May 2021

INTRODUCTION TO GENETIC ENGINEERING

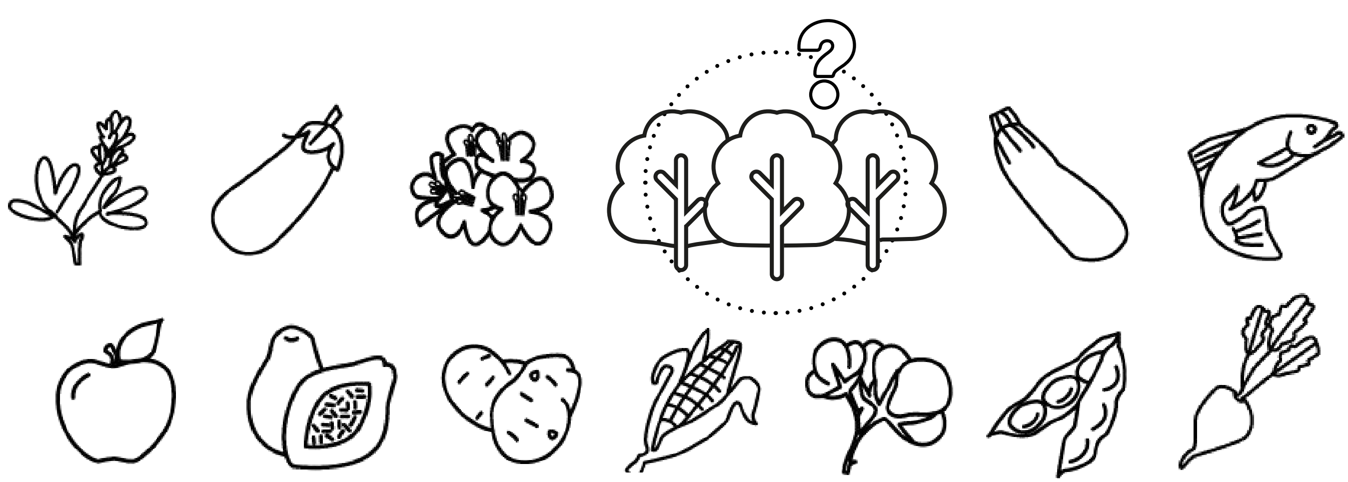
WHAT ARE GMOS?

Genetic engineering (also commonly called genetic modification) is a collection of laboratory techniques used to create genetically modified (GM) organisms, often abbreviated to GMOs or called genetically engineered (GE) organisms. It is sometimes referred to as modern biotechnology, but modern biotechnology is a broad term that also includes non-genetic engineering techniques.

There are concerns about releasing GMOs into the environment where they can interact with other organisms, and may have negative impacts on natural ecosystems or farming systems.[1] There are also concerns about the presence of GMOs in the food chain.[2]

Genetic engineering directly changes the genetic makeup (DNA) of an organism, bypassing normal plant or animal reproduction to create new characteristics. Genetic engineering includes techniques that make changes to DNA by inserting genetic material from the same, similar, or totally unrelated organisms, or, with genome editing, by introducing genetic material that acts as an “editor” to change DNA.

Genetically modified organisms (GMOs) are living organisms that have been genetically modified (genetically engineered) in the laboratory to have new characteristics.



First-generation genetic engineering techniques **insert genes**, at random locations, to permanently become part of the host organism's genome, creating new DNA sequences that result in a desired trait, such as herbicide tolerance. However, newer genetic engineering techniques, such as genome editing (also called gene editing), can create a new trait in an organism without leaving new DNA behind. Genome editing uses "DNA cutters" (nucleases) that are guided to a location within an organism's DNA, to **cut the DNA**. This cut DNA is then repaired by the cell's own repair mechanism which creates "edits" or changes to the DNA. The most frequently used genome editing technique is called CRISPR-Cas (often referred to as simply CRISPR), but other genome editing techniques follow similar principles.

