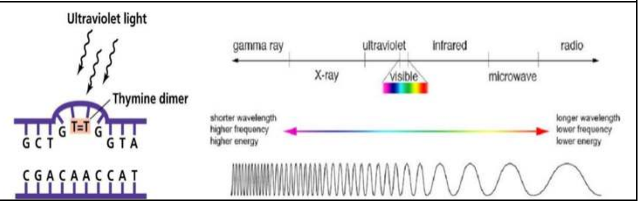
MODULE 6 – GENETIC CHANGE

MUTATION

HOW DOES MUTATION INTRODUCE NEW ALLELES INTO A POPULATION?

- explain how a range of mutagens operate, including but not limited to:
  – electromagnetic radiation sources
  – chemicals
  – naturally occurring mutagens

Mutation = a random/unpredictable change to DNA
Mutagens = environmental agents that modify the DNA sequence → mutations
- DNA undergoes structural change in base pairing because of mutagenesis
  - <u>Main genes where mutations cause cancer:</u> proto-oncogenes (DNA repair genes) and tumour suppressor genes

	Electromagnetic Radiation Sources
Definition	Radiating energy in which the frequency of the wavelengths cause mutations
Description	Ionising radiation has enough energy to break chemical bonds in DNA and free electrons from atoms or molecules due to shorter wavelengths and higher energy frequencies
Example	UV radiation from sunlight → skin cancer: - **<u>Pyrimidine dimer mutation</u>** results in adjacent pair of bases (2 thymine or 2 cytosine) on the same strand become attached to each other. This prevents them from pairing with bases on the complementary strand, causing the strand to end prematurely. This prevents replication and transcription, affecting both the cell cycle and gene products → doesn't allow 

	Chemicals
Definition	Chemicals that cause mutations if cells are exposed to them at high frequencies or for a prolonged period.
Description	These are usually structurally similar to bases in DNA and are often incorporated into DNA during replication → mispairing results in production of non-functional protein, impairing cellular processes - INTERFERES WITH CELL CYCLE
Example	- **Bromodeoxyuridine (5-BDU) – tricks. Polymerase into thinking it is thymine → inhibits (stops) cell replication** - <u>Polycystic Aromatic Hydrocarbons</u> – found in deposits of coal or oil, and produced when fuel is burned, found in plastics, pesticides and cigarettes ▪ PAH induces oxidative stress that provokes mutation – causes cancerous tumours → a base analog (can replace bases during DNA replication)

	Naturally Occurring Mutagens
Definition	Mutagenic agents that are present at normal levels in natural environment and the likelihood of such mutations increase with exposure and frequency

Description	Biological mutagens may trigger cancers from causing DNA damage and reducing the efficiency of DNA repair systems (releasing free radicals - oxygen species that cause oxidative stress → smoke)
Example	**Biological** (naturally occurring → produced by living things): - **Viruses** – replicate by inserting their DNA into host cells. This creates a disruption in normal cell function, and may lead to lasting mutational changes - **Bacterial infectious** – can induce inflammation, which may reduce efficiency of DNA repair systems, increasing the rate of mutations - **Transposons** – sections of DNA that spontaneously fragment and relocate within the genome and can disrupt DNA sequencing and functioning when inserted into chromosomal DNA - **Aflatoxin** → a mould that is grown on grains and is a toxic mutagenic substance **Non-biological** (naturally occurring in the environment) → metals such as mercury and lead = ionising radiation that is naturally occurring → breaks down the double helix of DNA within a cell

- compare the **causes, processes and effects** of different types of mutation, including but not limited to:
  - point mutation
  - chromosomal mutation

	Point Mutations (and frameshifts)	Chromosomal Mutations (block mutations)
Definition	A change to a single base in DNA, and can alter the function of the protein encoded by a gene	Blocks of genes are deleted, duplicated, inverted or translocated to another chromosome
Causes	Changes the amino acid sequences, and possibly the polypeptide protein produced	Can change the overall structure or the number of chromosomes in a cell is altered
Processes	see below	see below

Processes – Point Mutations (and frameshifts)

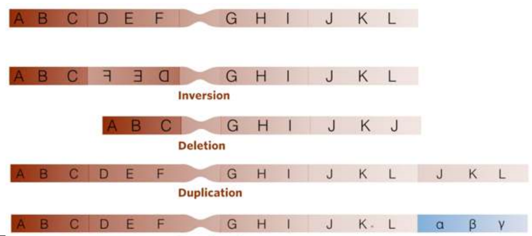
Point mutation	
	Single base substitution
Definition	A point mutation in which one base is replaced by another (TAG becomes GAG) → may alter the function of the protein produced
Example	Sickle cell gene point mutation that occurs in humans red blood cells = sickle cell anaemia. - It is a ‘missense mutation’ → the AA glutamate is substituted with valine, alters the shape of haemoglobin and results in a sickle shape = carries less oxygen, less likely to get malaria

Frameshift – affects the reading frame of amino acids are one is either added or deleted	
	Description
Single-base Insertion	The addition of a single nucleotide in a single DNA sequence
Single-base deletion	The elimination of a single nucleotide from a DNA sequence

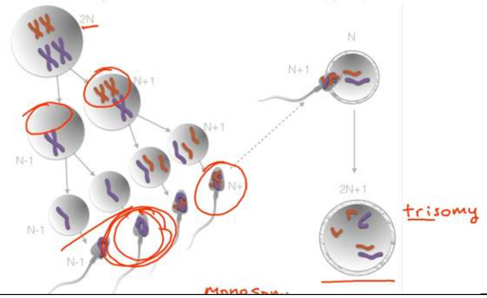
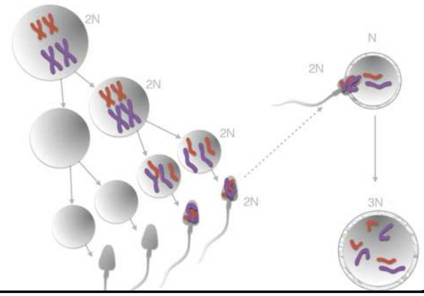
- Triploidy = 3 of every chromosome

