Compiled by Colleen Aldous, Muffy Koch, Christine Almeida and Oliver Corea under the auspices of the Public Understanding of Biotechnology programme, sponsored by the Department of Science & Technology.
Graphics by Jonathan Davies.

BIOTECHNOLOGY AND BIODIVERSITY

GRADE 11

PUBLIC UNDERSTANDING OF BIOTECHNOLOGY

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PUBLIC UNDERSTANDING OF
BIOTECHNOLOGY

Biotechnology and Biodiversity

Grade 11

Overview of the PUB Biotechnology and Biodiversity module for the FET curriculum

In light of the expanding use of biotechnology in all parts of daily life, society's ability to understand the new technologies and to make informed decisions about their use is critical to accessing the benefits the technology offers. How do we develop a realistic image of what biotechnology is? This is the task of the government's Public Understanding of Biotechnology (PUB) programme.

The scope of the PUB programme can be viewed at: www.pub.ac.za. This teaching module is one project aimed at scholars and educators - the very core of knowledge development. The module explores the impact of biotechnology on biodiversity, a significant area in modern life and living. The importance of biodiversity is unpacked in six units that fit comfortably into the current Ecology section of the Grade 10 curriculum. The importance of biotechnology in relation to biodiversity is unpacked in 12 units that are suited to the current Grade 11 genetics syllabus. However, the units are designed also to fit into a more general Grade 10 to Grade12 FET curriculum. Each unit provides a choice of activities, enabling educators and learners to adapt the material to their specific needs.

While the units have had specific input from a range of experienced Biology teachers, we believe the input will be ongoing, as it is only when the material is being used in the classroom that the required modifications and additions will be generated. As such, we encourage educators and learners to send feedback, including new ideas for activities, to the PUB programme for future updates. Send your feedback to PUB by fax (012 320 7803) or email (speakup@pub.ac.za). An electronic version of the module is available on the website.

The Biotechnology & Biodiversity module contents are summarised below:

Grade 10: Unit 1.	**Defining biodiversity:** A look at diversity in living kingdoms and what makes it change.
Grade 10: Unit 2.	**The value of biodiversity:** Biodiversity responds to change and supports survival and adaptation.
Grade 10: Unit 3	**The sensitivity of biodiversity:** Human development has had a negative impact on biodiversity.
Grade 10: Unit 4	**Agriculture and biodiversity:** Biodiversity plays a critical roll in food production and human nutrition.
Grade 10: Unit 5	**Linking biodiversity and biotechnology:** Using our understanding of biological processes to study and conserve biodiversity.
Grade 10: Unit 6	**What the world is doing to conserve biodiversity:** International efforts to both conserve biodiversity and use it for sustainable development.
Grade 11: Unit 1	**Defining Biotechnology:** Biotechnology is the identification and use of living systems to produce useful products using the biodiversity of the earth's gene pool.
Grade 11: Unit 2	**Genetic improvement-breeding and selection:** Having identified useful organisms from the biodiverse pool available, man initiated a process of genetic improvement to adapt organisms to local conditions, attempting to improve their yields and quality.
Grade 11: Unit 3	**Genetic improvement - mutation and cloning:** In the last century man's understanding of genetics developed to a point where he could go beyond selection and hybridization to genetically improve specific products.
Grade 11: Unit 4	**Genetic improvement- gene transfer:** Improved understanding of gene structure and function make it possible to move specific genes for specific characteristics reducing the constraints of multiple gene changes that occur with mutation and hybridization.
Grade 11: Unit 5	**Safeguarding biodiversity:** As genes have diversified through time, biodiversity provides a valuable resource of characteristics that need to be safeguarded.
Grade 11: Unit 6	**Sustainable use of biodiversity:** Biotechnology tools have provided new mechanisms to document and conserve evolving biodiversity. Man impacts on biodiversity. Biotechnology provides tools to access biodiversity and better understand its value. Biotechnology provides processes to use biodiversity sustainably.

Contents

Introduction

Biotechnology touches all the spheres of our lives on a daily basis. Medicinal and agricultural applications play particularly large roles and these roles continue to increase both in magnitude and importance. Along with this progress in biotechnology, we have to be aware that as the human race we have a responsibility to the environment. Every new innovation at hand should be assessed in terms of its impact on the environment. The link between biotechnology and biodiversity is being made worldwide and it is important to understand this link. It is with the aim of understanding this relationship that the authors have created two learning modules focusing on the link between biodiversity and biotechnology that may be included in the FET (Further Education and Training) Life Sciences Curriculum.

This, the first module is aimed at Grade 11 level and explains the link in terms of the responsibility man has towards the environment. The module is designed for implementation when the core knowledge area of "Study of the Environment" of the National Curriculum Statement (NCS) for the Life Sciences is being covered, although core knowledge components from the other three knowledge areas are also covered. The core knowledge components for "Study of the Environment" are

- Study the environment looking at the biophysical, social, economic and political systems
- Study the environment looking at the interrelationships of science, technology, indigenous knowledge systems and society with management and sustainability of the environmental resources and products

The material is developed bearing these guidelines in mind and including as many elements as possible where appropriate.

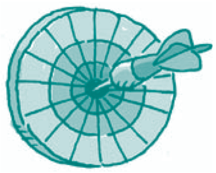
The NCS is also complied with in order to cover all of the Learning Outcomes (LO's) prescribed at the Grade 10 level. The materials and activities are designed to include elements of scientific investigation (LO 1), construction of scientific knowledge (LO 2), increasing awareness of the links between science, society and the environment and attitudes and values surrounding the link between science and society (LO 3). The LO's are not intended in the curriculum to represent 25% of the emphasis in teaching for each one. It is intended that they all get covered to some degree throughout the learning experience of the learner to ensure that they are all ultimately achieved. Each unit in this learning module attempts to cover at least one of the LO's. For each unit the intended LO's are stated as objectives at the beginning of each unit.

A further consideration to the NCS is taken with regards the assessment of tasks. The Assessment Standards for Grade 11 have been taken into consideration when designing the activities and the assessment tasks. Assessment tasks are designed to test for assessment standards included in the activities.

The nature of this module is one of minds-on activity. Being a written or on-line resource the focus is on reading to acquire knowledge and then using the knowledge in activities to create new ideas. It is designed to encourage debate and discussion to extend learning and therefore it is suggested that as many activities as possible be done collaboratively.

Much of the material used in the activities is taken from real world publications. This is in order to give the learners a global and authentic education beyond the topic. It is seen as appropriate that learners of Grade 11 level be exposed to examples beyond their immediate environment in order to make them aware of the world beyond. The language may be complex in some cases. Where appropriate this has been edited but in other places, collaborative learner participation will make the language problem surmountable.

Unit One - Defining Biotechnology



1.1 Objectives

Based on the activities and discussion in this unit, you will be able to:

Learning Outcome	Description of activity to achieve outcome
1 – Scientific enquiry and problem solving skills: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using enquiry, problem solving, critical thinking and other skills.	Each activity provides an opportunity to exercise at least one scientific process skill. Learners are required to create a poster showing the areas in which rice was cultivated over the ages (data handling). In the second activity learners are introduced to the concept of hypotheses and different schools of thought. Throughout the learners are required to seek out information from various sources.
2 – Construction and application of Life Sciences knowledge: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.	Learners follow the history of the development of biotechnology through the ages, using rice and cattle as examples. Terms defined: speciation, tectonic movement, genome, endemic, domesticate, breeding, hybridisation, natural selection, genetic diversity. These terms are illustrated in the texts provided.
3– Life Sciences, technology, environment and society: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.	Modern biotechnology methods are based on traditions of thought in the past. The history of rice makes learners aware of the origin of this staple food, and its use by different cultures. Requirements by different societies have placed different selective pressures on various species. The value that humans have placed on beasts of burden in different societies has had an impact on the appearance of cattle today. Domestication of animals plays a large role.

1.2 Background Information

Background information supplied here comes from http://www.krysstal.com/inventions_02.html

Biotechnology has involved the identification and use of living organisms and their systems to produce products that are useful to mankind to improve chances of survival and quality of life. This selection is made from a huge pool of biodiversity on our earth. The following table shows how man has slowly gained more control over his environment and tamed it to his advantage:

Table 1: Inventions 10 000 BC to 4000 BC

Invention	When	Where	Notes
Fixed Settlements	9000 BC	Mesopotamia	in modern Iraq
Use of Copper	9000 BC	Mesopotamia	
Wheat, Pea, Olive Cultivation	8500 BC	Mesopotamia	
Domestication of Sheep, Goat	8500 BC	Mesopotamia	first use of milk
Pottery	7900 BC	China	
Rice and Millet Cultivation	7500 BC	China	Yangtze Delta
Domestication of Pig	7500 BC	China	
Banana Cultivation	7000 BC	New Guinea	
Sugar Cane Cultivation	7000 BC	New Guinea	
Sesame, Barley Cultivation	7000 BC	Indus River	in modern Pakistan
Aubergine Cultivation	7000 BC	Indus River	also called Eggplant
Domestication of Cattle	7000 BC	Indus River	cow, ox
The Yoke	7000 BC	Mesopotamia	power from animals
Coffee	7000 BC	Ethiopia	date uncertain
Weaving	6500 BC	Middle East	modern Israel, Lebanon
Domestication of Donkey, Cat	6000 BC	Egypt	cats for pest control
Fig Cultivation	6000 BC	Egypt	
Granary	6000 BC	Indus River	storage of excess food
Metal Smelting, Casting	6000 BC	Middle East	
Alcohol (Wine)	5400 BC	Mesopotamia	
Concrete	5000 BC	Central Europe	floor slabs for huts
Chili, Avocado Cultivation	5000 BC	Central America	
Scales, Balance	5000 BC	Egypt	
City States and Nations	4500 BC	Mesopotamia Indus River Yellow River	civilisation
Musical Instruments	4500 BC	Europe	pipes made of bone
Metalwork	4500 BC	Egypt	
Bridges	4000 BC	Africa	
Domestication of Horse	4000 BC	Ukraine	
Ox Drawn Plough	4000 BC	Mesopotamia	
Cosmetics, Fragrances	4000 BC	Egypt	

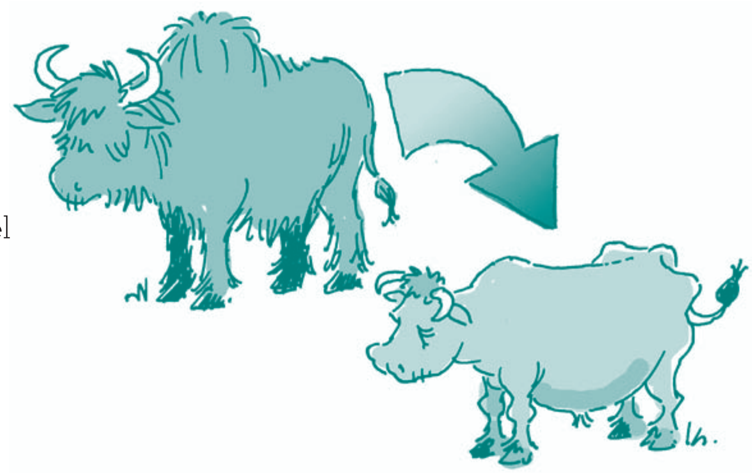
Key Moments

Early humans had been nomadic, following herds and roaming to new areas to gather food. They lived in family groups where every member had to contribute to acquiring food. Two key developments were the building of fixed settlements and the cultivation of certain plants for food. This changed the entire way of life for humans. Fixed settlement and regular food supplies meant that there was more leisure time. Humans could think and specialise. Not everyone had to produce food. Farming could give a food surplus. Some individuals could develop other skills (like making pottery) that they could exchange for food.

