Cloning and Engineering

FIGURE 4: These cereal plants can grow in soil with little water.

As the world's population increases, so does the demand for food. Long periods of drought in many areas of the world threaten food production because many commercial crops are not adapted to dry climates. To maintain food production as land becomes drier, scientists engineered plants that are drought resistant.

Gather Evidence Other strategies for growing food in dry climates include water conservation, sustainable farming practices, and improved fertilizers. Make a list of possible criteria for evaluating drought-resistant crops along with the other solutions.

Cloning Organisms

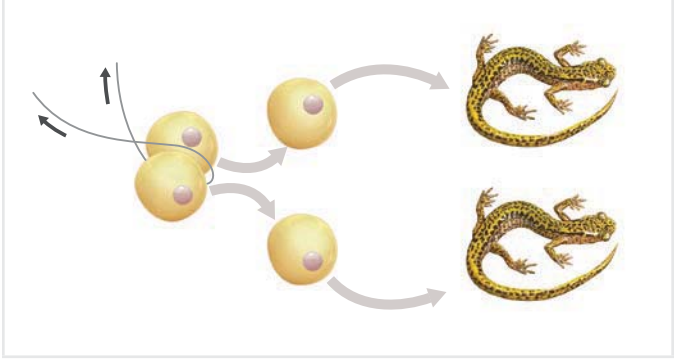
FIGURE 5: Some plants produce "pups," or genetically identical offspring.

Many plants produce genetically identical offspring, or clones, through asexual reproduction. Humans have cloned plants for thousands of years by taking cuttings from one plant and planting them, producing clones. When the offspring, or "pup," of a spider plant, shown in Figure 5, is planted, a genetically identical plant grows. Humans clone plants with desirable traits, such as bigger or more flavorful fruit. Eventually these traits appear more often in the new population.

Bacteria produce clones through binary fission, a type of asexual reproduction. In binary fission, a bacterial chromosome is replicated. The cell splits into two daughter cells that are genetically identical to the mother cell. Making clones ensures beneficial traits, such as resistance to antibiotics, spread quickly in a bacterial population.

Cloning has a low success rate in more complex organisms, such as vertebrate animals. Advances in genetic engineering, though have made it possible to produce artificial mammalian clones. The sections below describe breakthroughs in cloning.

FIGURE 6: The embryo twinning process.



Embryo Twinning

In 1903, Hans Spemann separated the cells of two-celled salamander embryos. The separated cells continued to develop normally, resulting in two salamanders (Figure 6). Spemann determined that vertebrates can be "twinned" to form identical organisms. This experiment showed that embryonic cells have a full set of genetic material. So, each cell has the potential to grow into a complete organism.

Nuclear Transfer

Cloning mammals involves replacing the nucleus of an unfertilized egg with the nucleus of a cell from the animal that is being cloned. The egg cell is implanted into a surrogate mother to develop as it would during a normal pregnancy. The resulting offspring is a clone. Some of the milestones in nuclear transfer are shown in Figure 7.

FIGURE 7: Milestones in the advancement of cloning techniques.

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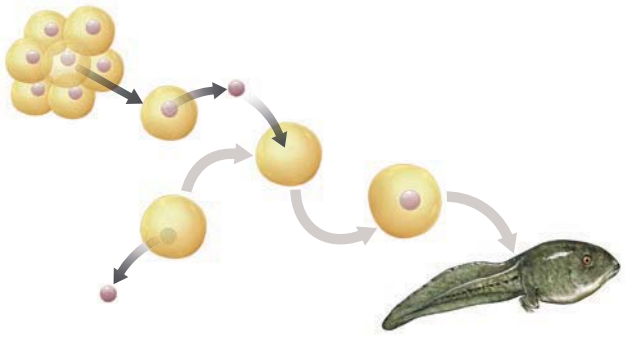
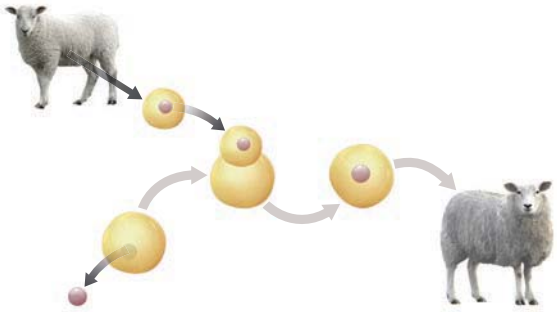


