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INTRODUCTION

Genome Editing in Food and Farming

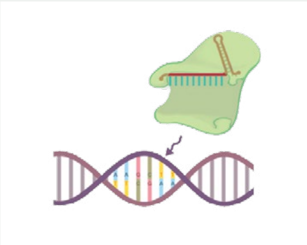
Genome editing techniques are a type of genetic engineering, resulting in the creation of genetically modified organisms (GMOs).

Genome editing, often called gene editing, is a collection of new genetic engineering techniques that alter the genetic material (usually DNA) of plants, animals and other organisms. These techniques aim to insert, delete or otherwise change a DNA sequence at a specific, targeted site in the genome.

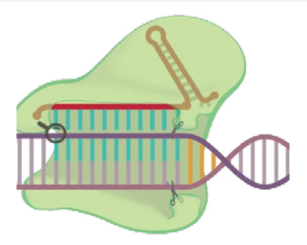
The genome is the entire set of genetic material in an organism, including DNA.

Genome editing, generally, uses DNA cutters that are guided to a location within an organism's DNA and used to cut the DNA. This cut DNA is then repaired by the cell's own repair mechanism, which creates "edits" or changes to the organism. The most frequently used genome editing technique is called CRISPR-Cas9 or CRISPR, but other techniques follow similar principles.

How Genome Editing Works



"DNA cutters" (nucleases) are guided to a location (the target site) on an organism's DNA.



The DNA cutter docks onto the target site and cuts through the DNA.

The repair of DNA is then initiated and occurs either with (SDN-2) or without (SDN-1) a synthetic repair template. Alternatively, genes can be inserted (SDN-3).

The DNA is now "edited". However, in reality, genome editing is prone to creating unintended changes and errors that can lead to unexpected effects in the genome-edited organism.

Genome editing is a set of new genetic engineering techniques that alter the genetic material of plants, animals and microbes, most often using DNA cutters that are guided to a location within an organism's DNA and used to cut the DNA. This cut DNA is then repaired by the cell's own repair mechanism, which creates "edits" or changes to the organism.

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 often confer a trait, such as herbicide tolerance. In contrast, almost all genome editing techniques insert genetic material into a cell that is then guided to a specific DNA target site to perform "edits." This means that, with genome editing, the inserted genetic material makes changes to the genome to enable a new trait, but does not necessarily have to become incorporated into the resulting genetically modified organism (GMO).

Genome editing techniques are leading to more genetic engineering experiments with a wider range of plant and animal species. In particular, genome editing techniques are being used to genetically engineer animals, including insects.

There is currently one genome-edited organism on the market in Canada: a herbicide tolerant canola from the company Cibus. It was developed using the technique called ODM (oligonucleotide-directed mutagenesis) which does not use a guided DNA cutter, but instead introduces a short strand of DNA that attaches itself to the organism's DNA at a particular location and causes a change to that DNA.

Unexpected and unpredictable effects

Genome editing can be imprecise, and cause unexpected and unpredictable effects.

Many studies have now shown that genome editing can create genetic errors in the genome-edited organism, such as "off-target" and "on-target" effects. These effects can lead to unexpected and unpredictable outcomes, such as changes in protein composition, in the resulting GMO.

- Genome editing techniques can create unintended changes to genes that were not the target of the editing system. These are called **"off-target effects."** For example, the CRISPR-Cas9 system can make unintended edits to the host's DNA at additional sites to the target location.

Genome editing can be imprecise, and cause unexpected and unpredictable effects.

- Genome editing can also result in unintended **"on-target effects,"** which occur when a technique succeeds in making the intended change at the target location, but also leads to other unexpected outcomes.
- Genome editing can inadvertently cause extensive **deletions and complex re-arrangements** of DNA in the genome-edited organism.
- **Unwanted DNA can unexpectedly integrate** into the host organism during the genome editing process. For example, foreign DNA was unexpectedly found in genome-edited hornless cows.

Despite these many potential impacts, there are no standard protocols yet to detect off-target and on-target effects of genome editing, nor to evaluate them, for instance for food and environmental safety.

Sometimes intended changes that are created by genome editing techniques are described as "mutations" because only very small parts of DNA are altered and no novel genes have been intentionally introduced. However, **even small changes in a DNA sequence can have big effects**.

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. For example, one small genetic change can impact an organism's ability to express or suppress other genes.

Gene Drives

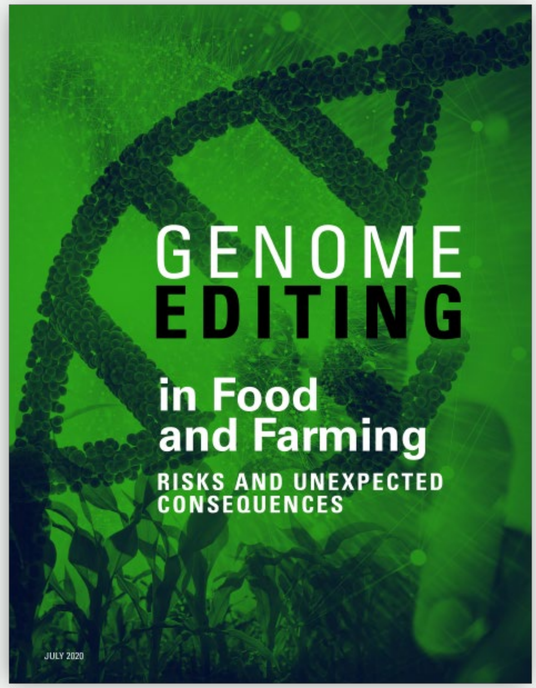
Genome editing is facilitating experiments to create a powerful technology called "gene drives." Gene drive organisms are designed to intentionally push particular genes through an entire population in the wild, causing the new genes to be eventually inherited by all offspring in subsequent generations. For example, gene drives could be used in insect or weed populations, to stop them from reproducing effectively. The most advanced research so far proposes to use gene drives to prevent *Anopheles gambiae* mosquitoes – which transmit the parasite that causes malaria – from reproducing effectively, thus reducing the size of their populations.

Unlike GMOs that are confined to agricultural use, gene drive organisms are expressly designed for intentional, long-lived release into the wild. **Once gene drive organisms are released, they cannot be recalled**.

Recommendations

- The **safety** of all genetically engineered organisms needs to be thoroughly assessed in transparent processes that rely on independent science.
- All genetically engineered foods should be **labelled** for consumer information.
- The **utility and social worth** of using genome editing techniques to develop new crop plants, animals, and other organisms for food and farming needs to be evaluated. Farmers and other members of the public should be consulted in the process of evaluating risks and benefits.
- Governments should support the tremendous wealth of genetic diversity, and the tools and knowledge held by farming communities, by investing in **agroecology**.
- There needs to be a **global moratorium** on the release of gene drive organisms.

More Information



For details and references read the new report: Genome Editing in Food and Farming: Risks and Unexpected Consequences

The report provides an overview of genome editing and its associated risks, as part of an effort to encourage broad public discussion about the possible implications of using genetic engineering in food and farming, and the ways in which decisions over the use of the technology should be made.

Available online at: **www.cban.ca/GenomeEditingReport**

For updates or to find out more, visit: **www.cban.ca/genome-editing**

The Canadian Biotechnology Action Network (CBAN) brings together 16 groups to research, monitor and raise awareness about issues relating to genetic engineering in food and farming. CBAN members include farmer associations, environmental and social justice organizations, and regional coalitions of grassroots groups. CBAN is a project on MakeWay's shared platform. **www.cban.ca**