



National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Biology Level 3

This exemplar supports assessment against:

Achievement Standard 91607

**Demonstrate understanding of human manipulations of genetic transfer
and its biological implications**

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assists teachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

	Grade Boundary: Low Excellence
1.	<p>For Excellence, the student needs to demonstrate comprehensive understanding of human manipulations of genetic transfer and its biological implications.</p> <p>This involves linking biological ideas about human manipulations of genetic transfer (EN 3) and its biological implications (EN 4). Linking ideas may involve justifying, relating, evaluating, comparing and contrasting, and analysing.</p> <p>This student has demonstrated comprehensive understanding by using corn plants as a case study. Biological ideas are used to describe and explain selective breeding (1) and genetic corn plant cloning (3).</p> <p>Some biological ideas are used to explain the biological implications of selective breeding (2) and cloning of corn plants (4) relating to genetic biodiversity and ecosystems.</p> <p>Some biological ideas and their biological implications are linked by comparing and contrasting both manipulations of genetic transfer (5).</p> <p>For a more secure Excellence, the student could:</p> <ul style="list-style-type: none"> • explain the biological implications of each manipulation more thoroughly. For example inbreeding depression and monoculture in selective breeding. • include more detail linking biological ideas about both human manipulations of genetic transfer and their biological implications. For example by justifying the use of whole corn plant cloning over the selective breeding of corn.

1 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 corn crops. Biologists have since begun genetically manipulating corn for desirable traits such as increasing production, decreasing wastage because of pests and making the corn more appealing to consumers. 2 Genetically modifying corn plants, however, has had wider biological implications.

1 Selective breeding of corn was originally done by ancient farmers saving kernels from the best plants as seeds for the next year's crops. They chose kernels with specific traits such as the ability to grow well in various climates, soil types and produced 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. This means only the best or most suitable kernels will reproduce and the gene pool of the next generation will have a higher frequency of the favoured genes. 2

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. 1

1 Selective breeding has become easier with time, as people found ways to figure out an organism's genotype. With this knowledge, farmers can now deliberately cross two members 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 indirect 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.

1 Since humans have begun selectively breeding corn, the genetic diversity has decreased as kernels are being selected for certain qualities and those qualities only. Another biological implication 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. Its scarcity will have implications on other things. For instance, 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. 2

3 Genetic cloning of whole corn plants is another way to produce crops with desirable traits. The techniques used allow scientists to 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 biologists have more control throughout the process. It is relatively easy 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 have been modified for specific beneficial traits to assist with pest resistance and herbicide tolerance. The technique used for cloning of Bt corn is a form of transgenesis, which is when genes from one organism are transferred to another organism of a different species. Bt corn came about to try to prevent corn crops being destroyed by pests such as insects. '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 particular insects, and found that it has two types of toxins. One of the types is cytolysins (Cyt) which are toxic to insects such as beetles and flies. The other type is the crystal delta-endotoxins (Cry) which are 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, which act as scissors to cut out the desired gene. The gene is then inserted into a corn 'expression cassette'. From there the expression cassette is inserted into the Ti-plasmid by putting the cassette into a plasmid, this means 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. This technique is used because *Agrobacterium* is a naturally occurring soil bacterium that infects some plants and causes crown gall disease.

4 A biological implication of pest resistant (Bt corn) is that there will be 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.

5 For a population to survive it must have variation in its gene pool. There are advantages and disadvantages involved with both selective breeding and whole corn plant cloning. Both manipulations decrease genetic diversity and put the species being manipulated at risk. In plant cloning, 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 began to manipulate the species there was 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. A species may become so specialised as a result of selective breeding that it is no longer suitable, and it is not possible to undo that. If a species is wiped out due to little genetic variation, it will have consequent effects on other organisms around it because it is part of an ecosystem and food chain/web. This may result in environmental issues and also shortages in other species and/or food supplies.

