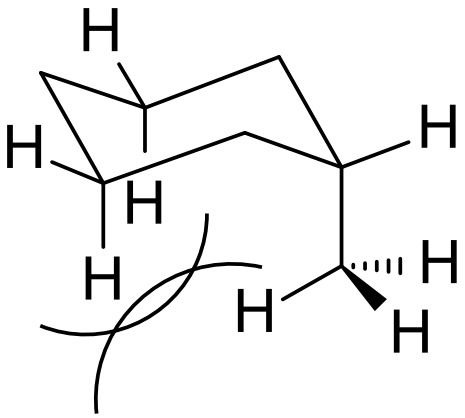
1,3-diaxial interactions



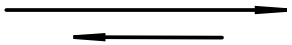
ball-and-stick model

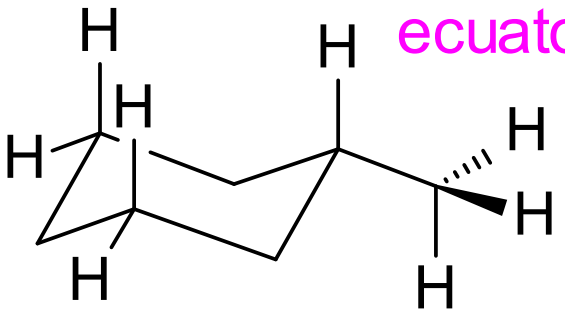
Axial Steric Interactions in Cyclohexanes





axial



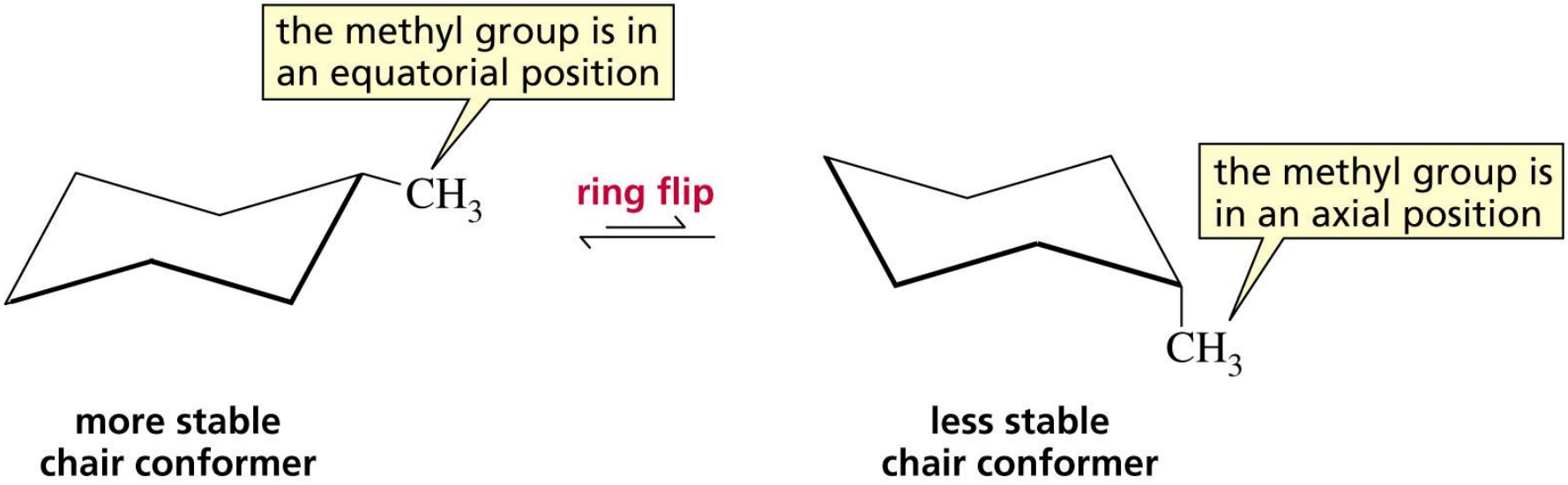


ecuatorial

Los sustituyentes axiales interfieren con los hidrógenos axiales de los carbonos 3 y 5.

¿Qué confórmero espera que prevalezca en el metilciclohexano a temperatura ambiente?

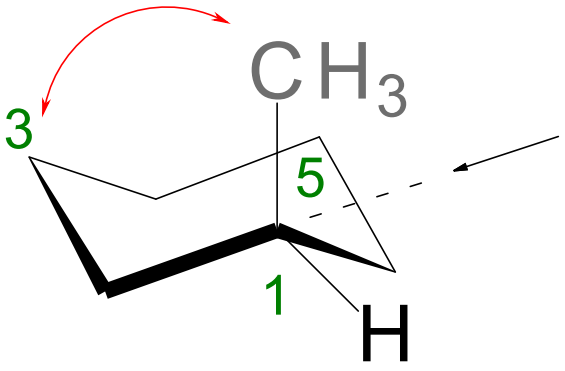
¿Podría estimar la diferencia en energía?



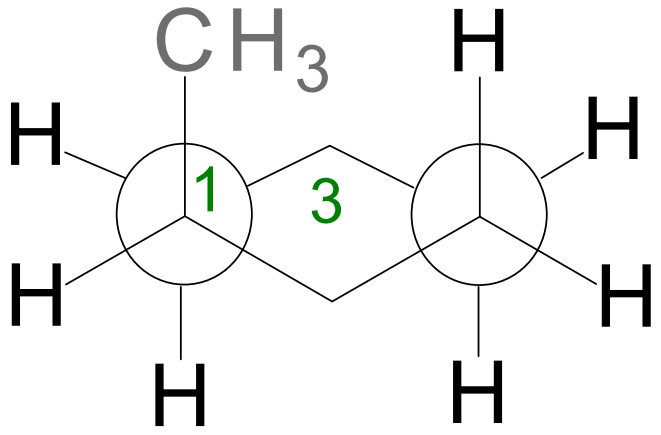
Favorecido por 1.8 kcal mol^{-1}
(7.53 kJ mol^{-1})

Cuando el metilo está en posición axial:

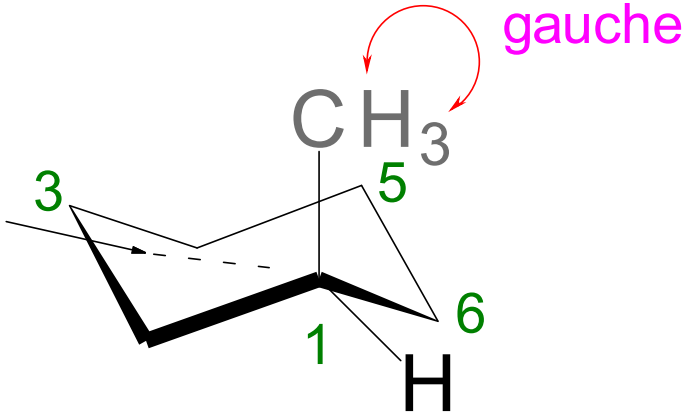
gauche



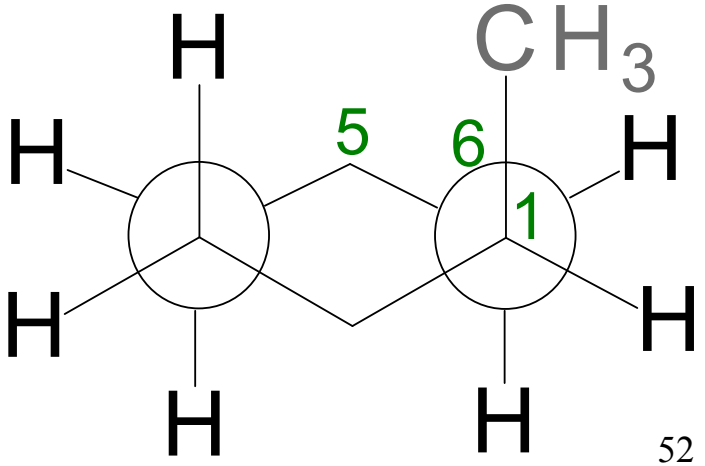
Dibuje la proyección de Newman correspondiente observando a través del enlace C1-C2.



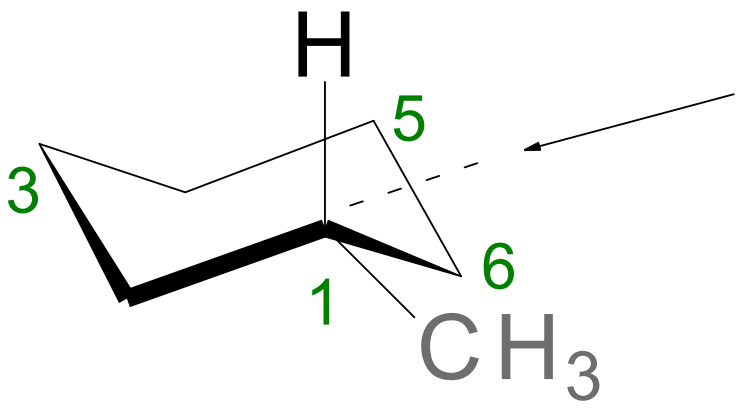
gauche

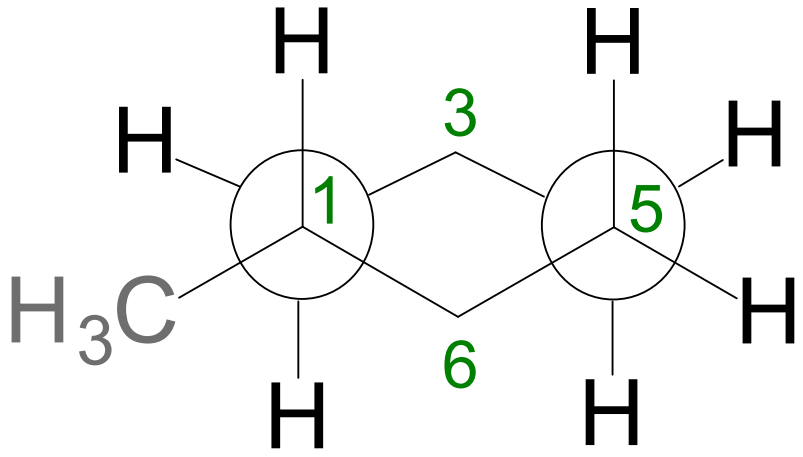


Dibuje la proyección de Newman correspondiente observando a través del enlace C1-C6.



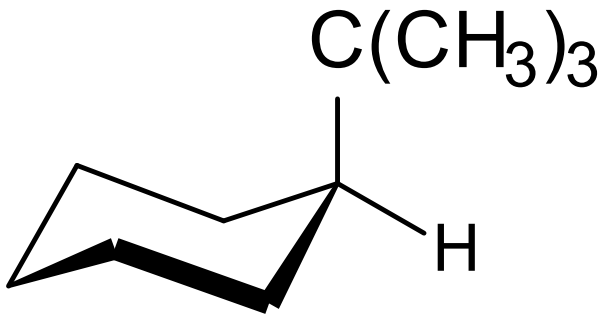
Cuando el metilo está en posición ecuatorial:

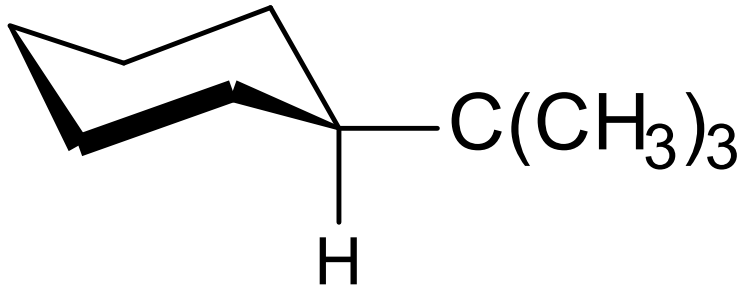




Dibuje la proyección de Newman a través del enlace C1-C6 en la conformación donde el metilo esté ecuatorial. Mostrando el metilo ecuatorial *anti* al C5.

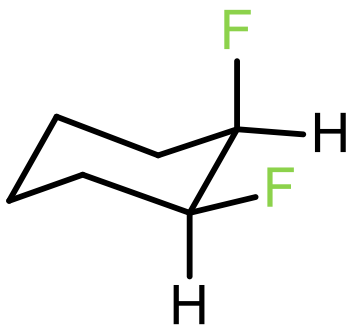
Prediga el confórmero que se encuentra en mayor proporción del siguiente ciclohexano sustituido y explique su respuesta



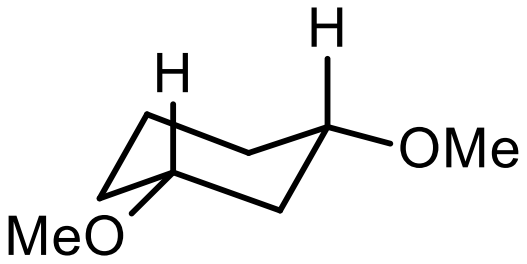


Ciclohexanos disustituidos

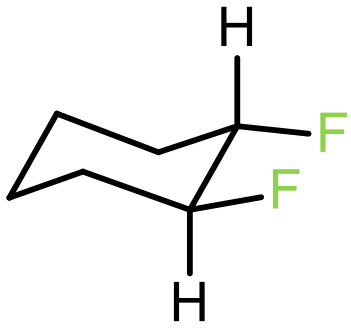
Considere las siguientes estructuras e indique si son *cis* o *trans*.



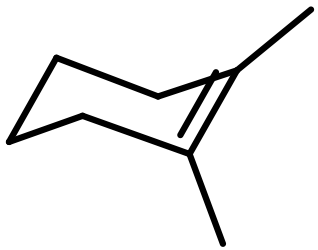
(**a**)



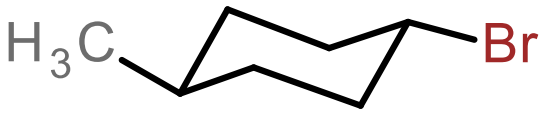
(**b**)



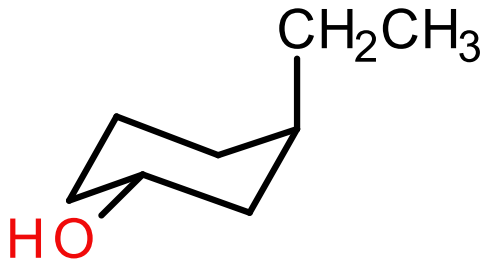
(**c**)



(**d**)

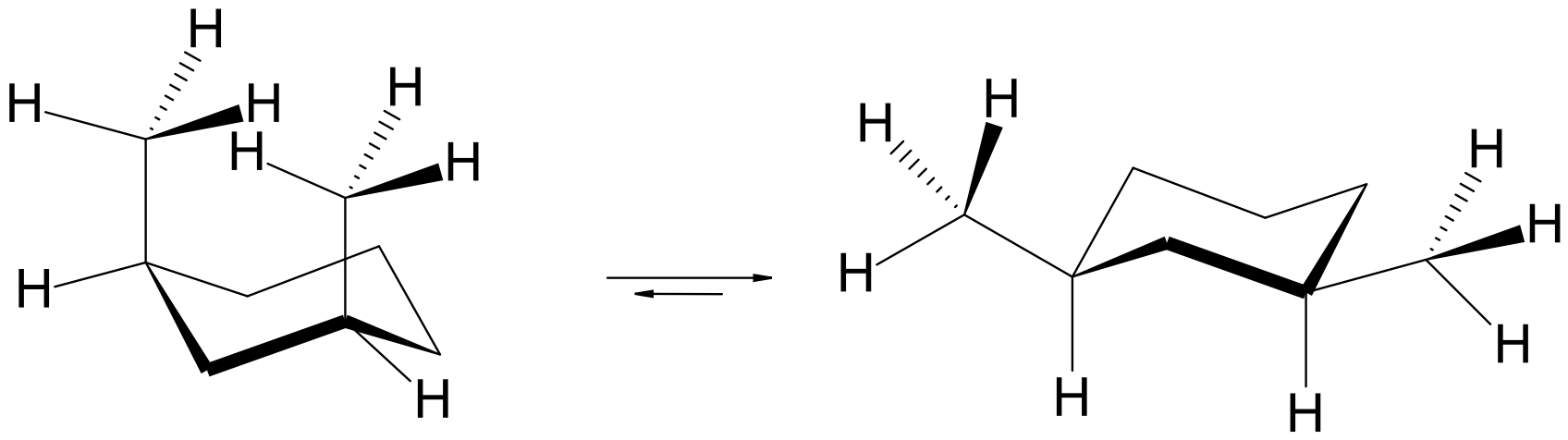


(**e**)



(**f**)

Dos conformaciones son posibles para el *cis*-1,3-dimetilciclohexano. Determine cuál es la más favorecida.



diaxial (a,a)

diecuatorial (e, e)

Dibuje las conformaciones del *trans*-1,3-dimetilciclohexano y determine cuál es la más estable.

Recuerde que los isómeros *cis* y *trans* no se pueden interconvertir, ellos no están en equilibrio

Ejercicios:

1. (**a**) Dibuje ambas conformaciones silla del *cis*-1,2-dimetilciclohexano, y determine cuál confórmero es el más estable.
(**b**) Repita esto para el isómero *trans*.
(**c**) Prediga cuál isómero (*cis* o *trans*) es más estable.

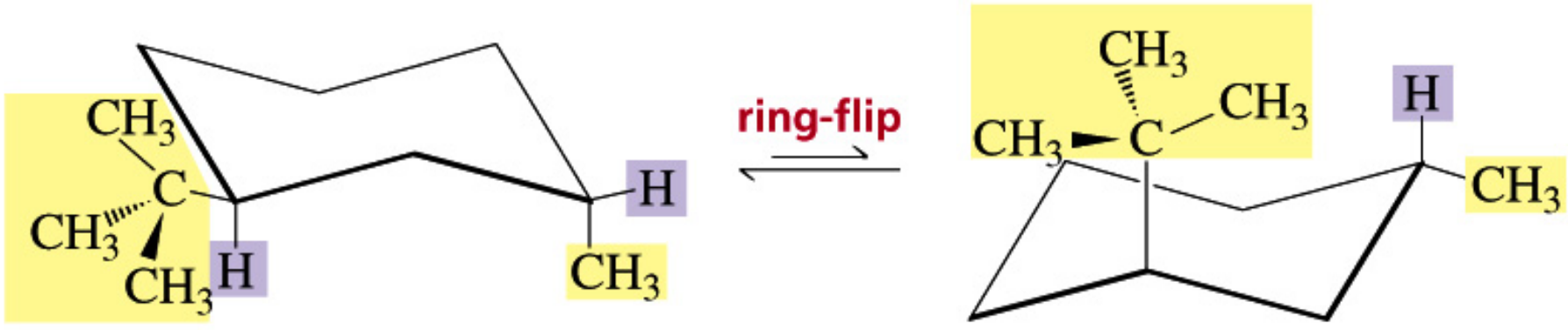
2. (**a**) Dibuje ambas conformaciones silla del *cis*-1,4-dimetilciclohexano, y determine cuál confórmero es el más estable.
(**b**) Repita esto para el isómero *trans*.
(**c**) Prediga cuál isómero (*cis* o *trans*) es más estable.

Sustituyentes de tamaños diferentes

Dibuje la conformación silla más estable del *trans*-1-etil-3-metilciclohexano.

Ejercicio:

1. Dibuje la conformación silla más estable del *cis*-1-etil-2-metilciclohexano.
2. Dibuje la conformación silla más estable del *cis*-1-etil-4-isopropilciclohexano

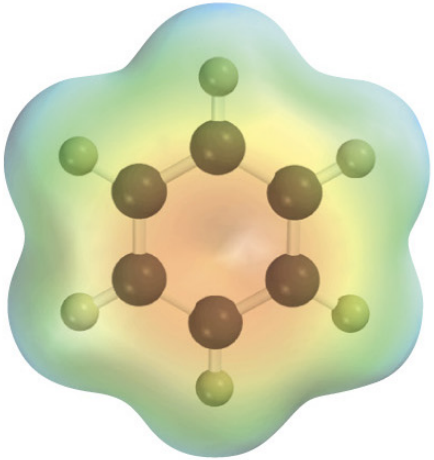


more stable

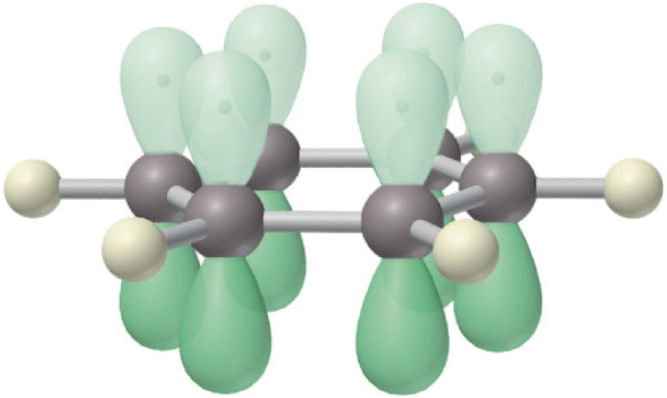
less stable

trans-1-*tert*-butyl-3-methylcyclohexane

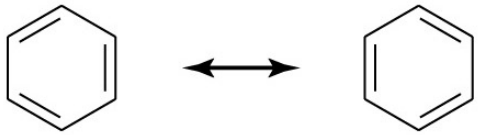
Benceno



(a)



(b)



(c)

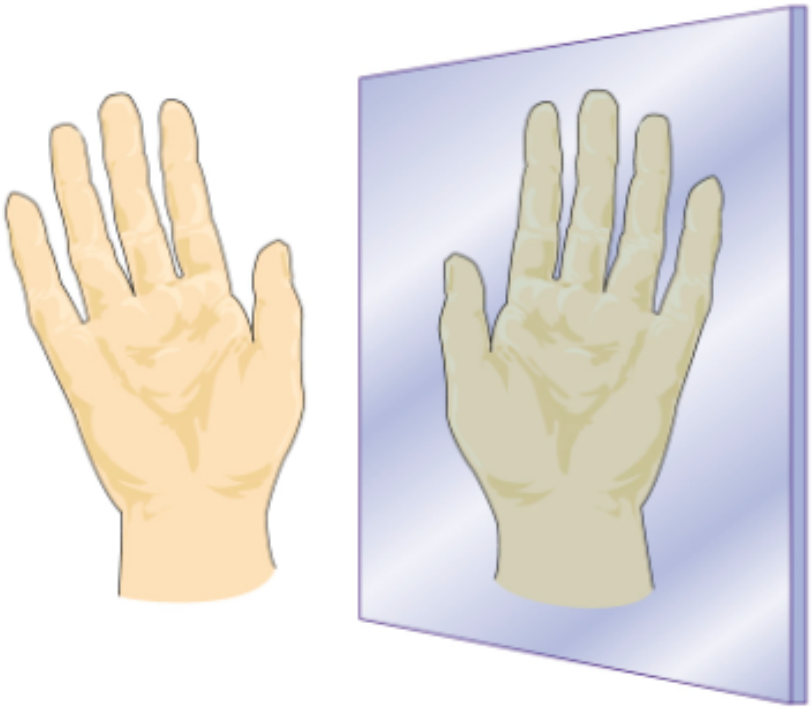
Quiralidad

Quiralidad de objetos y de moléculas

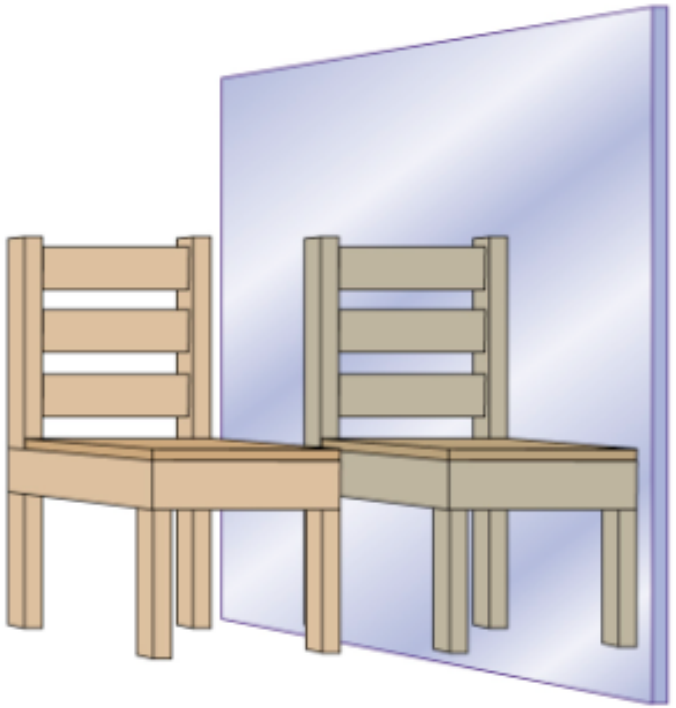
Lonicera sempervirens

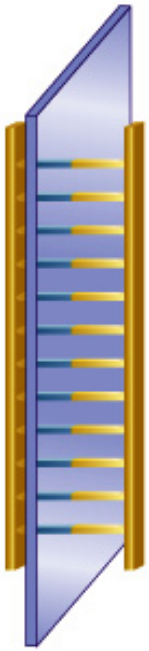
Quiral (del griego *cheir*, “mano”): cualquier objeto que no pueda ser superpuesto a su imagen especular.

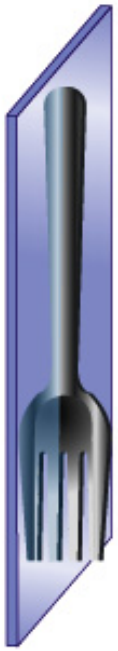
Original and mirror images of a hand and a chair