The use of fire allowed stone to be replaced by metal. Metals were first extracted from ores over a domestic fire. Metal was easier to mould into required shapes and was stronger. It could also be used for glittering ornamentation. The first chemists brewed coffee and wine. The domestication of large animals (the beasts of burden) gave human beings enormous power in agriculture, transport and warfare. Around 4500 BC, human settlements began to band together into cities and states. Civilisation had begun.

Table 2: Large Animal Domestication

Animal	**Ancestor**
Sheep	Asiatic Muflon Sheep
Goat	Bezoar Goat
Cow (Ox, Cattle)	Aurochs
Pig	Wild Boar
Horse	Wild Asiatic Horse
Arabian Camel	Wild Arabian Camel
Bactrian Camel	Wild Central Asian Camel
Llama, Alpaca	Guanaco (Andes)
Donkey	African Wild Ass
Reindeer	Siberian Reindeer
Water Buffalo	Asian Buffalo
Yak	Himalayan Wild Yak
Bali Cattle	Banteng
Mithan	Gaur



These are the beasts of burden that have increased the power available to humans. Power to move things, power to cultivate larger areas of land, power and mobility in war, power to have abundant meat available. Of the 200 or so large animals in the world, only the above 14 have ever been domesticated in all of human history. Many small animals have been domesticated (for example, dog, cat, and guinea pig). These smaller animals help humans in a number of ways (protection, pest control, pets) but the large animals give humans power. Their domestication was therefore a key step in the development of humans. Many factors must combine together for an animal to be domesticated. Even if a single factor is missing, domestication will not occur. Animals can be caught in the wild and tamed. They are considered to be domesticated if they can be bred and changed. Cheetah and elephant are two animals that can be tamed but have never been domesticated. These are the factors that will allow an animal to be domesticated and all must be present:

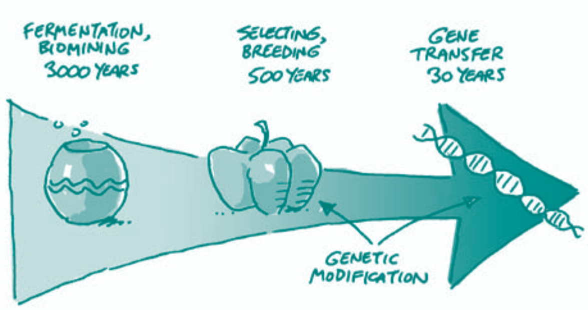
- **What they eat.** Herbivores eat plants. These are easier to obtain than the meat required by carnivores. None of the large carnivores has been domesticated because it would require too much effort and would use too many resources. Animals that eat common plants (like grass) are easier to domesticate and more useful than animals that eat a single type of plant found in limited areas. **Koalas**, who only eat eucalyptus leaves, are too fussy eaters to be domesticated.

- **How quickly they grow.** Animals that grow quickly are worth keeping. Long growing periods make animals like **gorillas** and **elephants** unsuitable for domestication.
- **How they breed.** Not all animals can breed in captivity. Some require a mating ritual that is too elaborate to be carried out in a confined area. This excludes animals like **cheetah** (who require several males to chase a single female over a large area) and **vicuña** (who require a long and complex mating ritual).
- **How they behave.** Animals need to be quiet and well behaved around humans if they are to be usefully domesticated. Animals that are unpredictable or attack people are not good candidates. This excludes **bears**, the **African buffalo**, **zebras**, **hippopotamus**, and **elk**.
- **How they react to danger.** When there is danger, some animals seek protection in herds, will stand their ground, and avoid running. These animals are suitable for domestication. Others are nervous, fast and have a tendency to panic. These animals are not suitable for domestication and include **deer**, **antelope** (both fast runners), and **gazelle** (who leap in panic if confined).
- **How they socialise.** Animals that have a tendency to herd together can be kept in a confined space. If they also have a social hierarchy there will be a dominant member that is the leader. These types of animals are very suitable for domestication. If humans are able to replace the dominant animal member, they can then lead the herd. A shepherd or even a sheepdog can herd sheep. Some animals:
    - herd but groups are territorial so can't be mixed together (many **deer**);
    - herd for part of the year but are territorial at other times (**rhinos**, and most African **antelope**);
    - have no dominance hierarchy so do not follow humans (American **bighorn sheep**); and
    - are solitary and do not mix well together (**leopard**).

The following table looks at the geography of large animal domestication:

Region	**Large Animals**	**Domesticated Animals**
Eurasia	72	13
Sub-Saharan Africa	51	0
The Americas	24	1
Australia	1	0

This section has looked at early biotechnology – the traditional use of plants, animals and microbes. Since then we have had conventional (Breeding, selection, mutation) and now modern biotechnology (molecular, DNA, gene transfer). The subsequent units will investigate this development of man's ability to harness the value of biology and biodiversity.



(Diagramme: time line from traditional to conventional to modern biotech)

Activity 1.1

Rice is a staple food all over the world. It is a very important source of carbohydrate. How and why did our ancestors tame rice? You can find the following information at www.riceweb.org. It is printed out for you here in case you do not have access to the web. Study the passage and answer the questions as you progress through it.

Here you will find a brief history of rice and some general information sources. There is so much to discover as one digs deeper into the world of rice that it cannot all fit in *RiceWeb*. We will use the General Information Sources area to point out some other sources as well as highlights or new linkages to explore. We hope that the many other World Wide Web sites that can be accessed through *RiceWeb* will also provide links from their sites to *RiceWeb*.

A Brief History of Rice*

* From the publication Rice: Then and Now by R.E. Huke and E.H. Huke, International Rice Research Institute, 1990.

Introduction

Rice is intimately involved in the culture as well as the food ways and economy of many societies. For example, folklore tells us that when the Kachins of northern Myanmar (Burma) were sent forth from the center of the Earth, they were given the seeds of rice and were directed to a wondrous country where everything was perfect and where rice grew well. Rice is an integral part of their creation myth and remains today as their leading crop and most preferred food. In Bali, it is believed that the Lord Vishnu caused the Earth to give birth to rice, and the God Indra taught the people how to raise it. In both tales, rice is considered a gift of the gods, and even today in both places, rice is treated with reverence, and its cultivation is tied to elaborate rituals.

QUESTION 1

Find out where Burma and Bali are and show them on the map of the world. You have a map at the end of this activity.

Chinese myth, by contrast, tells of rice being a gift of animals rather than of gods. China had been visited by an especially severe period of floods. When the land had finally drained, people came down from the hills where they had taken refuge, only to discover that all the plants had been destroyed and there was little to eat. They survived through hunting, but it was very difficult, because animals were scarce. One day the people saw a dog coming across a field, and hanging on the dog's tail were bunches of long, yellow seeds. The people planted these seeds, rice grew, and hunger disappeared. Throughout China today, tradition holds that "the precious things are not pearls and jade but the five grains", of which rice is first.

According to Shinto belief, the Emperor of Japan is the living embodiment of Ninigo-no-mikoto, the god of the ripened rice plant. While most modern Japanese may intellectually dismiss this supernatural role, they cannot deny the enormous cultural importance of rice on life in their country - and so it is in much of the rice world.

QUESTION 2

Go back to the map and show where China and Japan are.

Origin and Diffusion of Rice

Diffusion in this context means the spread. So we will be looking at how growing rice spread across the world.

The origins of rice have been debated for some time, but the plant is of such antiquity (so old) that the precise time and place of its first development will perhaps never be known. It is certain, however, that the domestication of rice ranks as one of the most important developments in history, for this grain has fed more people over a longer period of time than any other crop.

The earliest settlements of those persons responsible for domestication undoubtedly were in areas offering a wide range of plant and animal associations within a limited geographical area. Such sites offered a variety of food sources over a span of seasons to societies dependent on hunting and gathering for their food supply. These earliest settlements might well have been near the edge of the uplands, but on gently rolling topography and close to small rivers that provided a reliable water supply. For centuries, humans maintained themselves by fishing in the rivers, hunting in the forests, and gathering edible plant products. The earliest agriculture, a simple form of swidden, may have developed by accident when women of the settlement recognized that the mix of plant life growing around the midden was especially rich in edible forms. The earliest agriculture was probably focused on plants that reproduced vegetatively, but the seeds of easily shattering varieties of wild rice such as *Oryza fatua* may have found their way to the gardens at an early date.

Question 3

What is a midden?
Why do you think middens gave rise to agriculture?

If these assumptions are correct, then domestication most likely took place in the area of the Korat or in some sheltered basin area of northern Thailand, in one of the valleys in southwestern China, or in Assam.

Cultivated rices belong to two species, *O. sativa* and *O. glaberrima*. Of the two, *O. sativa* is by far the more widely utilized. *O. sativa* is a complex group composed of two forms endemic to Africa but not cultivated, and a third from, *O. rufipogon*, having distinctive partitions into South Asian, Chinese, New Guinean, Australian, and American forms. The subdivision of *O. sativa* into these seven forms began long ago and came about largely as a result of major tectonic events and worldwide climatic changes.

Question 4

What does "O." stand for in the above paragraph? What are 'tectonic events'? Why would 'tectonic events and worldwide climatic changes' have caused O. sativa to develop seven different strains?

The earliest and most convincing archaeological evidence for domestication of rice in Southeast Asia was discovered by Wilhelm G. Solheim II in 1966. Pottery shards bearing the imprint of both grains and husks of *O. sativa* were discovered at Non Nok Tha in the Korat area of Thailand. These remains have been confirmed by scientific testing as dating from at least 4000 B.C. This evidence not only pushed back the documented origin of cultivated rice but, when viewed in conjunction with plant remains from 10 000 B.C. discovered in Spirit Cave on the Thailand-Myanmar border, suggests that agriculture itself may be older than was previously thought. No parallel evidence has been uncovered in Egyptian tombs or from Chaldean excavations.

Early Spread of Rice

From an early beginning somewhere in the Asian arc, the process of diffusion has carried rice in all directions until today it is cultivated on every continent except Antarctica. In this early heart area, rice was grown in forest clearings under a system of shifting cultivation. The crop was grown by direct seeding and without standing water. Rice was grown on "farms" under conditions only slightly different from those to which wild rice was subject. A similar but independent pattern of the incorporation of wild rices into an agricultural system may well have taken place in one or more locations in Africa at approximately the same time.