	Grade Boundary: High Merit
2.	<p>For Merit, the student needs to demonstrate in-depth understanding of human manipulations of genetic transfer and its biological implications.</p> <p>This involves using biological ideas to explain:</p> <ul style="list-style-type: none"> • how humans manipulate genetic transfer (EN 3), and • the biological implications (EN 4) of these manipulations. <p>This student has demonstrated in-depth understanding by using corn plants as a case study. Biological ideas are used to describe and explain selective breeding (1) and cloning of corn plants (3).</p> <p>Some biological ideas are used to explain the biological implications of selective breeding (2) and corn plant cloning (4), relating to genetic biodiversity and impact on ecosystems.</p> <p>An attempt has been made to link biological ideas about selective breeding and cloning of corn plants, and their biological implications (5).</p> <p>To reach Excellence, the student would need to give further evidence linking biological ideas about both human manipulations of genetic transfer and its biological implications.</p> <p>For example by comparing and contrasting them, or justifying using whole corn plant cloning over the selective breeding of corn.</p>

Student 2: High Merit

NZQA Intended for teacher use only

Farmers began selectively breeding corn around 10,000 years ago by choosing the most favourable corn kernels to plant.

Biologists can now genetically manipulate corn for desirable traits. Genetically modifying corn plants, however, has had wider biological implications.

1 Selective breeding of corn was originally done by ancient farmers saving kernels from the best plants as seeds for the next year's crops. They chose kernels with specific traits such as the ability to grow well in various climates, soil types and produced 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. This means only the best or most suitable kernels will reproduce and the gene pool of the next generation will have a higher frequency of the favoured genes. 2 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. 2 Even though its phenotype may seem to be suitable, the genotype (and therefore phenotype) of its offspring may not be suitable. 1 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.

1 Selective breeding has become easier with time, as people found ways to figure out an organism's genotype. With this knowledge, farmers can now deliberately cross two members 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 indirect 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.

1 Since humans have begun selectively breeding corn, the genetic diversity has decreased as kernels are being selected for certain qualities and those qualities only. Another biological implication 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. Its scarcity will have implications on other things. For instance, 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. 2

Genetic cloning of whole corn plants is another way to produce crops with desirable traits. The techniques used allow scientists to 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 biologists have more control throughout the process. It is relatively easy 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 have been modified for specific beneficial traits to assist with pest resistance and herbicide tolerance. The technique used for cloning of Bt corn is a form of transgenesis, which is when genes from one organism are transferred to another organism of a different species. Bt corn came about to try to prevent corn crops being destroyed by pests such as insects. '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 particular insects, and found that it has two types of toxins. One of the types is cytolysins (Cyt) which are toxic to insects such as beetles and flies. The other type is the crystal delta-endotoxins (Cry) which are 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, which act as scissors to cut out the desired gene. The gene is then inserted into a corn 'expression cassette'. From there the expression cassette is inserted into the Ti-plasmid by putting the cassette into a plasmid, this means 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. This technique is used because *Agrobacterium* is a naturally occurring soil bacterium that infects some plants and causes crown gall disease.

A biological implication of pest resistant (Bt corn) is that there will be 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.

As there is little genetic variation in selective breeding, if a species is wiped it will have effects on other organisms as part of an ecosystem and food chains and food webs. The aim of plant breeders is to assemble a collection of genes in a crop like corn to make it useful and as productive as possible. The world population has topped seven billion people and is expected to double in the next 50 years. Ensuring an adequate food supply is a major challenge in years to come to ensure the survival of the human species.

Corn plant cloning takes more time to set up than selective breeding because of the more complex science behind it. But once perfected, it is very quick to clone and genetically modify corn plants. Farmers do not have to select traits and wait for their crops to grow to be able to select seeds to use. With selective breeding it may take years of trial and error to see any progress.

	Grade Boundary: Low Merit
3.	<p>For Merit, the student needs to demonstrate in-depth understanding of human manipulations of genetic transfer and its biological implications.</p> <p>This involves using biological ideas to explain:</p> <ul style="list-style-type: none"> • how humans manipulate genetic transfer (EN 3), and • the biological implications (EN 4) of these manipulations. <p>This student has demonstrated some in-depth understanding by using corn plants as a case study. Biological ideas are used to describe and partly explain selective breeding (1) and cloning of corn plants (3).</p> <p>Biological ideas are used to describe and explain the biological implications of selective breeding (2) and corn plant cloning (4), by relating this to genetic biodiversity and the impact on ecosystems.</p> <p>An attempt has been made to link biological ideas about selective breeding and cloning of corn plants, and their biological implications (5).</p> <p>For a more secure Merit, the student could use biological ideas to give a more in-depth explanation of:</p> <ul style="list-style-type: none"> • how humans manipulate genetic transfer in selective breeding and corn plant cloning • the biological implications of both manipulations of genetic transfer. <p>For example, by explaining how Bt corn disrupts an ecosystem by killing non-target insects that feed on nearby plants that have Bt corn pollen on them.</p>

