BIOLOGY

Blueprint of Life – Transgenic Species: Analyse information from secondary sources to identify examples of the use of transgenic species and use available evidence to debate the ethical issues arising from the development and use of transgenic species.

Questions

1. What is a transgenic species?

- Transgenic species are organisms which have had one or more genes introduced into their genome from a different species using genetic engineering techniques. This is done in such a way that the transgenic species will exhibit new properties and pass them on to future generations. Recombinant DNA technology is commonly known as the main technique used to produce transgenic species. One example of a transgenic species is BT (*Bacillus thuringiensis*) cotton. Bt cotton is cotton that is genetically engineered with Bt (Bacillus thuringiensis), a bio-toxin that acts as a pesticide killing specific insects.

2. Recombinant DNA technology produces transgenic species. Briefly outline the steps involved in Recombinant DNA technology. (Include diagrams)

- Recombinant DNA is a form of genetically engineered DNA that is created by taking DNA strands from one organism and combining or inserting these strands into the DNA of a host organism of a different species. Its production involves a number of steps:

- Initially, a target gene is identified in a certain species.

- The gene is then isolated from that species by cutting it out of its DNA strand. This is done through the use of restriction enzymes (or restriction endonuclease) that cut DNA into smaller pieces at specific recognition nucleotide sequences known as restriction sites. EcoRi is an example of a common restriction enzyme. There are over 600 restriction enzymes that are available commercially.

- The ends of the cut have an overhanging piece of single-stranded DNA. These are called "sticky ends" because they are able to base pair with any DNA molecule containing the complementary sticky end.

- A suitable plasmid which acts as the vector is selected and isolated from a bacterium. Plasmids are molecules of DNA that are found in bacteria separate from the bacterial chromosome.

- The plasmid is then cut open by the same restriction enzyme at a specific site forming more sticky ends.

- Both the gene from the donor DNA and the vector have complementary sticky ends and thus can pair with each other when mixed in a process called annealing.

- DNA ligase is used in order to strengthen the bonds of both sticky ends resulting in the formation of the recombinant DNA. Ligase is an enzyme that can catalyse the joining of two large molecules by forming a new chemical bond.

- Once the recombinant DNA is formed it needs to be replicated many times in order to be useful. This can be done in vitro, via the Polymerase Chain Reaction (PCR), or in vivo (inside the cell) using unicellular prokaryotes (e.g. E. coli), unicellular eukaryotes (e.g. yeast), or mammalian tissue culture cells. (*PCR is a technique frequently used in molecular biology to amplify a single or few copies of a piece of DNA of across several orders magnitude, generating millions of copies of a particular DNA sequence in a short period of time*).

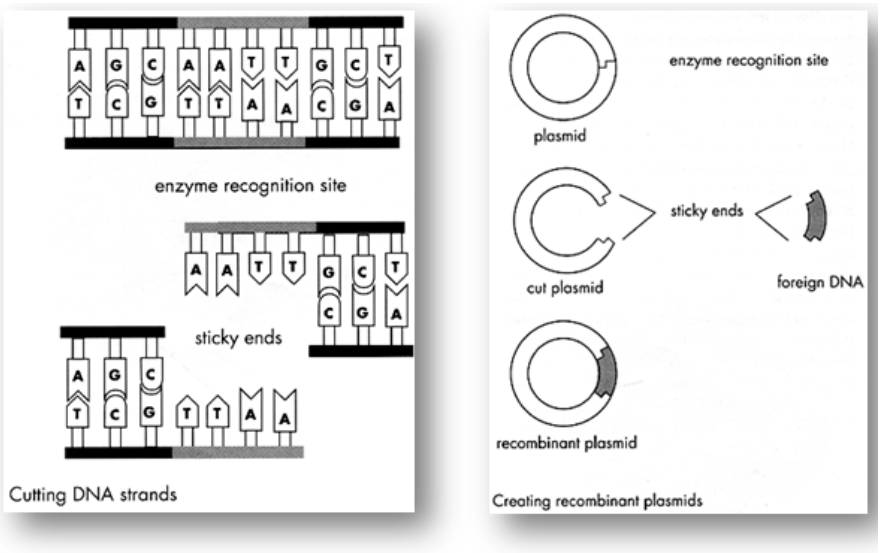

Diagram source: http://www.accessexcellence.org/RC/AB/WYW/wkbooks/SFTS/activity6.php

