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Human body consists 95% of only four elements:

65% oxygen

18% carbon

10% hydrogen

3% nitrogen

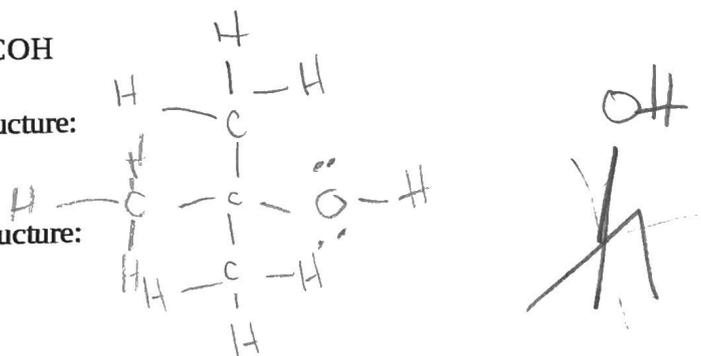
These four elements are primary components of organic compounds. Below are exercises that would help you draw organic structures and understand different notations.

1. Write the indicated structural formula for the following organic molecules.

a) $(\text{CH}_3)_3\text{COH}$

Draw full structure:

Draw line structure:

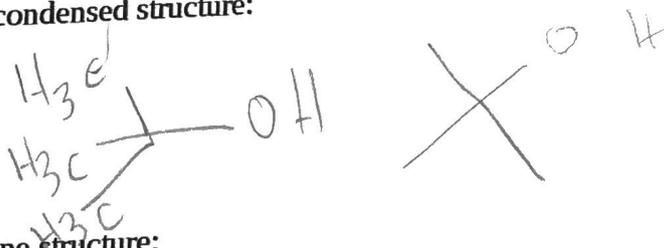


b)

Draw condensed structure:

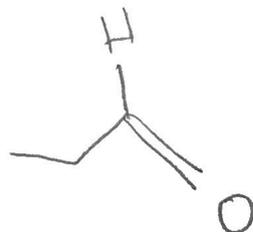
c)

Draw line structure:



d) $\text{CH}_3\text{CH}_2\text{CHO}$

Draw skeletal formula:



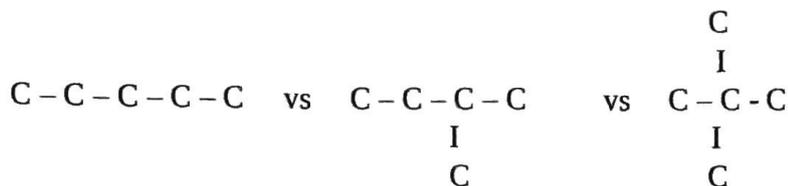
e)

Draw line formula:

- **Watch Learning Module Functional Groups video- on drawing line diagram and condensed str and Isomers and complete the following exercises:**

Isomers

You can draw different skeletal structures for the molecular formula C_5H_{12} . All of them are isomers. Even though they have the same number and type of atoms, they are not the same molecules.

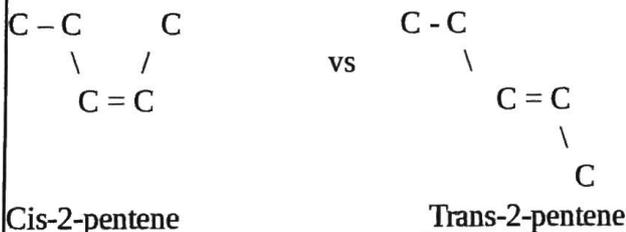


1. Add hydrogen atoms to complete the structures above.

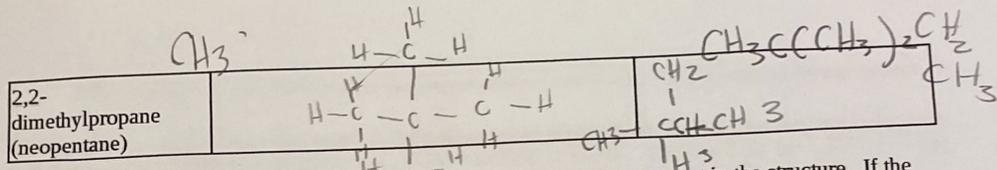
Each constitutional isomer is created because a **bond is broken**; this is different than structures that are obtained by free rotation of bonds. These are called conformers. No bonds are broken when conformers are formed.