Student 3: Low Merit

NZQA Intended for teacher use only

1 Selective breeding of corn was originally done by ancient farmers by choosing kernels with specific traits such as the ability to grow well in various climates, soil types and produced the largest number of kernels. A kernel is a seed that has resulted from a female egg fertilised by a male pollen grain. This means only the best or most suitable kernels will grow and reproduce. Over time, the quality of the crop will increase as the favoured offspring reproduce repeatedly.

2 However, planting a kernel from a corn plant that appears to have one or more 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. 1 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.

1 Selective breeding has become easier with time. The offspring of selectively bred corn plants will inherit similar genes, traits and DNA from its selectively bred parents. Farmers can now deliberately cross two members 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 indirect selection of desirable traits. MAS can be useful for traits that are difficult to measure or are expressed late in development. The process for MAS includes mapping and then using this information for marker assisted selection.

2 Since humans have begun selectively breeding a number of crop plants, including corn, the genetic diversity of these plants has decreased. A biological implication 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. 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. Its scarcity will have implications on other things. For instance, it could have detrimental effects on ecosystems if one species is removed from a food chain.

3 Genetic cloning of whole corn plants is another way to produce crops with desirable traits. The techniques used allow scientists to introduce certain genes into a plant without having to go through the risky trial-and-error process of selective breeding, as biologists have more control throughout the process. It is relatively easy to add certain genes one species may not naturally possess. Genetically modified corn crops include Bt corn. These crops have been modified for specific beneficial traits to assist with pest resistance and herbicide tolerance. The technique used for cloning of Bt corn is a form of transgenesis, which is when genes from one organism are transferred to another organism of a different species. Bt corn came about to try to prevent corn crops being destroyed by pests such as insects. '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 corn cells in order to reduce the damage done by pests like the European corn borer (ECB) that eats corn stems.

To make Bt corn, biologists start with a plasmid in *Agrobacterium tumefaciens*. Plasmids are genetic structures that can replicate independently of chromosomes, and this particular type

3

of plasmid is used often as a means to transfer genetic information from one organism to another. *Agrobacterium tumefaciens* is used as the vector because it has a large plasmid. The plasmids that have the Bt gene inserted can be used to add the gene to target cells in corn. Cells are taken from the corn and the cell walls removed. They are grown on a nutrient and treated with recombinant *Agrobacterium*. These cells form a callus which is further treated with hormones and then grown into transgenic corn plants. The large plasmids become incorporated in the host corn cell's DNA. By cloning corn plants, the rate of crop yield can be improved. This technique is used because *Agrobacterium* is a naturally occurring soil bacterium that infects some plants and causes crown gall disease.

A biological implication of pest resistant Bt corn is that there will be less 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.

