OVERVIEW

Genes are everywhere! Genes are the basic biological structures that make up plants, animals, and people. Scientists, including botanists and geneticists, discover more about how genes work. The study of genes and genetic modification (GM) can be used to create life-saving medicines. GM technology also protects crops and animals from harmful environmental threats like global warming and can help them become more nutrient-rich. The manipulation of genes for better productivity, resilient plants and animals, and even medicinal use is not without controversy. Many people refuse to consume genetically modified organisms (GMOs) and others fear that gene therapies may be unsafe for plants, animals, and people.

More than a decade ago, the US National Institute of Health (NIH) launched the Human Genome Project. It was thought that genetics would lead to discoveries about why people get sick and how to cure disease. Today patients still have little idea of how genetic testing works, what purpose tests may serve, and/or whether they should get tested for certain conditions. Even though research projects like the Human Genome Project and cloning successes like Dolly the sheep generated lots of conversation about genetics, scientists know very little about how to apply their data for practical applications to plants, animals, and people.

To date, farmers have widely adopted GM technology. Between 1996 and 2013, the total surface area of land cultivated with genetically modified crops increased by a factor of 100. This growth encompassed approximately 1,750,000 km (432 million acres) of land. By 2014 in the United States, GM crops made up the planted area of 94% of soybeans, 96% of cotton, and 93% of corn. GM technology has expanded quickly into the developing world as well. By 2013, more than 18 million farmers grew 54% of the world's GM crops in developing countries. Many scientists believe that through genetic modification and increased plant growth a solution to the world's food scarcity can be found. With an ever-growing worldwide population, could genetic modification be the solution to feeding hungry people around the globe?

Despite promising arguments that genetic modification can have positive results, safety continues to be a big concern around the world. Even though genetically engineered crops have been helping produce greater yields of crops with higher nutritional values since the 1970s, most developed nations do not consider GMOs safe. Across more than 60 countries around the world, including Japan, Australia, and the countries of the European Union, there are significant regulations and even outright bans on the production and sale of GMOs. Many consumers are taking matters into their own hands and choosing not to eat foods that contain GMOs. Some businesses even require that all foods containing GMOs be labeled so they can be identified by consumers. In 2014, a survey by the Pew Research Center found that 57% of Americans said it's generally "unsafe to eat genetically modified foods," however, the World Health Organization (WHO), the American Medical Association (AMA), the National Academy of Sciences (NAS), and the American Association for the Advancement of Science (AAAS), have all declared that no good evidence showing that GMOs are unsafe exists.

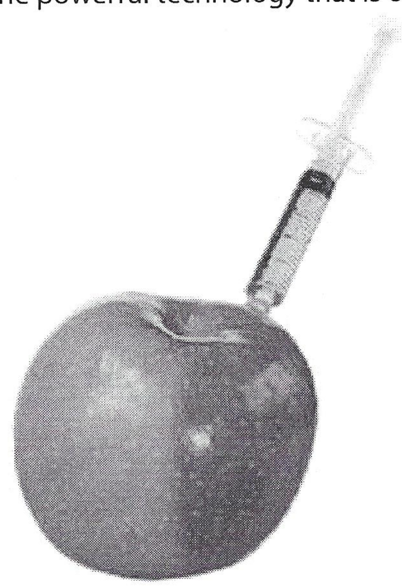
Critics claim there are serious ethical, ecological, and economic issues with genetic modification techniques. The largest debates surround the ethical implications, safety, and potential for political and economic war that may come with genetic modification, especially in humans. Is it okay that domesticated animals are being genetically modified to produce proteins that have applications for human medicine? Should scientists continue their research in hopes of finding proteins that will control blood clotting or kill cancer cells? If we are able to create designer babies, should we?

Already, genetically modified animals are being utilized to grow transplant tissues and human transplant organs, a concept called xenotransplantation. Implications involving genetic modification are not fully understood. GM crops can cross-pollinate with non-GM crops, creating unpredictable characteristics in plants that can be dangerous to humans. Bioherbicides and bioinsecticides can be added to crop seeds, but are not always effective.

Promising research is underway that indicates genetic study and manipulation are here to stay. A new technique called gene editing allows scientists to target a particular strand of RNA and replace it with a new strand. This method has been described as being similar to the cut-and-paste feature in word processing programs. By activating or de-activating portions of genes, researchers can document how specific adjustments to the genetic code can change an organism. In Britain, researchers used a "self-limiting" gene to control an invasive species of moth that causes serious damage to cabbages, kale, and other crops. Still, other researchers are focused on making plants resilient to drought conditions, which is of increasing importance as food scarcity is quickly becoming a global issue.

Another core technique of genetic engineering is the process of recombining DNA to give it new traits by removing DNA from one organism and inserting it into the DNA of another organism. Recombinant DNA can be used to make crops resistant to pests or disease. It can also make livestock leaner or larger. In medicine, the technique is used to create drugs, vaccines, and to reproduce important human hormones and proteins.

