**Carbonyl Compounds**: Besides alcohols, ethers, and peroxides, there is another class of organic compounds that contains oxygen. In each case, there is a carbon doubly bound to an oxygen:

$$\backslash C = O$$

This is called the **carbonyl group**.

There are basically three main kinds of carbonyl compounds: **Aldehydes** and **Ketones** and Carboxylic Acids (and derivatives). In all of them the carbonyl carbon is bound to at least one carbon atom. The difference between the two members of the first group is that in aldehydes the carbonyl carbon is also bound to a hydrogen atom:

$$H \diagdown C = O$$
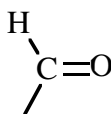
while in ketones, the carbonyl carbon is bound to two carbon atoms:

$$C \diagdown C = O \diagup C$$
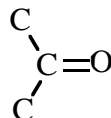
The last group, carboxylic acids and its derivatives have the more electronegative elements of oxygen or nitrogen bonded to the carbonyl carbon. This changes the chemistry of these compounds in comparison to aldehydes and ketones. The carbonyl group and the amino group are two of the most important **functionalities** in biochemical applications. We will leave the discussion of these properties until we get to biochemistry.

Nomenclature of Aldehydes and Ketones: The two types of carbonyl compounds we will be focusing on are quite different from each other chemically. To distinguish between them, IUPAC decided to give them different "suffixes". All aldehydes end with an "**al**" (not to be confused with "ol"), and ketones end in "**one**". If a compound has both groups it is considered an aldehyde since this group has priority over the ketone.

The carbonyl carbons in aldehydes are always the first carbon (so-called **terminal** carbonyls). So, in naming them, you never have to give the position of the C=O. However, the carbonyl in ketones can be anywhere EXCEPT the first carbon (in which case you would have an aldehyde). The only exception to this is the cyclo-alkane carbonyls, where the carbonyl carbon is part of the ring.

A couple of examples are:
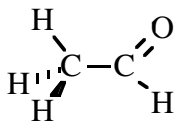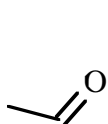
Ethanal CH_3CHO 2 propanone CH_3COCH_3

(acetaldehyde)   (acetone)
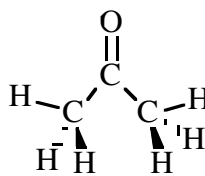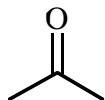
When there is more than one carbonyl on the main chain, we employ the "dione", trione" type naming. There are not many cases where more than one aldehyde type carbonyl is present. However, in cases where the aldehyde carbonyl is "away" from the main chain, we use the suffix "**carbaldehyde**" to denot the CHO moiety. For example:
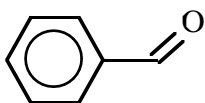
benzene carbaldehyde (benzaldehyde)

If the carbonyl is part of a side chain, and the side chain is bound to the main chain at the carbonyl carbon, the side chain is given the suffix "**oyl**". So, for the ethanal case, the side chain version would be "**ethanoyl**".

In some cases, the main chain cannot be considered a ketone. In these cases, the =O is called an **oxo** group. This is especially true if the carbonyl is part of a side chain that is NOT bound to the main chain at the carbonyl carbon. Also, if the molecule has both an aldehyde and a ketone carbonyl group, then the ketone carbonyl is denoted "oxo".

Synthesis of Carbonyls: Since the two types are different, you might think that there are different ways to make each of them. Actually, the methods of making an aldehyde will also make a ketone, but not vice versa. Therefore, we will try to make some sense of the syntheses, without making it too complicated.

The general approach is to oxidize an alcohol. 1° alcohols are used to yield aldehydes, and 2° alcohols are used when ketones are desired. However, 3° alcohols DO NOT give any carbonyl.

The oxidation process must be done very gently for aldehydes. Otherwise, you can over oxidize the alcohol to produce a carboxylic acid. The reagents needed are somewhat beyond the scope of this course. For ketones, on the other hand, you can essentially really "beat up" on the alcohol, and still get the desired product. One such reaction is:
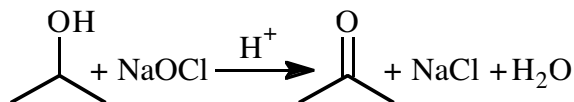
The reagent, NaOCl - sodium hypochlorite, is simply household bleach!