When you have double or triple bond it allows spatial isomers to form as well because the atoms around double or triple bonds are no longer free to rotate. These are called cis/trans isomers.

Skeletal structures with the molecular formula C_5H_{10} , showing cis/trans isomers

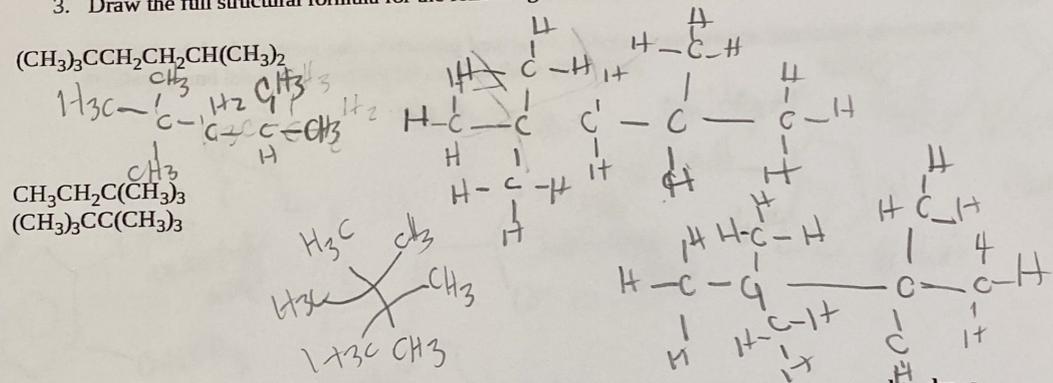


Later in the semester we will learn about the importance of cis and trans isomers in function of Lipids. A class of organic species, fatty acids, makes up many lipids. Compare the following two fatty acids:



**Parentheses are commonly used to indicate that an arm or branch is present in the structure. If the parentheses occur at the beginning of a condensed structure, the group(s) inside the parentheses is connected to the carbon immediately following the parentheses. If the parentheses occur in the middle or the end of a condensed structure, the group(s) inside the parentheses is connected to the carbon immediately preceding the parentheses.

3. Draw the full structural formula for the following condensed structures:

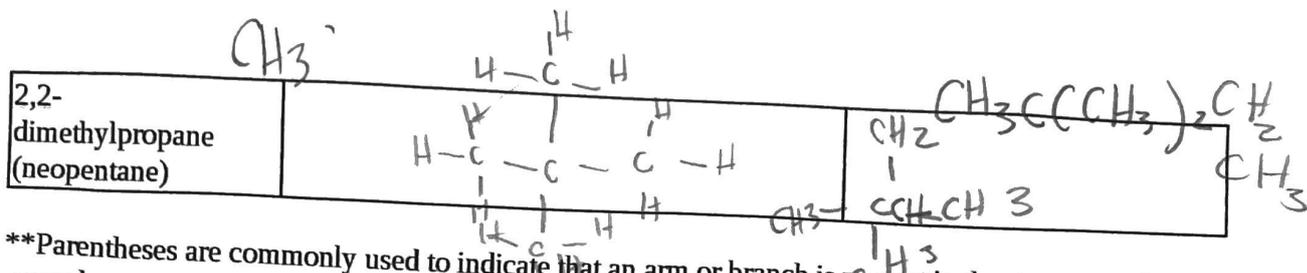


4. Determine if the following sets of molecules are identical or isomers. You may need to draw them in a different form in order to decide.

- (a) (b)
- (a) (b)

