Organic Nomenclature

A Handbook for Naming Organic Molecules for Year 11-12 Chemistry in Australia

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RACI Chemistry Education Group

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Handbook Contents

Introduction

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Purpose

The purpose of the document is to clarify the nomenclature of organic compounds in the context of the new Australian and state curriculums. In general, all curriculum nomenclature requirements are aligned with IUPAC requirements.

Structure

For each functional group, the following will be provided:

- Summary information
- Extra naming rules or conventions relevant to the functional groups
- Worked examples for naming molecules where required in any State or Territory

Selected reactions will be shown for some functional groups.

How to use this document

This document is intended for use by Australian chemistry teachers to clarify naming conventions for organic molecules. It may be used as supplementary material to support or extend students.

This document may also be useful for first year chemistry course convenors, to confirm the functional groups they would expect students to be familiar with.

Feedback and corrections

Please contact Genevieve.Firmer@sydney.edu.au if you have feedback on this document. Comments on curriculum contents should be accompanied with the relevant state and curriculum page number.

Scope – functional groups included in this document

Table 1. Organic functional group requirements by curriculum. ✓ shows functional groups explicitly mentioned in the curriculum documents. Notes on the syllabus requirements are current as of June 2022.
Please note that functional groups outside the syllabus are occasionally assessed in some year 12 examinations. Please refer to recent examination documents, marking guidelines and official examiner's reports in your State or Territory to determine which functional groups may need to be included in your teaching plan. This document attempts to cover naming guidelines for all possible functional groups across the country.

Functional Group	Extent	AC[1]	SACE[2]	HSC[3]	QCE[4]	WACE[5]	TCE[6]	VCE[7]
Alkanes	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓	✓				✓
	Name		✓	✓	✓	✓	✓	✓
Branched alkanes	Recognise		✓	✓		✓		
	Draw		✓	✓				
	Name		✓	✓		✓		
Alkenes	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name		✓			✓		✓
Alkynes	Recognise			✓			✓	✓
	Draw			✓				✓
	Name							✓
Alkyl halides	Recognise			✓	✓		✓	✓
	Draw			✓	✓			✓

	Name			✓				
	Primary, Secondary, Tertiary				✓			
Benzenes	Recognise					✓	✓	✓
	Draw							✓
	Name							
Alcohols	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name		✓	✓		✓		✓
	Primary, Secondary, Tertiary		✓	✓	✓		✓	✓
Aldehydes	Recognise		✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name		✓	✓		✓		
Ketones	Recognise		✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name		✓	✓		✓		
Carboxylic acids	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name		✓	✓		✓		✓
Esters	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓		✓	✓		✓
	Name		✓			✓		✓
Amines	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name		✓	✓		✓		

	Secondary, Tertiary							
Amides	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓	✓	✓	✓		✓
	Name			✓		✓		
	Primary, Secondary, Tertiary							
Amino acids	Recognise		✓		✓	✓	✓	✓
	Draw		✓					
	Name							
Nitriles	Recognise				✓			
	Draw				✓			
	Name							
Cyclic hydrocarbons	Recognise							
	Draw							
	Name							
Carboxylates	Recognise		✓	✓	✓	✓	✓	✓
	Draw		✓					✓
	Name							
Polymers	Recognise	✓	✓	✓	✓	✓	✓	✓
	Draw		✓			✓		
	Name							
Proteins	Recognise	✓	✓		✓	✓	✓	✓
	Draw		✓					
	Name							
Carbohydrates	Recognise	✓	✓		✓			✓
	Draw		✓					
	Name							

Triglycerides	Recognise		✓		✓			✓
	Draw		✓					
	Name							

1. **AC** – Australian Curriculum. Provides a template for all state curricula.
2. **SACE** – South Australian Certificate of Education. Taught in South Australia and the Northern Territory.
3. **HSC** – Higher School Certificate. Taught in New South Wales and the Australian Capital Territory.
4. **QCE** – Queensland Certificate of Education. Taught in Queensland.
5. **WACE** – Western Australian Certificate of Education. Taught in Western Australia.
6. **TCE** – Tasmanian Certificate of Education. Taught in Tasmania.
7. **VCE** – Victorian Certificate of Education. Taught in Victoria. The updated curriculum for teaching in year 11, 2023 is now available on the VCE website. This nomenclature document will be updated to reflect the new curriculum in the next iteration.

General Rules

All organic functional groups follow the same general naming process.