It was in China that the processes of puddling soil (making small ponds so that puddles of water could be held, creating rice paddies) and transplanting seedlings were likely refined. Both operations became integral pats of rice farming and remain very widely practiced to this day. Puddling breaks down the internal structure of soils, making them much less subject to water loss through percolation. In this respect, it can be thought of as a way of extending the utility of a limited supply of water. Transplanting is the planting of 1- to 6- wk-old seedlings in standing water. Under these conditions, the rice plants have an important head start over a very wide range of competing weeds, which leads to higher yields. Transplanting, like puddling, provides the farmer with the ability to better accommodate the rice crop to a finite and fickle water supply by shortening the field duration (since seedlings are grown separately, and a higher density) and adjusting the planting calendar.

Movement to western India and south to Sri Lanka was also accomplished very early. The date of 2500 B.C. has already been mentioned for Mohenjo-Daro, while in Sri Lanka, rice was a major crop as early as 1000 B.C. The crop may well have been introduced to Greece and neighboring areas of the Mediterranean by the returning members of Alexander the Great's expedition to India ca. 344-324 B.C. From a center in Greece and Sicily, rice spread gradually throughout the southern portions of Europe and to a few locations in North Africa.

Question 5

Show the areas where rice spread to on the map below.

Interestingly enough, medical geographers in the 16th century played an important role in limiting the adoption of rice as a major crop in the Mediterranean area. During the 16th and early 17th centuries, malaria was a major disease in southern Europe, and it was believed to be spread by the bad air of swampy areas. Major drainage projects were undertaken in southern Italy and wetland rice cultivation was discouraged in some regions. In fact, it was actually forbidden on the outskirts of a number of large towns. Such measures were a significant barrier to the diffusion of rice in Europe. The suspicion that ricefields caused malaria did not entirely disappear with the end of the Renaissance.

As a result of Europe's great Age of Exploration, new lands to the west became available for exploitation. Early European settlers introduced rice cultivation to the New World. The Portuguese carried rice to Brazil, and the Spanish introduced its cultivation to several locations in Central and South America. The first record for North America dates from 1685, when the crop was produced on the coastal lowlands and islands of what is now South Carolina. Slaves brought from Madagascar may well have carried the crop to this area. Early in the 18th century, rice spread to Louisiana, but not until the 20th century was it produced in California's Sacramento Valley. The introduction in the latter area corresponded almost exactly with the timing of the first successful crop in Australia's New South Wales.

Question 6
Show all the other regions where rice has been cultivated on your map.

Question 7
In your groups, prepare a poster that will show the history of rice cultivation in the world. The poster should contain a simple story that can be read quickly by passing spectators at a school function. (About 200 words in large print)

Question 8
List the grains other than rice that are readily available in your nearest shop. Try and find where they were originally cultivated.

Map of the world to show where rice is grown.

Map from: august1.com/courses/ ibl/ibl-append.htm

Activity 1.2

How and why did our ancestors tame cattle? Cattle have played a big role in the development of our civilization and life style. Read the following passage and answer the questions to gain knowledge about how cattle became domesticated.

The passage comes from two different sources that you can access at the following websites:
http://www.unh.edu/news/archive/2000/february/sk_20000215oxen.html
http://news.nationalgeographic.com/news/2002/04/0411_020411_africacattle.html

Gene Study Traces Cattle Herding in Africa

Ben Harder, for National Geographic News, April 11, 2002

Mixed Results

An extensive new study of genetic variation in African cattle sheds light on how the domestication of cattle unfolded differently in Africa than elsewhere in the world.

History changed with the beginning of farming and the domestication of animals. Following centuries of people cultivating soil with picks and spades, the first draft animal was put to work in early agriculture. The ox was used long before the horse and other equine animals (such as the donkey) became domesticated. Oxen provided the draft power that helped create an agricultural revolution by allowing farmers to till more land, harvest crops in a timely manner, and transport crops and other goods in large quantities over great distances.

The first oxen were most likely domesticated in southeastern Europe and western Asia, most likely in Greece and Turkey. Cattle husbandry in that region was common 7000 years ago. Other than the domestication of the dog, domestication of cattle was the most important step in manipulating the animal world and exploiting the land for agricultural purposes. Cattle supplied the meat, milk, leather, manure and power for agriculture.

African herders rely on cattle for food and other basic needs, and as beasts of burden. (Beasts of burden are animals that carry or pull heavy items i.e. draft animals). Migrations of people and their herds and trade have caused the path of how cattle domestication occurred in Africa to become muddled. Now, by studying the DNA of cattle in 23 countries, an international team of scientists is filling in the picture.

Evidence suggests that sheep and goats, first domesticated in the Near East, were imported into Africa through colonization and ocean-going trade. Scientists have long speculated

that the domestication of cattle also occurred first in the Near East and that the practice of herding cattle was similarly imported. But new evidence suggests that Africans independently domesticated cattle.

Belgian geneticist Olivier Hanotte, who headed the new study, said the research "reconciles the two schools of thought" about how cattle domestication occurred in Africa. "There were Near Eastern influences" on African herds, he said, "but they came after local domestication." Since then, there has been considerable mixing of African and Asian breeds.

Question 1

Who is Olivier Hanotte?
What do geneticists do?
What are the "two schools of thought" that Hanotte speaks about?

Unusual Pattern

In general, the domestication of cattle and other livestock has followed the establishment of agriculture. But archaeological research has shown that the domestication of cattle unfolded differently in Africa than elsewhere in the world. In many parts of Africa, people herded cattle long before agriculture was introduced from the Near East and south Asia. Some African groups that have herded cattle for centuries have never adopted agriculture at all, or have done so only recently. One example is the Masai of eastern Africa, who rarely slaughter cattle but instead mix the milk and blood of the animals to create a staple of their diet.

Question 2

How did cattle domestication differ between Africa and the rest of the world?

Intrigued by the uncommon pattern of cattle domestication in Africa, Hanotte moved to Kenya in 1995 in an effort to explain the development. He and other researchers in Europe began untangling layers of genetic information in cattle DNA to help answer major questions about the history of herding in Africa. Their findings offer scientists and herders a virtual history book describing how cattle, crucial to so many Africans, came to be so genetically diverse. The research also underscores why preserving that variety is essential.

Question 3

What does the writer mean when he says "genetically diverse"?

Genome is the total collection of genes that make one type of organism.

Hanotte and his colleagues analyzed more than a dozen segments of the cattle genome. The researchers compared this DNA material among many individual cattle belonging to 50 different herds in 23 African nations. Herders, scientists, and government officials in those countries aided the study by tracking down sometimes-remote herds, testing them, and transmitting the data to Hanotte and his team. When Hanotte and his colleagues analyzed the samples of cattle DNA, they found that the variation associated with certain segments of genetic code reveal a telling geographic pattern across Africa.

Question 4

What is the cattle genome?

The nature of genetic variation changed like the colours of a rainbow as the researchers looked at cattle from West Africa, Central Africa, and southern Africa. The greatest amount of genetic diversity was found among herds in Central Africa. Based on the data, Hanotte and his colleagues concluded that people living in Central Africa developed cattle domestication on their own, and that the techniques—or the herders themselves—gradually migrated toward the west and the south, spreading domestication across the continent.

Mixed Origins

In looking at the wide genetic variation among African cattle, the researchers found evidence of interbreeding between cattle native to Africa and an imported breed. Most modern African herds represent mixtures of two breeds: Africa's native cattle, called taurines (*Bos taurus*), and a slightly larger Asian breed, known as zebu (*Bos indicus*), which was domesticated before it arrived in Africa.

Long-distance trade across the Indian Ocean brought many domesticated plants and animals to Africa, including the chicken and camel and cereals such as finger millet and sorghum. Presumably, Hanotte said, trade also brought zebu bulls that farmers interbred with domesticated taurine cows, producing the mixed herds of today. Some variation in the African herds is also attributable to European influences, Hanotte said. These genetic contributions came in the past few hundred years, during Europe's colonial influence in Africa.

Question 5

Which two events changed the cattle that were endemic to Africa?
Why do you think the African people allowed interbreeding with imported cattle?

For thousands of years, animal farmers have gradually improved their livestock by selectively breeding animals with different desired traits to give the offspring valuable characteristics. Resistance to sleeping sickness is one trait that potentially could spread through selective breeding. Taurine cattle in one region of western Africa, unlike most livestock, are resistant to this parasite that causes the deadly disease. But the number of animals with the protective adaptation is dwindling, as local farmers give up their taurine herds for large zebu animals. Hanotte, along with other people, is worried by this trend. "The starting material for selective breeding is diversity," he said. "We can't afford to lose it."

Question 6

Discuss a major problem that can occur if all the endemic cattle are replaced with imported cattle.

Question 7

Explain the meanings of the following terms:

- **Domesticate**
- **Breeding**
- **Hybridisation**
- **Natural selection**
- **Genetic diversity**

Question 8

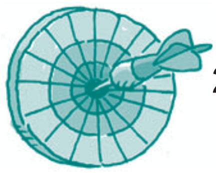
Apart from cows, goats and sheep, what other animals were domesticated and why?

Question 9

Why have zebras and rhinos not been domesticated?

Endemic means traditionally found in that area.

Unit Two - Man Selects From a Pool of Biodiversity



2.1 Objectives

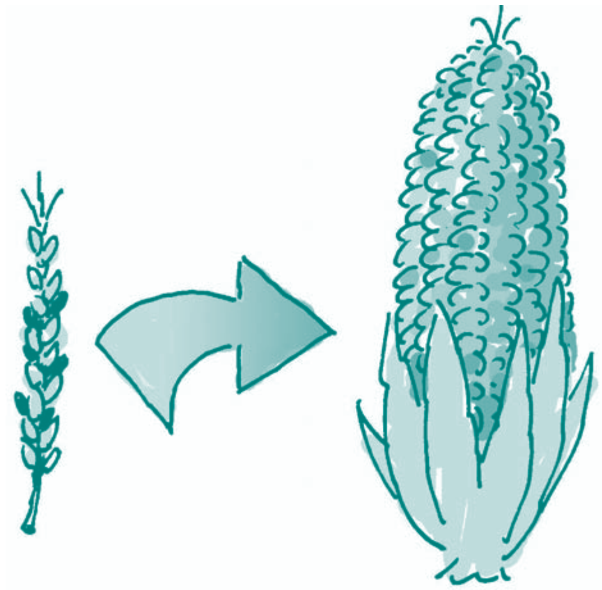
Based on the activities and discussion in this unit, you will be able to:

Learning Outcome	Description of activity to achieve outcome
1 – Scientific enquiry and problem solving skills: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using enquiry, problem solving, critical thinking and other skills.	Learners seek out information regarding the origin, development and modern varieties of certain cereal crops. Critical thinking skills include selecting and organising data as well as making inferences, deductions and conclusions from the data gathered.
2 – Construction and application of Life Sciences knowledge: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.	By means of selected texts and interpretative exercises the learner understands the concepts of germplasm, ploidy, special hybrids.
3 – Life Sciences, technology, environment and society: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.	Man has a long history of selective breeding. Crossing best yielders is an ancient practise. This is illustrated by selective texts outlining the history of cereals. Learners become familiar with the impact made by the development of cereal crops, including maize, on the development of different communities.