4

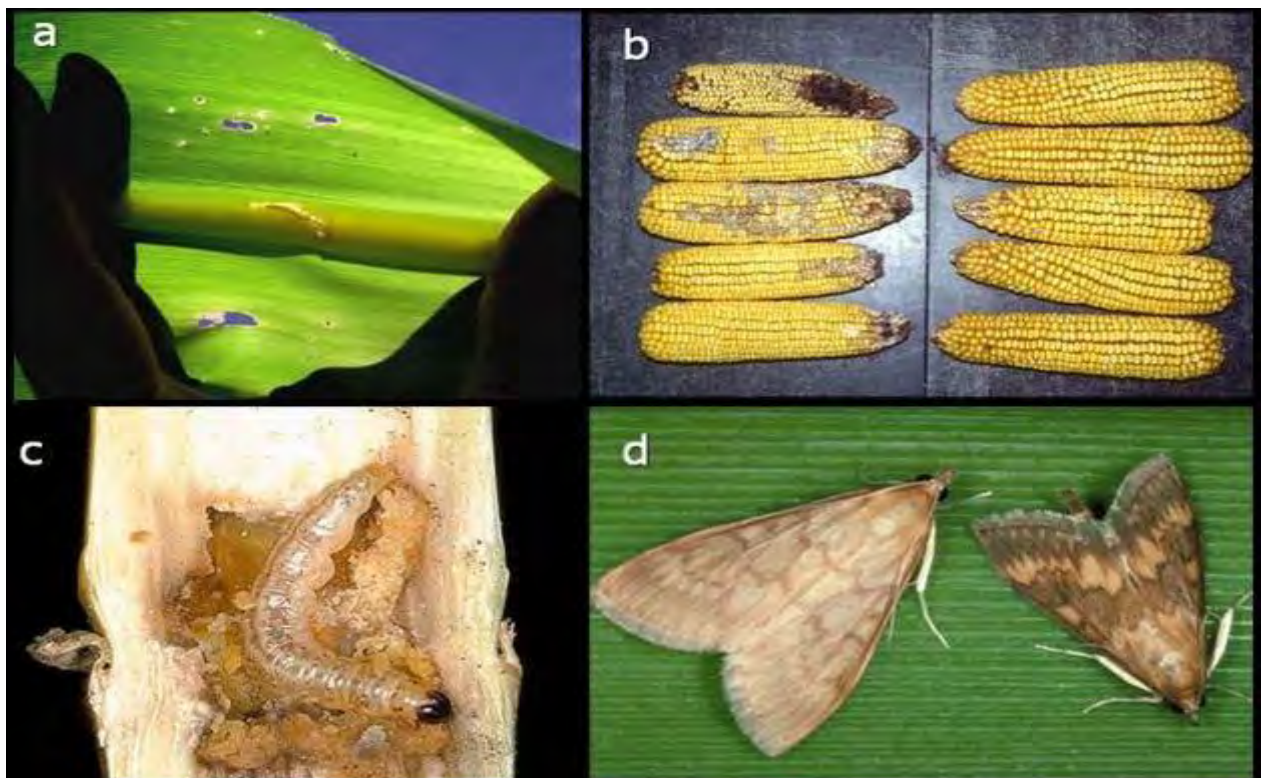


Figure 1
European corn borer: shotholes and tunnel in leaf midrib (a), damage and fungal infection in non-Bt maize (left) and Bt maize (b), stalk tunneling (c), and adult female (left) and male (d). [a, c, d photos courtesy of Marlin Rice, b photo courtesy of Gary Munkvold]

2

As there is little genetic variation in selective breeding, if a species is wiped it will have effects on other organisms as part of an ecosystem and food chains and food webs. The aim of plant breeders is to assemble a collection of genes in a crop like corn to make it useful and as productive as possible. The world population has topped seven billion people and is expected to double in the next 50 years. Ensuring an adequate food supply is a major challenge in years to come to ensure the survival of the human species.

2

	Grade Boundary: High Achieved
4.	<p>For Achieved, the student needs to demonstrate understanding of human manipulations of genetic transfer and its biological implications.</p> <p>This involves using biological ideas to describe human manipulations of genetic transfer (EN 3) and its biological implications (EN 4).</p> <p>This student has demonstrated understanding by using corn plants as a case study. Biological ideas are used to describe selective breeding (1) and describe and partly explain cloning of corn plants (3).</p> <p>Biological ideas are used to describe some biological implications of selective breeding (2), and describe and explain the implications of corn plant cloning (4), by relating this to genetic biodiversity and the health and survival of individuals.</p> <p>To reach Merit, the student would need to give further evidence using biological ideas to:</p> <ul style="list-style-type: none">• explain how humans manipulate genetic transfer in the selective breeding of corn plants• more thoroughly explain the cloning of whole corn plants as Bt corn• explain the biological implications of selective breeding of corn plants. <p>For example, by explaining the effect of Bt corn reducing the population of insects in an ecosystem, and the flow-on effect on reducing the population of birds that feed on those insects.</p>

1 In the past, selective breeding of corn was done by choosing seeds with features such as the ability to grow well in different climates, soil types and produced the most seeds. This means that only the best or most suitable seeds will grow and reproduce.

Planting a seed from a corn plant that appears to have one or more desirable features is not always reliable. 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 there would be a chance of the seed being homozygous recessive. This would mean that the particular phenotype expressed in the original corn plant would not be expressed in the new plant. 2

1 The offspring of selectively bred corn plants will inherit similar genes from its selectively bred parents. Farmers can now deliberately cross two members 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. Another method is marker assisted selection (MAS). MAS can be useful for traits that are difficult to measure or are expressed late in development. The process for MAS includes mapping and then using this information for marker assisted selection.