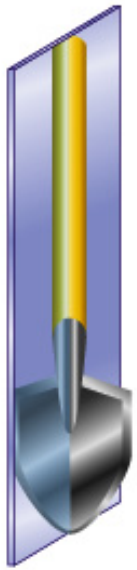


right hand left hand

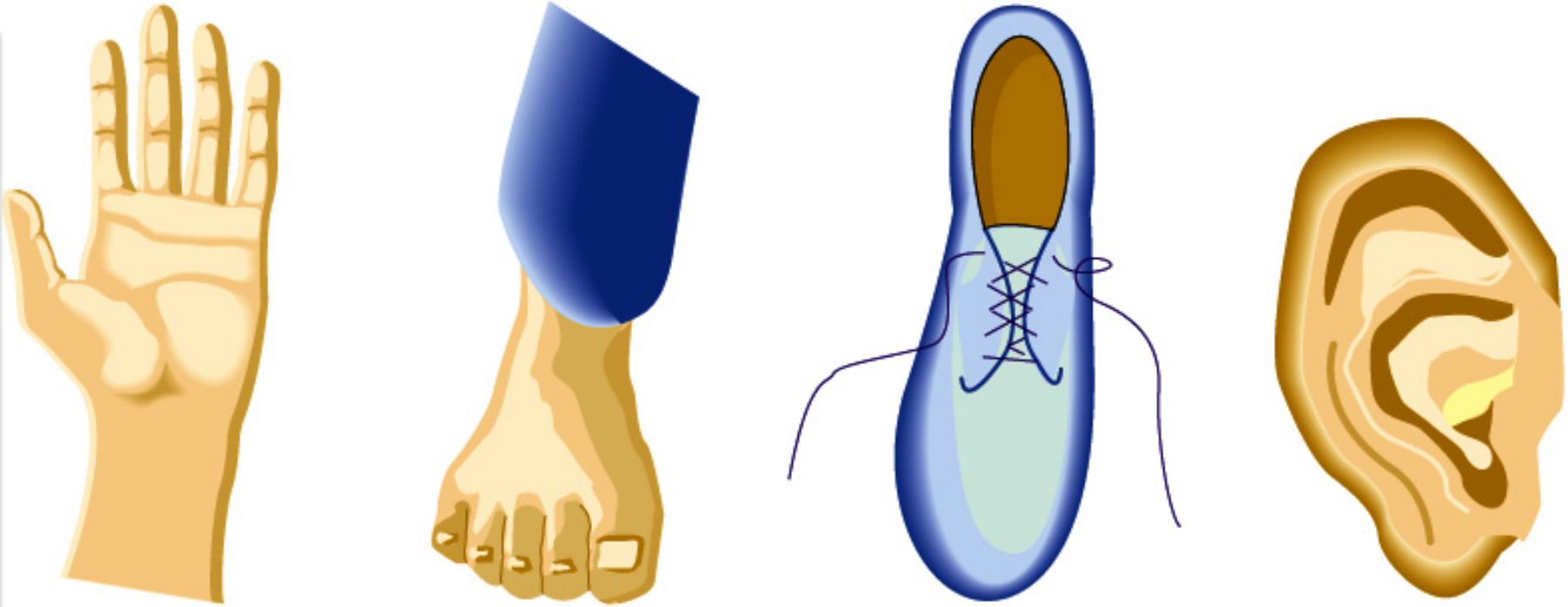




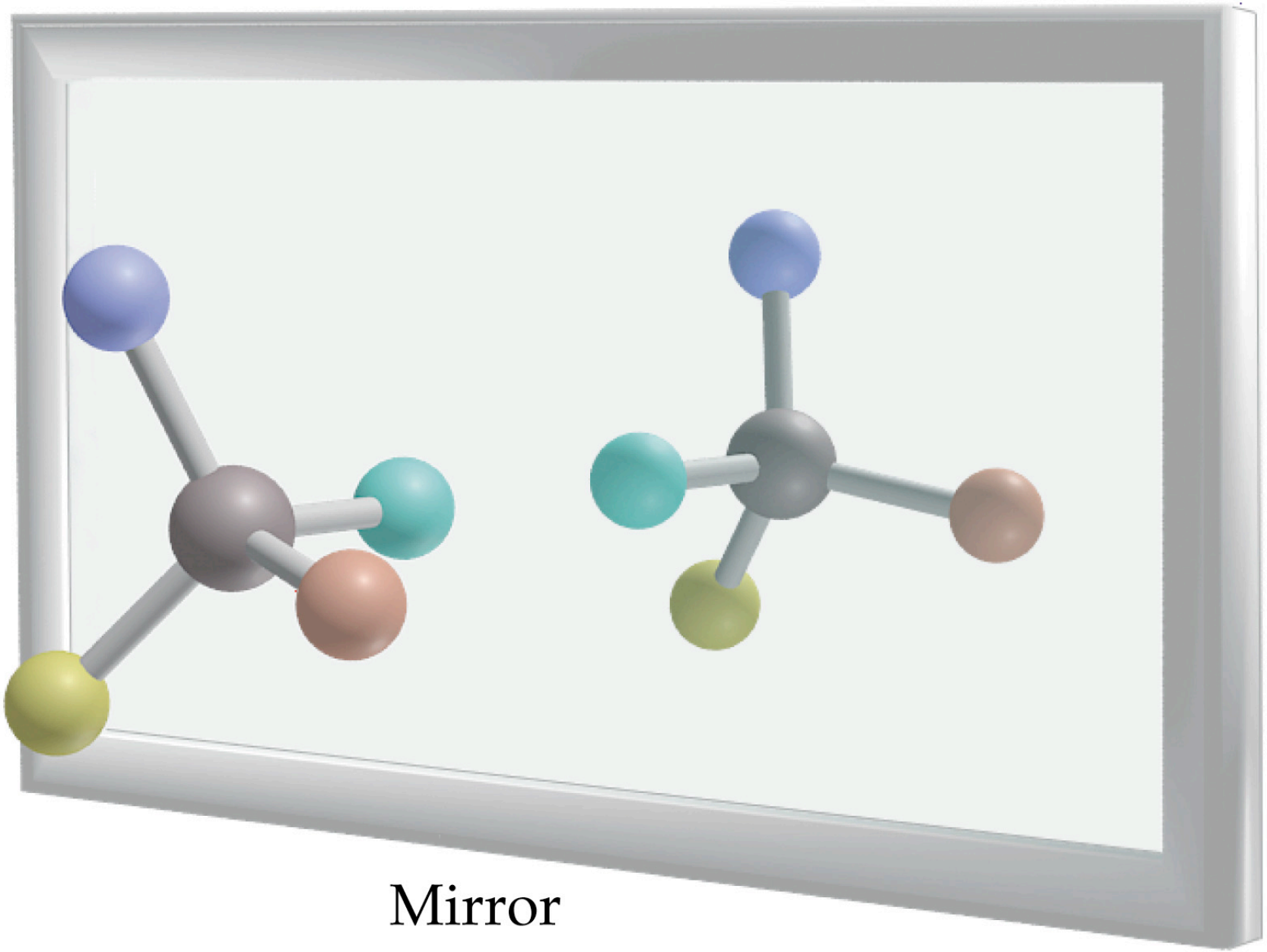




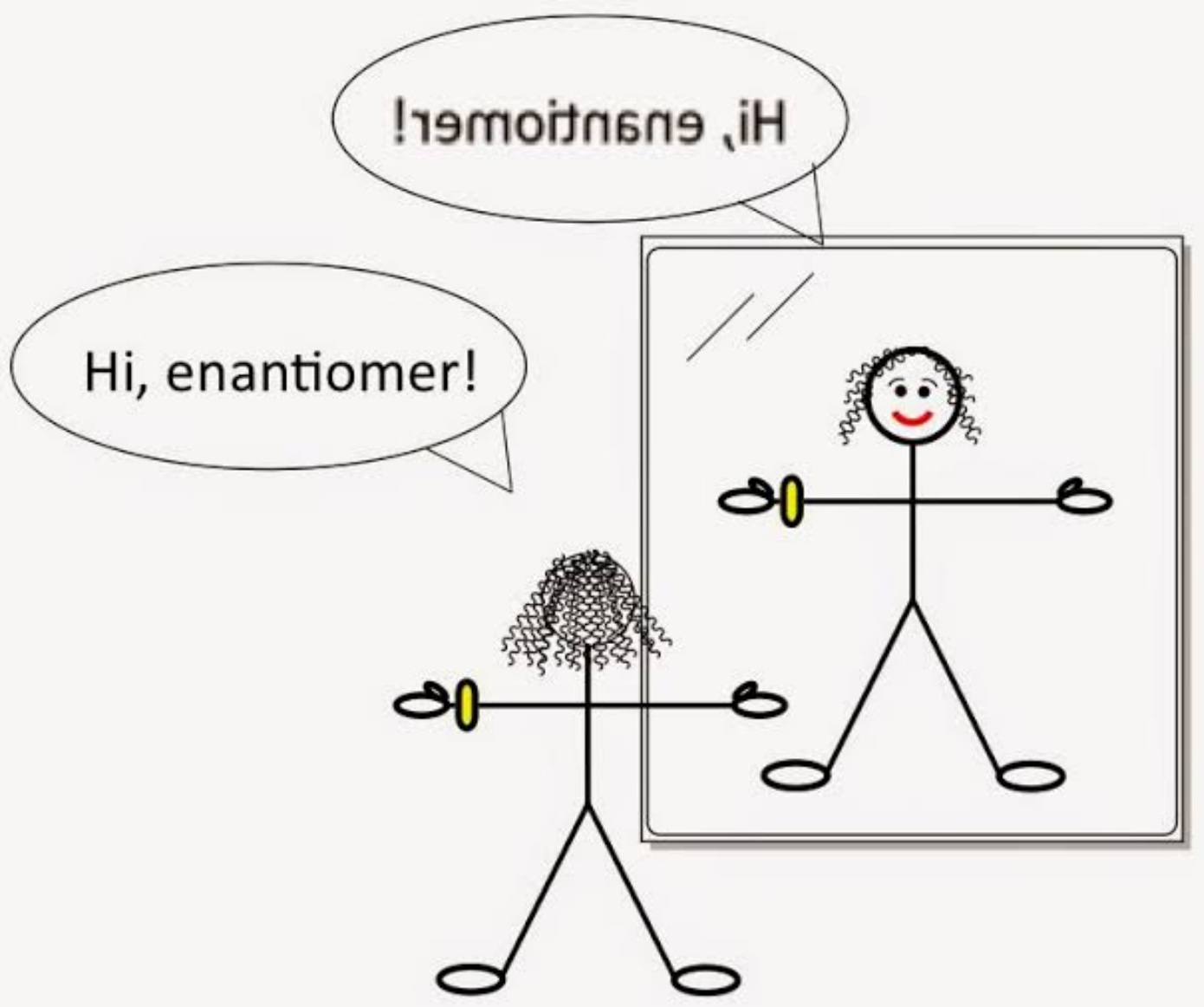
achiral objects

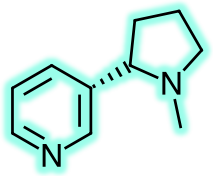


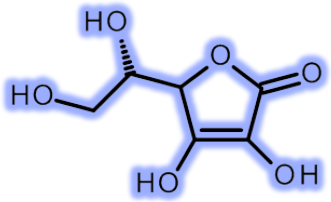
chiral objects

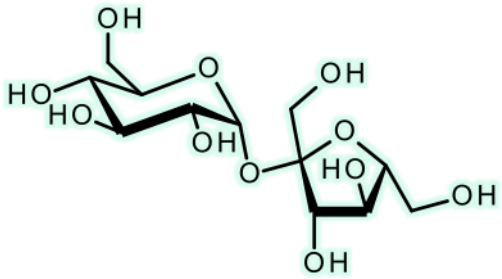


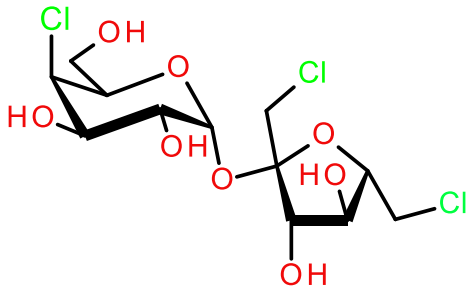
Mirror

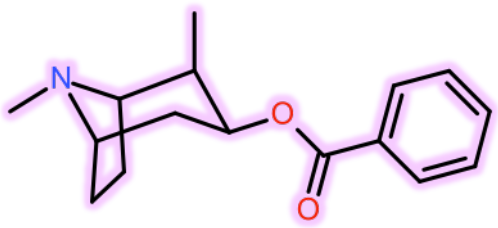

Hi, enantiomer!
Hi, enantiomer!

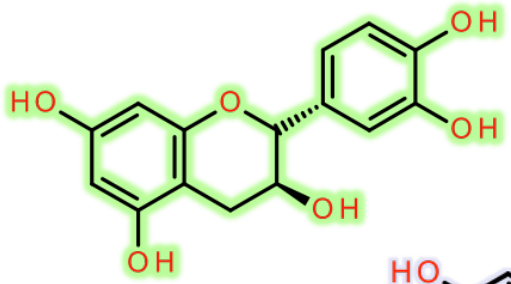

N
N

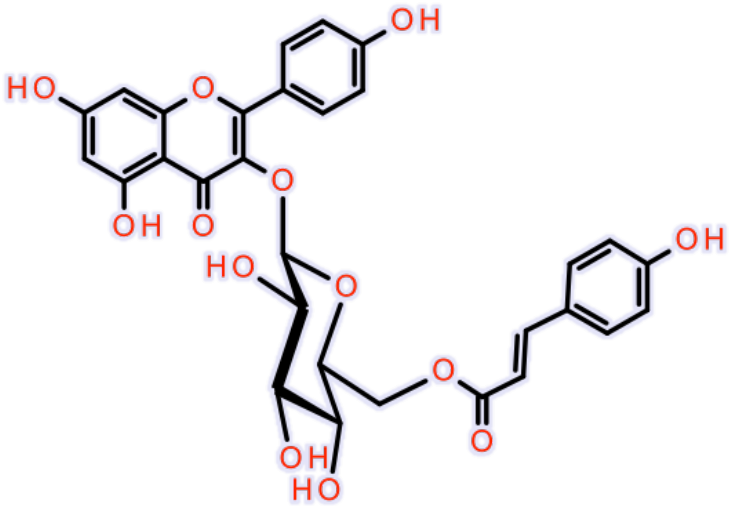

HO
HO
O
O
HO
OH

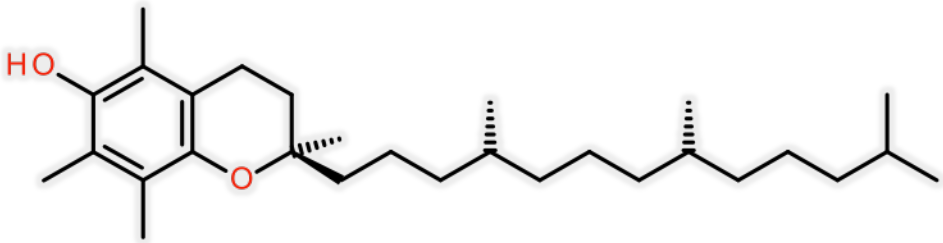

OH
HO
HO
O
OH
O
OH
HO
OH
OH


Cl
OH
HO
O
Cl
OH
O
HO
Cl
OH

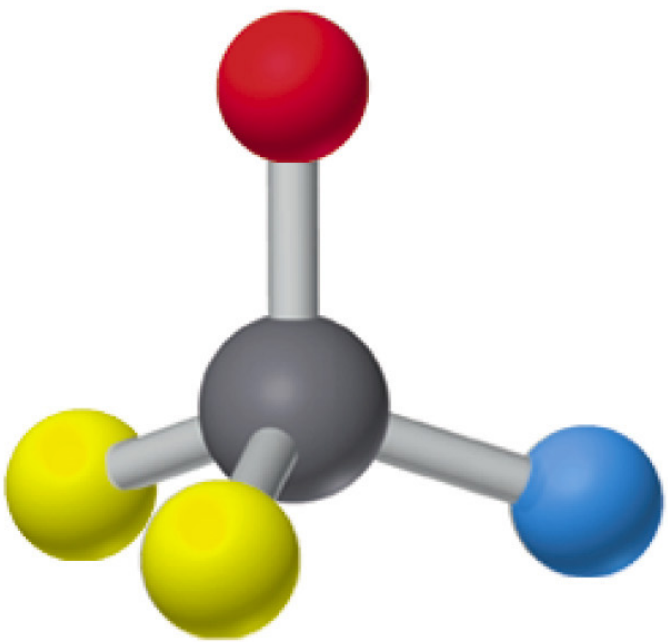

N
O
O


HO
O
OH
OH
OH
OH

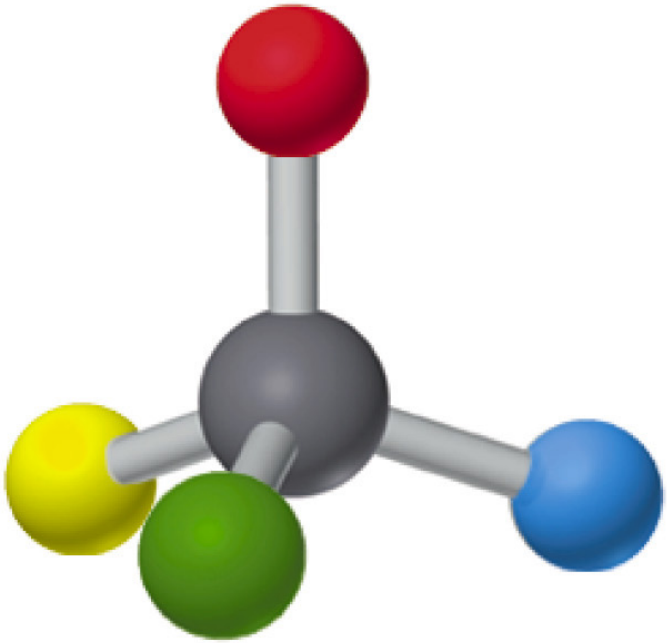

OH
HO
O
OH
O
O
HO
O
O
OH
OH
HO


HO
O

Centros de quiralidad, estereocentros



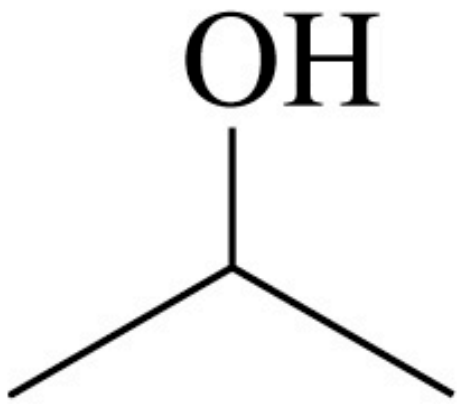
(a)



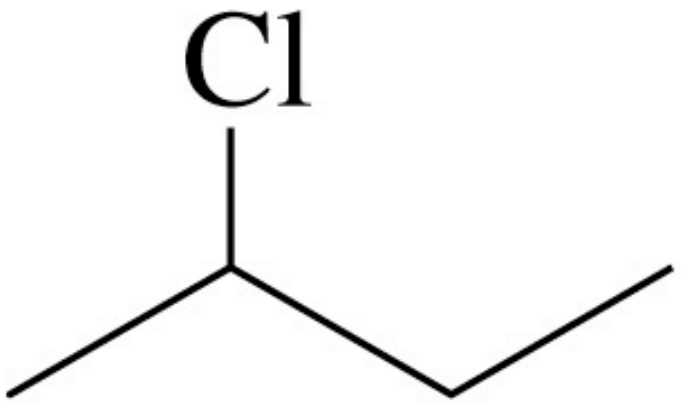
(b)

Identifique el carbono estereogénico señalándolo con un asterisco

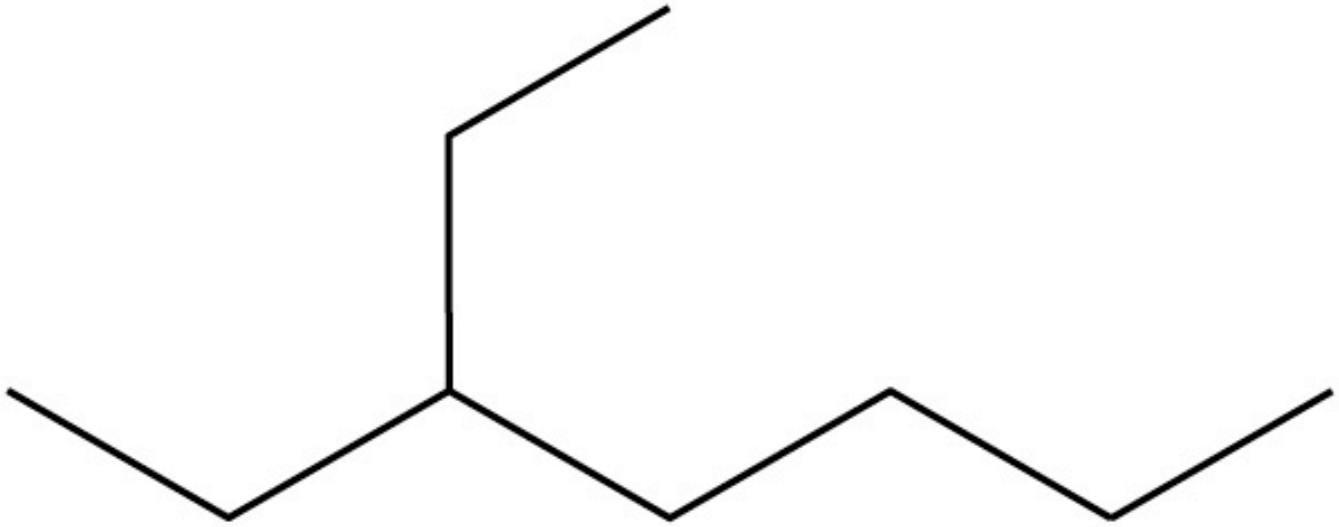
(a)



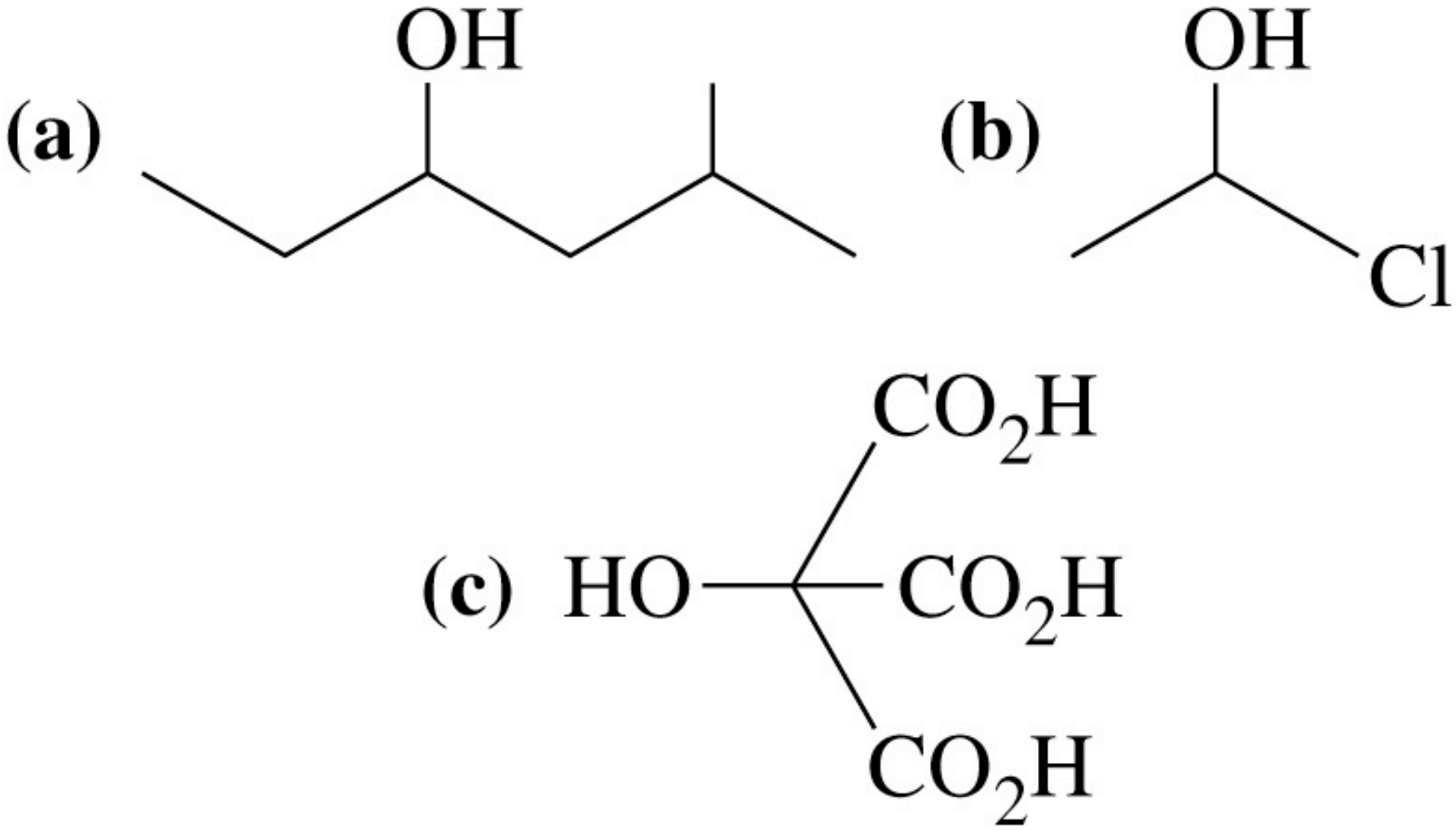
(b)



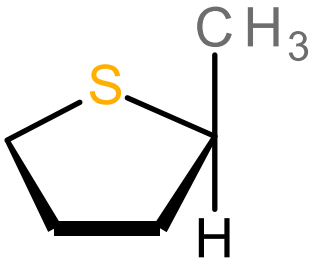
(c)

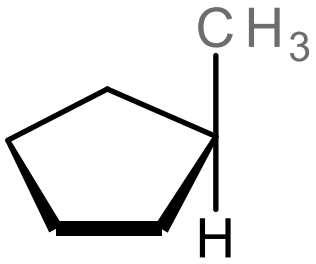


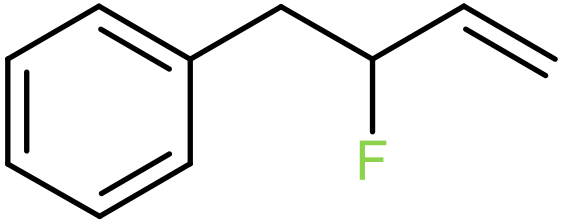
Identifique el carbono estereogénico señalándolo con un asterisco

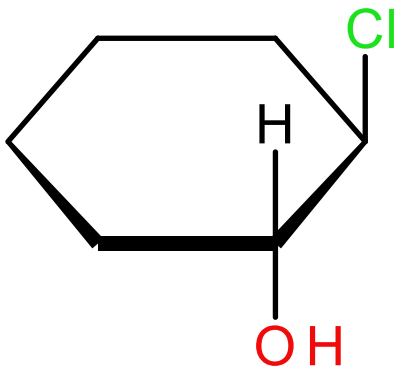


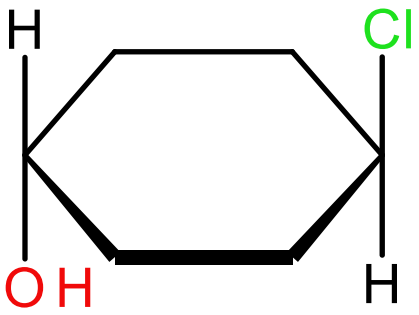
Identifique el(los) carbono(s) estereogénico(s) señalándolo(s) con un asterisco (*)

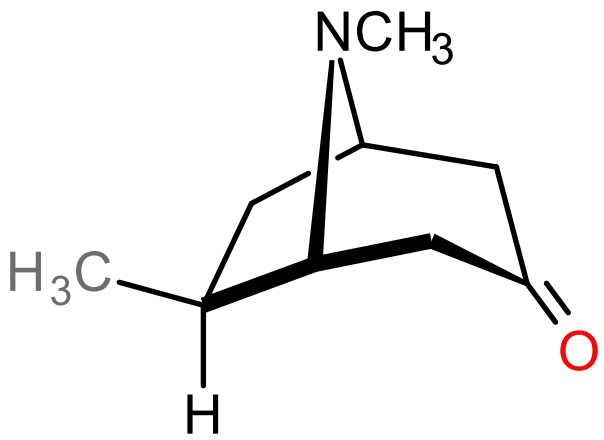




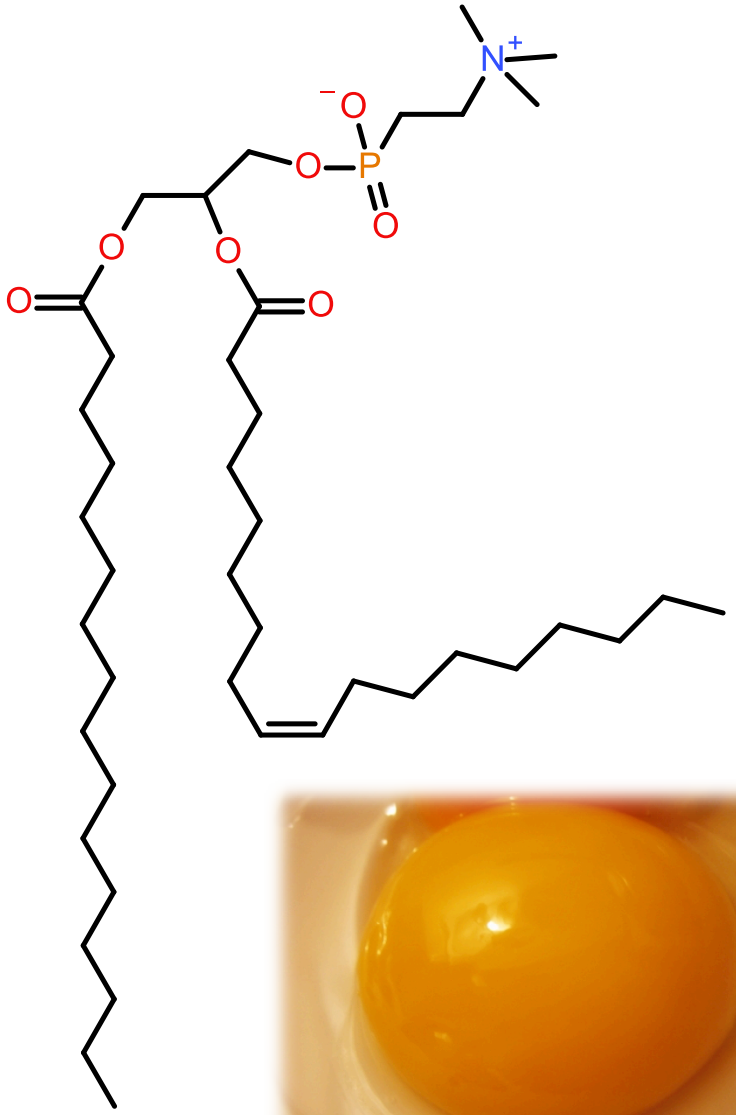




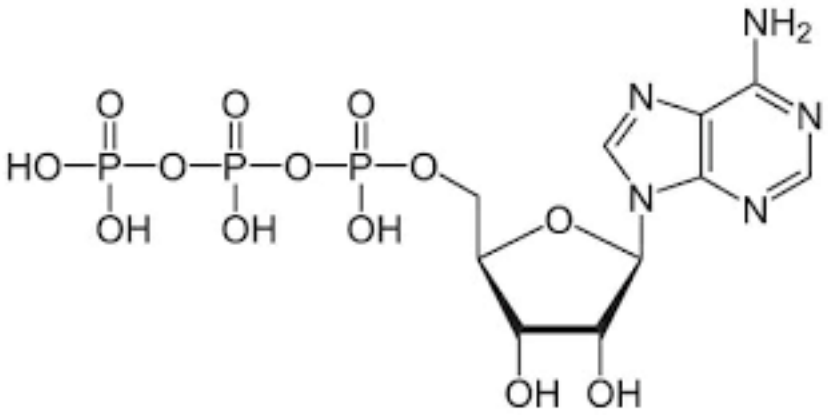




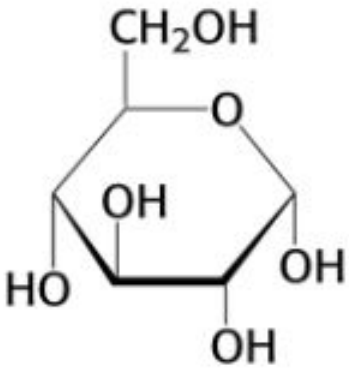
Identifique el carbono estereogénico señalándolo con un asterisco



lecithin

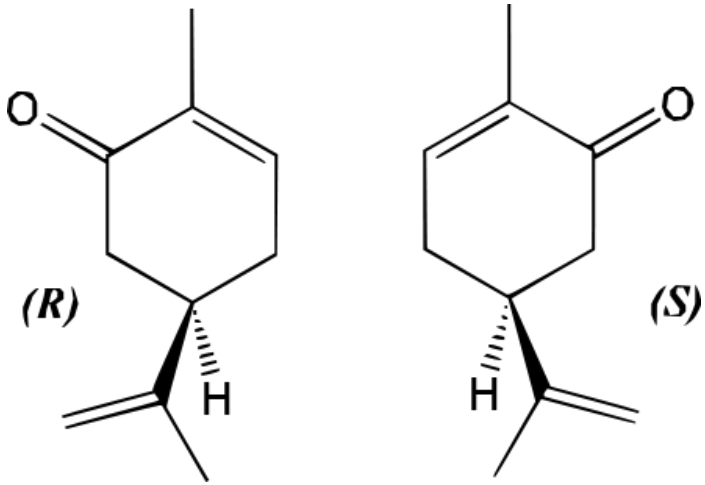


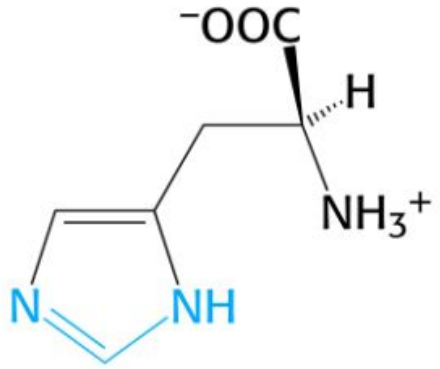
Adenosine triphosphate (ATP)