STEP 1: Identify the parent hydrocarbon chain

1.1 It should have the functional group with the highest priority[1]

1.2 It should have the maximum length

STEP 2: Count the number of carbons in the parent hydrocarbon chain and identify the appropriate prefix. If the parent chain is an alkane, add the -an suffix.

STEP 3: Identify the functional group with the highest priority and its suffix

STEP 4: Identify side chains. Count the number of carbons and identify their prefix and suffix

STEP 5: Identify any remaining functional groups (including double and triple bonds) and their suffixes

STEP 6: Number the parent hydrocarbon chain from the end that produces the lowest set of locants for, in order of precedence, functional groups, double and triple bonds and side chains

STEP 7: Numbers indicating the locant of the functional group are placed directly before the functional group portion of the name.

7.1 Names are listed alphabetically

7.2 If there is more than one of the same functional group, the prefix di- (2), tri- (3), tetra- (4) are used. These are not considered for alphabetical listing

7.3 If the functional group is in a position where no alternative position is possible, no number is required (e.g. ethan-1-ol could be written as ethanol)[2]

STEP 8: Write the complete name

8.1 Commas are written between numbers

8.2 Hyphens are written between numbers and letters

8.3 Successive words are combined into one word

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[1] The most recent release of the IUPAC Blue book has updated this rule such that chain length takes priority over alkene and alkyne substituents when determining parent chain. However, many Australian chemists and chemistry teachers have not changed their naming practices to align with these new guidelines, possibly leading to some confusion. For clarity, we have included footnotes throughout this document when relevant, and further detail and examples with updated nomenclature on page 49 (alkenes section). Your state examiner's report will include guidance when the exam markers update their expectations to align with the new rules.
For more information, see: Nomenclature of Organic Chemistry: IUPAC Recommendations and Preferred Names 2013, IUPAC Blue book, prepared for publication by Henri A Favre and Warren H Powell, by RSC Publishing, 2014 [ISBN 978-0-85404-182-4]; https://doi.org/10.1039/9781849733069. The section on parent chain identification can be found here: https://iupac.qmul.ac.uk/BlueBook/P4.html#44

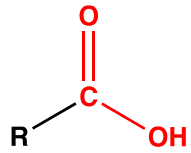
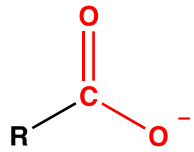
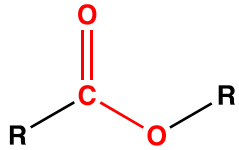
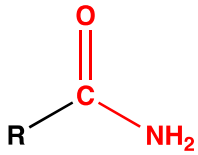
[2] It may be preferable to encourage students to always include locant numbers so that they are not inadvertently left off when needed.

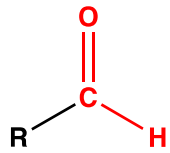
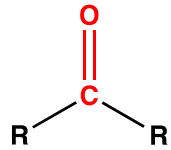
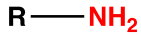
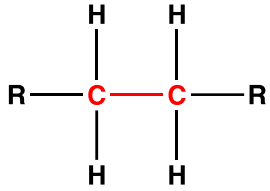
Functional Group Priority List

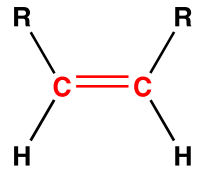
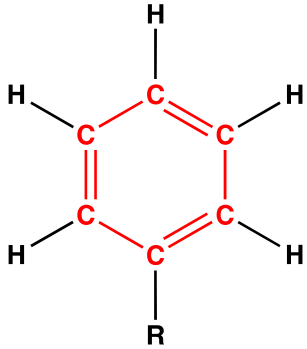
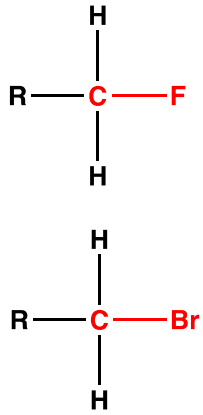
PRIORITY	FUNCTIONAL GROUP
1	*Carboxylic acid*
2	*Carboxylates*
3	*Esters*
4	*Amide*
5	*Nitrile*
6	*Aldehyde*
7	*Ketone*
8	*Alcohol*
9	*Amine*
10	*Alkane*
10	*Alkene*
10	*Alkyne*
11	*Benzene*
12	*Alkyl halide*

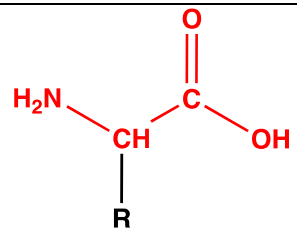
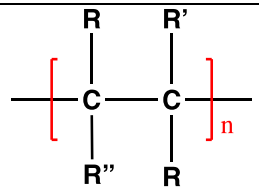
If two or more groups of the same priority are present, the ordering is alphabetical if locant sets are equivalent.

