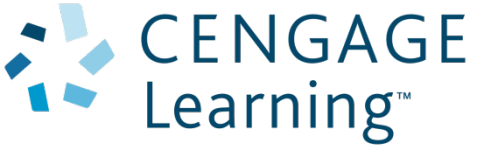
Chapter 7:
Biotechnology in agriculture and environmental conservatism



DNA identification technologies: recap

DNA technologies include all the tools and techniques used to build DNA profiles ('fingerprints'):

- single tandem repeats (STRs)
- restriction enzymes
- polymerase chain reaction (PCR)
- gel electrophoresis
- DNA sequencing
- gene markers
- genome mapping.

DNA identification technologies are applied in agriculture

Agriculture is the science of growing crops and livestock and cultivating the soil and microorganisms in which they grow.

DNA identification technologies can be used to accurately trace the genetics of desirable traits and to acquire those traits within a generation. This is enabling us to increase the availability and quality of food for the growing human population on Earth.

Using marker-assisted breeding, plant scientists can examine the DNA of seeds to find the ones that will produce the best plants. First, genetic ‘markers’ are identified in a plants’ DNA that are linked to important traits such as disease resistance, drought tolerance, yield, taste and nutrition.

Wheat breeding

To meet the future demands of a projected world population of 9.6 billion by 2050, wheat productivity needs to increase by 1.6 per cent each year.

CSIRO has used PCR and gel electrophoresis to reveal PCR markers that are now assisting farmers in identifying genes that improve rust resistance in wheat.

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Biotechnology in agriculture: DNA identification

Pork industry

Identification technologies are allowing pig farmers to select the pigs with the most desirable traits for breeding. Desirable traits include increased litter size and growth rate, and improved carcase quality (e.g. taste and tenderness).

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Recombinant DNA in agriculture

Scientists use molecular tools and techniques to modify food crops, which increases their nutritional value and crop yields. Biotechnology has also been applied to reducing the impact of pests on crops, thus increasing the amount of food available in developing countries.