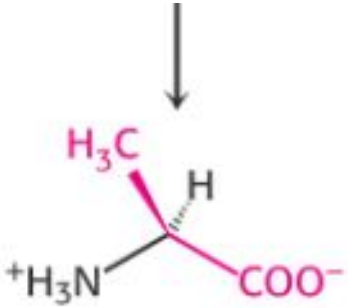
Glucose

carvone

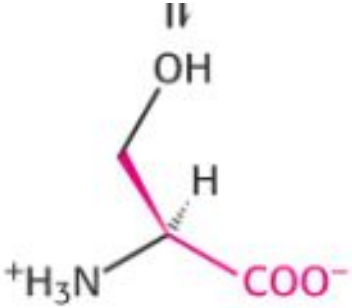




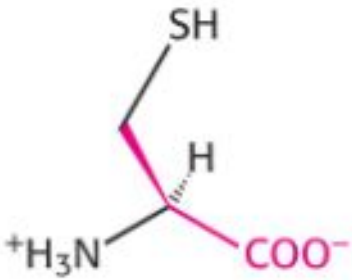
Histidine



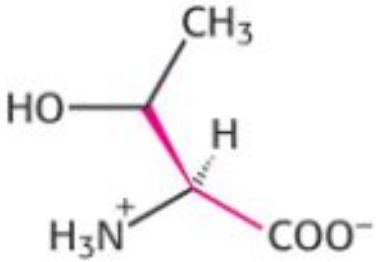
Alanine



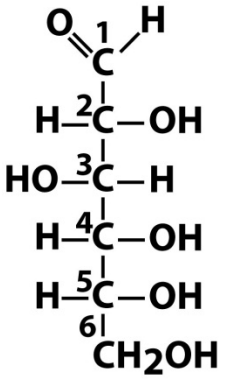
Serine



Cysteine

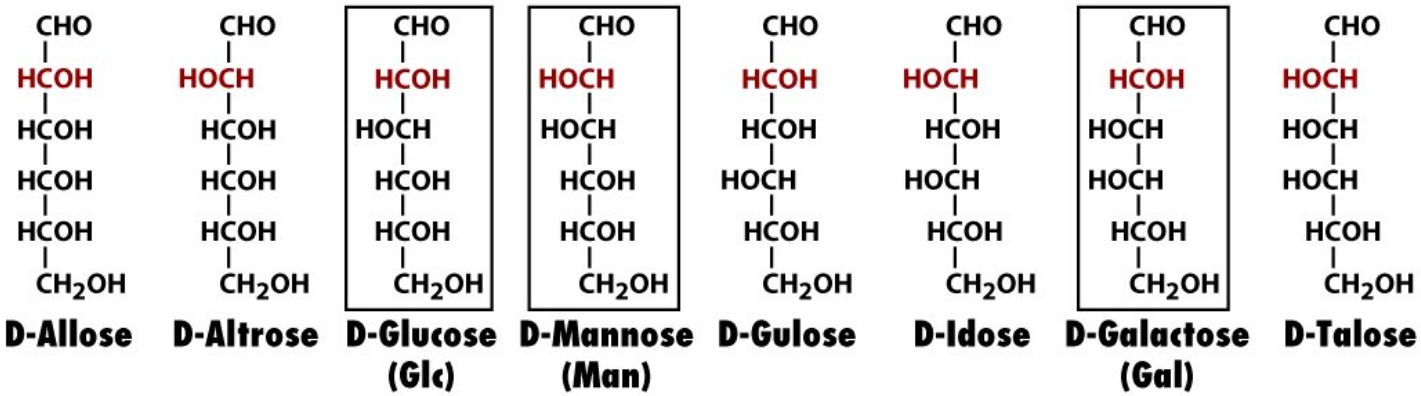


Threonine

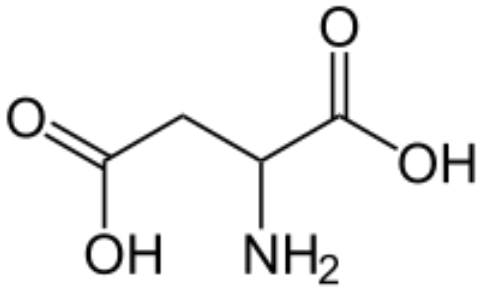


D-Glucose

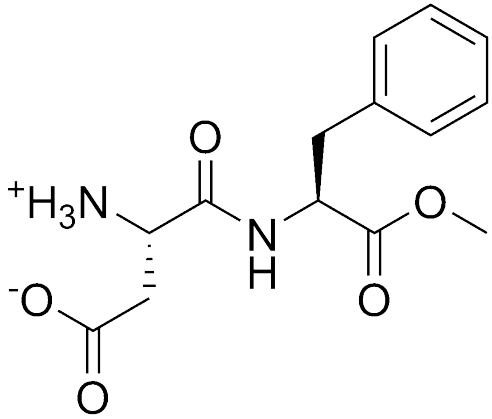
Unnumbered figure pg 207 Fundamentals of Biochem
© 2006 John Wiley & Sons



Aldohexoses

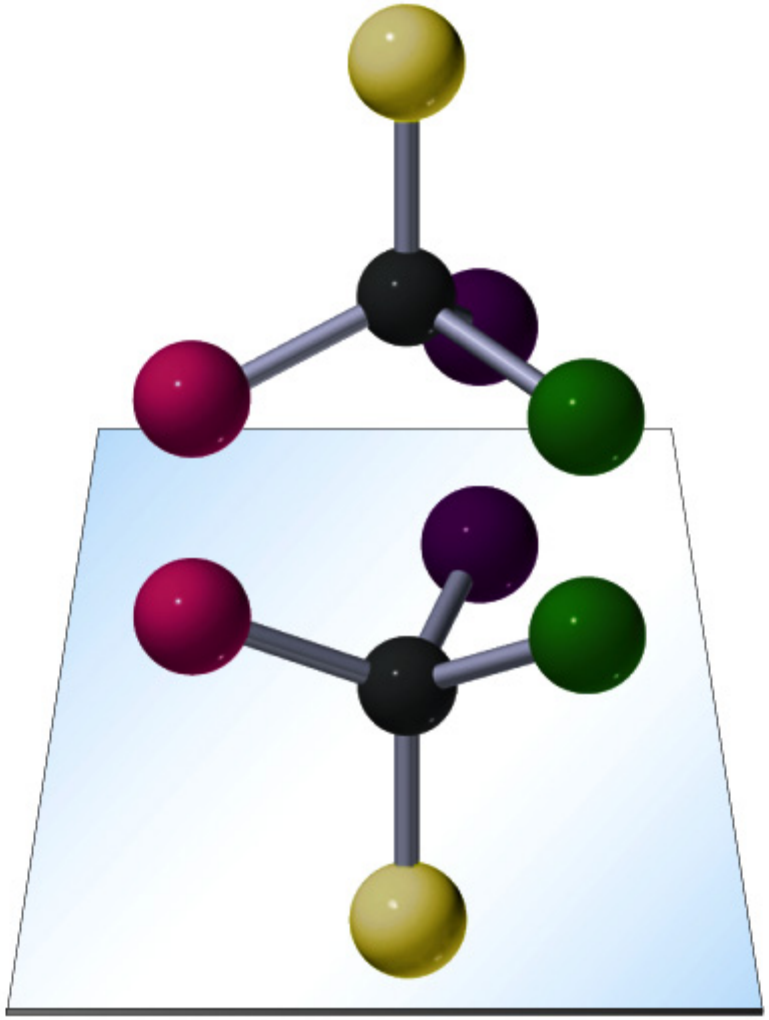


Ácido aspártico

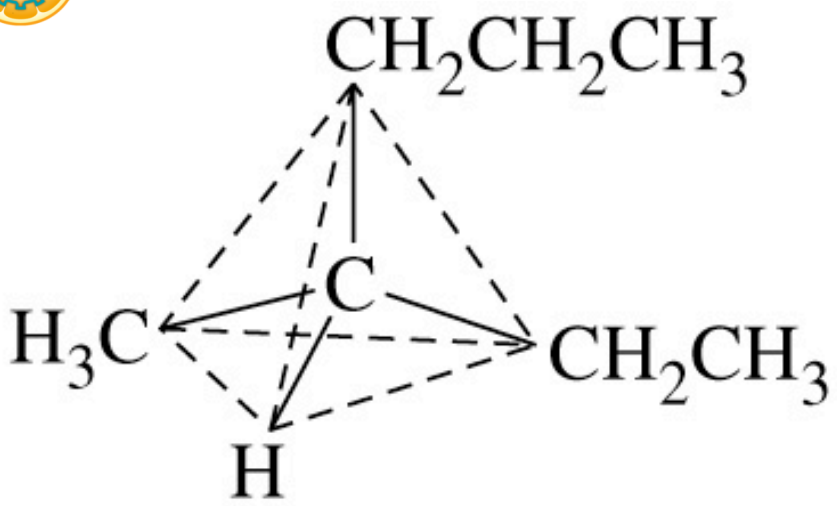


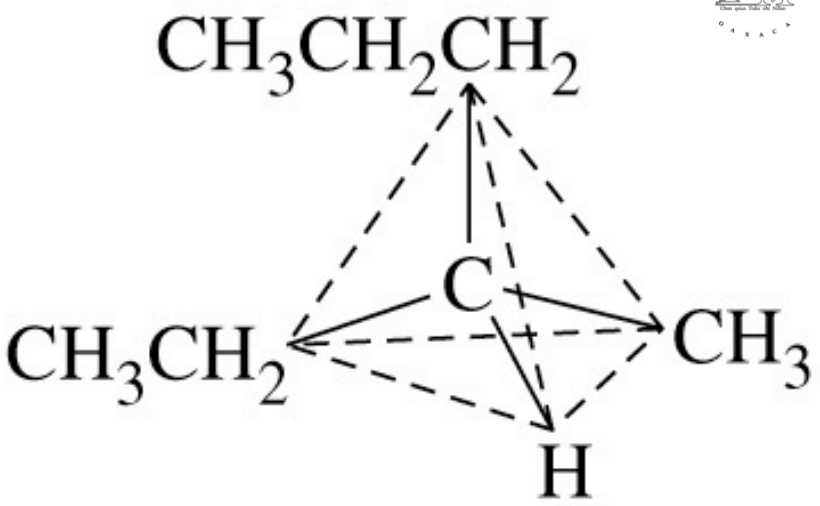
Aspartame

Enantiómeros

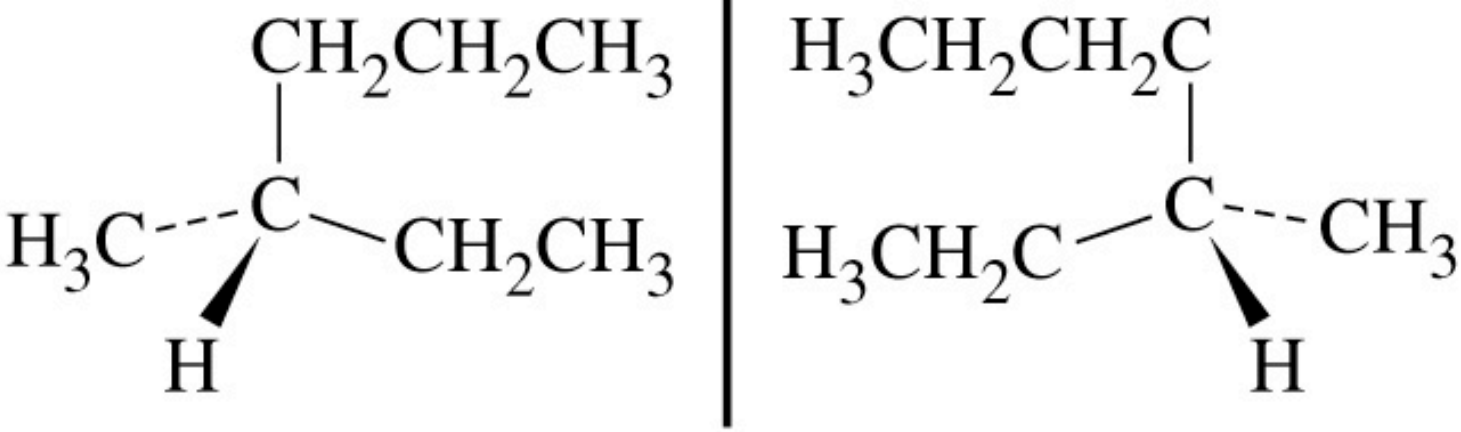


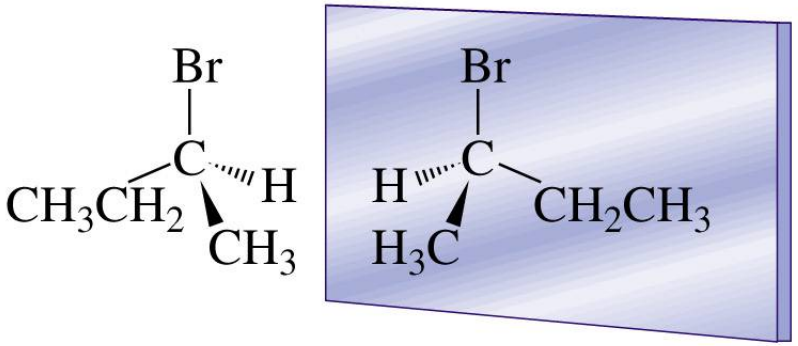
nonsuperimposable
mirror images


CH2CH2CH3
C
H3C
CH2CH3
H


CH3CH2CH2
C
CH3CH2
CH3
H

Mirror

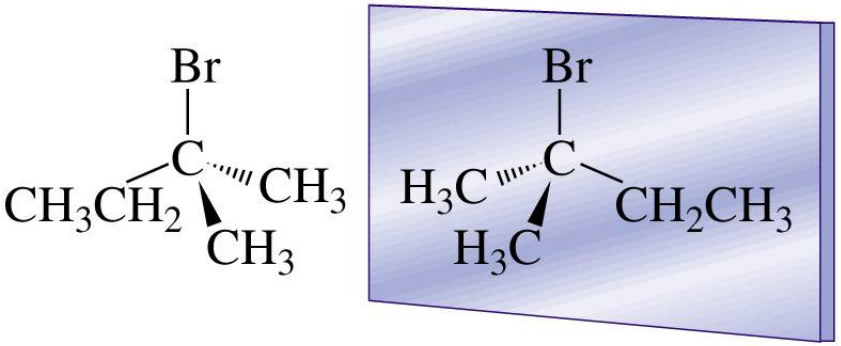

CH2CH2CH3
C
H3C
CH2CH3
H
H3CH2CH2C
C
H3CH2C
CH3
H



a chiral molecule

nonsuperimposable mirror image

enantiomers

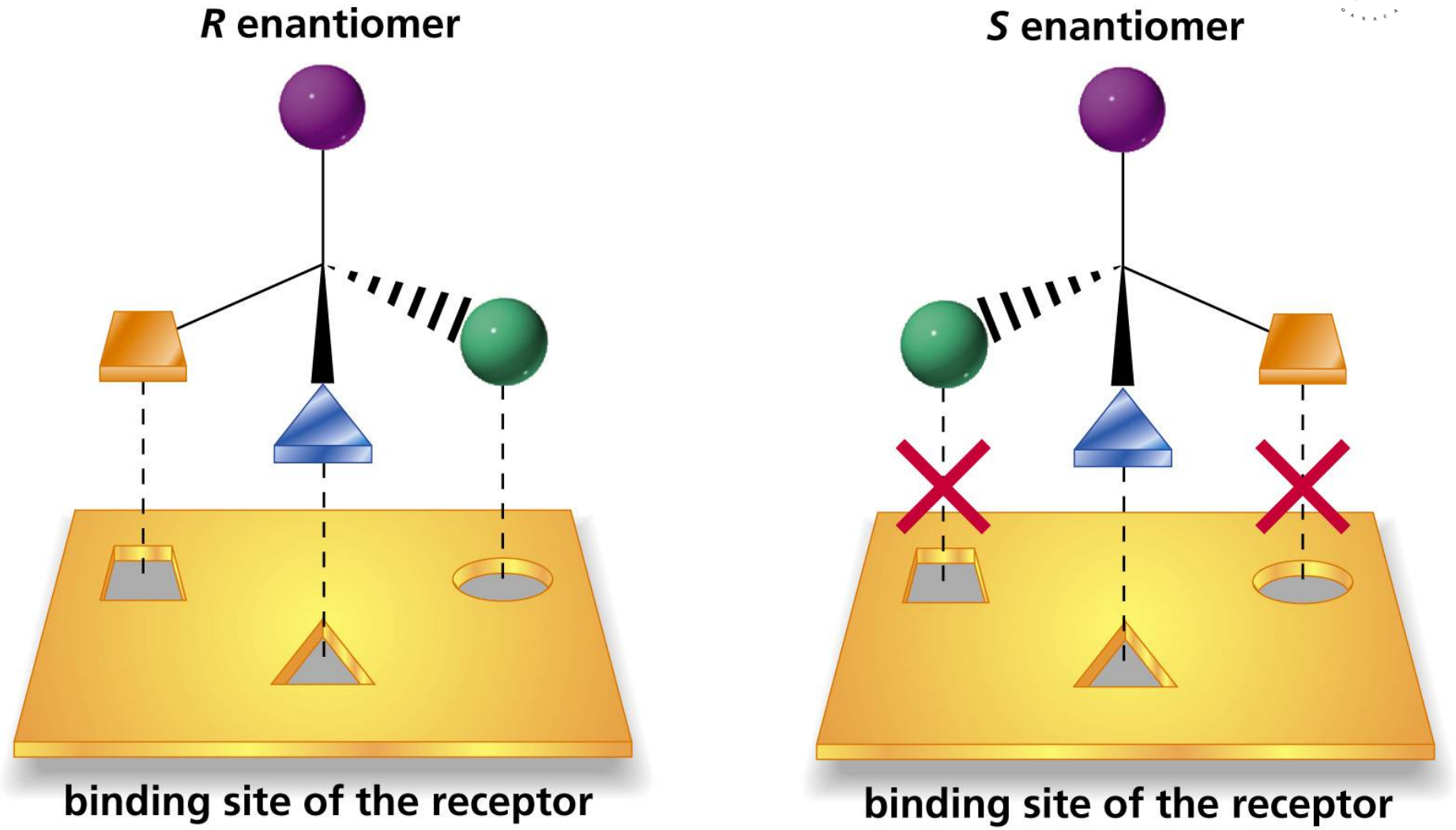


an achiral molecule

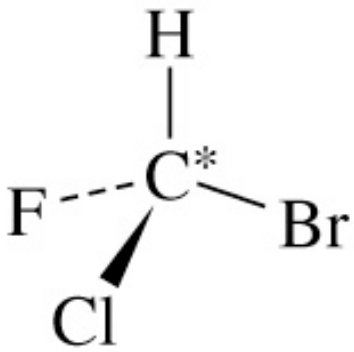
superimposable mirror image

identical molecules

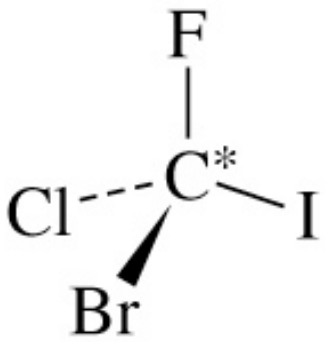
Receptor Binding Sites



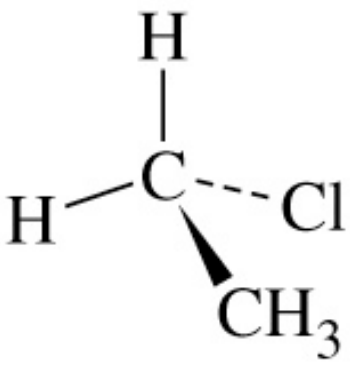
One enantiomer fits into the binding site and the other does not.



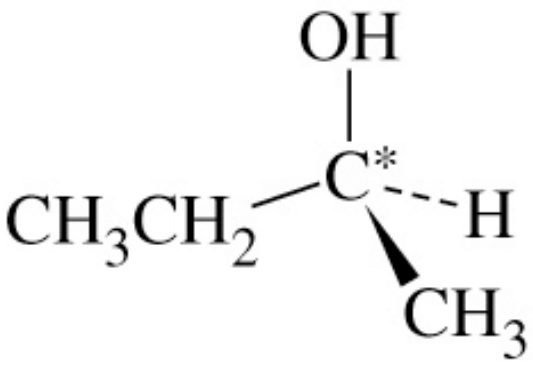
Chiral



Chiral

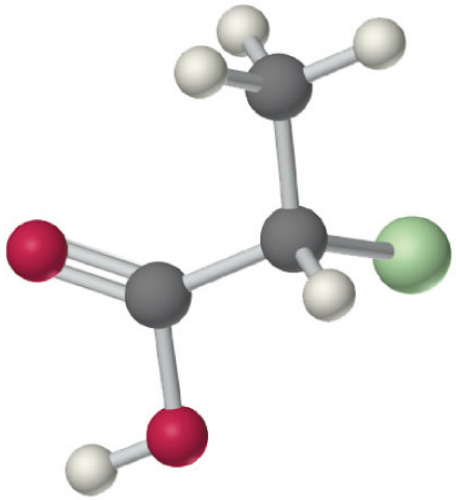


Achiral

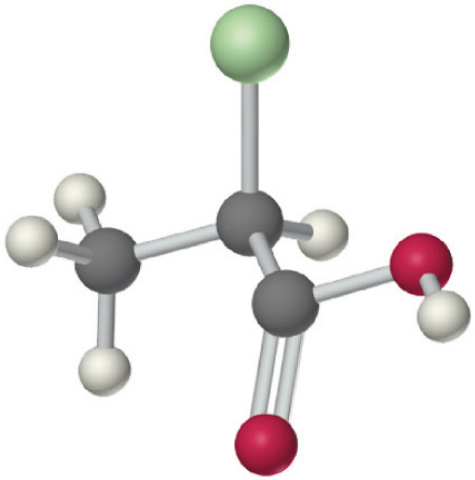


Chiral

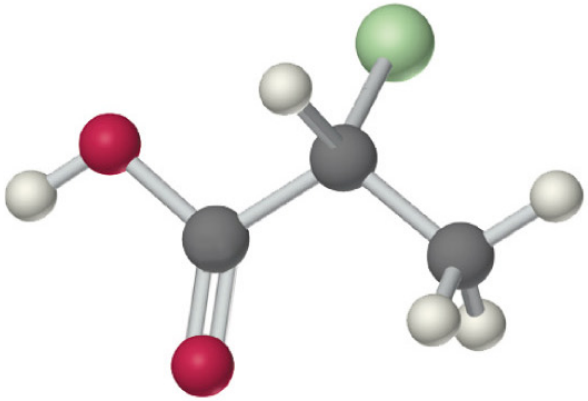
Two of the following three molecules are identical, and one is the enantiomer of the other two. Which one is the enantiomer?



(a)



(b)



(c)

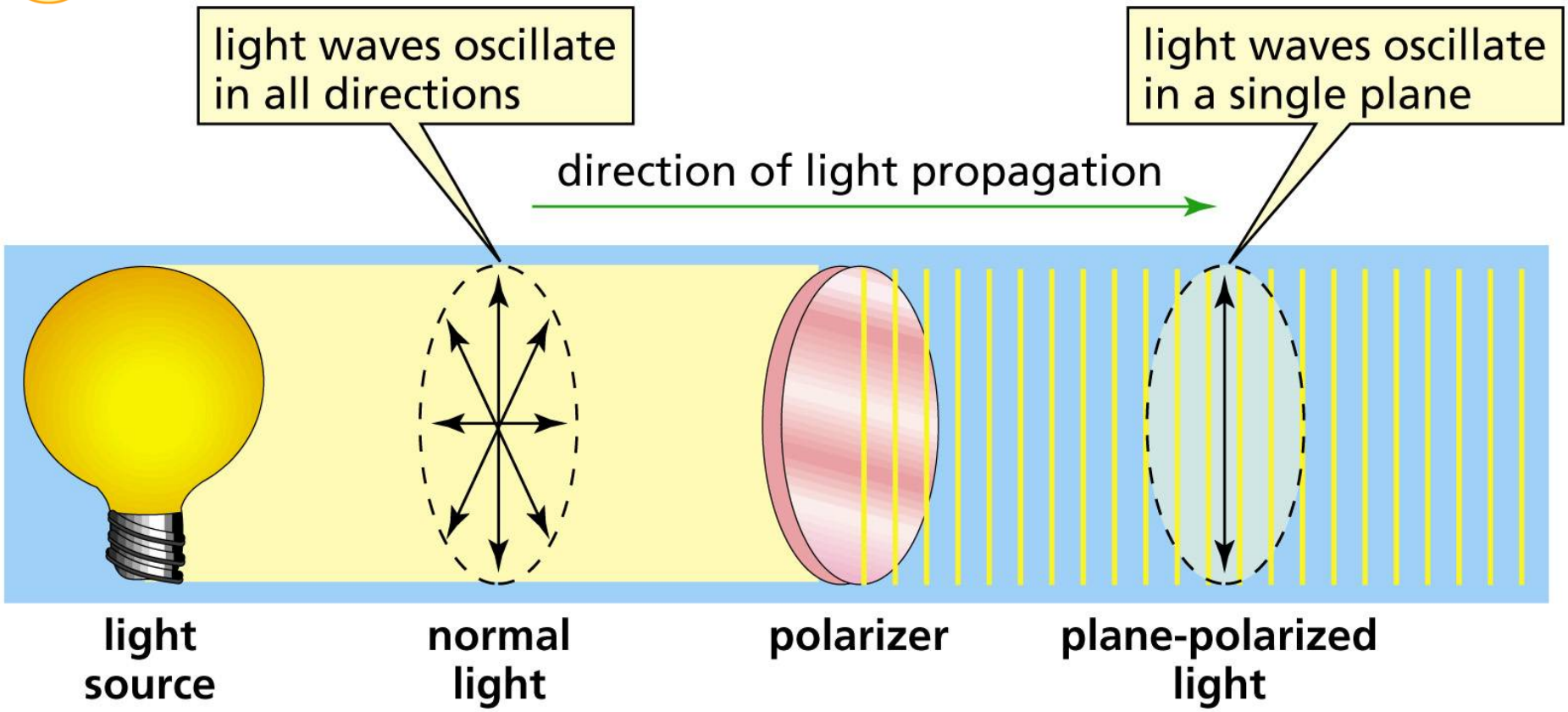
2-bromobutano...

	(*R*)-2-Bromobutano	(*S*)-2-Bromobutano
Punto de ebullición (°C)	91.2	91.2
Punto de fusión (°C)	-112	-112
Densidad	1.253	1.253

¿Cómo medimos entonces el enantiomerismo en el laboratorio?

Dirección en la cual rota el plano de la luz polarizada – Actividad óptica

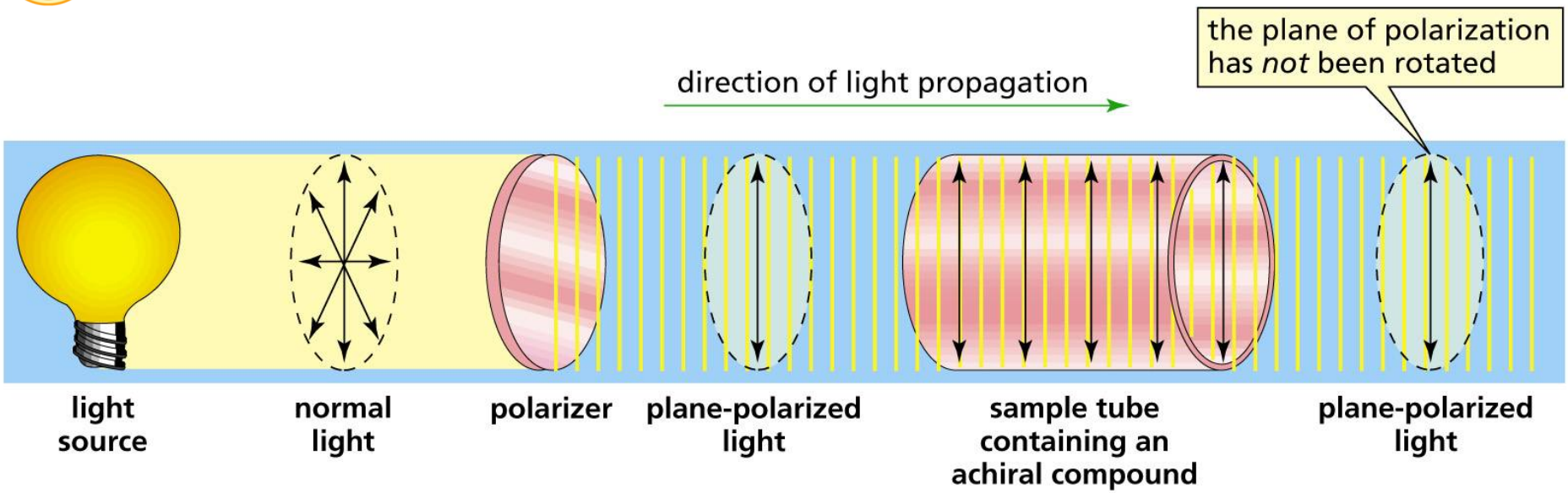
Plane-polarized Light



Plane-polarized light oscillates only in a single plane.

Plane-polarized light is produced by passing normal light through a polarizer such as a polarized lens or Nicol prism.