General Formula and Structure of Functional Groups

PRIORITY	FUNCTIONAL GROUP	GENERAL FORMULA	STRUCTURE/EXAMPLE	PREFIX (when functional group is not the highest priority group)	SUFFIX (when functional group is the highest priority functional group)
1	*Carboxylic acid*	-COOH		carboxy-	-oic acid
2	*Carboxylate*	$-COO^-$		carboxy-	-oate
3	*Ester*	-COOR		-oxycarbonyl-	-oate
4	*Amide*	$-CONH_2$		amido-	-amide

5	*Nitrile*	-C≡N		cyano-	-nitrile
6	*Aldehyde*	-CHO		oxo-	-al
7	*Ketone*	-C=O		oxo-	-one
8	*Alcohol*	-OH		hydroxy-	-ol
9	*Amine*	-NH_2		amino-	-amine
10	*Alkane*	-C-C-		-yl	-ane

10	*Alkene*	-C=C-		-enyl	-ene
10	*Alkyne*	-C≡C-		-ynyl	-yne
11	*Benzene*	C_6H_6		-phenyl	-benzene
12	*Alkyl halide*	R-X With X = halogen atom		root from halogen: fluro-, chloro-, iodo-, bromo-	-ane, -ene, -yne

	Amino acid	-CH(NH_2)-COOH			
	Polymer				

Note: An R or R' (R prime) or R^1 group indicates a molecular chain that is irrelevant to the diagram. See more information in the Key Terms section.

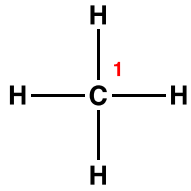
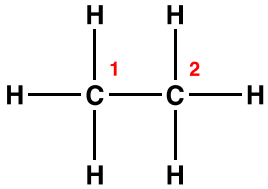
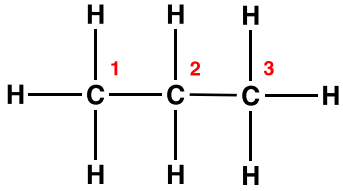
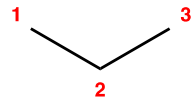
Parent Chain Identification and prefixes

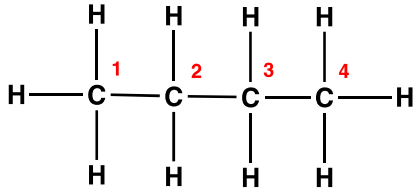
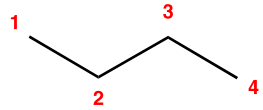
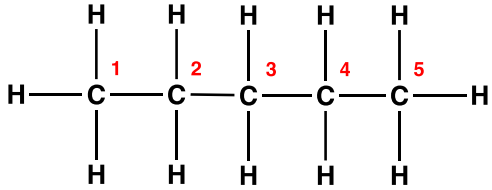
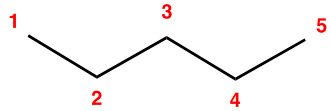
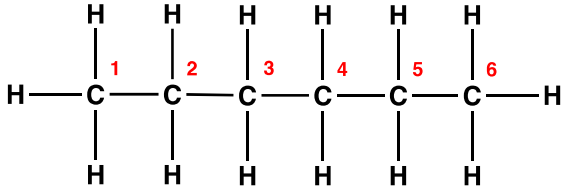
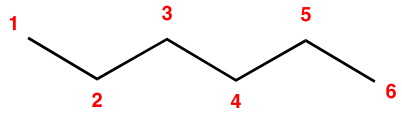
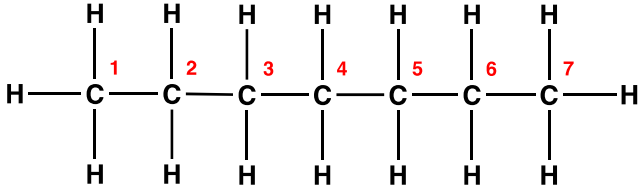
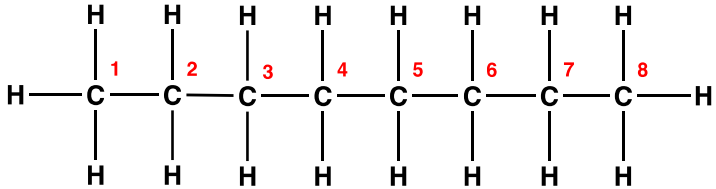
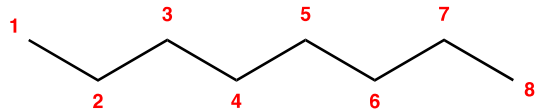
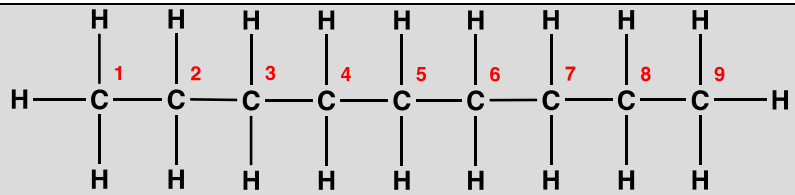
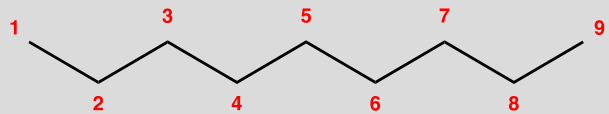
STEP 1 of the nomenclature process involves identifying the parent hydrocarbon chain.

