Keeping up with Genetic Engineering (Modification) – a relatively brief guide

The basics of genetics

DNA (deoxyribonucleic acid) is a molecule that in most organisms holds the patterns for producing proteins. Proteins are the molecules in organisms that get things done (for example balance the insulin levels in the human bloodstream, perform photosynthesis in plants or give eyes their colour). A genes is a portion of DNA that is responsible for the pattern for a specific protein. Some genes are fairly simple (like the gene for insulin), some less so (it takes at least six genes to give your eyes their colour) and just about all genes respond to their environment (an organism has no need for eye pigmentation in their liver or chlorophyll in their roots).

Genetic Engineering or Modification

This is the process of changing the DNA of an organism. It can be argued that humans have been modifying the genetics of the organisms around them for a very long time. More recently the techniques have become increasingly sophisticated. In 1973 the first genetically modified bacteria began producing human insulin from a human gene that had been added to the DNA of the bacteria. Since then the processes used to modify organisms have been researched extensively, been the subject of patents, lawsuits, celebrations and controversy.

Methods

Simple Selection – this is historically how humans have interacted with the genetics of plants and animals, by choosing the individuals to breed that have characteristics that are wanted (resilience, productivity, size, colour etc.). This has been part of the historical domestication of both plants and animals and has occurred over at least the last 10,000 years. It is a relatively slow process, taking place over generations and over time can give relatively stable varieties of plant and animal.

(example: domestication of plants and animals, polled cows, open pollinated seeds)

Characteristics: slow, utilises naturally occurring variation, permanent

Induced Mutations – more recently mutations have been induced in plant varieties by exposing their DNA to radiation or chemicals. Random mutations in DNA can cause a change which is permanent and occasionally beneficial. These traits are then bred normally until a stable variety is established (or a variety which can be crossed with another to produce a stable hybrid).

Hybrids – this involves crossing different varieties of the same species to get the best of both, however the following generation does not 'breed true' so many of the offspring of hybrids (usually at least 50%) will revert to the two varieties that were crossed. May include varieties produced from induced mutations above.

(example: F1 Hybrid seeds, does not retain positive characteristics, so hybrid seeds must be bought from seed companies for each generation)

Characteristics: can be more reliable, productive, disease resistant and consistent but only for that generation (non-permanent)

There is currently no requirement for seed companies to declare whether hybrid varieties (including organic hybrid varieties) have used induced mutations to produce the hybrid or not. Hybrid varieties are allowed in organic agriculture and specific hybrids have been developed to meet the demands of organic agriculture. Hybrid seeds are discouraged in biodynamic agriculture, but their use is allowed.

Genetic Modification – the old-fashioned process of genetic modification involves taking individual genes and trying to incorporate them into another organism as a permanent change to the DNA. This can mean that genes from one species (or more) are permanently added to another. For example, the first version of 'golden rice' (published in 2000, first growing trials in 2004) took genes from a daffodil and a soil bacterium and inserted them into the DNA of the rice plant so that the rice plant would make a precursor to Vitamin A in the grain (the rice plant usually makes this same precursor in the leaf, but not the grain). The 'insertion' part of the process was fairly random at that point in the research, either by using viruses to get the DNA into the cells or using a 'shotgun approach' that sprayed cells with DNA and made their membranes more permeable (using enzymes, chemicals or small electric shocks). A few of the rice cells took up the DNA in a way that incorporated it and synthesised the vitamin A precursor in the grain, the plants were then bred normally.

Any organism that contains genetic material originating from more than one species (transgenic) is considered a genetically modified organism (GMO) and is banned for use in organic and biodynamic agriculture (food, feed, animals etc.)

(examples: human insulin producing bacteria (1973), golden rice (2000), 'Roundup Ready' corn (1998))

Characteristics: slow and expensive to develop new strains, sometimes subject to patent laws, permanent

Cell Fusion Techniques– cell fusion takes genetic material from the same species but originating from two different cells and puts it together (this can be done by simple injection, the use of mild electric current or chemicals). This is a process that imitates natural fertilisation (genes from two individuals of the same species come together) and has been used to produce hybrid varieties which like the more traditional hybrid varieties will not 'breed true' but do contain genetic material from only one species (cisgenic).

(example: F1 hybrid varieties)

Characteristics: as hybrids above

Because these hybrids are not transgenic (from more than one species) they are not currently banned for use in organic agriculture, though they are banned for use in biodynamic agriculture. IFOAM (International Federation of Organic Agriculture Movements) has come to the conclusion that seeds that originate from cell fusion techniques should be banned in organic agriculture as they are genetically engineered. Problematically for both Demeter and for IFOAM, there is currently no requirement for seed companies to declare whether hybrids are the product of cell fusion techniques or traditional breeding.

