Polymers

Not traditionally associated with biological materials, polymers can nevertheless be produced from proteins, forming horny materials like keratin and chitin. Gengineers may design proteins that polymerize into plastics with desirable properties, then put genes to produce them into various plants and animals. An advantage of protein-plastics is that they are biodegradable, allowing easy recycling rather than polluting the environment.

Ceramics

Bone, silica, and calcium carbonate are some of the ceramic materials produced by organisms. Others could be crystallized out of raw chemicals by biological processes. Gengineered organisms could be designed to grow everything from ultra-pure crystals for use in precision electronics up to bulk construction material. They could also be used to synthesize artificial gemstones, both crystalline such as diamond and amorphous such as opal. Other ceramics with properties based on precise microscopic structure, such as light refraction, could also be grown organically.

Biological Control

Humans have been fighting pest species since prehistoric times. We pull up weeds in our gardens, spray insecticides on our crops, lay traps for mice, and scrape floating plants off our waterways. These labor-intensive and sometimes unsafe methods are never effective for long.

Biological control uses organisms to do the work of fighting pests for us. (Another method of controlling pests is to modify the pests themselves; see *Genetically Defective Vermin*, p. 87.)

The cost of species used for biological control is highly variable. They may be released en masse by government programs, or purchased by individual farmers or residents. A box of common insect agents such as ladybugs or lacewings costs $20-$100. Each contains a few thousand eggs or a few hundred adults, suitable for treating up to an acre of land. Engineered species would cost more.

Control Using Extant Species

The ancient Egyptians practiced biological control when they realized that keeping cats could hold mouse populations down. Some early Asian farmers encouraged ants to live amongst their crops, to protect them from other insects. Modern biological control began in 1762 when colonists successfully transported a species to a foreign location specifically to reduce vermin: mynah birds to control locusts on Mauritius. Scientists of 19th-century Europe controlled several crop-eating insects using parasitic wasps and predatory mites, and developed the principle of transferring native predators to control pests introduced into new areas. This technique has since been used many times to control both plant and animal pests, using agents as varied as insects, internal parasites like nematode worms, and fungi.

Using existing species as biological controls is attractive for a number of reasons. It is relatively cheap, as the animals breed themselves in the wild and spread to cover nearby infested areas. It also avoids the use of chemicals, which avoids any problems of toxicity in the environment or final product, and makes the products more attractive to consumers.

Discovering a suitable biological control agent takes more than just finding a naturally occurring predator on the pest organism. If released into a new ecosystem, such a creature could wreak havoc on the local native species as well – or instead of! – the desired target. Several attempts over the years have backfired in exactly this way: mongooses introduced to Hawaii to control rats have exterminated many bird species. Ideally, a control species will not prey on any species other than its intended target, and die off as the pest is brought under control. Nowadays, exhaustive testing is undertaken before releasing a control species to ensure this. The problem is, most candidates don't measure up.

Gengineered Control Species

Gengineering is an obvious way to produce species more satisfactory as biological control agents. Usually the trait needing modification will be the tendency to attack species other than the one to be controlled. This might be achievable with purely behavioral modifications, but a more reliable approach is to engineer a reliance on the target species or an aversion to other potential targets. The first method relies on finding some protein or nutrient supplied only by the target organism, and engineering the control species to die without it. The second method is more difficult as it requires finding substances in all other possible targets and engineering them to be poisonous or distasteful to the control organism.

Control Using Microorganisms

All of the principles discussed above can also be applied to biological control using microbes. There are additional considerations, however. The naturally occurring disease myxomatosis was used to control rabbits in Australia, until the remaining rabbits spread myxomatosis-resistant genes throughout the population. The next stage was to be a controlled release of rabbit calicivirus, but the virus escaped a highly secure experimental quarantine area on an offshore island in 1995 and spread to every state on the mainland within a few months, before anyone knew if the virus could affect native mammals.