



Because we are just starting our study of nomenclature, we will not deal with names that have stereochemical designations or unsaturation markers in this lecture: we will return to these components of systematic names later.

### **Formulating systematic names: The basic rules**

We first give a set of step-by-step rules for writing systematic names, then look at examples of the rules in action.

#### **Step # 1**

Determine the highest ranking priority functional group.

Certain functional groups are considered priority functional groups; each priority group is assigned a rank. A list of priority groups in order from highest to lowest rank is:

carboxylic acids > sulfonic acids > esters > amides > nitriles > aldehydes > ketones > alcohols > thiols > amines > alkenes, benzene > alkynes

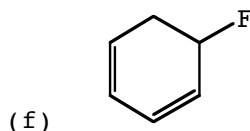
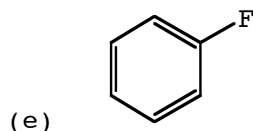
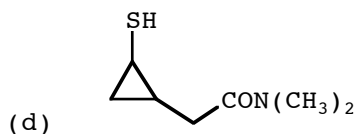
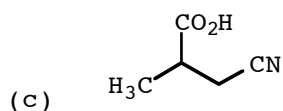
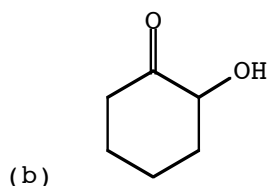
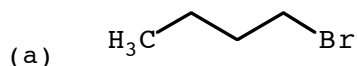
The ending of the systematic name identifies the highest ranking priority group in a molecule; the rules also provide for situations in which no priority group is present. The table below lists the priority group endings. Memorize the priority groups, their rank order, and these endings.

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<b>Priority group</b>	<b>Ending</b>
carboxylic acids	oic acid
sulfonic acids	sulfonic acid
esters	oate
amides	amide
nitriles	nitrile
aldehydes	al
ketones	one
alcohols	ol
thiols	thiol
amines	amine
alkenes	ene
benzene	benzene
alkynes	yne
none	ane

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**Problem** Determine the priority group ending of these molecules. Don't worry for now about the molecule's full name, just the ending.



**Answer** (a) No priority group: 1-bromobutane. (b) The ketone outranks the alcohol: 2-hydroxycyclohexanone. (c) The carboxylic acid outranks the nitrile: 3-cyano-2-methylpropanoic acid. (d) The amide outranks the thiol: 2-(2-mercaptocyclopropyl)-*N,N*-dimethylethanamide. (e) Fluorine is not a priority group, but benzene is: fluorobenzene. (f) This molecule is an alkene, not a benzene: 5-fluoro-1,3-cyclohexadiene.

### Step # 2

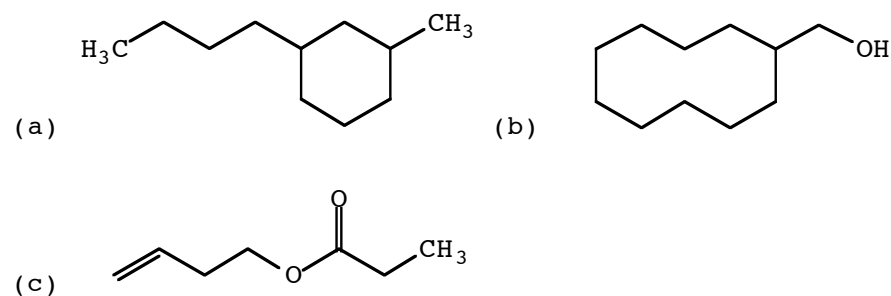
Find the parent.

The parent is the longest chain or the biggest ring of carbon atoms that bears the highest ranking priority group. If no priority group is present, the parent is simply the longest chain or the biggest ring of carbon atoms and the name ends in "ane". The number of carbons in the parent is designated by the following syllables. Memorize this list.