When crop plants like corn are artificially bred by selective breeding, there is a noticeable decrease in their genetic diversity. The plants share similar genes with each other which then increases the risk of genetic disease. Similarity within a species means that if the species comes into contact with a disease, there is a high chance of the whole species being wiped out. This will have implications on other things. For instance, it could have detrimental effects on ecosystems if one species is removed from a food chain. 2



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3 Genetic cloning of whole corn plants is another way to produce crops with desirable features. Humans have manipulated the genetic transfer of cloning of plants and animals to meet human demands, particularly those of today with modern culture and living. The genetic modification of an organism is a human manipulation. Bt-corn is a type of genetically modified organism (GMO). The modification of an organism to result in a GMO may involve either, altering an existing gene, adding a foreign gene or modifying an existing gene's expression. This is done to overcome selective breeding and its limitations, as selective breeding is the selection of particular plants and animals to be bred under domestication. Since the development of agriculture, the techniques of modifications resulting in a GMO were developed, but they too just as selective breeding also have their own limitations.

3 A genetically modified organism is a plant (or animal) that has been genetically modified through the addition of a small amount of genetic material from other organisms through molecular techniques. A gene that produces a feature of interest is identified and separated from the rest of the genetic material from a donor organism. Most organisms have thousands of genes; a single gene represents only a very small part of the total genetic makeup of an organism.

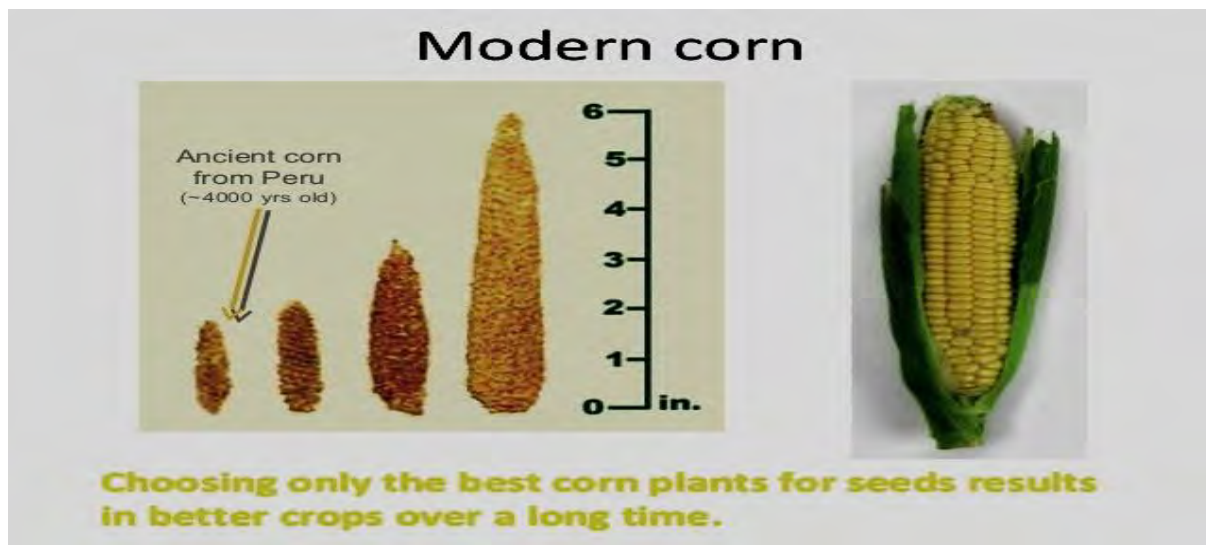
3 A donor organism can be a bacterium, fungus or even another plant. With Bt corn, the donor organism is a naturally occurring soil bacterium, *Bacillus thuringiensis*, and the gene of interest produces a protein that kills Lepidoptera larvae, in particular, European Corn Borer. This protein is called the Bt delta endotoxin. The Bt delta endotoxin was selected because it is highly effective at controlling Lepidoptera larvae, caterpillars. It is during the larval stage when most of the damage by European Corn Borer occurs. The protein is very selective, generally not harming other insects such as beetles, flies, bees and wasps). Genes from *Bacillus thuringiensis* (Bt) are inserted into corn crop plants to make them capable of producing the insecticidal toxin and therefore resistant to certain pests. Delta endotoxins rapidly affect the insect's digestive system, so damage to the plant stops soon after the insect is exposed to the toxin. Mortality may take several days, so the effects of delta endotoxins are very different from what can be expected from conventional insecticides. 4