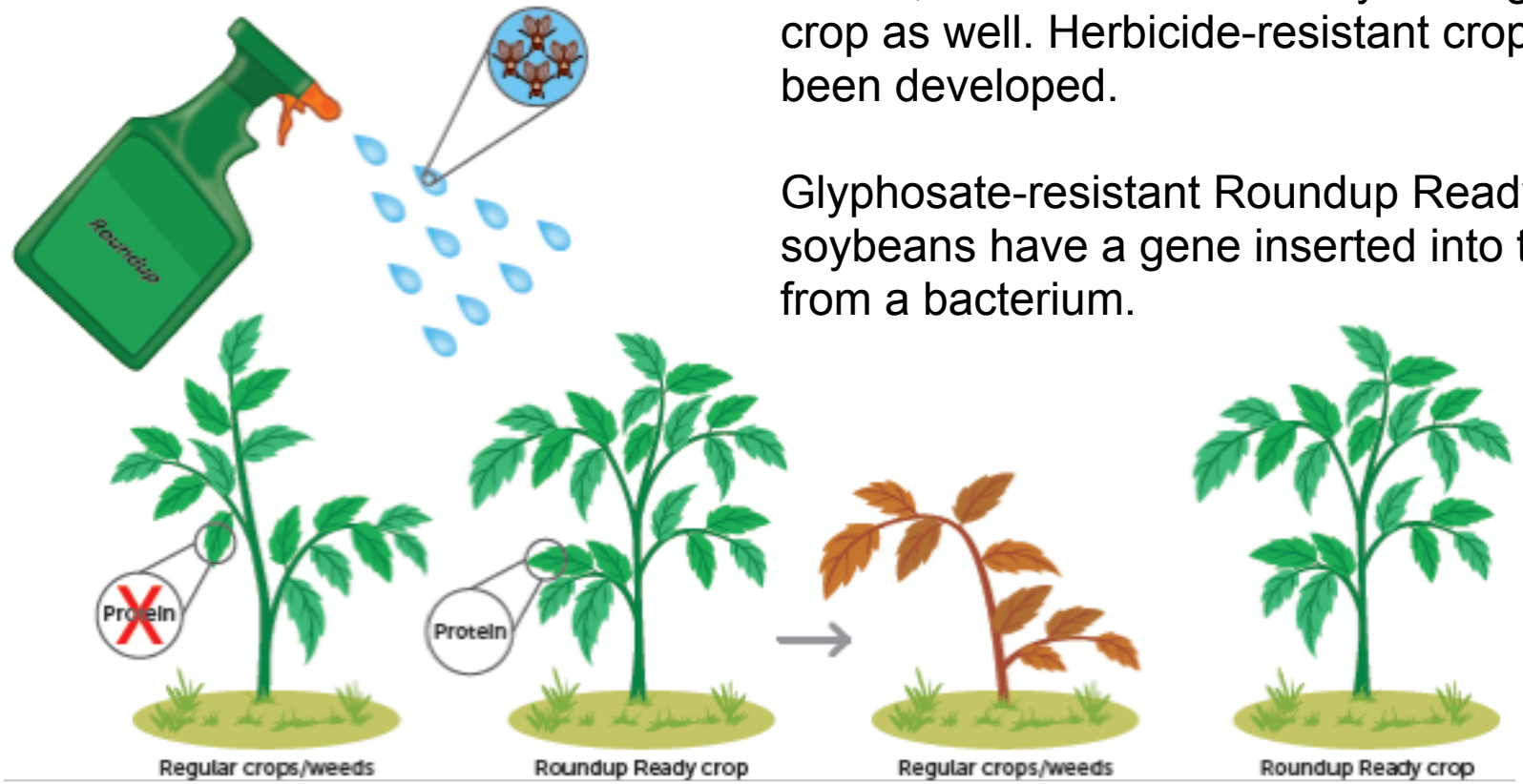
The process used for most of these applications is **transformation**: taking a gene from one species and inserting it into another to obtain a desired characteristic. The technology used for this process is termed **recombinant DNA technology**.

Biotechnology in agriculture: Recombinant DNA

Transgenic organisms engineered for herbicide resistance

Herbicides are substances used to control weeds, but herbicides usually damage the crop as well. Herbicide-resistant crops have been developed.

Glyphosate-resistant Roundup Ready® soybeans have a gene inserted into them from a bacterium.



Transgenic organisms engineered for disease resistance

Cotton plants are susceptible to cotton bollworm, caused by moths. The soil bacterium *Bacillus thuringiensis* (Bt bacteria) produces a range of proteins that are toxic to some insects. Genes from the bacterium are inserted into cotton plants, and the plants are protected from damage.

The use of genetically engineered cotton reduces the use of insecticides, cutting farming costs.

Transgenic organisms engineered for faster growth rate

Transgenic Atlantic salmon is known as Aqua-Advantage Salmon®. It is capable of growing at double the rate of conventional Atlantic salmon. The typical growth hormone-regulating gene in the Atlantic salmon was replaced with the growth hormone-regulating gene from Pacific Chinook salmon, along with a promoter gene from ocean pout).

AAP Photo/AP Photo/Aqua Bounty Farms

Biotechnology in agriculture: Recombinant DNA

Transgenic organisms engineered for increased nutrition

Golden rice is a transgenic organism created when a gene from the daffodil plant and a gene from a soil bacterium were extracted and inserted into a plasmid.

AAP Photo/ Erik de Castro/Reuters

The recombinant plasmid was then inserted into *Agrobacterium*. *Agrobacterium* reproduced, and was then mixed with rice plant embryos. The DNA was taken up by rice embryos, which expressed the two genes if the transgenesis process was successful.

Consumers of rice now have a source of Vitamin A precursor − β-carotene. Vitamin A deficiency is a major cause of death in developing countries.