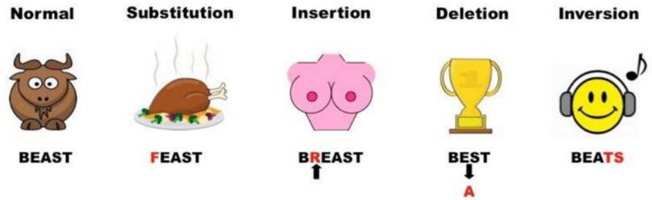
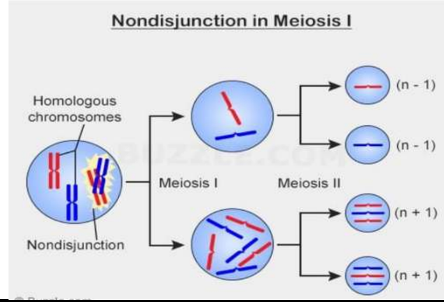
Processes – Chromosomal Mutations (block mutations)

Changes in Chromosome Structure	
	Description
Deletion	section of DNA removed → reduction in number of genes - ‘Block’ deletion
Insertion	section of DNA is duplicated and inserted. Effects on phenotype is dependent on size of the duplicate, location on chromosome and number of repeats
Inversion	a piece of chromosome is removed, inverted and re-inserted so that the sequence is in reverse order
Translocation	when a section of chromosome joins with another non-homologous chromosome leading to gene fusion



Chromosomal number mutations - a mutation in which a cell contains extra or missing chromosomes	
	Description
Aneuploidy	When an organism has an abnormal number of chromosomes – change in ploidy

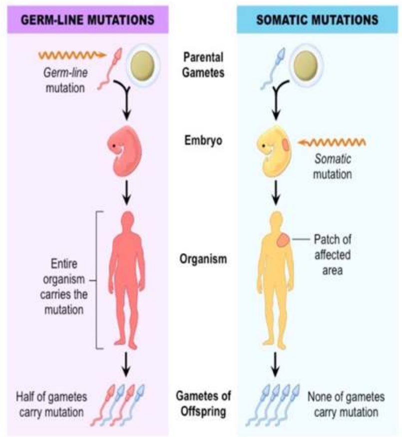
			- Trisomy – an extra chromosome → trisomy 21 = downs syndrome - Monosomy → deletion = missing chromosome  Polyploidy: Genome duplication – a cell in which there are 3 or more of each chromosome. Fatal to humans and most animals, however, is beneficial to plants 
	Effects on DNA	**Most result in a base substitution** → this may result in a different amino acid being inserted into a polypeptide during synthesis if the triplet does not code for the same acid as the original codon **FS** → the insertion or deletion of a base may shift the entire ‘reading frame’ of RNA if not a multiple of 3 (as codons are triplets), leading to a non-functional protein	Overall structure of chromosome is changed or number of chromosomes in a cell is altered Change in chromosome number: Aneuploidy occurs when an organism has an abnormal number of chromosomes - change in ploidy - Down syndrome = extra chromosome 21
	Effects on Phenotype	**Silent mutations**: when the altered base codon triplet codes for the same amino acid, leading to no phenotypic change **Missense mutations**: the amino acid change affects the protein being produced **Nonsense mutations**: changes the amnio acid to a stop codon, cutting the protein short	Dependent on whether the mutation induced is neutral/silent, or potentially fatal (missense, nonsense) Non-disjunction resulting in trisomy for X and Y chromones: - Turners Syndrome → only one X chromosome ▪ Low hair line

			▪ Short stature ▪ Kidney
			

- distinguish between somatic mutations and germ-line mutations and their effect on an organism

Somatic mutations – occur in a single body cell and cannot be inherited (only tissues derived from mutated cell are affected)
Germline mutations – occur in gametes and can be passed onto offspring (every cell in the entire organism will be affected)

	Somatic Mutations	Germline-mutations
Definition	Mutations that occur in somatic cells (non-reproductive cells) - skin cells, lunch cell, muscle cells, nerve cells etc.	Mutations that occur in a gamete or gamete producing cells
Cause	- can be caused by spontaneous mutations due to DNA replication errors prior mitosis - Usually caused by environmental factors (external mutagens) = skin exposure to UV radiation	- Causes can be the same as for somatic mutations. - They can also be caused by nondisjunction during meiosis (see notes on chromosomal mutations).
Effect on organism	- **Somatic mutations will be passed on to daughter cells**, and amplified → observable phenotypic difference in the tissue - **The mutations only affect the cells that are produced** by replication of the cell that mutated - **Somatic mutations are not passed on to offspring** as they are not associated with gametes in any way, → no new alleles being introduced into a population - **The earlier a mutation occurs, the greater its effect will be on an organism’s phenotype** ▪ **Cancer is a common result of somatic mutations** – as affected cell divides, a specific area of tissue with the mutation may develop, but the mutation will not alter the genetic composition of other cells	- Germ-line mutations **have little effect on the individual who gave rise to the mutation as they only affect gametes produced.** - **These mutations are passed onto offspring** → As the embryo forms, the mutation is replicated via mitosis in every cell of the embryo, affecting all cells in the resulting offspring (including gametes). - **Germ-line mutations can lead to the generation of new alleles within a population** ▪ E.g. sickle-cell anaemia, cystic fibrosis, colour blindness
Example	- A mutation of the tumour suppressor genes such as BRCA1 and BRCA2 which encode a protein that regulates the cell cycle → could lead to cancer but won’t be passed on to offspring	- Albinism – germline mutations can change the gene pool of a population, as they introduced new alleles int the population



	Summary	Somatic mutations within individuals differ in their effect. While they may or may not lead to phenotypic changes in the individual, they do not generate new alleles within a population as they cannot be inherited by offspring.	Germ-line mutations can be a direct source of new alleles at a population level because they can be passed on to future generations of a species. If these new alleles are expressed as differences in phenotype, they can be acted upon by selective pressures in the environment (natural selection). Undesirable mutations will be removed from the population (they decrease chances of survival) and beneficial mutations that increase chances of survival will become more prevalent over time.

- assess the significance of ‘coding’ and ‘non-coding’ DNA segments in the process of mutation

= maintaining the integrity of DNA is essential for cell functioning.

