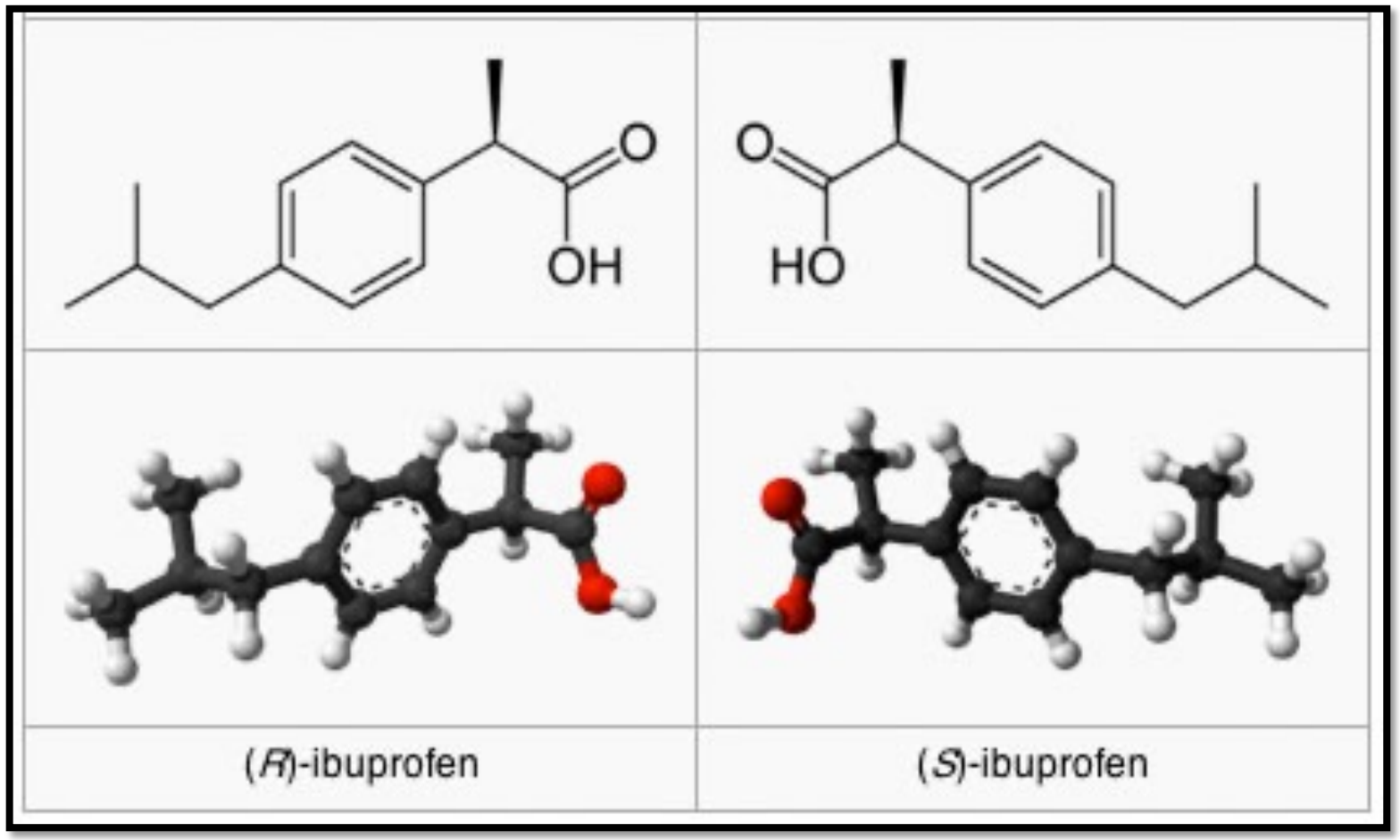
Drug	Effects	Effective Enantiomer	Ineffective Enantiomer
Ibuprofen	Reduces inflammation and pain	 *S*-Ibuprofen	 *R*-Ibuprofen

$C_{13}H_{18}O_2$ $C_{13}H_{18}O_2$



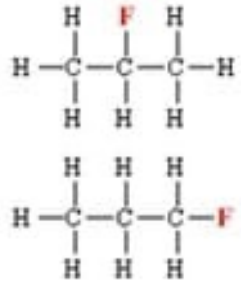
(*R*)-ibuprofen (*S*)-ibuprofen

Isomers

- Same molecular formula.
- Different structures and properties.

Constitutional (structural) isomers

- Different connectivities.



Stereoisomers (spatial isomers)

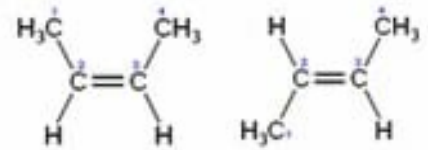
- Similar connectivity.
- Different spatial arrangements.

Diastereomers

- Not mirror images

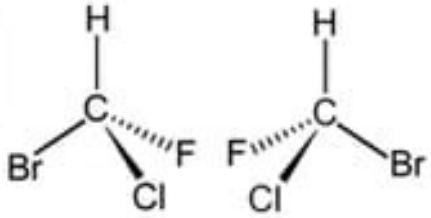
e.g.

Cis-trans isomers



Enantiomers

- Mirror image
- Non-superimposable

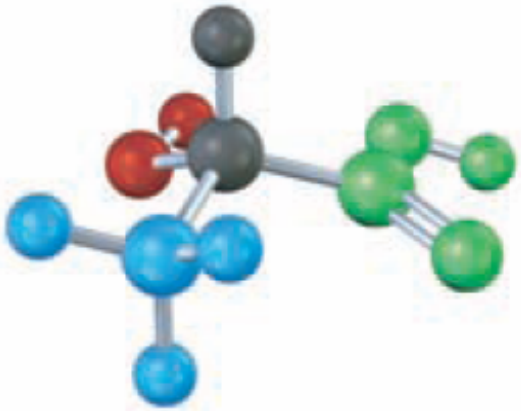


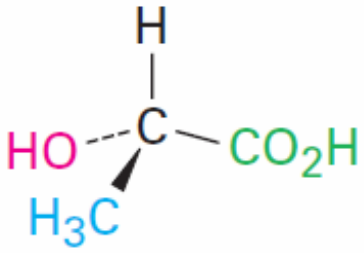
Enantiomers

- ✓Mirror image
- ✓Non-superimposable

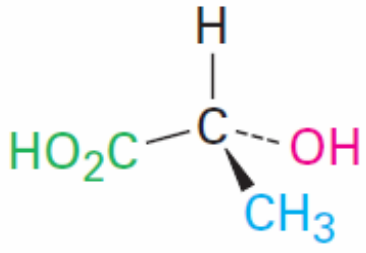
2-hydroxypropanoic acid

(Aka lactic acid!)

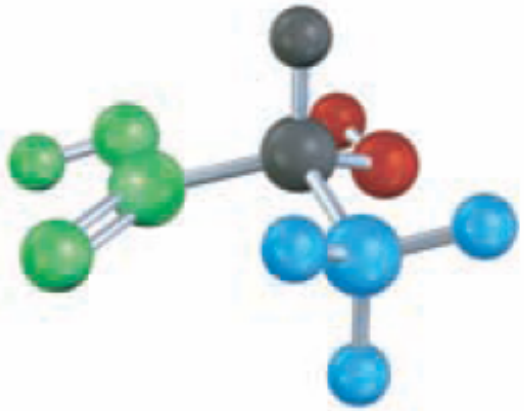




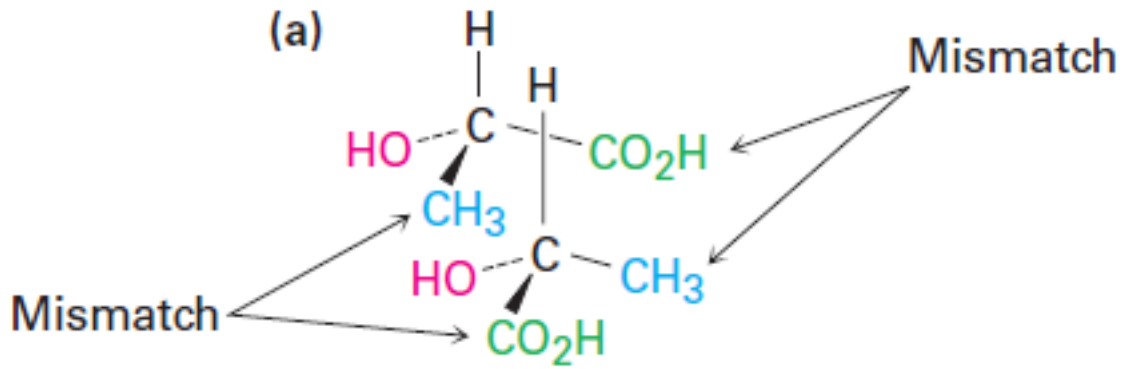
Lactic acid

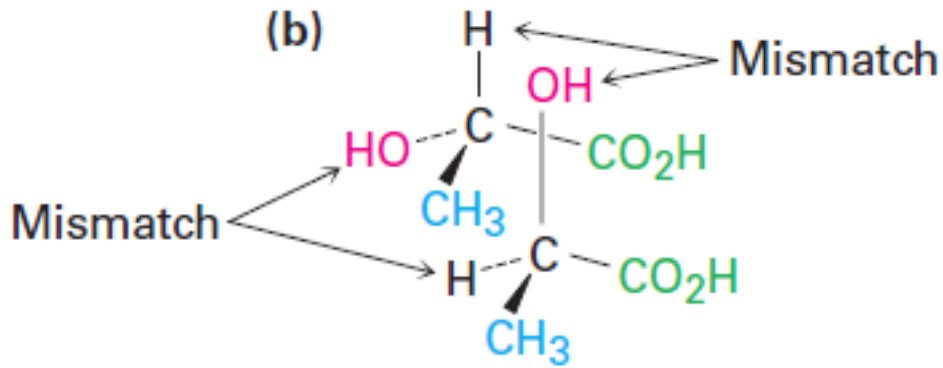


Lactic acid



Connectivity	Similar
Mirror image	Yes
Superimposable	?



