So we are talking about the functional groups that are important in organic chemistry. And so far we have seen alkanes, alkene, alkyne and aromatic hydrocarbons. Now we are going to talk about alcohols, ethers and amines. And these are three very important functional groups, not only for organic chemistry, but for biochemistry as well.

Now alcohols are molecules that contain OH groups. Basically you have a carbon, that has an OH attached to it and that is called an alcohol. Ethers contain another oxygen, but now the oxygen does not have an H attached to it, it has two carbons attached to it. So if you have a COH that is an alcohol. COC is an ether. Amines are molecules that contain nitrogen. And they can have either hydrogen or carbon bound to the nitrogen and that doesn't matter, they are always called an amine. So this can be an NH or an NC. It can be three carbons or two carbons and a hydrogen; they are all amines.

Now alcohols are very important. The nomenclature of alcohols is as follows. You name alcohols similarly to the way that we named alkanes and alkenes. You start with the Greek prefix, in this case methane, and you end up with ol. So this is methanol. And this is everybody's favorite alcohol, ethanol. In fact this is the active ingredient in Everclear. Everclear is just 95% alcohol by volume. So ethanol is two carbons, ethene-ol. Propynol is a three-carbon alcohol. But now we have to indicate with propynol, where the alcohol is. It can either be the 1-carbon or the 2-carbon. This is 1-propynol; it is at the first carbon. You notice that I did not call it 3-propynol, because 3-propynol is a higher number. Whenever you name alcohols, you name them with the lowest number, in other words this would be 1-propynol, it is at the one carbon. And you start naming the carbons where the alcohol is to make that the lowest number. This would be 2-propynol, so here is carbon one, carbon two. The alcohol is on the second carbon of the molecule. This would be two methol, 2-propynol, in other words there is a methyl group at the two position and alcohol at the two position of propynol. But the common name for this would be tertbutenal.

Another nomenclature of alcohol that is important is to indicate the kind of alcohol that you have. You can either have a primary alcohol, in which case we have a ; a secondary alcohol in which case we have a CHOH. Basically what this means is that the carbon that bears the alcohol in the primary alcohol case has one of the carbons attached to it and two hydrogens, but in this secondary alcohol case, the carbon that is bearing the alcohol has two carbons attached to it one hydrogen. And this would be a tertiary alcohol, where the carbon has three other carbons attached to it – the carbon that bears the alcohol does. So a primary alcohol, secondary alcohol CHOH, tertiary alcohol COH with three carbons.

Nomenclatures of ether is also pretty straightforward. Again you have the suffix ether at the end and in this case you have to indicate what is on the two sides of the oxygen. Recall that ethers have carbons on either side of them; in this case we have ethyl groups on either side – that is diethyl ether. Here is methyl butyl ether. Methyl group on one side, butyl group on the other. And this is methyl tetra butyl ether, this is the tetra butyl group and that is the methyl group. This is called MTBE - that is a very important additive in gasoline. It was introduced with the phase out of citra-ethyl lead as an octane enhancer and also as a carbon monoxide reductant. And we will talk more about this later. Not in this tutorial, but a separate tutorial.

Amines are named similarly. This time you have to indicate what is all around the amine. And in the case of an amine, this is methylamine. There is one methyl group, with two hydrogens on the amine. This is also called a primary amine. Amines that have a single carbon on them are called primary amines. A secondary amine is an amine that has two carbons on it. In this case we have to name both the carbon groups. This would be methyl ethylamine. It is a secondary amine that means that it has two carbons and one NH. Here is tri ethylamine, it has three carbons attached to it, hence the word tri ethyl. So this would be a tertiary amine. Tertiary amine is an amine that has three carbons attached to it. Primary amine has one carbon. Secondary amine has two. That is all straightforward as well.

Now alcohols and amines have a very important property called hydrogen bonding. And it is very important to understand this because this is a property that is prevalent in biochemistry as well. Something that we will talk about again when we talk about biochemistry.

Now to understand hydrogen bonding we really have to understand acid based reactions very well. So let's review what an acid base reaction consists of. In an acid base reaction, you have a strong base, let's call this B. And the strong base has a pair of electrons on it. That is what makes it a base. This pair of electrons can attack an acid. An acid is HX. The X is a good leader group, that's what makes this a good acid. Now this is a Brønsted base and
Bronsted acid. That means that the acid is a proton donor and the base is a proton acceptor. When this acid base reaction occurs, you generate a bond between the base and the proton you generate this BH bond and displace X minus. So the pair of electrons attacks the H and displaces the X minus to give you this product.

