Genetic Modification

Learning Outcomes

- *21.1.1* – **State** that bacteria are useful in genetic modification due to their rapid reproduction rate and their ability to make complex molecules
- *21.1.2* – **Discuss** why bacteria are useful in genetic modification, limited to:
  a) few ethical concerns over their manipulation and growth
  b) the presence of plasmids
- *21.3.1* – **Describe** genetic modification as changing the genetic material of an organism by removing, changing or inserting individual genes
- *21.3.2* – **Outline** examples of genetic modification:
  a) the insertion of human genes into bacteria to produce human proteins
  b) the insertion of genes into crop plants to confer resistance to herbicides
  c) the insertion of genes into crop plants to confer resistance to insect pests
  d) the insertion of genes into crop plants to improve nutritional qualities
- *21.3.3* – **Outline** the process of genetic modification using bacterial production of a human protein as an example, limited to:
  a) isolation of the DNA making up a human gene using restriction enzymes, forming sticky ends
  b) cutting bacterial plasmid DNA with the same restriction enzymes, forming complementary sticky ends
  c) insertion of human DNA into bacterial plasmid DNA using DNA ligase to form a recombinant plasmid
  d) insertion of recombinant plasmids into bacteria (specific details are not required)
  e) multiplication of bacteria containing recombinant plasmids
  f) expression in bacteria of the human gene to make the human protein
- *21.3.4* – **Discuss** the advantages and disadvantages of genetically modifying crops, including soya, maize and rice

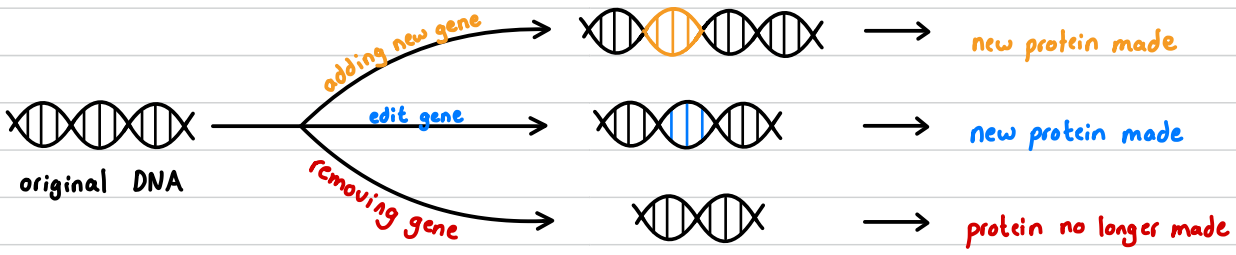
Genetic Modification of Bacteria

Genetic Modification: changing the genetic material of an organism by removing, changing or inserting individual genes, typically from an unrelated species

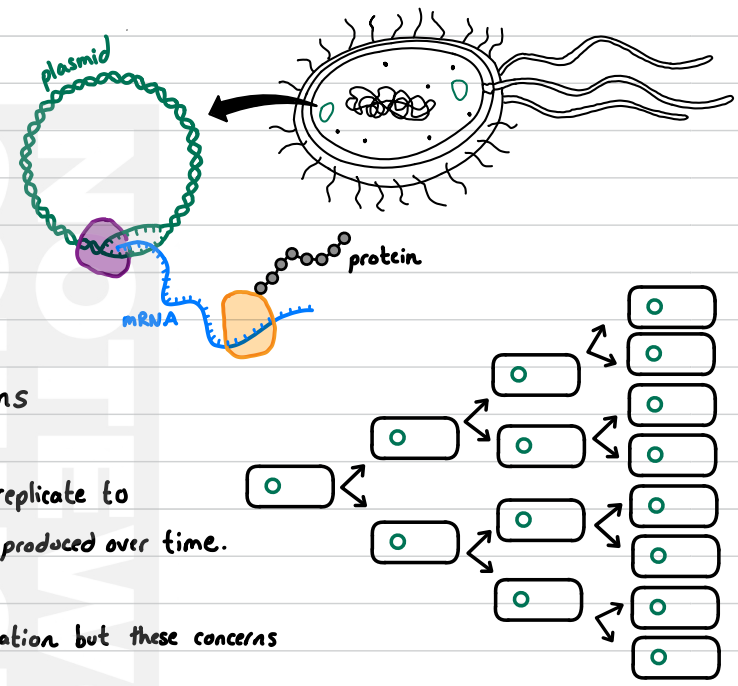
↳ also known as 'genetic engineering', the result is a Genetically Modified Organism or GMO