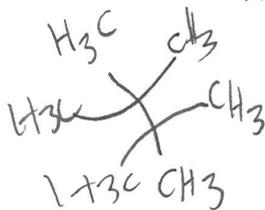
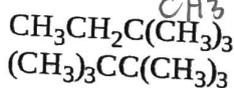
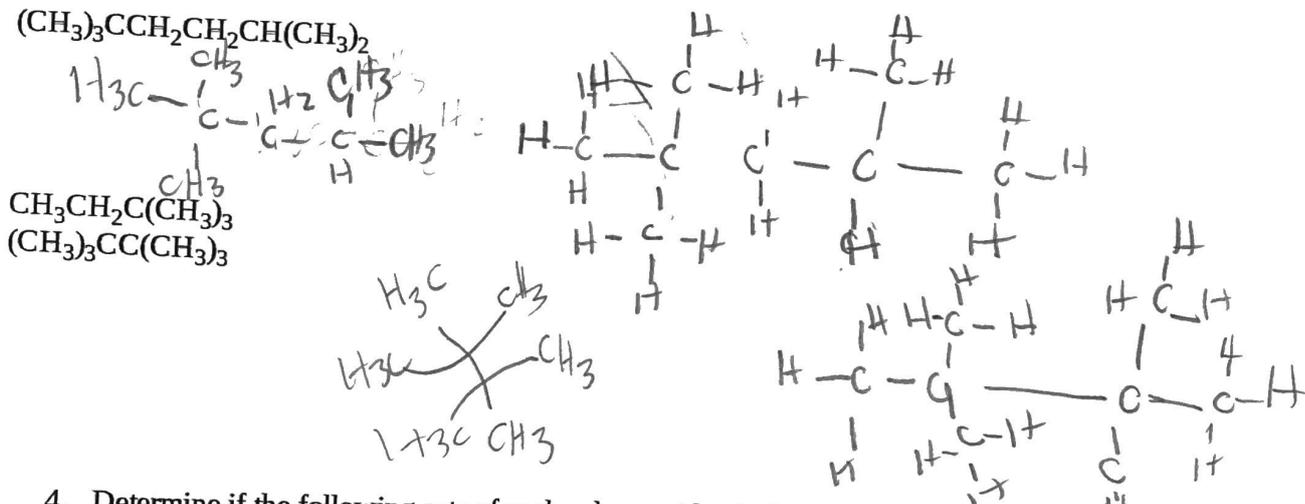
• Watch Learning Module Functional Groups video and complete the following exercises:

5. Drugs with similar physiological properties often have similar molecular structures, including some of the same functional groups. Structures for the **four leading analgesics** are shown below.



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(a)

(b)

(a)

(b)

• Watch Learning Module Functional Groups video and complete the following exercises:

5. Drugs with similar physiological properties often have similar molecular structures, including some of the same functional groups. Structures for the **four leading analgesics** are shown below.

All four have at least one benzene ring but each has specific substituents and functional groups.

Identify all functional groups. For some of the complex functional groups, it helps to draw a full structure of that group first. Make sure all atoms have correct number of bonds. Note that I use the words aromatic and benzene interchangeably.