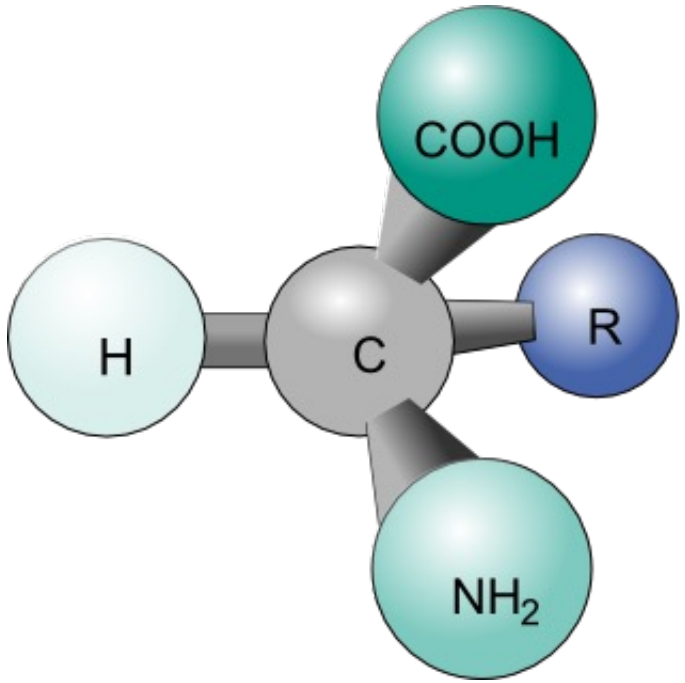


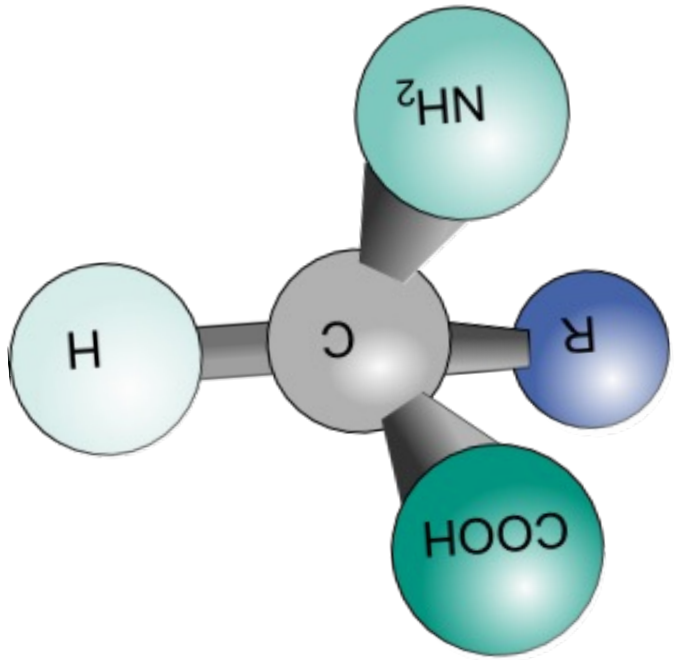
Connectivity	Similar
Mirror image	Yes
Superimposable	No

Molecules that are not identical to their mirror images are kinds of stereoisomers called

Enantiomers

(Greek *enantio,* meaning "opposite")

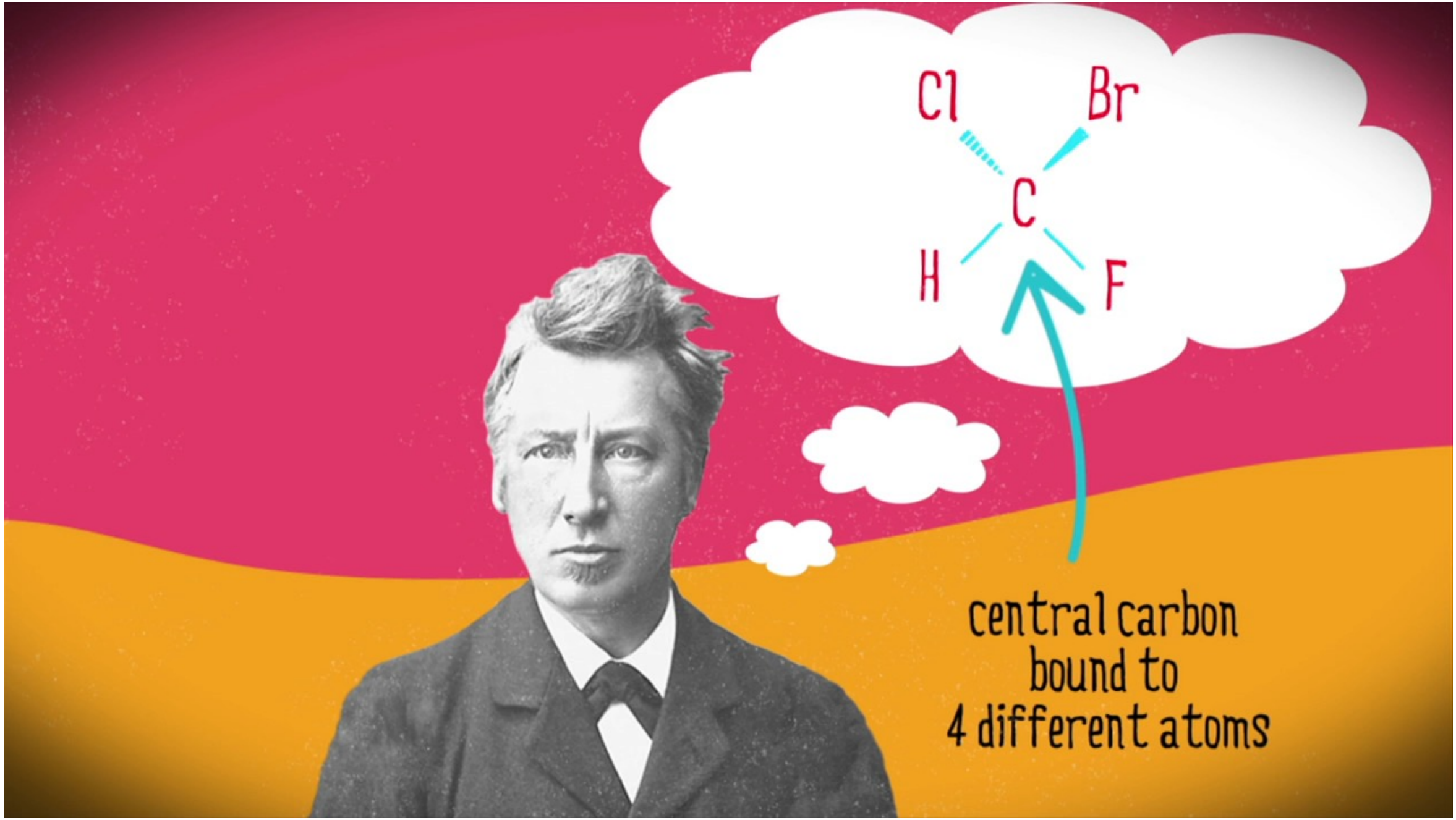

COOH
H
C
R
NH2

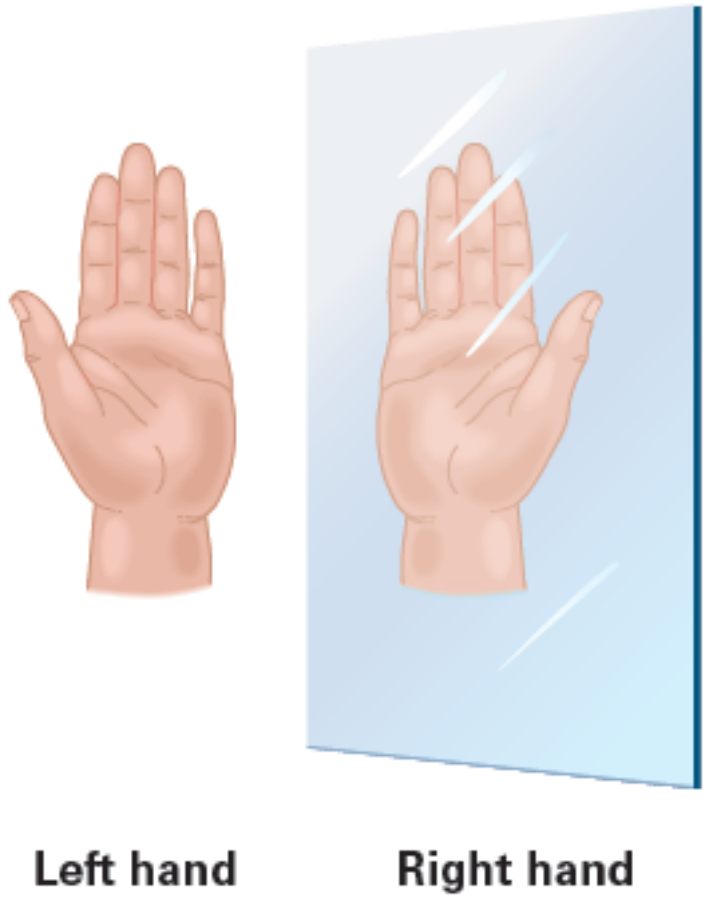

NH2
H
C
R
COOH

But there are some questions...

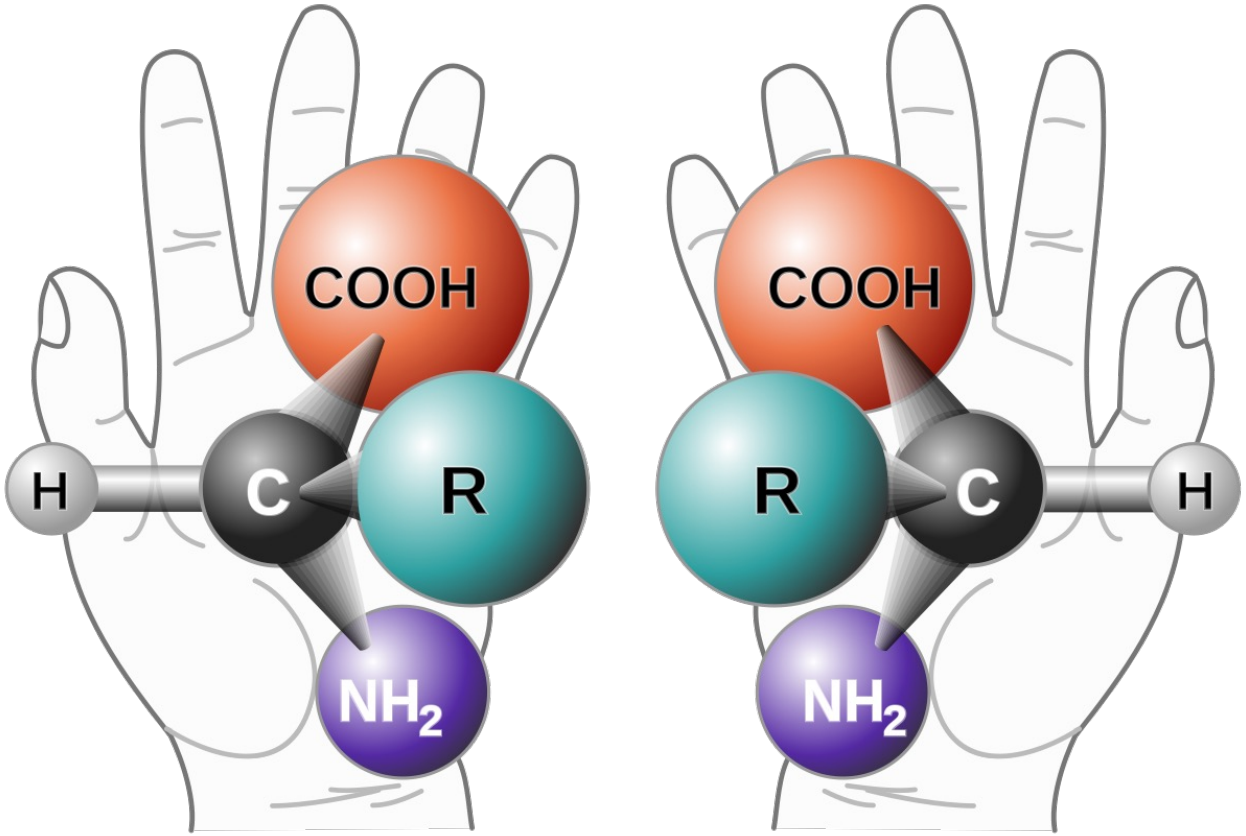
- Do all the molecules have enantiomers?
- What kind of molecules can be enantiomers?