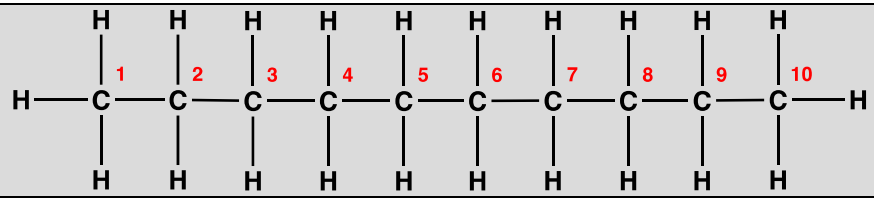
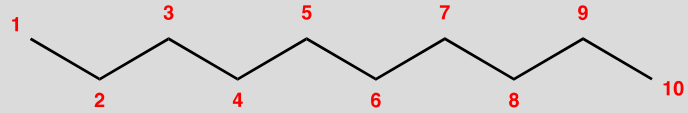
The parent hydrocarbon chain is the longest unbranched chain that defines the appropriate carbon name stem. It should (in order of priority):

1. Contain the functional group with the highest priority. If there are no functional groups,
2. Have the maximum length or contain the highest number of carbon atoms.

STEP 2 involves identifying the appropriate prefix, as determined by the number of carbons in the parent chain.

No. of C	Prefix	Structural formula	Skeletal formula
1	Meth-		Not used.
2	Eth-		
3	Prop-		

4	But-		
5	Pent-		
6	Hex-		
7	Hept-		
8	Oct-		
9	Non-		

10	Dec-		

Note: Not all courses expect students to name carbon chains up to C10. Check your curriculum documents for guidance.

Types of chemical representations

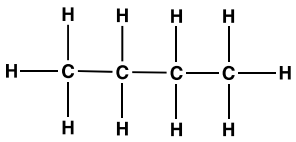
A wide range of representations are used to communicate chemical structures. Each has different characteristics and is suitable in different situations. Students should be able to easily convert between the different representations required in their chemistry course. In addition, the ability to convert these 2D representations into 3D models is preferred.

Please check your curriculum documents, past exam papers and chief examiner's reports for specific guidance on which formulae are required, and the names used to refer to each formula, in your state or territory.

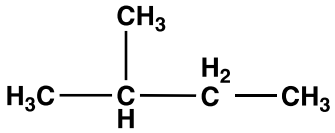
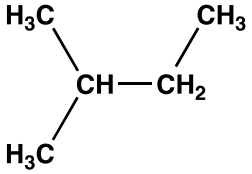
Full Structural Formula

Also referred to as Extended Formula or a Fishbone structure.

In many states, extended formulae are required to be drawn with 90° bond angles. This is intended to provide clarity for students learning structural representations for the first time. This is not the preferred method in tertiary studies or beyond.

