

Chirality

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|------------------------|--------------------------|
| 1. At a glance | 2. Chiral or achiral? |
| 3. Assigning R and S | 4. Wedges and hashes |
| 5. Optical activity | 6. Why chirality matters |
| 7. One-minute revision | |

1 At a glance

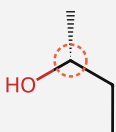
Chiral = not superimposable on its mirror image

- A **chiral** molecule cannot be laid exactly on its mirror image (IUPAC definition).
- The commonest cause is a **stereocentre**: a carbon carrying four different groups, marked C*.
- A chiral molecule and its mirror image are a pair of **enantiomers**.
- Each stereocentre is named **R** or **S** using the Cahn–Ingold–Prelog (CIP) rules.
- Enantiomers rotate plane-polarised light by equal amounts in opposite directions: (+) or (–).

The word comes from the Greek *kheir*, hand: your left and right hands are the everyday example of chirality.

2 Chiral or achiral?

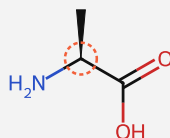
Look at each carbon: if it carries four **different** groups, it is a stereocentre and the molecule is usually chiral. Ringed carbons below are the stereocentres.



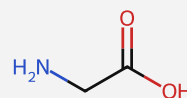
(R)-Butan-2-ol
chiral: C2 has H,
OH, CH₃, C₂H₅



Propan-2-ol
achiral: two CH₃
groups on C2



(S)-Alanine
chiral: the natural
amino acid



Glycine
achiral: two H
atoms on C α

- A molecule with a **plane of symmetry** or a **centre of symmetry** is achiral, even if it contains stereocentres (meso compounds).

- Most chiral molecules contain a stereocentre, but it is not strictly required: some allenes and biaryls are chiral without one.

Compare whole groups, not just the first atom.

In 3-methylpentane, C3 carries two ethyl groups, so it is not a stereocentre. In 3-methylhexane, C3 carries ethyl and propyl, so it is.

3 Assigning R and S: the CIP rules

- **Step 1. Rank the four groups** by the atomic number of the atom attached to the stereocentre: higher atomic number, higher priority (Br > Cl > O > N > C > H).
- **Step 2. Break ties** by moving outwards: compare the sets of atoms attached to each tied atom, highest first, at the first point of difference.
- **Step 3. Double bonds count twice:** C=O is treated as a carbon bonded to two oxygens.
- **Step 4. Point priority 4 away** from you.
- **Step 5. Trace 1 → 2 → 3:** clockwise = **R** (*rectus*, right); anticlockwise = **S** (*sinister*, left).

Group on C2 of lactic acid	Atom attached	Atoms on that atom	Priority
-OH	O (8)	H	1
-COOH	C (6)	O, O, O	2
-CH ₃	C (6)	H, H, H	3
-H	H (1)	none	4

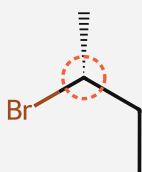
Shortcut: priority 4 pointing towards you.

If the lowest-priority group is on a wedge (towards you), trace 1 → 2 → 3 as drawn, then reverse the answer: clockwise means S, anticlockwise means R.

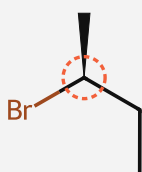
Try it on the 3D lactic acid in Quadrant I: tap the three buttons and watch the path run clockwise for (R) and anticlockwise for its mirror image.

4 Drawing a stereocentre: wedges and hashes

A solid **wedge** points towards you, a **hashed** bond points away, and plain lines lie in the page. Swapping any two groups turns R into S.



(R)-2-Bromobutane
priorities: Br > C₂H₅ >
CH₃ > H



(S)-2-Bromobutane
its enantiomer

Structures drawn and R/S checked by computer (RDKit, CIP rules). This is the same molecule that turns inside out in the SN₂ lesson.

5 Optical activity

A solution of one enantiomer rotates the plane of plane-polarised light; a polarimeter measures the angle α . Clockwise rotation is **(+)**, dextrorotatory; anticlockwise is **(-)**, laevorotatory.

$$[\alpha]_D = \alpha \div (l \times c) \quad \bullet \quad l \text{ in dm, } c \text{ in g mL}^{-1}$$

Enantiomer	Smell	Specific rotation $[\alpha]_D$
(R)-(-)-Carvone	spearmint	-61°
(S)-(+)-Carvone	caraway seeds	+61°

Data: Wikipedia, 'Carvone'. Equal and opposite rotations: the signature of an enantiomer pair.

R/S and (+)/(-) are unrelated.

R and S come from the structure and the CIP rules; (+) and (-) come from a polarimeter measurement. An (R) compound can be (+) or (-): (R)-carvone happens to be (-).

- A **racemic mixture**, written ($\pm$), contains equal amounts of both enantiomers. The rotations cancel, so it is optically inactive.
- Separating a racemate into its two enantiomers is called **resolution**. Louis Pasteur first did it in 1848, by sorting mirror-image crystals of a tartrate salt by hand.

6 Why chirality matters

- Living things build with one hand: the amino acids in proteins are the L forms, almost all of which are (S).

- Smell and taste can tell enantiomers apart, as the two carvones show.
- Drugs: (*R*)-thalidomide is a sedative and (*S*)-thalidomide is linked to birth defects. The two interconvert in the body, so even a pure single enantiomer would not have been safe.

How can the body tell mirror images apart?

Enzymes and receptors are chiral themselves. Like a right-handed glove that fits only a right hand, they bind one enantiomer far better than the other.

7 One-minute revision

1. Chiral: not superimposable on its mirror image; the mirror pair are enantiomers.
2. Stereocentre: a carbon with four different groups; compare whole groups.
3. CIP: rank by atomic number, break ties outwards, double bonds count twice.
4. Priority 4 away: clockwise R, anticlockwise S (reverse it if 4 points towards you).
5. (+)/(-) is measured, not predicted; a racemate ($\pm$) is optically inactive.

Organic Pulse · free notes by Dr. Sandeep G. Sontakke. Main sources: Clayden *et al.*, *Organic Chemistry* (2nd ed.), ch. 14; OpenStax/LibreTexts *Organic Chemistry*, sections 5.1–5.5; IUPAC Gold Book, 'chirality'.

Watch the shorts: youtube.com/@OrganicPulse-y9q