	Coding DNA	**Non-coding DNA**
Definition	DNA that codes for proteins - Exons = coding DNA	DNA that does NOT code for proteins - introns = non-coding DNA → effect gene expression
Mutations in region of DNA	Directly affects the sequence and type of amino acids in a protein and therefore its function, which may lead to a phenotypic change.	Scientists have recently discovered the fatal consequences of mutations in non-coding DNA, especially in those that have a regulatory function.
Assess its significance in process of mutation	Mutations of genes in coding DNA becomes serious when proteins involved in DNA repair are affected. These enzymes are responsible for correcting errors in the sequence of bases, and if affected, will increase the chance and rate of mutations arising from errors in replication. Mutations in tumour suppressor genes may be carcinogenic and mutations that trigger proto-oncogenes can reduce cell death by promoting cell division, which can be fatalistic to an organism’s survival.	<u>**Gene expression**</u> Despite there being no protein end-product, non-coding DNA contain regulatory sequences that promote ‘switch-on’ or ‘switch-off’ genes and code for products other than proteins such as rRNA and nuclear RNA, which have important functions in the process of gene expression. - Small nuclear RNA determines which introns are spliced out of DNA - rRNA is the machinery that regulates translation of DNA <u>**Embryonic development**</u> Research also showed that such mutations in germline cells were linked to developmental and congenital abnormalities (birth defects) <u>**Disease susceptibility**</u> Some mutations in regulatory DNA (enhancer, promoter, silencer) are associated with higher predisposition to non-infectious and infectious disease - Obesity, heart disease → non-infectious Only if a mutation occurs in the exon will it be copied into the RNA by the DNA polymerase and translated at the ribosome and will have significance
Summary	Mutations in coding regions are highly significant in terms of generating new alleles in a population. By definition, genes are coding regions, and alleles are different versions of those genes that arise due to mutations. Conversely, mutations in non-coding regions may have a significant impact on gene expression, however they have no role in the introduction of new alleles due to the fact that they are not changing the genes themselves in any way.	

- **Missense mutations –** a mutation in which the wrong amino acid is encoded → the change to the DNA results in a protein that is also changed
- **Nonsense mutations –** a point mutation which creates a stop codon and the polypeptide have no more amino acids added to it
- **Silent mutations –** a point mutation in a coding region of the DNA which despite being in an exon, produces no change to the polypeptide encoded, as the genetic code is degenerate

Junk DNA → serves neither protein-coding or regulatory function. Research has suggested its origins from viruses where <u>transposons and retrotransposons</u> introduce variation and keep the genome diverse in a population.

- investigate the causes of genetic variation relating to the processes of **fertilisation, meiosis, and mutation**

Genetic variability is crucial in populations as minimal variation may create a static and unchanging population susceptible to extinction in the future by natural selection.

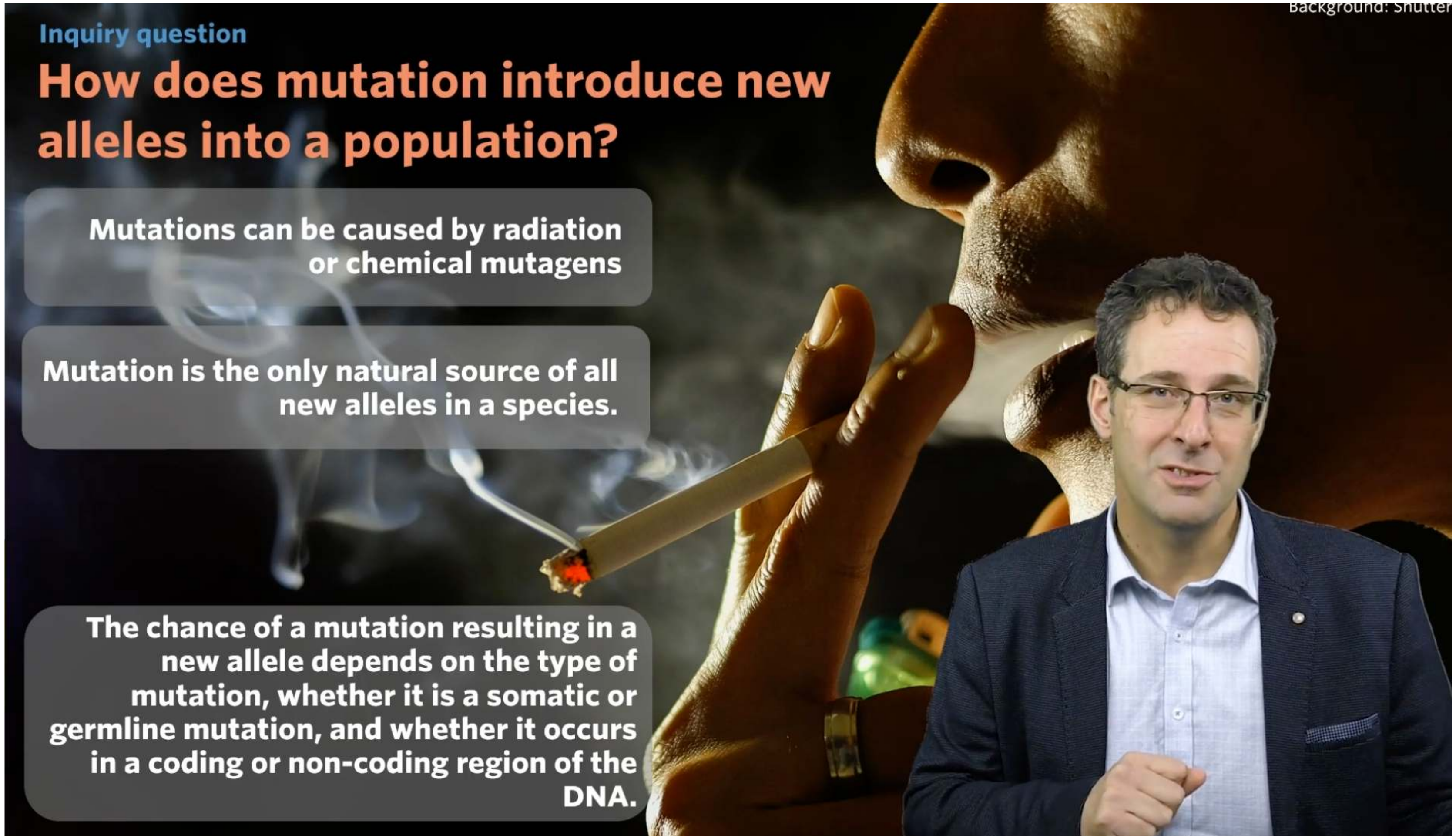
	Definition	Process	How variation is increased
Fertilisation	Occurs during sexual reproduction when 2 gametes combine to form a zygote.	- Paternal and maternal gamete fuse to form a zygote - The full set of chromosomes is restored (23 pairs, 46 in total)	- Random selection of gametes - Interaction of dominant and recessive genes from chromosomes of 2 different parent organisms
Meiosis	The formation of gametes	- The production of gametes (sperm and ovum) - One parent cell becomes 4 daughter cells, each with half the number of required chromosomes (one chromatid of each chromosome)	- **Mutations during DNA replication** – interphase - **Random segregation** – alleles randomly separate - **Independent assortment** – in metaphase one it shuffles the paternal and maternal alleles (chromosomes) resulting in alleles for different traits unrelatedly sorted into gametes - **Crossing over** – when homologous chromosomes exchange genetic material in meiosis, this allows the recombination of alleles or new combinations of alleles
Mutation	Occurs during DNA replication **prior to cell division**; result in **new alleles** (not just a rearrangment) - Mutation = source of new alleles	- Somatic or germ line mutation introduce new alleles. - Mutation in an exon → the polypeptide produced may not work, or may work less well, or work differently ▪ Can be advantageous or disadvantageous	**Mutations increase the number of alleles for a trait.** - Germline mutations that have remained in the genome **Affect the composition of gene and proteins** - Positive → more effective enzyme or desirable trait - Negative → extinction of the organism