So this is what happens when you have a strong acid and a strong base, you get a full interaction between BH, you get a full bond. But suppose you have a weak acid and a week base? Here is an example where I have a base here, and it is a weak base, and I have an acid here and it is a weak acid. Let's say that the base is a nitrogen, oxygen, or a sulfur base – a neutral molecule. And the acid is an alcohol or an amine or an SH molecule, something like this. Well the base is not strong enough to fully deprotonate this weak acid. But that doesn't mean that no interaction exists, there is going to be an interaction that exists between the lone pair on the base and the proton. In other words the proton is going to be partially shared with the base. There is going to be some interaction here, but you are not going to break the HX bond all the way. So what is going to happen is we will have this weak BH interaction and we will weaken slightly, the HX bond, but overall energetically this is lower in energy than just B by itself and HX by itself. And that is a hydrogen bond. You have a weak bond between the base and the hydrogen.

Now if you look at the structure of the alcohols, there are ideal for doing this. They are weak bases and this lone pair that is the weakly basic site. This H that is the weakly acidic site. They are also weak acids. They are pretty weak acids in other words. Alcohols are weaker acids than water. But nevertheless, they are acidic enough to where they can form hydrogen bonds, and that is exactly the kind of acidity that we need to get a good hydrogen bond. So here I have indicated lone pair on oxygen, and here I have indicated the proton of the alcohol, and there is an interaction between the lone pair and the oxygen and the proton. This proton is starting to pull off this H, but it is not pulling it off all the way. All it has is some weak interaction there. The same is true of this H and that lone pair and this H and that lone pair. And in the end what you have when you have these alcohols in solution is an extended hydrogen bond array, where all these molecules are interacting with each other. That is in solution. Obviously, to get these out of solution to get them in the gas phase, you have to break these bonds. These are very weak hydrogen bonds, you've got to break them to get the molecules in the solution, and that is going to have an effect on boiling points, as you will see in a minute.

Amines similarly have these properties. Now the lone pair on the amine is more basic than the lone pair on the oxygen. So that is a good base, it can do its thing as far as being a base goes, but the acid here, the NH, is an even weaker acid than an alcohol OH. So this is now, if I called the OH a weak acid, this would be a very weak acid. And the problem is, that this is such a weak acid that the hydrogen bonding in the amines is not as strong as the hydrogen bonding in the alcohols. But again, the hydrogen bonding in the amines takes place on the same general form. You have the lone pair on the nitrogen, that is going to attack the H, it is going to try and deprotonate it, but it is not going to be able to because it is not a very strong acid, and now we will just have this interaction between the lone pair and the H on another amine. That will continue with this amine as well. It will try to deprotonate this H, but it won't be able to. But still you will have some interactions, and likewise with this lone pair and that H, there is going to be an interaction there. So again, you are going to form an extended hydrogen bond network, but the hydrogen bonds are weaker because the NH is weaker acid here. It is not willing to donate the H to a nitrogen.

Now I should point out that in order to have a hydrogen bond, you must have a slightly acidic, very weakly acid proton. Alkanes, compounds that contain CH are not strong enough to participate in hydrogen bonding. Alkanes do not hydrogen bond. So even if you had a lone pair of compound acid base and you had an alkane in there, it would not hydrogen bond, because the CH bond of the alkane is not at all acidic. The same is true with alkene and aromatic hydrocarbons. It has to be an NH, OH or SH.

Okay. So what are the consequences of hydrogen bonding? Well, the first consequence in an increase in boiling point. If you look at three comparable molecules here, dimethyl ether, dimethyl amine and ethanol, these three molecules have about the same Van der Waals interactions. They are about the same molecular weight. So the Van der Waals interaction in these three are going to be comparable, but if you look at the boiling points of these three, diethyl ether has a boiling point of minus 25 and dimethyl amine has a boiling point of plus 7. This difference is 32 degree. That is the contribution of hydrogen bonding in the dimethyl amine. Hydrogen bonding is such that it takes 32 degrees more heat to boil the molecules in a solution. With ethanol, now the boiling point is 78 degree and this difference between minus 25 and 78 is much larger as you can see and that is an indication that the hydrogen bond in ethanol is a much stronger hydrogen bond than it is in diethyl amine.
So I would point out also that this ether only has CH bonds. It does not have any OH bonds, so we cannot hydrogen bond. All it can do is have simple Van der Waals interactions. So basically the contribution of hydrogen bonding can be profound in the boiling points as we see the difference between this molecule and this isomer dimethyl ether, these two are isomers.

Now to summarize what we have seen so far. We have talked about a number of functional groups. The functional groups we are talking about include alkanes. That is essentially the absence of a functional group that is just a CH bond that has sigma bonds and no pi bonds. We have talked about alkenes, carbon-carbon pi bonds, alkynes, contain triple bonds, aromatic hydrocarbons, alcohols, amines and ethers. And here is a molecule that contains all the functional groups that we have discussed so far. This is the aromatic hydrocarbon. Here is an alkene, carbon, and carbon pi bond. Here is an OH that is a primary alcohol. Another OH, secondary alcohol, an amine – this is the secondary amine; it contains two carbons and one H. An alkyne, CC triple bond, and of course, the alkane portion would be wherever we don’t have any functional groups and so this molecule is functionalized so it would not be called an alkane.