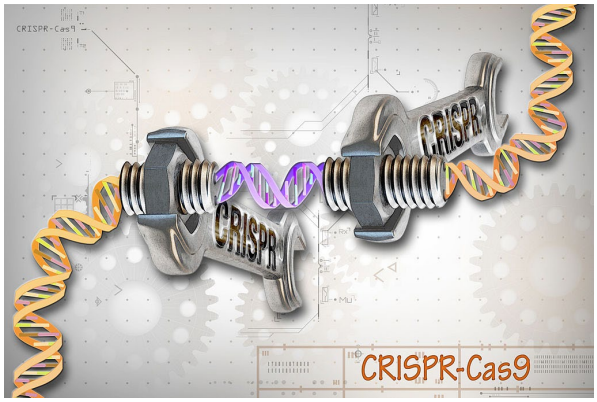
BACKGROUND INFORMATION

Gene Editing Technology



Wikimedia Commons / public domain

Throughout history, humans have strived to create better versions of existing plants and animals through selective breeding. Since the 1970s, scientists have been able to genetically modify living things by "cutting and pasting" DNA. In 2013, scientists developed a new technique for genetic modification called the CRISPR/Cas9 system (called CRISPR, pronounced "crisper," for short). CRISPR identifies and uses repeating patterns in DNA and works like a search-and-replace function in a word processor. It allows scientists to edit genomes with much more precision, efficiency, and flexibility than they had with prior techniques. It is also faster, lower cost, and easier to use than previous technologies. Because of its potential to eliminate pests or the diseases they carry, or even edit human embryos, Science Magazine named CRISPR the 2015 Breakthrough of the Year.

How CRISPR Works

Using this technique, scientists can add, change, or take out genes that make up the DNA of living things. For example, a segment of DNA linked to an inherited disease could be removed and replaced with a segment from a healthy individual that is not linked to the disease. If a change is made early enough in an organism's development, the change can be passed down to offspring. Changes that are made to specific cells, such as the lungs of a person with cystic fibrosis, would not be passed down.

The CRISPR technique is only useful when scientists know what gene causes the desired or undesired characteristic. For example, scientists have identified the specific mutated gene that alone can cause the deadly disease cystic fibrosis. On the other hand, a mosquito's ability to find humans has not been mapped to specific genes and likely involves a combination of genes. Using CRISPR to replace the mutated cystic fibrosis gene with an unmutated one should be much simpler than changing the mosquito's sense of smell.

Legal and Ethical Considerations

CRISPR is still a very new technology and has both known and unknown risks. Many of the useful aspects of the CRISPR technique also cause some concern: faster, lower cost, more accessible techniques may mean more people editing genomes, including those with less scientific or ethical training. Some people worry about whether it should be used in certain circumstances, or at all.

Technology also often progresses faster than regulations can keep up. Some policy makers recognize that the use of this technology is not addressed by current genetic modification regulations. When processes like gene editing happen outside of well-regulated settings, there are fewer traditional safeguards in place to ensure compliance with ethical norms.

One important factor in regulating a technology is being able to identify where it is being used. Unlike other techniques, CRISPR does not leave any specific identifying markers in the genome that other forms of genetic modification do, although it could be modified to do so. This makes it more difficult to monitor and regulate its use. However, gene drives do leave an identifying mark, unlike standard CRISPR modifications.

Gene Drives

Normally, genes have only a 50% chance of being passed on, which means that changes made with CRISPR might disappear from the population over time. However, some genes found in nature are more likely to be passed on to offspring. By using elements of these genes, engineers have developed gene drive systems. Genes with gene drives spread through the population quickly over just a few generations, even if they are not helpful for the organism. The faster an organism reproduces, the sooner the new gene will be the only version found in the population.

Some scientists suggest that we could release a second gene drive that would reverse the first gene drive if something went wrong. This strategy would not completely return the population to "normal" because the genes from the second gene drive would still be present.

CRISPR editing tools are available on the market.

CRISPR gene editing kits
Kits are available for specific applications starting at $130, and go up to $2,000 for a wider range of applications.
www.thermofisher.com

Lab mice with CRISPR edits
Research mice are available with a wide variety of genetic modifications.

Many products using CRISPR are in development. There's no limit to theoretical future uses.

Health and medicine
Cancer treatments
Vaccinations
Alzheimer's treatments
Parkinson's treatments
MRSA treatments
Blindness treatments

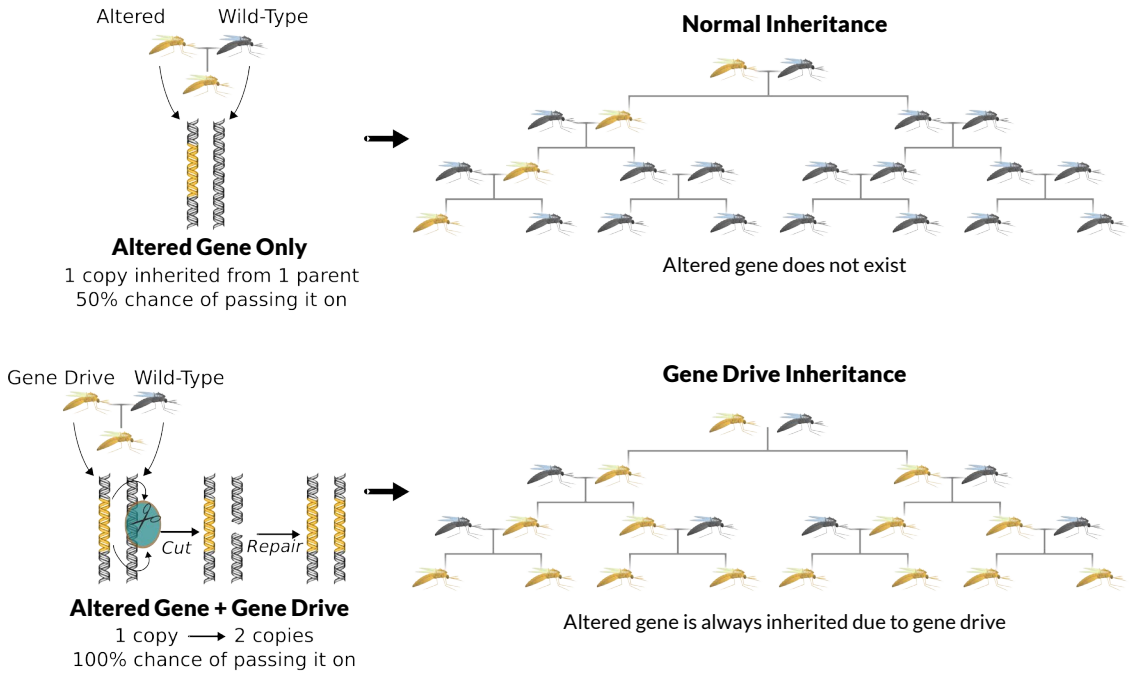
Research
Pigs
Mice
Marmosets/monkeys
Ferrets
Goats
Etruscan tree shrew

Disease transmission
Mosquitoes
Ticks
Aquatic snails

Environment
Microbes for biofuel
Bees
Koi carp
Invasive species management

Pets
Dogs
Micropigs

Food
Non-allergenic eggs
Cattle, salmon, chicken
Wheat, rice, barley
Potatoes
Tomatoes
Broccoli
Corn
Soybeans



Normal inheritance outcomes change when a gene drive is introduced

Kevin Esvelt, MIT Media Lab