Genetically Modified Organisms

Genetically Modified = The introduction of a foreign gene (**transgene**) from an unrelated species into the genome of an unrelated organism, resulting in the expression of that gene in the transgenic organism

Significance/Benefits of Transgenic Plants
Bt corn

- Source of gene:
  - Bt toxin gene from ***Bacillus thuringiensis***
  - Promoter decides which parts of the plant the gene is expressed in
- Possible Techniques:
  - *Agrobacterium* vector containing modified Ti plasmid with Bt toxin gene inserted into protoplasts
  - Bombardment of callus using gene gun
  - Electroporation of protoplasts
- Gene product:
  - Transgenic corn expresses Bt gene to produce Bt toxin
  - Bt toxin kills specific insect pests which have specific enzymes in their gut that activates the Bt-toxin ⇒ Causes gut wall to break down
- Benefits
  - Crops not damaged ⇒ ↑ Yield + Quality of crops
  - ↓ Use of insecticides
    - ↓ Costs for farmers
    - ↓ Indiscriminate killing
    - No danger of insecticide runoff into the environment
  - Does not harm humans/other insects as Bt toxin is specific
  - Burrowing insects also affected by Bt-plants, not just surface dwelling insects
  - Biodegradable unlike synthetic pesticides

Golden rice

- Source of gene:
  - **Phytoene synthase** gene from **daffodil**
  - **Carotene desaturase** gene from ***Erwinia uredovora*** bacteria
  - Endosperm specific promoter
- Technique:
  - Genes inserted into Ti plasmids of *Agrobacterium tumefaciens* vector which is used to infect rice embryos in tissue culture
  - Transgenic rice plants crossed with local rice varieties to ensure that the rice is well adapted to local conditions
- Gene product:
  - Transgenic rice converts natural compound in rice to beta-carotene, a precursor of Vitamin A

- Benefits:
    - ↑ Nutritional quality ⇒ Prevents development of night blindness and reduces susceptibility to diseases in poor countries where people can't afford Vitamin A pills ⇒ Golden rice can form part of staple diet to supplement Vitamin A

Flavr Savr tomatoes

- Problem: Normal tomatoes tend to ripen rapidly and soften as **polygalactonurase** hydrolyses pectin in plant cell walls ⇒ Mushy fruits ⇒ Damaged during transport + Shorter shelf life ⇒ Farmers have to harvest tomatoes that are still green and allowed to ripen later ⇒ Less flavour ⇒ Loss of quality
- Source of gene:
    - Tomatoes modified with an **antisense** gene for **polygalactonurase** enzyme
- Technique:
    - Insert polygalactonurase antisense gene into Ti plasmids of *Agrobacterium tumefaciens* vector which is used to infect explants of tomatoes
- Gene product:
    - Transgenic tomato produces antisense polygalactonurase mRNA
    - Antisense mRNA binds to mRNA strand for polygalactonurase ⇒ Ribosome cannot gain access to mRNA + Double stranded RNA quickly degraded by RNases ⇒ Prevents translation of polygalactonurase mRNA into the polygalactonurase enzyme
- Benefits
    - Transgenic tomatoes allowed to ripen on the vine for longer while tomatoes remain firm ⇒ Fuller flavour ⇒ ↑ quality
    - Better shelf life ⇒ ↑ profits of retailer
    - Fruits less damaged after transportation ⇒ ↓ losses for farmer ⇒ ↑ profits

Glyphosate-resistant Soybean

- Problem: Herbicides tend to be broad spectrum in their effects and would harm both weeds and crop plants leading to loss of yield
- Source of gene:
    - EPSP gene coding for glyphosate-based herbicide resistance from CP4 strain Agrobacterium
- Gene product:
    - Bacterial gene codes for an enzyme that breaks down glyphosate herbicides
    - Weeds affected by herbicides but soybean plants not
- Benefits
    - ↑ Quality and yield of plants as ↓ competition for water and nutrients from weeds
    - Herbicides can be freely used to eliminate weeds without affecting the soybean crops

Significance/Benefits of Transgenic Animals

Atlantic salmon

- Source of gene:
  - Growth hormone gene from Chinook salmon
  - Promoter from ocean pout antifreeze gene
- Technique:
  - Microinjection of gene constructs (e.g. recombinant plasmids) into fertilised eggs of Atlantic Salmon
- Gene product:
  - Growth hormone gene expressed continuously throughout the year even during winter months
- Benefits:
  - ↑ Growth rate as able to grow throughout the year ⇒ Reach marketable size faster ⇒ ↑ Turnover rate ⇒ ↑ Yield ⇒ Salmon meat more readily available + Cheaper to consmers + ↑ Profits for producers
  - ↑ Feed conversion efficiency ⇒ ↓ Cost of feeding the fish ⇒ ↑ Profits for producers + Cheaper for consumers
  - Better environmental tolerance as growth hormone expressed continuously throughout the year
- Negative impacts:
  - Transgenic salmon may escape into the wild and outcompete wild type salmon
- Solution:
  - Only sterile, triploid female fish produced ⇒ Unable to reproduce even if they escape into wild
  - GM salmon farms located inland, far away from large water bodies

Heart-healthy meat

- Source of gene:
  - Fat-1 gene from roundworm *Caenorhabditis elegans*
- Gene product:
  - Transgenic pork contains 8% omega-3 fatty acids compared to only 1%
- Benefits:
  - ↑ Level of omega-3 fatty acids protects against heart disease