Chirality


Cl
Br
C
H
F
central carbon
bound to
4 different atoms

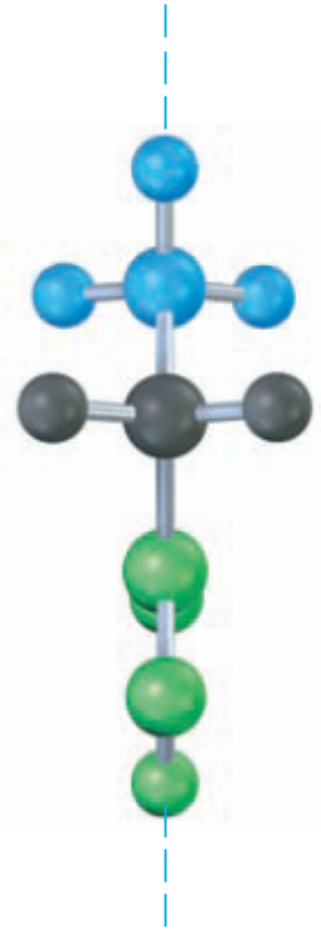


Our hands aren't identical; rather, they're nonsuperimposable *mirror images*.

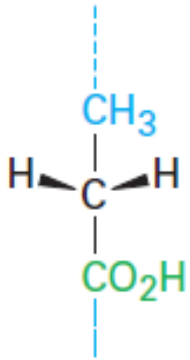


A molecule that is not identical(non-superimposable) to its mirror image is said to be **chiral.**
(**ky**-ral,from the Greek *cheir,* meaning "hand").

A molecule is **not chiral (achiral)** if it has a plane of symmetry



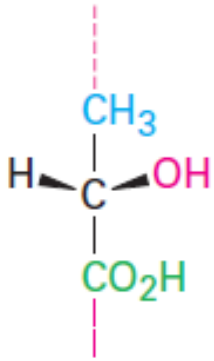
Symmetry plane

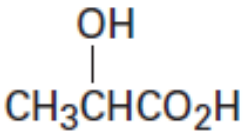


$CH_3CH_2CO_2H$

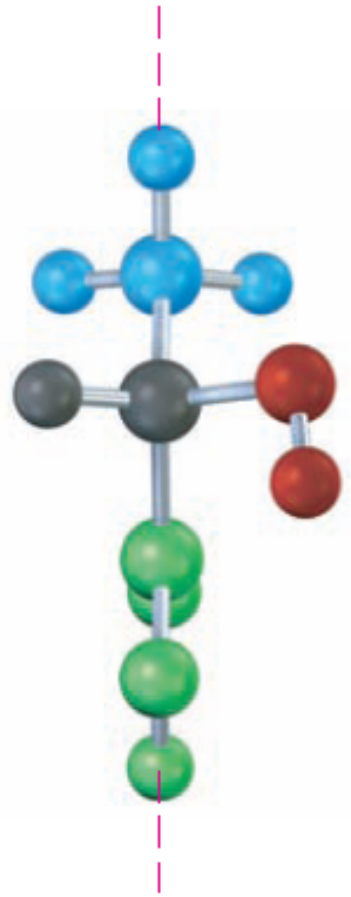
Propanoic acid (achiral)