Why do this? → By manipulating and altering the genetic code, desired characteristics can be achieved or removed

How does this work? → Genetic code provides instructions for proteins. Changing code, changes gene expression and proteins made, which alters characteristics



Bacteria are ideal candidates for genetic modification for several reasons:



① They contain small circular pieces of DNA in the form of plasmids. These plasmids are easy to modify as they are very short sequences and can be easily cut and re-assembled using enzymes.

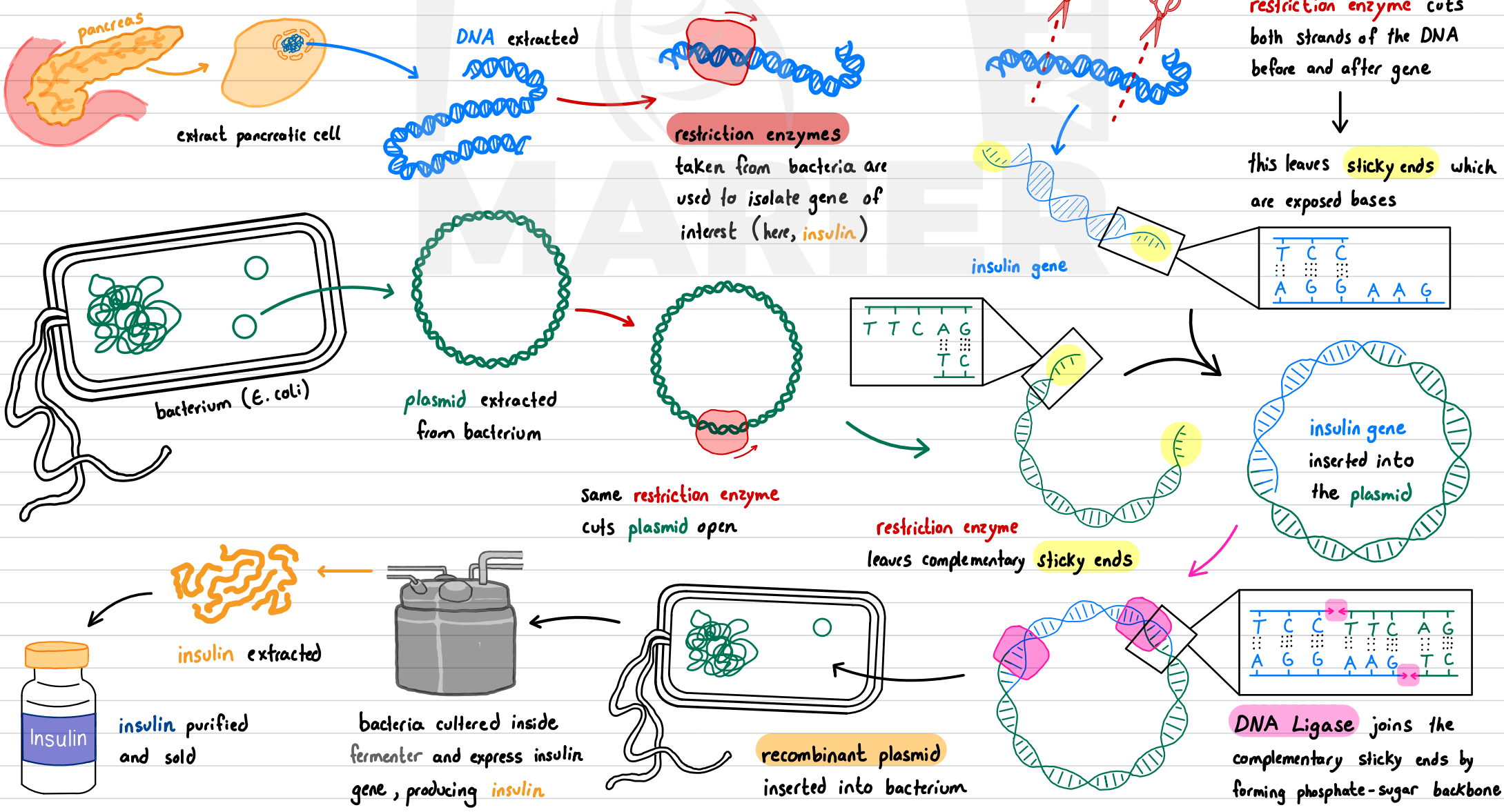
② They are able to produce complex molecules, such as proteins. Despite being very different, bacteria use the same genetic code that humans do. In fact all organisms do. Therefore, genes from different species can be incorporated into the DNA of bacteria and they will transcribe and translate these proteins