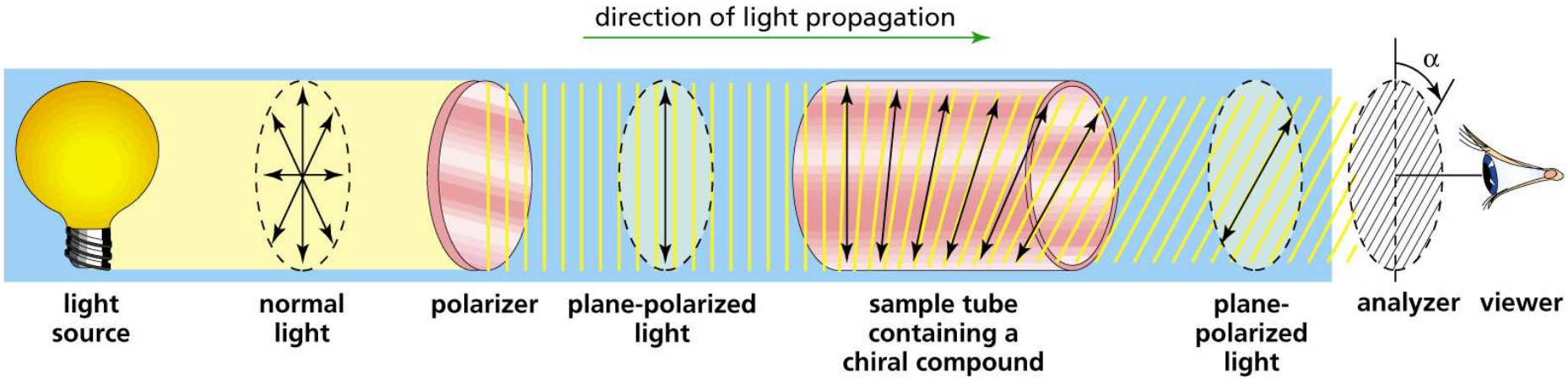
Achiral Compound in Plane-Polarized Light



An achiral compound does not rotate the plane of polarized light. It is optically inactive.

When plane-polarized light passes through a solution of achiral molecules, the light emerges from the solution with its direction of polarization unchanged, because there is no asymmetry in the molecules.

Chiral Compound in Plane-Polarized Light



A chiral compound rotates the plane of polarized light in either a clockwise or counterclockwise direction.

If one enantiomer rotates the plane of polarized light in a clockwise direction, its mirror image will rotate the plane of polarized light by an equal amount but in the opposite direction.

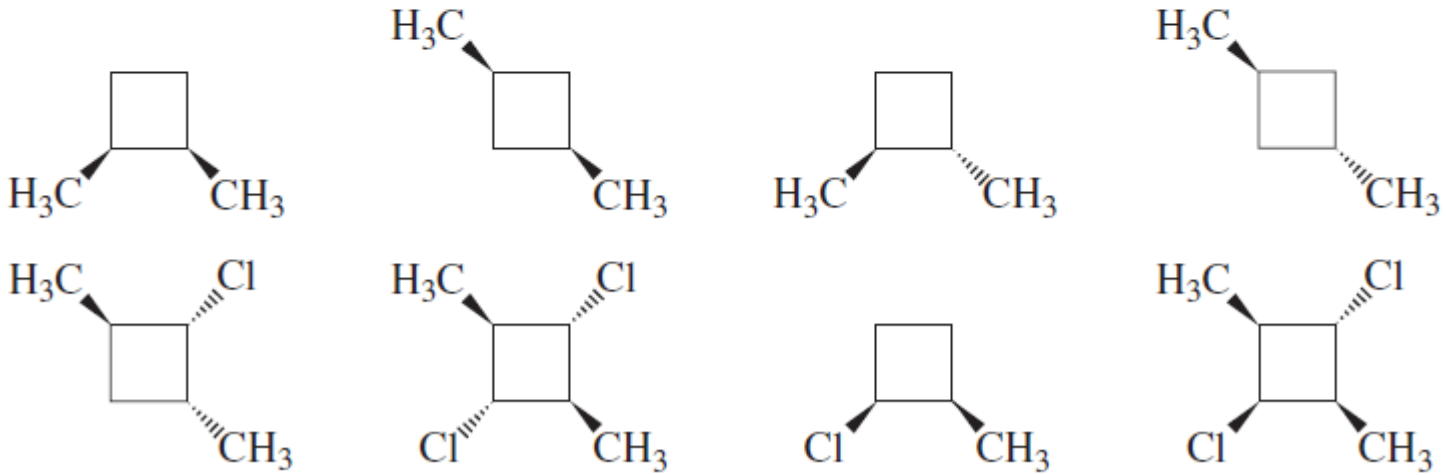
PROBLEM 26◆

Which of the following compounds has a stereoisomer that is a meso compound?

a. 2,4-dibromohexane
b. 2,4-dibromopentane
c. 2,4-dimethylpentane
d. 1,3-dichlorocyclohexane
e. 1,4-dichlorocyclohexane
f. 1,2-dichlorocyclobutane

PROBLEM 27 SOLVED

Which of the following are chiral?



PROBLEM 36◆

What is the absolute configuration of the following?

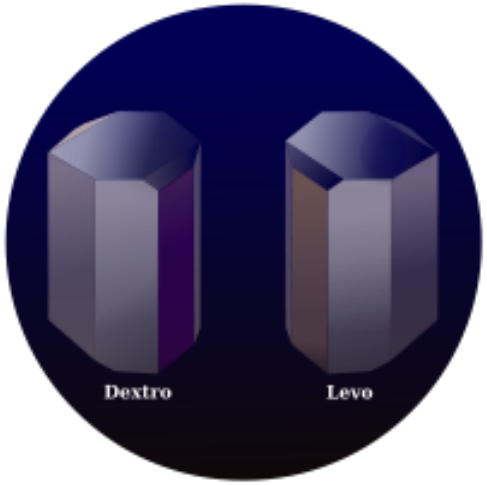
a. (−)-glyceric acid
b. (+)-isoserine
c. (−)-glyceraldehyde
d. (+)-lactic acid

PROBLEM 37◆

Which of the following is true?

a. If two compounds have the same relative configuration, they will have the same absolute configuration.
b. If two compounds have the same relative configuration and you know the absolute configuration of either one of them, you can determine the absolute configuration of the other.
c. If two compounds have the same relative configuration, you can determine the absolute configuration of only one of them.
d. An *R* reactant always forms an *S* product.

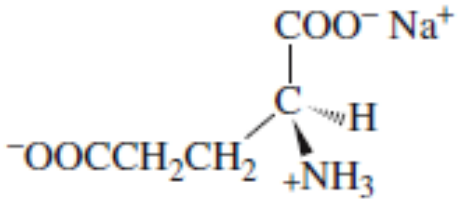
Resolución de una mezcla racémica



Pasteur, L. *C.R. Acad. Sci. Paris* **1848**, *26*, 535-539.

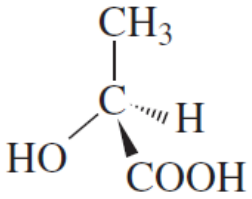
PROBLEM 14◆

(*S*)-(+)-Monosodium glutamate (MSG) is a flavor enhancer used in many foods. Some people have an allergic reaction to MSG (headache, chest pains, and an overall feeling of weakness). "Fast food" often contains substantial amounts of MSG, and it is widely used in Chinese food as well. MSG has a specific rotation of +24°.

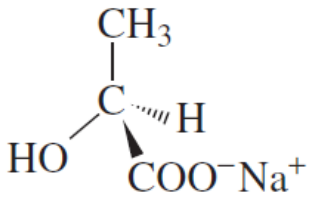


(*S*)-(+)-monosodium glutamate

a. What is the specific rotation of (*R*)-(−)-monosodium glutamate?
b. What is the specific rotation of a racemic mixture of MSG?



(*S*)-(+)-lactic acid



(*S*)-(–)-sodium lactate

PROBLEM 13◆

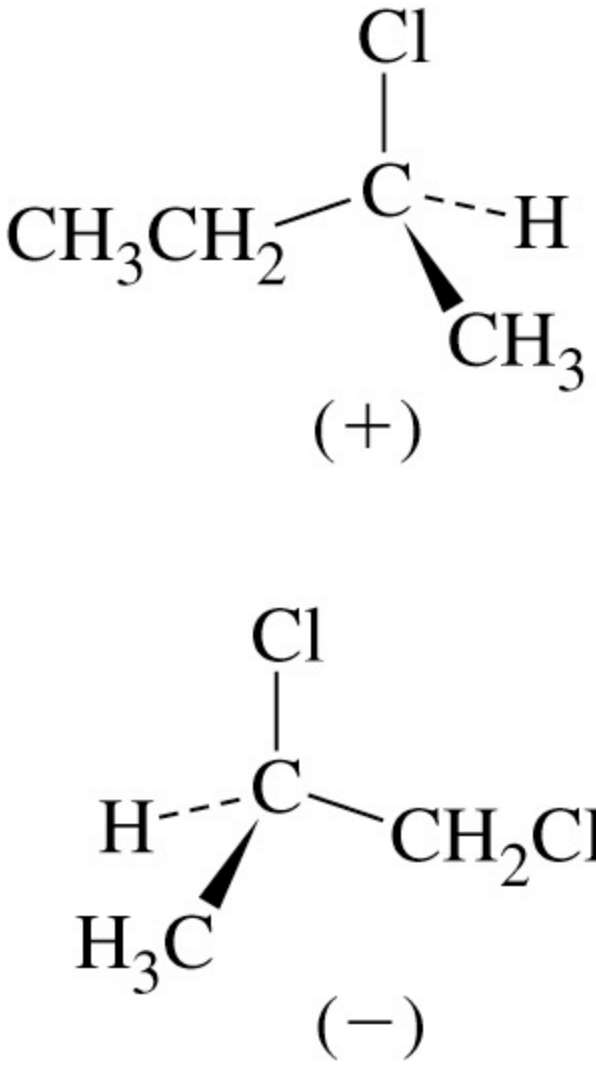
a. Is (*R*)-lactic acid dextrorotatory or levorotatory?
b. Is (*R*)-sodium lactate dextrorotatory or levorotatory?

Rotación específica: Es la rotación producida por 1.00 g de muestra en 1.00 mL de disolución, colocada en un tubo de longitud de 1.00 dm a determinada temperatura y a una longitud de onda específica.

Dextrorrotatorio (+)
Levorrotatorio (-)

$$[\alpha]_D^{20} = \frac{\alpha}{lc}$$

α = rotación observada en el polarímetro
c = concentración, g/mL
l = longitud de la celda de la muestra (longitud de la trayectoria), en decímetros (dm)



Mezcla racémica

The enantiomers of 2-chlorobutane

PROBLEM 15◆

(+)-Mandelic acid has a specific rotation of +158°. What would be the observed specific rotation of each of the following mixtures?

a. 25% (−)-mandelic acid and 75% (+)-mandelic acid
b. 50% (−)-mandelic acid and 50% (+)-mandelic acid
c. 75% (−)-mandelic acid and 25% (+)-mandelic acid

PROBLEM 16◆

Naproxen, a nonsteroidal anti-inflammatory drug, is the active ingredient in Aleve. Naproxen has a specific rotation of +66° in chloroform. One commercial preparation results in a mixture that is 97% optically pure.

a. Does naproxen have the *R* or the *S* configurtion?
b. What percent of each enantiomer is obtained from the commercial preparation?

Cuando uno de los enantiómeros del butan-2-ol es colocado en el polarímetro, se observa una rotación de 4.05° en sentido inverso del giro de las manecillas del reloj. La solución fue hecha por 6 g de (-)-butan-2-ol a un total de 40 mL, y se colocó en el tubo de 200 mm del polarímetro para su medición. Determine la rotación específica de este enantiómero del butan-2-ol.

R = $[\alpha]_{D}^{20} = -13.5°$, ¿y para el otro enantiómero?

Ejercicio: Una disolución de 2.0 g de (+)-gliceraldehído, $HOCH_2$-CHOH-CHO, en 10 mL de agua fueron colocados en una celda de 100 mm. Usando la línea D de sodio, una rotación de +1.74° se encontró a 20°C. Determine la rotación específica del (+)-gliceraldehído.

Optical Activity in depth: Consider that (*S*)-2-bromobutane has a specific rotation of +23.1° and (*R*)-2-bromobutane has a specific rotation of -23.1°

Question: Determine the optical purity of a racemic mixture.

Answer: The specific rotation, [α], of the racemate is expected to be 0, since the effect of one enantiomer cancel the other out, molecule for molecule.

Optical purity, % = 100 $[a]_{mixture}$ / $[\alpha]_{pure\ sample}$

= 100 (0) / +23.1°

= 0%

Question: Determine the enantiomeric excess of the racemic mixture.

Answer: You would expect [*R*] = [*S*] = 50%.

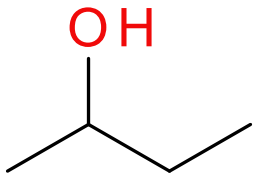
ee% = 100 ([*R*]-[*S*]) / ([*R*]+[*S*])

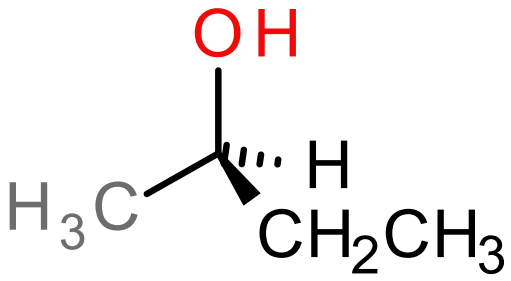
= 100 (50-50) / (50+50)

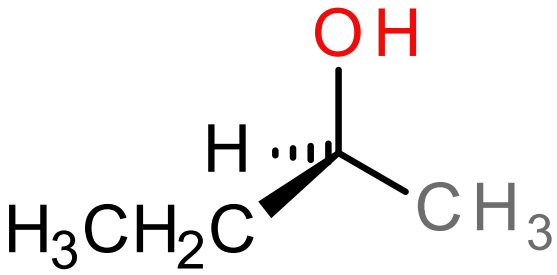
= 0%

Let's consider something a bit harder.....

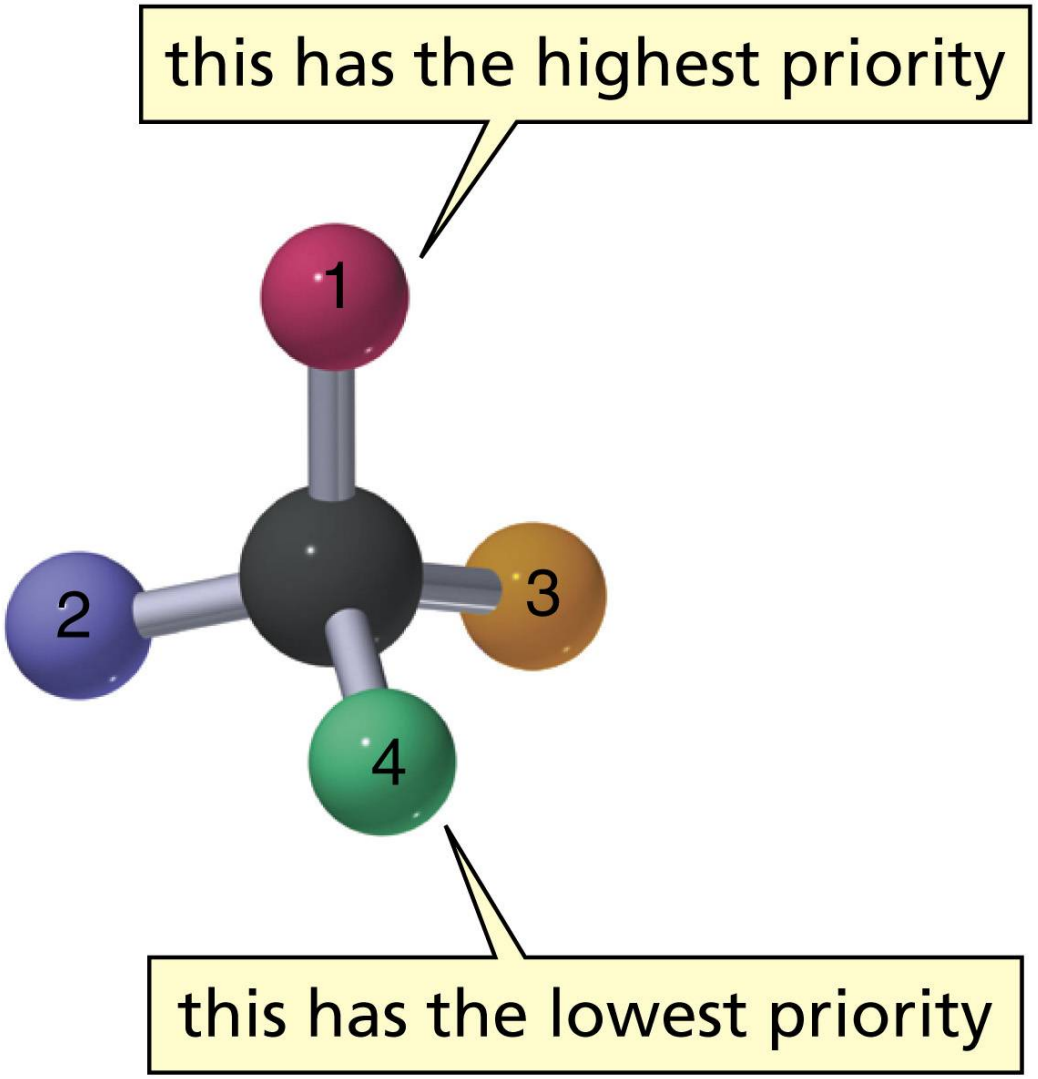
Orden en el que están colocados los grupos alrededor de un átomo de carbono estereogénico

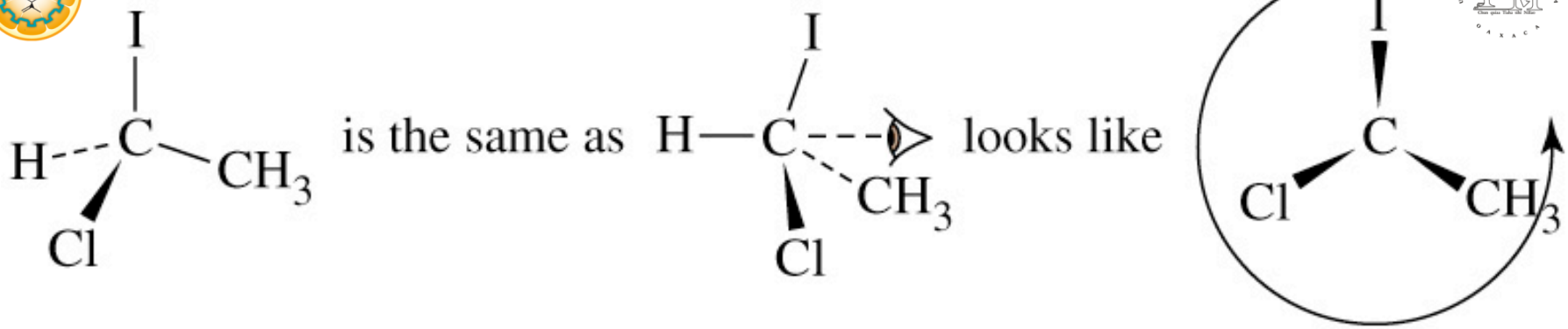






Cahn-Ingold-Prelog


this has the highest priority
1
2
3
4
this has the lowest priority

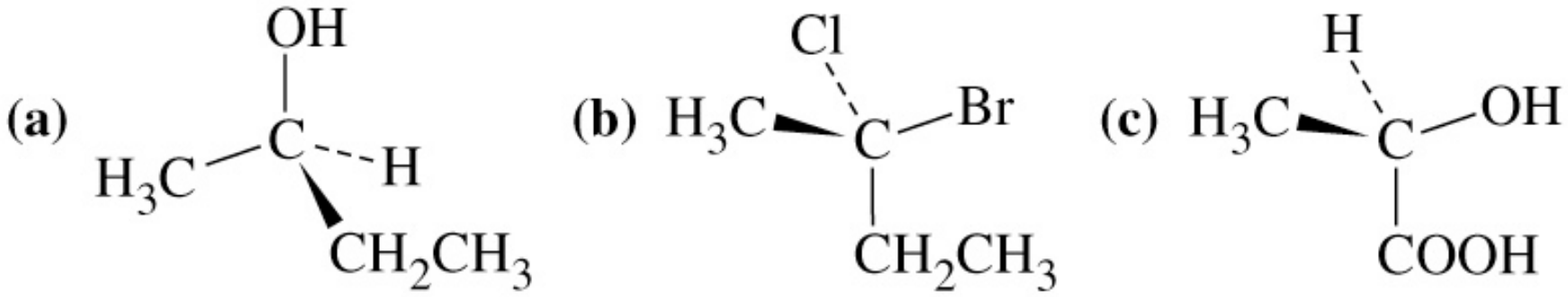


Priority I > Priority Cl > Priority C

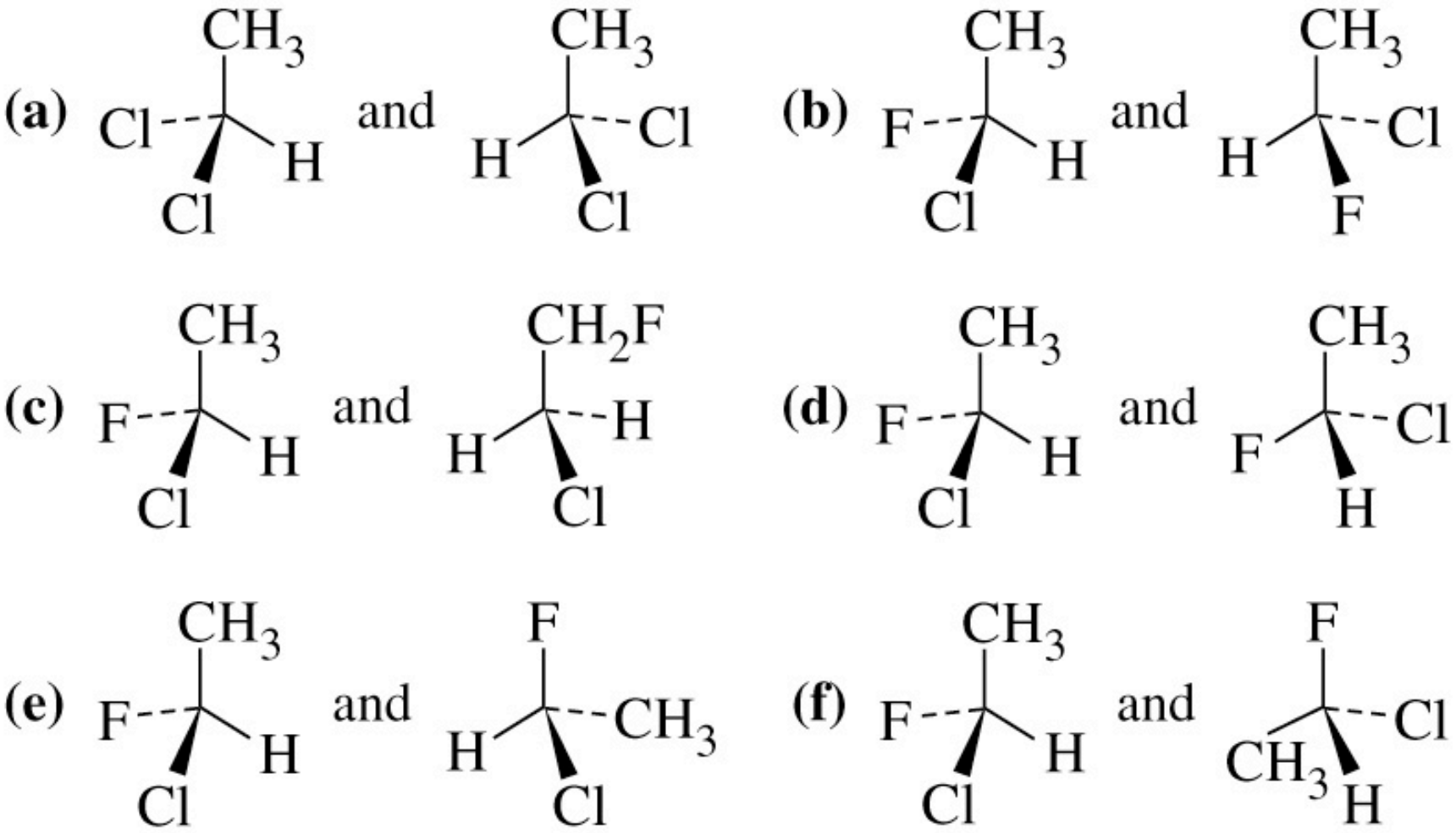
(*S*)-1-cloro-1-yodoetano

If this is clockwise, then the center is *R* (Latin: *rectus* = right)
If this is counter clockwise, then it is *S* (Latin: *sinister* = left)

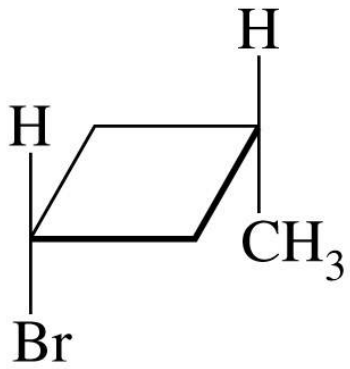
R ó S



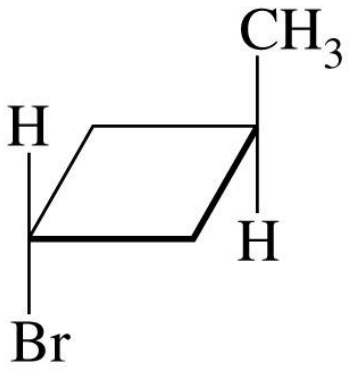
¿Isómeros o la misma molécula?



Chirals?



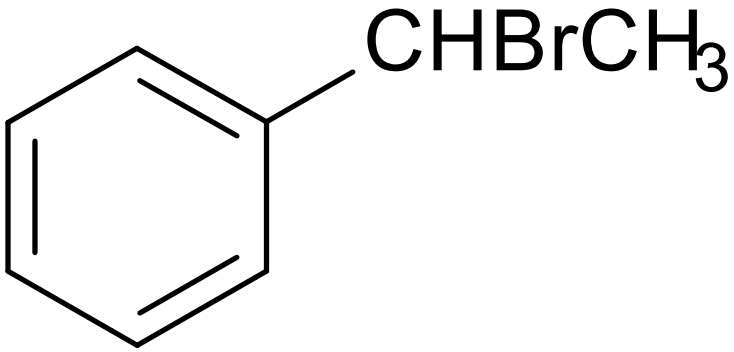
cis-1-bromo-3-methylcyclobutane

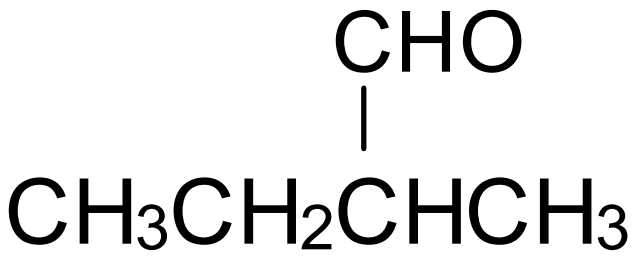


trans-1-bromo-3-methylcyclobutane

cis- and *trans*-1-bromo-3-methylcyclobutane do not have enantiomers because they have a plane of symmetry. The *cis* isomer and the *trans* isomer are the only stereoisomers of this compound

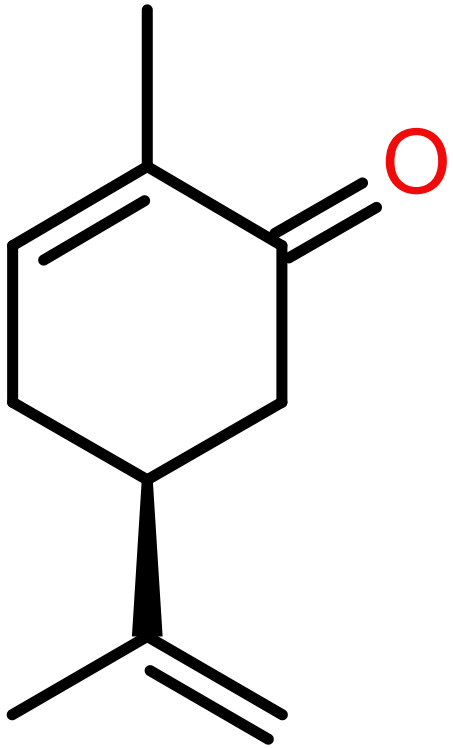
Trace las fórmulas en perspectiva para los enantiómeros de cada uno de los compuestos siguientes.



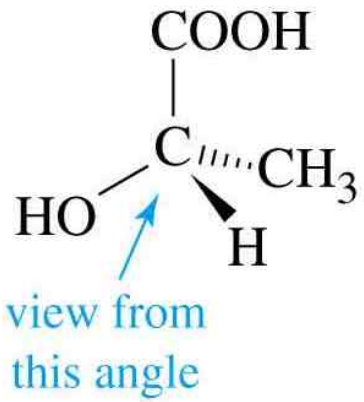


1. Dibuje los enantiómeros del 1,3-dibromobutano y marque cada uno de ellos como (*R*) ó (*S*).

2. La estructura de la carvona se muestra abajo. Encuentre el carbono estereogénico y determine si es *R* ó *S*

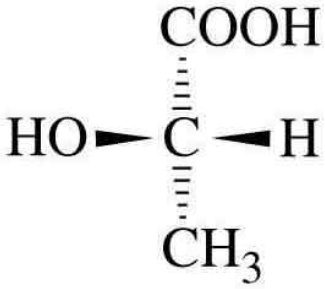


Fischer Projections

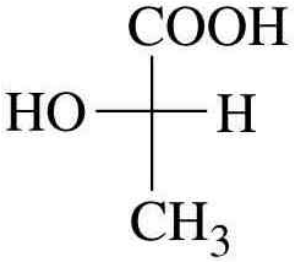


(*S*)-lactic acid
perspective drawing

=



=



(*S*)-lactic acid
Fischer projection

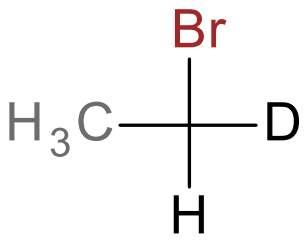
Ejercicios:

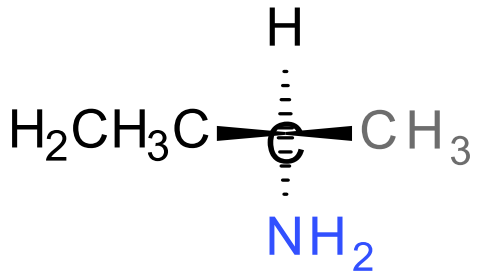
1. Dibuje la estructura que muestre la configuración absoluta de:

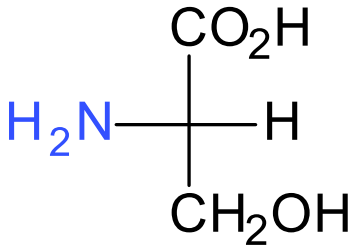
(a) (*R*)-3-bromoheptano y

(b) (*S*)-pentan-2-ol

2. Asigne a cada una de las siguientes moléculas la configuración (*R*) y (*S*):

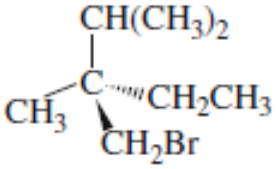
(a) 

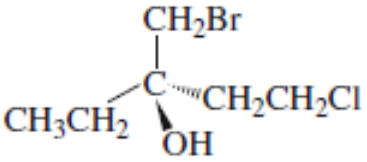
(b) 

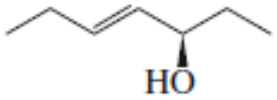
(c) 

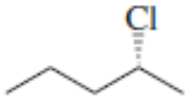
PROBLEM 8◆

Indicate whether each of the following structures has the *R* or the *S* configuration:

a. 