Transgenic organisms engineered for increased yield

Yield refers to a measure of a crop per unit area of land cultivation, and to the crop's seed generation itself.

A team of scientists at Murdoch University have increased the protein content of wheat by more than 14 per cent in a new high-yielding variety of wheat known as Tungsten®, which can be grown in poor-quality soils with low production costs. It is currently ready but waiting for commercialisation.

Fairfax Photos/Paul Rovere

Transgenic organisms engineered for tolerance

Climate change is an alteration in the pattern of climate over a long period of time, and may be due to a combination of natural and human-induced causes.

This has led to extreme weather conditions, which can be the source of adverse environmental conditions.

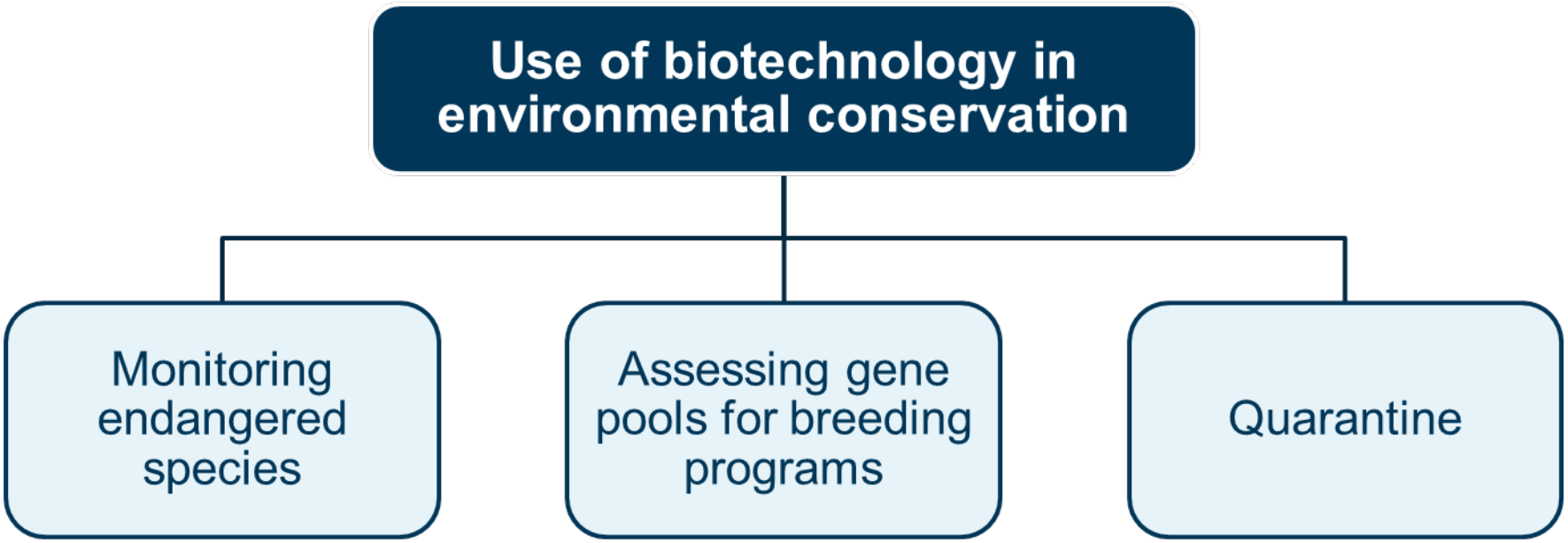
Some abiotic factors, or adverse conditions, affecting crops include extreme temperatures, drought, flooding, high salinity and deficient soil nutrients.

Monsanto Australia gained approval to grow, sell and use drought-tolerant, transgenic corn in Australia in 2010. This new variety of corn was genetically modified to tolerate cultivation under water-limited conditions.

