smells remarkably like a female bee"—an elaborate stratagem that ensures that male bees will be dusted with pollen and carry it to other orchids. But the tenacious dandelion is another story. Though the dandelion grows bright flowers inviting to bees and produces pollen, these are sterile vestiges of an earlier time when the weed reproduced sexually. Today's dandelions reproduce by asexual parthenogenesis: Each seed will grow, without being fertilized, into an exact genetic copy of its parent plant.

Sex has some obvious advantages. For a species adapting to a changing environment, "the myriad natural variations that sex produces can spell the difference between success and failure, survival and extinction." The chief disadvantage of sex is uncertainty. Because male and female each contribute half of their offspring's genes, the result can be the worst of both worlds—an individual inferior to both of its parents.

A few plant and animal species have resolved the dilemma by relying on two means of reproduction. A single strawberry plant, for example, can take over an entire meadow by reproducing asexually—the plant sends out runners (called "stolons") that put down roots and then send out more runners. And yet, strawberries also flower and form seeds that are spread much farther afield than runners.

Aphids, coral polyps (whose shells form coral reefs in the tropics), and rust fungi are among the many organisms that fluctuate between sexual and asexual reproduction. And in general, there is a pattern to the changes, notes Stebbins. "As long as the environment is favorable, they reproduce asexually, multiplying greatly those genetic plans that have already proved themselves fit." But once they saturate their habitats or if their environment changes radically, they reproduce sexually, assuring that the next generation will be different and, thus, will have a better chance of survival.

For thousands of plant species, then, sex is only necessary *sometimes*. Most animals, however, cannot escape it. The reasons are unclear. More complex than plants, animals may be more susceptible to harmful mutations, Stebbins speculates. Sex may be the device by which mistakes are erased, since, in most cases, both parents must possess a genetic blemish to pass it on to their offspring.

Where Computers Fear To Tread

"Synthesizing Chemicals by Computer" by James B. Hendrickson, in *Technology Review* (Apr. 1984), Room 10-140, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

It is easy for laymen to imagine that scientists everywhere are rushing headlong to computerize their laboratories. A few scientists, however, are still unenthusiastic about computers.

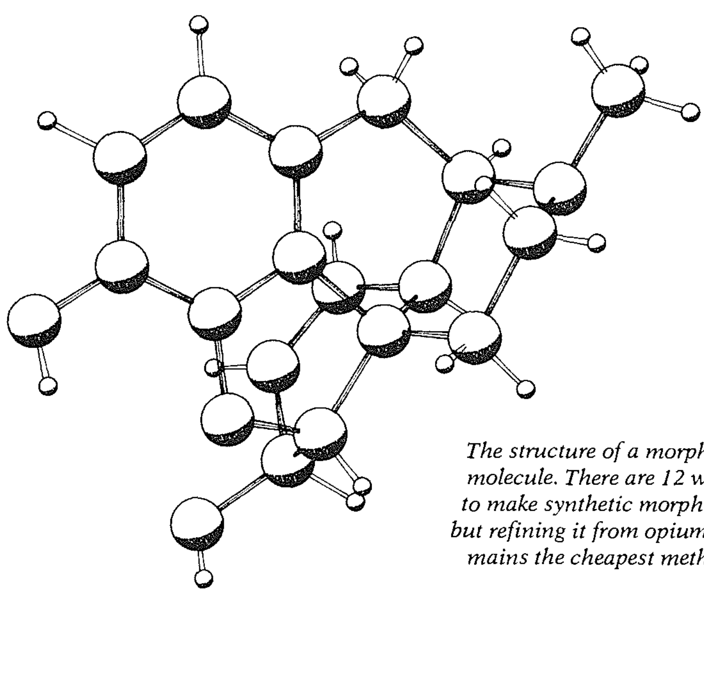
The holdouts are organic chemists, writes Hendrickson, himself a chemist at Brandeis. Since the mid-19th century, they have created some eight million compounds, of which perhaps 500,000 have found practical uses—all without the aid of computers. The chemists have replicated natural material, such as quinine and indigo, and created entirely new substances, such as aspirin, Novocain, and Valium. The color mauve did not exist before organic chemists cooked it up in the laboratory during the 1890s. It was an instant fashion sensation. Indeed, Hendrickson and his colleagues have created innumerable hues never seen before.