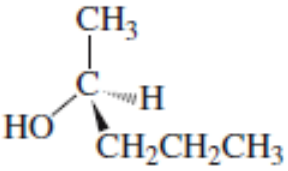
b. 

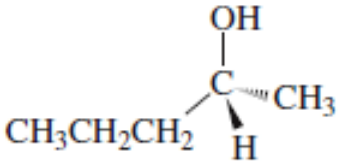
c. 

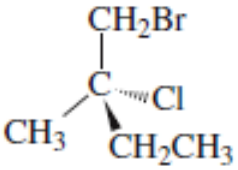
d. 

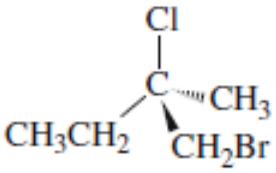
PROBLEM 9◆ SOLVED

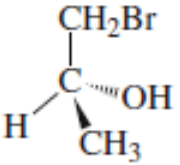
Do the following structures represent identical molecules or a pair of enantiomers?

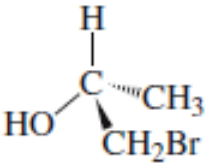
a. 

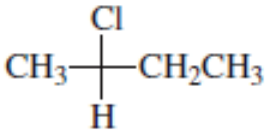
and 

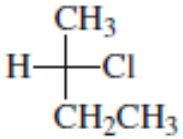
b. 

and 

c. 

and 

d. 

and 

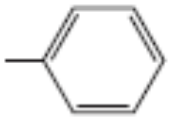
PROBLEM 10◆

Assign relative priorities to the following groups:

a. $-CH_2OH$ $-CH_3$ $-CH_2CH_2OH$ $-H$

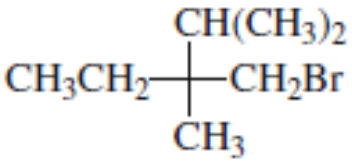
b. $-CH{=}O$ $-OH$ $-CH_3$ $-CH_2OH$

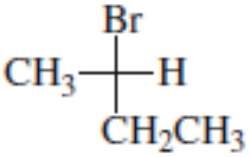
c. $-CH(CH_3)_2$ $-CH_2CH_2Br$ $-Cl$ $-CH_2CH_2CH_2Br$

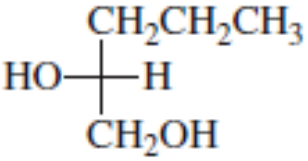
d. $-CH{=}CH_2$ $-CH_2CH_3$  $-CH_3$

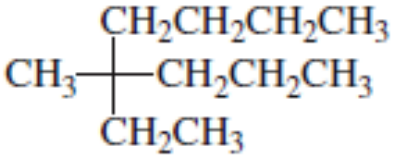
PROBLEM 11◆

Indicate whether each of the following structures has the *R* or the *S* configuration:

a. 

c. 

b. 

d. 

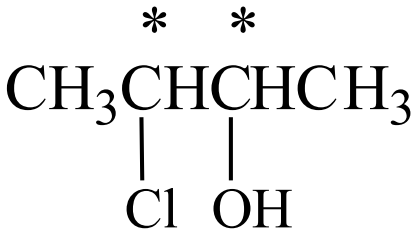
Más de un carbono estereogénico

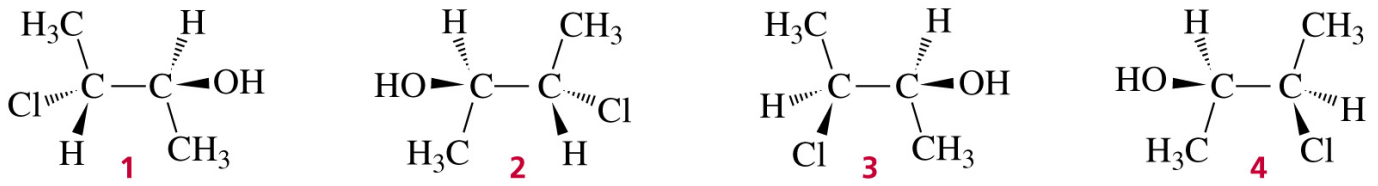
R, *S*

Con dos carbonos estereogénicos ¿cuántos estereoisómeros diferentes tendría?

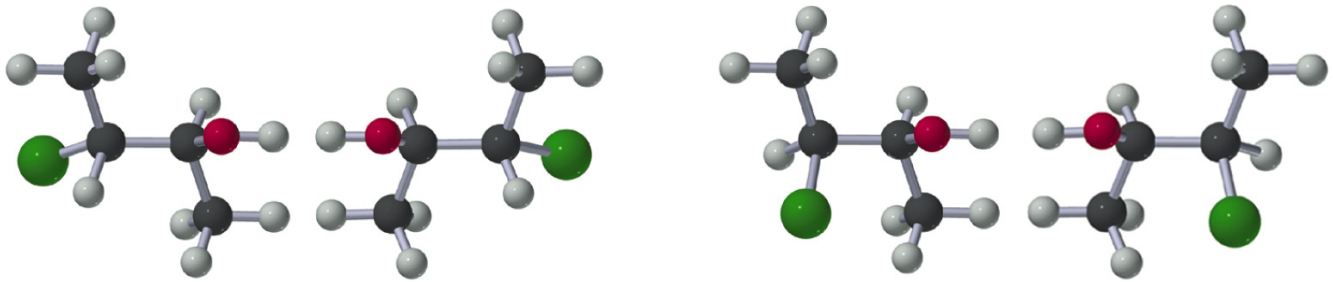
¿Cuál es el número máximo de estereoisómeros para cada uno de los compuestos siguientes? (**a**) 1,2-dibromo-1-fenilpropano; (**b**) 1,2-dibromo-1-fenil-2-metilpropano; (**c**) 2,3,4,5-tetrahidroxipentanal.

Isomers with more than one chiral carbon: a maximum of 2^n stereoisomers can be obtained



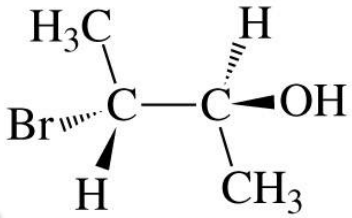


perspective formulas of the stereoisomers of 3-chloro-2-butanol (staggered)

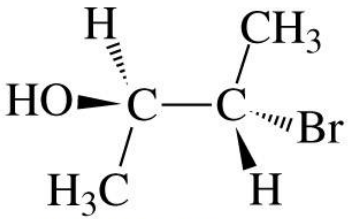


stereoisomers of 3-chloro-2-butanol

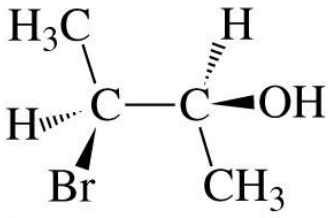
Diastereomers are stereoisomers that are not enantiomers



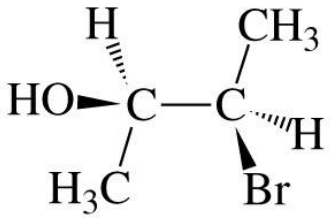
(2*S*,3*R*)-3-bromo-2-butanol



(2*R*,3*S*)-3-bromo-2-butanol

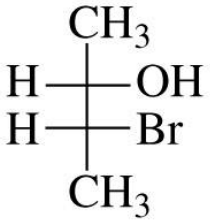


(2*S*,3*S*)-3-bromo-2-butanol

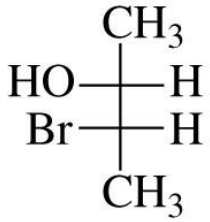


(2*R*,3*R*)-3-bromo-2-butanol

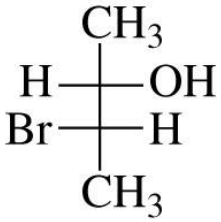
perspective formulas of the stereoisomers of 3-bromo-2-butanol



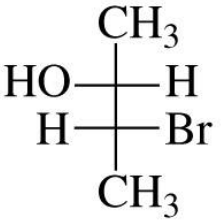
(2*S*,3*R*)-3-bromo-2-butanol



(2*R*,3*S*)-3-bromo-2-butanol



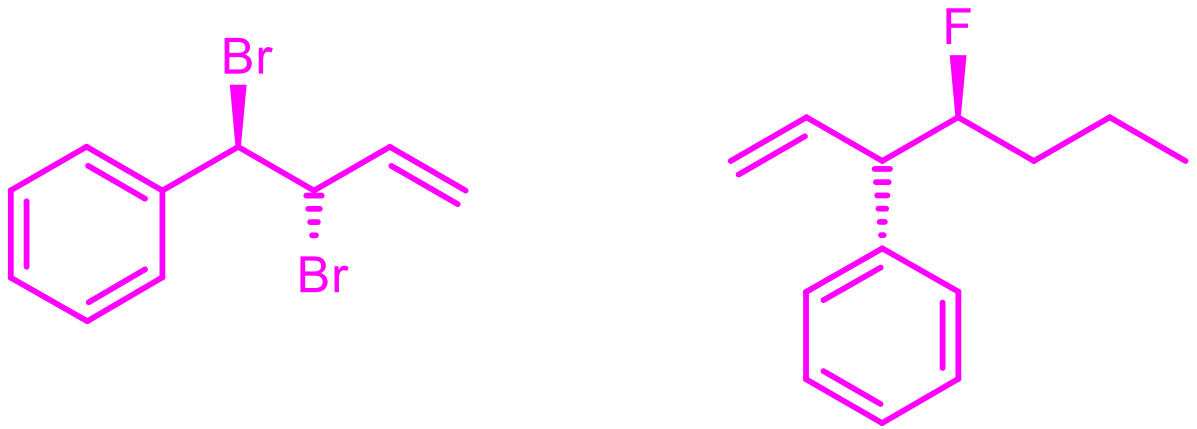
(2*S*,3*S*)-3-bromo-2-butanol



(2*R*,3*R*)-3-bromo-2-butanol

Fischer projections of the stereoisomers of 3-bromo-2-butanol

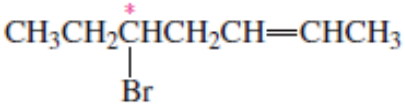
1. Asigne la configuración absoluta de cada uno de los carbonos estereogénicos.



2. Encuentre todos los estereoisómeros del 2,3-diclorobutano

PROBLEM 18

The following compound has only one asymmetric carbon. Why then does it have four stereoisomers?



PROBLEM 19◆

a. Stereoisomers with two asymmetric carbons are called _____ if the configuration of both asymmetric carbons in one isomer is the opposite of the configuration of the asymmetric carbons in the other isomer.

b. Stereoisomers with two asymmetric carbons are called _____ if the configuration of both asymmetric carbons in one isomer is the same as the configuration of the asymmetric carbons in the other isomer.

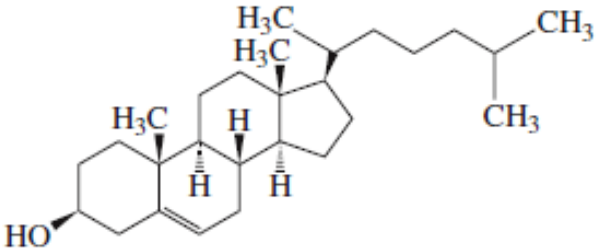
c. Stereoisomers with two asymmetric carbons are called _____ if one of the asymmetric carbons has the same configuration in both isomers and the other asymmetric carbon has the opposite configuration in the two isomers.

PROBLEM 20◆

a. How many asymmetric carbons does cholesterol have?

b. What is the maximum number of stereoisomers that cholesterol can have?

c. How many of these stereoisomers are found in nature?



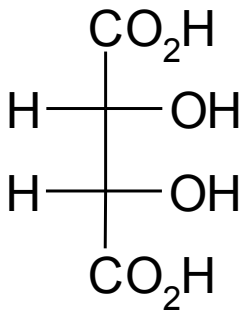
cholesterol

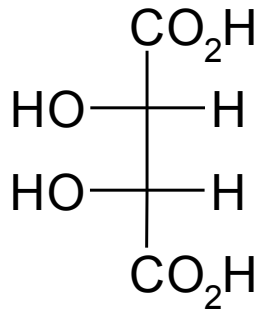
Ejercicio: Dibuje los estereoisómeros del 2,3,4-trihidroxibutanal y determine la relación entre ellos (enantiómeros o diastereómeros).

¿Podría encontrar un plano de simetría en el *cis*-1,2-dibromociclohexano?

Compuestos *meso*

Ácido tartárico





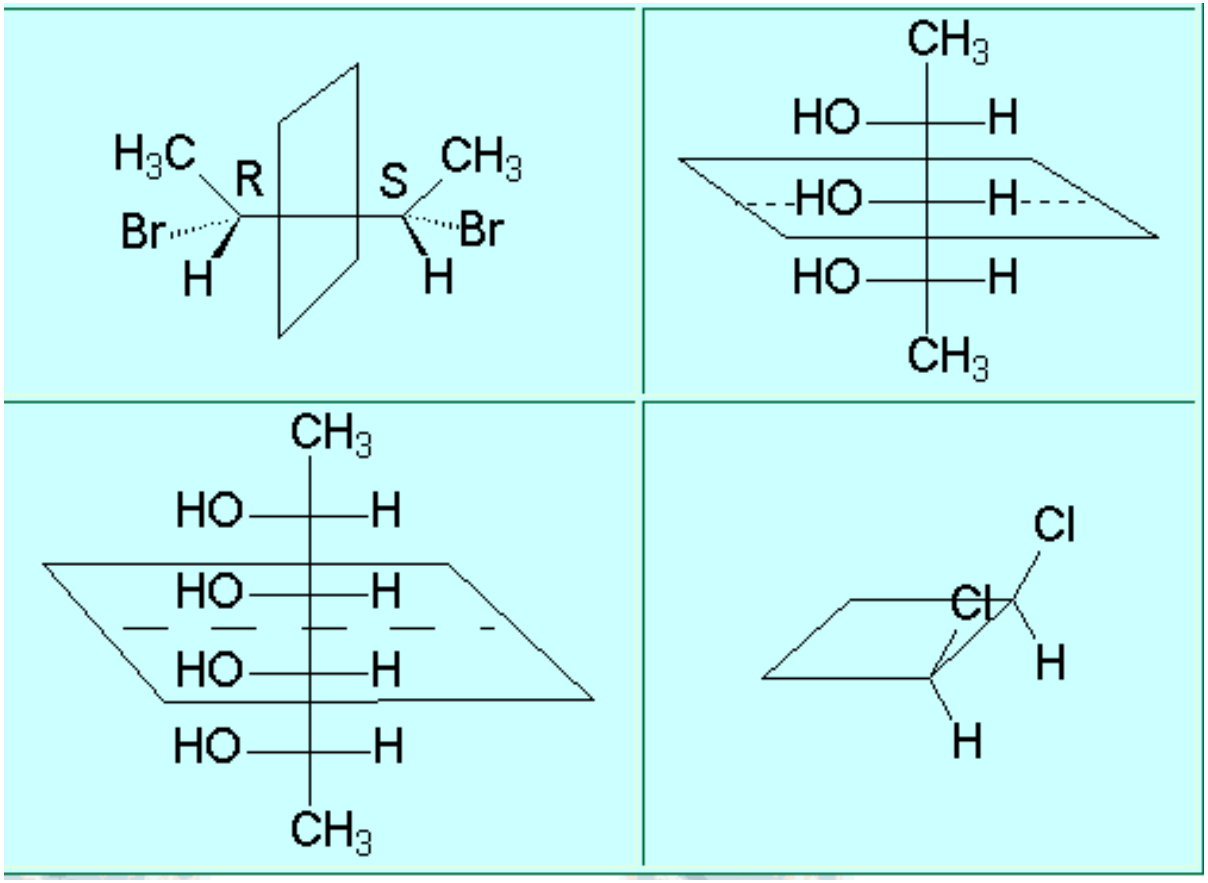
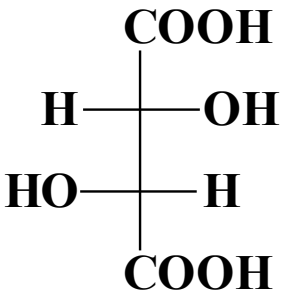
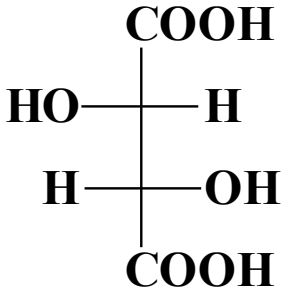


Table 5.1 Physical Properties of the Stereoisomers of Tartaric Acid

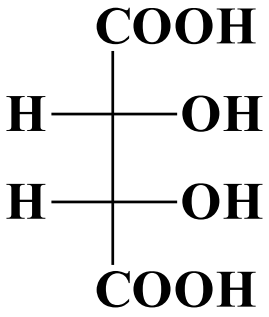
	Melting point, °C	$[\alpha]_D^{25\ °C}$	Solubility, g/100 g H_2O at 15 °C
(2*R*,3*R*)-(+)-Tartaric acid	170	+11.98°	139
(2*S*,3*S*)-(−)-Tartaric acid	170	−11.98°	139
(2*R*,3*S*)-Tartaric acid	140	0°	125
(±)-Tartaric acid	206	0°	139



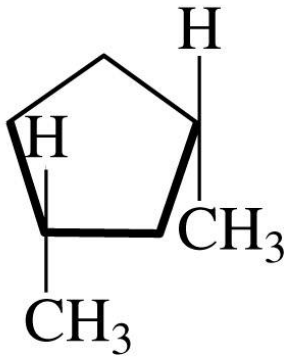
(2*R*,3*R*)-tartaric acid



(2*S*,3*S*)-tartaric acid

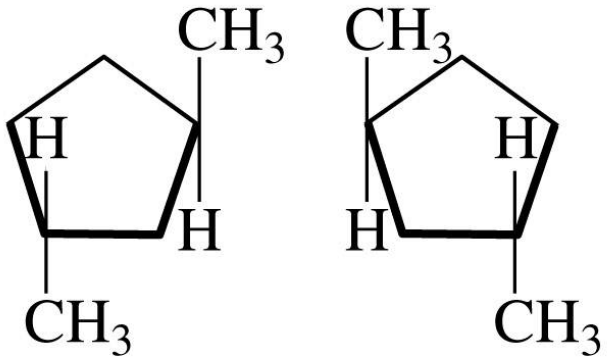


(2*R*,3*S*)-tartaric acid



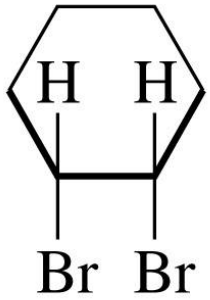
cis-1,3-dimethylcyclopentane

a meso compound



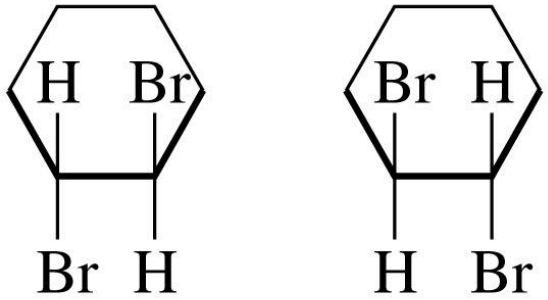
trans-1,3-dimethylcyclopentane

a pair of enantiomers



cis-1,2-dibromocyclohexane

a meso compound

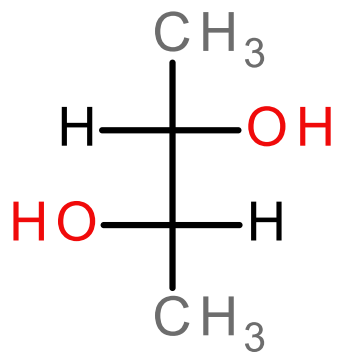


trans-1,2-dibromocyclohexane

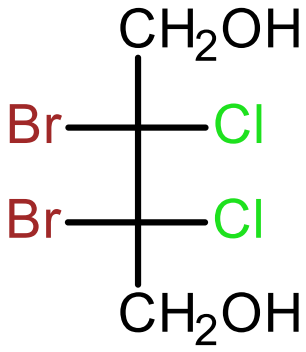
a pair of enantiomers

Determine cuáles de los compuestos siguientes son ópticamente activos

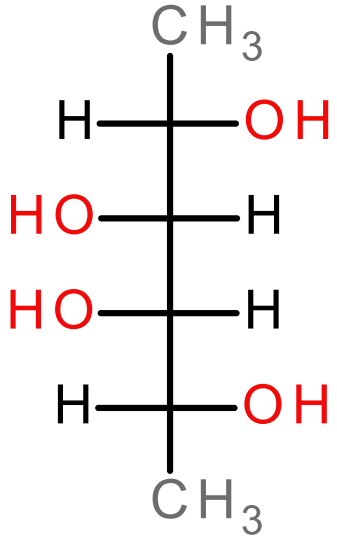
(a)



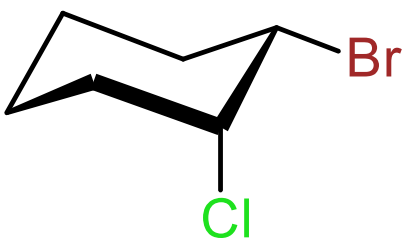
(b)



(c)

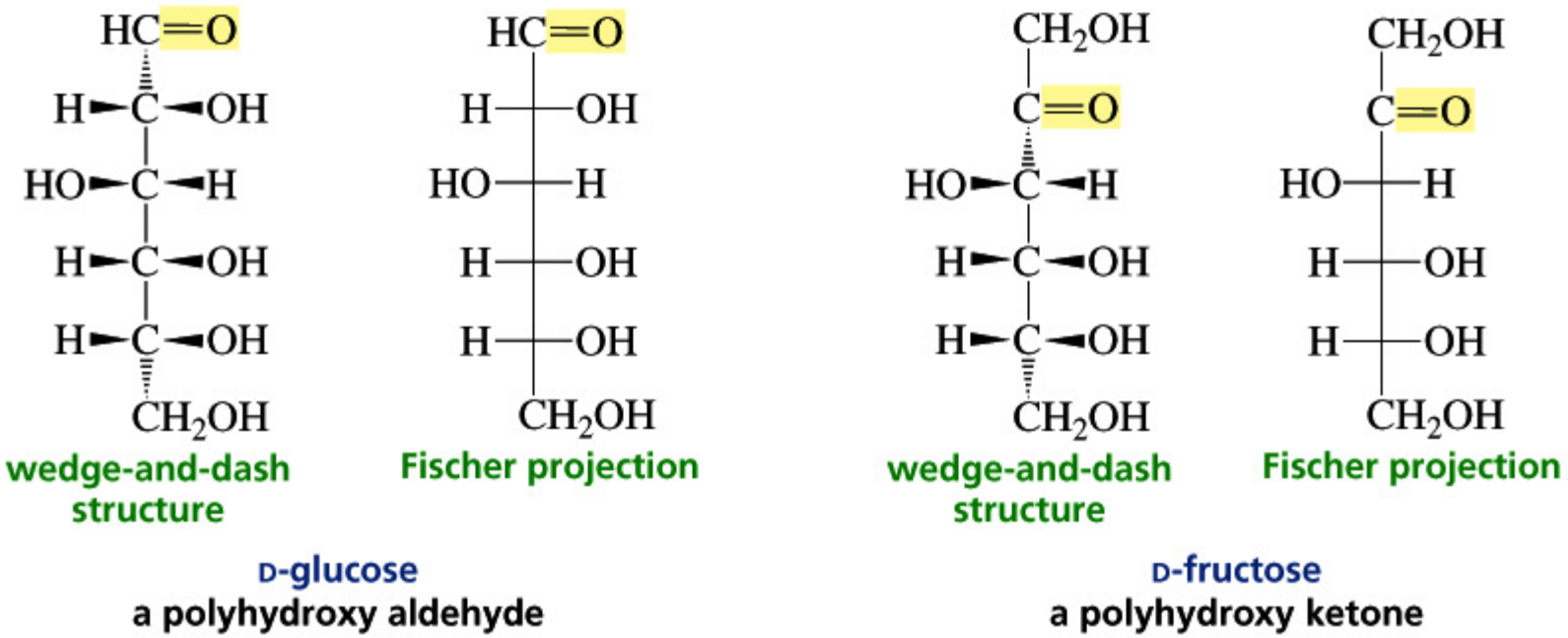


(d)



Carbohydrates

They have the molecular formulas $C_n(H_2O)_n$

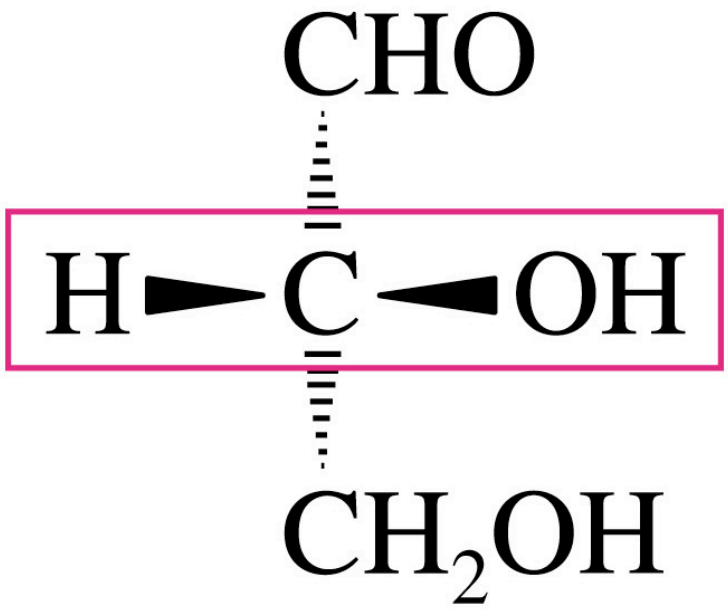


D-glucose
a polyhydroxy aldehyde

D-fructose
a polyhydroxy ketone

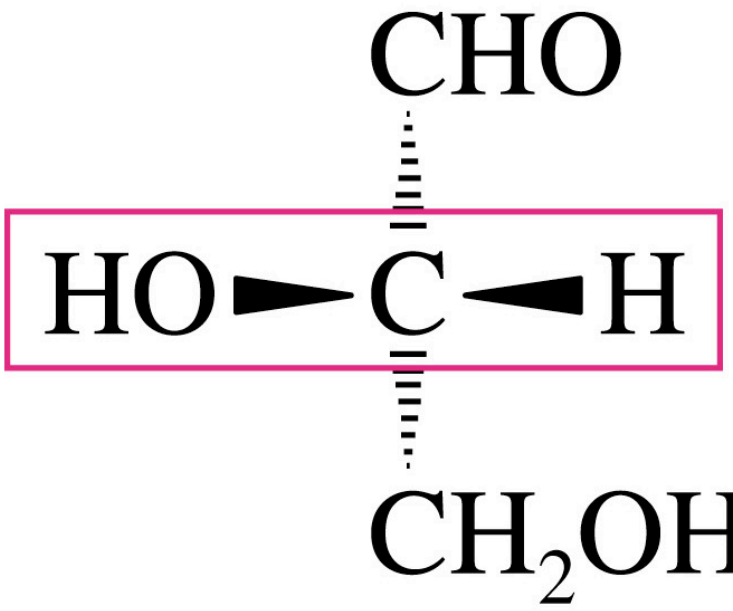
Compounds that can be hydrolyzed to polyhydroxy aldehydes or polyhydroxy ketones are also classified as carbohydrates