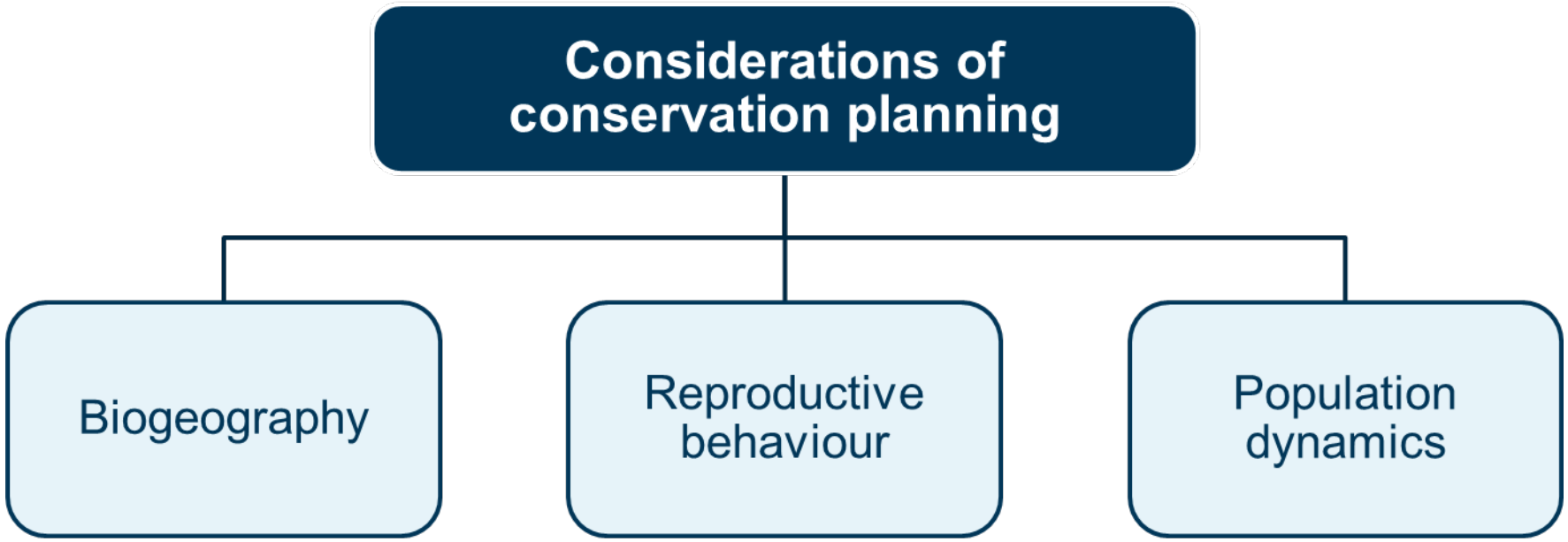
Biotechnology in conservation: DNA identification

Conservation biology

Conservation biology is the integrated study of ecology, physiology, evolution, molecular biology and genetics with a view to sustaining biological diversity at all levels. It is a broad approach to preserving what remains, and determining the care and attention needed for protecting it for the future.



Conservation requires careful planning



Monitoring endangered species

Monitoring **endangered species** is a crucial part of conservation, because it helps scientists identify species threatened with extinction and provides evidence of the effectiveness of conservation strategies. Monitoring data can be used to diagnose the causes of population decline and to measure management effectiveness.

Factors that are monitored may include behaviour, geographical movements, reproduction, diversity, population size (births/deaths/migration) and population growth.

Spectrum Ecology

Assessing gene pools for breeding programs

Biotechnologists can use various techniques, including DNA profiling, to selectively breed individuals. This is a common practice in **captive breeding programs** (conservation breeding programs) of threatened species such as the mountain pygmy possum, Tasmanian devil and the orange-bellied parrot.