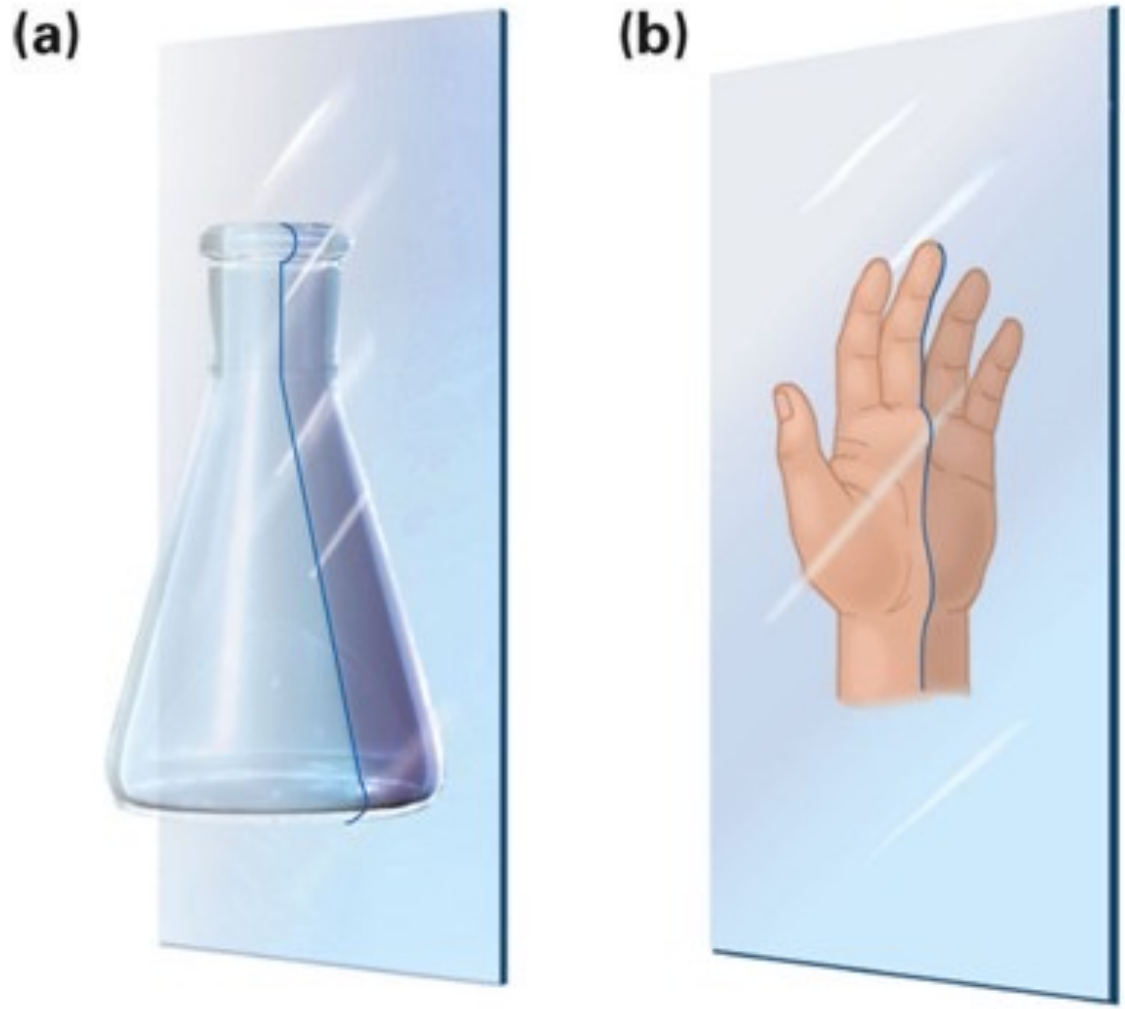
Not symmetry plane

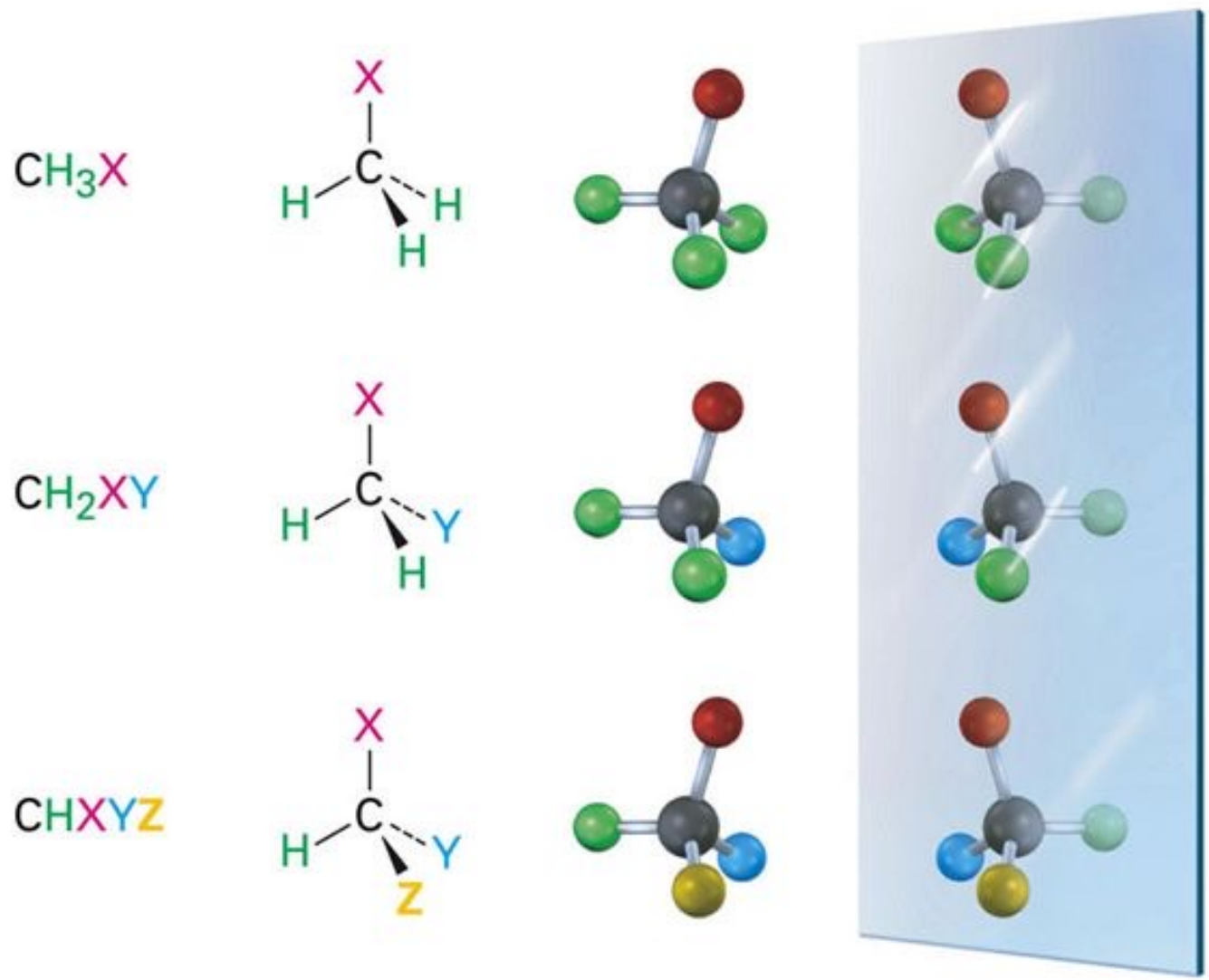


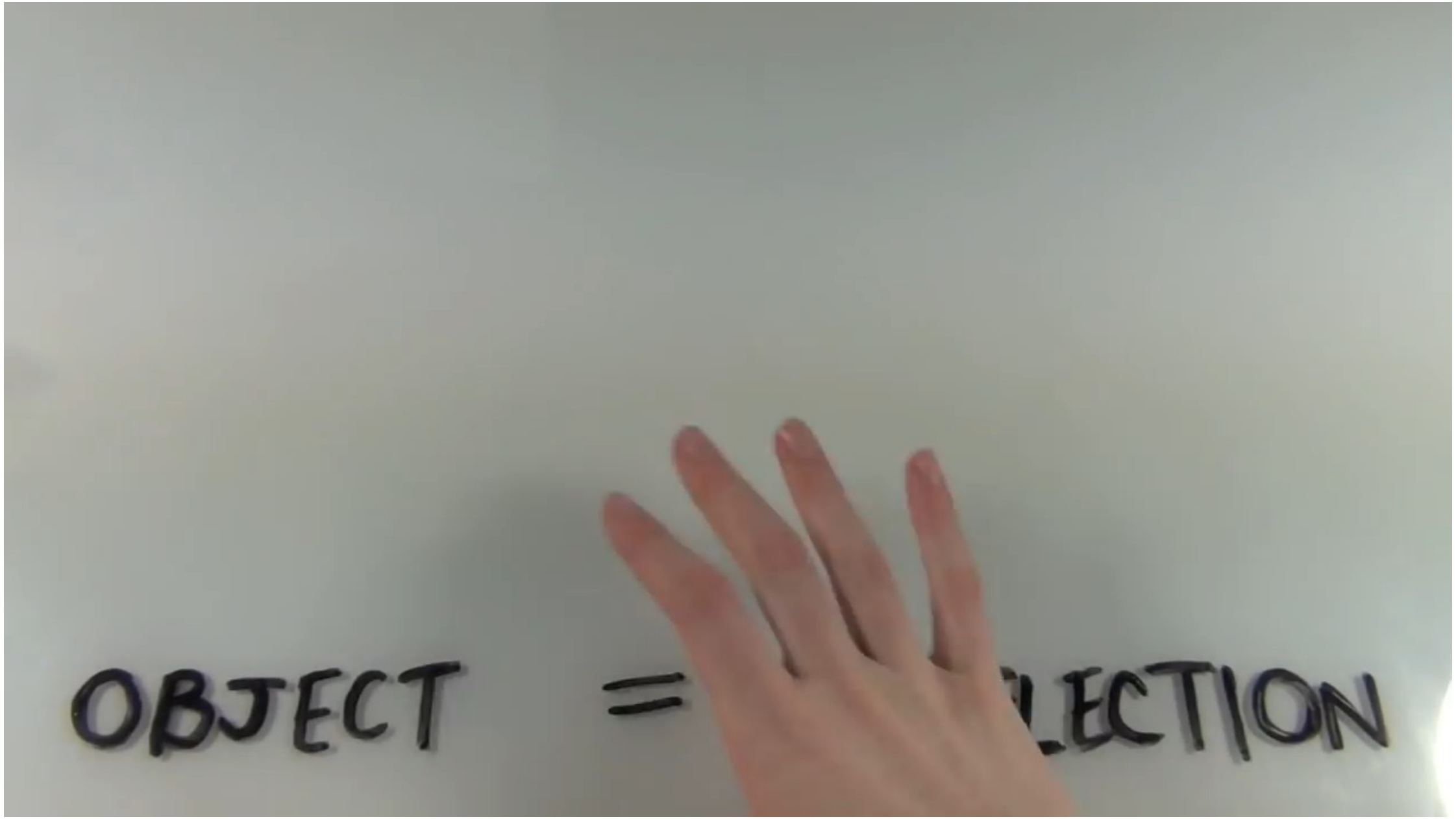


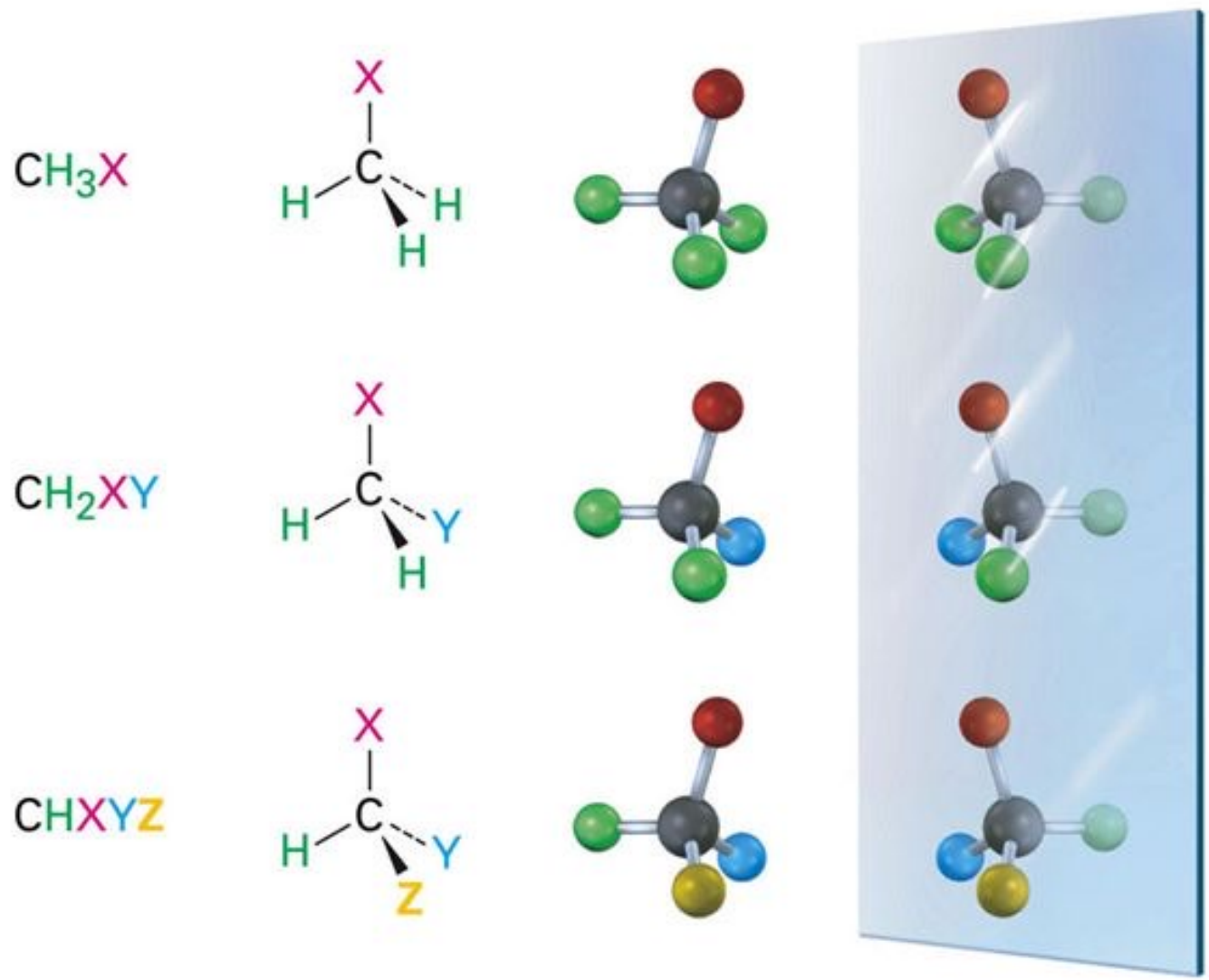
Lactic acid (chiral)




(a)
(b)


CH3X
X
H
C
H
H
CH2XY
X
H
C
Y
H
CHXYZ
X
H
C
Y
Z

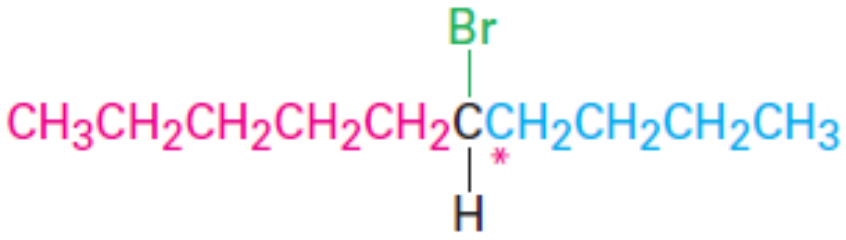

OBJECT
=
LECTION


CH3X
X
H
C
H
H
CH2XY
X
H
C
Y
H
CHXYZ
X
H
C
Y
Z

Chirality Center

(stereocenter, asymmetric center, stereogenic center)

- Tetrahedral carbon atom bonded to four different groups



5-Bromodecane (chiral)