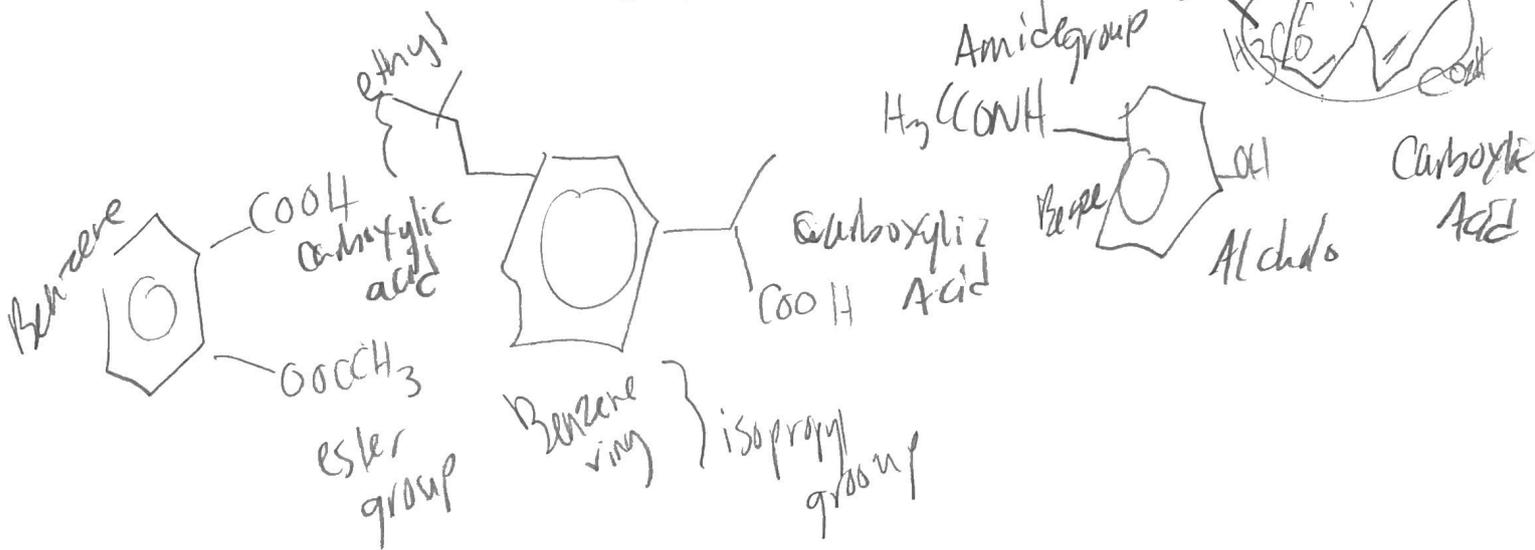
Aspirin

Ibuprofen

Acetaminophen

Naproxen

6. For each of the following add all missing lone pairs, and use your generic functional group sheet to identify and label the functional groups in these molecules



7. The following molecules represent a big class of biomolecules – Carbohydrates or sugars. Below are Fisher projections of some common monosaccharides.

Monosaccharides (one sugar unit)

- What functional groups do you observe? Circle them and label
- Are carbohydrates likely to be soluble in water? Why or why not?

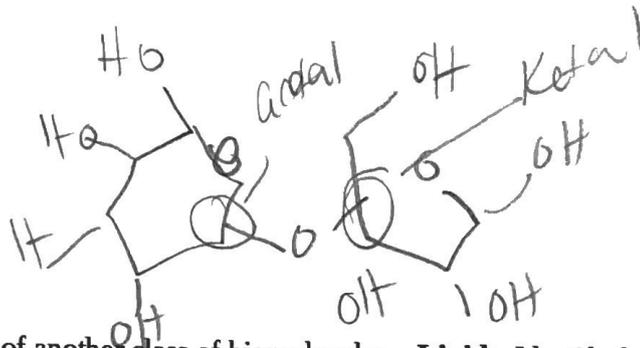
Disaccharides (two sugar units) are represented by Haworth projections

maltose

lactose

sucrose

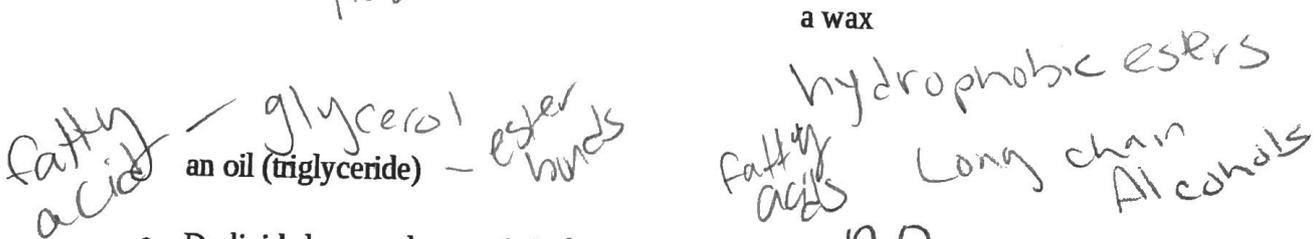
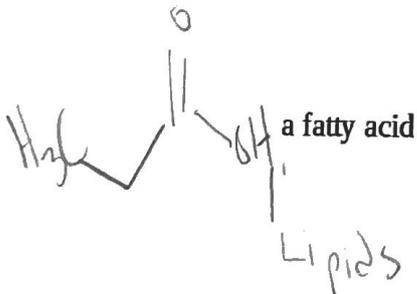
- Find acetal and hemiacetal functional groups. Circle them and label



8. Below are members of another class of biomolecules – Lipids. Identify functional groups in these molecules, circle them and label.

a steroid

a prostaglandin



- Do lipids have a characteristic functional group? — NO
- Are they likely to be soluble in water? Why or why not?