a Embryonic cell nuclear transfer



b Somatic cell nuclear transfer

In 1952, Robert Briggs and Thomas King performed the first successful nuclear transfer (Figure 7a). The nucleus from an embryonic frog cell was inserted into an egg cell with its nucleus removed. The egg cell then developed into a tadpole. This experiment demonstrated that nuclear transfer could be used to clone organisms.

Scientists later adapted nuclear transfer methods to produce clones of other animals, including mammals. Further research led to new techniques which allowed the use of other cell types as nuclear donors, eliminating the need to use embryos.

In 1996, Dolly the sheep became the first mammal cloned from an adult somatic, or body, cell (Figure 7b). Somatic cells are differentiated, so many genes not necessary for the cell's function are deactivated. These genes must be reactivated for cloning to succeed. Of 277 attempts in this experiment, only Dolly survived.

Cloning After Dolly

Milestones in cloning after Dolly include cloning primates, producing sheep from genetically engineered cells, cloning endangered animals, and creating stem cells from somatic cell nuclear transfer. New advances in cloning have raised ethical concerns, such as concerns regarding human cloning.

Pet cloning is one of these advancements. Several companies offer cloning services that will produce an exact genetic copy of a pet. Though they are genetically identical, these animals often look and act differently than the original pet.

Gather Evidence Why is a clone not an exact copy of a donor animal? Consider the effect of genetics and environmental conditions. Use evidence to support your answer.

FIGURE 8: A cloned puppy with the genetic father.

Cloning Ethics

Henrietta Lacks died of cervical cancer in 1951. Before she died, a researcher took a sample of her tumor. From this sample, scientists made the first "immortal" cell line, named HeLa for the first two letters of Henrietta's first and last names. Unlike other cells, HeLa cells did not die when cultured in the lab. The cells divided indefinitely, providing a never-ending source of cells for scientific research. From the polio vaccine and cloning to AIDS research and experiments in space, HeLa cells have been a cornerstone of science for more than half a century.

FIGURE 9: Henrietta Lacks

Most of this research took place without the knowledge or permission of Henrietta Lacks or her family. This raises the issue of cloning ethics. Ethics are principles that set standards of right or wrong for a person or group. As advances in genetics continue, discussions about ethics and treatment of genetic material become more important.

Language Arts Connection Further research the story of Henrietta Lacks. Should individuals have control over their genetic material? How would you feel if your genetic material was taken without permission? Use evidence to support your claims.

Engineering Genes

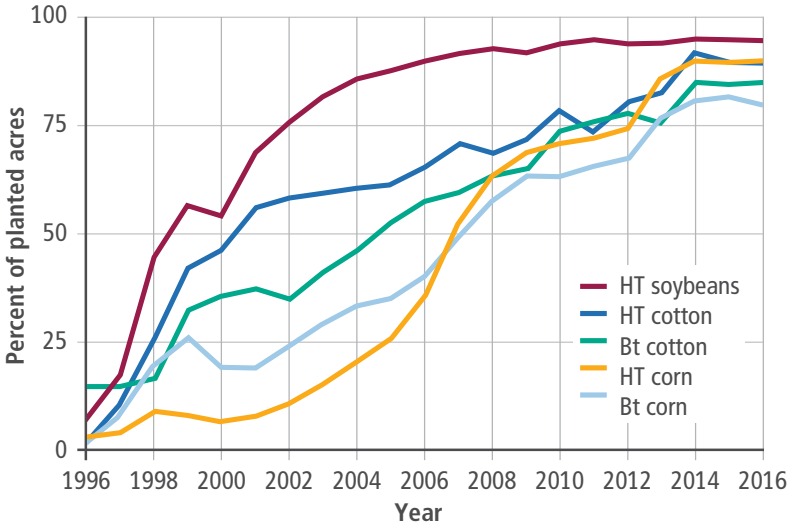
Genetic engineering is the process of altering the genetic material of an organism, changing its traits or introducing a new, desirable trait. Once a desirable trait has been successfully inserted into a genome, the new genome—and trait—can be passed on to future generations using cloning. An organism with one or more genes from another organism inserted into its genome is called a transgenic organism.

