Rubber

Background:

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Think of rubber and you probably think of elastic bands, car tires, or pencil erasers. But this super-stretchy material actually finds its way into tens of thousands of different products—everything from rubber stamps and waterproof shoes to surfing wetsuits, swimming caps, and dishwasher hoses. Rubber, which has been commonly used for over 1000 years, once came entirely from natural sources; now rubber products are just as likely to be made artificially in chemical plants. That's largely because we can't produce enough natural rubber to meet all our needs. And that, in turn, is because rubber is so fantastically useful. Let's take a closer look at one of the world's most amazing materials!

What is Rubber?

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When people talk about "rubber", they don't usually specify what kind. There are many different kinds of rubber, but they all fall into two broad types: natural rubber (latex—grown from plants) and synthetic rubber (made artificially in a chemical plant or laboratory). Commercially, the most important synthetic rubbers are styrene butadiene (SBR), polyacrylics, and polyvinyl acetate (PVA); other kinds include polyvinyl chloride (PVC), polychloroprene (better known as neoprene), and various types of polyurethane. Although natural rubber and synthetic rubbers are similar in some ways, they're made by entirely different processes and chemically quite different.

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Natural rubber is made from runny, milky white liquid called latex that oozes from certain plants when you cut into them. (Common dandelions, for example, produce latex; if you snap off their stems, you can see the latex dripping out from them. In theory, there's no reason why we couldn't make rubber by growing dandelions, though we'd need an awful lot of them.) Although there are something like 200 plants in the world that produce latex, over 99 percent of the world's natural rubber is made from the latex that comes from a tree species called *Hevea brasiliensis*, widely known as the rubber tree. This latex is about one third water and one third rubber particles held in a form known as a colloidal suspension. Natural rubber is a polymer of isoprene (also known as 2-methylbuta-1,3-diene) with the chemical formula $(C_5H_8)n$. To put it more simply, it's made of many thousands of basic C_5H_8 units (the monomer of isoprene) loosely joined to make long, tangled chains. These chains of molecules can be pulled apart and untangled fairly easily, but they spring straight back together if you release them—and that's what makes rubber elastic.

Synthetic Rubber:

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Synthetic rubbers are made in chemical plants using petrochemicals as their starting point. One of the first (and still one of the best known) is **neoprene** (the brand name for polychloroprene), made by reacting together acetylene and hydrochloric acid. **Emulsion styrene-butadiene rubber (E-SBR)**, another synthetic rubber, is widely used for making vehicle tires.

How is Rubber Made?

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It takes several quite distinct steps to make a product out of natural rubber. First, you have to gather your latex from the rubber trees using a traditional process called **rubber tapping**. That involves making a wide, V-shaped cut in the tree's bark. As the latex drips out, it's collected in a cup. The latex from many trees is then filtered, washed, and reacted with acid to make the particles of rubber coagulate (stick together). The rubber made this way is pressed into slabs or sheets and then dried, ready for the next stages of production.

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By itself, unprocessed rubber is not all that useful. It tends to be brittle when cold and smelly and sticky when it warms up. Further processes are used to turn it into a much more versatile material. The first one is known as **mastication** (a word we typically use to describe how animals chew food). Masticating machines "chew up" raw rubber using mechanical rollers and presses to make it softer, easier to work, and more sticky. After the rubber has been masticated, extra chemical ingredients are **mixed** in to improve its properties (for example, to make it more hardwearing). Next, the rubber is squashed into shape by rollers (a process called **calendering**) or squeezed through specially shaped holes to make hollow tubes (a process known as**extrusion**). Finally, the rubber is **vulcanized** (cooked): sulfur is added and the rubber is heated to about 140°C (280°F).

Where does Rubber come from?