Long hydrocarbon chains — hydrophobic

In Soluble in water

9. Another class of biomolecules is called Peptides or Proteins.

Ser-Val-Thr-Phe (a tetrapeptide)

Asp-Ala-Lys-Cys-Asn (a pentapeptide)

- Do peptides/proteins have any characteristic functional groups? (Note that some of the amino groups and carboxylic acid groups are in their ionized form)
- Are peptides/proteins likely to be soluble in water? Why or why not?

Amide

Soluble

10. Antibiotics are substances which are usually produced by a microorganism that inhibit the growth of other microorganisms. However, nowadays synthetic compounds with such action are also called antibiotics. A person falls victim of the infectious disease when invading microorganisms (disease-causing bacteria or pathogens) multiply faster than the body's immune system can destroy them. Antibiotics either help immune system to destroy the pathogens, or prevent their replication.

Penicillin and Cephalosporin based antibiotics kill growing bacteria by preventing normal development of their cell walls. Bacteria's cells rely on rigid wall structure, made of crossed-linked protein chains. Penicillins and Cephalosporins block an enzyme which facilitates formation of cross-links, causing the cell to burst.

Penicillin resembles acyl-D-Ala-D-Ala, one of the fragments of the enzyme transpeptidase (TP). So instead of attracting TP, the penicillin molecule is attracted, but doesn't initiate a cross-linking.

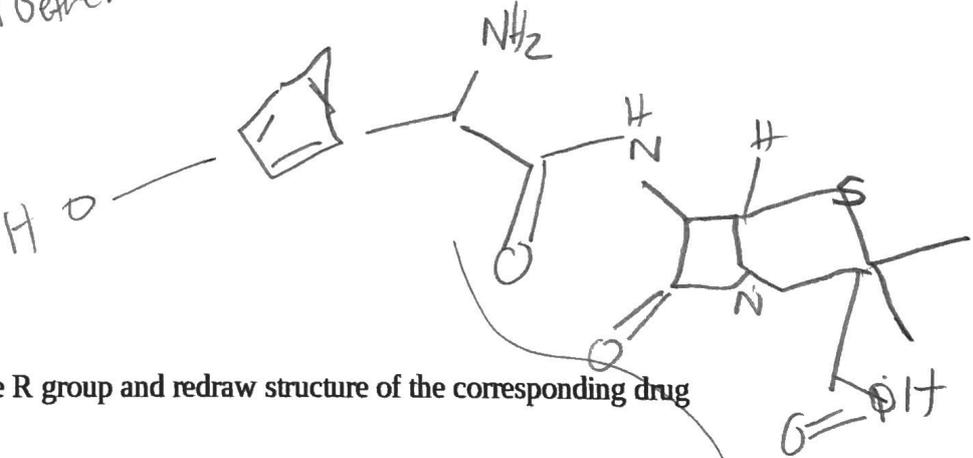
Penicillin

enzyme

Other antibiotics work by interfering with the synthesis or functioning of bacterial DNA. Although the deaths from the infectious diseases declined drastically, the overuse of antibiotics lead to emerging of new strains of bacteria which are resistant to the antibiotics that once were able to kill this bacteria.

- Identify as many functional groups as you can in each antibiotic below:

Amox
phenol, Amine, Amide, Carboxylic Acid
thioether



- Choose one R group and redraw structure of the corresponding drug

Amox

- Chose one antibiotic from the cephalosporin family and draw its structure with correct R1 and R2

11. **Viruses** are infectious particles (chemical parasites) that replicate only inside the cell of a living organism (any living organisms: they can attack bacteria as well as animals and humans!). While doing so they take over the DNA of this organism. It is difficult to attack the cells reproducing viruses without also attacking the host's own cells. That is why there are practically no effective treatments for viral infection except vaccinations. Luckily, viral infections in animals provoke an immune response that usually eliminates the infecting virus. Some of the viruses are so powerful, our bodies are not able to do it on their own, but vaccines can also produce immune responses, which confer an artificially acquired immunity to the specific viral infection. Even so some viruses including those that cause AIDS and viral hepatitis evade these immune responses and result in chronic infections. **Antibiotics have no effect on viruses**, but several antiviral drugs have been developed.

Common antiviral medication used for treating AIDS, called AZT, resembles thymidine (one of the building blocks of DNA) and is able to attach itself to the viral DNA. Once there, its structure prevents further addition of the DNA blocks and cell division ceases.