D and L Series of Sugars



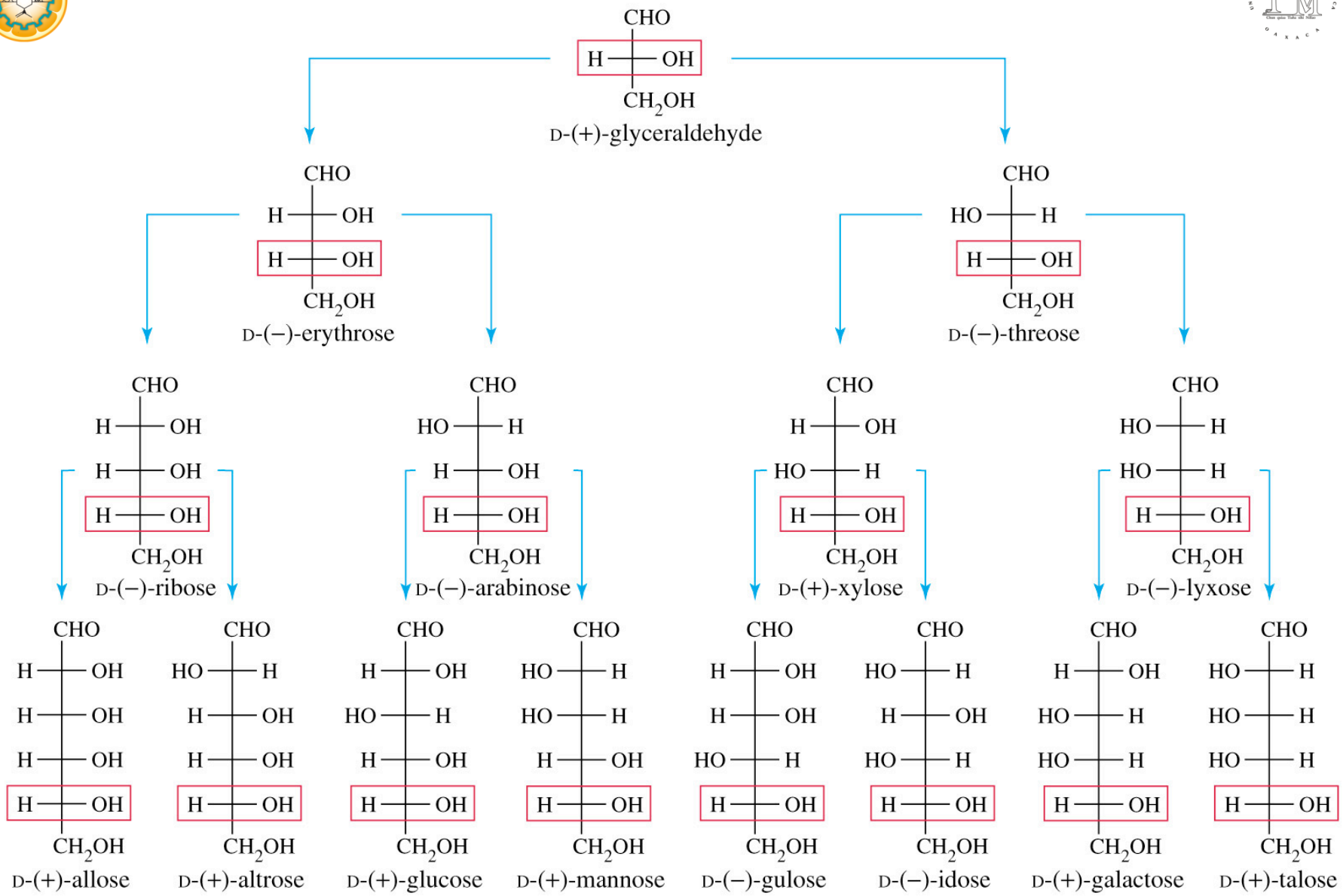
(+)-glyceraldehyde

D series of sugars

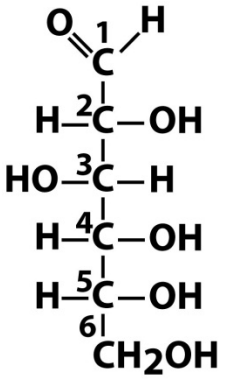


(−)-glyceraldehyde

L series of sugars

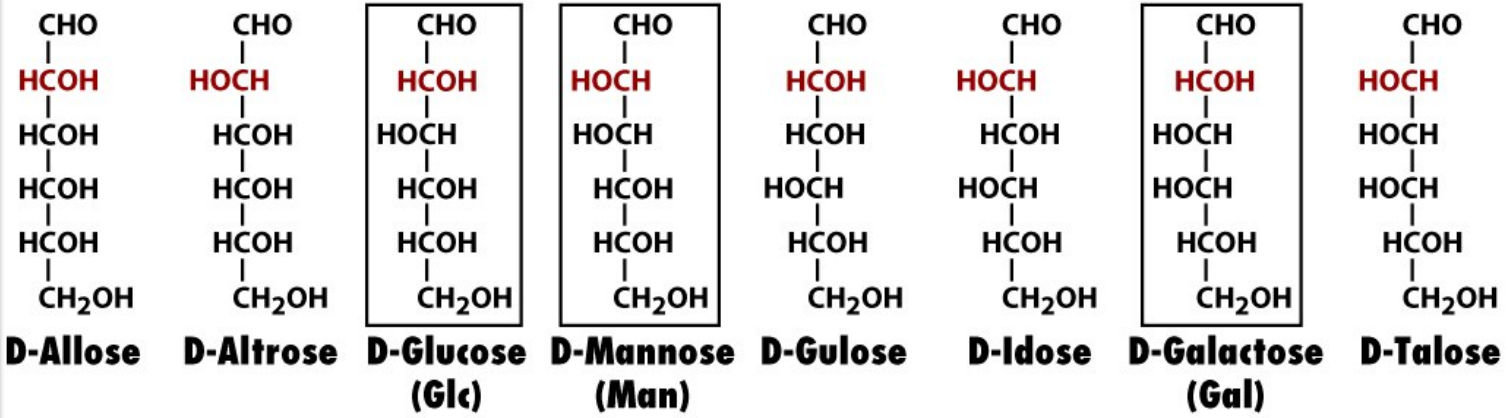

CHO
H OH
CH2OH
D-(+)-glyceraldehyde
CHO
H OH
H OH
CH2OH
D-(−)-erythrose
CHO
HO H
H OH
CH2OH
D-(−)-threose
CHO
H OH
H OH
H OH
CH2OH
D-(−)-ribose
CHO
HO H
H OH
H OH
CH2OH
D-(−)-arabinose
CHO
H OH
HO H
H OH
CH2OH
D-(+)-xylose
CHO
HO H
HO H
H OH
CH2OH
D-(−)-lyxose
CHO
H OH
H OH
H OH
H OH
CH2OH
D-(+)-allose
CHO
HO H
H OH
H OH
H OH
CH2OH
D-(+)-altrose
CHO
H OH
HO H
H OH
H OH
CH2OH
D-(+)-glucose
CHO
HO H
HO H
H OH
H OH
CH2OH
D-(+)-mannose
CHO
H OH
H OH
HO H
H OH
CH2OH
D-(−)-gulose
CHO
HO H
H OH
HO H
H OH
CH2OH
D-(−)-idose
CHO
H OH
HO H
HO H
H OH
CH2OH
D-(+)-galactose
CHO
HO H
HO H
HO H
H OH
CH2OH
D-(+)-talose

Chapter 8 Opener Fundamentals of Biochemistry, 2/e



D-Glucose

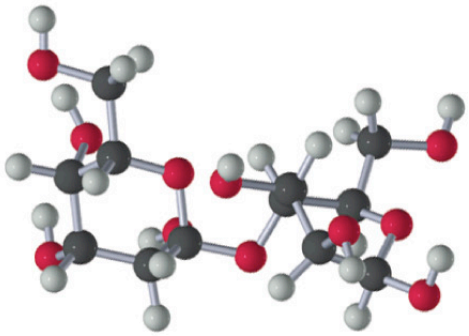
Unnumbered figure pg 207 Fundamentals of Biochem
© 2006 John Wiley & Sons

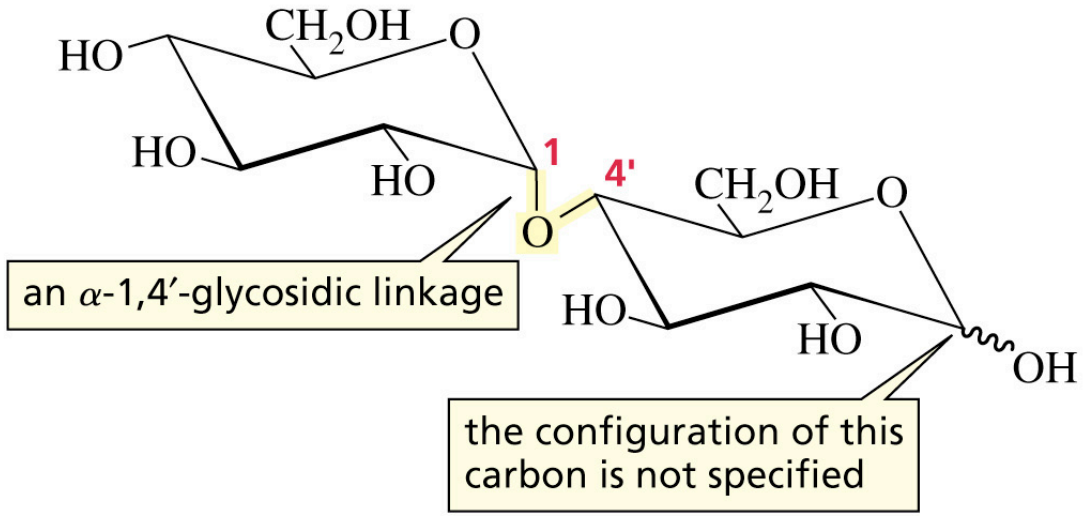


Aldohexoses

Disaccharides

Composed of two monosaccharide subunits hooked together by an acetal linkage



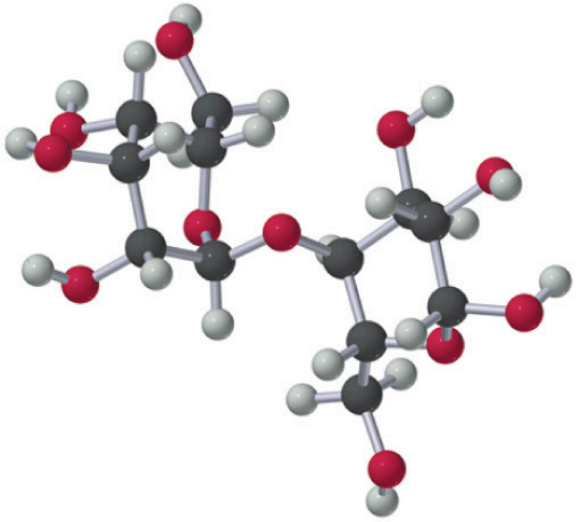


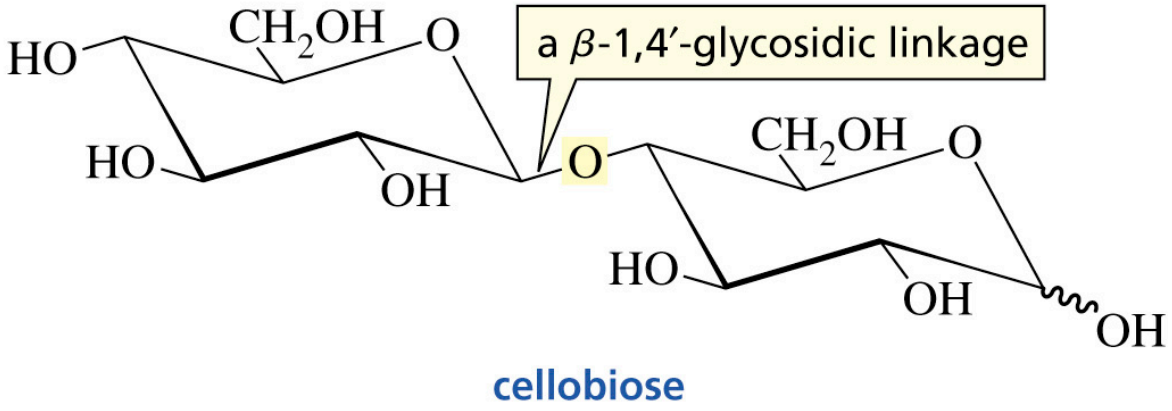
maltose

In α-maltose, the OH group bonded to the anomeric carbon is axial

Maltose is a reducing sugar

In cellobiose, the two subunits are hooked together by a β-1,4'-glycosidic linkage

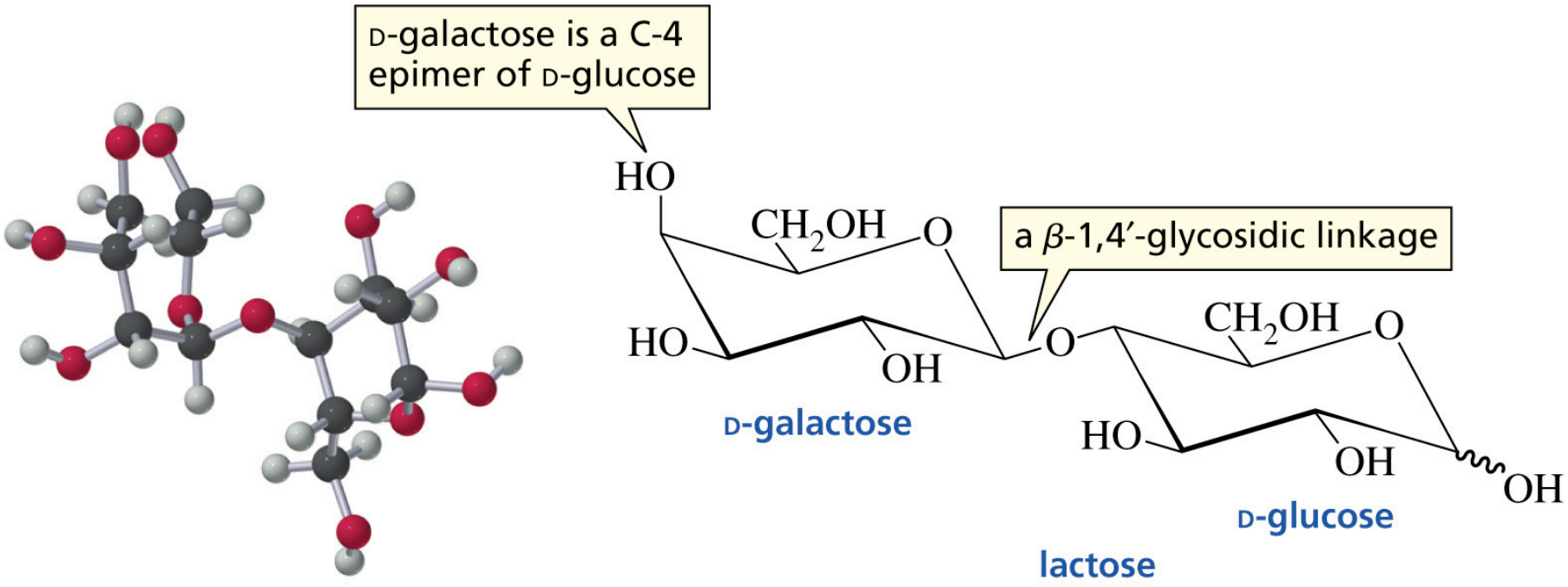




cellobiose

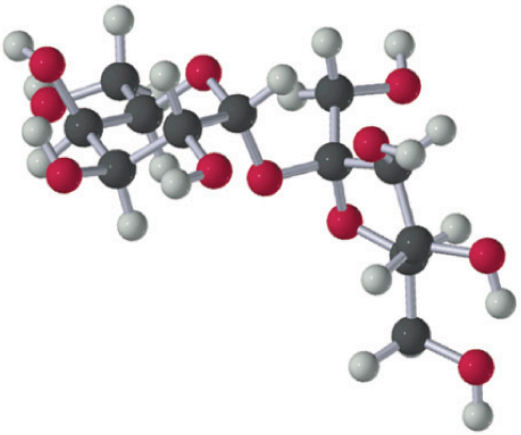
Cellobiose is a reducing sugar

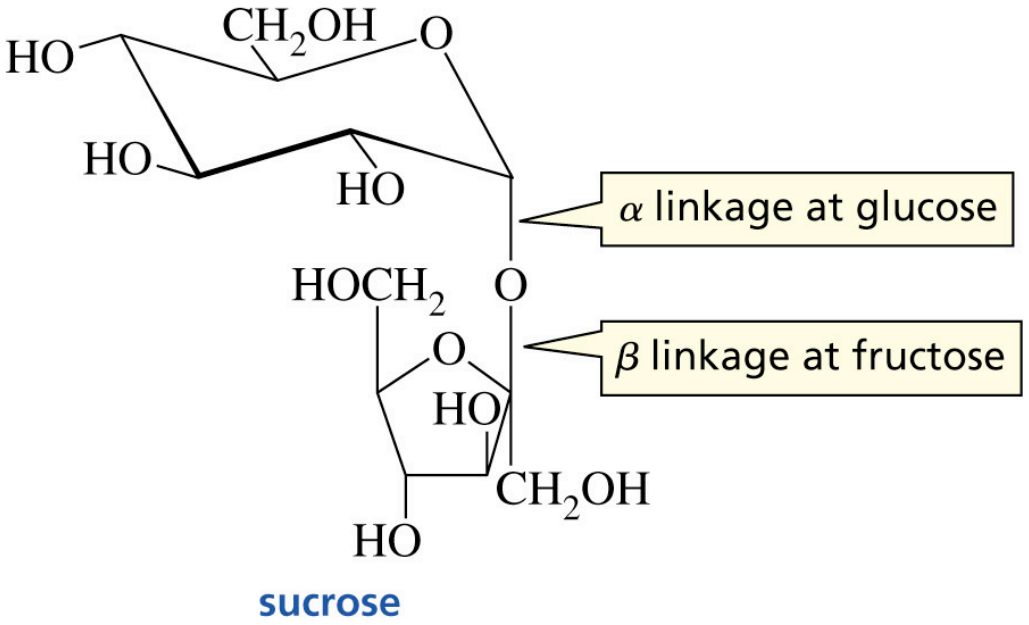
In lactose, the two different subunits are joined by a β-1,4'-glycosidic linkage



Lactose is a reducing sugar

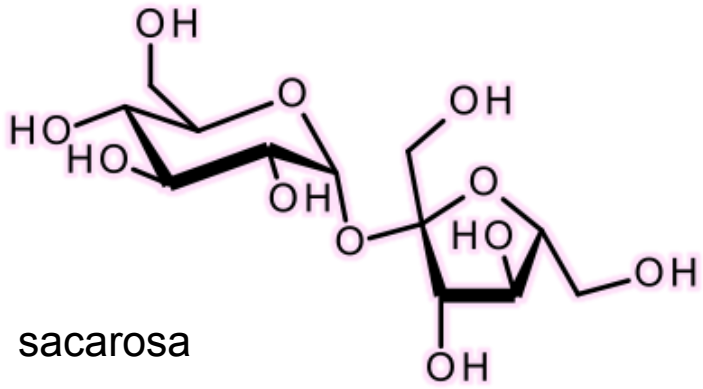
The most common disaccharide is sucrose



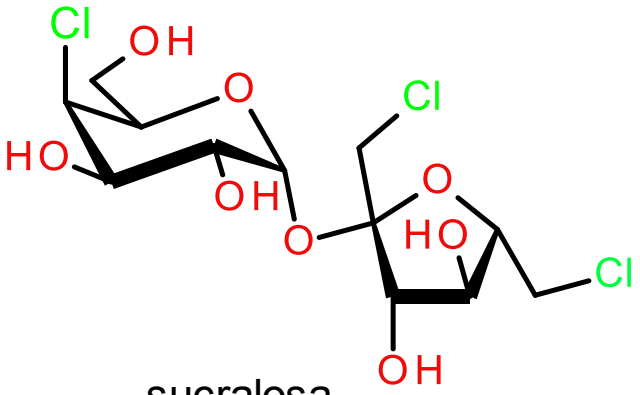


sucrose

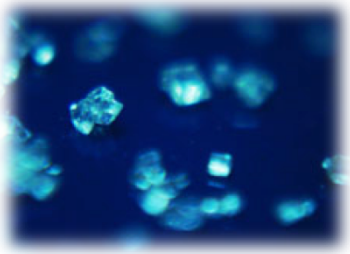
Sucrose is not a reducing sugar



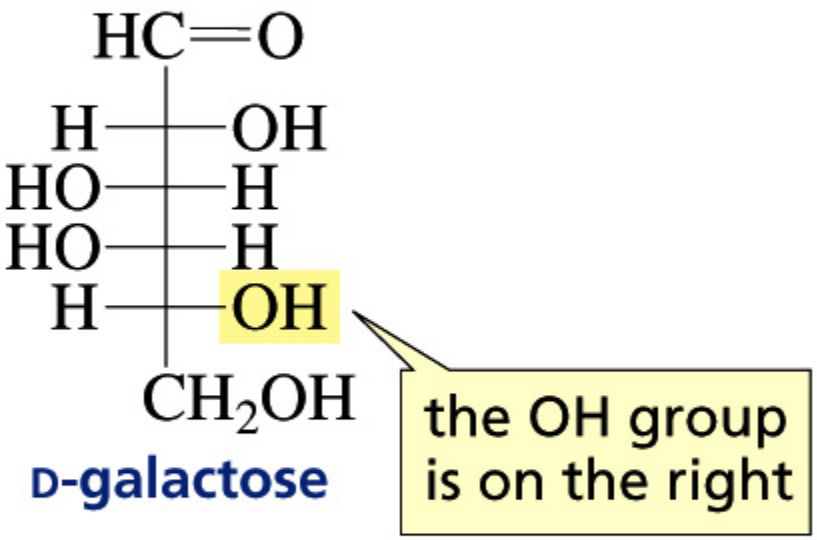
sacarosa

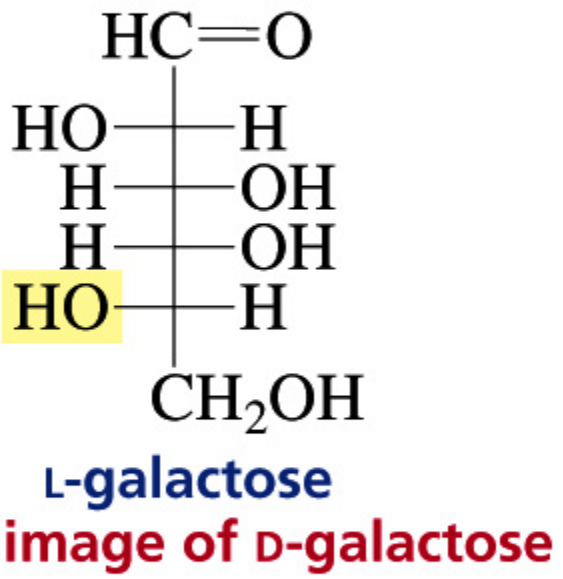


sucralosa
(*splenda*)

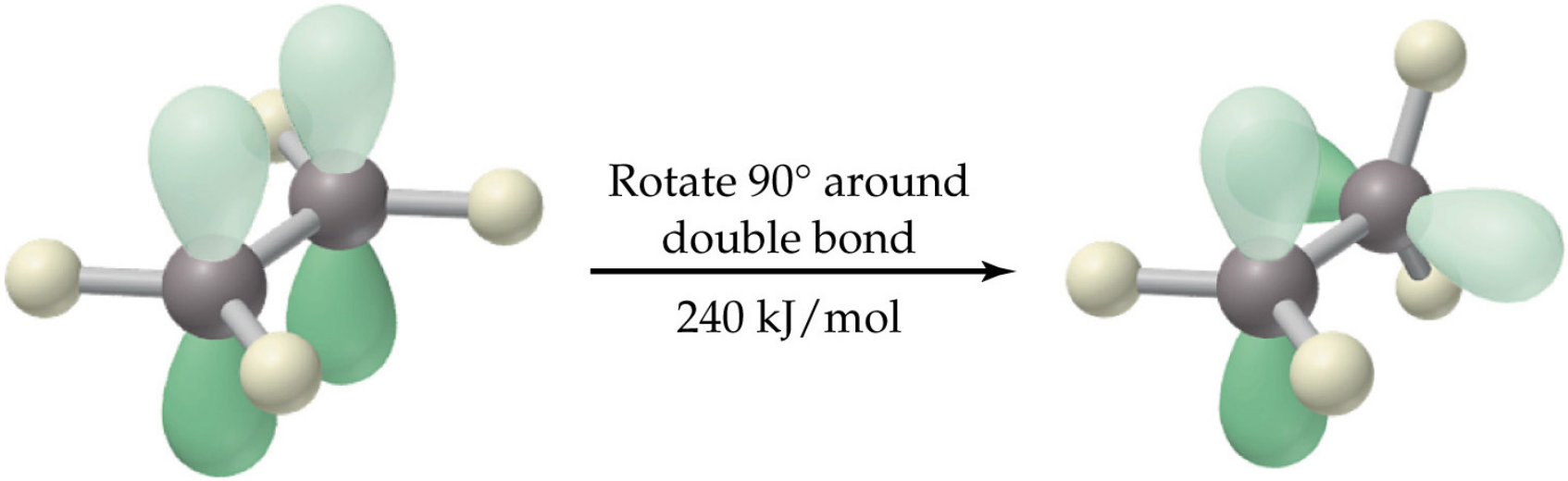


D and L notations are used to describe the configurations of carbohydrates



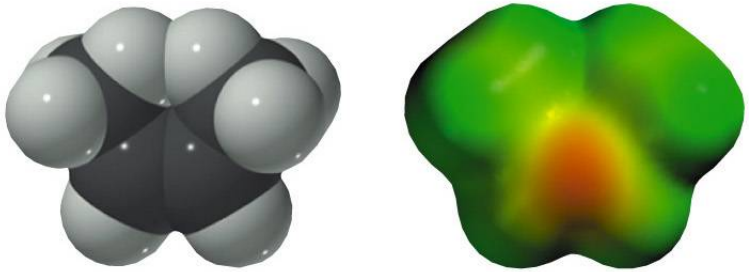


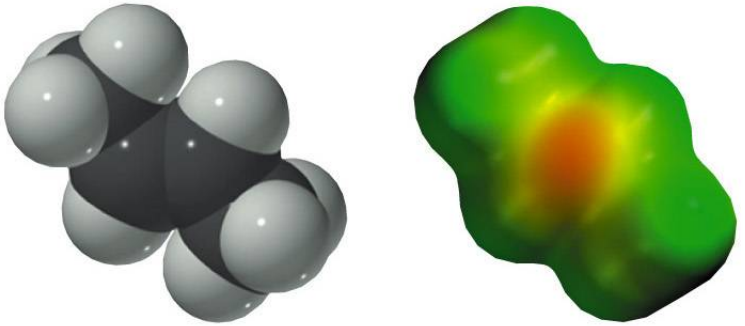
Isomería geométrica

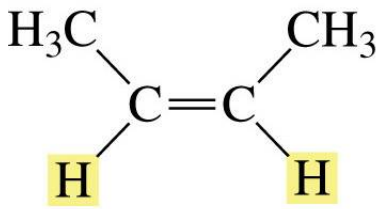


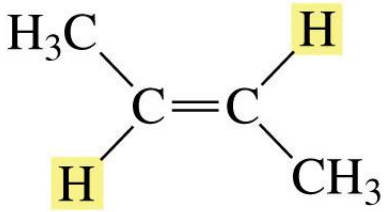
Pi bond—*p* orbital overlap

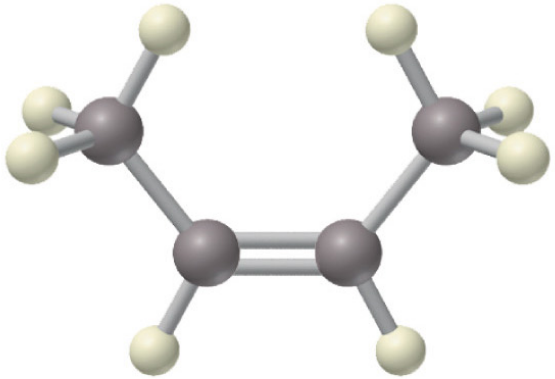
Broken bond—no *p* orbital overlap



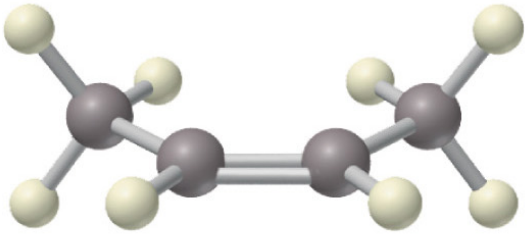



H3C
CH3
C
C
H
H

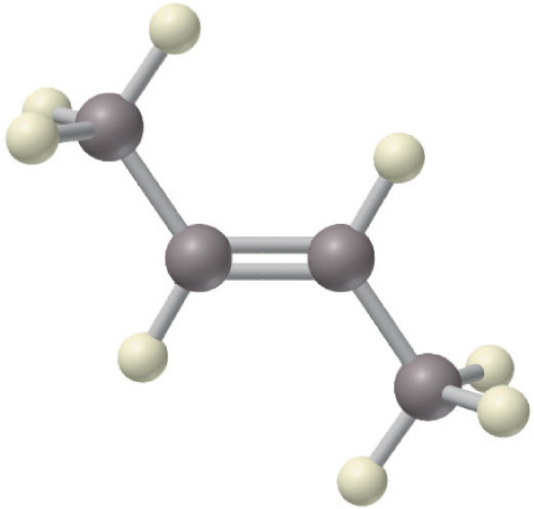

H3C
H
C
C
H
CH3



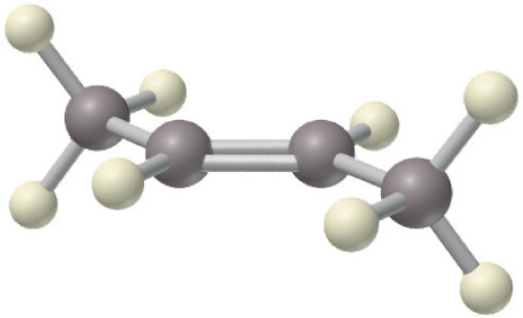
(Top view)



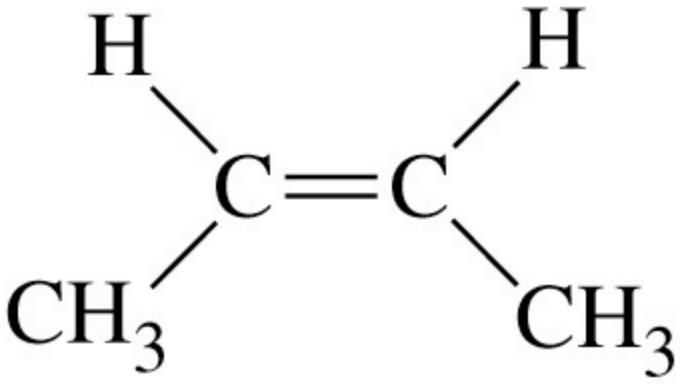
(Side view)



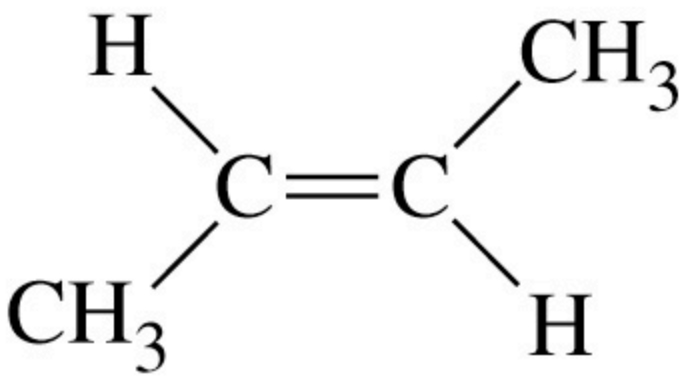
(Top view)



(Side view)



(**a**) (*Z*)-but-2-eno
p.e. = 3.7°C

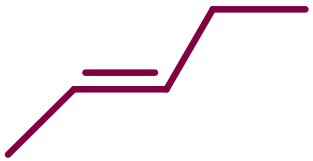


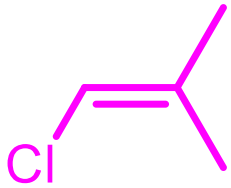
(**b**) (*E*)-but-2-eno
p.e. = 0.9°C

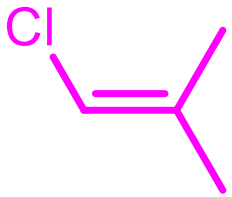
E = *entgegen* “opuestos”
Z = *zusammen* “juntos”

¿Isómeros geométricos o no?