- evaluate the effect of **mutation**, **gene flow and genetic drift** on the **gene pool** of populations

Factors that cause changes in allele frequency within a Population			
	Description	**Effects on the Gene Pool of Population**	**Evaluation**
Mutation	Changes in the DNA sequence during meiosis that leads to the formation of new alleles - new alleles can only be introduced into the gene pool of a species by mutation	<u>Very few mutated alleles are advantageous and selected to increase in frequency –</u> this is because if an environment is stable and an abnormal phenotype is introduced into the population, it is highly likely that the mutation will not benefit the organism's survival. - Deleterious mutations are usually acted upon by natural selection and removed from the population. - Neutral mutations are considered an 'evolutionary back-up' as they can provide variations that have no immediate effect but may provide a selective advantage in the future if sudden changes to the environment were to ensue.	Creates new alleles and increases the gene pool of a species = can be advantageous or disadvantageous
Gene flow	**The transfer of genetic information from one population into another by migration** - Involves existing individuals leaving and new ones entering the population by migration and immigration. Does not necessarily have to be of the same species.	- Add gametes/alleles from a population - increase variation - Take away genes/alleles from a population - decrease variation - Overall - change the allele frequency - If individuals can enter and leave the population it can create a gene flow and in	It is very significant as it can lead to evolution
Genetic Drift	**Change in allele frequency due to random chance which may not necessarily be of benefit to the surviving alleles**.	Removing alleles by removing ones carrying the alleles 1. Bottleneck Effect – an example of genetic drift in which the frequency of alleles is changed due to a **near extinction event**	It is very significant as it is a mechanism for evolution, as it may have no effect but it may

		- The remaining individuals in a population may not be an accurate representation of the allele and genotype frequencies of the original.	2. Founder Effect – individuals becoming geographically isolated from original population = not an accurate representation of the entire population - The formation of a new population by a non-representative sample of individuals from the parent population	also have an irreversible, detrimental effect.

Gene pool – the total number of alleles of all genes in a population of a species at a particular time = diversity of a species
- Allele frequency → the relative frequency of an allele at a particular gene locus in a population



GENETIC TECHNOLOGIES

DOES ARTIFICIAL MANIPULATION OF DNA HAVE THE POTENTIAL TO CHANGE POPULATIONS FOREVER?

- **Investigate the uses and advantages of current genetic technologies that induce genetic change**

- The aim of reproductive technologies is to pass on desirable characteristics to the next generation

Reproductive Technology	Uses	Advantages	Disadvantages	Example
Selective Breeding	Process whereby humans can control which males and females are bred and produce offspring with desirable traits. Both parent individuals are different varieties of the same species so that the resultant offspring is fertile.	- **Hybrid vigour** – healthier offspring with enhanced characteristics from parents - **Improved quality and longevity of livestock**	- **Relies on chance –** if desirable characteristics end up in the new individual. - **Time consuming and costly –** no guarantee for success of mating, requires transportation of whole animals, risk of injury while mating - **Reduce genetic diversity** – selectively bred organisms are being reproduced in preference to wild organisms (wild organisms have more genetic variation)	Selectively bred Friesian bulls and jersey cows = produce larger amounts of creamy milk
Artificial Insemination	Collecting sperm from a chosen male with desirable characteristics and artificially introducing it into several selected females. - Livestock industry = animals - Fertility treatment = humans	- **Cost-effective** and reduces the danger to animals of injury in transit or during mating - **Semen can last a long time** and inseminate many females = many offspring - **Used in conservation** to increase endangered species	- **Costly** – specialised equipment - **Time consuming** - **Injury to the female** if not carried out correctly - **Genetic diversity is reduced** – offspring of a herd have same father (alleles in the gene pool reduced) - Specific alleles of a few selected genes will become predominant in the herd and alternative alleles will be lost - There is a high chance that a disease could have a devastating impact on the herd	- Sheep = produced higher wool yield or improved meat - Cattle = better quality meat or greater milk production
Artificial Pollination	Removing the stamens of a flower and dusting the pollen on the stigma of another flower on the same or different plant of the same species	- Offspring with desirable characteristics can be passed onto **future generations** - **New trait varieties**	- **Reduced biodiversity –** overuse can lead to crops that are too similar - **Not ensure desirable traits**	- disease resistant fruit - Greater yield of crops
In Vitro Fertilisation (IVF)	Egg is fertilised outside of the female and in a petri dish. Resulting zygotes are cultured until they have progressed to an early stage of development. The fresh/frozen cultured embryo is inserted using a catheter into the uterus of the biological mother.	- Favoured when there is **decreased fertility in one or both parents** - **Avoid disease and birth defects** = genetic screening of embryos	- **Reduction in genetic diversity** – large numbers of viable embryos are produced from a small selection of parents - **Genes for infertility that would not have been passed on are now inherited by offspring –** these alleles will further increase in the population rather than being selected against by nature. - **Trial and error** = death of some embryos - **Expensive**	
Gene Therapy	Involves inserting a normal allele for a dominant trait into cells of a person suffering from a recessive genetic condition like SCID			

- compare the processes and outcomes of reproductive technologies, including but not limited to:
  – artificial insemination
  – artificial pollination

	Processes	Outcome	Assessment
Artificial Insemination	<u>Collecting sperm from a chosen male with desirable characteristics and artificially injecting it into females to induce pregnancy</u> - Livestock industry = animals - Fertility treatment = humans TOY STORY BULL – gave sperm to 5 million females and genetic diversity decreased	- **Transporting frozen sperm** – cost-effective and reduces risk of injury in transit or during mating - **Many females can be inseminated** by the sperm of one male	- **Reduces biodiversity** – use of sperm from one male - **Conservation programs** - to save an endangered species for rapid and human-controlled fertilisation - **Costly** – specialised equipment
Artificial Pollination	<u>Removing the stamens of a flower and dusting the pollen on the stigma of another flower on the same or different plant of the same species</u>	- **Creation of new varieties =** higher-quality traits - **Hybridisation**: e.g. Maize (corn) is a hybrid with an increased germination rate, greater uniformity and increased yield	- **Gives the breeder total control of which breeds are crossed** - **Increased susceptibility to disease** and other abiotic/biotic stresses - **Decreasing dependence on biotic pollinators** can interfere with natural ecosystems