2.2 Background Information

Having identified useful organisms from the biodiverse pool available, man initiated a process of genetic improvement to adapt the organisms to improve their desired characteristics. The desired characteristics are those that would benefit man the most, for example, production of more edible parts of a plant or livestock and better disease resistance.

The very first techniques man would have used in his crop selection would have been simply to keep some of the seed from the best yielding plants to replant the following season. In animals he would have crossed his best yielding female animals with males that were also good yielders. Thus the woolliest ram was crossed with the woolliest ewes and better wool producing lambs were born than would have been the case if average wool yielders were mated. This process of selecting the best for breeding is called selective breeding. And so ancient man continued to keep his best seed and cross the best with the best until his crops and livestock hardly resembled the first organism selected from nature. Today almost every organism farmed throughout the world looks very different to its ancestor that was selected by ancient man for farming.



Although selective breeding changed organisms from their wild forms to the more modern forms we see today that suit us well, we have to bear in mind that the environment continues to change. Because of this continual change, we will never have an optimum crop or livestock form that will be perfect for all time. New diseases occur, increased yields are required for expanding populations and extra nourishment per capita are just some of the pressures that farmers are faced with that will require further breeding or genetic change of crops and livestock.

The important point to realise here is that for millennia man has genetically altered the selected organisms that he farms with, but he has not reached the point where he can merely stop and say "We have the perfect crops and livestock and no more improvements are needed". Man has to respond to changes in the environment and the needs of people by continuing to change the genetics of his farm organisms.

With modern advancements of the last century, we have added several techniques to this modification arsenal that assist in genetic manipulation. Before we look at those in more detail, let us have a look at how our ancestors have brought some of our important foodstuffs and farm animals from the wild to the forms we find them in now.

We will start off by looking at how man selected a simple grain of grass and changed it into a staple cereal used world-wide today. We look at some selections he has made where nature has thwarted progress and finally we look at where the selection has gone wrong and should be more controlled.

Activity 2.4.1

Use your imagination to picture what might have happened several thousands of years ago as our ancestors changed from a nomadic to a more settled way of life. Read the following passage to develop your mental image then answer the questions at the end.

A group of around four hundred primitive people walked away from their African homeland into south east Asia. They were faced with new environments that posed new problems to solve, but also new opportunities to make survival easier. As time moved on, this group gave rise to new generations, increasing the numbers in the group too. The group split into smaller groups and again ventured on through south east Asia looking after themselves. Soon south east Asia was inhabited by different groups of people who looked after themselves in different environments.

These very first people lived a nomadic lifestyle, moving through forests and fields looking for fruit, vegetables and meat. They gathered the seeds of plants and ate them. After removing the "glumes," or husks, early people simply chewed the kernels raw or cooked. Early people discovered a particular type of nourishing edible grass in the fertile areas. They remembered where they harvested the nourishing seeds and returned to the same area year after year to harvest them again for food. As the centuries went by, the descendants of the nomads realised that they could harvest more seeds than they needed and store them for use when they were no longer available in the fields. So instead of only being able to eat the seeds when the plants were ready, they could save some for the winters too. They also realised that they could plant the seeds in tilled soil to increase the yield for their use.

Perhaps they tried to plant the seeds they took home but found that they only grew in fertile areas. So when the groups started to cultivate the seeds they had to move to the fertile regions and settle there while they nurtured their crops. The nomadic lifestyle changed and the first settlements or villages started springing up. People now had sufficient time to think and plan. They thought about such things as improving their harvest, their village and their lifestyle. They began observing the changing seasons and cycles of the moon, stars and planets. Over time, they understood the meaning of seasons better. The ability to cultivate grain marked the beginning of civilization. Once people settled in one place, crafts, arts and communication - verbal and written - flourished. People needed to exchange views and understand each other, so verbal language began developing. Not long afterwards, a series of symbols were invented as means of communication - the origin of written language. Religious practices, economic and political power, and even wars resulted, making the availability and control of wheat a vital part of human history.

All this was caused by man's use of seeds of wheat.

Now different villages around the south east Asian fertile crescent all selected their own wheat seeds from their harvests. Selection was based on reliability of growth and harvest, productivity, disease-resistance, and suitability for their food use. This select grain was used for seed the next year. Over the years different communities had slightly different wheat varieties with different characteristics being expressed in different intensities. So some areas had a wheat variety that tasted really good and made excellent bread, but only a few seeds were produced in each ear. Other areas might have had wheat with ears full of plump seeds but the plants succumbed to disease after any particularly heavy rainfall. Each group had their own germplasm.

What is germplasm?

(Adapted from http://www.westerngrains.com/forfarmers/ir208a.html)

"In textbook terms, germplasm is the collective hereditary genetic material of a life form combining the variations of many different, very closely related entities. Essentially, it's the material that houses an organism's blueprint for life. Plant germplasm includes genes that determine everything from how a crop yields to how well it stands up to disease.

Germplasm has been around for as long as life itself, but the term is distinctly modern, one that has become more common as science has advanced. As plant breeding has taken crop science down to the level of molecules, germplasm has become the term used to describe the raw material that plant breeders manipulate to develop new crop varieties.

In crop breeding circles, germplasm used to be thought of mainly as physical plant material - something that could be touched and seen. Today, it's viewed more specifically as the genetics within a plant, independent of the plant itself. This is an indication of the new power of science to identify and work with genes at the molecular level."

Discuss the following questions in groups. Use all the resources you have available, including the internet, to source information to inform your discussions. Formulate comprehensive answers that you will later present in class.

1. What characteristics were sought after in wheat in ancient times? (The answer is in the text).
2. What do you think the term "germplasm swapping" means? If necessary, find out by doing an internet search or speaking to a biologist in your community.
3. How would the people in our story above have benefited from "germplasm swapping"?
4. What would 'germplasm' have meant to ancient man as opposed to what it would mean to a wheat scientist today?

5. Why is it important for African communities to preserve their cassava germplasm?

Cassava is a drought tolerant root crop grown throughout Africa, Asia and South America. It is an important staple food. It is reproduced by stem cuttings, so no sexual reproduction occurs and no seed is collected.

6. Many cereals were also included in early man's agriculture. These included, from oldest to youngest, millet, oats, rice, barley and wheat, with rye and maize following. Select one of these cereals (not rice or wheat) and find out as much as you can about where it originated, how and where it developed and how many varieties are available today.

Activity 2.4.2

Two stories are given below about the origin of wheat, how it is used and what impact it has had on cultures. The stories are written by different writers: the first by scientists, the second by a lay writer, possibly a high school essay.

1. Read these two stories and consider their differences in the light of who wrote the text.

2. Both writers consider what impact the cultivation of wheat had on the development of communities. In sub-Saharan Africa the staple cereal is maize. Consider how maize cultivation impacted on early African communities in South Africa and illustrate this in a poster for the classroom.

3. Early European communities in South Africa probably brought seed with them from Europe. Debate how these seeds fared in our soils and how the seeds may have adapted to local growing conditions.

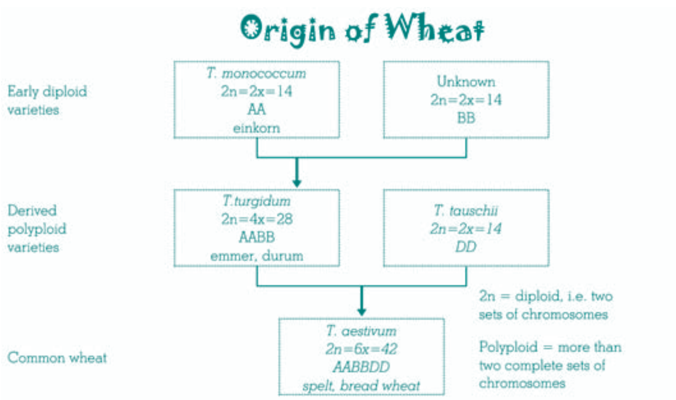
4. Wheat is largely unsuited to growing in Africa. Consider how the conversion from wheat to maize may have occurred on commercial farms. Illustrate this in a poster that shows the factors that put pressure on the emigrant farmers to change their favoured crop from wheat to maize.

Article 1. History and Origin of Wheat

http://web.utk.edu/~bcannon/

Wheat is grown on more land area worldwide than any other crop and is a close third to rice and corn in total world production. Wheat is well adapted to harsh environments and is mostly grown on wind swept areas that are too dry and too cold for the more tropically inclined rice and corn, which do best at intermediate temperature levels. Wheat is believed to have originated in south western Asia. Some of the earliest remains of the crop have been found in Syria, Jordan, and Turkey. Primitive relatives of present day wheat have been discovered is some of the oldest excavations of the world in eastern Iraq, which date back 9000 years. Other archaeological findings show that bread wheat was grown in the Nile Valley about 5000 B.C. as well as in India, China, and even England at the same time.

The exact origin of common wheat (*Triticum aestivum* L.) remains a mystery with many parts of its history unknown. However, the best information currently available indicates that an ancestral species in the Middle East evolved into various diploid (2n=14) progeny (*Triticum monococcum*). Among these diploid genera and species are: the ancestors of durum and common wheat, rye, barley, and numerous botanical grasses. The evolutionary process of the early beginnings of wheat is known as divergent evolution. After divergent evolution, a reverse process began known as convergent evolution. In this process, many of the diploid species hybridized and formed polyploids (having more than two complete genomes). The best example of an early polyploid is Emmer wheat (*Triticum turgidum*), which is a tetraploid (4n=28). One cultivar of Emmer wheat underwent a mutation which caused the bases of the glumes to collapse at maturity which made separation of the seed from the chaff easier, and this mutation was known as Durum wheat. These free-threshing wheat varieties could produce raised breads. Durum wheat now is grown mostly for pasta and noodles in areas of low rainfall. The final step in the production of modern bread wheat resulted from Emmer (4n) being crossed with *Triticum* sp. (2n), which yielded (*Triticum aestivum*) the 6n progeny of the cross. *Triticum aestivum* is therefore a hexaploid that contains genetic material from three different species.



This figure is adapted from a powerpoint presentation by Jochum Wiersma (http://www.nwroc.umn.edu/16)

Ploidy describes the number of chromosome sets in an organism.
Haploid = one set (from either the mother or father parent
Diploid = two sets (usually one from each parent, like humans)
Polyploid = more than two sets of chromosomes

Article 2. Wheat

Source (edited): From Wheat To Flour. Revised Edition, 1976, Washington DC, Library of Congress Catalogue Card No. 76-27767. http://www.bogasariflour.com/english/ref_wheat.htm

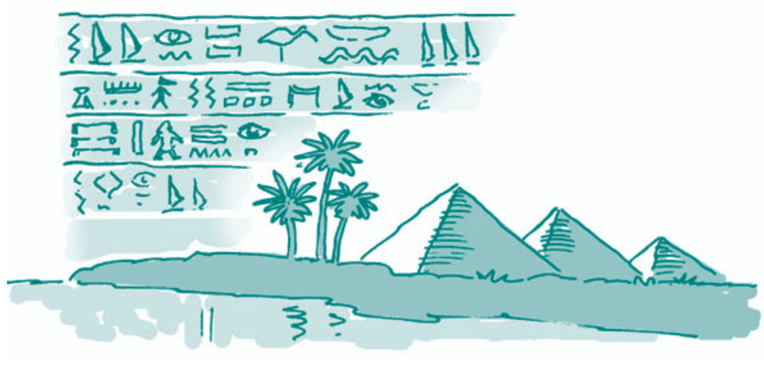
For more than 10 000 years, wheat and wheat-based products have been a pioneer of mankind's welfare, freed mankind from the shackles of nomadic living, introduced agriculture and trade and made them freely practice art and science. We can say that modern civilization grows from one seed of wheat. The significance of wheat nowadays is not comparable with its position in the history of mankind. Mankind proves to have cultivated wheat before they learned to keep records. Wheat cultivation is as old as civilization itself.

