Mankind has been manipulating genetics for thousands of years. Long ago, early civilizations realized that certain traits of crops, animals and humans were hereditary. The modern-day mapping of all human genes raised the possibility of learning precisely which genes control which traits and then directly altering their DNA codes. For years, those tasks were both challenging and hit-and-miss. But a new technology on every geneticist's tongue is changing that.

Crispr-Cas9, more commonly called Crispr, is a gene-editing system. It is so simple, cheap and effective that it promises to change mankind's relationship with genetics. Champions of Crispr believe it could help control pests, increase food production and eliminate human diseases. Others worry that it could be used to create designer babies, dangerous mutants and biological weapons.

The Situation
Labs and companies in at least 83 countries are experimenting with Crispr. They hope to kill off malaria-carrying mosquitoes, make wheat resistant to mildew and produce eggs suitable
for people allergic to them. A group of scientists at Harvard is even trying to bring a woolly mammoth back from extinction.

The most attention-grabbing experiments relate to human disease. In experiments with human cells, researchers have used Crispr to repair a mutation that causes blindness and to remove HIV from immune cells. In late 2015, researchers published results on the first successful use of the method to treat mature animals. They used Crispr to repair a gene in mice with muscular dystrophy. Once they did, the muscles in the animals’ bodies became stronger. These experiments suggest that similar gene-editing cures could eventually be used to treat humans.

Controversially, some labs are using Crispr to experiment with human germ-line cells. These are cells such as sperm, eggs and zygotes, which pass genetic material to children. In 2015, a group of Chinese researchers published results of a Crispr experiment on human embryos, or fertilized eggs. Even though the scientists said the embryos could not grow into babies, the study was still controversial.

**How Crispr-Cas9 Works**

Until a few years ago, altering an organism’s genome was a cumbersome process, usually involving insertion of long strands of DNA or entire genes. Now scientists can cut and paste precise units of the genome.

![Diagram of how Crispr-Cas9 works](image)

1. **Researcher identifies a specific sequence of DNA to modify.**
2. **Researcher engineers a guide RNA to match the targeted DNA sequence. Guide RNA is attached to a DNA-cutting enzyme known as Cas9.**
3. **Guide RNA finds targeted DNA sequence on the genome. Cas9 cuts the DNA strand at the target, preparing it for repair or replacement.**
4. **DNA repairs itself. Engineered sequence of DNA can be inserted into the gene to further modify it.**

**The Background**

Crispr-Cas9 is a simple immune system designed to fight off invaders. Japanese scientists first noticed it in bacteria nearly 30 years ago. It is made up of sequences of genetic code broken up by pieces of genes from past invaders. These gene pieces help bacteria identify the invaders when they appear again. This allows the Cas9 enzyme to slice through them.

For a long time, scientists did not understand how the system could chop through and replace DNA. Then, in 2012, researchers at the University of California, Berkeley published a
breakthrough paper. They discovered how to make "guides" that allow Crispr to skim along DNA, targeting exactly the right spot to make a slice. Soon afterward, another group of scientists said they'd adapted Crispr for use in human cells.

Any researcher with basic skills and a few thousand dollars' worth of equipment can employ Crispr. This creates enormous space for both scientific breakthroughs and abuse. The gene-editing system isn't perfect, at least not yet. It makes unintended cuts in DNA as often as 60 percent of the time, with effects unknown.

**The Argument**

Decisions about whether to use Crispr to treat people who are already sick could be made through a straightforward consideration of risks and benefits, once these are better understood. The issues arising from germ-line editing, however, are philosophical as well as medical. The potential to do good is enormous: eliminating a genetic disease from a family forever. But if something goes wrong, the consequences are potentially eternal, too. They could affect future generations who had no say in the matter.

Some scientists worry that germ-line editing would invite enhancements of babies for nonmedical reasons. For example, babies could be engineered to be extremely intelligent. Philosopher Nick Bostrom and author Carl Shulman argued in a 2013 paper that this might be a good thing. They say that cognitively enhanced individuals could produce ideas and inventions that improve life for everyone.