- investigate and assess the effectiveness of cloning, including but not limited to:
  – whole organism cloning
  – gene cloning

	Gene Cloning	Therapeutic Cloning	Whole Organism Cloning
Definition	Producing identical copies of one gene (recombinant DNA)	<u>Cloning techniques developed to produce therapies for disease.</u> Involves the production of stem cells genetically identical to the donor which may be used to treat diseases → diabetes.	<u>Creation of a new molecular organism that is genetically identical to its parent</u> - artificial, embryo-splitting → animals - cuttings → plants
Process	1. The target gene is identified and cut from the source organism using restriction enzymes (enzymes produced by bacteria) 2. Plasmids are isolated from the bacteria 3. The restriction enzymes ‘cut’ DNA, breaking the hydrogen bonds. These enzymes create sticky ends sequences of overhanging single-stranded DNA 4. The complementary sticky ends from the target gene and the plasmid connect through base pairing affinity, and annealed using DNA ligase 5. The new recombinant plasmid is reinserted into host bacteria through transformation 6. The host bacteria expressed many copies of the target gene, producing large amounts of target protein (insulin). This protein can be extracted from the cells, purified, and used in humans - yea producing gene	1. A nucleus containing genetic material is removed from a cell of a patient 2. The genetic material is inserted into a denucleated egg cell 3. This new cell begins to divide 4. After a couple of days I would have divided into an embryo, and embryonic stem cells can be removed 5. These stem cells are cultured in a way that they remain in the undifferenced state 6. These cells will be genetically identical to the cells of the patient whose DNA was used	Derived from the somatic cells of a mature organism by the process of **<u>SCNT (somatic cell nuclear transfer)</u>** 1. Somatic cell is extracted and starved of nutrients to stop cell division in a laboratory 2. Egg cell from another organism is enucleated using a micropipette (nucleus is removed) 3. Somatic cell is inserted into the enucleated egg cell and treated with electricity, forcing them to fuse together to form a ‘fertilised’ egg cell 4. Electric shock triggers cell division and embryo develops in-vitro 5. Embryo is implanted into surrogate - Dolly the sheep
Effective assessment	<u>MOST EFFECTIVE</u> Allows genes that are lacking in certain organisms to be amplified at a relatively fast and efficient rate	<u>EFFECTIVE IF DONE PROPERLY</u>	<u>LIMITED EFFECTIVENESS</u> - The produced organism is not strictly identical to the parent organism as somatic

	- E.g. human insulin growth hormone - Time-efficient	Due to using pluripotent stem cells, they can grow into any kind of cell in the body and treat many diseases by replacing dysfunctional cells. No risk of immunological rejection as the cloned cells are genetically identical to the patient. However, 100s of attempts are needed as the eggs fused with the somatic nuclei are not stable and often do not propagate.	cells are the source of genetic material, any mutation acquired in that cell will be passed down - Mitochondria present in the cytoplasm of the donor egg contains DNA which is passed onto the cloned organism. Therefore, the clone has a different mitochondrial genome from its target parent organism - Environmental factors also influence phenotype - Very expensive and time-consuming process, so its effectiveness is limited
Ethical considerations	**WHOLE ORGANISM CLONING:** - Exacerbation of pre-existing low animal welfare in large-scale farming practices - Same techniques used in animal and human cloning raises moral, legal and religious concerns - Religious perspective → certain religions prohibit activities that uphold humans as superior over animals - Unforeseen health risks and consequences - Is not cost-efficient - raises issues of equity of access		

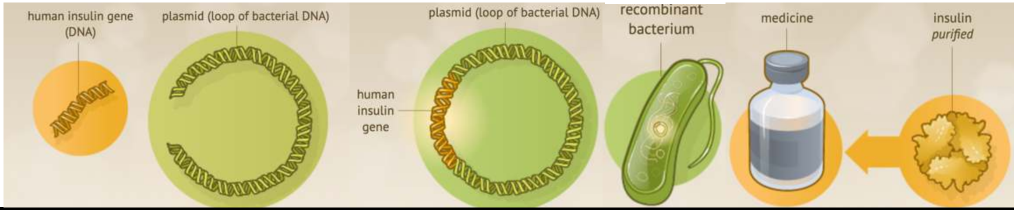
- describe techniques and applications used in recombinant DNA technology, for example:
  – the development of transgenic organisms in agricultural and medical applications

- <u>**Recombinant DNA technologies aim to insert a gene from one species into the genome of another**</u>
- Transgenic Species have a gene from another species. Method is:
  i) Restriction Enzymes are used to cut DNA in specific places. These enzymes are also known as gene scissors or gene shears.
  ii) Restriction enzymes form 'sticky ends' at the extremities of gene of interest
  iii) The gene is interest is then multiplied by PCR or use of plasmid in bacterial cell.

Industry	Transgenic Technology
Agriculture	<u>BT COTTON</u> A transgenic plant species with a gene from a bacterium which codes for a protein, for it is eaten by a caterpillar, it is converted to an active form the kills the caterpillar - The Bt gene is *cut* from the soil bacterium (*Bacillus thuringiensis*) and transferred (*pasted*) into cotton plant embryos. This is done using a second bacterium (*Agrobacterium tumefaciens*) as a vector - Once the gene is inserted, the transgenic cotton plants produce a protein which kills the caterpillar which was eating the cotton plant
Medical	<u>INSULIN</u> - Target the human insulin gene, then remove a plasmid from the bacterial DNA and insert the human insulin gene into the plasmid - The plasmid is then returned to the bacteria, and put the recombinant bacteria in fermentation tanks

Short Term	Long Term
Increases biodiversity → the characteristics allow them to survive and pass on favourable characteristics	**Loss of biodiversity** → as the same characteristics are being passed on each generation

- They then use the gene to produce human insulin, this is purified and used as a medicine



● Evaluate the benefits of using genetic technologies in agricultural, medical, and industrial applications

Agricultural	Medical	Industrial
- Crops and animal varieties that are better suited for their environment ▪ high salinity or drought - Plants that are pest resistant ▪ Bt cotton - Enhanced nutrient levels ▪ Golden rice → increase vitamin A, and reduce malnourishment - Larger and faster growing GM animals. ▪ Atlantic salmon → recued need for intensive farming	- Help individualise treatments - Pharmaceuticals developed faster, more efficiently and better suited to humans ▪ Human Insulin for diabetic treatment through recombinant DNA, rather than use of pig or cow insulin. - Monoclonal antibodies (MAB’s) artificially produce antibody producing cells that target specific antigens. ▪ Helpful for cancer treatment where body is supported to produce antibodies for cancer cells	- GM plants to produce environmentally friendly chemicals that can replace non-renewables ▪ plastics - GM plants and bacteria to absorb heavy metal pollution

● Evaluate the effect of biodiversity of using technology in agriculture

Biotechnology may increase or decrease the genetic diversity

- **Short term** → introduced genes broaden the gene pool in a population
- **Long term** → if selected desirable genes constantly replace other varieties of genes, genetic diversity will decrease.