The History of Wheat

No one knows the origin of wheat but where it was first cultivated, where mankind first appeared, i.e. in South-east Asia. It is even figured out that mankind has used wheat as food at least ten thousand through fifteen thousand years BC. In 1948, an archaeologist from the University of Chicago found an ancient village in Iraq, built 6700 years ago. In the ruins, the archaeologists found two types of wheat which are similar to today's wheat. The first humans were nomads, who were always moving along forests and fields to find their means of living. Until one time, they found a kind of grass, i.e. wheat, which was edible. In those days, they marked the place, return annually to harvest the edible grass.

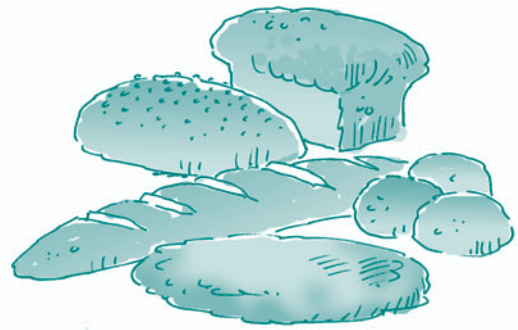
After passing several centuries, they began to realize that wheat could be kept to fulfil their need for food in winter, and seeds of wheat could be planted in spring. Because wheat is only suitable for fertile land with sufficient rainfall, finally they moved to that place. To live around the site of their wheat field and to utilize their harvest, the ancient mankind made a kind of shelter. If the land was indeed wide and fertile, many other families would come and join them, and they would build small villages for the sake of common security. When they were not living as nomads anymore, they had sufficient time to think and make plans, such as improving their harvest, their settlement and their pattern of life. They began observing the changing seasons, and the longer they did this, the more they understood the meaning of time. Gradually nomadic communities transformed themselves into agricultural communities. Due to the need to exchange views and mutually understand each other, verbal language began developing. Not long afterwards, a series of symbols were invented as a means of communication, the origin of written language. All of these developments were caused by seeds of wheat.

There are so many kinds of our daily food containing wheat that we sometimes are not aware of them. For instance bread, the most popular food made from wheat, has been found among ruins of an ancient village near a lake in Switzerland. However, it is estimated that wheat was the first food mankind chewed after they peeled the kernel's skin off. Wheat, which is found during excavation of ancient towns, often takes the form of carbon; its skin is likely to be peeled through heating process. Heated or dried kernels indeed make their skin easily peeled off. Other varieties of cereal, such as corn, popcorn, rice, and early varieties of wheat can be popped out of their skin. It is vaporization of moisture trapped inside that makes the seeds pop out.



One interesting fact about wheat is that it is still consumed primitively in many parts of the world. Primitive equipment used in early ages of wheat civilization is still used to-day. With the development of mankind's writing capability, the story about wheat was recorded in history. Several bronze tablets dated back the ninth century BC telling of activities of wheat milling and a bakery in Assyria were found. In the fifth century, Herodotus, an ancient Greek historian, wrote about bakery in Egypt. Several cemetery walls along the Nile show illustration about wheat planting, harvesting, milling and bread baking. They also found storage of wheat and hardened bread in various cemetery buildings. Even Egyptians used to sift flour for making bread, and this was usually carried out by the upper classes. It is commonly agreed that Egypt is the first place where mankind made bread which can rise.

Reference to wheat can also be found in other parts of the world. Ancient inscriptions in China explain about wheat cultivation in 2700 BC. Up to now, wheat is still considered sacred in several places in China. In 300 BC, Theophrastos, a Greek, wrote about varieties of wheat growing along the Mediterranean. A number of records, artefacts, and results of excavation in ancient towns show progressive development of wheat milling and bread baking in Greece and Rome up to the Middle Ages.

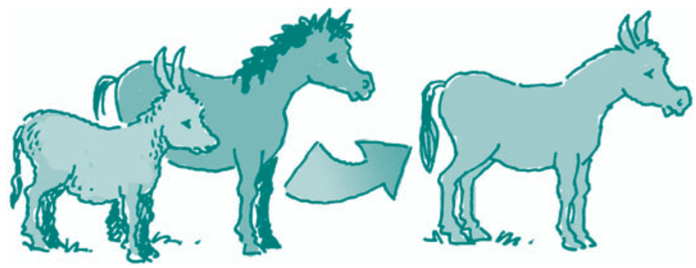


Speculation regarding the first rising bread is still ongoing among scientists. After mankind learnt about wheat grinding, they also learnt to make various kinds of porridge, from the thin to the thick, by adding water. If the weather condition is favourable, porridge dried outside will be naturally fermented. This method was later used by man to make beer or rising dough. By adding a little water, yeast present in the flour made the dough rise, such as sourdough bread eaten by American explorers. Activities to make bread and beer increased in line with increasing capability and skill of mankind. Out of many varieties of cereal, it is only wheat that has cellular structure suitable to make raised bread products.

Activity 2.4.3

Special hybrids

(Information from http://wwwequisearch.com/breeds/m_r/muleprofile062401/)



Sometimes nature has not allowed man to select the best for his needs and develop the organism further on his own. This is the case with the mule. Our ancestors crossed donkeys and horses for various reasons since ancient times but what characterizes them is their stubbornness. This may be because of their high level of intelligence and strong instinct for self-preservation. These traits may make them more difficult to train, but may also make them the dependable, loyal companion that their owners cherish so much. Mules have a diverse history. The Hittites held them as far more valuable than a chariot horse, and the mule was the favoured mount of the kings of Israel in Biblical times. In the Middle Ages, the mule was the chosen mount of the clergy.

To keep a stock of mules, horses (*Equus caballus*) and donkeys (*Equus asinus*) have been deliberately crossed. A male mule cannot be mated with a female mule to breed more mules the way a good cow and bull can be bred to produce better calves. The horse and the donkey have differing numbers of chromosomes so meiosis in a mule cannot occur properly resulting in infertility.

Use the Internet to search for information on mules and then answer the following questions:

1. Find definitions for the following terms; jack, jenny (or jennet), stallion, mare, hinney.
2. By looking at the Latin names for the horse and the donkey, make a statement about the relationship between the two species.
3. Mules have physical characteristics drawn from both parents but its conformation (i.e. size and shape) comes from its mother. However some characteristics of mules are always the same. What are some of these characteristics?
4. What are ligers and tigons? After defining them, write a paragraph on each, using information from the Internet.
5. Find the Latin names for the parents of ligers and tigons. Make a statement about the relationship between the two species.
6. Are ligers and tigons sterile like mules?
7. What is a li-liger?
8. What are other hybrids of these hybrids called?

For the following two questions you have to think about using the knowledge you have of taxonomy and genetics. You will not find these answers on the Internet.

9. What is the difference in the relationship between the parents of a mule and the parents of a liger?
10. How can the difference in sterility between the hybrids be explained?

Activity 2.4.4

Fast Growing Broilers

Man has on occasion changed an organism so much to suit his own desires that it has resulted in cruelty to the animal. A particular case in point will be the way he has tried to get a chicken to grow as big as possible in as short a time as possible to eat.

Read the following passage and think about answers to the questions contained in the text.

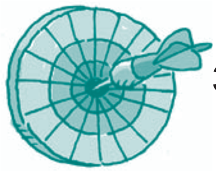
> Chickens are bred mainly for two purposes – egg laying capacity and maximum meat mass. Chickens bred for eggs will be selected based on the number of eggs the hen lays in a certain period. Such a hen does not have to be meaty and plump because she serves her purpose through laying eggs. She will earn her keep by laying eggs. Broilers are chickens bred for their meat quality. In order for the farmer to make a profit he has to get a chicken to an edible size as quickly as possible. Broilers will therefore be selected on their speed of growth and stocky shape. The selection for these characteristics has resulted in some broilers growing so quickly that their bones cannot hold their weight and they have severe problems with their legs. Some are so deformed eventually that they cannot walk properly at all. They outgrow their legs, heart and lungs and many suffer and die of heart disease.

1. It can be argued that if the bird is slaughtered at a stage before these complications set in then they are not really a problem. This means that just as the bird reaches adult size, although not yet mature as an adult, it is slaughtered and eaten before it can pick up any problems resulting from being overfed. However, what is the problem the farmer has in terms of his long-term business if he carries on with this practice?

To prevent this from happening, farmers tried to feed the broilers a restricted diet. BUT, one of the effects of breeding for quick growth is at the same time they were bred for their voracious appetites. So now restricted feeding which would be good for the skeletal formation of the broiler actually results in the birds being hungry much of the time. And a hungry bird is an unhappy, stressed bird.

2. When you consider the problem of overfeeding with the problem of trying to keep some breeding stock, what solution would you propose for the broilers welfare? Explain your answer in detail.

Unit Three - Genetics



3.1 Objectives

Based on the activities and discussion in this unit, you will be able to:

Learning Outcome	Description of activity to achieve outcome
1 – Scientific enquiry and problem solving skills: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using enquiry, problem solving, critical thinking and other skills.	Learners investigate the techniques used to clone animal tissues and illustrate their summaries by means of a poster. Learners explore different biotechnological methods, collate the data and present their findings by means of a poster. Scientific texts are interpreted, summaries are made in diagrammatic form and applied knowledge is synthesised into an essay.
2 – Construction and application of Life Sciences knowledge: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.	By means of carefully structured texts and guided exercises learners become familiar with the following term: Hybridisation, radiation, chemical mutation, gene transfer, cloning. Various biotechnological methods are introduced and illustrated with practical examples: micropropagation, somatic embryogenesis, cell suspension cultures, germplasm conservation, molecular markers and genetic transformation. Real-life examples include tissue culture of bananas and the production of transgenic flowers.
3 – Life Sciences, technology, environment and society: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.	Population pressures create a constant demand for new varieties. Various articles and structured exercises allow the learner to appreciate the increasing demands made on forestry, the development of commercial tree hybrids and the impact of forestry on biodiversity. Articles relating to the cloning of animals, applications of cloning in food production and health care are critically discussed, debated and presented in various other formats. Learners discover the advantages of indigenous plant nurseries to traditional healers.