Bovine somatotropin for injection into lactating cows

- Source of gene:
  - BST gene
- Technique:
  - BST gene ligated to a vector which is used to transform *E. coli*
  - Transformed *E. coli* expresses BST gene which is used to produce large quantities of BST
  - BST extracted, purified and injected into lactating cows
- Benefits:
  - ↑ Milk to feed ratio + ↑ Milk yield + ↑ Weight of cattle ⇒ ↑ Profits for farmers

- Negative impacts:
    - ↑ Incidence of mastitis
    - ↑ Costs due to constant injections
    - No respect for animals

Porcine somatotropin for injection into pigs

- Source of gene:
    - PST gene
- Technique:
    - PST gene ligated to a vector which is used to transform *E. coli*
    - Transformed *E. coli* expresses PST gene which is used to produce large quantities of PST
    - PST extracted, purified and injected into lactating cows
- Benefits:
    - ↑ Feed efficiency ⇒ ↑ Growth rate ⇒ ↑ Profits
    - ↓ Fat content ⇒ Leaner meat ⇒ ↑ Nutritional qualities
- Negative impacts:
    - ↑ Joint and skeletal problems
    - ↑ Costs due to constant injections
    - No respect to animals

Negative Social Implications + Solutions (possible essay)
Environmental

- ↑ Pest resistance
    - Pest resistant crops act as selection pressure ⇒ Resistant pest selected for ⇒ Proliferation of resistant individuals in the population
    - Solutions:
        - Release sterilised adult insects into the wild ⇒ Resistant insects due to random mutations very rare, likely to end up breeding with sterilised moths ⇒ Will not produce resistant offspring
        - Change a small part of the toxin gene to produce toxins that the pests are now susceptible to
- Creation of superweeds
    - Herbicide resistant genes could be passed to related weed species via cross-pollination/horizontal gene transfer ⇒ GM crop-weed hybridisation ⇒ Creation of superweeds
    - Farmers incur more costs trying to eliminate these super weeds from infiltrating their farmlands
    - Solutions:
        - Greater isolation distances by planting border of unrelated plants
        - Buffer zones around GM crops to reduce gene flow
- Negative effect on biodiversity
    - GM organisms may outcompete native species due to increased competitive

abilities ⇒ Disrupt natural ecosystem
    - Solutions:
        - GM salmon engineered to be triploid, rendering them sterile to prevent them from interbreeding with wild type salmon
        - Grown in land-based containers far from rivers/oceans, reducing risk of escaping into the wild
- Non-target organisms may be adversely affected
    - Accumulation of toxins in predators of BT plant's pests
    - Loss of food source of predators due to death of pests
    - BT pollen may be transferred to other plants, killing insects that feed on those plants

Medical

- Toxicity
    - May produce secondary metabolites that may be toxic to humans/livestock
    - Toxins not normally harmful may react with chemicals in the body
    - Solution:
        - Safety assessments and regulations
- Allergies
    - Allergenic properties of food proteins from a source that causes an allergic effect may be conferred onto host plant (e.g. Nuts)
    - Solution:
        - Safety assessments and regulations
- Antibiotic resistance marker genes
    - May be transferred to environmental bacteria or bacteria in human intestine ⇒ Development of antibiotic resistant bacterial strains
    - Solutions:
        - Removal of marker genes before commercialisation
        - Use of other selectable markers e.g. X-gal/Fluorescence tags
- Nutritional qualities of GM crops
    - Introduction of foreign genes may alter nutritional quality of crops into forms that cannot be metabolised/absorbed ⇒ Disruption in balance of nutrients
    - Solution:
        - Adequate safety assessments and regulations to ensure safety for consumption

Negative Ethical Implications + Solutions (possible essay)

- Exploitation of animals for food and medical research may cause suffering in animals
    - e.g. Animals may not be biologically capable of withstanding additional stress in ↑ growth rate/↑ production of milk etc
    - e.g. Oncogene introduced into mouse to investigate effect of oncogene ⇒ Cancer in the mouse

- Cloning techniques may be applied to humans → Unnatural
- Allows for **<u>eugenics</u>**
    - Babies may be produced by introducing favourable genes using techniques from genetic modification
    - Exacerbates social and income inequality as not everyone can afford the technology + Decreased tolerance for human diversity
- Religious implications
    - GM food may contain genes from prohibited foods of certain religious and ethnic groups
    - Solutions:
        - Label GM food

Genetic Engineering in Plants
Vector: *Agrobacterium tumecfaciens*

- Soil dwelling bacterium → Contains Ti plasmid → T-DNA region can insert into genome of infected plant cell

Technique

- Ti plasmid isolated from A. tumefaciens
- Tumour inducing genes removed from Ti plasmid + Insert selectable marker e.g. Kanamycin/Herbicide resistance
- Make a recombinant plasmid containing gene of interest
    - Gene of interest linked to plant promoter so that gene can be expressed in plant cell
    - Gene of interest and Ti plasmid cut using same restriction enzymes ⇒ Produces complementary sticky ends ⇒ Gene anneals with Ti plasmid via complementary base pairing
    - DNA ligase forms phosphodiester bonds between adjacent nucelotides ⇒ Seals the nick
- Transfer recombinant plasmid into plant cell genome using *A. tumecfaciens* vector via protoplast culture
- Ti plasmid integrates T-DNA region into plant chromosomal DNA
- Select for transformed cells using Kanamycin/Herbicide-containing media
- Using plant tissue culture techniques, induce callus formation from transformed cells ⇒ Generate an adult plant