Example – Genetically modified soybeans

- **Short term** → GM soybean has increased biodiversity because an additional gene (from Agrobacterium tumefaciens which make them resistant to the herbicide glyphosate) has been added to the gene pool.
- **Long term** → widespread use of GM soybean in USA, Brazil, Argentina and possibly other countries will decrease biodiversity because more GM soybeans crops will be grown rather than the old varieties.

● Interpret a range of secondary sources to access the influence of social, economic and cultural contexts on a range of biotechnologies

Social	Economic	Cultural
– the physical and social setting in which people live - The biotechnological techniques include the wealth of the individual and the economic status of the country	– the research and development of genetically modified food is huge - Advantage – produced in greater volumes for the same or less cost, so the farmer receives greater financial returns and the consumer pays less - Disadvantage – small-scale farmers in developing countries cannot afford to buy the seeds of genetically modified crops = unequal distribution of	– shared meanings, ideas, beliefs and characteristics of people that make ups society - The values and religious beliefs may influence their opinions about biotechnologies

		wealth between developed and developing countries	
	Example → DNA Fingerprinting - Advantage – investigators can solve problems with a high degree of accuracy - Disadvantage – expensive and time consuming and may not be available in all parts of the world Ethical issues → potential discrimination, as well as privacy and ownership.	**Example → GM Atlantic Salmon** Produce greater volumes than the natural species = cost of GM salmon is reduced and income of farmers can increase	**Example – Christian views of IVF** - IVF was frowned upon by members of religious traditions as the process was seen as "playing God", which was deemed an unnatural and immoral ability

Biotechnology Increasing Biodiversity	Biotechnology Decreasing Biodiversity
1. In the short term, GM crops and organisms will add diversity to populations 2. Biotechnology can bring back lost characteristics through DNA cloning 3. Selection of suitable breeding partners through genetic monitoring will improve birth rates 4. DNA profiling allows the tracking of poachers to a specific location.	1. In long term, GM crops and organisms with dominate over population due to favourable characteristics, reducing variation. 2. Can bring overexploitation of animals 3. Selective breeding may breed out native characteristics. Eg Bt Corn contains gene Bacillus thuringiensis in its genome which releases toxins whenever caterpillars feed off of the crops. In result, caterpillar population declines in ecosystem, disrupting food web and leading to further organism loss. Also, artificial insemination decreases genetic variation and hence biodiversity as one males sperm can be preserved and used for large amounts of offspring.

BIOTECHNOLOGY

HOW DO GENETIC TECHNIQUES AFFECT EARTH'S BIODIVERSITY?

- **investigate the uses and applications of biotechnology (past, present and future), including:**

Biotechnology – any technology that utilises biological systems, living organisms, or parts of this to develop or create different products
- Involves the use of genetic techniques to study genetic phenomena and apply refined knowledge of biological processes to make efficient use of technologies.

Uses and applications of biotechnology			
	Past	Present	Future

Use	Ancient Biotechnology – limited understanding of biochemical processes (1000's of years ago)	Classical biotechnology – Pasteur and Mendel (1800-mid 1900's)	Modern biotechnology – discovery of DNA and its manipulation	Advances in genomics, and how proteins are expressed in cells will be used for infectious diseases, cancer, and other genetic disorders
Application	- Food production – use of living cells to make bread, cheese and wine	Pasteur –**fermentation** was not a chemical but a biological process - Agriculture - Medicine and antibiotic production	- DNA manipulation – splicing, amplification, recombinant DNA - DNA analysis/visualisation – gel electrophoresis, DNA sequencing and profiling - Biofuels – renewable and produces less pollution	- The manufacture of synthetic cells and organs, and the transplantation of organs from animals into humans - Using CRISPR, genes can be spliced and inserted with pinpoint accuracay

Past Biotechnology		
	Description	Example
Agriculture	Selective breeding – the human manipulation of living organisms, ensuring selected individuals possess desirable characteristics that could be passed onto the future generations - Stronger and healthier offspring = catering for the increase population	Friesian cows → larger and produce more milk yields than Jerseys Jersey cows → more nutrient rich and creamier milk - In the 1980's cross breeding of the hybrid vigour offspring occurred
Food Production	Fermentation is the use of microorganisms ie bacteria or yeast to chemically breakdown a substance. Since Ancient Egypt, this has been used to make bread, cheese and yogurt.	Ancient wheat → small grains and the seeds easily fell to the ground, less chromosomes and gluten content - higher nutritional content and increased crop yield, however, cannot reproduce without human intervention Modern wheat → more chromosomes and a higher gluten content due to genetic modification
Medicine and antibiotic production	The culturing of fungi in medicine led to the development of modern-day antibiotics such as antibiotic penicillin which inhibits the growth of Staphylococcus.	1. Turmeric → used to improve circulation, and has many anti-inflammatory benefits 2. Penicillium (fugus) → an antibacterial product which has revolutionised the treatment of infectious diseases cause by bacteria ▪ Both remedies are still used today
Plant selective breeding techniques		**Advantages:** - Bigger flowers - Higher nutrient values - Increase crop yield - Greater resistance to disease and drought **Disadvantages:** - Loss of variety in species - No control over genetic mutations - Lack of biodiversity = harder to adapt to selection pressures