- Identify functional group which is responsible for preventing viral DNA duplicating.

12

Benzene Alkynes

- What was the functional group on thymidine which was changed?
Another effective AIDS medication, which is used in combination with AZT, is Ritonavir.

- Generic formula for the cephalosporin family of antibiotics is shown below

- Chose one antibiotic from the cephalosporin family and draw its structure with correct R1 and R2

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- Identify functional group which is responsible for preventing viral DNA duplicating.

Benzene, Alkynes

- Locate the ether functional group in structure of Prozac and identify functional groups attached to the ether oxygen.
- 13. **Opioid Analgesics** are organic compounds containing atoms such as nitrogen and oxygen attached by covalent bonds to carbon. The functional groups in an analgesic determine how it interacts with pain receptors in the brain to stop or reduce pain. The characteristic functional groups in analgesics are

- Name these functional groups

Alcohol

Amides

Alkanes

The strongest analgesics are the opioid analgesics and they include morphine, codeine, and several other amines. The amine functional group in these compounds is essential to their ability to reduce pain.

Aromatics
benzenes

Alcohols
hydroxyl

Aromatics
Amides

Aromatics
Carboxylic
Acids

Morphine

Codeine

Heroin

These compounds have the ability to induce a state of euphoria, but morphine and compounds structurally related to morphine can also lead to dependence and, with repeated use, addiction; therefore, they are classified as narcotics. Opioids reduce pain by binding to the opioid receptors on the surface of brain cells. Morphine and its analogs activate the opioid receptor, initiating a sequence of biological events that, among other things, leads to a reduction in pain.

Modifying some of the functional groups in morphine produces compounds known as morphine analogs. Even slight changes to the functional groups in morphine can have a profound effect on the analgesic and addictive properties of a morphine analog. For example, codeine differs structurally from morphine at only one functional group. Due to this difference, codeine has only 15% of the potency of morphine as a painkiller, but it is much less addictive.

- What are the functional groups that make codeine and morphine different?

Amides

However, another change in functional groups in morphine produces the analog known as heroin, which is three times more potent than morphine, and extremely addictive.

- What is the functional group in morphine that is replaced?

Alcohols

- What functional group is present in heroin?

14. **Mild analgesics** do not have such strong pain-reducing effect but they also do not cause addiction.

1. Aromatic, Carboxylic acid, ester
2. Hydroxyl, Amide, aromatic
3. Carboxylic, Aromatic
4. Phenyl, ether, Amide
5. Carboxylic acid, ether, Aromatic, naphthalene ring

They reduce pain, inflammation and prevent blood clots. But all except one also have a very inconvenient and dangerous side effect – they can cause internal bleeding (stomach bleeding).

- Identify and label all functional groups in molecules above.
- What group(s) can be responsible for bleeding?

mild analgesics belong to what

The bleeding is because these analgesics inhibit production of prostaglandins. What are prostaglandins? They are chemicals secreted by the body's immune system when it fights off bacteria around wounds. Some prostaglandins cause pain, fever, and inflammation. Others regulate acid production in the stomach and maintain the mucus lining that protects the stomach from digesting itself (!) and also allow blood platelets to stick together and stop bleeding in wounds. Now drugs like aspirin slow down the production of these chemicals, non-selectively, prostaglandins that cause pain but also prostaglandins that stop bleeding. That means the blood platelets do not conglomerate and it causes lining of the stomach to bleed. Now chemistry. For example Aspirin (acetylsalicylic acid) is a weak acid. It is for the most part a nonpolar molecule due to the aromatic ring, but it contains a carboxylic acid group which under right conditions can donate a proton in aqueous solutions to water molecules and form its conjugate base (become ionized). Unfortunately, in the stomach, pH is very low and that means when you take regular aspirin it get ionized to its conjugate base form on its way to the stomach, but then immediately turns back into acid in HCl environment of the stomach (HCl donates its proton to it the conjugate base of aspirin). Thus it maintains insoluble in water but soluble in fat. Lining of the stomach, as well as all other organs, happens to be fat based. This is unfortunate for the aspirin because it is quickly absorbed by the stomach lining and inhibits production of prostaglandins there.