There are many different Bt corn hybrids available. Some experimental transgenic plants have caused allergic responses in humans. There are no known serious human health effects associated with Bt corn. However, a 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. Bt corn can adversely affect non-target insects if they are closely related to the target pest, as is the case with Monarch butterfly. These adverse effects are considered minor, relative to those associated with the alternative of blanket insecticide applications. 4

A biological implication of pest resistant Bt corn is that there is less genetic diversity in the species. If all the corn plants have identical DNA they will all be susceptible to the same things, such as diseases, drought and herbicides/pesticides. Bt corn has revolutionized pest control in a number of countries, but there still are questions about its use and impact on other species. Also, the control of insects by Bt corn has many scientists worried that overuse of Bt corn could produce pests resistant to Bt toxins. The resistance to Bt corn has already happened occurred for two moth species: fall armyworm, *Spodoptera frugiperda*, in Puerto Rico, and African stem borer, *Busseola fusca*, in South Africa, so this concern is warranted. 4

	Grade Boundary: Low Achieved
5.	<p>For Achieved, the student needs to demonstrate understanding of human manipulations of genetic transfer and its biological implications.</p> <p>This involves using biological ideas to describe human manipulations of genetic transfer (EN 3) and its biological implications (EN 4).</p> <p>This student has demonstrated understanding by using corn plants as a case study. Biological ideas are used to briefly describe selective breeding (1) and cloning of corn plants (3).</p> <p>Some biological implications of selective breeding (2) and corn plant cloning (4) are described by relating them to genetic biodiversity and the health and survival of populations and individuals.</p> <p>For a more secure Achieved, the student could use biological ideas more thoroughly to include specific details describing:</p> <ul style="list-style-type: none">• selective breeding and cloning of corn plants, and• the biological implications of these manipulations. <p>For example, by giving a more detailed description of the processes involved in both human manipulations genetic transfers, and the outcome of these on the evolution of the corn species population.</p>

1 The history of modern-day corn begins at the dawn of human agriculture, about 10,000 years ago. Ancient farmers in what is now Mexico took the first steps in domesticating maize when they simply chose which kernels (seeds) to plant. These farmers noticed that not all plants were the same. Some plants may have grown larger than others, or maybe some kernels tasted better or were easier to grind. The farmers saved seeds from plants with desirable characteristics and planted them for the next season's harvest. This process is known as selective breeding or artificial selection. Maize cobs became larger over time, with more rows of kernels, eventually taking on the form of modern maize.



The study of genetics shows that corn's wild ancestor is a grass called teosinte. This plant doesn't look much like maize, especially when the seeds are compared compare to those of corn. However at the DNA level, they are both very similar; they have the same number of chromosomes and a remarkably similar arrangement of genes. In fact, teosinte can cross-breed with modern maize varieties to form maize-teosinte hybrids that can go on to reproduce naturally.

Planting a seed from a corn plant that appears to have one or more desirable features is not always reliable. Even though its phenotype may seem to be suitable, the genotype of its offspring may not be desirable. If the original plant had a recessive gene in its genotype there would be a chance of the seed being homozygous recessive. The particular phenotype expressed in the original corn plant would not be expressed in the new plant.

1 The offspring of selectively bred corn plants will inherit similar genes from its selectively bred parents. Farmers can now deliberately cross two members 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. Another method is marker assisted selection (MAS).

When crop plants like corn are made by selective breeding, there is a noticeable in a decrease in their genetic diversity. The plants share similar genes with each other which then increases the risk of disease. Similarity within a species means that if the species comes into contact with a disease, there is a chance of the whole species being wiped out. This will have effects on other things like ecosystems if one species is removed from a food chain.

2

Genetic cloning of whole corn plants is another way to produce crops with desirable features. Bt-corn is a type of genetically modified organism (GMO). It has been genetically modified through the addition of a small amount of genetic material from other organisms through molecular techniques. A gene that produces a feature of interest is identified and separated from the rest of the genetic material from a donor organism. Most organisms have thousands of genes; a single gene represents only a very small part of the total genetic makeup of an organism.