Genetic engineering can mean, for example:

- Inserting genes from either closely related or totally unrelated organisms
- Changing some or all of the DNA in a gene sequence
- Moving, deleting, or multiplying genes within a living organism
- Splicing together pieces of existing genes, or constructing artificial ones.

WHAT IS DNA?

DNA – short for deoxyribonucleic acid – is the main component of an organism's genome. The genome carries all the genetic information that defines that organism and is found in the nucleus, mitochondria and chloroplasts (of plants) of every cell. Within the genome, sequences of DNA form genes, which can number in the tens of thousands.

GMO FOODS

In Canada, farmers grow GM corn, canola, soy, sugar beet, and some alfalfa. In the US, farmers grow these GM crops as well as GM papaya, squash, apples, potatoes, and cotton.[3]

Together, the US and Canada grow 44% of all the GM crops in the world. 87% of all GM crops are grown in North and South America.[4]

88% of all the GM crops grown around the world are herbicide-tolerant, meaning that the plants are genetically engineered to survive spraying by specific herbicides. Some of these crops are also genetically engineered to be toxic, and therefore resistant, to certain insect pests. The remaining 12% of the world's GM crops are only insect-resistant. Less than 1% of GM crops have another GM trait such as virus-resistance.[5]

The world's first GM animal for food is a GM fast-growing Atlantic salmon that is now being produced in tanks on land in Canada and the US.

Just three GM seed companies – Bayer, Corteva, and Syngenta - control 48% of the global seed market and 53% of the global pesticide market.[6] After buying Monsanto which was the world's largest seed company, the company Bayer owns 22% of the seed market and 18% of the pesticide market.

For more information on GM foods in Canada visit **www.cban.ca/gmfoods**
For information in the US visit **www.cfs.center/shoppersguide**

GE TREES

Genetic engineering is being used to develop GE (GM) trees, with the intention of making it easier and cheaper to produce wood, fiber, fuel, and other products. For example, genetic experiments are underway to engineer trees to grow faster, be resistant to insects and diseases, tolerate herbicide sprayings, and have altered wood composition.

In the US and Canada, researchers are requesting approval to plant a GE disease-resistant American chestnut tree in the wild. They are proposing to use this GE tree to replace or "restore" the American chestnut species that has been widely decimated by a blight disease.

However, because nature is so complex, releasing a GE tree into the wild would be a risky experiment that could impact entire forest ecosystems. For example, we cannot know how any GE tree will impact insects, birds and other wildlife, especially because trees live for such a long time.

There is also no way we can guarantee that a genetically engineered tree will function as planned in the wild. In the case of the GE American chestnut tree, the blight is likely to adapt and continue killing the trees.[3]

For more information about GE trees visit **www.stopgetrees.org**

WHAT IS GENOME EDITING?

Genome editing, **sometimes called gene editing**, is a collection of new genetic engineering techniques that aim to insert, delete, or otherwise change a DNA sequence at a specific, targeted site in the genome. These techniques, such as CRISPR, are in the news because they are extremely powerful, opening up new potential for medical treatments but also leading to experiments with a wider range of plant and animal species.

Most of the new gene editing techniques insert genetic material into a cell that is then guided to a specific DNA target site to perform "edits."

Generally, genome editing uses DNA cutters that are guided to a location within an organism's DNA and used to cut the DNA. In the simplest types of genome editing, this cut DNA is then repaired by the cell's own repair mechanism, which creates "edits" or changes to the organism's DNA.

Even small changes in a DNA sequence can have big effects. For example, in humans, the health disorder known as sickle cell anaemia is caused by a single change (a point mutation) in the person's DNA.[8]

Genome editing is sometimes described as precise because of its ability to target a specific site in the genome for change. However, many studies show that **genome editing can create genetic errors**, even if the intended changes are small.[9] Several types of genetic errors have been recorded. These include: unexpected changes to DNA at sites other than the target site (off-target effects); accidental large deletions or reversals of sections of DNA; and misreading of DNA leading to changes in protein composition.

