NATIONAL SENIOR CERTIFICATE EXAMINATION
SUPPLEMENTARY EXAMINATION – MARCH 2019

LIFE SCIENCES: PAPER II

SOURCE BOOKLET

SECTION A

QUESTION 1

Read the following article and use the information in the sources, as well as your own knowledge, to answer the questions on page 2 and 3 in the question paper.

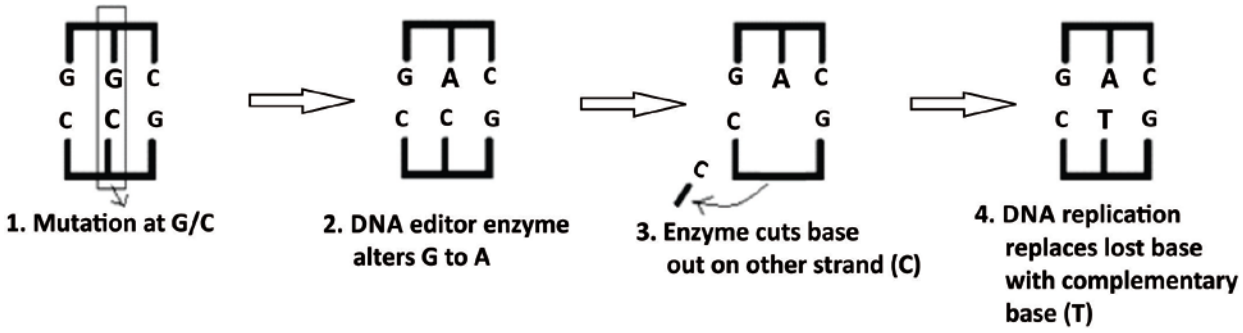
New enzyme rewrites the genome

Researchers have built an enzyme that can perform a previously impossible DNA swap, directly changing a single DNA base pair. The new enzyme, known as a base editor, may one day enable genome surgery that erases harmful mutations and writes in helpful ones.

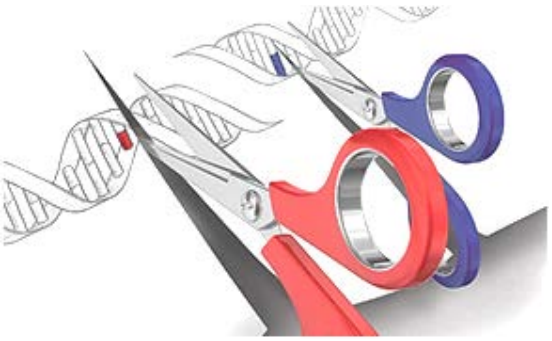
This enzyme targets individual point mutations. It changes the incorrect base on one strand to the correct one, and then snips out the complementary base on the other strand. The cell itself then replaces the gap in the strand with the correct base. This is illustrated below.

[Adapted: <www.sciencedaily.com>]

