James Bonner, professor of biology, taps a six-year-old rubber tree grown from seed at Caltech.

Research in Progress

More Rubber from the Rubber Tree

For over 20 years, James Bonner, professor of biology at Caltech, has directed some portion of his time to the study of the synthesis of rubber, one of the most important materials which plants supply to man. When natural supplies of rubber were cut off during World War II, Dr. Bonner helped establish the program for the production of rubber from guayule, a native American plant. This served as a stopgap for necessary supplies while the chemical synthesis of rubber substitutes was set up on a large scale.

Dr. Bonner's interest in rubber continued until solution of the question of how rubber plants make rubber was finally achieved three years ago. Last fall he addressed the first world-wide conference on rubber in Kuala Lumpur, Malaya. The conference, sponsored by the Rubber Research Institute of Malaya, was attended by over 300 scientists, all experts on rubber. There, Dr. Bonner described how the rubber tree, one of nature's most efficient chemical factories, transforms carbon dioxide and hydrogen into the long hydrocarbon molecules which appear as rubber in the liquid latex. This knowledge has evolved in the past 12 years, from continuing research on the rubber tree – much of which has been done at Caltech by Dr. Bonner and his associates.

Actually, most of the significant knowledge about rubber synthesis has been obtained in the past four years. The cornerstone for this present knowledge is the fact that all of the carbon atoms of rubber are derived from acetate. This applies not only to rubber but also to the other isoprenoids such as the essential oils and steroids (important in people as hormones), all of which have as their molecular base the five-carbon substance isoprene.

The rapidly increasing yields of rubber from the rubber tree dramatically exemplify how science benefits practical affairs. During the past 20 years the rubber tree has been made to increase its yield five times. This has been done by painting hormones and antibiotics on the tree trunk to improve latex flow and by using new methods of tapping the latex vessels which are the latex-containing pipes in the bark of the tree. Scientists expect to double the rubber tree's output again, mainly by applying the new knowledge of the synthesis of rubber.

In the United States, synthetic rubber is widely used – partly because it is cheaper than natural rubber. In the world as a whole, however, twice as much natural rubber is used as synthetic rubber. The amounts of rubber used each year are rapidly increasing as more and more of the world's people shift from feet to seat, from walking to automobiles.

Anesthetics — A New Theory

Anesthetics, in various forms, have been used throughout the ages in an effort to relieve pain. But scientists have never been able to find out how anesthetics actually worked. The common belief is that anesthetics induce unconsciousness and insensitivity to pain by dissolving in the fatty substances of the brain and changing these substances in some unknown manner. Now a new theory has been advanced by Linus Pauling, professor of chemistry at Caltech – the first detailed molecular theory of anesthesia ever proposed.

The Pauling theory holds that anesthetics bring unconsciousness because they cause the formation of tiny crystals which reduce conductivity and interfere with the electrical activity of the brain. The action, according to this theory, takes place on the fluid part of the brain. (Brain tissue contains 78 percent water and only 12 percent fatty substances.) It is believed that only one-tenth of one percent of this fluid material needs to be converted into minute crystals to induce unconsciousness and insensitivity to pain.

The microcrystals that might be formed when anesthetics reach the brain would be much smaller than a brain cell, but large enough to contain hundreds or thousands of water molecules. Unlike ice crystals, which could damage brain tissue by expanding, these crystals do not expand.

It is known that water, in liquid form, is a conductor of electricity, but in crystals or ice it is a poor conductor. Even without an anesthetic, cooling the brain from 10 to 20 degrees below the normal temperature of 98.6 will cause unconsciousness. Dr. Pauling assumes that when brain tissue is cooled, small hydrate crystals form in the tissue, entrapping some of the ions and electrically-charged side chains of protein molecules. The formation of these microcrystals would then interfere with the electrical activity of the brain and cause unconsciousness.

The new theory indicates that molecules of an anesthetic agent such as chloroform fit into cavities in the framework of the water molecules constituting the hydrate microcrystals in such a way as to stabilize these crystals, and to allow them to form at a higher temperature, even at normal body temperature. This action would cause unconsciousness just as the cooling action does.

Dr. Pauling's theory could offer an explanation for many phenomena. For instance, divers, working under high pressure, sometimes suffer from anesthesia caused by nitrogen in the air they are breathing. Molecules of nitrogen do not interact with water molecules very strongly, but the interaction is strong enough to stabilize hydrate microcrystals when the pressure of the nitrogen is great, as it is for a diver at considerable depth. Replacing the nitrogen with helium prevents this effect, because helium atoms have a very small attraction for other molecules and therefore do not stabilize the formation of crystals.

One of the most puzzling facts about anesthesia has been that the rare gas xenon is an almost perfect anesthetic agent – and yet it is completely unreactive chemically. Its only known property is that of forming hydrate crystals – a fact that is extremely interesting in the light of Pauling's theory. As in his explanation of the action of ordinary anesthetics, the attractive action between the atoms of xenon and the molecules of water in hydrate crystals, makes xenon one of the most effective anesthetic agents known.

Another interesting feature of the new theory is that it has permitted the prediction to be made that certain mixtures of anesthetic agents should be more effective than one agent alone. The hydrate microcrystals that form in the brain have cavities of different sizes to accommodate anesthetic molecules of different sizes. The smallest chamber in which an anesthetic molecule can fit is formed by 20 water molecules, the next larger by 24, and a still larger by 28. If, as it is assumed, the hydrate microcrystals that form in the brain contain all three kinds of chambers, then anesthesia could be accomplished more easily by using mixtures of molecules of different sizes.

The Pauling theory may also have importance to other parts of the body than the brain. It is probable that hydrate microcrystals form in tissues of other parts of the body and that the properties of the tissues may then be changed to some extent.

The new theory is being subjected to more experimentation in the Caltech chemistry laboratories as a part of the research devoted to development of a detailed understanding of the properties of living organisms in terms of their molecular structure. The new findings by Dr. Pauling were developed in the course of a program of investigation of the chemical basis of mental disease, being carried out at Caltech with the support of the Ford Foundation and the National Institutes of Health.