**Case Study: Corn (Maize)** Mexicans began selectively breeding corn around 10,000 years ago. By choosing the most favourable corn kernels to plant, they were unconsciously using artificial selection to improve their crops. Biologists have since begun genetically manipulating plants like corn for desirable traits such as increasing production, decreasing wastage because of pests, and making the corn more appealing to consumers. Genetically modifying corn plants, however, has had wider biological implications.

Ancient farmers saved kernels with specific traits for the next year’s crops such as the ability to grow well in various climates, soil types and produce the largest number of kernels and kernel rows. Each kernel is a seed that has resulted from a female egg fertilised by a male pollen grain. The most suitable kernels reproduce and the gene pool of the next generation has a higher frequency of the favoured genes. Over time, the quality of the crop will increase as the favoured offspring reproduce repeatedly. However, planting a kernel from a corn plant that appears to have one or some of the desirable traits is not always reliable. The outcome of selective breeding is not always guaranteed, because of hidden genes and mutations that can happen. Even though its phenotype may seem to be suitable, the genotype (and therefore phenotype) of its offspring may not be suitable. If the original plant had a recessive gene in its genotype that was not expressed in its phenotype, and its egg was fertilised with a male pollen grain that also had a recessive gene, there would be a chance of the kernel being homozygous recessive. This would mean that the particular phenotype expressed in the original corn plant would not be expressed in the new plant.

Selective breeding has become easier with time, as people found ways to figure out an organism’s genotype. Farmers can now deliberately cross two of the same species that both possess either homozygous dominant or homozygous recessive genes and almost guarantee a purebred offspring. The first way was by using a test cross. By crossing one organism that is showing the dominant form of a trait with another of the same species that is homozygous recessive for the same trait; it is possible to determine the other organism’s genotype from the traits expressed in the offspring. Other more efficient methods like marker assisted selection (MAS) are now used for selection of a genetic determinant of a trait of interest. MAS can be useful for traits that are difficult to measure, exhibit low heritability, or are expressed late in development. Steps for MAS include firstly mapping the gene or quantitative trait locus (QTL) of interest by using different techniques and then use this information for marker assisted selection. The markers to be used should be close to gene of interest in order to ensure that only a minor fraction of the selected individuals will be recombinants. Generally, not only a single marker but rather two markers are used in order to reduce the chances of an error due to homologous recombination.

Another biological implication of selective breeding is that the outcome may not be completely successful because of linked genes. Linked genes are those that are found on the same chromosome and tend to be transmitted together. For example, alleles for both kernel colour and kernel size lie on the same chromosome. A farmer may select a kernel that is the desirable size, but with that trait may also come a negative trait such as susceptibility to disease, infertility, or the wrong colour, etc. The negative consequences of using and/or reproducing that plant would probably outweigh the positive features. Similarity within species also means that if the species comes into contact with a disease, there is a high chance of the whole species being wiped out. It could have detrimental effects on ecosystems because if one species is removed from a food chain it will impact all other species in the chain.

Transgenesis is another way of producing whole corn plants crops with desirable traits. Scientists introduce certain genes into a plant without having to go through the risky trial-and-error process of selective breeding, and have a higher success rate because they have more control throughout the process. It is relatively easily to add certain genes one species may not naturally possess. Genetically modified corn crops include Bt corn, Bt sweet corn and Roundup Ready Corn. These crops are modified for specific beneficial traits to assist with...
pest resistance and herbicide tolerance. Bt corn is developed using a form of transgenesis, when genes from one organism are transferred to another organism of a different species. ‘Bt’ stands for the soil bacterium *Bacillus thuringiensis*. This pathogen produces toxins that act as insecticides and kill insects. Scientists insert a gene from the bacterium into a corn cell in order to reduce the damage done particularly by the European corn borer (ECB) that eats corn stems. To make Bt corn, biologists start with a Ti-plasmid (tumour inducing plasmid) in *Agrobacterium tumefaciens*. Plasmids are genetic structures that can replicate independently of chromosomes, and this particular type of plasmid is used often as a means to transfer genetic information from one organism to another. Researchers investigated how the Bt bacterium kills insects, and found it has two types of toxins. One of the types is cytolysins (Cyt), toxic to insects such as beetles and flies. The other type is the crystal delta-endotoxins (Cry), toxic to moths and butterflies. Scientists found that Cry is toxic to the ECB. The Bt Cry gene is extracted from the *Bacillus thuringiensis* bacterium using enzymes called restriction endonucleases, acting as scissors to cut out the desired gene. The gene is then inserted into a corn ‘expression cassette’. The expression cassette is inserted into the Ti-plasmid, meaning millions of copies of it can be produced. The duplicates of the foreign gene are then inserted into the corn cell genome where the cells reproduce and generate new plants that are resistant to insects like the European corn borer. These plants can then be propagated vegetatively to produce many clones of the Bt corn.

A biological implication of pest resistant (Bt corn) is very little genetic diversity within the population, as the plants have been cloned and reproduced from the same one plant, meaning all their genes will be identical. In the same way that little genetic variation affects selectively bred plants, it will affect genetically modified plants. If all the corn plants have identical DNA they will all be susceptible to the same things, such as; particular diseases, drought, floods, bad soil quality and herbicides/pesticides, etc. Another biological implication of Bt corn is the possible negative effects it can have on populations other than those intended. A study done in 1999 found that Bt corn is also toxic for Monarch butterfly larvae. They suffered a significant decrease in fitness when their normal diet was dusted with Bt corn pollen. The effect of Bt corn on other species does not only affect the particular species, but also a whole ecosystem and food chain/web within it. If one organism becomes scarce, it will influence the way the other species in the chain interact and survive.

For a population to survive it must have variation in its gene pool. There are advantages and disadvantages involved with both selective breeding and using transgenesis for corn crops. Despite some benefits, selective breeding is both imprecise and inefficient, as thousands of genes combine at once and the offspring plant may not receive the exact combination of genes the breeder intended. Without MAS, there is no way of knowing whether the desirable genes are in the male or female gamete. Genetic diversity is largely affected in both forms of genetic manipulation, more so by using transgenesis. Both manipulations cause a sizable decrease in the gene pool of populations, and put the species being manipulated at risk. This creates a knock-on effect with the survival of a population. Transgenesis has the biggest effect, as each individual is an identical copy of the last, meaning they contain the same genetic material. Selective breeding involves breeding more specific traits where these genes are then increased in the gene pool, however, the rest of the individual's genes making up other features is left to chance, allowing for a wider variety of genes in their gene pool. In transgenesis, there is a smaller risk of the species being wiped out as the original plant will still exist, even after some of its DNA has been manipulated. In selective breeding, once humans begin to manipulate the species there is no going back. The original plant is no longer there to reproduce; there are only the crops that are being selectively bred in the present. Selective breeding is a slow process of trial and error; and very time consuming as many generations may be required before planting and producing the ideal individual. Transgenesis takes a while to perfect because of the more complex science behind it. However, once the desired organism is selected, there is not the need to go through multiple generations before achieving the desired result. In some ways, it can also be a time-consuming process because of its high failure rate. Several genes may need to be added before a successful phenotype is produced.