Functioning of DNA base editor



DNA editing



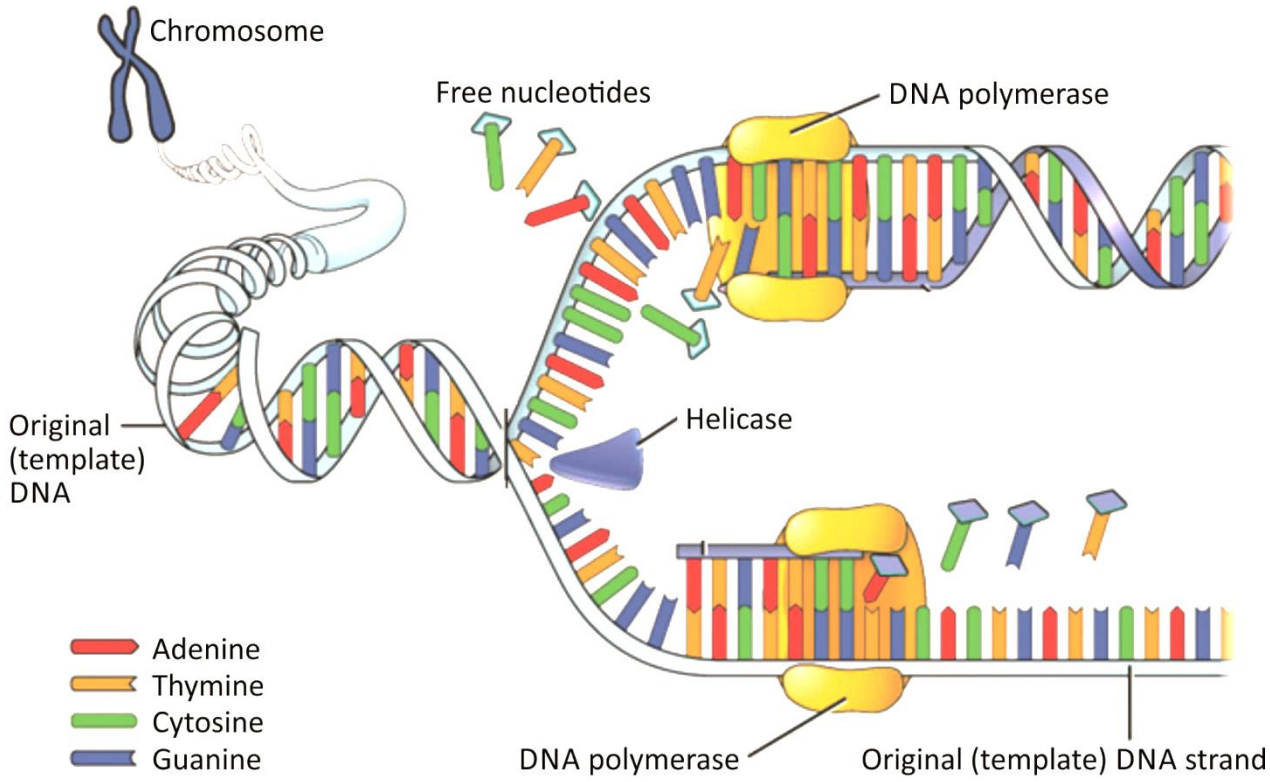
[Adapted: <hips.hearstapps.com>]

Some genome editing tools, such as the method known as CRISPR/Cas9, break through the sugar-phosphate backbone of **both** strands of DNA and then rely on the cell to fill in the gap with a desired DNA sequence. But making this break can lead to errors, such as the random insertions or deletions of nucleotides.

Base editors are more precise tools. "CRISPR is like scissors, and a base editor is like a pencil and eraser", says David Liu, a chemical and molecular biologist at Harvard University.

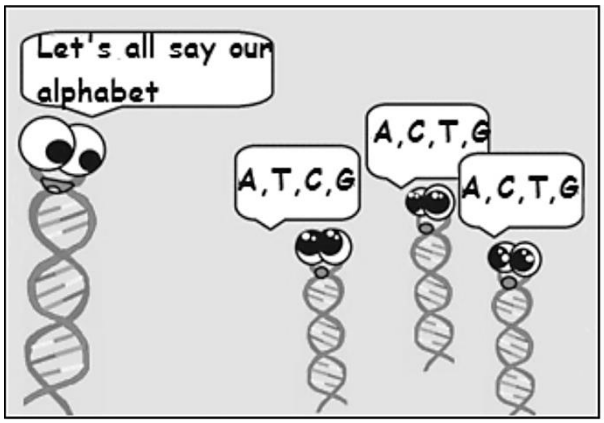
Haemochromatosis is a genetic condition in which iron levels in the body build up over time. This condition is caused by a point mutation. This DNA base editor has been used to fix the haemochromatosis mutation in cells taken from sufferers of the condition.

