

CRISPR – the latest breeding technology explained

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What is CRISPR?

When it comes to the latest breeding technology, many of us have probably heard of the acronym CRISPR, one of the better-known tools in the world of genome editing. CRISPR-Cas, which stands for **C**lustered **R**egularly **I**nterspaced **S**hort **P**alindromic **R**epeats and its associated protein called **Cas**, work together like a pair of molecular scissors to directly edit the native genomes of various organisms, plants, animals, and even humans, in a very precise and predictable manner. The efficiency and precision of CRISPR-Cas tools are enabling scientists to accelerate the breeding process by allowing desired characteristics and improvements to be achieved in a fraction of the time normally required with conventional breeding practices. The versatility of its use and widespread applications suggests that the technology is poised to deliver solutions to feed the world, protect the planet and mitigate climate change. But let us take a step back and look at the origins of the CRISPR-Cas discovery.

Learning from Nature

The discovery of CRISPR dates back to the turn of the century when scientists recognised that CRISPR forms part of the natural defence system that bacteria use to fight invading viruses.

How does it do this? When viruses attack bacteria, they take over their hosts by injecting

their DNA into bacterial cells. The bacteria respond by incorporating small segments of DNA from the invading virus into its own genome. These viral DNA segments are what is known as CRISPR and is used as an early warning system to protect bacteria from future attacks by the same virus. When viral infections re-occur, the CRISPR segments identify and flag the matching DNA of the invading virus, which triggers its associated Cas9 enzyme into action, to splice up the viral DNA and disable the virus.

By gaining an understanding of how CRISPR works in nature, scientists were quickly able to adapt and improve the science of CRISPR-Cas technology to target and edit DNA at precise locations in the genomes of a whole host of different organisms. In October 2020, Emmanuelle Charpentier and Jennifer Doudna were awarded the Nobel Prize in Chemistry for their ground-breaking work on developing CRISPR into a gene editing tool.

Utilising CRISPR as a gene editing tool

The rapid advancement of CRISPR-Cas breeding tools over the last decade has been catalysed by our improved understanding of DNA, the ability to sequence entire genomes of organisms and also knowing more about how specific genes function to express specific traits.

As a modern-day breeding tool, the CRISPR-Cas9 technology functions as a two-component system. The CRISPR component works like a homing device that guides the associated Cas9 scissors to snip the DNA at targeted sites, thus allowing deletions, edits, or additions to be made at specific sites within the organism's genome with the help of the cell's own DNA repair system that is tasked with fixing errors or breaks in the DNA strand. But as often happens in science, it continues to evolve and already there are newer adaptations of CRISPR available that do not involve cutting DNA, but instead are able to turn genes on or off. Other versions include "base editors," that are able to change one letter of the DNA code to another, without cutting DNA.

By directly altering the genetics of organisms, CRISPR tools are able to increase the genetic diversity of species, which in turn provides more genetic variation for traditional breeders to work with, thereby speeding up the breeding process. Long before CRISPR arrived, various other modern breeding tools were deployed to edit the genes of some plants and animals, but the drawback of these tools is that it was extremely expensive, cumbersome, concentrated on improvements in a limited number of traits and crops and required more years to successfully accomplish desired trait improvements. The major advantage of CRISPR technology over earlier breeding tools, is the ability to facilitate genetic improvements in a precise, less expensive, flexible, and easier to use system that is grounded in the science of nature. Another distinguishing benefit of CRISPR tools, is that many of the technology applications exclude the transfer of "foreign DNA" and instead result in products that are indistinguishable from similar products developed through traditional breeding methods or obtained through ubiquitous mutations that occur in nature.

Future prospects of CRISPR technology

The utility of CRISPR technology and its various applications carries the promise of potentially solving many of the great challenges of the 21st Century, from medical and health issues to environmental degradation as well as food and agricultural production challenges.

There is much excitement regarding CRISPR's potential to enhance the efficiency and sustainability of our food production systems, with applications that not only aim to benefit farmers, but also satisfies consumer needs. Consumer focused traits include foods that are gluten free, non-browning, have reduced allergen levels and with improved nutritional and shelf-life qualities. Farmer focused traits on the other hand, include applications addressing disease and pest mitigation, temperature extremes, stress, and drought tolerance, as well as improvements in crop yields. Despite the relative infancy of CRISPR technology, its widescale application and use to accelerate the plant breeding process is expected to deliver new food products to market quicker and at more affordable prices.

The first CRISPR edited food product has already hit the market in Japan. In 2021, Sicilian Rouge tomatoes genetically edited for higher levels of γ -aminobutyric acid (GABA), a health promoting compound shown to lower blood pressure and promote relaxation, went on sale in the Japanese market. The commercial release of the world's first CRISPR edited food product was a significant milestone. With thousands of scientists deploying CRISPR technology in a myriad of crops and traits in various laboratories across the globe, it is only a matter of time before more CRISPR edited products make their appearance. However, future production and access to CRISPR products will depend on which part of the world you live in. Because regulatory policy cannot keep up with rapid advances in science, CRISPR technologies do pose unique challenges to existing regulatory frameworks in terms of how it should be regulated.

Looking ahead - harmonisation of global regulatory frameworks as well as societal acceptance of these new editing technologies are some of the hurdles that need to be overcome for the full impact of CRISPR's innovation potential to be realised and to deliver on its promises to improve the productivity, resilience, and sustainability of our agricultural food production systems.