Adhesive and cohesive forces in glues

What does all this have to do with adhesives? Adhesive and cohesive forces are also at work in glues. Let's say you want to stick together two bits of wood, A and B, with an adhesive called C. You need three different forces here: adhesive forces to hold A to C, adhesive forces to stick C to B, and cohesive forces to hold C together as well. The first two are pretty obvious: the glue has to stick to each of the materials you want to hold together. But the glue also has to*stick to itself*! If that's not obvious, think about sticking a training shoe to the ceiling. The glue clearly has to stick both to the training shoe and to the ceiling. But if the glue itself is weak, it doesn't matter how well it sticks to the shoe or the ceiling because it will simply break apart in the middle, leaving a layer of glue behind on both surfaces. That's a failure caused when the adhesive forces are greater than the cohesive ones and the cohesive forces aren't big enough to overcome the pull of gravity.

Jam sandwiches may not be the first thing to spring to your mind when you think about adhesives, but the jam is working as a kind of glue. It's made of sugar and water: a classic adhesive recipe used since ancient times. If you use fairly strong bread, you can pick up a jam sandwich by just one corner of one slice and the whole thing will stay together in your hand—thanks to the jammy glue. Jam has pretty high cohesive forces (that's why jam can be hard to dig out of the jar with your knife), but its adhesive forces are high too. If you butter two pieces of bread and cover one slice with jam, then close up the sandwich, then peel it apart, you'll find there's some jam left on both surfaces. As you pull apart the sandwich, you'll find the jam breaking itself in two in lots of little strands. That's because the adhesive forces are stronger than the cohesive ones. Your jam sandwich "fails" due to a failure of cohesion.

Photo: When you put Marmite (or jam, if you prefer) on a single slice of bread, make a sandwich, then peel the sandwich apart, you'll find there's some Marmite on both slices. This ground-breaking scientific *experiment demonstrates a catastrophic cohesive failure of Marmite as a glue. Unlike most experiments, it also tastes good.*

How do cohesive forces work?

Now we know that adhesives work through adhesive and cohesive forces, we need to understand a bit more about how those forces themselves work. Let's start with cohesive forces. Water molecules join together with others because they're not symmetrical. One end has a slight positive charge, the other end has a slight negative charge, and the positive and negative ends of different molecules snap together like the opposite ends of magnets. That's a kind of electrical or electrostatic bonding. In metals, the atoms are strongly held together in a rigid crystal structure called a lattice (a bit like scaffolding or a climbing frame with atoms at the joins and invisible bars holding them together). You can easily separate one "piece" of water from another (by lifting some out with a spoon): the cohesive forces are quite weak. But you can't easily separate one bit of iron from another (with a spoon or anything else) because the cohesive forces are incredibly strong.

Water and iron are both pretty useless as glues, but for quite different reasons. Water could be an excellent glue because it sticks quite well to other substances (such as glass), but its cohesive forces are incredibly weak. You can stick paper to the wall by wetting it first, but you can usually peel it off quite easily too. When you peel, you're breaking the weak cohesive forces that hold one water molecule to another. Iron is no good as a glue because it's too preoccupied with sticking to itself to stick to anything else. All its forces are occupied internally, fixing one iron atom to another in a strong cohesive structure. There's nothing it can use to attach itself to other objects: its adhesive forces are virtually nonexistent.

How do adhesive forces work?

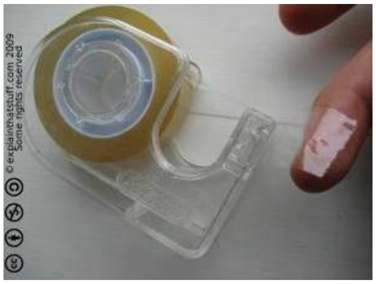
Now for the real question: what makes a gluey substance stick to something else? You may be surprised to hear that there's no single, simple answer—but that's not so surprising if you consider how many different types of glue there are and how many different ways in which we can use them. For each different glue, and each different surface we use it on, scientists think a combination of different factors are at work holding the two together. But the plain truth is: no-one exactly what's going on in every case.

One of the main factors is called **adsorption**. When you spread adhesive, it wets the surface you apply it to. Lots of very weak electrostatic forces between the glue molecules and the molecules in the surface (called van der Waals forces for the physicist Johannes Diderik van der Waals (1837–1923) who discovered them) hold the two things together. For adhesives to work well like this, they have to spread thinly and wet the surfaces very well. There's no actual chemical bond between the glue and the surface it's sticking to, just a huge number of tiny attractive forces. The glue molecules stick to the surface molecules like millions of microscopic magnets.

In some cases, adhesives can *make* much stronger chemical bonds with the materials they touch. For example, if you use certain glues on certain plastics, the glue and the plastic actually merge together to form a very strong chemical bond—they effectively form a new chemical compound at the join. That process is called **chemisorption**.

Absorption and chemisorption are *chemical* connections between the glue and the surface. Glues can also form *physical* (mechanical) bonds with the surface they're sticking to. Suppose the surface is porous (full of holes). The glue can seep into those holes and grip through them, like a climber's fingers grabbing holes in a rock face. That's called the **mechanical** theory of adhesives.

Another theory of how glues work suggests the adhesive can diffuse into the surface and vice-versa, with molecules swapping over at the join and mingling together. This is called the **diffusion** theory.



And one last explanation suggests adhesives can work by **suction**. Exactly how Post-It® notes work is a closely guarded (and very profitable) commercial secret. But some chemists who've studied the problem think their magic adhesive is made from masses of microscopic bubbles. When you push a Post-It® onto a table, some of the bubbles burst and form microscopic vacuums that stick the paper to the table like lots of tiny suction cups. When you peel away the note, you simply break the vacuum. You can reuse a note because not all the bubbles burst each time. But, gradually, all the bubbles do burst and the note loses its stick.

Photo: Sticky tape (also called Scotch® tape and Sellotape® after two well-known brands) is simply a pressure-sensitive adhesive on a convenient, transparent, film backing.

Why doesn't glue stick to the tube?

Adhesives are designed to work when they leave the tube—and not before. Different adhesives achieve this in different ways. Some are dissolved in chemicals called **solvents** that keep them stable and non-sticky in the tube. When you squeeze them out, the solvents quickly evaporate in the air or get absorbed by the surfaces you're sticking to, freeing the adhesives themselves to do their job. Plastic modeling glue works like this. It contains molecules of polystyrene in an acetone solvent. When you squeeze the tube, the glue spurts out and you can usually smell the very strong acetone as it evaporates. Once it's gone, the polystyrene molecules lock together to make strong chemical bonds. Glue doesn't smell when it's dry because all the solvent has vanished into the air. Some glues (such as synthetic, epoxy resins) have to be mixed together before they work. They come in two different tubes, one containing the synthetic resin and the other containing a chemical that makes the resin harden. The two chemicals are useless by themselves but, mixed together, form a tough, permanent adhesive.