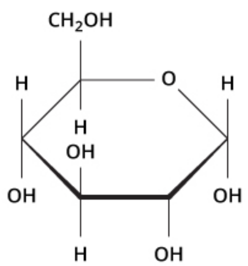
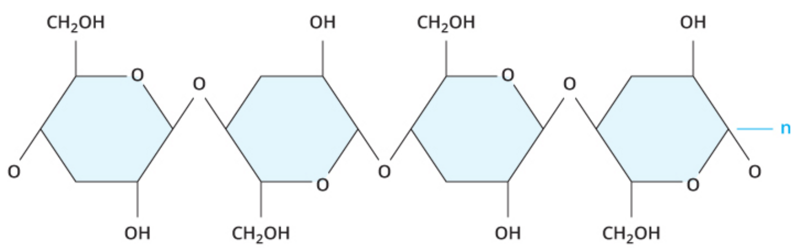
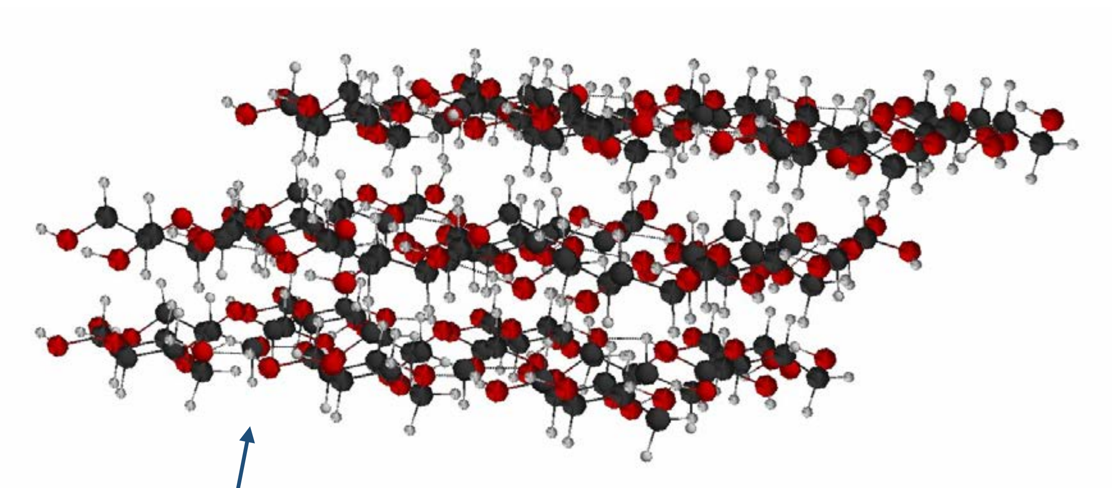
# What is Cellulose Acetate, and Why?
# A Plastic Film Made Out of Cotton??!!

Adapted from Patricia DePra: Westfield State College

Well, no, not really. Cotton is mostly cellulose, which is a polymer of glucose and grown by plants. Glucose molecules can be attached to each other in a number of different ways, by different types of chemical bonds.