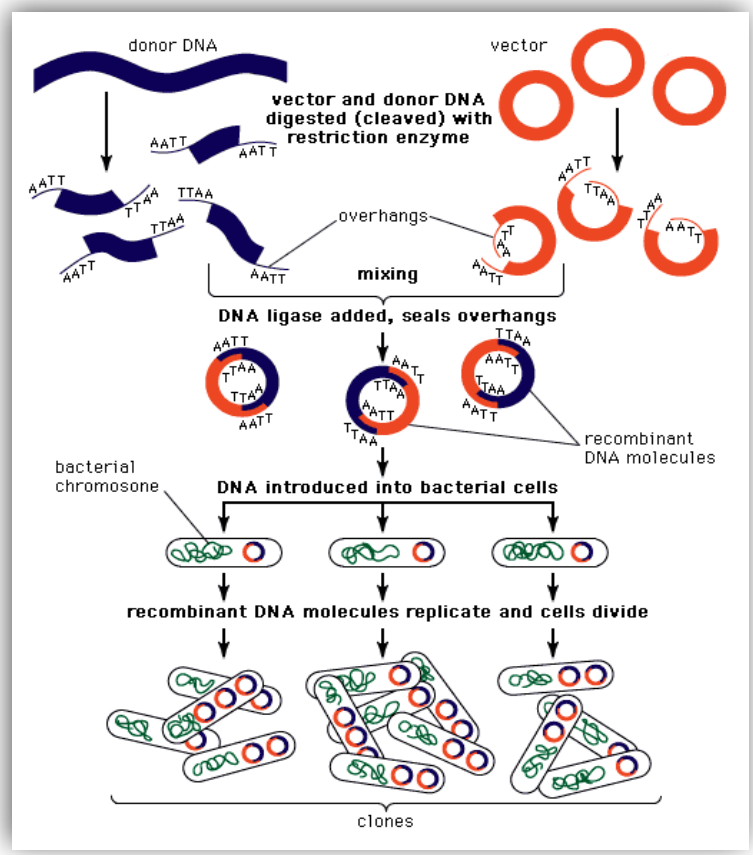

Diagram source: http://www.britannica.com/EBchecked/topic-art/493667/17930/Steps-involved-in-the-engineering-of-a-recombinant-DNA-molecule

3. Identify one plant and one animal species that have been genetically modified and answer the following questions:

A. Briefly discuss the method used and the reasons for this modification.

BT COTTON

- Bt cotton is cotton that is genetically engineered with Bt (Bacillus thuringiensis), a bio-toxin that acts as a pesticide killing specific insects.
- Initially, normal cotton seedlings are cut into small pieces and placed on a solid growth medium where they grow into calluses.
- After six week the callus cells are transferred to a liquid medium where growth hormones are added. This will enable callus cells to grow into cotton plant embryos.
- Through the use of restriction enzymes, the Bt gene is extracted from the bacterium Bacillus thuringiensis.
- The cotton plant embryos are dipped in a solution that contains a mixture of the vector (Agrobacterium tumefaciens) and the extracted Bt genes
- This allows the vector bacteria to inject the Bt genes into the cotton cells.
- The resulting embryos that contain Bt genes are then cultured in labs before they are planted in pots and grown in glasshouses.
- These plants are now said to be a transgenic species that contain in their genome a gene from a different species.

Reason for this modification:

Bacillus thuringiensis is a naturally occurring soil bacterium. It produces a chemical that kills caterpillars as well as similar insects. The gene that produces this certain chemical can be inserted into the genome of a cotton plant. The gene will then express itself in the cotton plant allowing it to produce its own pesticide that can kill pests feeding on it. This will consequently reduce the amount of pesticides needed in agriculture causing less harm for the environment. At the same time it helps in cost cutting with large scale economical benefits. Ultimately this modification of Bt cotton will allow a higher crop yield production.

KNOCKOUT MICE

- Knockout mice are genetically engineered in such a way that one or more genes are inactivated.
- A gene that is to be inactivated (‘knocked out’) is isolated from the DNA.
- Through the use of recombinant DNA technology, a new DNA sequence that contains the inactivated gene is prepared.
- Embryonic stem cells (ES) are isolated from a mouse blastocyst.

- The newly formed DNA containing the inactivated gene is incorporated into the ES cells. This is done using a delivery technique called electroporation (using electricity to transfer the DNA across the cell membrane)

- Engineered ES cells are inserted into a new blastocyst embryo taken from a female mouse.

- Blastocyst containing ES cells is implanted into a pseudopregnant mouse.

- Females give birth to a litter of offspring composed of pups that are wild-type (+/+), heterozygous (+/-), or homozygous (knockout; -/-) for the gene of interest.

- Heterozygous mice are further bred to propagate more knockout mice.

Reason for this modification:

It is known that the most closely related laboratory animal species to humans are mice for which the knockout procedure can be easily applied. Knocking out the activity of a gene allows scientists to deduce information on how a specific gene functions. This is done by essentially comparing the characteristics of knockout mice possessing the inactivated gene as opposed to normal mice. Mice also happen to share many genes with humans. Consequently, studying the characteristics of knockout mice can potentially give scientists information on how a similar gene may cause or contribute to disease in humans. Examples of research in which knockout mice have been useful include studying and modelling different kinds of cancer, obesity, heart disease, etc. Knockout mice also offer a biological and scientific context in which drugs and other therapies can be developed and tested. This modification has therefore the potential to save many lives.

B. Discuss the potential impact of the use of the above technology on the genetic diversity of the plant or the animal species.