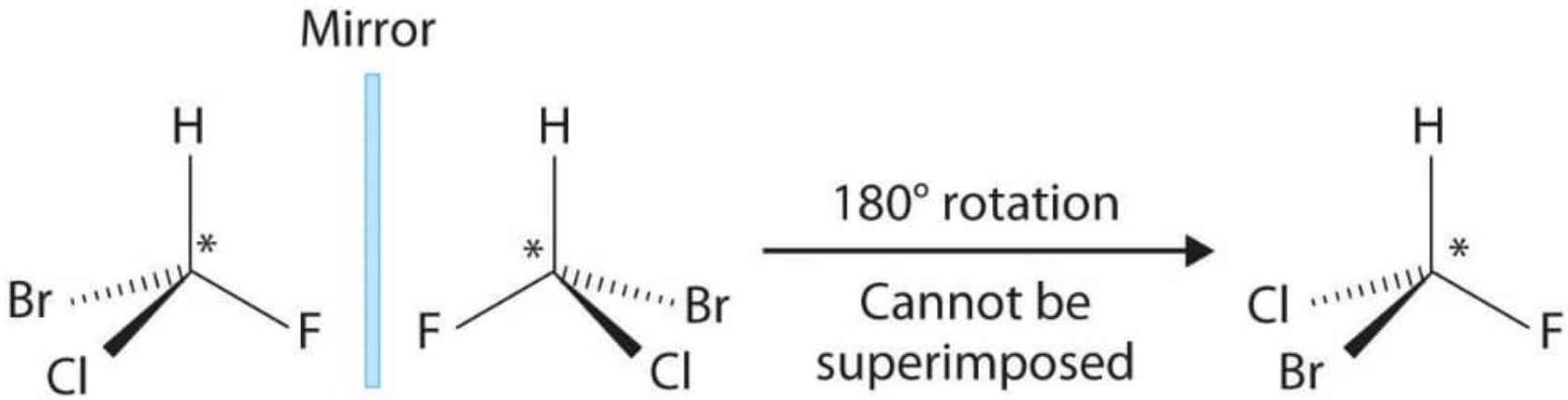
Substituents on carbon 5

—H

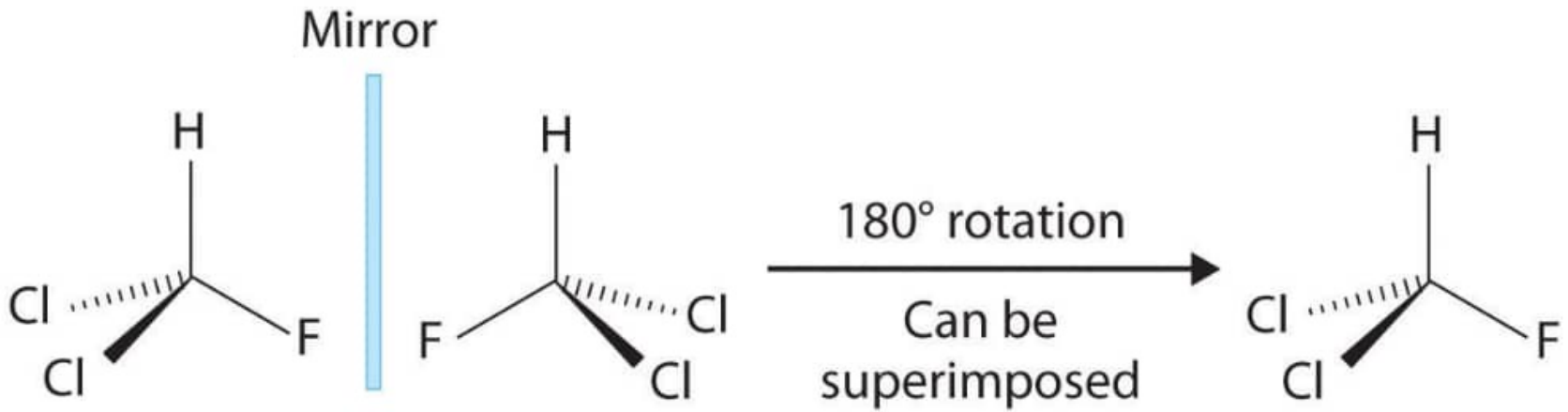
—Br

—$CH_2CH_2CH_2CH_3$ (butyl)

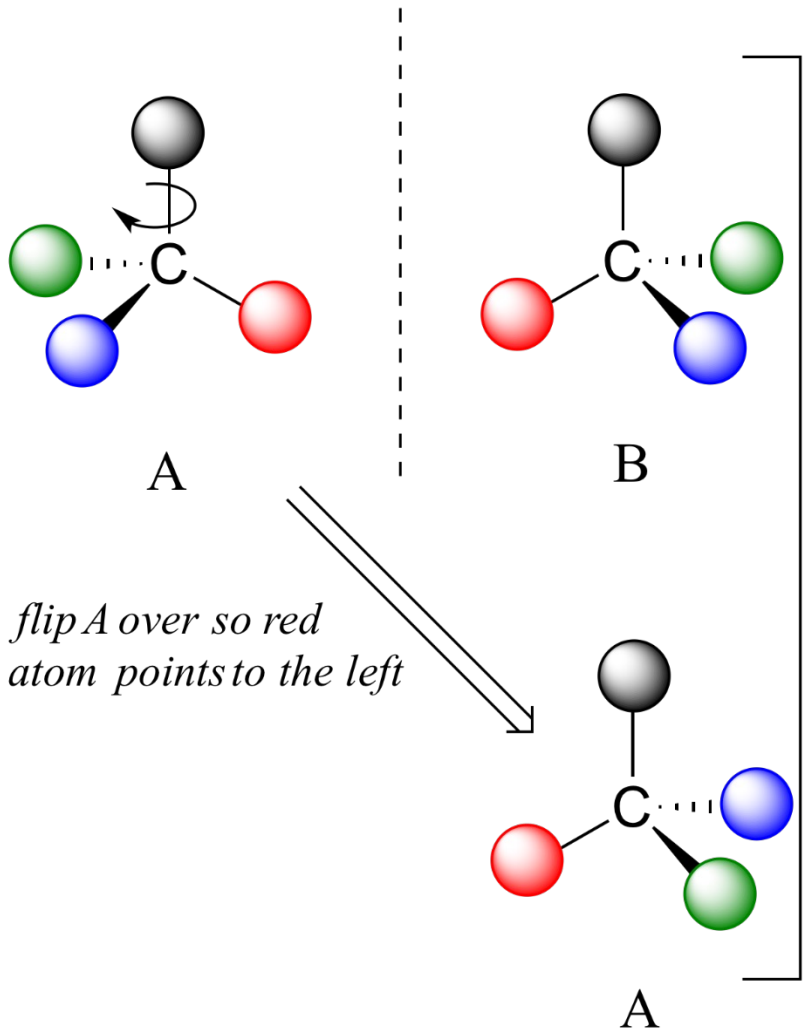
—$CH_2CH_2CH_2CH_2CH_3$ (pentyl)

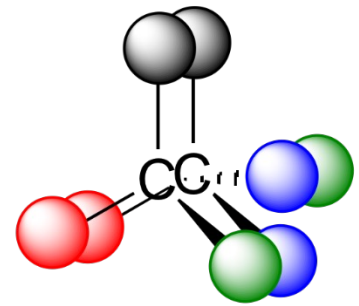


(a) Bromochlorofluoromethane

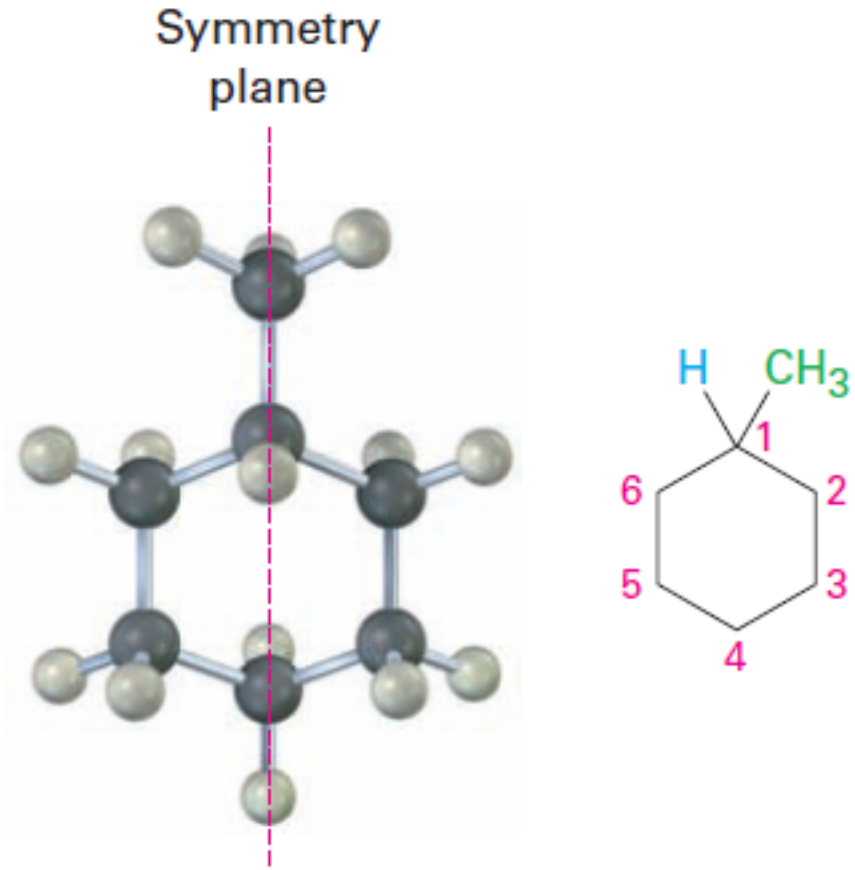


(b) Dichlorofluoromethane

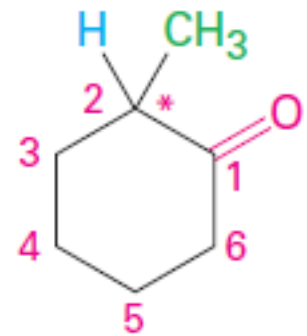


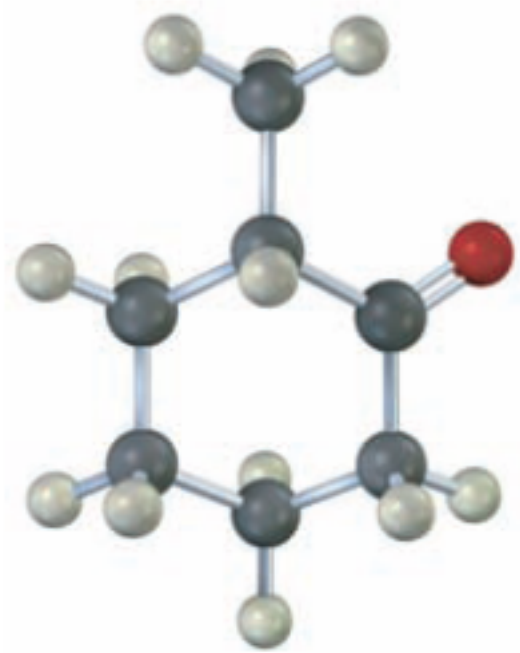


*A and B cannot be superimposed: they are **not** the same molecule!*



Methylcyclohexane
(achiral)