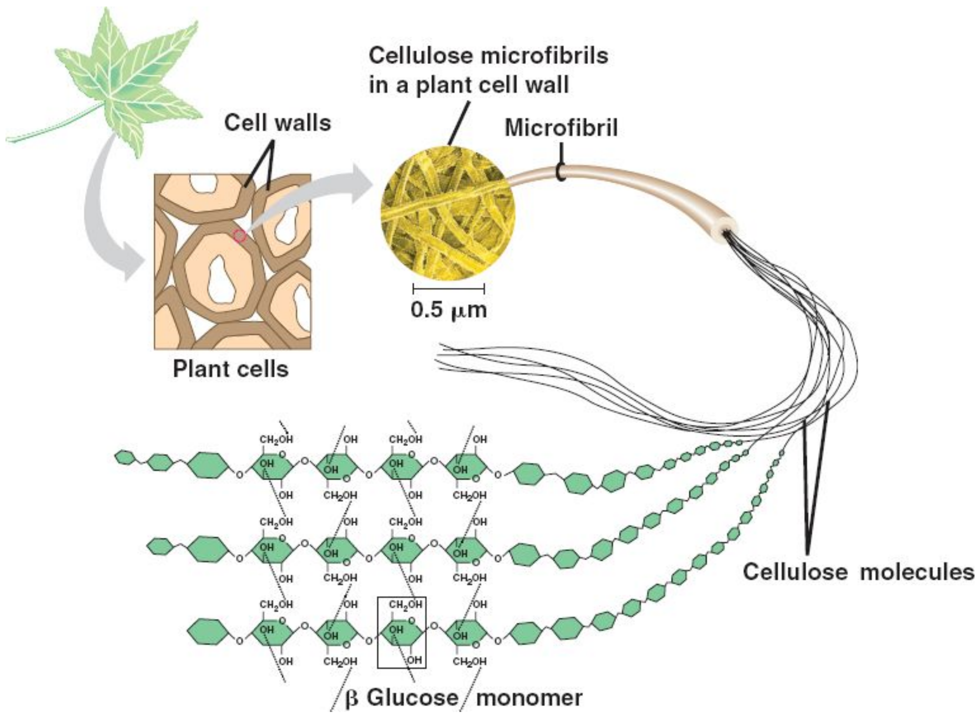




Within one chain of cotton cellulose, the glucose molecules are arranged so that the polymer is the most extended that it can be. Each glucose unit has three OH groups (hydroxyls) that can hydrogen bond to adjacent chains. This strong binding between chains (called intermolecular forces) makes for strong properties: cotton is tough, which is why we make clothes out of it. This same structure for cellulose is found in trees and most plants. Cellulose in trees is combined with two other components, hemicellulose (to fill in the empty places) lignin (the glue that binds it all together).

The result is a very stiff and strong material that can hold up the tallest trees. (Which, as a matter of fact, it does! The major structural component of wood is cellulose.)

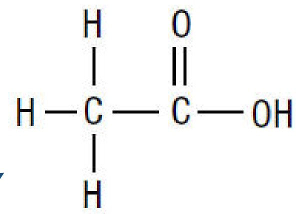
Because of this hydrogen bonding between the extended chains of cellulose, it's hard for any kind of solvent to squeeze in. Cotton just isn't soluble, really, which is good for us and plants: wouldn't want our clothes (and trees) dissolving and washing away when it rains. So, if we want to use it, we have to find a way to take the fibers from a cotton plant and spin those nature-made fibers into thread and other things.

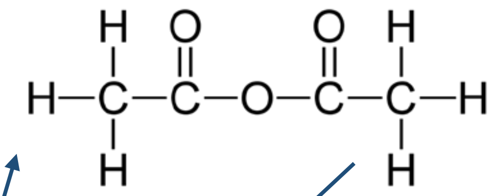



What would happen if we took away the ability of cellulose to hydrogen bond? The polymer chains would be free to move around and become all un-tangled up. That is, they couldn't interact with a solvent better and less with themselves.

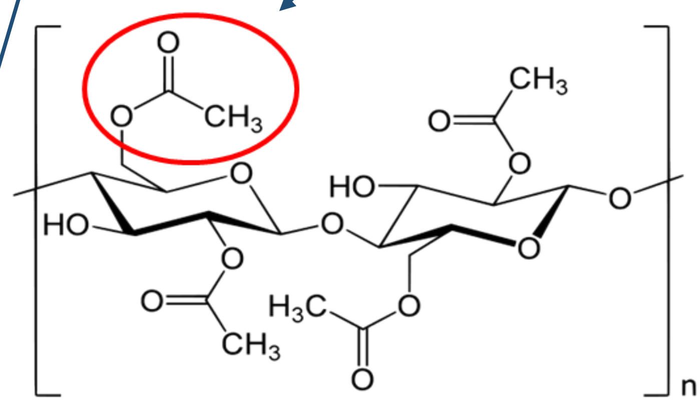
There's not much that we can do with raw cotton in terms of processing it, other than to make thread or yarn. But, that tangled up mess of polymer chains can also be made into films. Just imagine taking a big handful of that cooked spaghetti and smooshing it around on a plate to give a flat, smooth layer or film. You can't do that with the raw stuff.

So, how do we take away the hydrogen bonding? We have to block the OH group with something that <u>won't</u> hydrogen bond. A relatively cheap and easy way to do this is to replace them with acetate groups (or react them using chemistry). We use acetic acid to do this.