Example	Characteristics
	• ALL atoms are displayed using their chemical symbol • Bonding between atoms is explicit • Preferred conformation includes 90° bond angles • ALL bonds between atoms should be displayed

Condensed Structural or Semi-structural

Example	Characteristics
	• Bonds in the chain (both parent chain and branches) are displayed • Condensed formula is used for atoms attached to chain atoms • 90° bond angles • Potentially useful when discussing NMR • Bonds should clearly attach to the correct atom. Note the conformation of CH_3 group on each end of this example molecule is mirrored to indicate the C-C bond. Note the bond to the methyl group clearly attaches to the C, not H_3
	• 120° bond angles

Condensed Formula

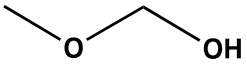
Example	Characteristics
$CH_3CH_2CH_2CH_3$	• Atoms are displayed • Bonding between atoms is implied by order of atoms • Understanding of bonding and functional groups is required to interpret • Brackets are used to denote side chains
CH_3OCH_2OH	
$CH_2(CH_2CH_3)CH_2CH_3$	

Skeletal

Also referred to as a line drawing.

This is the preferred representation of chemical structures at a tertiary level. They are most suitable for use by chemistry students who are confident in interpreting structural diagrams and recalling the required number of bonds for each element.

See the 'Parent Chain Identification' section for more guidance on counting carbons in skeletal structures.

Example	Characteristics
	• Carbons are indicated as 'points' at the end of lines, at the joint between two lines or end of a line • Carbon atoms always have four bonds. Unmarked bonds are assumed to be hydrogen bonds • 120° bond angles
	• Atoms which are not carbon are indicated using chemical symbol • Hydrogens that are not directly attached to a carbon atom are indicated

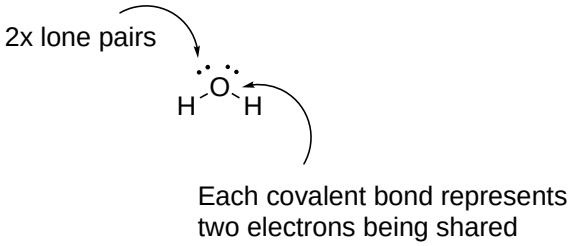
Molecular Formula

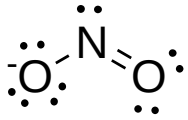
Example	Characteristics
CH_3COOH	• Number and type of atom is displayed • No structural information is provided
$C_6H_{12}O_6$	

Lewis structures

Lewis structures provide information about the number and position of valence electrons. They differentiate between electrons which are participating in a covalent bond, and those which are referred to as lone pairs.

Lewis structures are helpful for explaining the polarity of molecules.

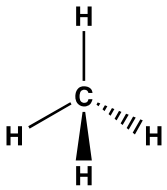
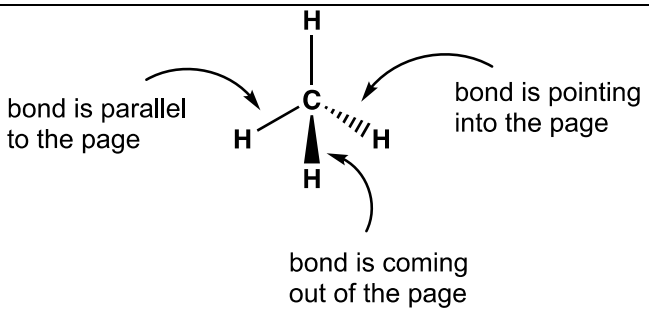


Example	Characteristics
	• Covalent bonds and lone pairs are arranged using VSEPR theory

Some courses require students to draw Lewis structures with 90° bond angles. Please check your curriculum documents for guidance.

3D structures

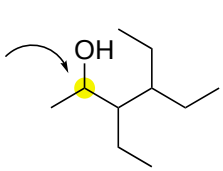
These representations are commonly used at tertiary level where 3D conformation of molecules is increasingly important. This may be covered in some year 11-12 courses where students learn about molecular shapes.

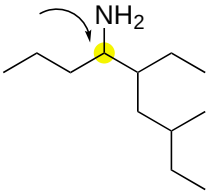
Example	Characteristics
	

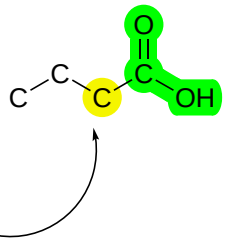
Free software such as MolView (https://molview.org/) can be used to show students 3D animations of molecules.