Diagram showing process of DNA replication

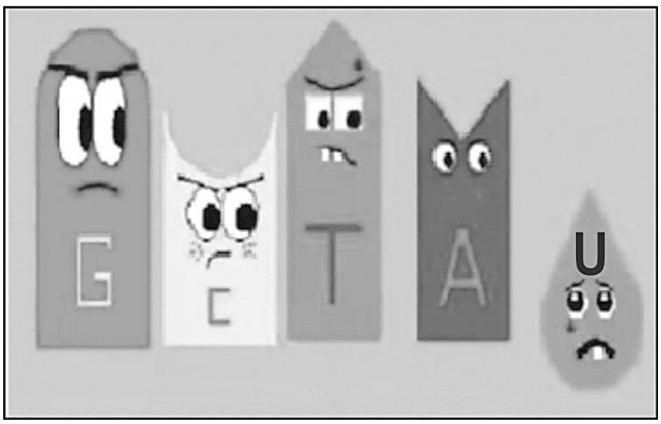


[Adapted from: <opentextbc.ca/anatomyandphysiology>]

CARTOON 1: DNA at school



CARTOON 2: DNA Club



[Adapted: <i.ytimg.com> and <hshpbiologyphoenixes.weebly.com>]

Liu warns that more work will be needed to "cure" diseases. Robin Lovell-Badge, a developmental geneticist from the Francis Crick Institute in London, described the new research as clever and important science. As with all gene editing discoveries, hurdles both technical and ethical remain. Verifying safety in animal studies, as well as in clinical trials, are significant challenges. In addition, researchers will have to determine the best way to deliver the base editor enzymes to the right tissue in the body and into the right cells. They will also have to figure out when in a patient's life is the best time to deliver a certain gene therapy.

[Adapted: Gaudelli, N. M., Komor, A. C., Rees, H. A., Packer, M. S., Badran, A. H., Bryson, D. I. & D. R. Liu. 2017. Programmable base editing of A•T to G•C in genomic DNA without DNA cleavage. *Nature*: 23 (7681): 464–471.]

QUESTION 2

Read the following article and use the information in the sources, as well as your own knowledge, to answer the questions on page 4 and 5 in the question paper.

Fabry disease

Fabry disease is an inherited enzyme deficiency that can shorten the lifespan of people who have it by as much as 40 years.

The disease is inherited in an X-linked recessive manner. The mutant allele which causes the condition results in a faulty enzyme being produced which leads to the accumulation of a fatty substance called Gb3 within the blood vessels and organs. The build-up of Gb3 can lead to problems in the kidneys, heart and brain. About 400 Canadians have Fabry disease. Fabry disease is estimated to occur in one in 40 000 to one in 120 000 live births.