③ They reproduce very quickly. Some bacteria can reproduce every 20 minutes! This means that 1 cell can replicate to 1 million in 7 hours! More bacteria means more of the modified gene will be expressed and more proteins produced over time.

④ There are few ethical concerns over manipulation and growth of bacteria. Some object to genetic modification but these concerns are more so for humans and animals.

Making insulin using bacteria

Normally, the pancreas produces the protein (hormone) insulin when it detects high levels of blood sugar. Insulin signals the liver to take-up store this glucose as glycogen. A Type I diabetic cannot produce insulin, which if untreated is fatal. A treatment is for the diabetic to inject themselves with insulin after meals. But where does this insulin come from and how is it made?

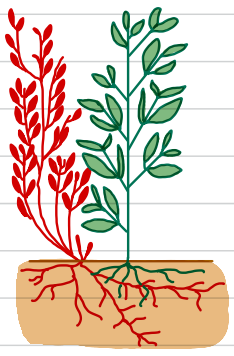


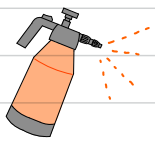
Genetic Modification of Crops

Agriculture is one of the most fundamental and important industries in the world. Crops are grown for not only human food use but also textiles, paper, feedstock and fuel. Crops may be genetically modified for a number of benefits:

Herbicide resistance

weeds or unwanted plants grow next to **crops** and cause a large reduction in their growth

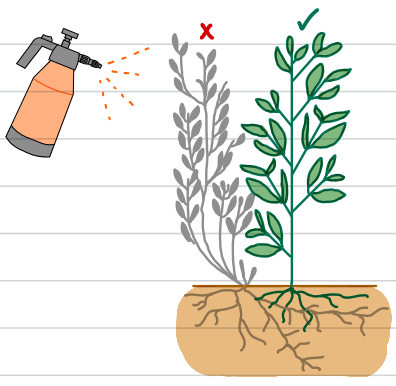




a solution is to spray a **herbicide** which kills plants

Problem: herbicides can also kill crops

solution →



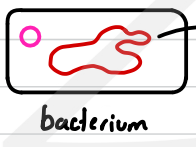
crops are genetically modified to be <u>resistant</u> to herbicides so that <u>only</u> the weeds are killed

<u>Example: Roundup-Ready Soy</u>

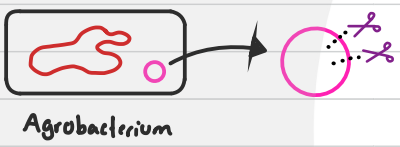
↳ Roundup is a herbicide, whose active ingredient is glyphosate. This chemical kills plants by inhibiting key amino acids from being synthesized.
↳ A bacterium mutant has a gene which prevents glysophate activity. This can be inserted into crops to make them immune.