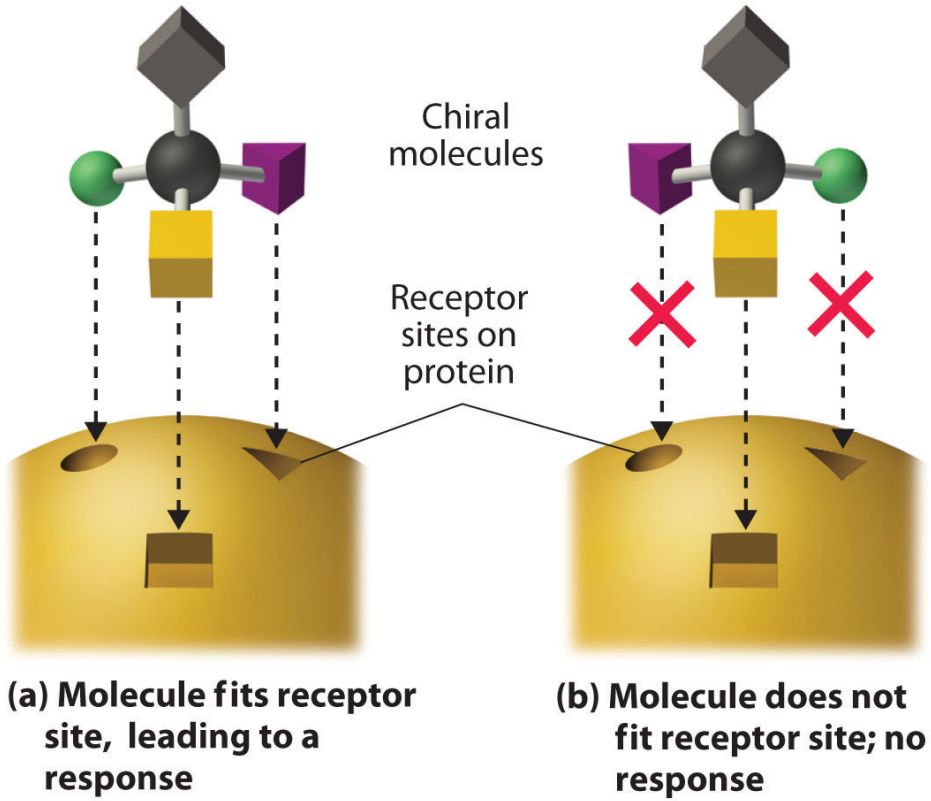
2-Methylcyclohexanone
(chiral)

So…

- The existence of enantiomers are determined by a concept known as ***chirality.***
- The mirror image of a ***chiral*** molecule (one without a plane of symmetry) is its isomer called ***Enantiomers***.

Now what?

Enzymes in our body often distinguish between the two enantiomers of a chiral substance.



Stereochemical Configuration

Cahn-Ingold-Prelog
Rules

Rule 1

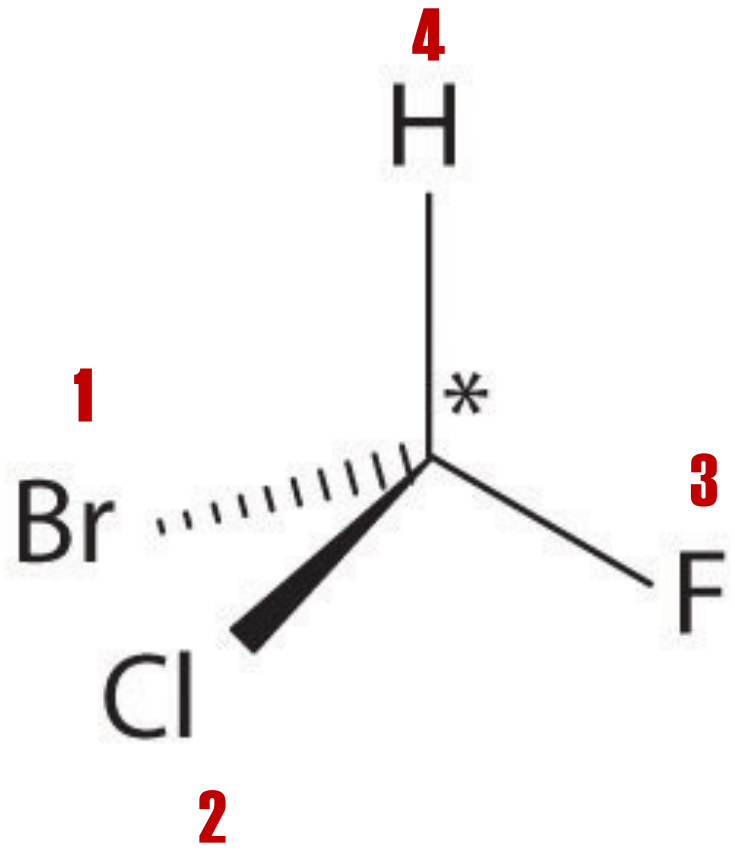
Look at the four atoms directly attached to the chirality center

Now rank them according to atomic number.

Higher atomic number → higher priority → 1

Atomic number	35		17		16		15		8		7		6	(2)	(1)
Higher ranking	Br	>	Cl	>	S	>	P	>	O	>	N	>	C	> ^{2}H	> ^{1}H	**Lower ranking**

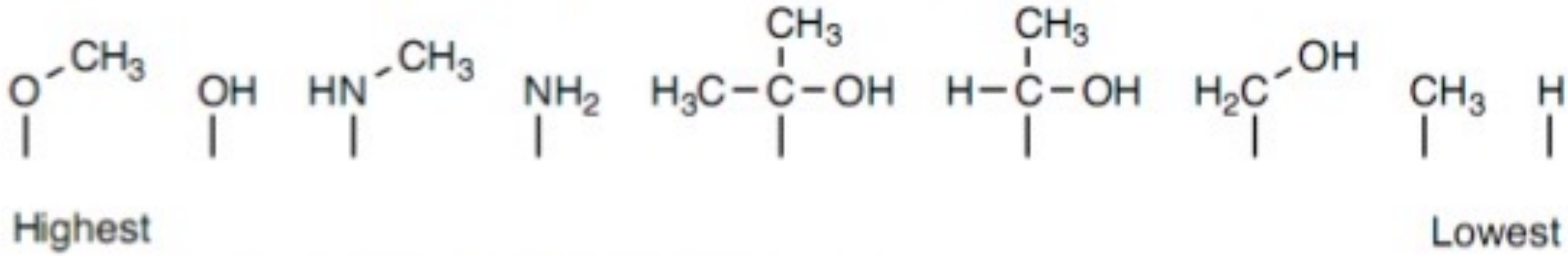
Bromochlorofluoromethane

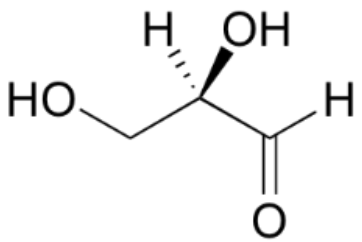


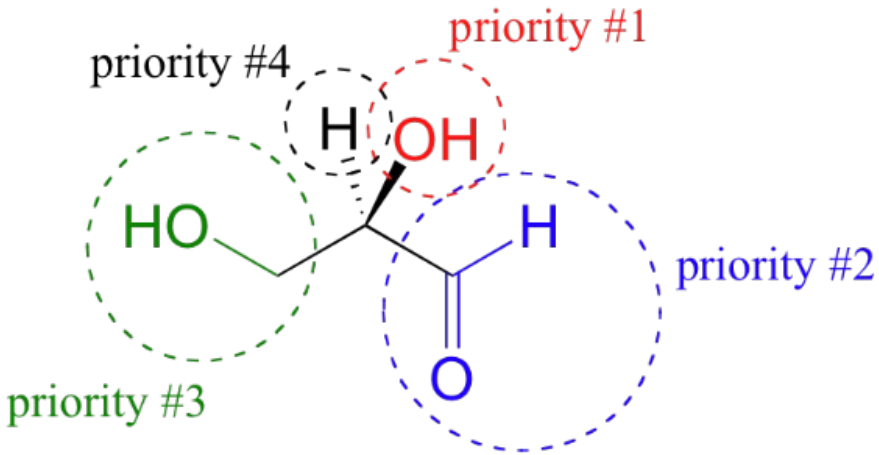
9	19.0
F	
Fluorine	
17	35.5
Cl	
Chlorine	
35	79.9
Br	
Bromine	
53	126.9
I	
Iodine	
85	210
At	
Astetine	

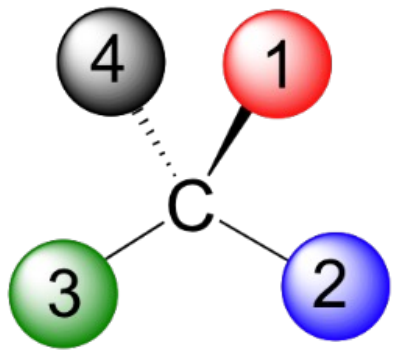
Rule 2

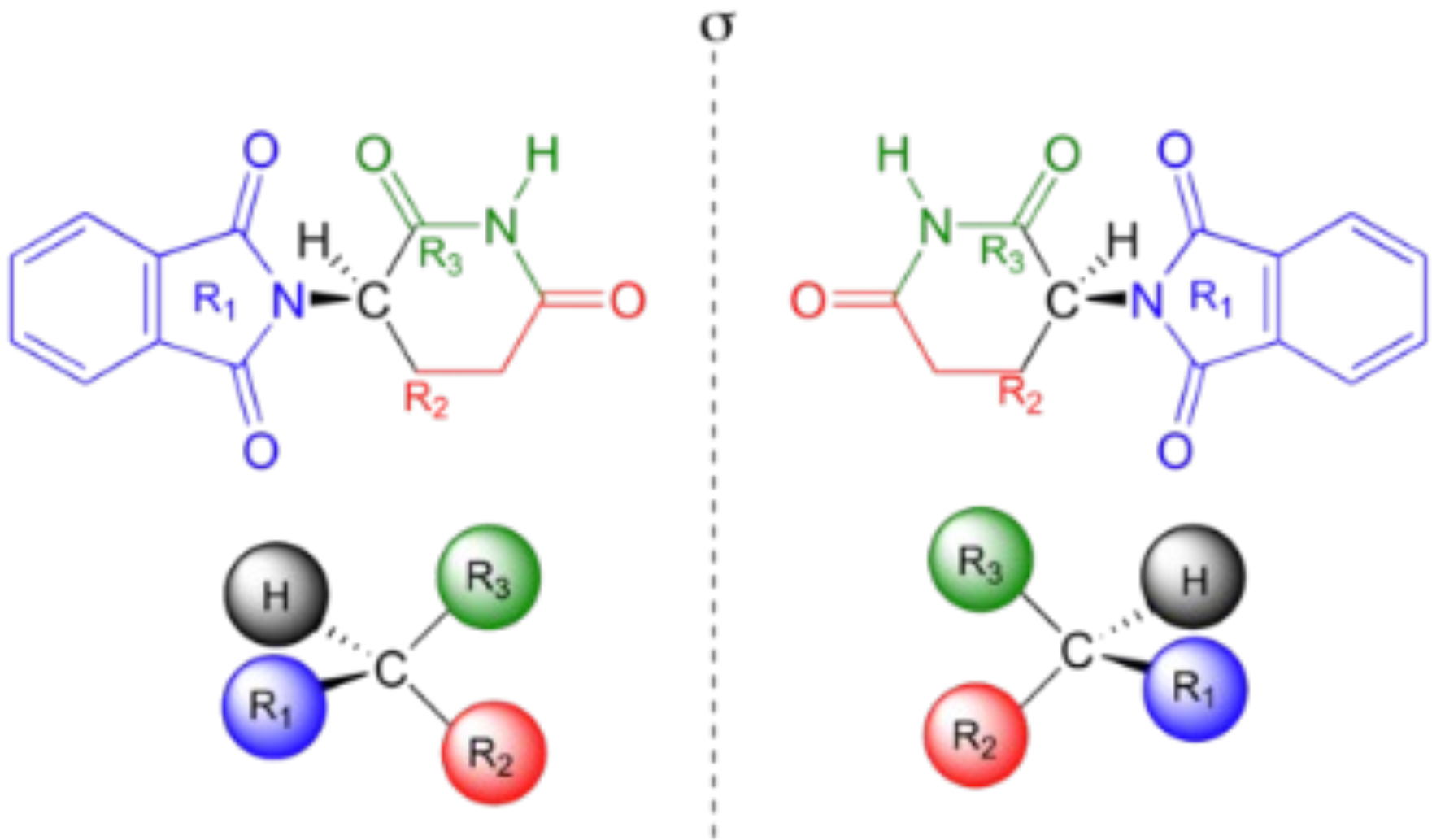
If a decision can't be reached by ranking the first atoms in the substituent, look at the second, third, or fourth atoms away from the chirality center until the **first** difference is found.