Manufacturing of gene therapy drugs

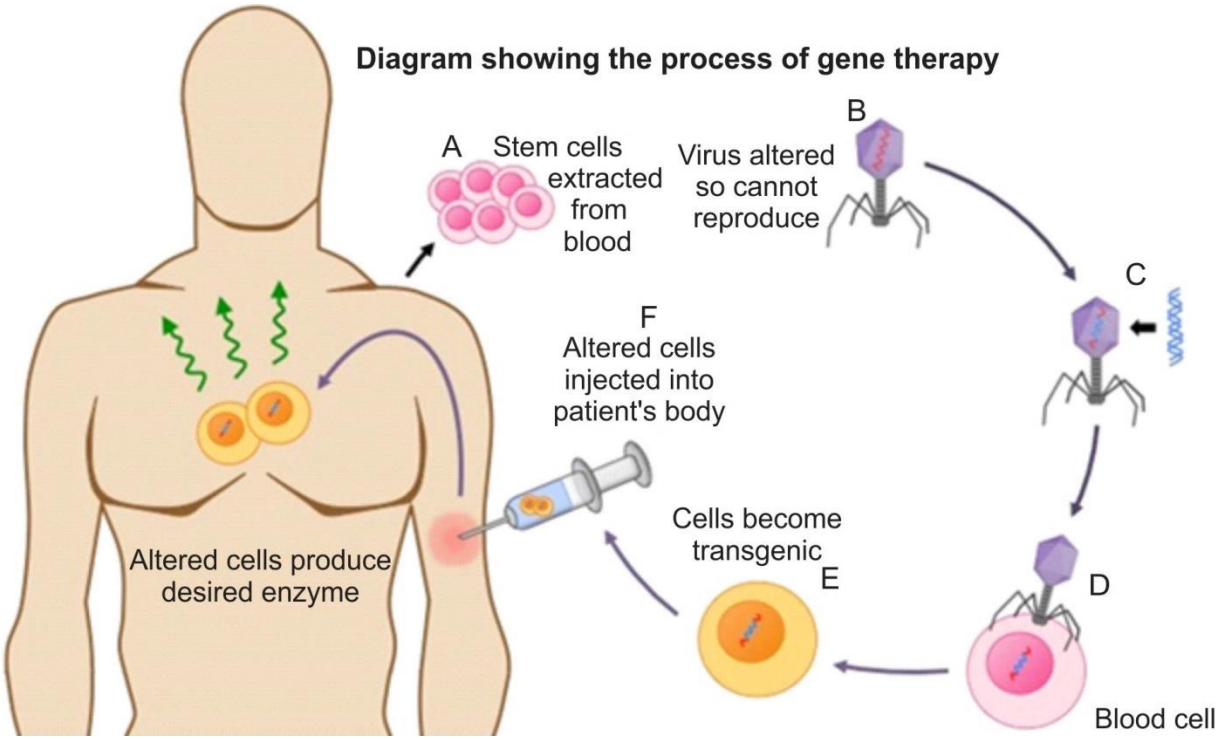
An Israeli company, Protalix, manufactures the missing enzyme that breaks down the Gb3 fat in Fabry patients. They have done this by inserting the working copy of the gene into carrot cells. These transgenic carrot cells then produce the missing enzyme. The enzyme is extracted and purified for human use. Fabry patients then have to be attached to a drip to deliver these enzymes directly into the blood. This treatment will have to be repeated for the whole of the patient's life. It is very expensive (about R3 million per year) but is safe and effective in treating the symptoms. It slows the progression of the disease but does not cure it.

Transgenic carrots

[Adapted: <www.cell.com/cell-chemical-biology>]

Canada launches first gene therapy trial for Fabry disease

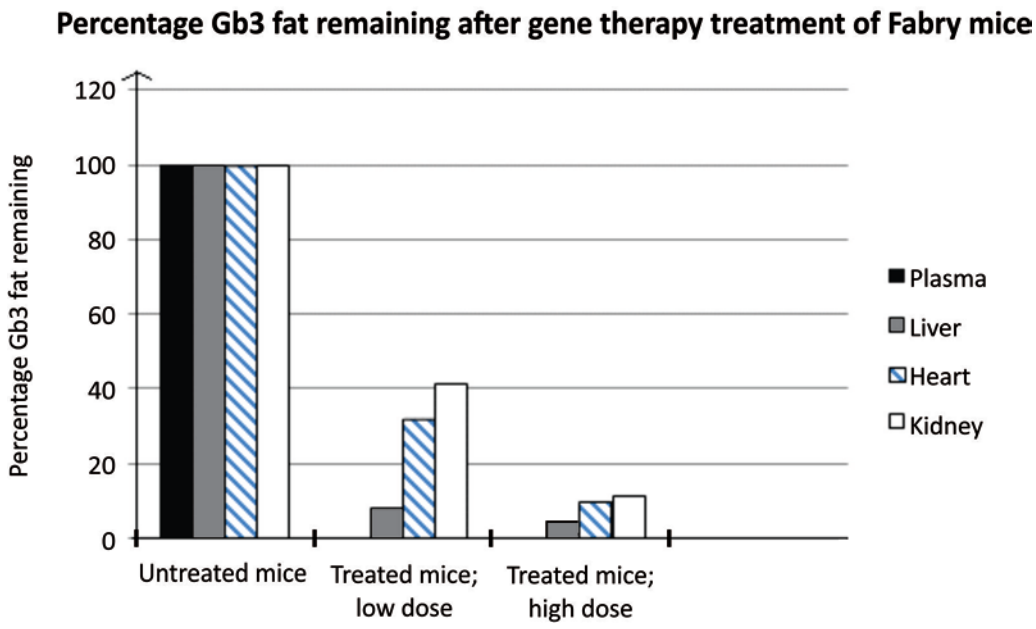
Researchers in Canada have launched the first gene therapy clinical trial in the world for Fabry disease. Researchers will first remove a quantity of unspecialised somatic cells (stem cells) from a Fabry patient's blood. Then a virus is modified so that it will not reproduce. The working copy of the gene for the enzyme is then inserted into the virus. The virus is then allowed to deliver the gene into the stem cells. During the final phase of the trial, researchers hope to transplant these stem cells back into the donor patient and the new, working copy of the gene will make the missing enzyme. Gene therapy will cure the disease. However, we cannot be sure that the virus will not cause an infection, or if it will insert the gene in the correct place in the stem cell DNA.