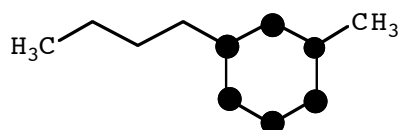
1	meth	6	hex
2	eth	7	hept
3	prop	8	oct
4	but	9	non
5	pent	10	dec

If the parent is a ring of carbon atoms, "cyclo" is written immediately before the syllables in the list above (e.g., cycloprop, cyclobut, cyclopent, etc.). The carbons in the parent either belong to a chain or to a ring: the parent is never a combination of carbon atoms belonging to a chain and to a ring.

Problem Write a heavy dot on the carbon atoms of the parent of these molecules.

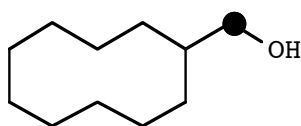


Answer (a) There are no priority groups, so the parent is the longest chain or the biggest ring of carbon atoms. The molecule has a four-carbon chain, a six-carbon ring, and a one-carbon chain; the six-carbon ring wins.



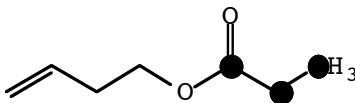
The systematic name (1-butyl-3-methylcyclohexane) reflects the fact that the parent is a six-carbon ring ("cyclohex") and that no priority group is present ("ane").

(b) The highest ranking priority group is an alcohol, which is on a one-carbon chain:



The systematic name (cyclodecylmethanol) reflects the fact that the parent is a one-carbon chain ("meth") and that the highest ranking priority group is an alcohol ("ol").

(c) The ester outranks the alkene:



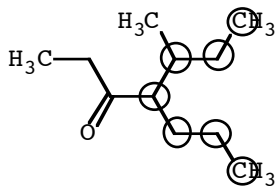
The systematic name (3-butenyl propanoate) indicates that the parent is a three-carbon chain ("prop") and that the highest ranking priority group is an ester ("oate").

### **Parent tiebreakers**

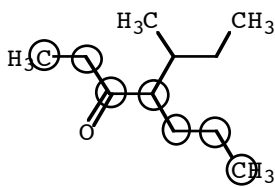
Atoms that are not part of the parent are part of a substituent. Identifying substituents comes into play when breaking ties between competing parents. Here are some situations that need a parent tiebreaker:

- Is the highest ranking priority group located on several chains of equal length or on several rings of equal size? – The parent is the chain or the ring that has the most substituents.
- Is no priority group present and are there several chains or rings of equal size? – The parent is the longest chain or the biggest ring that has the most substituents.
- Does the molecule have two priority groups of equal rank located on a chain of  $x$  carbons and on a ring also of  $x$  carbons? – The parent is the ring.
- Is no priority group present and does the molecule have a chain of  $x$  carbons and a ring of  $x$  carbons? – The parent is the ring.

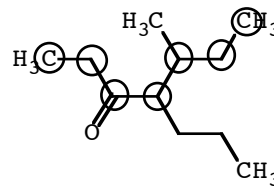
Example The molecule below has three seven-carbon chains. The chain in Structure A does not include the highest ranking priority functional group (the ketone) so it cannot be the parent. The chain in Structure B includes the highest ranking functional group and has one substituent. The chain in Structure C includes the highest ranking functional group and has two substituents. Thus, the chain in Structure C is the parent.



A

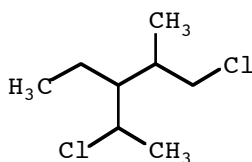


B

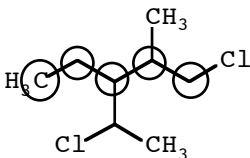


C

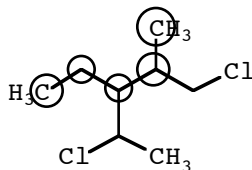
Problem The molecule below has no priority group, so the parent is the longest chain. However, it has five five-carbon chains. Mark out each chain. Circle the structure that has the five-carbon chain with the most substituents: that chain is the parent.