Present mendnology In present day, biotechnology revolves around genetic engineering which involves manipulating an organism's DNA to meet needs – cutting and pasting DNA.	
	Description
Reproduction Technologies	• *IVF*; involves forming a zygote outside of the women in a laboratory • *Artificial Insemination;* the deliberate introduction of sperm into a female's cervix to achieve pregnancy by other means than intercourse – decreases biodiversity as one male's sperm may be used to impregnate multiple females, spreading one genome. • *Artificial pollination;* Humans deliberately induce the pollination process by placing pollen on pistil – this decreases biodiversity as only pollen that produces desirable yield will be used. • *Cloning;* creating genetically identical replica of individual – decreases biodiversity as same genome is replicated.
Gene Therapy	Involves removing faulty genes through DNA splicing and replacing it with a functional gene. This is to treat disease ie cystic fibrosis or sickle cell anaemia. • DNA splicing: The required gene or section of DNA is spliced out using restriction enzymes. • DNA amplification: A polymerase chain reaction uses DNA polymerase enzyme to replicate DNA fragments many times

	• Recombinant DNA: DNA ligase enzyme is used to “glue” pieces of DNA together. ***Eg Aquaculture where transgenic salmon grow faster and oysters are disease resistant.***

<table>
<tr><th colspan="2">Future Biotechnology</th></tr>
<tr><td></td><td>Description</td></tr>
<tr><td>CRISPR</td><td>CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, which is a bacterial defences system that forms the basis for CRISPR-Cas9 genome editing technology.
- Scientists can permanently modify genes in living cells and embryos, and in the future, may make it possible to correct mutations at precise locations in the human genome to treat genetic causes of diseases
- It can be done efficiently and at low cost. It is now universally used in laboratories worldwide.
▪ E.g. Cystic Fibrosis</td></tr>
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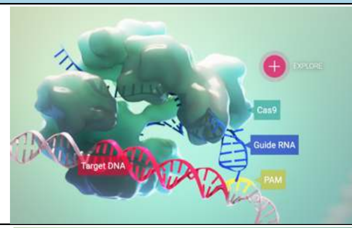
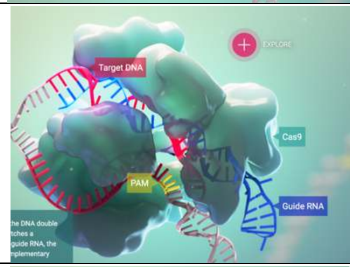
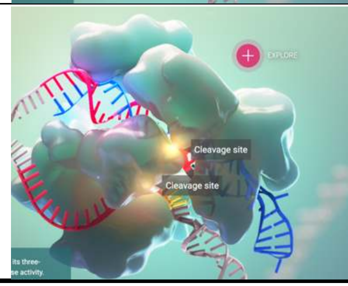
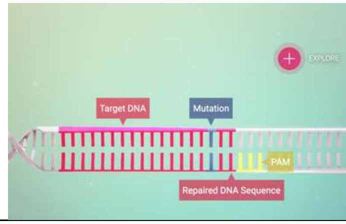
Steps involved		
STEP 1 – Targeting	Scientists introduce the Cas9-guide RNA complex into a cell (in this case, a human cell), where it randomly associates and dissociates with the DNA. Cas9 recognizes and binds to a three-nucleotide sequence motif called PAM that is abundant throughout the genome.	
STEP 2 – Binding	Once it binds to a PAM motif, Cas9 unwinds the DNA double helix. If the DNA at that location perfectly matches a sequence of about 20 nucleotides within the guide RNA, the DNA and matching RNA will bind through complementary base pairing.	
STEP 3 – Cleaving	The DNA-RNA pairing triggers Cas9 to change its three-dimensional structure and activates its nuclease activity. Cas9 cleaves both DNA strands at a site upstream of PAM.	

STEP 4 – DNA Repair	Cells contain enzymes that repair double-stranded DNA breaks. The repair process is naturally error-prone and will lead to mutations that may inactivate a gene. Cleaving DNA at a precise location is one of many applications of the CRISPR-Cas9 technology.	

Benefits	Limitations
- Simplicity and efficiency → Since it can be applied directly in embryo, CRISPR/Cas9 reduces the time required to modify target genes	- The effect of off-target can alter the function of a gene and may result in genomic instability, hindering it prospective and application in clinical procedure. - There is still occurrence of off-target with 3 to 5 mismatches within the distal part of the PAM

- Analysing the social implications and ethical uses of biotechnology, including plant and animal examples

Agricultural

	Description	Social Implications	Ethical Implications
Bt Cotton	A transgenic plant species with a gene from a bacterium which codes for a protein, for it is eaten by a caterpillar, it is converted to an active form the kills the caterpillar	- The patenting of seed may place certain farmer's who cannot afford product at a disadvantage – they will not sell as much product and will have to invest in manual pesticides.	- Plants rely on the transfer of pollen, via insects or the air, to breed and produce offspring, and it's difficult to control how they crossbreed in the wild → herbicide resistant weeds
Atlantic Salmon	Creating a transgenic species as they isolated the gene from the ocean pout and that protein activated the growth hormone gene to allow the salmon to grow faster all year so that the needs of the population will be met earlier 1. Identify gene in ocean pout 2. Cut out the gene and copy it using PCR and paste it into the developing eggs (fertilised eggs) so that the gene can be replicated	- The salmon may escape the filtrations and cross bred, however there is a very low possibility as they have been sterilised meaning they are unable to bred with wild salmon, and have a low chance of surviving in the wild	- Crossbreeding with wild populations →preventing genetically modified versions from mixing with the naturally existing populations of plants from which they're derived.

Industrial

	Description	Social Implications	Ethical Implications
Spider Silk	Refers to transgenesis where the spider's dragline silk gene is put into goats who then produce the protein in their milk	- Advances the development of products such as bullet-proof vests and air bags in vehicles. Additionally, the silk is helpful in manufacturing artificial ligaments, tendons, eye structures and jaw repairs. - Prevents need for $13,000 treatment of catheter infection as silk coating will prevent bacterial infection.	- A range of biological properties are used to synthesise spider silk, including E coli, Goats, Silkworms and Alfalfa. Therefore, raising concern to whether it is morally right to use an organism as a vehicle to benefit humans.

Knock-out Mice	Refers to lab mice which has been inactivated or a gene has been removed and replaced with an artificial piece of DNA. This provides clues on what the role of certain genes are by observing the effect on mice.	- Provides scientists with information that helps the medical industry better understand the gene causation of a disease in humans eg cancers, obesity, heart disease. - Can aid the development of therapies and drugs that treat disease in humans	- 15% of tested mice die due to process. Raising concern to whether it is moral to use the life of an animals for the better of a human or are we equal to them.