[Adapted from: <bioninja.com.au>]

An experiment to determine the effectiveness of gene therapy to treat Fabry disease was conducted using mice bred to be sufferers of the disease.

The control group received stem cells that had been unaltered, while the experimental groups received either low or high doses of stem cells that had been altered as shown above. The levels of Gb3 fat were measured in blood plasma, liver, heart and kidney samples taken from the mice in each group. The results are shown below.



[Adapted : <static2.seekingalpha.com>]

The Source Material from pages (vi–xi) relate to the essay on page 6 of the question paper.

QUESTION 3

SOURCE A

Seed companies can patent new crop varieties. This makes them the exclusive owner of these seeds. The owner then has the legal right to prevent others from using, producing, exchanging or selling them. This is to give companies a temporary monopoly so that they can collect a return on their investment without facing competition. To use patented seeds, farmers must make a payment to the owner of the patent. Farmers who buy patented seeds are also obliged to agree to a set of conditions; they will not reuse seed from their harvest for the following season; they will not experiment with the seeds; they will not sell or give them to anyone else.

[Adapted: <www.grain.org/article/entries>]

GMO Seeds: "Multi-national companies gaining total control over farming"

Food security campaigners are now more concerned than ever that farmers are turning dependent on large multinational corporations (MNCs) for seeds.

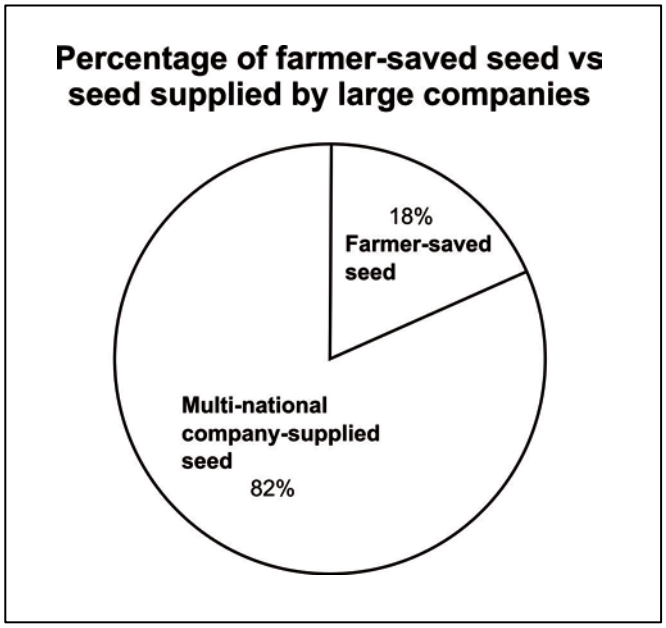
[Adapted: <globalresearch.ca/gmo-seeds>]

