Having It Your Way with Genes

With generation after generation of information mixing, changes in genes accumulate and the appearance or function of succeeding generations of a living organism can change dramatically. In nature, changes in genes arise from accidental alterations — mutations — and from the exchange of genetic information when organisms reproduce. With each alteration of the information that specifies their form and function, creatures become better or worse suited to their environment. The better suited tend to survive and reproduce (to mix and pass on their genes again).

Gene reshuffling creates diversity, causing animals of the same species to come to vary greatly in appearance. Such variation within a species often occurs naturally, but it can be accelerated when genes are purposefully recombined through selective breeding. Throughout history, humans have taken advantage of the possibilities for variation allowed by gene reshuffling to control the characteristics of other animals. Dog breeders do this, for example. All domestic dogs, from Mexican Chihuahua to Great Dane, belong to the same species, though they look radically different. Cats, horses, sheep, and cows have also been manipulated genetically by humans to emphasize certain characteristics that make them more useful or decorative.

Horticulturalists have been very selective in plant breeding, as well. U.S. grain crops, with their large seeds and huge yields, would be unrecognizable to ancient farmers. The flowers in almost every garden today are mostly selectively bred strains that didn't exist a century ago, and the same is true for most of the fruits and vegetables you eat.

Choosing chickens

By selecting only chickens with elaborate varieties of head plumage to breed with one another, breeders can quickly vary the appearance of successive generations of these showy chickens.

The decorative chickens you see above are widely varying descendants of much plainer ancestral chickens. At Plimoth Plantation in Massachusetts, agricultural scientists are selectively breeding highly specialized modern chicken species to try to produce ones with the characteristics of their seventeenth-century ancestors — a kind of reverse selective breeding.

Question.

What characteristics would the scientists try to achieve, given the environmental challenges to the original Plimoth chickens?

Answer...

The traits that would be selected for are likely to be muted colors, ability to thrive on sparse food, hardiness to cold and damp, quickness, and good vision.

Taking Gene Mixing into Our Own Hands

Since the mid-1970s we have been able to accomplish an entirely new kind of purposeful gene transfer, almost unimaginable before the discovery of the structure and function of DNA and proteins. We have learned to take specific lengths of DNA (genes from one organism) and insert them into another, in some cases turning that other organism into a "factory" for making specific proteins. The first such successful gene transfers were accomplished in 1979, when the genes that describe two human proteins, insulin and human growth hormone, were inserted into bacteria. These "genetically engineered" bacteria multiplied, producing large amounts of the two proteins. Now these proteins and others useful to humans are produced industrially in huge fermenter tanks that can hold thousands of gallons of bacterial cultures.

The same idea lies behind the genetic engineering of new food plants such as the New Leaf potato. With an inserted gene from a bacterium (*Bacillus thuringiensis*), this plant makes its own "natural" pesticide. The bacterial gene produces a protein that is toxic almost exclusively to the plant's principal predator, the potato beetle. Along with the rest of the plant's DNA, the gene for the toxin is reproduced in every cell of the potato plant as it grows, protecting it from being eaten by the beetles. Thus it is unnecessary to spray the potato plants with insecticides that might kill other, more benign insects.

Rice is a major food staple in the developing world, where hundreds of millions of people suffer from vitamin A and iron deficiencies. Lack of vitamin A leaves people susceptible to disease and progressive blindness. Lack of iron affects even more people and causes anemia, as well as playing havoc with the immune system. Recently, a new strain of rice has been engineered that includes bacterial genes for producing beta-carotene, a protein that the human body converts into vitamin A. This golden-grained rice also has genes that promote the accumulation of iron. Thus, people who eat this grain get, at one bite, their staple food and a vital vitamin and mineral supplement.

Question.

Who is engineering organisms, and why? It is important to note that there is a lot of controversy surrounding genetically engineers organisms and crop plants. What might be some of the objections to their use?

Answer...

This one is up to you.

DOING Science

Wen-Jing Hu et al. 1999. Repression of lignin biosynthesis promotes cellulose accumulation and growth in transgenic trees. *Nature Biotechnology* 17: 808-812.

Dr. Hu and his colleagues report in this paper that they have genetically engineered aspen trees to make them into more useful and faster-growing paper producers. (Aspen trees' structural cellulose chains are used to make paper, and the lignin molecules that "glue" the chains together gum up the papermaking process.)

Hu's research demonstrates a way to block the gene that produces an enzyme that aspen cells use to make lignin. The genetically engineered trees end up with half as much lignin in proportion to cellulose as normal aspens have.

With a lower proportion of lignin to cellulose, aspen trees are not only more easily and cheaply made into paper — the process uses less energy and fewer chemicals — they also grow faster. The lower proportion of lignin also makes it more practical to use these trees to produce ethanol and other biofuels.

Mixed-up corn

Here you can see the progressively larger edible seeds of selectively bred corn plants. The wild form, called teosinte, is on the left of the picture.