Key Terms

Alpha carbon: Refers to the carbon to which the functional group is directly attached. *This terminology is not explicitly required in all courses. Check your curriculum documents and past exams for guidance.*
The alpha carbon is relevant when determining whether an alcohol or amine is in a primary, secondary or tertiary configuration. It is also relevant when identifying α-amino acids.

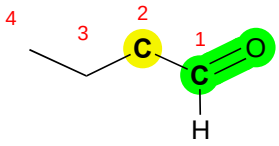


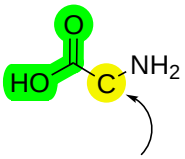




alpha carbon -
the carbon to which the carboxylic acid functional group is attached.

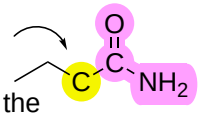
alpha carbon is attached to the carbonyl group





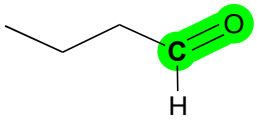
alpha carbon -
the carbon to which the carboxylic acid (highest priority functional group) is attached.

alpha carbon -
the carbon to which the amide is attached

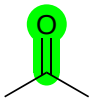


Carbonyl: Describes a functional group consisting of a carbon and oxygen double bonded together. For example:

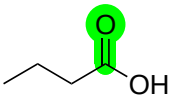
Aldehyde



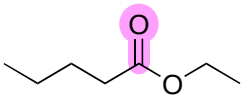
Ketone



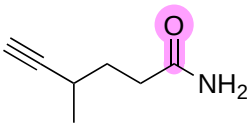
Carboxylic Acid



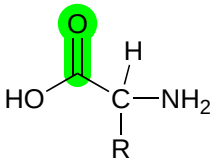
Ester



Amide



Amino Acid

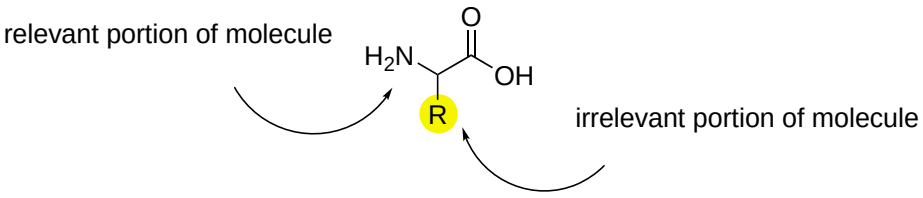


Functional Group: Side chain or functional group attached to the parent hydrocarbon chain replacing a hydrogen atom. The terms substituent and functional group can be quite different chemically, however, in nomenclature and for the purpose of this review they can be used interchangeably.

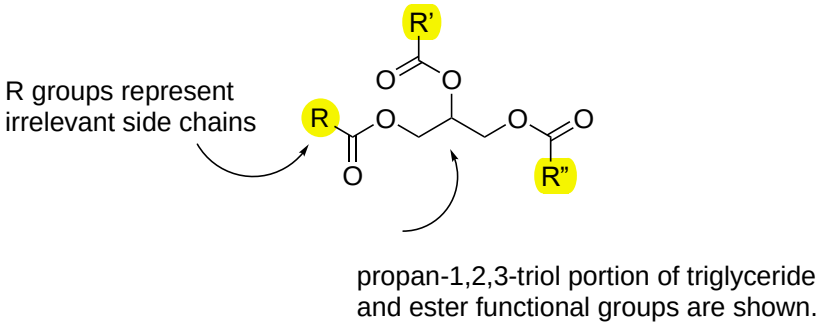
Locant: Refers to the specific carbon atom a functional group is found on. In nomenclature, numbers immediately before the functional group portion of the name. See Step 6 for instructions regarding numbering a parent hydrocarbon chain.

Parent hydrocarbon chain: The longest unbranched chain. It must contain the highest priority functional group. It defines the appropriate carbon name stem.

R group: Used to represent a substituent which is not relevant to the drawing. It can represent any chain or functional group. They are commonly used in larger molecular representations such as triglycerides and polypeptide.



R' and R" are used to represent R groups which are different when a molecule contains multiple substituents which do not need to be drawn. R^1, R^2 and subsequent numbers are also sometimes used.



Side Chain: Also referred to as a branch, a side chain refers to a chain of one or more carbons which comes off the parent hydrocarbon chain.

Substituent: A group of one or mole atoms that replaces a hydrogen atom on the parent chain.