Who owns nature? The seed industry

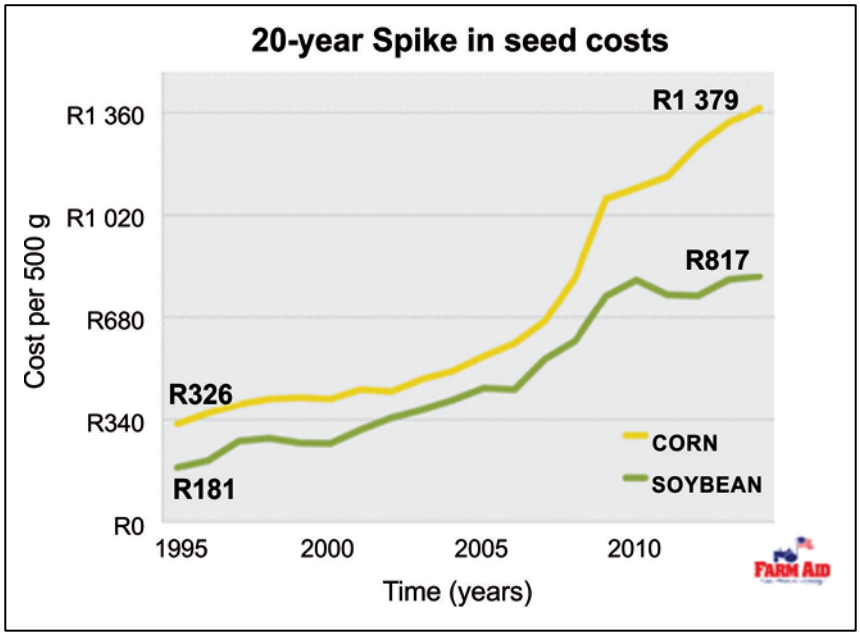
In the first half of the 20th century, seeds were overwhelmingly in the hands of farmers. In the decades since then, large companies have used intellectual property laws (legal rules for inventions) to modify the world seed supply – a strategy that aims to control plant DNA and maximise profits by eliminating farmers' rights. The lack of competition in the marketplace has reduced farmers' choices and enabled huge seed producing companies like Monsanto to raise prices as they want.

[Adapted: <gmwatch.org>]

SOURCE B



[Adapted: ETC Group]



[Adapted: Farm Aid]

Monsanto seeks intellectual property protection, including patents, to cover many of the traits and seed varieties we develop. These protections help to ensure we are paid for our products and for the investments we put into developing them. We sell these proprietary products in the market to provide a return to our shareowners and provide for our employees. Monsanto re-invests more than R34,6 million per day in research and development that ultimately benefits farmers and consumers. No business can survive without being paid for its products or services.

[Adapted: <Monsanto.com>]

Enforcement of intellectual property rights is normal and to be expected, says GianCarlo Moschini, a professor of economics at Iowa State University. Although "patents are sometimes questionable, without the protection of intellectual property, there would be no justification for a private company to invest the massive amount of resources they do in research and development to develop a new process, product or technology. If we want firms to invest in innovation, they have to be able to recoup their investment.

[Adapted: <whyfiles.org>]

SOURCE C

Do companies make farmers buy their seeds?

In most agricultural countries, the market for seed sales is open; therefore it is not possible for companies to "force" farmers to buy only one type of seed.

Farmers choose their own seeds based on what is best for their farms, market demand and local growing environment. Brian Scott, an Indiana farmer who grows corn and soybeans, talks about his experience purchasing seed for his farm. He explains:

"I think there is a notion out there among the general public that if farmers like myself buy seed from seed companies like Monsanto, I've suddenly lost choice in the way I run my business. Based on my experience, this is not the case. I choose what seeds I plant every year. I'm not locked into buying seed from one company from one season to the next.

Are there some rules to abide by whenever I sign one of these contracts? Sure there are. Do they have a detrimental effect on the way I choose to farm? I don't think so."

[Adapted: <gmoanswers.com>]

SOURCE D

If a farmer accidentally grows a patented seed on his property without buying it (i.e. if some seeds from his neighbour lands on his property), he can be sued for property theft.

[Adapted: <www.Alternet.org>]

The agricultural giant Monsanto has sued hundreds of small farmers in the United States in recent years in attempts to protect its patent rights on genetically engineered seeds that it produces and sells.