3.2 Background Information

Selecting and breeding for certain traits has been successful over the years. The problem is that it takes a long time to breed the organism that is being anticipated. If a farmer had a good strain of mielies that he wanted to improve by just one characteristic from another strain then he would have to cross them. Of the progeny that arose, most would have changes in the already good characteristics in the original parent(s). This would result in progeny that are not as good as the original parent(s). After several years of selecting many thousands of crosses from breeding the farmer might be lucky enough to find a single plant that has all the good properties of the original parent and just the one characteristic from the parent that he used for the improvement. To develop an improved strain from breeding has its own time consuming procedures. To sum it up: Breeding for change is hit and miss. As a result, it can be enormously time consuming and therefore also very expensive.

Over the last century mans understanding of genetics developed to a point where he can go beyond selecting and hybridizing to manipulate organisms for the product he wanted. Today it is essential that new varieties be created quickly to respond to urgent population pressures, environmental degradation and growing constraints. The growing knowledge of genetics has given man the ability to do just that. Today with molecular biology techniques the decades of breeding can be bypassed by using various genetic modification techniques.

Hybridizing is the combining of genes from two different parents.
It is commonly used in conventional breeding programmes.

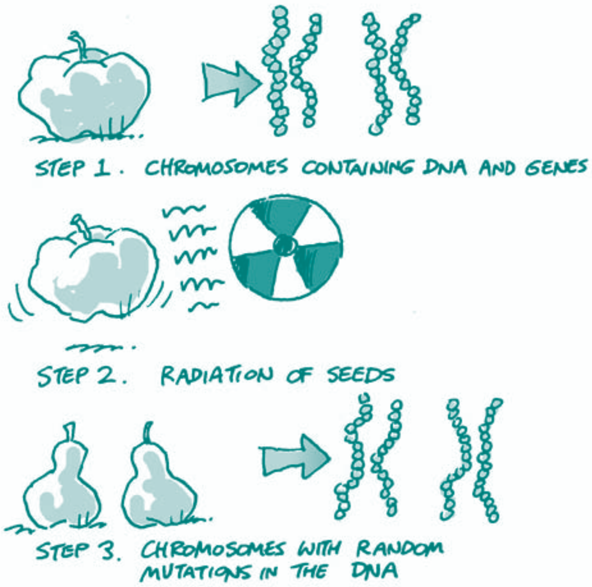
Broadly speaking the genetic modification of plants occurs by three mechanisms:

1. Hybridization: natural and through breeding
2. Radiation and chemical mutation: natural and in laboratories
3. Gene transfer: in laboratories

Radiation mutation has been used since 1963. In this process plant seeds are exposed to gamma radiation that mutates the DNA randomly. High doses result in too many mutations and the seeds are unable to germinate. Low doses cause a smaller number of mutations and, as long as none of these affect critical processes, the seeds germinate. Many are discarded, but those with observable differences (colour, shape, development time, resistance to pests and disease) are kept for further study. If they prove novel and beneficial they are included into plant breeding programmes and evaluated as new varieties.

Radiation mutation has produced 2252 new plant varieties. These include varieties of wheat, barley, oats, rice, soybeans, string beans, navy beans, potatoes, onions, cherries, apples, grapes and others.

The improvements have been to pest resistance, quality, yield and adaptability to specific environments.



These mutations also raise safety concerns, but these have been dealt with within the breeding programs where the new varieties are carefully assessed by the breeders to ensure that they are improved, safe, stable, uniform and novel.

Gene transfer is very easily explained but in reality it is more difficult to apply. All it means is the gene for the desired characteristic is identified in a donor organism, it is "cut" out of the DNA of that organism and then pasted into the recipient organism which we want to improve with the desired characteristic.

The power of gene transfer is the ability to take genes from any donor (microbe, plant, animal) and insert them into any recipient (microbe, plant, animal), giving breeders much for to work with when trying to improve an organism.

Activity 3.3.1

Animal Clones

Read the following article and cartoon and complete the exercises that follow:

This article can be found at http://news.bbc.co.uk/2/hi/africa/3007043.stm

Cow becomes Africa's first clone

A cloned calf has been born in South Africa, which scientists say is Africa's first cloned animal.

The female was born on 19 April and was the copy of a champion milk cow, which produced up to 78 litres of milk a day. "She's doing brilliant," veterinarian Morne de la Rey told BBC News Online. She has been named Futhi, which means "replica" or "repeat" in Zulu. Dr de la Rey said Futhi had been cloned using an "egg-shell free" or "zona-free" oocite technique, which is different from that used to make Dolly the sheep, the world's first animal cloned from an adult cell.

Record-holder

Futhi was the result of collaboration between the South African Embryo Plus centre and scientists at the Danish Agriculture Institute. Her white and black markings are almost identical to those of the donor cow, a Holstein heifer, referred to as LMJC865. The cow is South Africa's record-holding milk cow. She produced 20,426 kilograms of milk in 300 days, Dr de la Rey said. Futhi was born in Brits some 65 km north-west of Johannesburg. "Futhi is definitely Africa's first cloned animal," he said. Dr de la Rey said that they wanted to prove that it was possible to clone an animal in Africa. "In the short term, it's not commercially viable," he said. "We don't even know how much it cost." But he hopes that in the long-term, cloning will start making money for African farmers.

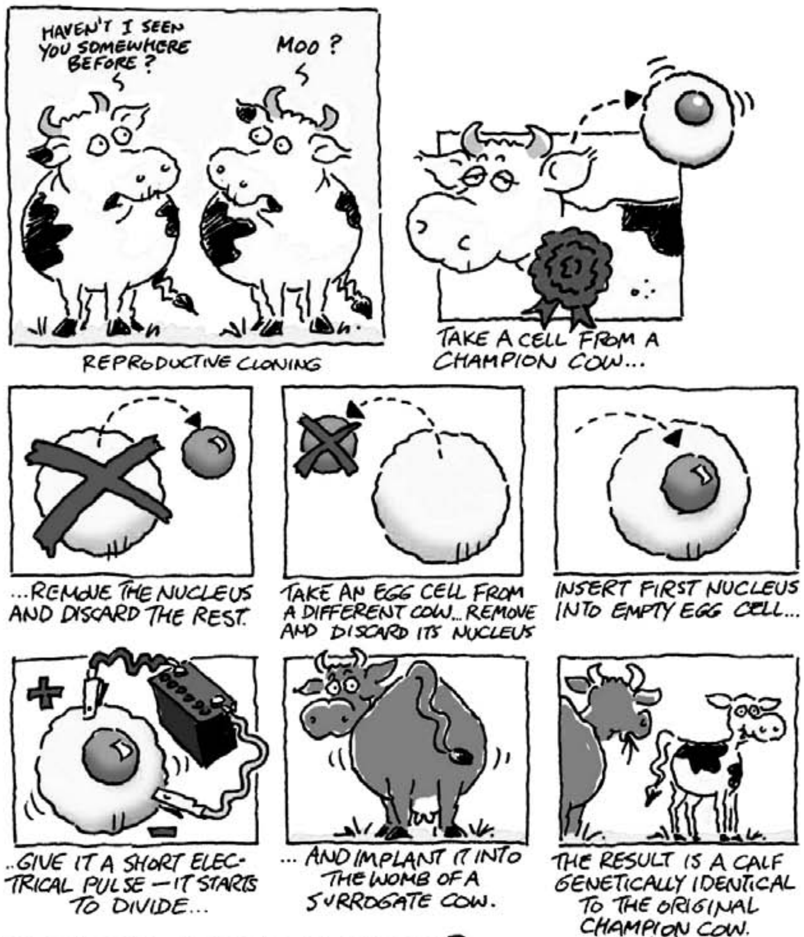
1. Debate what impact this new animal cloning technology will have on society. Your topic could be either "Animal cloning will lead to the destruction of civilization as we know it," or "Animal cloning will be the best answer for increased meat and milk production in this country."

2. Consider what benefits animal cloning could have for society with respect to food production and health care. Present these to the class.
3. Investigate what other animals have already been cloned and what benefits, if any, they offer. Present your findings to the class orally or as a poster.
4. Investigate what techniques are needed to clone an animal and present your findings to the class orally or as a poster.

5. Animal cloning suggests that it is now possible to clone human beings. Consider the ethics of this activity and present your thoughts as an essay.

HOW FUTHI WAS CLONED

Futhi is the first cloned animal in South Africa. Futhi, (meaning "again" in Zulu) is an identical copy of a nine year old Holstein cow and former milk-producing champion called LMJC 865. Instead of receiving half of her genetic information from each of two parents (from a sperm and egg), Futhi was made using a technique called cloning. She received 100% of her genetic material from LMJC 865 – who is not her mother, but her identical twin, nine years older than her!



WHAT DO YOU THINK ABOUT CLONING?

The Department of Science and Technology has launched a Public Understanding of Biotechnology programme to ensure a clear, balanced understanding of the scientific principles and potential of biotechnology, while promoting dialogue around its applications. The aim is not to state an opinion but to explain the science and related issues.

If you have opinions, questions or concerns about cloning or other areas of biotechnology, let's hear from you at **speakup@pub.ac.za** or fax (012) 320 7803.

DEPARTMENT OF SCIENCE AND TECHNOLOGY

PUBLIC UNDERSTANDING OF **BIOTECHNOLOGY**

Visit www.pub.ac.za for more information.

http://www.pub.ac.za/resources/docs/cartoon_futhi_eng.pdf

Activity 3.3.2

Biotechnology in the forest industry

Article 1

1. Article 1 below describes some of the biotechnology tools used to improve forestry trees in South Africa. Prepare a poster of these techniques showing how they impact on forestry, or on another area of plant-based industry, like horticulture.

2. Article 1 talks about the increasing demand for forestry products. List what these are and consider if there are other organisms (microbes, plants, animals) that could be developed to produce some of these products more cost-effectively than trees. Present your finding and thoughts as a poster or an essay on 'possible alternatives to forestry'.

3. Find out how any one of the biotechnology tools introduced in Article 1 are used to develop other plants, such as those used in medicine, horticulture, fibre production or food production. Present your findings in an essay on the application of one biotechnology tool for improving plant production in the various sectors.

Article 2

4. Article 2 introduces the commercial use of a new tree hybrid in Australia. Remembering that a hybrid is a cross between 2 species, draw a figure that illustrates the cross and the new variety. Give the names of the varieties used and list the benefits that result from the cross. If you have access to the internet, you should be able to work out which parent plant gave which characteristics (traits) to the new variety. Contact the company if you need to.

5. Article 2 indicates that a new hybrid will have considerable value to forestry in one area of Australia. If most forests are planted with this new hybrid the biodiversity of the commercial forests in that area will decrease. Consider what the benefits and concerns would be about reducing biodiversity in a forestry area. Present your findings in a poster or oral presentation.

Article 3

6. Article 3 primarily gives information about the role forestry plays in South African society and in rural populations. Investigate the value of trees to any rural community and present your findings to the class orally or as a poster.

7. Article 3 investigates the impact forestry has on biodiversity. Consider this issue and devise ways in which forestry could be managed to have less negative impact on local biodiversity. Present your findings to the class.