3

With Bt corn, the donor organism is a soil bacterium, *Bacillus thuringiensis*, and the gene of interest produces a protein that kills ECB (European corn borer) larvae. This protein is called the Bt delta endotoxin. The toxin was selected because it is highly effective at controlling ECB caterpillars. It is during the larval stage when most of the damage by European corn borer occurs. The protein is very selective, generally not harming insects in other orders (such as beetles, flies, bees and wasps). *Bacillus thuringiensis* (Bt) is a soil bacterium that produces insecticidal toxins. Genes from Bt can be inserted into crop plants to make them capable of producing an insecticidal toxin and therefore resistant to certain pests. The toxin affects the insect's digestive system, so damage to the plant stops soon after the insect is exposed to the toxin. Mortality may take several days, so the effects of delta endotoxins are very different from what we expect from conventional insecticides.

3

4

There are many different Bt corn hybrids available. While some experimental transgenic plants have caused allergic responses in humans, there are no known serious human health effects associated with Bt corn. A biological implication of Bt corn, however, 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 when their normal diet was dusted with Bt corn pollen. Bt corn can affect non-target insects if they are closely related to the target pest, as is the case with Monarch butterfly. These effects are considered minor, relative to those associated with the alternative of using insecticides.

4

Another biological implication of pest resistant Bt corn is that there is less genetic diversity in the species. If all the corn plants have identical DNA they will all be affected by the same things such as diseases and pesticides. Bt maize has revolutionized pest control in a number of countries, but there still are questions about its use and impact. The control of insects by Bt corn has many scientists worried that overuse of Bt corn could produce pests resistant to Bt toxins. Resistance to Bt corn has occurred for two moth species in South Africa, so this concern is warranted.

4

	Grade Boundary: High Not Achieved
6.	<p>For Achieved, the student needs to demonstrate understanding of human manipulations of genetic transfer and its biological implications.</p> <p>This involves using biological ideas to describe human manipulations of genetic transfer (EN 3) and its biological implications (EN 4).</p> <p>This student has demonstrated limited understanding by using corn plants as a case study. Some biological ideas are used to describe selective breeding (1) and cloning of corn plants (3). Biological implications of selective breeding (2) and corn plant cloning (4) are briefly considered by relating them to genetic biodiversity and the health and survival of populations and individuals.</p> <p>To reach Achieved, the student could use biological ideas to give a more detailed description of:</p> <ul style="list-style-type: none"> • selective breeding and cloning of corn plants, and • the biological implications of these manipulations. <p>For example, by giving further evidence describing the processes involved in both human manipulations of genetic transfers, and the outcome of these on the evolution of the corn species population at curriculum level 8.</p>