Making new chemicals is akin to an art, he says, and organic chemists are "jealous of their intuitive understanding of synthesis."

To create a chemical compound, the scientist must first decide upon the correct atomic formula. (To invent one useful new drug, a chemist may have to create and "audition" up to 10,000 useless compounds.) Then he must imagine the molecular structure in three dimensions. The formula for rubbing alcohol (C_3H_8O), for example, is the same as that for two other liquids—only the shape of the molecules is different.

But the hardest part of the chemist's job is figuring out how to make the new molecule. Usually, it must be built step by step through a series of chemical reactions. The chemist thinks the problem through backward: "Each product along the route back [from the new substance] can be seen as the result of several possible reactions, each of which means using different molecules one step earlier along the chain. The possibilities multiply spectacularly as chemists push back to reactions that involve simple starting compounds."

The more steps, the more room for error. The chemist's challenge is to pick from hundreds of possibilities the right reaction.



The structure of a morphine molecule. There are 12 ways to make synthetic morphine, but refining it from opium remains the cheapest method.

Computers may someday speed the art of synthesis, but so far they have helped little. The three-dimensional world of the organic chemist is hard to translate into the binary language of computers. And while a computer can list all the choices facing the scientist at each step of the way in building a new chemical, the scientist must still decide which offers the best chance of success. Hendrickson himself is working on computerized chemistry, but he doubts that much progress will be made until more of his colleagues "soften their resistance" and help develop a new computer technology appropriate to their unusual needs.

Inventing Plastic

"The Development of Plastics" by Herman F. Mark, in *American Scientist* (Mar.-Apr. 1984), P.O. Box 2889, Clinton, Iowa 52735.

Nearly everything in the industrialized world seems to be made of plastic or at least to contain some of it. Yet it was only a few decades ago that scientists began to understand this remarkable material.

As is so often the case with great discoveries, writes Mark, Dean Emeritus of the Polytechnic Institute of New York, plastic was first created by accident. In 1846, Swiss chemist Christian Schoenbein used his wife's apron to mop up some acids he had spilled and hung it in front of a hot stove to dry, whereupon it flared up and disappeared. Schoenbein had discovered cellulose nitrate. Others were quick to apply his finding to the manufacture of, among other things, explosives. A second step came in 1907, when chemist Leo H. Baekeland, an American, made the first plastic molecule that was entirely new, not a derivative of cellulose. "Bakelite" was soon used to make everything from billiard balls to gramophone disks.

But scientists did not begin to understand the chemistry of plastics until Germany's Herman Staudinger suggested in 1920 that "polymers," which include plastics, as well as wool, wood, and silk, were distinguished by the huge size of their molecules. One prominent chemist of the day objected that it was like being told that "somewhere in Africa an elephant was found that was 1,500 feet long and 300 feet high." In 1953, however, Staudinger received a Nobel Prize for his work.

Gradually, scientists have come to understand the structure of plastics: They are long chains of atoms. In their natural state, the chains are a more or less useless jumble. But they can be shaped in two ways to produce useful materials.

One way is to cause "crystallization" by applying mechanical force: The chains form themselves into relatively straight bundles, linked together by weak atomic bonds. The more crystallized a plastic is, the harder it is. Thus, the nylon in a fishing line is about 90 percent crystallized, the nylon in women's lingerie only 20 to 30 percent.

"Cross-linking" is the second treatment for plastics. It involves the formation of very strong chemical bonds between the "macromolecules." A plastic with the hardness of a television cabinet, for example, has far more chemical bonds between molecules than does the plastic of a surgeon's gloves.