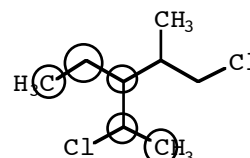
Answer



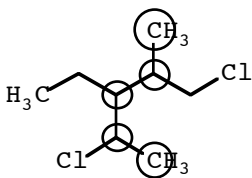
3 substituents



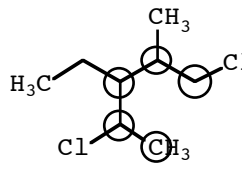
2 substituents



2 substituents

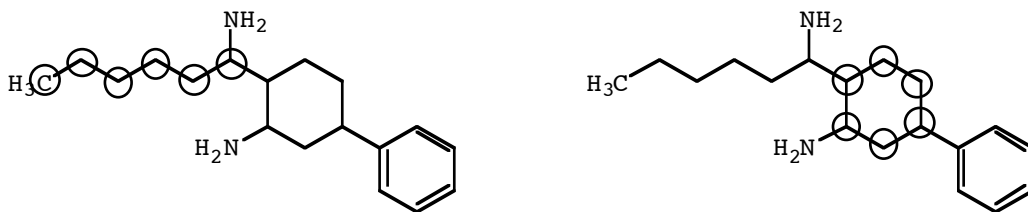


3 substituents

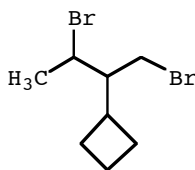


4 substituents  
parent

Example The highest ranking priority group on the molecule below is the amine. One amine is located on a six-carbon chain, whereas the other amine is located on a six-carbon ring. The parent is the ring.



**Example** The molecule below has no priority group, a four-carbon ring and a four-carbon chain. The parent is the ring.

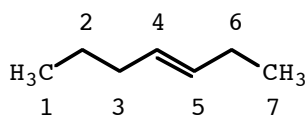


### Step # 3

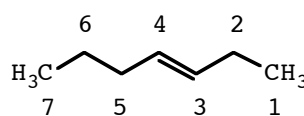
Number the carbons in the parent.

Each carbon in the parent gets a position number. The carbon that bears the highest ranking priority group gets the lowest number, but we must begin numbering from the end of the parent chain. If the molecule has no priority group, simply begin numbering from the end of the parent chain.

**Example** We can start numbering the carbon atoms in the molecule below from either end of the parent chain. One numbering system assigns the highest ranking priority group (the alkene) the 4 position, whereas the other assigns it the 3 position. We choose the numbering system that gives the lowest number to the carbon that bears the highest ranking priority group.



incorrect

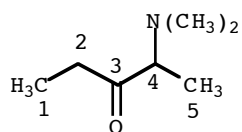


correct

### Numbering tiebreaker # 1

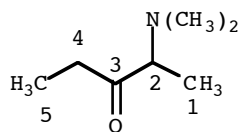
Frequently, there is more than one numbering system that gives the same lowest number to the carbon that bears the highest ranking priority group. In the molecule below, the ketone outranks the amine so we assign the ketone carbon the lowest possible number consistent with numbering from the end of

the parent chain. Regardless of whether we number left to right or right to left, the ketone carbon gets the 3 position:



highest ranking  
priority group @ 3

substituent @ 4  
incorrect numbering

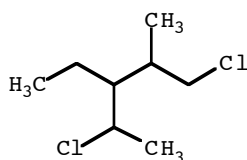


highest ranking  
priority group @ 3

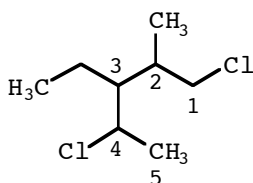
substituent @ 2  
correct numbering

To break the tie, we prefer the numbering system that gives the lowest number to a substituent at the first point of difference in the numbering systems.

Problem Number the carbons in the parent of this molecule.

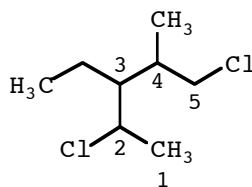


Answer We found the parent in a previous problem. There are two possible numbering systems, each beginning at a terminal carbon atom:



substituents  
@ 1, 2, 3, 4  
correct numbering

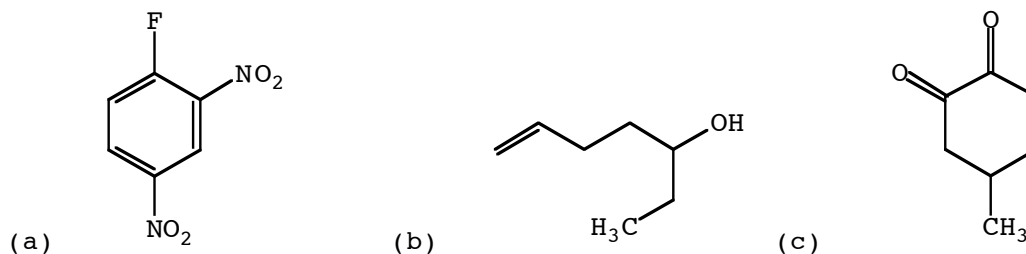
or



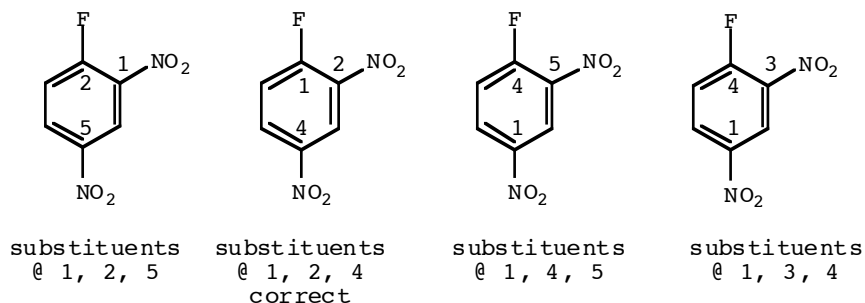
substituents  
@ 2, 3, 4, 5  
incorrect numbering

The winner is the numbering scheme that gives the lowest number to a substituent at the first point of difference in the numbering schemes. In the numbering schemes above, the "1" in the scheme on the left beats the "2" in the scheme on the right and is thus preferred.

Problem Number the carbons in the parent of these molecules.

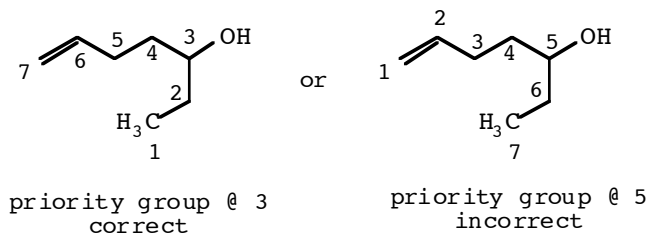


Answer (a) The possible numberings are

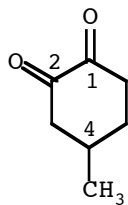


All the numberings have a "1" in the first position, so no decision about the correct numbering can as yet be made. Moving on to the next position, the numberings that have a "2" beat those that have a higher number. Moving on to the last position, a "4" beats a "5".

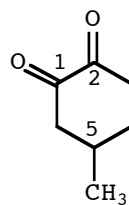
(b) The alcohol outranks the alkene so we give the carbon that bears the -OH group the lowest possible number; remember to begin numbering at the end of the parent chain.



(c) The ketones are the highest ranking priority groups. We want to give them the lowest possible number. There are two numbering systems that award the same lowest numbers to the two ketones:



priority groups @ 1, 2  
substituent @ 4  
correct



priority groups @ 1, 2  
substituent @ 5  
incorrect

The tie is broken by favoring the numbering system that gives the lowest number to a substituent.

#### Step # 4

Name the substituents.

Substituents that are composed entirely of carbon and hydrogen atoms arranged in a chain are called alkyl groups. Alkyl groups are named according to the number of carbon atoms in the chain. The smaller alkyl groups have two-letter abbreviations. Memorize these names and abbreviations.

1	-CH <sub>3</sub>	methyl (Me)	6	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub>	hexyl
2	-CH <sub>2</sub> CH <sub>3</sub>	ethyl (Et)	7	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>5</sub> CH <sub>3</sub>	heptyl
3	-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	propyl (Pr)	8	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>6</sub> CH <sub>3</sub>	octyl
4	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>3</sub>	butyl (Bu)	9	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>7</sub> CH <sub>3</sub>	nonyl
5	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub>	pentyl	10	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>8</sub> CH <sub>3</sub>	decyl

If the substituent is a ring of carbon atoms, "cyclo" is written immediately before the syllables in the list above (i.e., cyclopropyl, cyclobutyl, cyclopentyl, etc.).