The study, produced jointly by the Centre for Food Safety and the Save Our Seeds campaigning groups, has outlined what it says is a concerted effort by the multinational to dominate the seed industry in the US and prevent farmers from replanting crops from Monsanto seeds that they have produced.

Monsanto argues that it needs its patents in order to protect its business interests and provide a motivation for spending millions of dollars on research and development of hardier, disease-resistant seeds that can boost food yields.

[Adapted: <www.theguardian.com>]

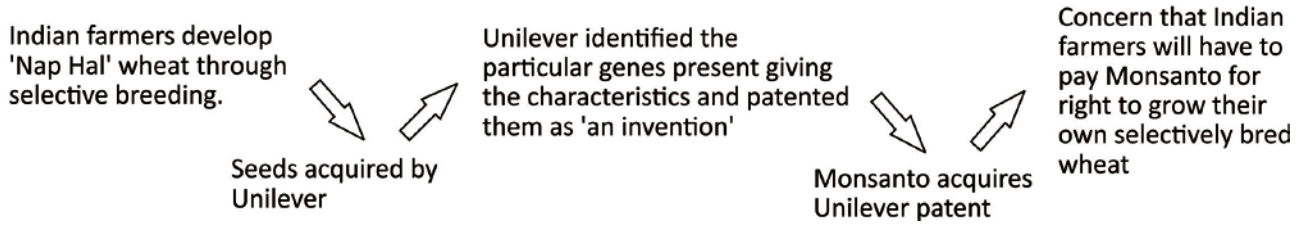
Seed rights – from farmer to multinational

An intense drive to patent agricultural biotechnologies may hurt those who should benefit most: people in developing countries.

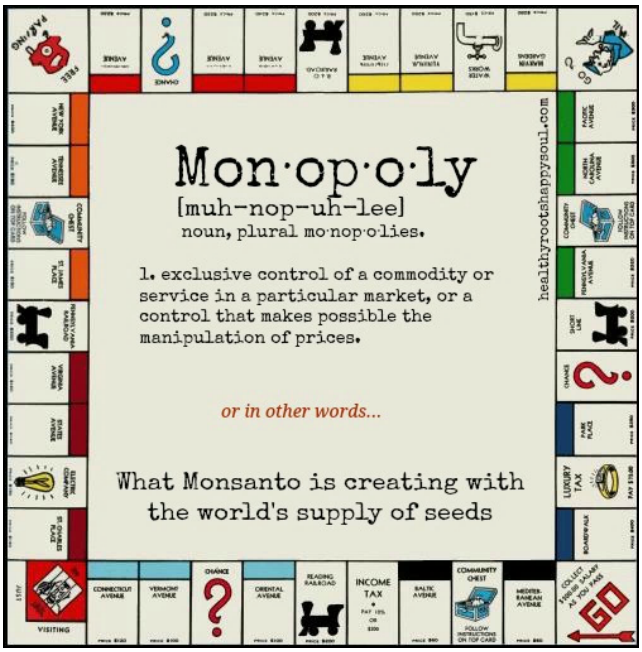
Patenting seeds increases their cost. Most farmers in developing countries are small-scale farmers who cannot afford expensive seeds. These farmers usually swap seeds with their neighbours, something that would not be allowed with patented seeds.

[Source: <http://www.biowatch.org.za>]

Monsanto's patent on Indian wheat (a variety of wheat that has a high gluten content)



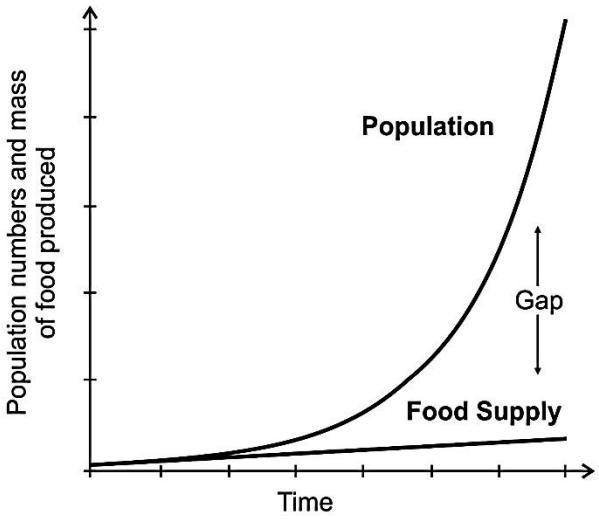
[Adapted: <www.theguardian.com/science>]



