A TREATISE ON DOING GOOD

It's not so hard for biologists to do societal good if the problems selected are simple enough.

by James Bonner

James Bonner's miniature replica of a section of the trunk of a rubber tree was presented to him at a National Rubber Conference in Kuala Lumpur, Malaysia.

My principal research is finding out how genes and chromosomes work, and in recent years my colleagues and I have discovered quite a lot. No doubt one day some of our findings may even be useful. But the fallout of public good is still in the future, and today there is increasing demand for science to be relevant, for it to solve or at least ameliorate social problems. A growing number of people are looking at science and scientists with a what-have-you-done-for-me-lately? attitude.

In response, we have the National Science Foundation setting up its Research Applied to National Needs Program; the National Institutes of Health announcing a goal of curing cancer by 1975; and Caltech establishing its Environmental Quality Laboratory to help solve urgent societal problems.

While such directions are being pursued on a high-priority level, let's remember that doing good can be effected in an infinite number of ways. There are all kinds of areas where it's not only easy, but takes relatively little time. Since I have had a few absorbing experiences as a consultant in the line of useful scientific activity, I would like to put into the record two of my modest attempts to do something useful.

I start with a historical digression. During World War II, I was requested by our government to help find out how to produce rubber. All rubber then came from the rubber tree, *Hevea*, grown mainly on plantations in Malaya and Indonesia. When the Japanese occupied these countries in 1941, our rubber supplies were cut off. The Emergency Rubber Program, to which I was assigned, carried out massive experiments on the cultivation of rubber-producing plants that would grow in the United States:

My experience with the Emergency Rubber Program did not produce a whole lot of rubber, but I did learn that no one knew how rubber trees make rubber.

---

guayule, goldenrod, Russian dandelion, and others. We also produced rubber from the usual rubber tree, *Hevea*, which grows wild in tropical Mexico and Guatemala. The rubber emergency was, of course, eventually met by finding out how to synthesize rubber substitutes chemically. The substitutes were much less satisfactory than real rubber but better than nothing at all.

My experience with the Emergency Rubber Program did not produce a whole lot of rubber—perhaps about enough to recap a couple of bicycle tires—but I did learn that no one knew how rubber trees make rubber. I took up this problem after the war, and in 1960 the Malaysian government invited me to the capital, Kuala Lumpur, to talk about rubber matters with rubber producers and with scientists of the Rubber Research Institute of Malaya, the biggest and best research institute in all of southeast Asia.

As a result of my first visit I was asked five years ago by the Malaysian government to become an adviser on all matters of development, and in 1967 I went to Malaysia again and spent a month looking over the situation to determine where the most good might be done. In Malaysia the rubber crop is the greatest contributor to the gross national product, a prime source of capital formation and of foreign exchange, and the principal factor in Malaysian development. Obviously, in view of the central importance of the rubber economy, the best place for me to do good was in rubber, and this made my biochemical research into the rubber-making process useful.

The rubber tree produces its rubber as a latex—that is, rubber particles suspended in an aqueous solution of proteins. Latex is produced and contained in long, pipe-like cells in the bark. Sugar, made by photosynthesis in the leaves, moves down to the bark through another series of "pipes" and leaks into the latex cells where various appropriate enzymes convert it to rubber. Eventually, rubber constitutes 35 percent of the latex.

At this level the rubber-making enzymes turn off, and the latex just sits there until the rubber tapper comes along to collect it. The tapper removes a spiral of bark from a third of the tree's circumference. The latex, under a pressure of about 10 atmospheres, squirts out of the cut vessels, runs down into a little spigot fastened to the end of the cut, and drips into a cup below. As flow continues, latex moves to the tapping cut from further and further away. It flows more and more slowly until, in about an hour, it coagulates at the cut.

After the flow ceases, water from within the tree flows into the latex cells, signaling them to produce enzymes. In about 48 hours rubber concentration is back up to 35 percent, and the tree is ready for tapping again. The tree may be tapped like this every other day forever. In this way over a million tons of rubber a year are produced in Malaysia, each acre yields an average of a half ton a year, and one billion dollars a year flows into the economy.

When the rubber tree is tapped, latex flows to the cut from as much as two feet away before it stops. Since the tree may be 50-60 feet tall, it is obvious that it would be nice to get more of the tree into the action. Two taps separated by six or eight feet are practical; in fact, they double the yield. But tapping from a stepladder consumes too much time. The question in 1967 was how to get more of the tree to supply latex, and to resynthesize each day, from a single tapping cut. We already had a hint of sorts.

In the late 1950's it had been found in Malaysia that application of the compound 2,4-D to the bark of the tree beneath the tapping cut caused latex to flow 10 to 15 percent longer than normal. In South Vietnam, at the time a considerable rubber producer, it had been found that applications of copper sulfate to the bark do exactly the same thing, and cause exactly the same sort of increase in yield. How can two such diverse chemicals cause the same end result? It would seem impossible.