Minden Pictures/Photographer Suzi Eszterhas

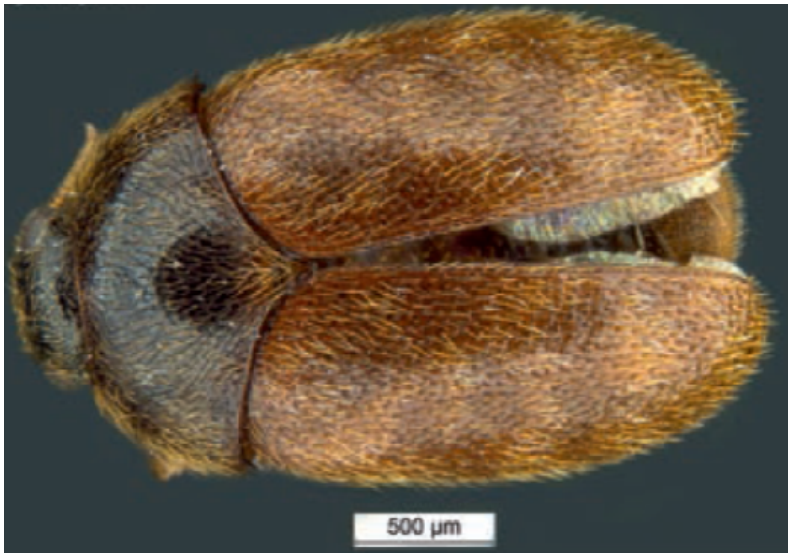
Devil's Heaven is a dedicated conservation breeding program situated within Tasmania Zoo's precinct. Featuring advanced biosecure breeding pens, Devil's Heaven has been home to a successful breeding population of Eastern Province devils for more than 10 years.

Biotechnology in conservation: DNA identification

Quarantine

Quarantine is the isolation of organisms that have arrived from elsewhere or been exposed to an infectious or contagious disease. They are monitored until scientists confirm the suspected organism is not, or is no longer, present. DNA 'fingerprint-type' techniques enable biosecurity officers fast and accurate identification of pest species.

Example:
The Khapra beetle is considered to be the most serious pest of stored grain in the world. It is a quarantine-status pest in Australia.



AAP Photo/DAFWA

Recombinant DNA in conservation: bioremediation

Bioremediation is the deliberately introduced or naturally occurring consumption and breakdown of environmental pollutants by microorganisms. The process is used to treat contaminated water and soil.

Chlorinated hydrocarbon 1,2,3-trichloropropane (TCP) is a toxic and carcinogenic non-natural compound with several useful industrial applications.

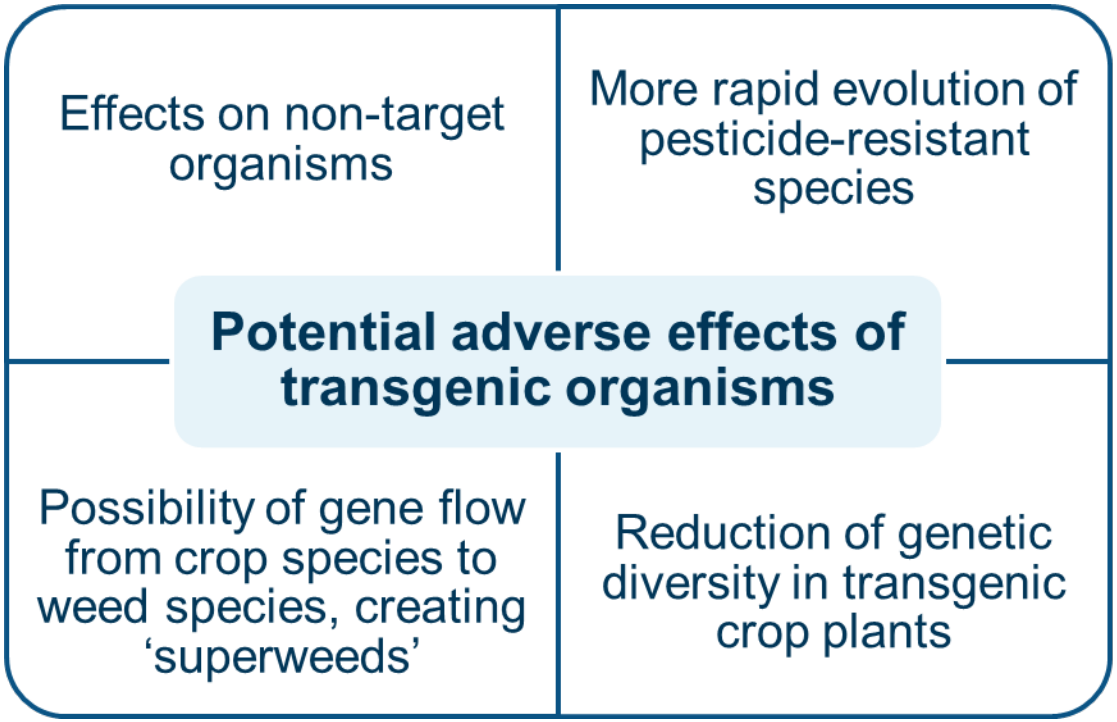
TCP has a higher density than water, so it moves easily into deeper groundwater layers, leading to widespread contamination. It then infiltrates drinking water, becoming a hazard for ecosystems.