Genetically modified (GM) crops are becoming more widely used by farmers. If a farmer plants clones of GM crops, then he or she knows the desired trait is present in the entire population. However, this would also decrease genetic diversity, a necessary feature for a robust and flexible population.

Analyze Compare the risks versus the benefits of using cloned, GM plants instead of GM plants propagated through sexual reproduction.

Adoption of Genetically Engineered Crops in the U.S., 1996-2016

FIGURE 10: The usage of genetically engineered crops in the United States.



Sources: USDA, Economic Research Service using data from Fernandez-Comejo and McBride (2002) for the years 1996–99 and USDA, National Agricultural Statistics Service, *June Agricultural Survey* for the years 2000–16.

In the early 1990s, the FDA approved genetically engineered plants for human consumption in the United States. Insect resistance and herbicide resistance are among the most common genetic modifications in crops, as shown in Figure 12. Much of the genetically modified corn produced is fed to livestock, but GM corn does appear in the human food supply as ingredients such as high-fructose corn syrup and corn starch. No long-term studies have found negative side effects from eating GM plants.

Genetic Engineering in Bacteria

Recombinant DNA technology, combining the genes from more than one organism, is a key element of genetic engineering. The organisms can be from the same species or different species. One method of producing recombinant DNA is to add foreign DNA to a plasmid. In bacteria, a plasmid is a small, circular segment of DNA that is separate from the bacterial chromosome. The foreign DNA that is inserted into the plasmid is then expressed by the bacteria.

Bacteria naturally recombine their DNA by absorbing plasmids from the environment or by exchanging plasmids between two bacteria. There can be multiple plasmids within a bacterium, and each one is able to replicate independently from the bacterial chromosome. Genetically modified bacteria are able to produce antibiotics, insulin, therapeutic proteins, and other types of proteins.

Imagine foreign DNA containing a gene for producing human insulin is inserted into a plasmid. Because plasmids self-replicate, numerous copies of a plasmid can exist within a bacterium. Plasmids are shared with daughter cells during binary fission, and bacteria divide at relatively fast speeds. A handful of bacteria with a plasmid coding for human insulin can quickly become a manufacturing center for a protein.

Collaborate Genetically engineering bacteria to produce drugs can be cheaper than producing the drugs in a lab. Discuss the impacts cheaper drugs may have on society and science.

FIGURE 11: Bacterial plasmid

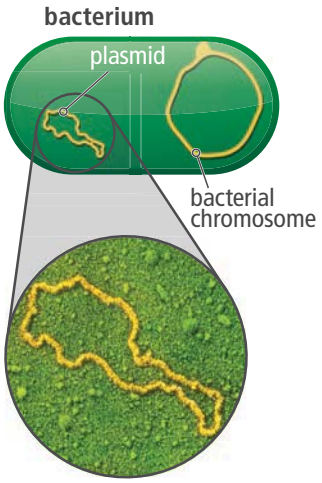


FIGURE 12: Recombinant DNA.

Engineering

Editing Genes with CRISPR

Genetically engineering organisms requires the ability to cut DNA strands in specific places. Precisely cutting DNA can be difficult, time-consuming, and costly work. To solve this problem, genetic engineers needed to find an easier, faster, and cheaper method for precisely cutting DNA.

As it turns out, bacteria use a mechanism for precise DNA cuts called CRISPR, named for the clustered regularly interspaced palindromic repeats (CRISPRs) in bacterial DNA. These repeated sequences surround segments of viral DNA that bacteria have been exposed to. An enzyme uses the information in this viral library to target and cut viral DNA, preventing viral replication.