The DNA that codes for the genome editing components can also accidentally become a part of the GMO.[10] For example, in one the first genome-edited GM animals developed (a hornless cow, not on the market), DNA from the genome editing repair template was inadvertently integrated into the cow's genome. Importantly, this error was not discovered by the product developers, but by scientists in the US government.[11]

All types of genetic engineering can cause unexpected and unpredictable effects, whether one, a few, or no genes are inserted. This is because the functioning of genes is coordinated by a complex regulatory network that is still poorly understood. This means that it is not possible to predict the nature and consequences of all the interactions between altered genetic material and other genes within an organism. Such effects, alongside the intended trait in the resulting GMO, can have an impact on food and environmental safety.

FOR DETAILS

- "Genome Editing in Food and Farming: Risks and Unexpected Consequences," Canadian Biotechnology Action Network, 2020. **www.cban.ca/GenomeEditingReport**
- "GMOs in Your Grocery Store: Ranking Company Transparency," Canadian Biotechnology Action Network, 2020. **www.cban.ca/grocerychainranking**
- "Biotechnology for Forest Health? The test care of the genetically engineered American chestnut", The Campaign to STOP GE Trees, Biofuelwatch and Global Justice Ecology Project, 2019. **www.stopgetrees.org**

FOR MORE INFORMATION

Canadian Biotechnology Action Network (CBAN)
www.cban.ca

The Campaign to STOP GE Trees
www.stopgetrees.org

Centre for Food Safety (US)
www.centerforfoodsafety.org

Friends of the Earth U.S.
www.foe.org/issues/food-and-technology/

1 Canadian Biotechnology Action Network (2015) Are GM Crops and Foods Better for the Environment?

2 Canadian Biotechnology Action Network (2015) Are GM Foods Better for Consumers?

3 Check www.cban.ca/gmfoods for updates.

4 ISAAA (2020) Global status of commercialized biotech/GM crops in 2019. ISAAA Brief No. 55. 2020.

5 Ibid.

6 ETC Group (2019) Plate tech-tonics: mapping corporate power in big food.

7 The Campaign to STOP GE Trees, Biofuelwatch and Global Justice Ecology Project, 2019. Biotechnology for forest health? The test case of the genetically engineered American chestnut.

8 Clancy, S. (2008) Genetic mutation. Nature Education 1: 187.

9 For a review, see Kawall, K., Cotter, J. & Then, C. (2020) Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32: 106.

10 Modrzejewski, D., Hartung, F., Sprink, T., Krause, D., Kohl, C. & Wilhelm R. (2019) What is the available evidence for the range of applications of genome-editing as a new tool for plant trait modification and the potential occurrence of associated off-target effects: a systematic map. Environmental Evidence 8 doi:10.1186/s13750-019-0171-5; Kosicki, M., Tomberg, K. & Bradley, A. (2018) Repair of double-strand breaks induced by CRISPR-Cas9 leads to large deletions and complex rearrangements. Nature Biotechnology 36 :765-771; Skryabin, B.V., Kummerfeld, D.-M., Gubar, L., et al. (2020) Pervasive head-to-tail insertions of DNA templates mask desired CRISPR-Cas9–mediated genome editing events. Science Advances 6: eaax2941.

11 Norris, A.L., Lee, S.S., Greenlees, K.J., Tadesse, D.A., Miller, M.F. & Lombardi, H.A. (2020) Template plasmid integration in germline genome-edited cattle. Nature Biotechnology 38: 163-164; Young, A.E., Mansour, T.A., McNabb, B.R., Owen, J.R., Trott, J.F., Brown, C.T., Van Eenennaam, A.L. (2020) Genomic and phenotypic analyses of six offspring of a genome-edited hornless bull. Nature Biotechnology 38: 225–232.

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Stop Genetically Engineered Trees