Ether substituents are called alkoxy groups. Their names are formed by replacing the "yl" of the alkyl group name with "oxy". The smaller alkoxy groups have abbreviations. Memorize these names and abbreviations.

1	-OCH <sub>3</sub>	methoxy (OMe)	6	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub>	hexoxy
2	-OCH <sub>2</sub> CH <sub>3</sub>	ethoxy (OEt)	7	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>5</sub> CH <sub>3</sub>	heptoxy
3	-OCH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	propoxy (OPr)	8	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>6</sub> CH <sub>3</sub>	octoxy
4	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>3</sub>	butoxy (OBu)	9	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>7</sub> CH <sub>3</sub>	nonoxy
5	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub>	pentoxy	10	-OCH <sub>2</sub> (CH <sub>2</sub> ) <sub>8</sub> CH <sub>3</sub>	decoxy

If the ether oxygen is bonded to a ring of carbon atoms, "cyclo" is written immediately before the syllables in the list above (i.e., cyclopropoxy, cyclobutoxy, cyclopentoxy, etc.).

Sulfide substituents are called alkylthio groups. Their names are formed by adding "thio" to the end of the alkyl group names. The smaller sulfide groups have abbreviations. Memorize these names and abbreviations.

1	-SCH <sub>3</sub>	methylthio (SMe)	6	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub>	hexylthio
2	-SCH <sub>2</sub> CH <sub>3</sub>	ethylthio (SEt)	7	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>5</sub> CH <sub>3</sub>	heptylthio
3	-SCH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	propylthio (SPr)	8	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>6</sub> CH <sub>3</sub>	octylthio
4	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>3</sub>	butylthio (SBu)	9	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>7</sub> CH <sub>3</sub>	nonylthio
5	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub>	pentylthio	10	-SCH <sub>2</sub> (CH <sub>2</sub> ) <sub>8</sub> CH <sub>3</sub>	decylthio

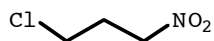
If the sulfide sulfur is bonded to a ring of carbon atoms, "cyclo" is written immediately before the syllables in the list above (i.e., cyclopropylthio, cyclobutylthio, cyclopentylthio, etc.).

Some other important substituent names to memorize are:

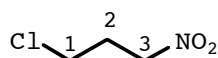
-F	fluoro	-Cl	chloro	-Br	bromo
-I	iodo	-NO <sub>2</sub>	nitro		

### Numbering tiebreaker # 2

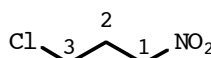
Substituent names sometimes play a tiebreaking role in determining the correct numbering of the parent. Consider this molecule:



There are no priority groups, so the parent is simply the longest chain of carbon atoms. We begin numbering the parent three-carbon chain from a terminal carbon and select the numbering system that gives the lowest number to a substituent at the first point of difference in the numbering systems. The possible numberings are

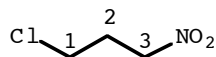


substituent  
@ 1, 3

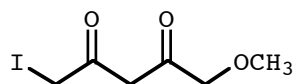


substituent  
@ 1, 3

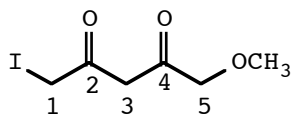
Both numbering systems assign the same set of numbers to the substituents. To break the tie, we select the numbering system that assigns the lowest number to the substituent that is first alphabetically. Thus, because "chloro" is alphabetized before "nitro", the correct numbering is



Problem Number the carbons in the parent of this molecule.