Bt cotton is a successful crop and is replacing other varieties of cotton in commercial agriculture. However, the use of transgenic species has vast impacts on genetic diversity. Initially, there is an increase in genetic diversity; a gene from one species is placed into another species thus increasing the gene pool for that species. In the long term however, having a monoculture as a result of genetic engineering may lead to a reduction in the gene pool. This is further aggravated from the cloning of these plants, as it is found more convenient than genetically engineering all plants individually. Widespread monoculture reduces the ability of farmers to react to changes in the environment, such as new pests or rapid climate change. The potential for Bt cotton becoming susceptible to diseases could cause problems in a changing environment and whole crops could be wiped out if a disease that attacks that specific gene emerged. This is due to the lack of genetic variation. There is also the potential for Bt resistance insects to arise in a population which can prove disastrous in crops with limited biodiversity. As a precaution farmers growing Bt cotton in the USA now plant 20 per cent of their crops with non-Bt cotton to try to ensure that the insect populations do not become Bt resistant.

4. Using an example, discuss how this process has changed the direction of scientific thinking.

Diabetes mellitus type 1 is a result from autoimmune destruction of insulin-producing beta cells of the pancreas. It is fatal unless treated with insulin. Biosynthetic "human" insulin is currently manufactured for widespread clinical use using recombinant DNA technology. This was achieved by inserting the insulin gene into a suitable vector, the E. coli bacterial cell, to produce insulin that is chemically identical to its naturally produced counterpart, thus having a much lower chance of inducing a reaction because it is not a foreign protein. Prior to the development of recombinant DNA technology however, insulin was harvested from the bovine (cow) and porcine (pig). Bovine and porcine insulin worked very well for the vast majority of patients, but some could develop an allergy

or other types of reactions to the foreign protein. There were also concerns of long term complications resulting from the regular injection of a foreign substance. It is also an expensive technique and is impractical in case of mass production considering a projected decline in the production of animal derived insulin. These factors prompted scientists to search for an alternative method in order to produce insulin. This has been achieved using Recombinant DNA technology. The production of Biosynthetic human insulin using this technology is more reliable, cost-effective and sustainable than extracting and purifying the abattoir by-product. Therefore, recombinant DNA technology has changed the direction of scientific thinking so that potential medical applications of that technology are now better realised leading to an increase in the research done in that field.

5. Critics of gene technology say it is not risk free. Using an example, discuss the biological and ethical issues arising from the use of this technology.

Biotechnology and genetic engineering have created many potential benefits that have been observed. However, as soon as the potential benefits of transgenic species become apparent, the possible dangers also become evident. The production and use of transgenic species raises many biological and ethical issues. Roundup Ready soy beans are an example of a transgenic species. Roundup is a herbicide widely used in agriculture. Roundup Ready soy beans have been genetically modified to be tolerant to Roundup.

Farmers can spray crops with the herbicide to kill competing weeds without killing the soy bean crop.

Producing transgenic species like Roundup Ready soy beans involves combinations of genes that have never existed and are unlikely to naturally occur. This is viewed by some as interfering with nature and further regarded as 'playing God's role'. The process of genetic engineering also challenges the integrity of the species involved which is regarded as unethical. It is believed that each species has a right to exist as a separate identifiable entity; genetic manipulation on the other hand, acts to blur what is viewed as the organism's 'necessary distinctions'.

Another ethical aspect is the 'terminator technology' or GURT (Genetic use restriction technology). This concept is designed to genetically switch off a plant's ability to germinate a second time. In doing so, this would force farmers to buy new seeds for Roundup Ready soy beans each year. This would facilitate complete dominance and control for a few multinational corporations. An international outcry led to the abandonment of this practice. However, the use of crops that are resistant to certain herbicides, with a single company owning both seeds and herbicides, continues. Some consider this a conflict of interest.

Another alarming dimension is transcending the species barrier. This can occur by cross-pollination between transgenic crop-plants and their normal relatives. This may facilitate an uncontrollable spreading of transgenic crops. In this case, genetically modified soy beans may escape the farms where they are intended to be raised and invade natural ecosystems, resulting in genetically modified (GM) crops outcompeting native plants and as a consequence upsetting the natural ecosystem. This also has the capacity to speed up the genetic change in a species which may change the natural process of evolution.

In addition, there are a number of concerns in regards of the long term health risks of GM soy beans. GM foods could trigger new allergies and contain toxins that may be harmful. As well, there is a potential for new diseases to emerge, since some crops are modified using the DNA from viruses and bacteria.

Furthermore, biodiversity is lost as the gene pool of soy beans is lowered. This is quite risky as species become susceptible to diseases and may consequently result in mass extinctions of soy beans in case of rapidly changing environments.

Human rights should also be observed. Consumer opposition to GM foods is growing as awareness is increased, therefore correct labelling of GM foods should be followed so that consumers are aware of what they eat. This is particularly important so that vegetarians are able to avoid food with animal DNA and not eat it unknowingly.

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