ARTICLE 1

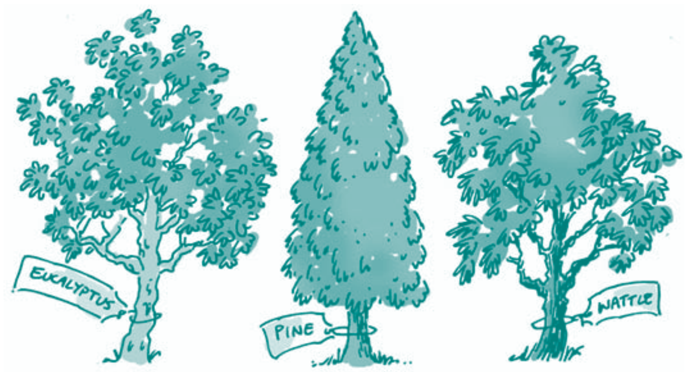
Using biotechnology forestry development

(Adapted from "Developments in the use of Biotechnology in Commercial Forestry Tree Improvement Programmes in South Africa". M.P. Watt , F.C. Blakeway , B. Herman , N. Denison. XI WORLD FORESTRY CONGRESS. Antalya, Turkey, 13 to 22 October 1997.)

Summary

As the South African population and its demand for forest products increases, and land available for forests declines. Concerted efforts are needed to ensure sustainable forest production. Although the traditional practices of tree culture and tree breeding remain important in forestry activities, existing conventional breeding and production programmes are limited by the long growth cycle of forest trees and the problems breeders have to distinguishing between genetic traits and environmental effects. Biotechnology and its associated disciplines of biochemistry, physiology and genetics, play an important role in addressing some of these issues. Plant biotechnology methods offer current and future applications for tree improvement programmes in South African forestry.

Introduction

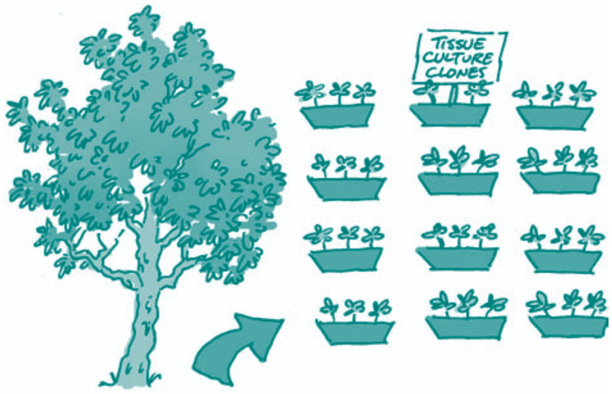


World demand for forest products is increasing rapidly and shortages have been forecast to occur in the near future. Although traditional forest improvement programmes are helping in the industrialised world, efforts have lagged in the developing countries where the shortages will be most felt. Further, if indigenous forests, grasslands and floral biodiversity are to be preserved in southern Africa, commercial forestry production needs to be carefully managed. Consequently, there is an urgent need for research to increase the productivity (yield) and quality (superior wood, best stem form, uniformity, resistance to environmental stresses) of important forest trees, such as *Eucalyptus*, *Pinus* and *Acacia* spp.

Biotechnology, together with biochemistry, physiology and genetics, plays an important role in addressing these issues in tree improvement, selection of best genes, mass propagation and biodiversity conservation, to name a few. It is in this context that a research programme was initiated in 1989 between the University of Natal and Mondi Forests. Its main goal is to develop biotechnological techniques to assist tree-breeding programmes. It is hoped to achieve improved production without needing more land, or by using marginal land more effectively.

Biotechnology techniques used in forestry breeding and production programmes

Biotechnology is the management of biological systems for the benefit of humanity and it includes the conventional methods of plant breeding and cultivation. Additionally, "modern" biotechnology offers many new techniques for overcoming the constraints of large tree sizes, slow growth and reproduction. Some of the biotechnology techniques in use today are discussed below.



Micropropagation

Currently, increased production of selected, superior tree varieties (genotypes) is being accomplished with the help of micropropagation. Cost-efficient tissue culture techniques have been developed for most of the important forestry species: eucalyptus, pine and wattle. The process begins with cuttings taken from plants that are known to grow well. In a laboratory, these cuttings are induced to grow between 10 to 40 shoots by adding special growth hormones. Each shoot is removed, planted and induced (with different hormones) to grow roots. The rooted shoots are then acclimatised (hardened-off) in soil in a greenhouse. At Mondi Forests, 30 to 50 tree clones are used regularly to produce about 4 200 eucalyptus plants monthly.

Results indicate that growth rates, uniformity and quality of the micropropagated plants are equal or better than those produced conventionally, by collecting and planting seeds. If the better growth rates are maintained in the plantations, it may be possible to harvest the trees before seven years, which is the current time needed for eucalyptus trees in South Africa to mature.

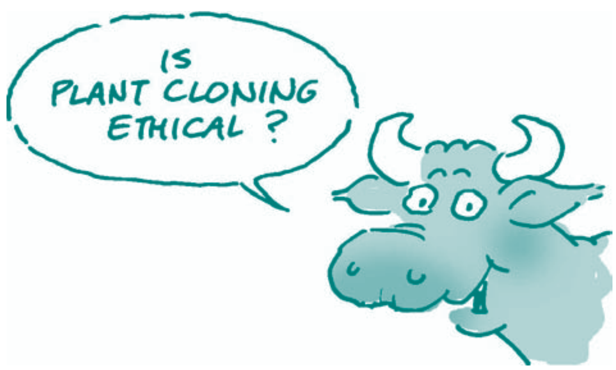
Micropropagation is the mass production of millions of plantlets in tissue culture. These are sold as improved planting material. They are often clones (genetically identical) and disease free.

Somatic embryogenesis

Somatic embryogenesis is the production of embryo-like structures (baby plants) from non-reproductive (vegetative) cells. This technique offers a number of improvements over micropropagation. The most significant benefit is that it results in plantlets that have both root and shoot buds, so hormone treatments are not needed to develop shoots and roots. Also, plantlets developed from these somatic embryos have tap root systems The first eucalyptus plantlets produced by somatic embryogenesis were planted in 1988 in South Africa and it is interesting to note that these plants started flowering a season before plants produced from seed.

Cell suspension cultures

A cell suspension culture consists of uniform and actively growing cells dispersed in a liquid culture medium. These tree cell suspensions offer an excellent tool for research and as recipients for new genes, inserted for genetic modification. These cell suspensions also offer a way to store tree types cost effectively for long periods in a frozen state. This helps breeders to keep gene banks of

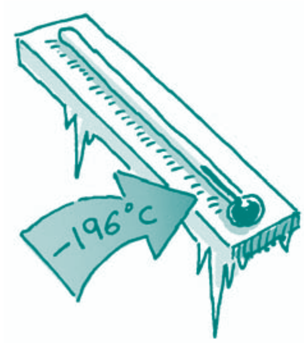


useful tree varieties and to keep a wide diversity of genes available for future breeding programmes.

Germplasm conservation

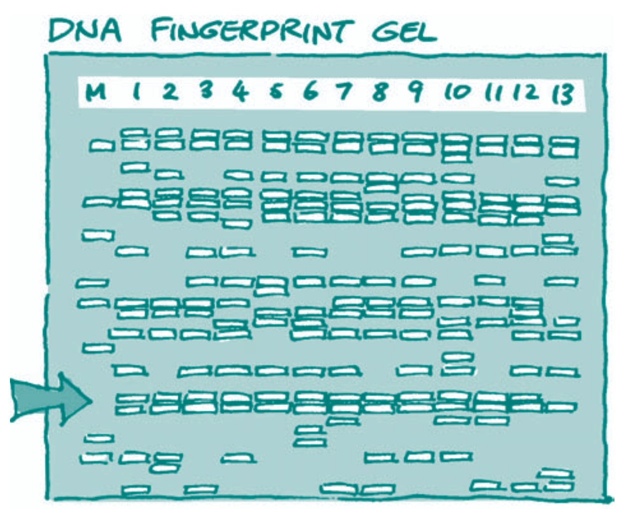
In common with agricultural crops, a tree breeder has to develop varieties for specific growing areas without losing the genes from old varieties. These genes may be needed in the future to cope with changes in environment, growing methods, end use, pests or diseases. This can be achieved by storing plant material (tissues or cells) under minimal growth storage (temperature below 10°C, reduced oxygen supply, reduced nutrients, etc.) or frozen liquid nitrogen (cryopreservation).

Germplasm describes all the different varieties of a single organism.



Minimal growth storage provides a medium-term solution only, as cultures lose their viability after a few months. In South Africa eucalyptus is stored under minimal growth conditions (very low nutrient medium, 4°C) for six months, without loss of viability. Under cryopreservation (at -196 °C) biological material may be stored indefinitely. As only very small pieces of tree material can survive the freezing stress, plant parts used for cryopreservation include buds, tissue cultured cell clumps, cell suspensions and pollen. Before freezing the plant tissues need to be prepared. This usually means treatment with cryoprotectants (e.g. glycerol, sucrose) that minimise freeze damage to the plant cells. The major benefit is the ability to store tree varieties without need for land, planting and management costs.

Molecular markers



In the breeding and selection of new tree varieties it can be difficult to see the improvements caused by gene rearrangements. Protein changes are used to identify some new characteristics, but DNA markers allow for the identification, or "fingerprinting", of unique, individual genotypes (collection of genes that make a specific variety). At present, the most popular of the DNA marker system is the PCR-based (polymerase chain reaction-based) DNA technique that is also used in animals, microbes and humans (e.g. forensics). This technique allows for positive identification of individuals and the comparison of gene similarities (relationships) between individuals. DNA profiles have already been established for many important tree species and the varieties within these groups. These DNA profiles (molecular markers) help breeders to identify which offspring from crosses are the best to keep in the breeding programme and which ones can be destroyed without losing important genes. As such, this technique saves money and time in forestry breeding programmes.

Genetic transformation

The ability to genetically engineer forest tree species has enormous potential applications for tree improvement. In recent years there have been a number of reports of successful gene transfer into tree species. Mostly these genes are for resistance to pests or to speed up growth, but some novel applications are also being tested, e.g. trees that can remove cadmium from contaminated soils. Genetically modified trees are undergoing field trials in the US, Canada, the EU, Australia and South Africa. No commercial releases have yet been approved.

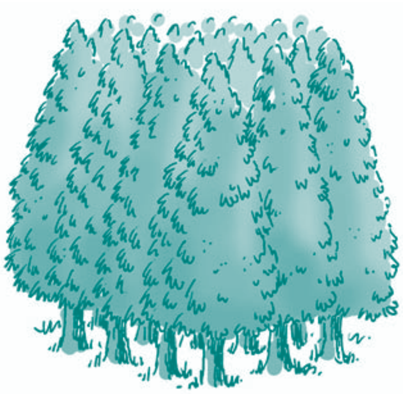
Concluding remarks

Applied biotechnology has allowed important technical achievements world-wide over the past 10 years. Several of these techniques, such as tissue culture, already have direct applications in forestry breeding and production programmes in South Africa. Cryopreservation of germplasm allows the storage of potentially tree varieties in the laboratory rather than in the field. Technologies such as DNA markers are being used to speed up breeding programmes as well as to identify novel genes in important tree species. The challenge that lies ahead will be to gain a better understanding of tree development, in order to maximise the benefits offered by biotechnology.