CRISPR-Cas 9 – this system was adapted from a naturally occurring genome editing system in bacteria and takes advantage of an organism's own DNA repair mechanism. Instead of the shotgun approach of previous genetic modification techniques, CRISPR-Cas 9 allows a much more specific and targeted insertion of a gene into the DNA of an organism. The gene to be inserted can be synthesised or naturally occurring in the same species or another one. The difference with CRISPR-Cas 9 is really in the precision of insertion, which is why it is often called **gene editing**. If a genome is sequenced (like humans or corn) then it is possible to choose the specific location in the genome for a novel gene to be inserted. The organism's own repair enzymes then repair the DNA so that the change is permanent and passed on to the next generation (if the change is made in embryonic cells or sex cells). This is a relatively recent development with research intensifying between 2011 to 2015, and due to the more precise nature of the process it is also a shorter and relatively inexpensive process (compared to the old fashioned genetic modification techniques which took a decade and large investment to develop a single new strain).

Because the incorporation of the new gene into the DNA is permanent and done by the organism's own repair system, this is very difficult to trace. If the new organism is transgenic, it is classified as a genetically engineered organism, if it is cisgenic, this is less clear. There is debate about its use in organic seed development, it is not allowed in biodynamic seed and plant breeding.

(example: DuPont will bring the first CRISPR-Cas 9 developed corn seeds to market in 2020, they will be cisgenic with genes all from corn plants, not transgenic)

Characteristics: as genetic modification above, though the possibilities are likely to be quicker (less than five years to market), less expensive and more precise.

Conclusions:

Human interference with genetics has developed over a long span of time and current practice exists on a continuum. Genetics is a long-term process, and even the newest methods require time, effort and money in development. In addition, with **all** breeding techniques, unintended consequences are likely, unpredictable and may take plenty of time to become visible.

In the organic world there is active debate about the latest techniques. Klaas Martens, an American long-term organic farmer has commented that if CRISPR-Cas 9 crops use genes from within the species then he would be interested in using them (on a case by case basis), whereas transgenic crops he would not[1]. The United States Department of Agriculture has decided that gene edited organisms (using CRISPR Cas 9) that are not transgenic will not be treated, regulated or labelled as GMOs (which we assume means that they will be allowed under USA organic standards). The National Organic Standards Board in the USA seems to disagree. IFOAM states that 'from a biological point of view cells are the lowest entity of self-organized life, and technological intervention below that level, such as is the case with cell fusion techniques is not in line with the values of organic agriculture[2].' In fact, IFOAM also clarified that in their view CRISPR-Cas 9 gene editing, should be treated as genetic modification and therefore is not appropriate for use in organic agriculture[3]. The European Commission has not made its position clear yet.

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[1] https://newfoodeconomy.org/klaas-martens-organic-gene-editing-crispr-gmo/
[2] https://ifoam.bio/en/news/2017/10/19/ifoam-organics-international-releases-strategy-replacing-cell-fusion-cultivars
[3] https://ifoam.bio/en/news/2018/01/11/organic-food-and-farming-movement-calls-regulation-new-genetic-engineering

UPDATE: since this article was written the European Court of Justice has ruled on new genetic techniques - http://organic-market.info/news-in-brief-and-reports-article/eu-new-genetic-engineering-methods-considered-genetically-modified.html

So, what are the acceptable boundaries? In the recognition that genetics isn't everything and that genetics and environment interact on many levels (cellular, organ and organism), how can we judge what kind of genetics we want?

While we debate what we find acceptable, there are a few certainties. Until there is a demand for more information about how genetics have been developed, we will live with the fact that there are organic hybrid seeds that have been produced with radiation, exposure to chemicals and cell fusion techniques. Growers will not know what has produced their seeds unless they ask and are aware of the possibilities. The organic sector will need support to actively consider what meets organic principles and draw their own conclusions.

From a biodynamic perspective (and according to Demeter standards) the boundaries are much more clear – seeds from cell fusion and CRISPR Cas-9 gene editing are not allowed, open pollinated seeds are encouraged as are local breeds, but the practical access in quantity requires a long-term view, support and investment.

Further reading:

https://shop.fibl.org/chen/mwdownloads/download/link/id/155/

https://ifoam.bio/en/news/2017/10/19/ifoam-organics-international-releases-strategy-replacing-cell-fusion-cultivars

http://www.foodsafetynews.com/2014/05/draft-a-gmo-conundrum-organic-mutageniccell-fusion-hybrid-seeds-are-genetically-engineered/#.WxpAMEgvxPY

https://www.ncbi.nlm.nih.gov/books/NBK215771/