The gene encoding improved haloalkane dehalogenase (*dhaA31*) was placed into a plasmid and cloned. An engineered haloalkane dehalogenase gene was introduced into the bacterium *Pseudomonas putida* MC4. The transgenic *Pseudomonas putida* is used in the bioremediation of the pollutant TCP.

Ethical issues associated with transgenic organisms

Effects on genetic diversity and the environment

The implications of gene technology and the issues associated with the application of gene technology have to be considered. Using transgenic organisms may have adverse effects on genetic diversity and on the environment.



Ethical issues associated with transgenic organisms

Arguments for and against biotechnology

For	Against
Biotechnology is natural; genetic engineering has existed for years; for example, farmers breed specific cattle to achieve the desired traits. Biotechnology is simply an extension of this process.	Biotechnology is not natural; selective breeding only involves individuals from the same species, yet biotechnology is transferring genes across species, which rarely happens naturally.

Ethical issues associated with transgenic organisms

Arguments regarding positive and negative effects of biotechnology on the environment

Possible positive effects	Possible negative effects
Herbicide-resistant crops are resistant to a herbicide that is not very toxic to the environment. This enables the farmers to use more of this herbicide rather than use a more toxic herbicide, which may be damaging to the environment.	Herbicide-resistant crops may encourage farmers to use more herbicide on their crops, which could potentially be more damaging for the environment.
So far, researchers have found that there is little transfer of genes between species.	There may be gene transfer between closely related species; weeds may become resistant to the herbicide.
	We may not know what gene transfers have occurred.
	We may not know what transgenic organism has escaped into the environment.

Ethical issues associated with transgenic organisms

Arguments for and against genetically engineering foods with respect to public health

For	Against
Biotechnology can vastly improve the health, nutritional value and growth capacity of agricultural species, and therefore greatly help to combat a global food crisis and benefit public health.	Selective breeding has provided us with crop improvements in the past and can be a source of steady improvement in crop quality.
There are strict guidelines that aim to ensure all genetically engineered food is as safe as non-genetically engineered food. The genetic code is common in all living species.	The long-term effects of genetic modification of crops are essentially unknown.

Cloning by nuclear transfer

Cloning is the process of making an identical copy of an original. The process of cloning by nuclear transfer came to prominence when Dolly the sheep was cloned in 1996.

Nuclear transfer involves removing mature donor somatic cells from a mature animal and a recipient egg cell from another mature animal of the same species.

The donor cell, with the intact nucleus, is fused with a ‘hollow’ egg, cultured for about a week, then cell division is activated and the developing blastocyst is surgically implanted in the surrogate mother.

The offspring is genetically identical to the nucleus donor.

Cloning using nuclear transfer has not been without controversy. The success rate of live births is low.

Cloning a calf by nuclear transfer