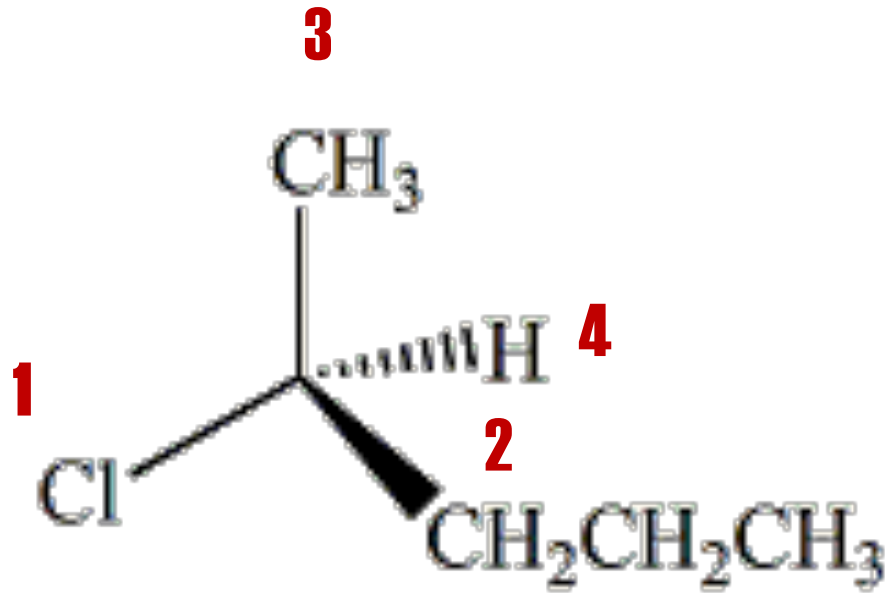

Highest
Lowest




priority #1
priority #4
priority #2
priority #3

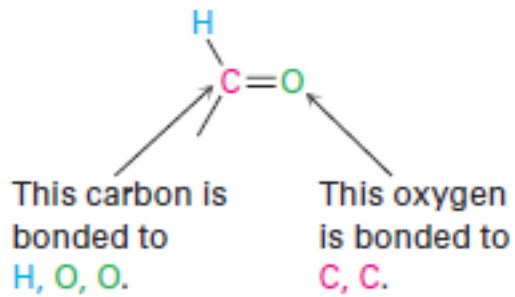

4
1
C
3
2


σ
O
O
H
H
N
R3
R1
N
C
O
R2
O
H
N
O
R3
H
C
N
R1
O
R2
O
H
R3
C
R1
R2
R3
H
C
R1
R2

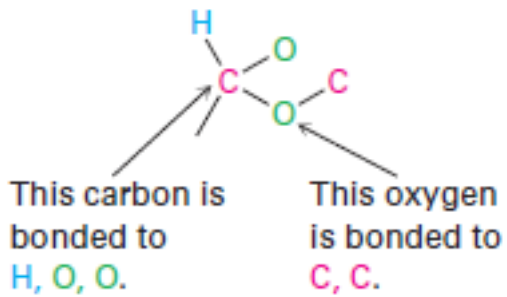

3
CH3
H
4
1
2
Cl
CH2CH2CH3

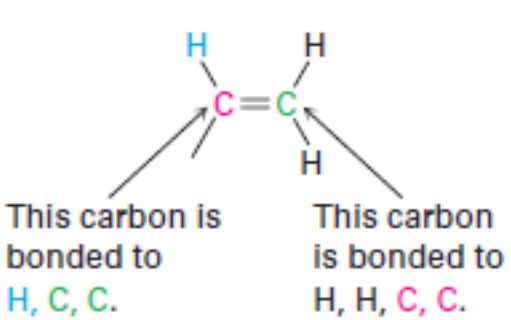
Rule 3

Multiple-bonded atoms are equivalent to the same number of single-bonded atoms.

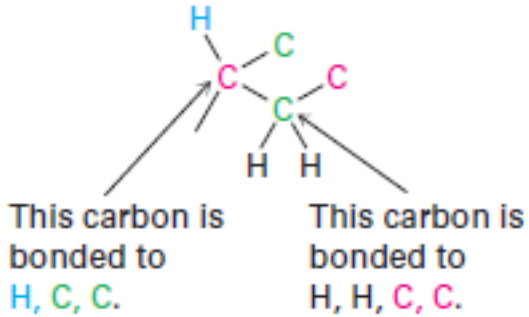


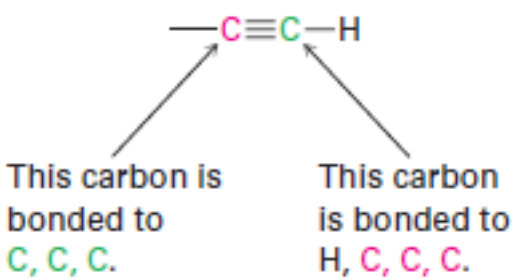
is equivalent to



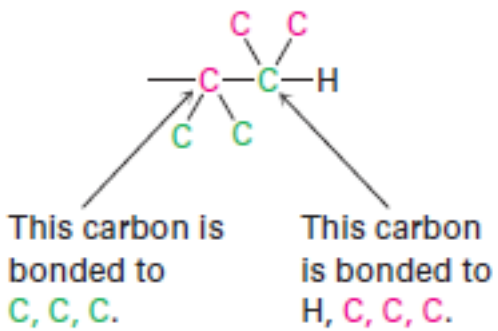


is equivalent to

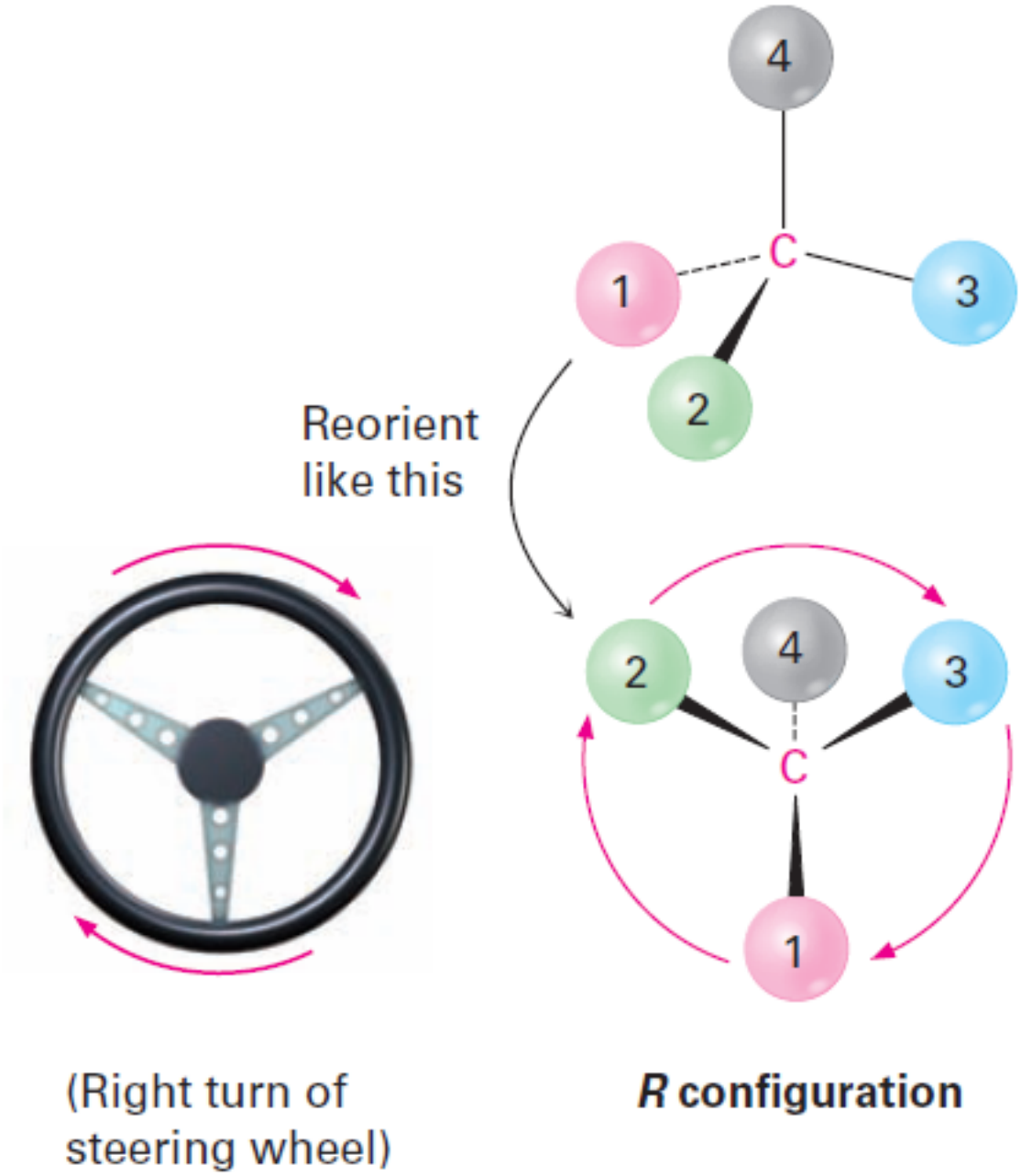




is equivalent to



If a curved arrow drawn from the highest to second-highest to third-highest ranked substituent (1 , 2 , 3) is **clockwise**, we say that the chirality center has the ***R* configuration** (Latin *rectus,* meaning "right")