As its name suggests, the rubber tree *Hevea brasiliensis* originally came from Brazil, from where it was introduced to such countries of the Far East as Malaysia, Indonesia, Burma, Cambodia, China, and Vietnam. During World War II, supplies of natural rubber from these nations were cut off just when there was a huge demand from the military—and that accelerated the development of synthetic rubbers, notably in Germany and the United States. Today, most natural rubber still comes from the Far East, while Russia and its former republics, France, Germany, and the United States are among the world's leading producers of synthetic rubber. The world's largest single source of latex rubber is the Harbel Rubber Plantation near Monrovia in Liberia, established in the 1920s and 1930s by the Firestone tire company.

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Vulcanized Rubber?

Rubber—the kind you get from a tree—starts off as white and runny latex. Even when it's set into a product, this latex-based, natural rubber is very squashy, pretty smelly, and not very useful. The kind of rubber you see in the world around you, in things like car and bicycle tires, is vulcanized: cooked with sulfur (and often other additives) to make it harder, stronger, and longer lasting.

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So what's the difference between raw, latex rubber and cooked, vulcanized rubber? In its natural state, the molecules in rubber are long chains that are tangled up and only weakly linked together. It's relatively easy to pull them apart—and that's why latex rubber is so stretchy and elastic. When latex is vulcanized, the added sulfur atoms help to form extra bonds between the rubber molecules, which are known as cross-links. These work a bit like the trusses you see on a bridge, tying the molecules together and making them much harder to pull apart.

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What is Rubber Used for?

The physical and chemical properties of a material dictate what we use it for. Even if you know absolutely nothing about the real-world uses of rubber, you can probably make some very good guesses. For example, everyone knows rubber is strong, stretchy, flexible (elastic), durable, and waterproof, so it's no surprise to find it used in things like waterproof clothes and wellington boots, sticking plasters, and adhesives.

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The most important use of rubber is in vehicle tires; about half of all the world's rubber ends up wrapped around the wheels of cars, bicycles, and trucks! You'll find rubber in the hard, black vulcanized outsides of tires and (where they have them) in their inner tubes and liners. The inner parts of tires are usually made from a slightly different, very flexible butyl rubber, which is highly impermeable to gases (traps them very effectively), so tires (generally) stay inflated for long periods of time.

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The fact that rubber can be made either soft or hard greatly increases the range of things we can use it for. Soft and stretchy latex is used in all kinds of everyday things, from pencil erasers, birthday balloons, and condoms to protective gloves, adhesives (such as sticky white PVA), and paints. Harder rubbers are needed for tougher applications like roofing membranes, waterproof butyl liners in garden ponds, and those rigid inflatable boats (RIBs) used by scuba divers. Because rubber is strong, flexible, and a very poor conductor of heat and electricity, it's often used as a strong, thin, jacketing material for electrical cables, fiber-optic cables, and heat pipes. But the range of applications is truly vast: you'll find it in everything from artificial hearts (in the rubber diaphragms that pump blood) to the waterproof gaskets that seal the doors on washing machines!

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Neoprene (polychloroprene) is best known as the heat-insulating, outer covering of wetsuits—but it has far more applications than most people are aware of. Medical supports of various kind use it because, tightly fitted, it compresses and warms injured bits of your body, promoting faster healing. Since it's flexible and waterproof, it's also widely used as a building material, for example, as a roof and floor sealant, and as a spongy absorber of sound and vibration in door and window linings.

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Although the world has a vast appetite for new rubber, we also produce a huge quantity of rubber waste, especially from discarded vehicle tires—and that's becoming an important raw material in its own right. According to the Rubber Manufacturers Association, the United States alone produced almost 270 million waste rubber vehicle tires in 2011, which is about a third of all the tires used worldwide. While some of these are retreaded and others are ground up to make a low-grade aggregate that can be used for the floors in things like children's playgrounds, over half of them are wasted (either burned as a fuel or buried in landfills). Rubber manufacturers have recently turned their attention to recycling tires in all kinds of new ways, making everything from mouse mats and sports bags to shoe soles and car components.