Process:

remove DNA and using restriction enzymes, cut out gene for glysophate resistance

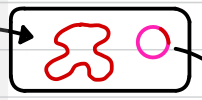


remove plasmid and using same restriction enzyme, cut open plasmid



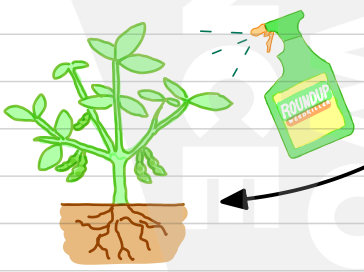
using ligase, insert gene for resistance into plasmid, forming recombinant plasmid

insert recombinant into agrobacterium



allow agrobacterium to infect and inject gene into soy cell's DNA

soy cells grown in culture

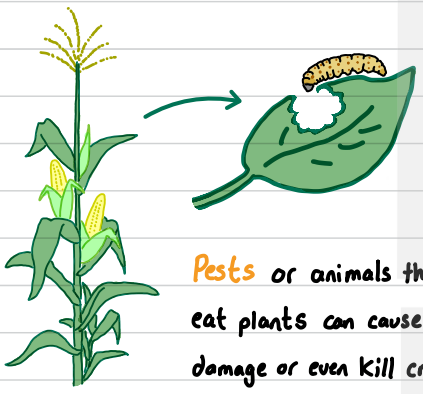


GM soy plant grown from cells
herbicide can now be used

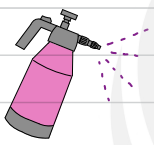
Advantages:
- ✓ resistant to herbicides
- ✓ yield increases due to less competition
- ✓ less crop damage from weeds
- ✓ overall less herbicide use = less cost

Disadvantages / Risks:
- x weeds may become tolerant to herbicide, creating 'superweeds'
- x GM gene may spread into other plants
- x Glyphosate may be carcinogenic

Pesticide resistance



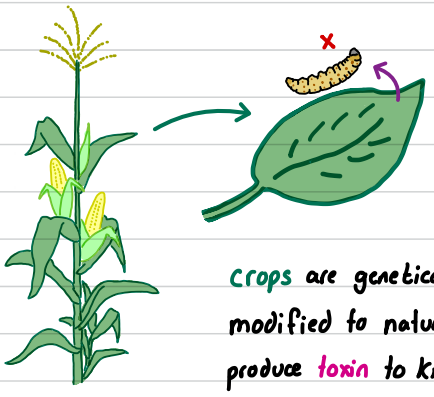
Pests or animals that eat plants can cause damage or even kill crops



a solution is to spray pesticide which kills the insect pests

Problem: pesticides degrade over time and need to be continually sprayed

solution →



crops are genetically modified to naturally produce toxin to kill pest

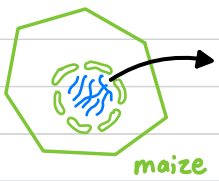
<u>Example: Bt maize</u>

↳ Bacillus thuringiensis (Bt) is a soil bacterium that produces proteins toxic to insects like European corn borer
↳ the gene for the protein is inserted into the genome of the crop (such as maize or cotton) so it can express this toxin and kill pests that feed on it

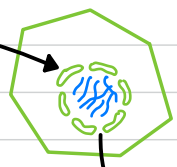
Process:

remove DNA and using restriction enzymes, cut out gene for toxin

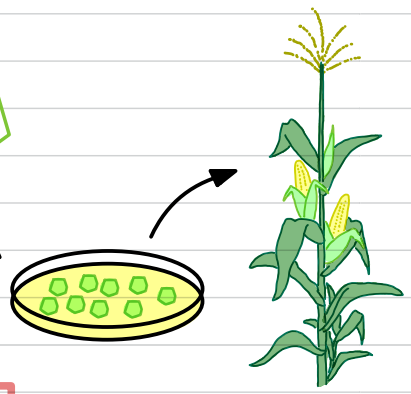
extract DNA from maize and using same restriction enzyme, cut open DNA



using ligase, insert Bt gene into maize DNA and into maize cell



maize cells cultured



Bt maize grown from cells
toxin naturally produced

Advantages:
- ✓ less crop damage ∴ increased productivity
- ✓ less pesticides used ∴ reduced cost
- ✓ toxins produced by plant continually