Student 6: High Not Achieved
 NZQA Intended for teacher use only

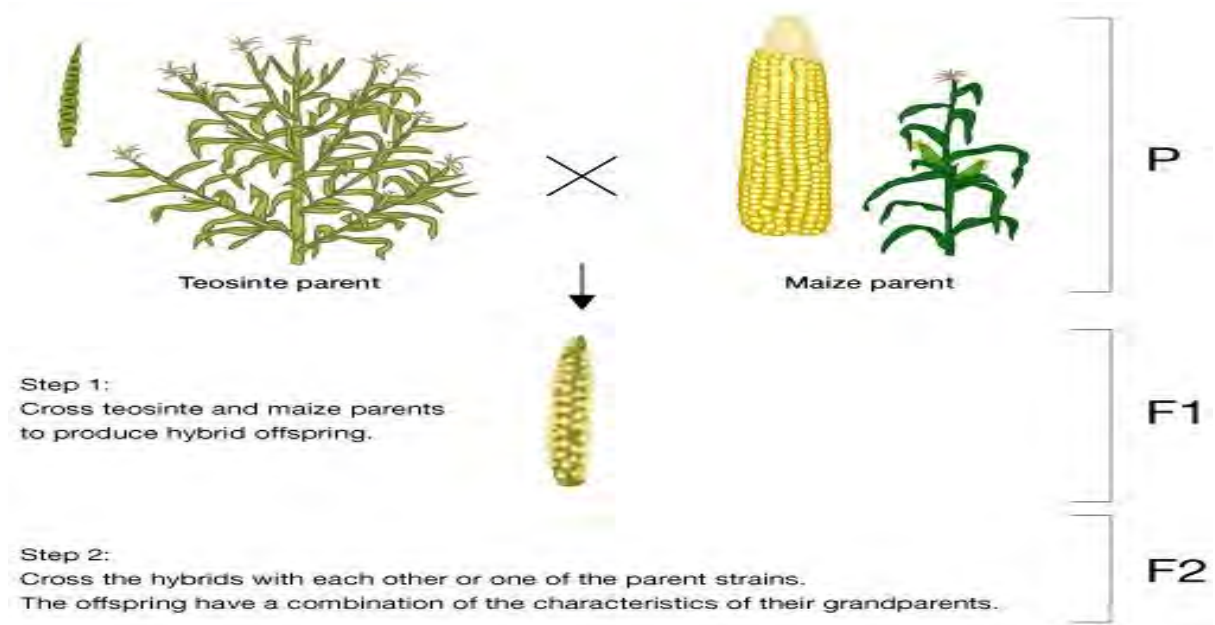
1

The history of modern-day corn begins at the dawn of human agriculture, about 10,000 years ago. Ancient farmers in what is now Mexico took the first steps in domesticating maize when they simply chose which kernels (seeds) to plant. These farmers noticed that not all plants were the same. Some plants may have grown larger than others, or maybe some kernels tasted better or were easier to grind. The farmers saved seeds from plants with desirable characteristics and planted them for the next season's harvest. This process is known as selective breeding or artificial selection. Maize cobs became larger over time, with more rows of kernels, eventually taking on the form of modern maize.



More maize is harvested each year than any other grain. The thousands of maize varieties grown around the world provide food for people and livestock.

The identity of corn's wild ancestor remained a mystery for many decades. Through the study of genetics, we know today that corn's wild ancestor is a grass called teosinte. Teosinte doesn't look much like modern day corn, but at the DNA level, the two are very alike.



The Evolution of Corn (University of Utah)

Planting a seed from a corn plant that has one or more desirable features is not always reliable. Even though its phenotype may seem to be suitable, the genotype of its offspring may not be desirable. If the original plant had a recessive gene in its genotype there would

2

be a chance of the seed being homozygous recessive. The particular phenotype expressed in the original corn plant would not be expressed in the new plant.

① The offspring of selectively bred corn plants inherit similar genes from its parents. Crossing two members of the same species having either homozygous dominant or homozygous recessive genes almost guarantees a purebred offspring. 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.

When crop plants like corn by selective breeding, there is a noticeable in a decrease in their genetic diversity. The plants have similar genes with each other which then increases the risk of disease. Similarity within a species means that if the species comes into contact with a disease, there is a chance of the whole species being wiped out. This will have effects on other things like ecosystems if one species is removed from a food chain. ②

Plants have an advantage over animals as a single cell may be able to grow into a plant. Corn can be cloned through transgenesis. Transgenic techniques insert DNA into a plant cell through protoplast fusion and biolistic or ballistic methods (gene gun). Cloning of whole corn plants can also produce crops with desirable features. Bt-corn is a type of genetically modified organism (GMO). A gene of interest which will have a desired characteristic is removed by the use of restriction enzymes. The gene is then cloned by PCR (polymerase chain reaction) or vectors and inserted into a host organism ③

③ With Bt corn, the gene donor organism is a soil bacterium, *Bacillus thuringiensis*, and the gene of interest produces a protein that kills ECB (European Corn Borer) larvae. The protein is very selective, generally not harming insects in other orders (such as beetles, flies, bees and wasps). The toxins rapidly damage the insect's digestive system, so damage to the corn plant is reduced or stops. ④

Some transgenic plants have caused allergic responses in humans. There are no known serious human health effects associated with Bt corn. However, a biological implication of Bt corn is the possible negative effects it can have on populations other than those intended. A study found that Bt corn is also toxic for Monarch butterfly larvae. Bt corn can adversely affect non-target insects if they are closely related to the target pest, as is the case with Monarch butterfly. ④

A biological implication of pest resistant Bt corn is that there is less genetic variation in the species. If all the corn plants have identical DNA they will all be affected by the same things such as diseases. The control of insects by Bt corn has many scientists worried that overuse of Bt corn could produce pests resistant to Bt toxins. ④