Physical Characteristic of Carbonyl Compounds:

Generally, aldehydes and ketones have strong odors, often pleasant (e.g. benzaldehyde smells like almonds). They are used as solvents, and the smaller ones are soluble in water. This is due to an interaction called a **hydrogen bond**. This is NOT a true bond, but a strong **intermolecular force**. It occurs when a hydrogen that is covalently bonded to either an oxygen or a nitrogen is brought into close proximity to another oxygen or nitrogen. In the case of acetone in water, the interaction looks like:
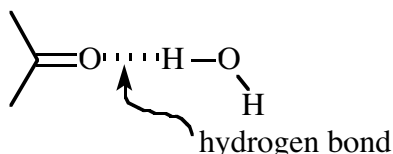

This interaction is what holds proteins together (between C=O and N–H). This is also the interaction that allows formaldehyde, a gas, to be used in embalming. The gas dissolves readily in water (to form formalin) which is what is actually used to preserve bodies.

Reactions of Carbonyls: The carbonyl oxygen is, not surprisingly, a Br nsted-Lowry base. This is an important feature that is used in many of the reactions that carbonyls undergo. The first reaction we will encounter is the **nucleophilic addition** to the carbonyl. There are two main categories, one in which the nucleophile replaces the oxygen:
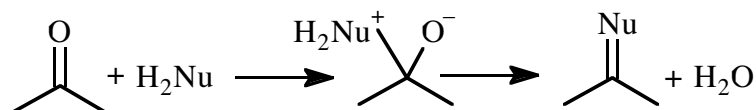

And the other, where the nucleophile AND the oxygen are connected to the carbonyl carbon:
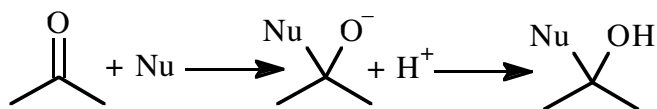
In both of these cases, the nucleophile is represent by "Nu".

An example of the first case is the addition of ammonia, NH_3, or a 1° amine to the carbonyl. The resulting molecule (which contains a C=NH group) is called an **imine**. (Adding a 2° carbonyl forms something called an **enamine**, where the double bond shifts from a C=N to a C=C)

An important example of the second kind of addition is called **acetal** formation. In this reaction, alcohol acts as the nucleophile:
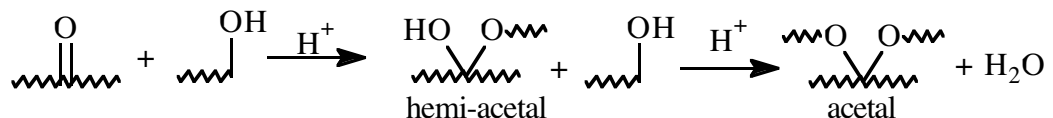

The reason this reaction is so important is that it is used to **protect** the carbonyl group. What this means is that when another part of the molecule is under-going a reaction that could conceivably also react with the carbonyl, by making the carbonyl into an acetal, it is no longer reactive. To unprotect the carbonyl, excess acid is added, which breaks the ether bonds, forming a **geminal diol**:
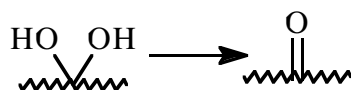
The geminal diol is very unstable and quickly forms a carbonyl.

Another class of reactions that carbonyls undergo is **reduction**. In these reactions, hydrogen is added across the C=O, to yield CHOH.

Aldehydes also react with each other in the presence of OH^-. The reaction is called a **condensation**, and the product is called an **aldol** (i.e. aldehyde and alcohol):
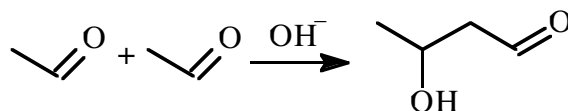
This also occurs with ketones. The only condition that must be met is that the carbon adjacent to the carbonyl must have a hydrogen atom on it. This is due to the mechanism.