Nombre a cada uno de ellos



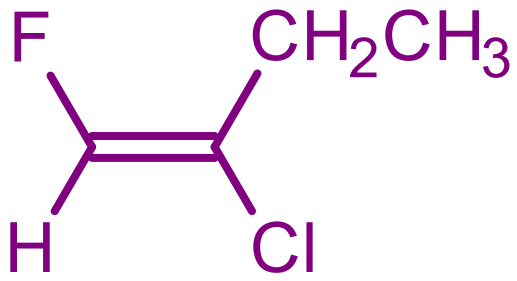


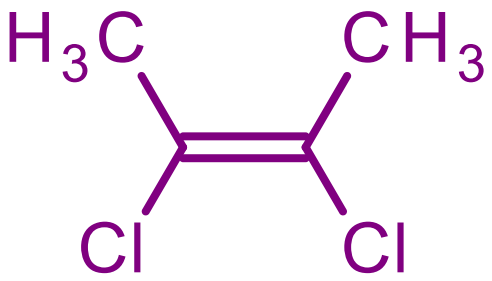


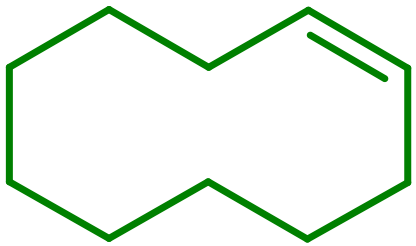
E = *entgegen* “opuestos”

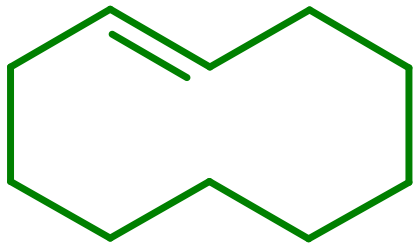
Z = *zusammen* “juntos”

Identifique la configuración con el sistema (*E*) y (*Z*)



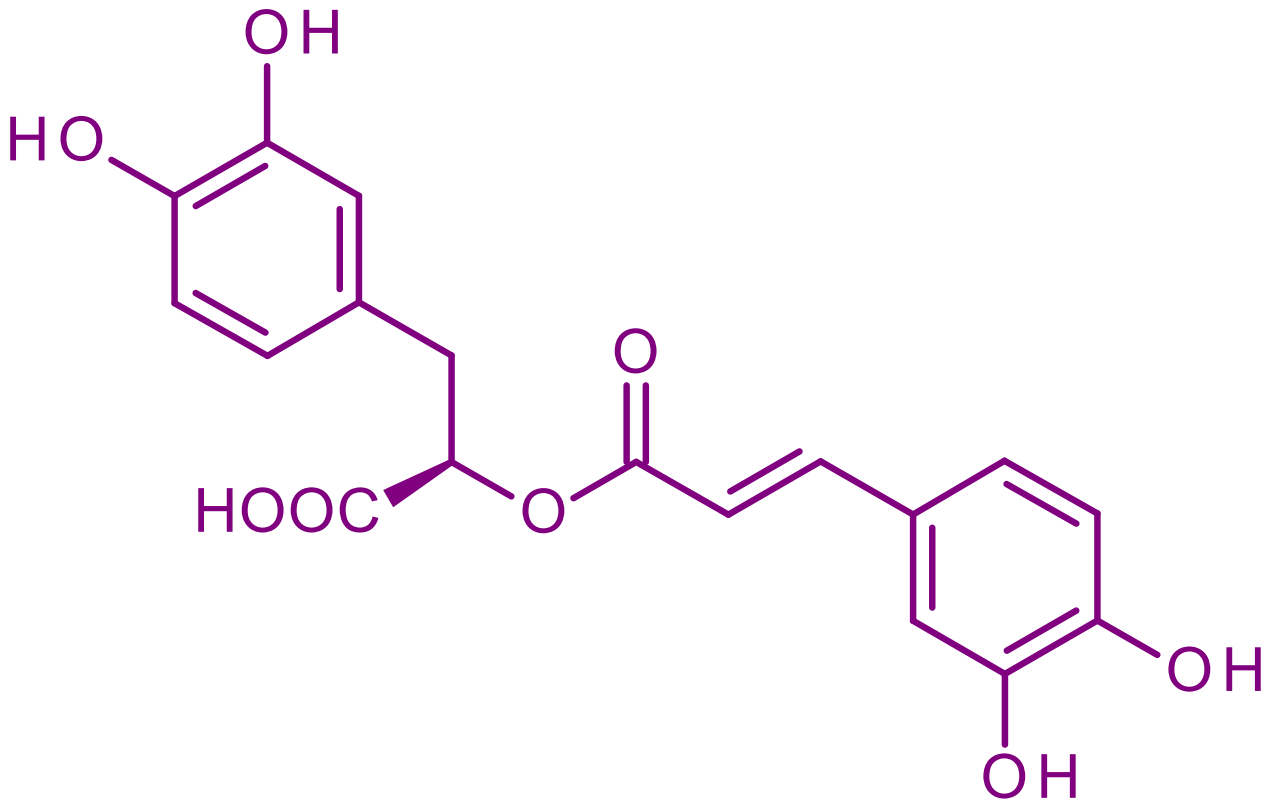




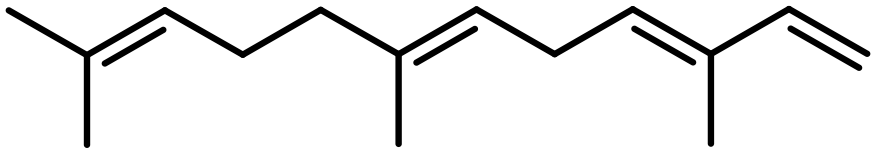


...el de 8 carbonos

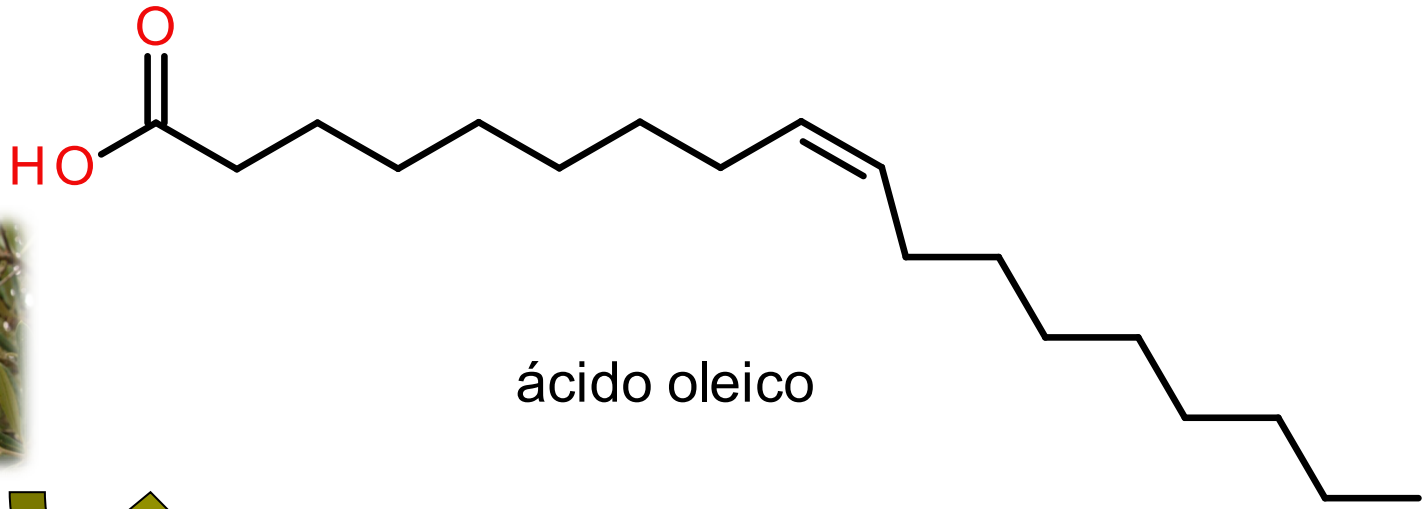
E = *entgegen* “opuestos”
Z = *zusammen* “juntos”



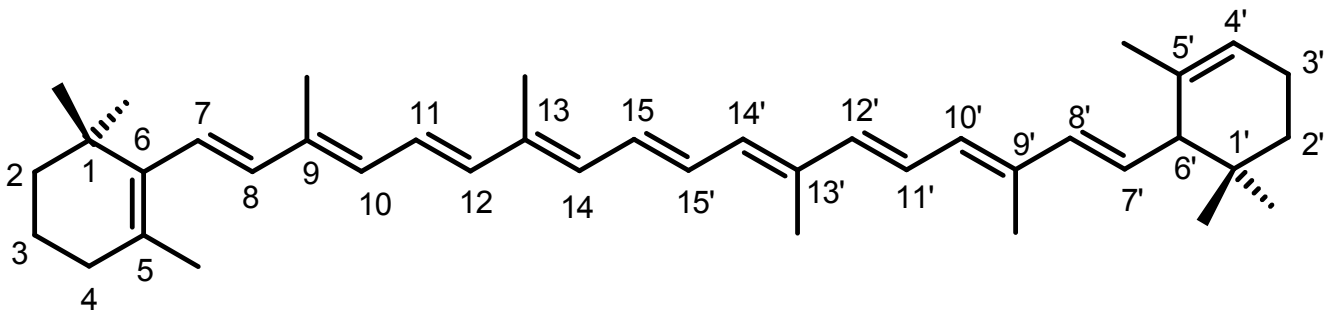
Ácido rosmarínico



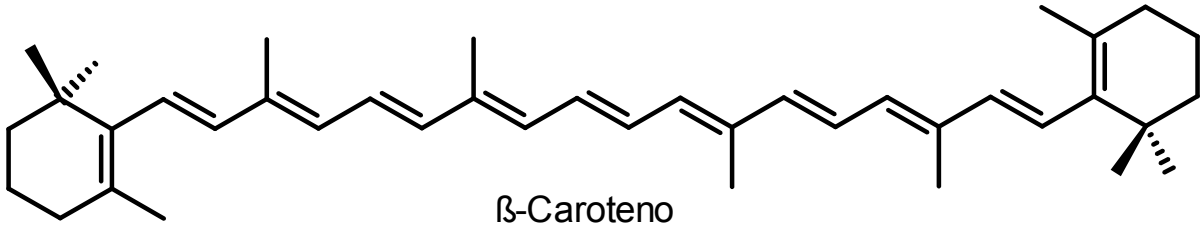
α-farneseno (encontrado en la capa cerosa de la cáscara de manzana)



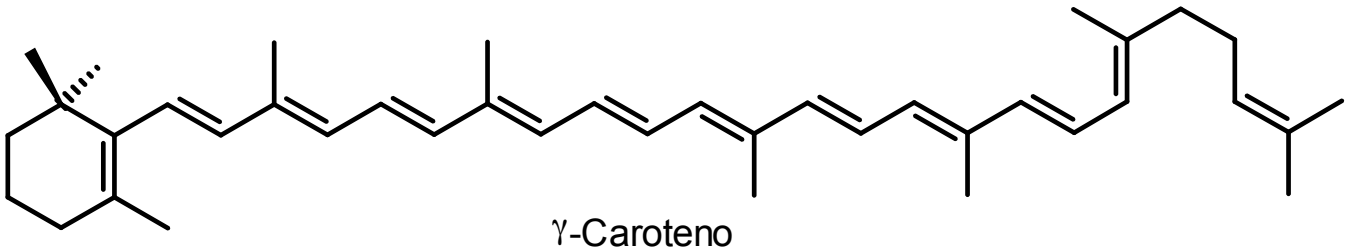
ácido oleico



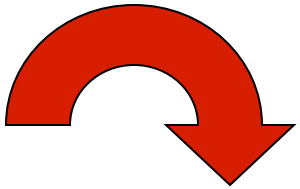
α-Caroteno

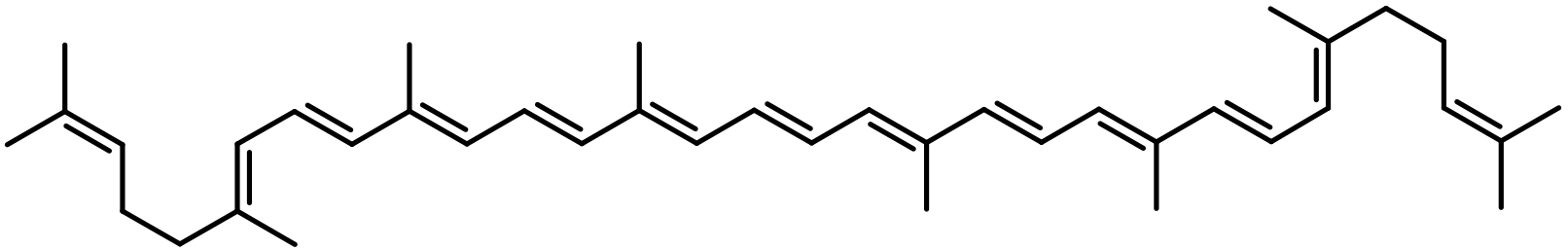


ß-Caroteno



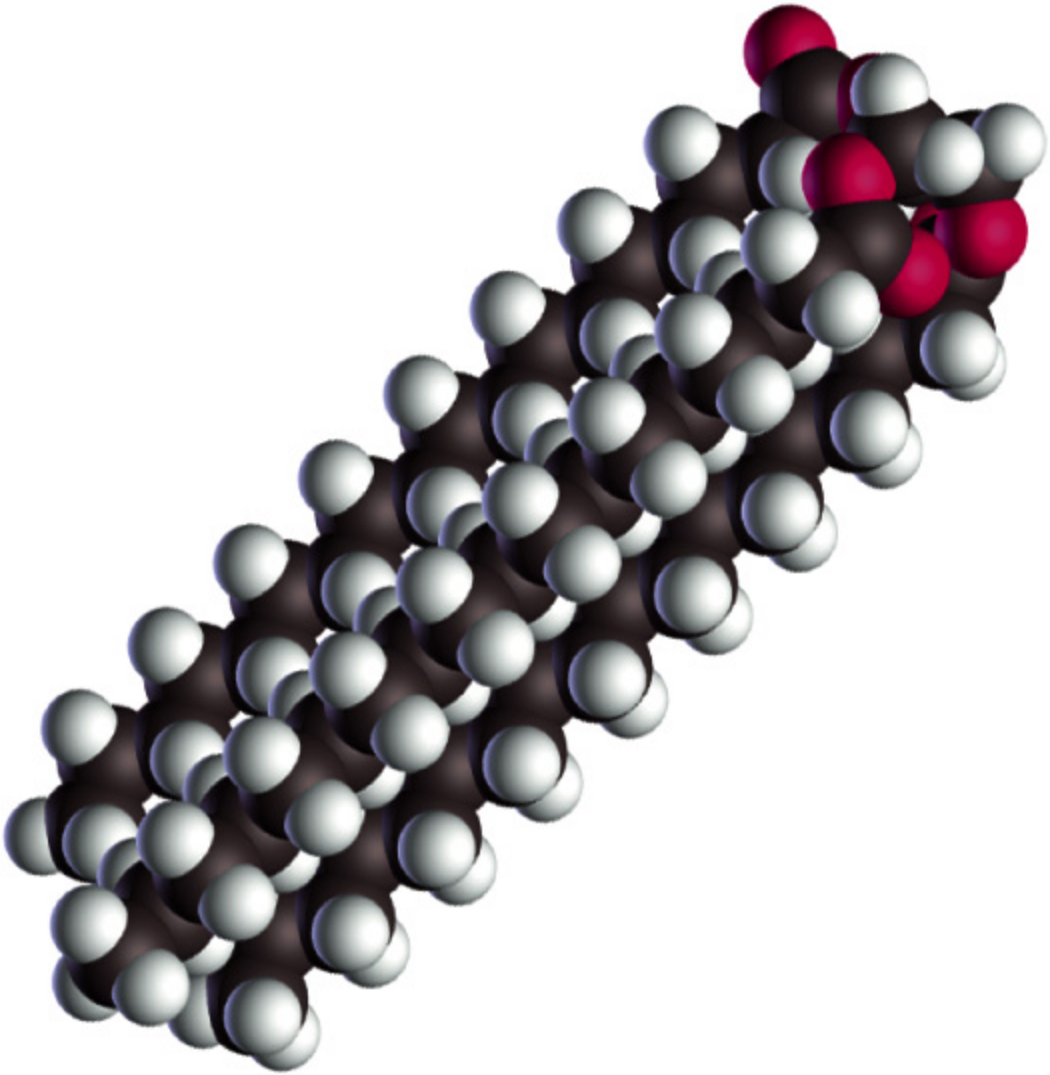
γ-Caroteno





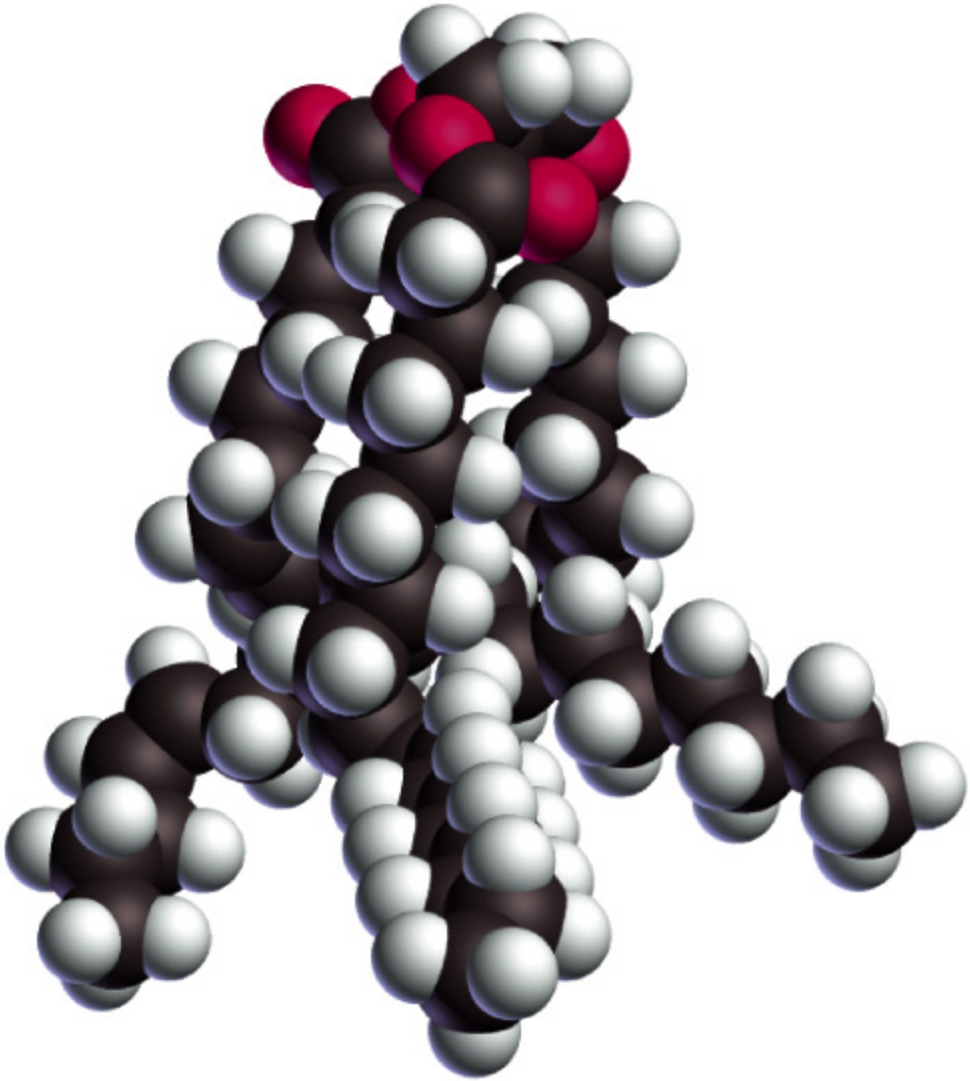
licopeno

Fats are triacylglycerols existing as solid or semisolid state at room temperature



a fat

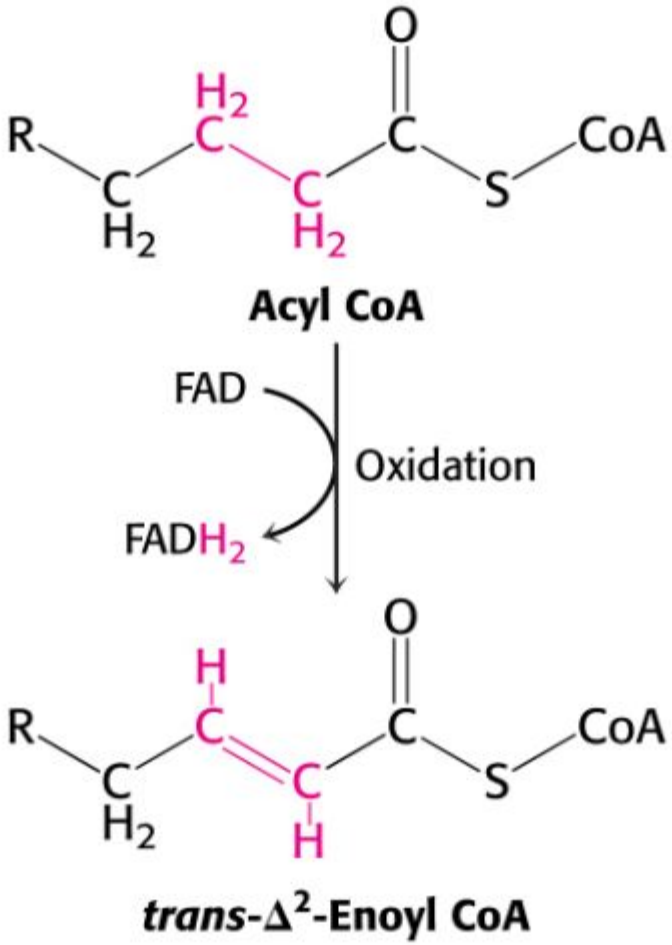
Oils are liquid triacylglycerols

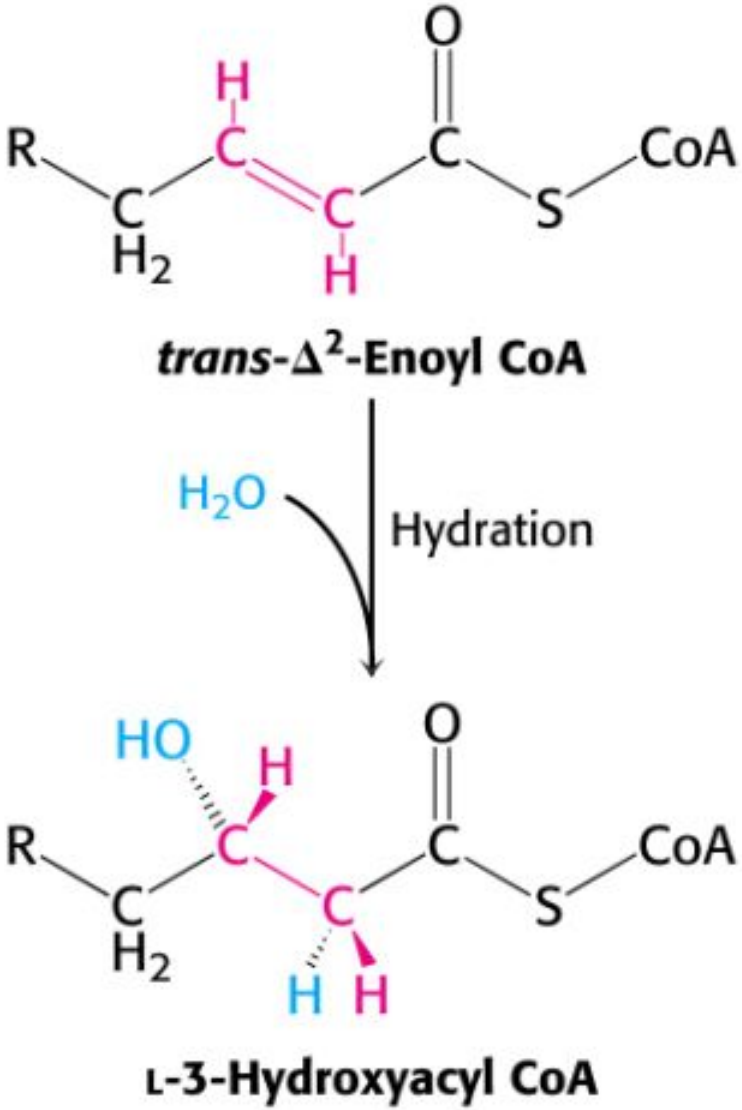


an oil

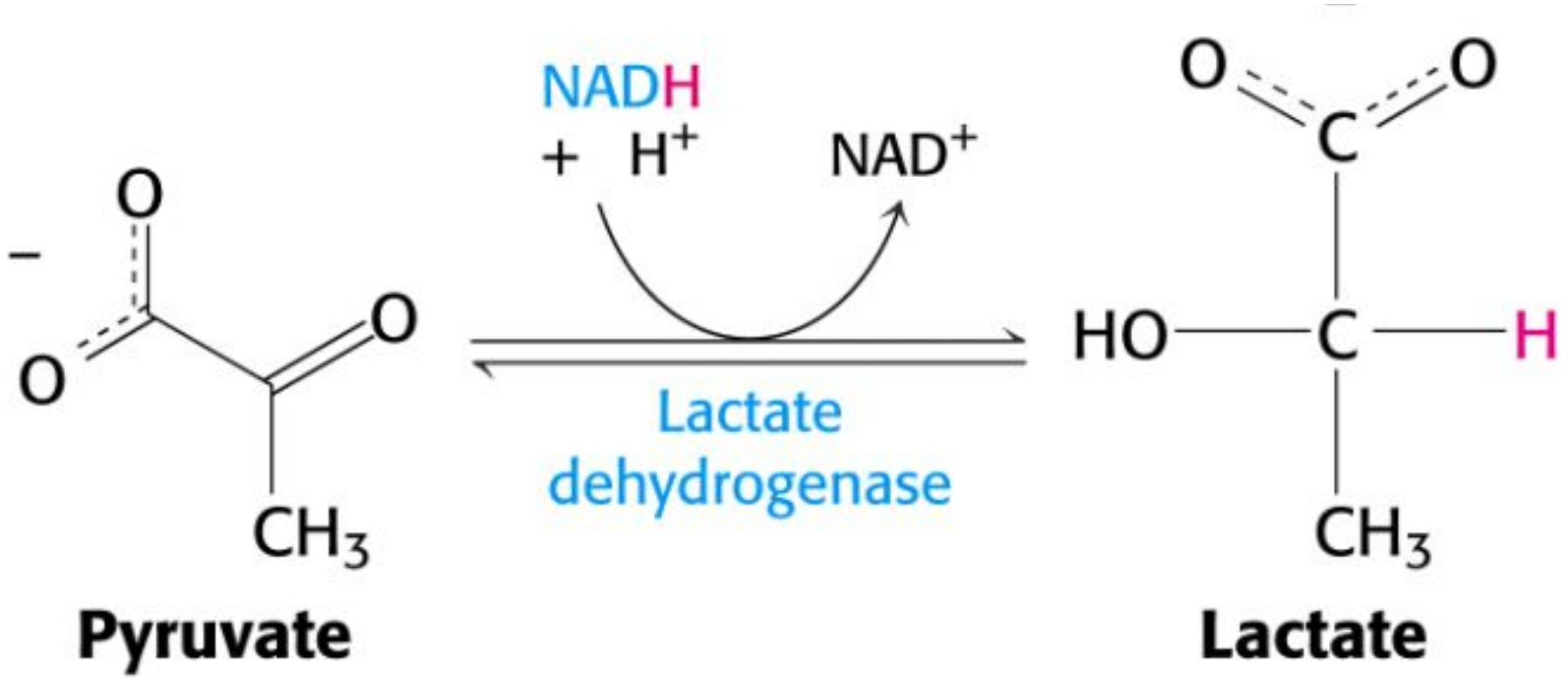
Estereoquímica de las reacciones catalizadas por enzimas

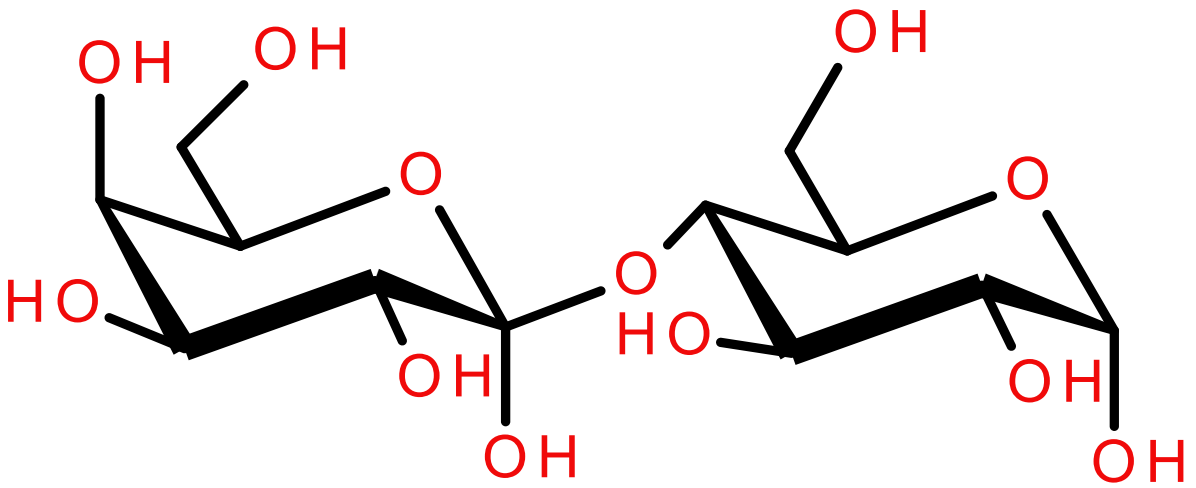
En la oxidación de ácidos grasos (catabolismo)