[Adapted: media-cache-ak0]

SOURCE E

Increase in world population size and food supply over time



[Adapted from: <sites.google.com>]

Golden rice – genetically modified to contain genes to make compounds that the human body converts into vitamin A

More than 1 000 000 children die each year from vitamin A deficiency

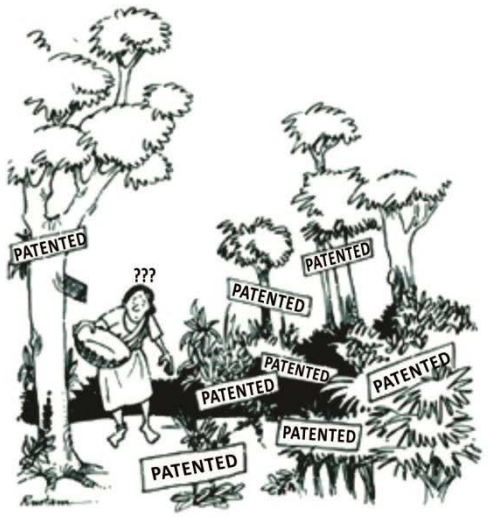
Golden rice will be distributed free to subsistence farmers. Monsanto is one of the companies to grant free licences

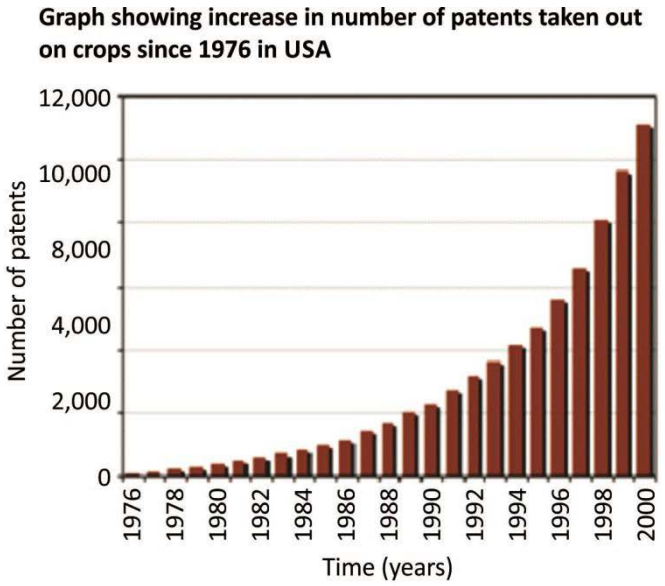
Only if farmers make more than R136 000 per year will they have to pay royalties (fees) to grow the seed

Farmers are permitted to keep and replant seed

[Adapted: Dobson, R. 2000. *Royalty-free licenses for genetically modified rice made available to developing countries*. Bulletin of the World Health Organisation, 78 (10): 1281]

SOURCE F





[Adapted: <cdn1.globalissues.org>] [Adapted: <www.agbioforum.org>]

SOURCE G

Can't plant and replant?

Corn productivity per acre has risen six-fold since before World War II due to improvements in varieties, and although the do-not-replant restrictions imposed by Monsanto and others arose with GM seeds in the 1990s, farmers long ago lost the incentive to replant top strains of maize.

This is because the most productive corn varieties are grown from plants made by crossing two inbred strains, giving their seeds "hybrid vigour". The next-generation seeds grown from hybrid seeds, however, are far less productive. And so, farmers being logical, responded to the incentive by starting to buy new seed every year. The resulting income was used by the seed companies to breed better genetics – better seeds.

[Adapted: <whyfiles.org>]