To explain why it was not impossible requires another digression. During the years 1966-69 the division of biology at Caltech had worked on a crash program to try to find out how to harvest oranges mechanically. Florida faced a crisis because of a new law prohibiting the importation of Mexican labor to handpick the state's massive commercial crop of oranges. Our help was recruited by the director of the Citrus Research Division of the U. S. Department of Agriculture, a Caltech alumnus and former student of mine, William C. Cooper (MS '36, PhD '38).

We already knew that fruits or leaves fall off of plants in response to the gas ethylene. This substance, a plant hormone, travels to the base of leaf or fruit and turns on genes for making enzymes. The enzymes digest the adjacent cell walls, weakening the cells which join fruit or leaf to stem so that the fruit or leaf drops off. To solve Florida's problem we concentrated on trying to find out how to get oranges to produce ethylene to make themselves fall off the tree. Copper sulfate turned out to be

> The world's ability to gobble up rubber is still increasing exponentially. Everyone appears to want wheels.

excellent for this purpose. Sprayed on fruit, and in particular in combination with ascorbic acid, it damaged cells, which caused the fruit to produce ethylene. It was already known that the application of 2,4-D in other plant tissues causes ethylene production.

Ultimately our group found a usable, totally non-toxic, biodegradable material—now approved by the Food and Drug Administration. Named cycloheximide, its spray on orange trees makes the ripe fruit fall off, but it doesn't affect either green fruit or leaves. Today Florida's oranges—and this means 200 million boxes a year—are increasingly being harvested by first spraying the trees with cycloheximide to decrease pull strength of the fruit, then blowing oranges off with a wind-blast, and finally picking them up with an oversized vacuum cleaner.

The problem is solved. Insofar as it is a societal problem—and it certainly was a Florida societal problem—a societal problem has been cured.

End of digression and back to Malaysia. Both 2,4-D and copper sulfate cause ethylene production in plants—although, to be sure, in different plants. Could it be that both agents cause *Hevea* bark to produce ethylene, and might it be that ethylene is the common agent through which both work?

We and our colleagues at the Rubber Research Institute of Malaya wrapped the trunk of a rubber tree in a big polyethylene bag. We brought a cylinder of ethylene gas from Bangkok, got a skilled tapper to tap the tree, and then injected ethylene into the bag. The result was spectacular! The latex flowed from the cut for several days. In fact, the tree oozed from every insect puncture wound. We concluded that we really had something.

But it is very unhandy to apply ethylene to trees in polyethylene bags, just as it's no use having the tree leak uncollectable latex. Better control of application had to be invented. The director of the Rubber Research Institute of Malaya, Dr. B. C. Sekhar, set up an interdisciplinary committee to tackle all the problems at once. It quickly developed that an excellent way to apply ethylene to *Hevea* is in the form of the compound ethrel (chloroethylphosphonic acid), which—in alkaline solution—decomposes spontaneously to form ethylene, HCl, and phosphoric acid. The ethrel is dissolved in palm oil, a local product, and applied with a paintbrush to a two-inch-wide strip below the tapping cut. As the chemical slowly diffuses into the bark, it is converted to ethylene, which causes the latex flow to continue for several hours rather than for one. It also results in latex draining from about six feet away from the tapping cut instead of from two. A single application is effective for at least two months; a second application may be made with equal effect; and the treatment costs 25 cents an acre. The yield of rubber per acre is doubled under the least favorable conditions and tripled under the most favorable.

In the fall of 1968 our experimental work was far enough advanced to justify the setting up of large-scale field trials. These were done in every Malaysian state, and with every important variety of rubber tree. The trials have been under way for several years, and no damage is evident to any of the trees.

I am happy to report that now the new technology is spreading like wildfire throughout the rubber tree area in Malaysia. It seems clear that this one innovation will, by itself, double the gross national product of Malaysia and thus help to speed the transition of that country from an agricultural to a modern, industrial, technological society.

But will all that increased natural rubber supply depress its worth? Not likely. The world's ability to gobble up rubber is still increasing exponentially. There are still more people without wheels than with them, and everyone appears to want them. Natural rubber's place in the world is assured. The United States is Malaysia's biggest customer, followed by Japan, Russia, and mainland China. In the United States airplane tires and all large heavy-duty off-the-highway tires must be made with *Hevea* rubber; so must most of the passenger car radial tires—and the use of radial tires is growing rapidly.

So my conclusions are: (1) It's not so hard for biologists to do societal good if the problems selected or presented are simple enough. Basically it's not difficult to make oranges fall off trees in Florida, and it will certainly save those Florida folks a lot of backaches; and (2) it would appear to be easier to do really meaningful societal good in a developing country with a technological problem than to do the same thing in a developed country. Imagine trying to double the gross national product of our own country in five years.

And finally—to try is good, to succeed sublime!