Disadvantages / Risks:
- x pests may become resistant to toxin
- x non-target insects can be killed
- x can cross-breed creating super weeds

Genetic Modification of Crops

Biofortification

It is important for health to consume food with high, varied nutritional content, containing vital minerals and vitamins

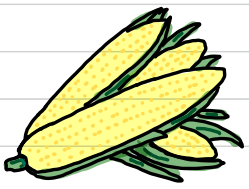
Problem: those in poverty or in developing countries have limited access to these foods and are often restricted to few crops

Solution

crops are **biofortified** - via genetic modification
genes that code for nutrients are added, allowing the crop to provide otherwise missing nutrients

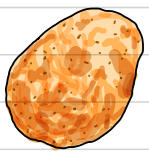
Golden rice

gene for Vitamin A added to rice
↳ low Vitamin A leads to blindness



Iron maize

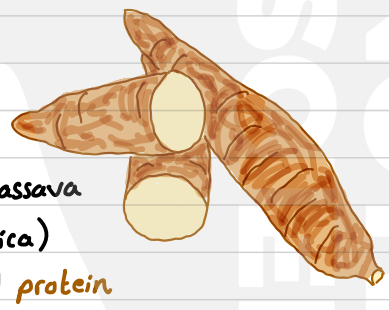
gene inserted into maize to increase iron uptake
↳ low iron leads to anemia



Protato

Gene that increases protein production added to potato

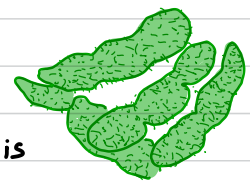
GM Cassava



Genes inserted into cassava (a staple food in Africa) for increased iron and protein

Gluten-free wheat

Gene inserted into wheat to prevent the production of gluten - which is a major food allergy



Vitamin E soy

Gene for Vitamin E is inserted into crops like soy
↳ Vitamin E good for heart health

Advantages:

- ✓ crops provide new or more of a key nutrient - helps with nutritional-decifiency
- ✓ biofortified crops often larger, increasing yield from growth

Disadvantages / Risks:

- x bacteria used to transfer genes could be resistant antibiotics and spread to other bacteria
- x GM foods may contain residues that cause allergies
- x genes for vitamin precursors may become toxic

When deciding whether to adopt a new process / technology, it is crucial to <u>evaluate</u> its use

evaluate: make an **appraisal** (decision) by **weighing up** (determine which is more significant) the **strengths** (advantages / pros / benefits) and **limitations** (weaknesses, cons, risks)

* evidence should be based on objective, peer-reviewed studies

Assessment Tasks

Answer the following questions:

(1) Animals have also been genetically modified for various reasons such as salmon, pigs, mosquitoes, cows, and chickens
Research one GM animal of your choice and describe:

a) how it is genetically modified
b) why it is genetically modified
c) advantages
d) disadvantages/risks
e) your appraisal – i.e. should we or should we not do this and why?

(2) Research and describe one example of genetic modification (not found in this lesson) for each of the following:

a) human genes are inserted into bacteria to make human proteins
b) genes are inserted into crops to confer resistance to herbicides
c) genes are inserted into crops to confer resistance to pesticides
d) genes are inserted into crops to improve nutritional qualities

(3) Other than herbicides and pesticides, what else might a crop be genetically-modified to be resistant to? Explain

(4) Overall, complete the table below, summarizing the pros and cons of GMOs as a whole

	Advantages	Disadvantages/Risks
Economic		
Environmental		
Human health		