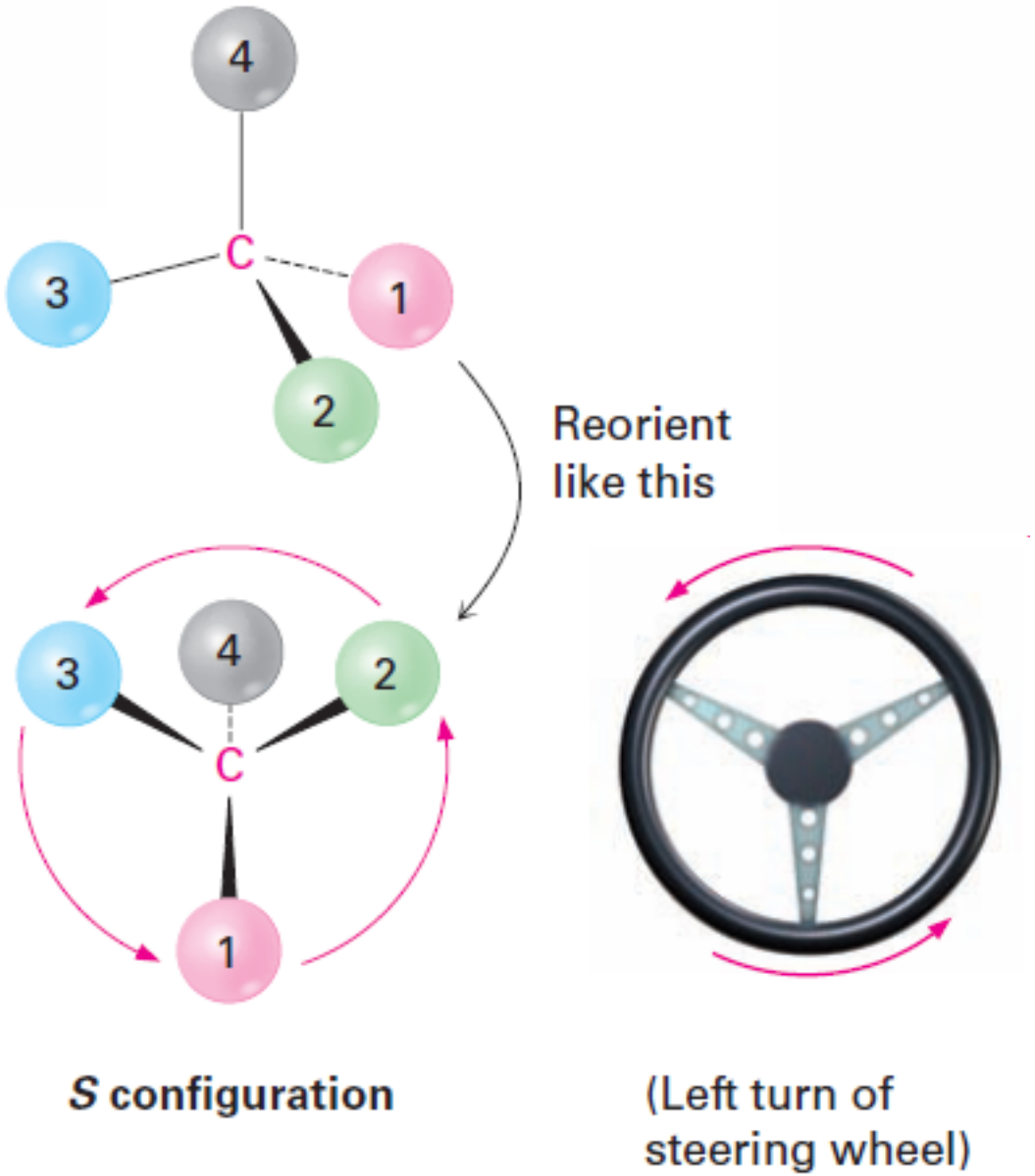
If an arrow from 1 , 2 , 3 is

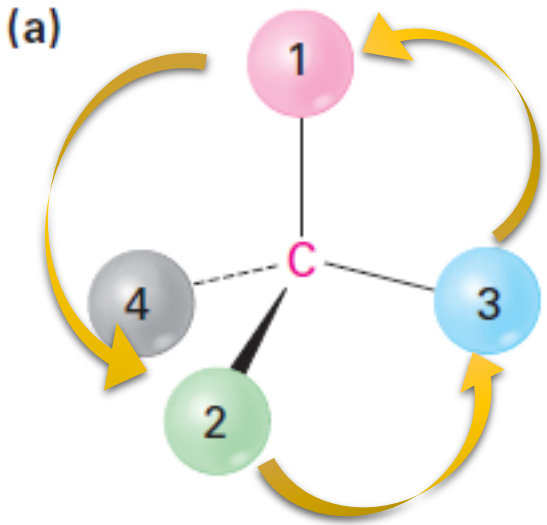
counterclockwise,

the chirality center has the

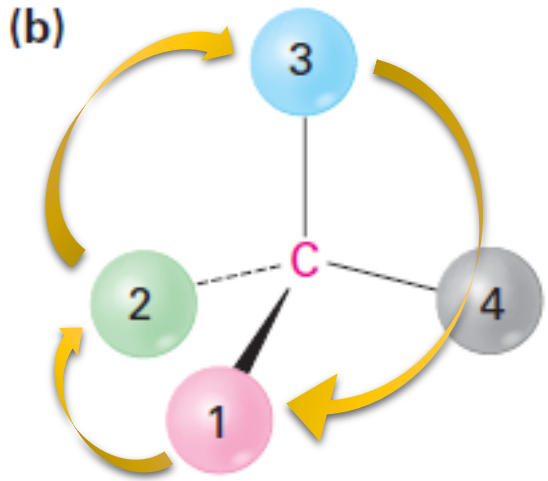
***S* configuration**

(Latin *sinister*, meaning "left")

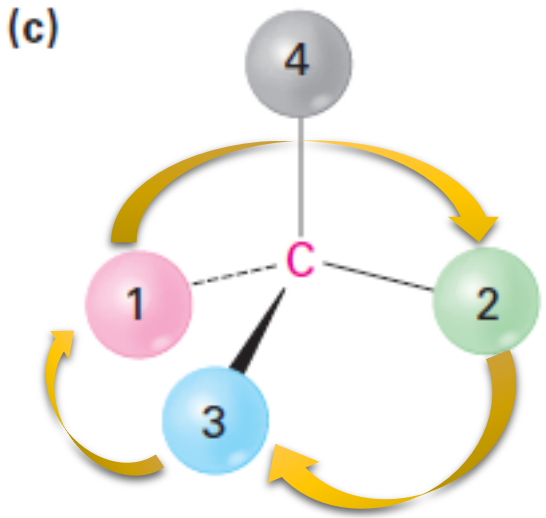




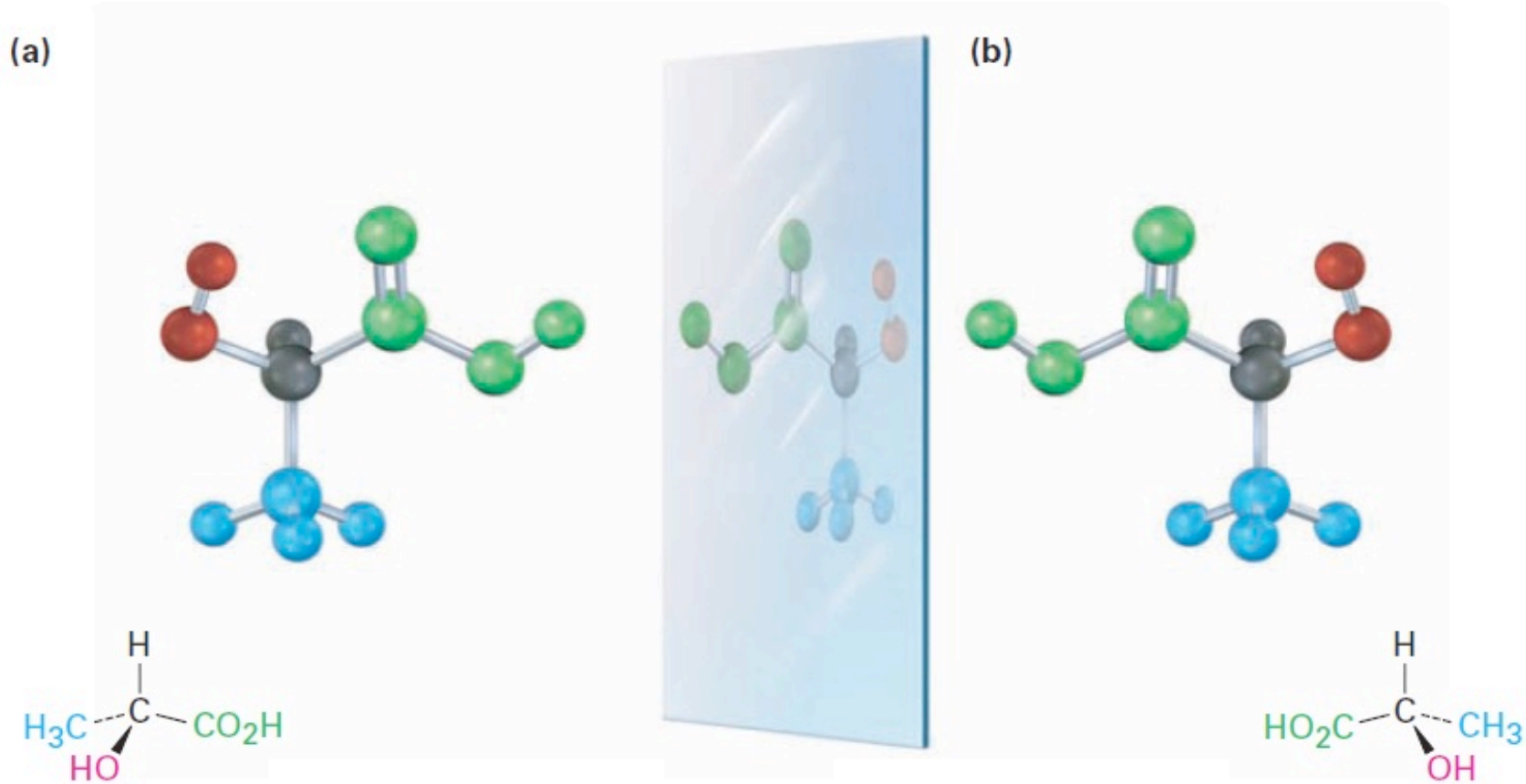
S



R



S


(a)
(b)
H
H3C
C
CO2H
HO
H
HO2C
C
CH3
OH