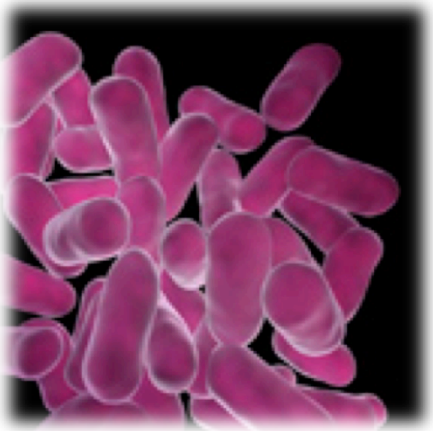

R
H
C
O
C
CoA
C
S
H2
C
H
trans-Δ2-Enoyl CoA
H2O
Hydration
HO
H
R
C
O
C
CoA
C
S
H2
C
H H
L-3-Hydroxyacyl CoA

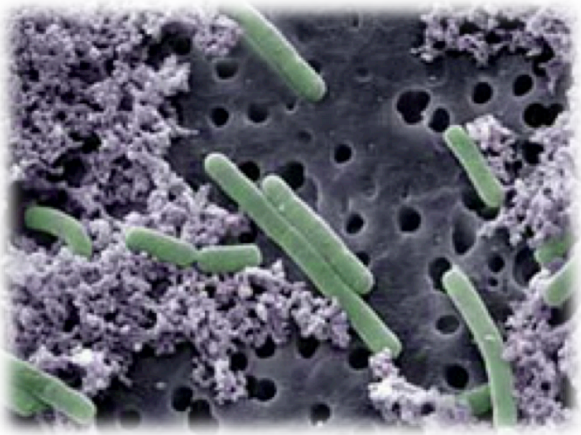
En la fermentación láctica



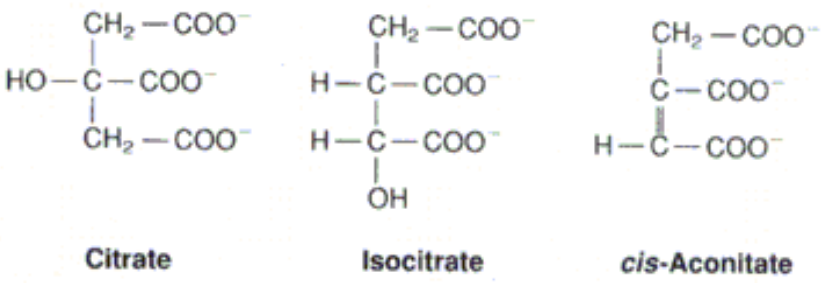


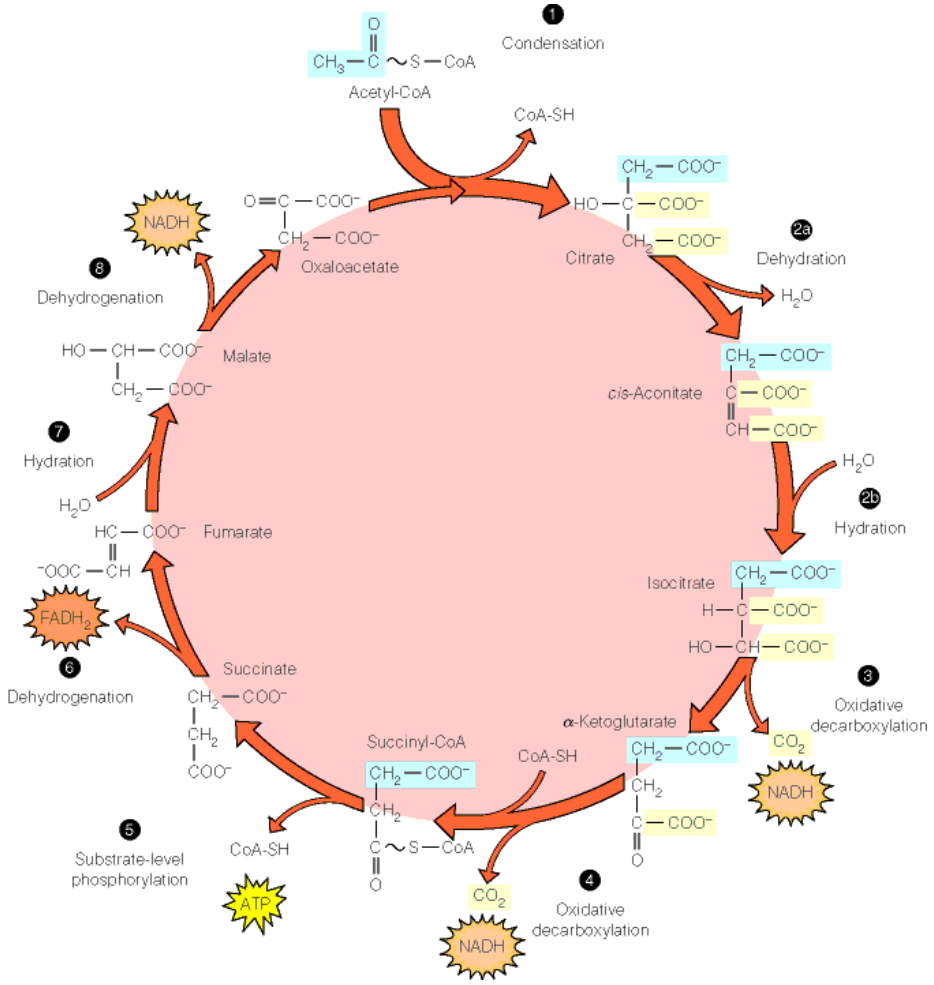
lactosa





Lactobacillus casei

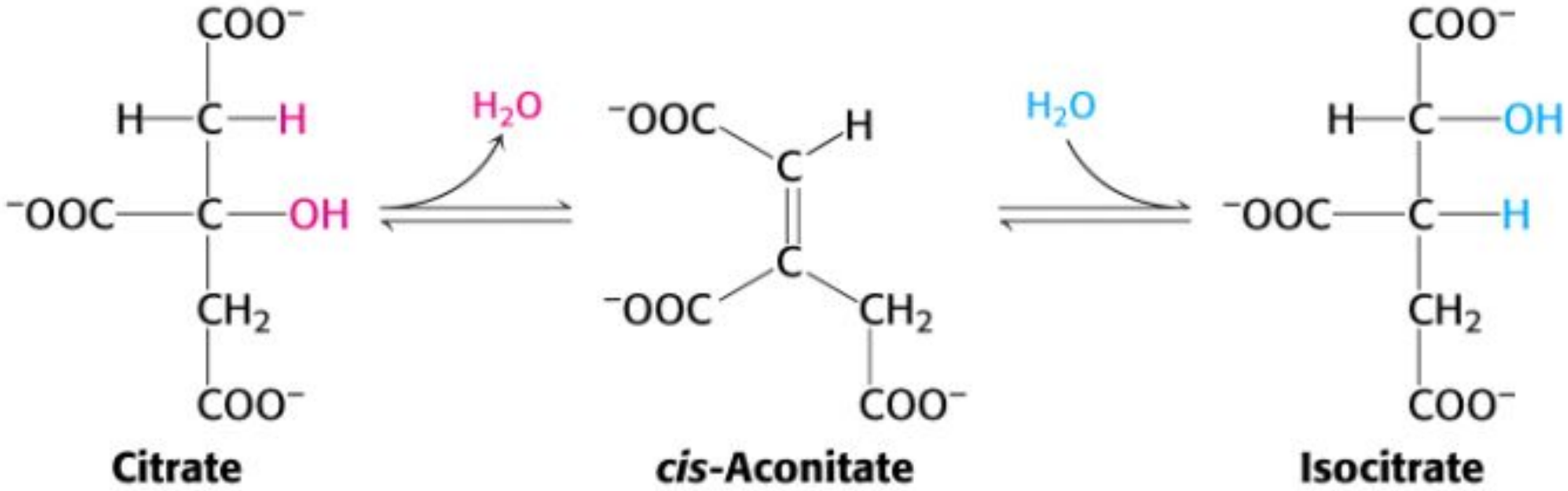




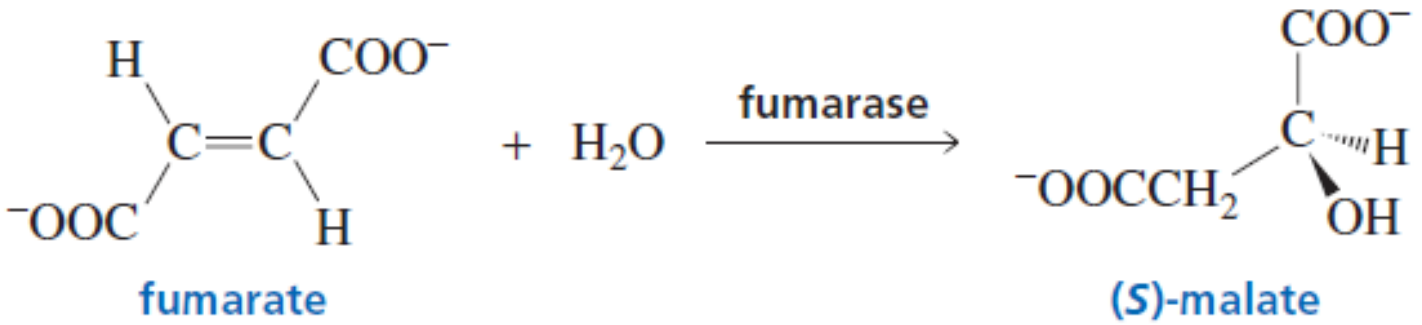
Hans Adolf Krebs

Nobel Prize in Physiology or Medicine 1953

El citrato se isomeriza a isocitrato



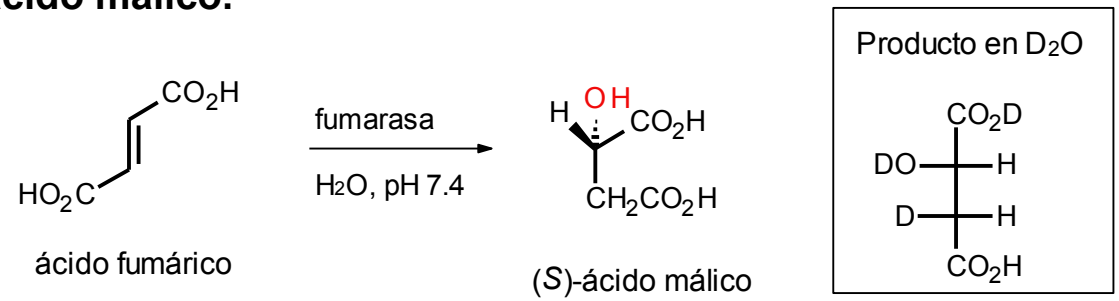
Citrate ***cis*-Aconitate** **Isocitrate**



fumarate

(*S*)-malate

Muchas reacciones catalizadas enzimáticamente son similares a las reacciones que nosotros usamos en síntesis orgánica. Las enzimas tienden a ser estereoespecíficas en sus reacciones, y la inducción asimétrica es común. La reacción siguiente, parte del ciclo de los ácidos tricarboxílicos de la respiración celular, recuerda a las reacciones que hemos estudiado; sin embargo, la reacción catalizada por la enzima da solamente el enantiómero (*S*) del producto, ácido málico.



ácido fumárico

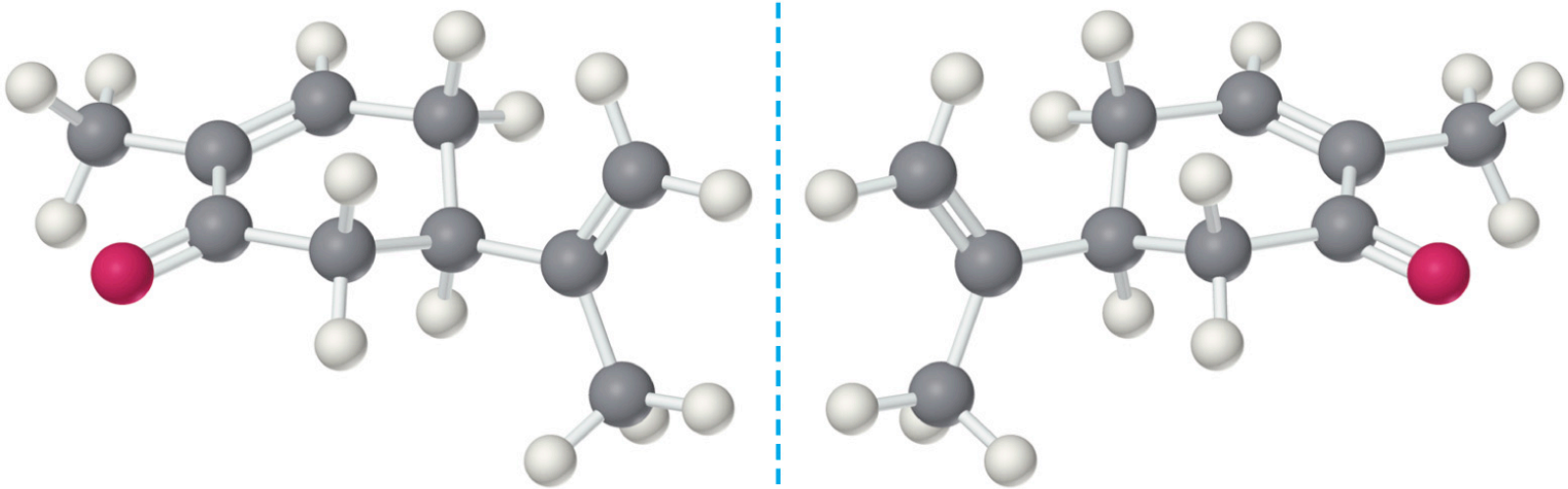
(*S*)-ácido málico

¿Qué tipo de reacción realiza la fumarasa?
¿El ácido fumárico es quiral?
¿El ácido málico es quiral?
¿En la reacción catalizada por la enzima, el producto (ácido málico) es ópticamente activo?
¿Si nosotros llevamos a cabo la reacción en el laboratorio usando ácido sulfúrico como catalizador, podría esperar que el producto (ácido málico) fuese ópticamente activo?
¿Usted espera que la enzima fumarasa sea una molécula quiral?
Cuando la reacción se lleva a cabo en D_2O, *sólo* el producto es el estereoisómero dibujado arriba (en el recuadro) el que se obtiene. No se forma ni el estereoisómero ni el enantiómero.
¿Es la reacción catalizada por la enzima una reacción *syn* o *anti*?

Observar nuevamente algunas moléculas...

Importancia

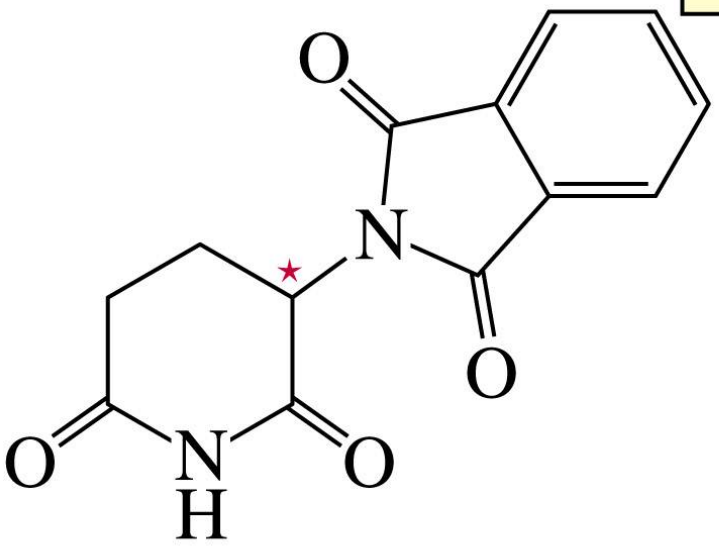
Mirror

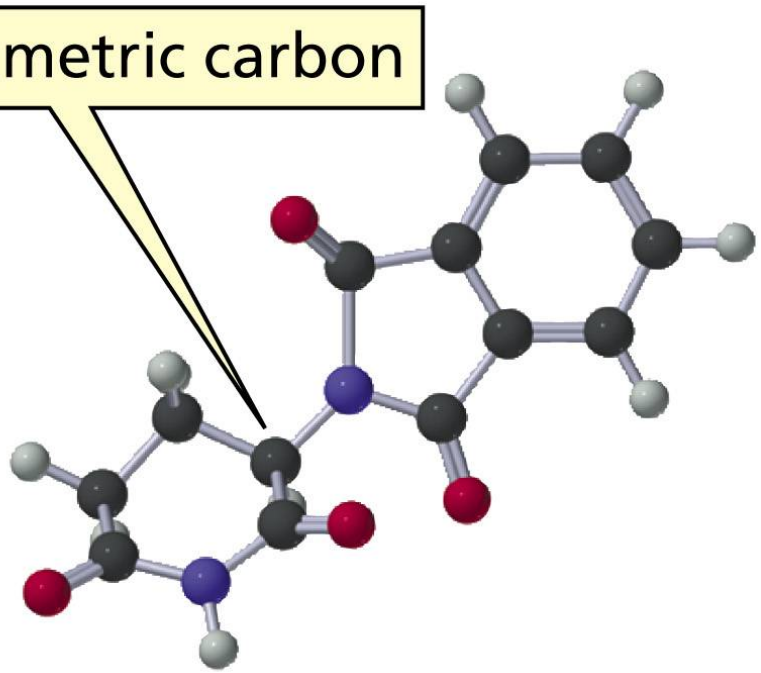


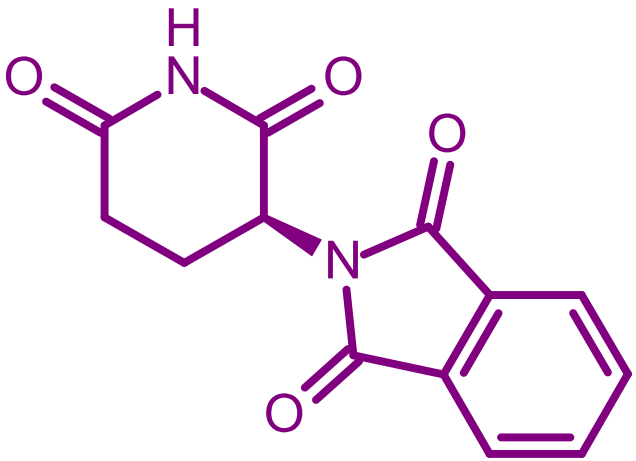
"Left-handed" carvone
(odor of spearmint)

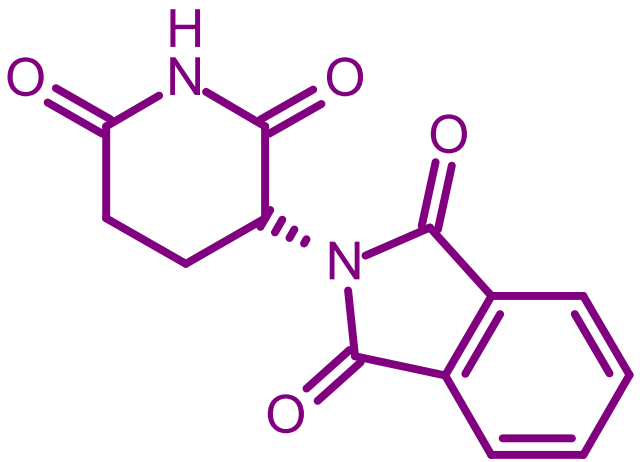
"Right-handed" carvone
(odor of caraway)

Talidomide

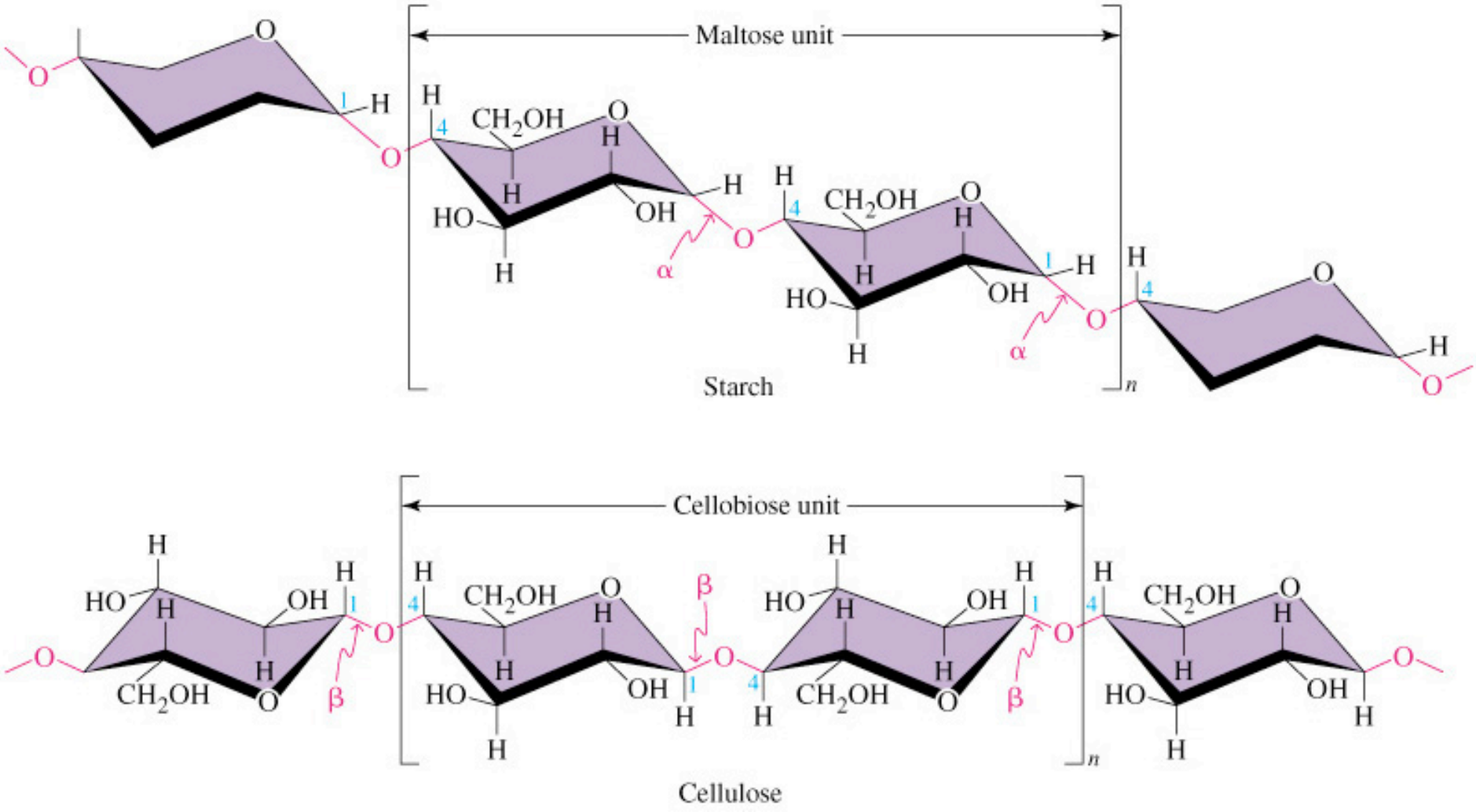




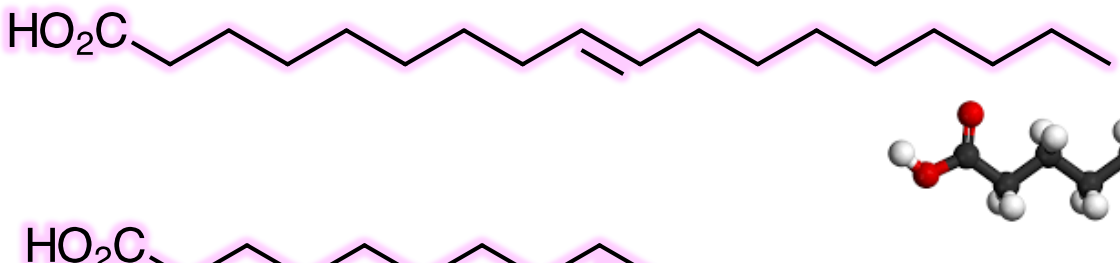


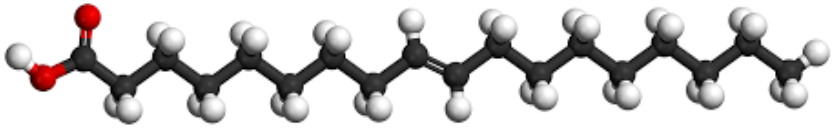


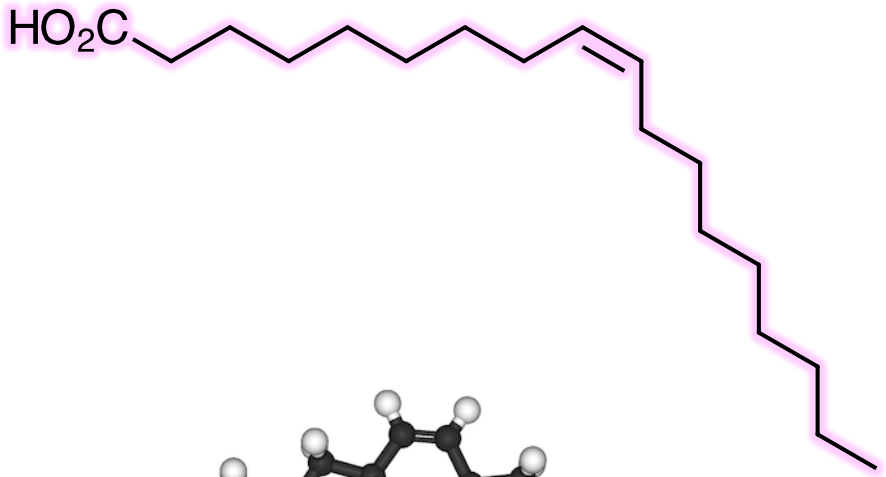
Enzimas glucosidasas α- y β-

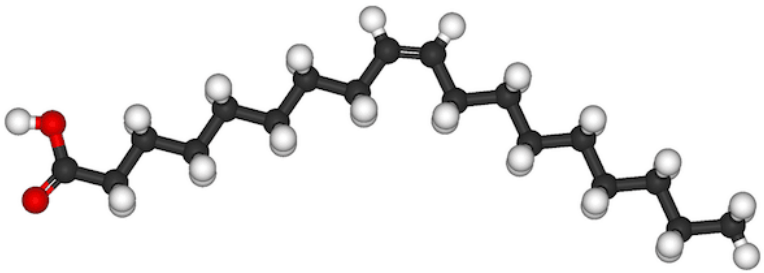


Diet and Heart Disease

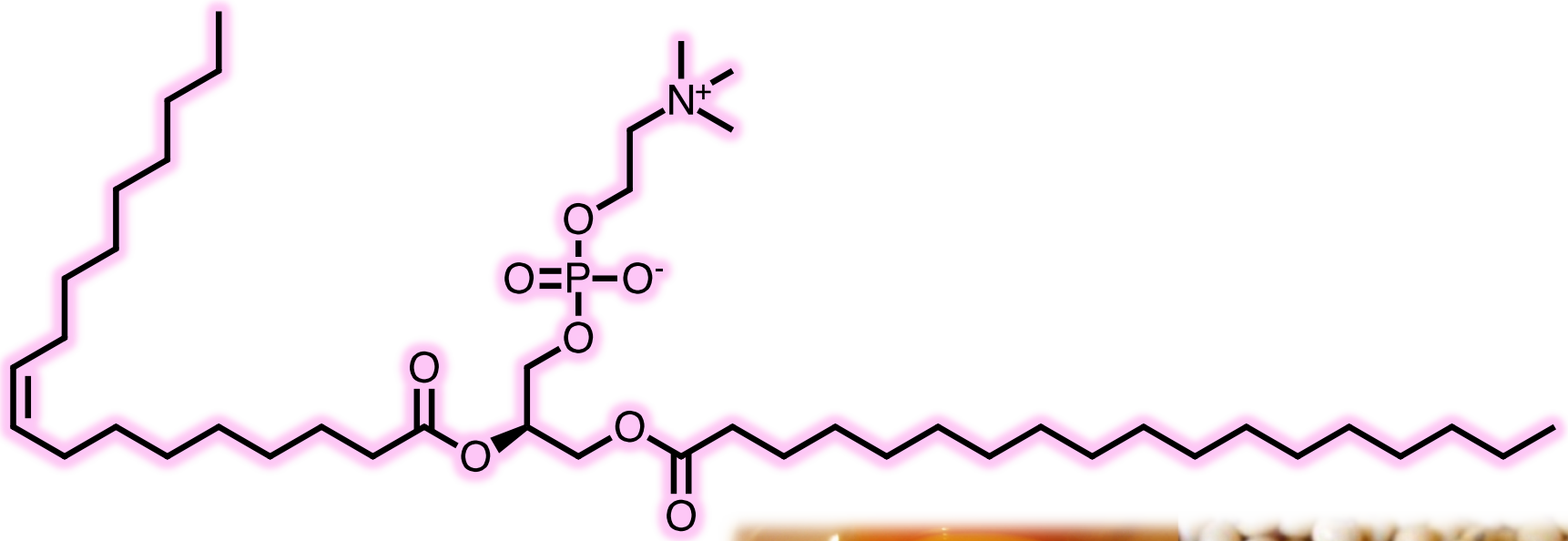








Functional Foods



Lecithin
(Phosphatidylcholine)

Estereoquímica de una reacción