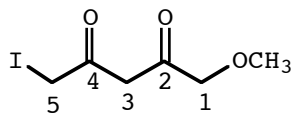


Answer We seek first of all to give the highest ranking priority group (the ketones) the lowest possible numbers consistent with starting the numbering at the end of a chain. Regardless of whether we number left to right or right to left, the priority groups come in at 2 and 4. To break the tie in the priority numbering, we seek to give the lowest number to a substituent at the first point of difference in the numbering systems. Again, regardless of whether we number left to right or right to left, the substituents come in at 1 and 5. To break the tie in the substituent numbering, we award the lowest number to the substituent that is first alphabetically, that is, to "iodo" because it is alphabetized before "methoxy".



priority groups @ 2,4  
substituents @ 1, 5

correct numbering



priority groups @ 2,4  
substituents @ 1, 5

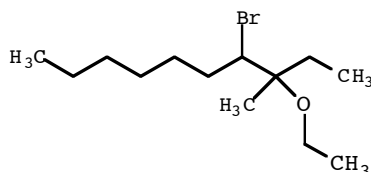
incorrect numbering

### Step # 5: Write the name

Recall that systematic names consist of five components, written left to right in this order:

[stereochemistry] [substituent list] [number of carbons in the parent]  
[unsaturation marker] [priority group ending]

Substituents are written in alphabetical order along with their position numbers. Thus, the compound below is called 4-bromo-3-ethoxy-3-methyldecane.

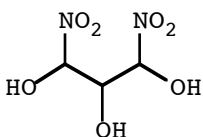


Note that hyphens separate numbers from words.

If there is more than one of the same highest ranking priority group or substituent, a replicating prefix indicating how many such highest ranking priority groups or substituents are present is written immediately before the name of that highest ranking priority group or that substituent. The table below lists the replicating prefixes. Memorize these terms:

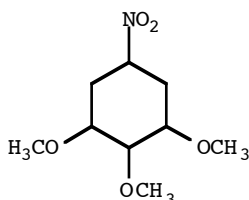
2	di	5	penta	8	octa
3	tri	6	hexa	9	nona
4	tetra	7	hepta	10	deca

Example The compound below is called 1,3-dinitro-1,2,3-propanetriol.



The "di" indicates that there are two  $\text{-NO}_2$  groups and the "tri" indicates that there are three  $\text{-OH}$  groups. Note that commas separate numbers from numbers and hyphens separate numbers from words.

Replicating prefixes are normally ignored when alphabetizing, but there is an exception to this rule: we will consider this exception later. Thus, the compound below is called 1,2,3-trimethoxy-5-nitrocyclohexane because the "m" of "methoxy" comes before the "n" of "nitro".