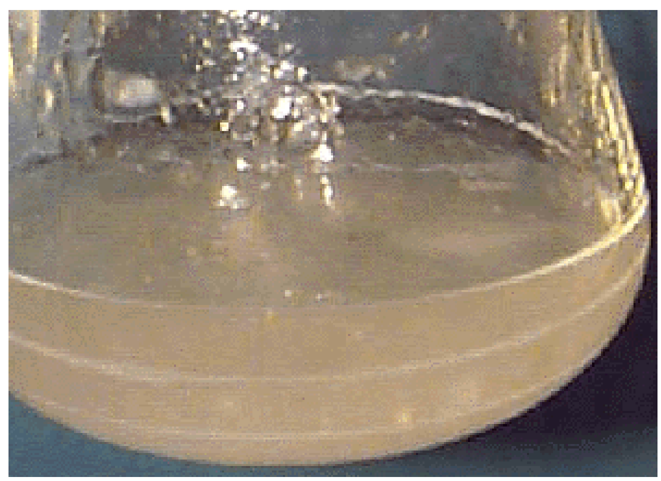




Acetic acid is what gives vinegar its sour taste, but soaking the cotton balls in vinegar won't work (don't even bother -- you'll just make cotton balls that smell like pickles!). We'll have to go into the lab and use 100% acetic acid (also called "glacial acetic acid) and acetic anhydride. (Acetic anhydride is just two acetic acid molecules put together with the loss of a water molecule. It's kind of a sneaky way to have extra-concentrated and more reactive acetic acid.)



After all of the acid is added, it looks like the cotton is dissolving. What's really happening is a chemical reaction. As the cellulose OH groups are replaced with acetate groups, it all becomes more soluble. The chains spread apart, and get less tangled up. Now THIS is something that we can work with!

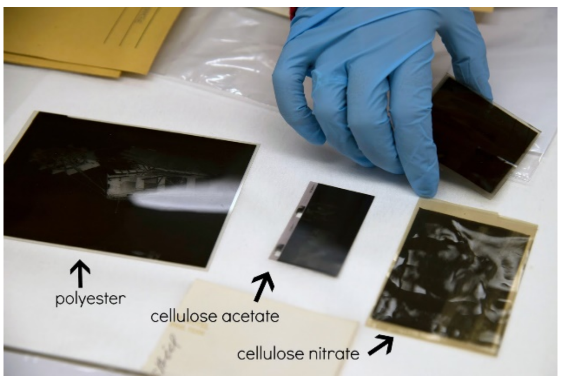


We haven't put the names together yet, but you probably guessed what this new stuff is -- cellulose acetate!

Cellulose acetate isn't soluble in water (which makes sense -- there's nothing on the cellulose acetate chain that can hydrogen bond with water). We use this property to purify it. When we stir water into the reaction mixture, the cellulose acetate precipitates out as a solid. After filtering it and pouring pure water over it to wash away the excess acid, we have solid cellulose acetate.

Now, up above we mentioned that each glucose linked up in a cellulose molecule has three OH groups available. Substituting one, two, or three of those OHs with acetates will result in different properties of the polymer films. As a matter of fact, cellulose acetate is often identified by "percent acetate". If it has at least 92% of its OH groups replaced by acetates, it can *legally* be called "cellulose triacetate." (I'm not kidding, there are laws about this!)






Wear eye protection, lab coat, gloves, and work in a well-ventilated area.

Add 20 ml glacial acetic acid, 5 ml acetic anhydride, and 3 drops sulfuric acid into a 250-ml flask. The sulfuric acid is a catalyst for the reaction. Mix or swirl the flask.

Place 0.5 g cotton into the flask. Ensure the cotton is fully submerged in the solution. Place a stopper lightly on the flask. The reaction takes about 8 hours and is complete when the cotton is fully dissolved. If warmed in a water bath, the reaction only takes ½ hour.

Gently pour the solution into a beaker containing 100 ml cool water. The cellulose acetate will precipitate out of solution. Pour the water and cellulose acetate gel into a funnel containing filter paper. (Washing it several times with water will remove excess acid). The cellulose acetate will collect on the filter, and can be dried and/or scraped off with a blade. By washing with water, we are making cellulose diacetate, which is actually desired because it will readily dissolve in solvents like acetone and lacquer thinner. Cellulose triacetate is harder to dissolve.

Once dissolved in solvent, the cellulose acetate can be made into sheets and/or shapes of various kinds. It will shrink when drying. Industrially, it is melted into shapes to avoid shrinkage.

There are lots of interesting YouTube videos on molding, extruding, and shaping plastics, including recycling various plastics into usable materials. Check these out!