What will be the long-term impact of genetic modification of plants and animals? How can scientists with limited information predict the result of these genetically modified plants and animals for future generations? If plants and animals are genetically modified to resist pathogens, will new, more resistant pathogens wipe out entire plant and animal populations in the future? Already, GM has led to international controversy, trade disputes, protests, and restrictive regulations on commercial products containing genetically modified organisms. How do we move forward in a way that betters humanity for many generations to come using the powerful technology that is offered by genetic manipulation?



Terms and Definitions

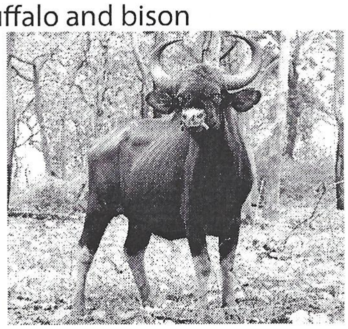
adaptation: a change or the process of change by which an organism or species becomes better suited to its environment

Animal and Plant Health Inspection Service (APHIS): a United States Department of Agriculture agency, responsible for protecting animal health, animal welfare, and plant health

biopharmaceutical: a medicinal product manufactured in, extracted from, or semi-synthesized from biological sources

biotechnology: the exploitation of biological processes for industrial and other purposes, especially the genetic manipulation of microorganisms for the production of antibiotics, hormones, etc.

bovine: an animal of the cattle group, which includes buffalo and bison



cell: the smallest structural and functional unit of an organism, typically microscopic and consisting of cytoplasm and a nucleus enclosed in a membrane

chromosome: a threadlike structure of nucleic acids and protein found in the nucleus of most living cells that carries genetic information in the form of genes

clone: to make an identical copy of an organism through DNA replication

disease resistant: the reduction of pathogen growth

deoxyribonucleic acid (DNA): a self-replicating material present in nearly all living organisms that carries genetic information

embryo: an unborn offspring in the process of development

Federal Food, Drug, and Cosmetic Act (FFDCA): a set of laws passed by Congress in 1938 giving authority to the US Food and Drug Administration (FDA) to oversee the safety of food, drugs, and cosmetics

Food and Drug Administration (FDA): the federal agency in the US responsible for protecting and promoting public health through the regulation and supervision of food and drug safety

gene: a unit of heredity that is transferred from a parent to offspring and determines some characteristic of the offspring

gene expression: the process by which possession of a gene leads to the appearance in the phenotype of the corresponding character; the process genetic instructions are used to synthesize gene products

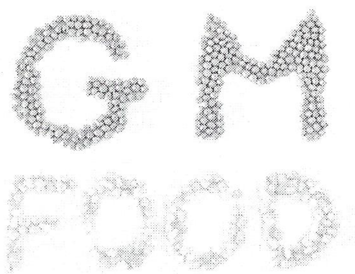
gene sequencing: the figuring out of the order of DNA nucleotides, or bases, in a genome; the order of As, Cs, Gs, and Ts that make up an organism's DNA

gene therapy: an experimental technique that uses genes to treat or prevent disease; the transplantation of normal genes into cells which are missing specific genes or to replace defective cells in order to correct genetic disorders

genetic engineering: the use of tools of modern biotechnology and molecular biology to introduce new characteristics or traits into organisms

genetic mutation: a permanent alteration in a gene's DNA sequence resulting in a sequence that differs from what is found in most organisms

genetically modified organism (GMO): an organism whose genome has been altered by the techniques of genetic engineering so that its DNA contains one or more genes not normally found



genome: the complete set of genes or genetic material present in a cell or organism

genomics: a discipline in genetics that applies recombinant DNA, DNA sequencing methods, and bioinformatics to sequence, assemble, and analyze the function and structure of genomes

herbicide: a substance that is toxic to plants and is used to destroy unwanted vegetation

heritable: transmissible from parent to offspring

hybrid: the offspring of two plants or animals of different species or varieties (a mule is a hybrid of a donkey and a horse)

metabolism: the chemical processes that occur within a living organism in order to maintain life

molecular characterization of the construct: a description of the DNA construct and how it is assembled

pathogen: a bacterium, virus, or other microorganism that can cause disease

pesticide: a substance used for destroying insects or other organisms harmful to cultivated plants or animals

phenotypic characteristic: the expression of a specific physical trait such as stature or blood type, based on genetic and environmental influences

plant geneticist: a botanist concerned with the origin and evolution of plants through its genetics

ribonucleic acid (RNA): a polymeric molecule that plays a role in coding, decoding, regulation, and expression of genes; one of the three major biological macromolecules that is essential for all known forms of life (along with DNA and proteins)

tissue: any of the distinct types of materials of which animals or plants are made, consisting of specialized cells and their products

trait: a distinguishing quality or characteristic, typically one belonging to a person, plant, or animal

transgenic: containing genetic material artificially transferred from another species

virus: a small infectious agent that replicates only inside the living cells of other organisms

vitamin: any of a group of organic compounds that are essential for normal growth and nutrition; required in small quantities from the food intake because they cannot be synthesized by the body