CRISPR is exciting for genetic engineers because it provides a very precise method for cutting DNA at a specific point. Cutting DNA easily and accurately simplifies the process of replacing defective genes with functional genes. This is one of the more difficult tasks in gene therapy, but one with the greatest potential benefits to humans. New ways to apply the CRISPR system to scientific problems are still being discovered. As with most genetic advances, the excitement surrounding the prospective benefits of CRISPR is tempered by the ethical concerns raised by such a powerful gene-editing tool.

Gather Evidence In what ways do you think CRISPR can advance the field of genetic engineering? What concerns do you think people might have about CRISPR?

Genetic Engineering in Plants

One of the most common methods for genetic modification in plants is the use of bacterial plasmids. A gene for a desired trait is inserted into a plasmid, and the plasmid is added to a plant cell. When the plant cell is infected, the recombinant DNA is inserted directly into the plant genome, modifying the plant. The plant expresses the bacterial DNA as well as its own.

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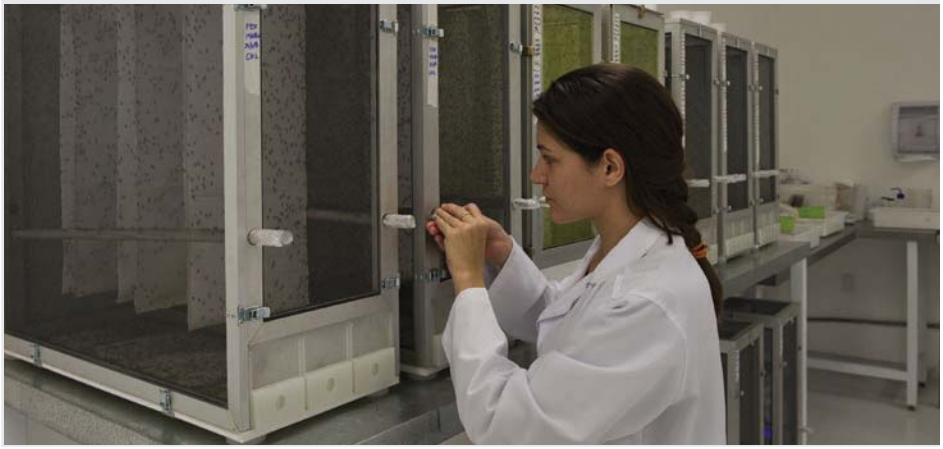
Hands-On Lab

Modeling Genetic Engineering
Simulate the techniques used by genetic engineers to modify genes in humans using recombinant DNA technology.

Genetic Engineering in Animals

Animal models of human diseases are valuable tools in medical research. These models allow scientists to study the disease process, from the genetic basis of a disease to how it responds to chemical substances. Through genetic engineering, scientists have been able to develop more and better models to study disease.

FIGURE 13: A scientist studies genetically modified mosquitoes.



Model Draw a flow chart that demonstrates how genetically engineering mosquitoes can reduce the risk of illness in humans.

Consider the use of genetically modified mosquitoes to prevent the spread of disease. Mosquitoes act as vectors for many diseases. A vector carries foreign DNA into another cell or organism. One species, *Aedes aegypti*, is known to transmit the viruses for yellow fever, chikungunya, dengue, and Zika. Dengue is one of the leading causes of illness and death in tropical and subtropical regions. There is no vaccine for dengue, and the best way to minimize dengue cases is to minimize bites from infected mosquitoes.

To solve this problem, scientists engineered mosquitoes so they required a human-made drug to survive. When modified male mosquitoes are released into wild populations, they breed with wild females, passing the drug-dependency gene to their offspring. The affected males die soon after breeding, and any offspring die before maturity without access to the drug. Several field trials demonstrated that release of mosquitoes modified in this way can effectively control mosquito populations.

The possibility of unintended effects is a big constraint to this solution. The potential unintended effects of releasing genetically engineered mosquitoes into the wild is not fully understood. There may be tradeoffs for scientists and society between the risks of unintended effects and the benefits of smaller mosquito populations.

Explain There typically are tradeoffs when selecting a solution to a problem. Genetically engineered crops may be able to help farmers produce greater yields, but a tradeoff is the reduction in the genetic variation in crops, making crops more susceptible to disease. What other tradeoffs exist for this solution?