Medical			
	Description	Social Implications	Ethical Implications
CRISPR	- Used to create more crops - Cures genetic diseases - Edit genes in living cells - A GENE EDITING TOOL Malaria resistant mosquitos Gene drive – the mosquitos carry not only the gene for malaria resistance but also the CRISPR gene editing tool. This creates a gene drive which increases the chance of all offspring carrying the desired gene - There is a gene to make the crisper protein and the gene for resistance - Gene editing technology as part of its gene, and crisper replaces it with the malaria resistant gene	- Developing countries are supported by the developed countries, and rely on them → can only access the treatment through developed countries	- Gene manipulation is considered unethical by some groups in society as it’s an unnatural process - Ethics of using a gene drive – change a species in a short period of time and reduces biodiversity - **It can be used to change characteristics in any species in a short period of time**
Insulin treatment		- Modern highly specialised equipment which makes it unavailable for people in developing countries, so they can’t access insulin that is a better tolerated treated and placed at a higher risk	- Due to the treatment manipulating the patients DNA, the pigs and cows are no longer farmed under tight sterile conditions
IVF			

Conservation			
	Description	Social Implications	Ethical Implications
Rhino conservation program	Biotechnology can be used to enhance the populations of threatened species e.g., African and Sumatran Rhino. - Breeding programs aim to maximise hybrid vigour (crossbreeding different varieties of organisms which results in stronger, healthier offspring than inbreeding). The Australian rhino project has been established and rhinos	- Kept in captivity and not able to roam, increasing biodiversity and hence the species can last longer - Artificial genetic technologies to design individuals in species and is playing god - Not everyone would agree to spend money on breeding threatened species, as some people will suggest on improving medical assistance for terminal disease	- Human intervention – nit a natural process as it is artificial insemination - Uncertain whether the rhino in captivity are string and healthy enough to be in the wild with the right combination of genes to allow them to survive in the wild – as they are in zoos their environment is not mirrored

	from Africa were brought to Monarto Zoo’s safari park near Adelaide.		

- **Researching future directions of the use of biotechnology**

The rapid evolution of biotechnology applications is exciting, but also potentially threatening. Genetic technologies may be used for the benefit of humankind, but there is also the possibility of misuse, to the detriment of humans and the environment.

- Does the threat of abuse of a technology mean we should not explore it further?
  - No, biotechnologies should only be used by qualified professionals to conquer an issue. There are many pro and cons, however the pros outweigh the cons

CRISPR – recent developments in biotechnology that has enormous implications for the future in a genome editing technique

- CRISPR-Cas9 is an enzyme used to snip DNA at a particular base so it can be attached to a ‘guide’ RNA that targets a specific complementary nucleotide sequence
- Genes can be spliced and inserted with pinpoint accuracy
  - Cure neurological disorders → Alzheimer’s and schizophrenia
  - The easy use and accuracy about CRISPR raises concerns about germline gene editing and the creation of ‘designer babies’

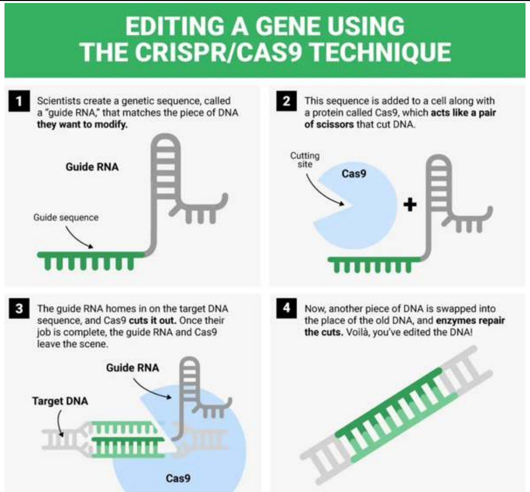
- **Evaluating the potential benefits for society of research using genetic technologies**

CRISPR Technology

- Successfully tested in embryos to treat mutation that leads to heart disorder called hypertrophic cardiomyopathy.
- Also used to reduce severity of genetic deafness in mice. Meaning with further research it could be applied to humans
- Creating mushrooms that don’t brown as easily or edit bone-marrow cells in mice to treat sickle-cell anaemia.
- Can develop drought resistant crops and extinguish malaria carrying mosquitoes.

Other ways to benefit society;

- Make crops more nutritious to aid health in developing countries
- To prevent genetic disease through mutation ie Huntington’s
- Powerful new antibiotics/ anti-viral which can target specific bacteria’s
- Gene drives which can alter entire species eg eradicating malaria vectors by only allowing reproduction of males.



- **Evaluating the changes to the Earths biodiversity due to genetic technologies**

Biodiversity of crops:

Soybean or corn crops transgenic genetically engineered by Monsanto to be resistant to Roundup (herbicide) are being grown widely by many farmers instead of pure bred crops. If G.E. crops are found to be susceptible to a disease or environmental change, then there are less varieties available, with genetic variations, to survive the selective pressure

Decreasing Biodiversity	Conservation of Biodiversity	Increasing Biodiversity
- GM crops involves selecting favourable traits and breeding them →fewer crop varieties → decreases gene pool and possible extinction. - GM animals may interbreed with native populations → transgene becomes more abundant and other genes die out → decreases gene pool.	- GM crops → increased crop productivity without destroying large amount of land → reduces land clearing → preserves habitats → conserves biodiversity. - Genetic techniques can predict the genes of offspring → helps select individuals for breeding	- GM crops can reintroduce genes that have died out → increases gene pool. - Artificial insemination and pollination introduce genes into a population → increases gene pool → increases biodiversity. HOWEVER, if these new genes have favourable characteristics that aid

- Genetically modified plants can adversely affect organisms such as bees - GM organisms pose a risk through breeding or cross-pollination, with potential for invasive species to develop in wild with GM characteristics eg herbicide resistance.	programs → helps endangered species e.g. Northern quolls were endangered - Biotechnology increases conservation methods such as biofuels made of renewable alternatives to fossil fuels.	survival, the introduced genes will outcompete the natives which decreases biodiversity.

Genetic Technology	Effect on Biodiversity
Artificial Insemination	• Can increase by introducing new genes into females which makes an unusual genetic combination • Decreases Biodiversity if one male's sperm is used to fertilise multiple females. Therefore, limiting the genetic combinations found in the species zygotes.
Artificial Pollination	• Can increase by introducing new genes to plants • Decreases Biodiversity if one favourable pollen will be used among farmers to fertilise many plants due to greater quality or yield produced.
CRISPR	• Can increase biodiversity by introducing new genes which code for new traits in population. • However, can also decrease Biodiversity by creating species variant that aid survival and takes over allele frequency. • Can also reduce by manipulating whole species through gene drives.
Cloning	• Decreases biodiversity by genetically replicating an individual and preventing the unique combination of gametes. • Can also conserve and increase frequency of rare alleles in population by making replica's.

re. This may cause the species to die out.