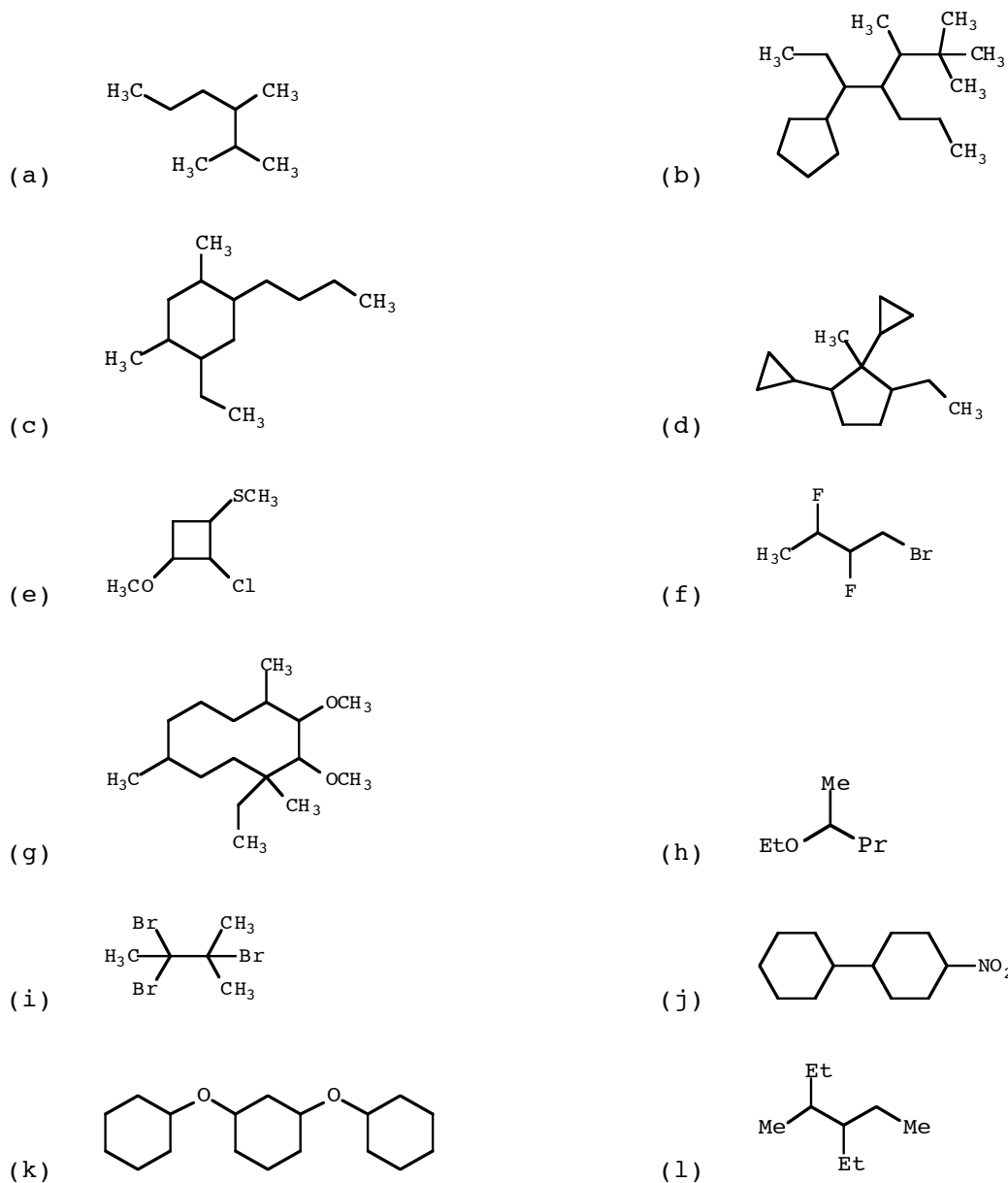


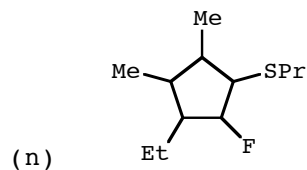
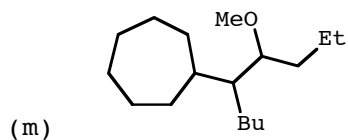
"Cyclo" is not a replicating prefix: do not ignore it when alphabetizing.

### Problems

Whew! There are a lot of rules to keep track of when writing a systematic name! A good place to begin gaining experience in naming compounds is to work some problems dealing with compounds that do not have a priority group. We will consider the nomenclature of the priority groups in a later lecture.

Write the systematic name of these compounds.





Answer (a) 2,3-dimethylhexane (b) 5-cyclopentyl-2,2,3-trimethyl-4-propylheptane (c) 1-butyl-5-ethyl-2,4-dimethylcyclohexane (d) 1,2-dicyclopropyl-5-ethyl-1-methylcyclopentane (e) 2-chloro-1-methoxy-3-methylthiocyclobutane (f) 1-bromo-2,3-difluorobutane (g) 1-ethyl-2,3-dimethoxy-1,4,8-trimethylcyclodecane (h) 2-ethoxypentane (i) 2,2,3-tribromo-3-methylbutane (j) 1-cyclohexyl-4-nitrocyclohexane (k) 1,3-dicyclohexoxycyclohexane (l) 3-ethyl-4-methylhexane (m) 5-cycloheptyl-4-methoxynonane (n) 1-ethyl-2-fluoro-4,5-dimethyl-3-propylthiocyclopentane

Problem Draw the structure of these compounds: (a) 1-butyl-2-fluoro-6-methylcyclononane; (b) 1-chloro-4-ethyl-2-nitrocyclopentane; (c) 1,1-diethylthioethane; (d) 1,1,1,2,2,6-hexachlorohexane

Answer