ARTICLE 2.

Cloned pines grow better timber faster - Australia.

Adapted from Australian Government Press Release, 17 October 2003. Found at LSN 21 Oct 2003
http://www.lifesciencesnetwork.com/news-detail.asp?newsID=5048



The conversion of Queensland Government-owned exotic pine plantations in the south-east of the State to clonal forests will produce better timber in a shorter period, Primary Industries Minister, Henry Palaszczuk, says. Inspecting DPI Forestry's (an Australian company) clonal plantings at Beerburrum north of Brisbane, Mr Palaszczuk said the plan was to convert the entire 130 000 hectares of exotic pine plantation in south-east Queensland to clonal plantings.

"DPI Forestry is planting a hybrid of Caribbean pine and Slash pine that can be harvested years earlier rather than the normal 30-year rotations, and the timber is of better quality. It will ensure more competitive and higher quality timber for the marketplace, whether it is for housing construction, plywood, furniture or fencing. This puts DPI Forestry, and in turn the Queensland timber industry, at the forefront of commercial pine forestry nationally and internationally."

Mr Palaszczuk said the trees boasted tolerance of wetter sites and wind firmness as well as straightness, finer branching and more uniform wood density. "For Queensland's Au$1.7 billion timber industry, this means consistent wood quality, with straightness, smaller knots and more useable timber from each log."

DPI Forestry's plantations supply more than 80% of timber to the industry. The company produces more than 3 million clonal pine cuttings for planting in south-east Queensland each year at its own nurseries.

Clonal plantings refer to the planting of genetically identical plants derived from a single parent through tissue culture techniques.

ARTICLE 3.

The State of Forestry in South Africa Today (shortened)

http://www/polity.org.za/html/govdocs/green_papers/forest2.html 13 Oct 2003

This section provides background information to the policy debate and a useful resource on forestry and the forestry industry in South Africa. (Written around 1996.)

1. Relationships between people and forestry

1.1.1 Introduction: who are the stakeholders?

All South Africans have a stake in forestry in South Africa. We all benefit, or should benefit, from products such as construction timber, paper, mining timber, fuel wood and other products that satisfy our material needs. We all benefit from the environmental values of our forests and woodlands. Shareholders of the 400 or more companies, which have invested in forestry, are also important stakeholders. But the people most involved in forestry are rural people and the workers in the forest industry.

Rural energy

One-third of households in South Africa are estimated to rely on fuelwood. Women in these households often walk great distances to fetch firewood. Average time spent this way is estimated conservatively at five hours per household per week. Use of this kind is estimated at about 11 million tons of wood per year, of which about 6.6 million tons is estimated to be harvested from natural woodlands. The amount of wood consumed for household needs equates nearly to that used in the formal forestry industry, which provides sales of R8 billion per year.

However, alternatives to woodfuel are not readily nor soon available. Rural households spend excessive time on collecting wood because there is no way of earning money to buy fuel. The current, massive household electrification programme will first deliver to urban communities, and will require decades to reach the majority of families in the countryside. In the mean time, sources of wood are being depleted.

Influence of manmade forests on biodiversity

The density of plantations with closed canopies eliminate the majority of grassland and other native species that previously occurred in the natural habitat.

Nevertheless, some species do survive in plantations either by dispersing into the new habitat or by remaining and adapting to the changed habitat. For example, a study on the Eastern Shores of Lake St Lucia in Zululand indicated that 64 plant species were recorded within plantations, compared with 114 species in the adjacent secondary grasslands and

142 species in the adjacent secondary thicket and forest. The plantations replaced these two vegetation types. A total of 330 plant species were recorded in young pine plantations along the Mpumalanga Escarpment. Most of these species were weedy species or woody species, and in general were not grassland species. Nevertheless, biodiversity is substantially reduced. In the Western Cape, natural vegetation surrounding plantations has three times as many birds as adjacent young plantations and ten times as many birds as adjacent old plantations.

At a larger scale, i.e. the scale of the landscape, the impacts of afforestation (creating more forests) on biodiversity are less severe than at the scale of planted habitats because on average about 60% to 70% of the average forest estate is planted to trees, with most of the unplanted areas being managed for conservation.

Disruption of natural ecological processes such as fires is another major impact of afforestation on biodiversity at the landscape scale. Fires would have occurred naturally in most habitats, but are now being excluded or controlled. Furthermore, annual firebreaks in grassland areas adjacent to plantations are undertaken during early autumn. Fire during autumn is not a good season for maintaining grassland biodiversity. The result of these disruptions to fire disturbance processes in grassland is a change in grassland composition and a loss of species.

Other effects include fragmentation of habitats, which inhibits animal and plant dispersal processes with the potential to cause local extinction, disruptions to hydrological processes, which often cause wetlands to dry up, with the associated loss of wetland species, and the spread of invasive exotic trees and shrubs from the plantations (most endangered plant species like the fynbos are threatened by these invasives).

Thus, though forest estates do contribute to conservation of biodiversity, the indirect effects of afforestation would need to be carefully managed.

Overall, afforestation reduces biodiversity, a cost which is inevitable if we are to meet our needs for wood. The concerns presently are that:

- affected habitats and species should be adequately conserved in appropriate reserves as well as on forest estates where possible;
- afforestation should continue where justifiable, but should not proceed in areas important for the conservation of biodiversity;
- effective assessment is needed to ensure that proposed afforestation is properly evaluated in terms of biodiversity impacts.

Some experts maintain that too much afforestation has occurred, and that it must be reduced. This is especially in areas of attractive scenery, or special conservation value. Afforested land is being cleared in the Eastern Shores of St Lucia for this reason. Pressures are mounting to do so in districts such as those along the Drakensberg.

Activity 3.4.3

Banana tissue culture

Article 1, below, is a report from the Philippines on the opening of a new banana tissue culture laboratory. What impact could tissue culture have on the biodiversity of bananas planted in the country and what could the laboratory do to ensure that biodiversity remains high?

Article 2, below, shows how biotechnology is being used in South Africa to provide healthy planting material and to conserve indigenous plants.

a. Would you say that the introduction of banana tissue culture has decreased or increased the biodiversity of bananas in South Africa and how would you support your answer?
b. Develop a poster for the Institute that advertises its indigenous plant nursery to traditional healers in the area.

Article 3, below, introduces a tissue culture project in Kenya. Part of the project is designed to document (record) local cultivars and conserve them. How is this being done and what importance might this have in the future? What differences are there likely to be between planting material on commercial farms and among 2000 small scale farmers? Present your answer as a one-page essay with examples.

Article 4, below, is a description of tissue culture work in the Pacific region. Yams and bananas are important crops in Central and East Africa. Black Sigatoka is a huge problem in Uganda where savoury and sweet bananas are the staple food. Could the ORE project help Uganda? Write a letter to the Ugandan government suggesting that they contact ORE and how you think the ORE project could assist them.

ARTICLE 1.

DA-CAR Opens Banana Tissue Culture Laboratory

Robert L. Domoguen, June 8, 2003 (adapted)

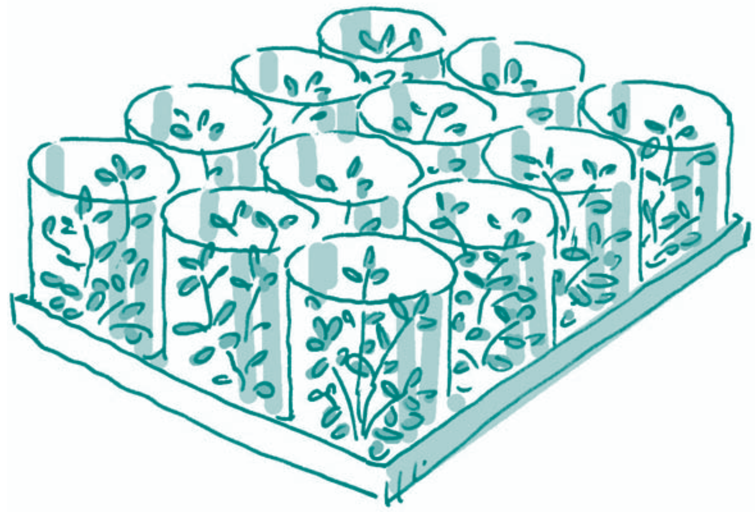
http://members.tripod.com/da-car/news/2003/jun/da-car_opens.htm 13 Oct 2003

The Department of Agriculture (DA-CAR), Philippines, is now operating a plant tissue culture laboratory. This facility is currently based at the department's Regional Crop Protection Center (RCPC) in Baguio City.

The laboratory is tasked to produce 10000 *in vitro* (in glass containers), disease-free plantlets of bananas this year in support of the on-going banana rehabilitation program in the region. Aside from the production of banana plantlets, the laboratory is also involved in the production of disease-free seeds of potato and strawberry, reported Mr. Ruben Dulagan, Regional Coordinator of the GMA - High Value Commercial Crops program.

According to Mr. Lito Mocati, a technical staff member of the GMA program, the bunchy top virus affects almost all banana-producing municipalities in 80 % of the region's production areas. The bunchy top virus is considered as a major disease affecting banana plants and production. Affected plants have bunchy leaves and do not grow or bear fruit.

Bananas such as *Saba*, *Lakatan*, *Latundan*, *Bungulan* and others, are planted on about 8790 hectares of land in the region. The major banana producing municipalities are all participating in the programme.



The current average yields of bananas is 130 - 150 fingers per bunch, which is equivalent to 11 tons per hectare. GMA technology demonstration projects in the region have shown that by using *in vitro* tissue cultured banana planting material, the yield of bananas can be increased to 180 - 200 fingers per bunch or 14 tons per hectare, reported Mr. Mocati.

However, the Bureau of Plant Industry (Los Banos) remains the major source of *in vitro* tissue cultured and disease-free planting materials in the Philippines. This indicates that the new laboratory can expand considerably with the current demand for good banana planting material.

ARTICLE 2.

Biotechnology at the Agricultural Research Council in Nelspruit (adapted)

http://www/arc/agric/za/institutes/itsc/main/highlights/biotech.htm 13 Oct 03

Through the years this programme has played a vital role in the establishment of tissue culture techniques for various subtropical crops such as citrus, pineapples, bananas, avocados, mangoes, granadilla, ginger, papaya and pepper.

Bananas

Some of these methods were so successful that the propagation method of an entire industry (i.e. banana) is now based on tissue culture. Techniques for various other crops have been established during the past 25 years. **These achievements set the stage for the practical implementation of biotechnology and the various successes flowing from the programme are proof of that.**

Plant establishment and growth in the nursery and field has always been an obstacle in the tissue culture industry. Establishment and growth of banana plants in the nursery was significantly improved by the addition of *Bacillus* spp. (common soil bacteria) to the soil of the plants in the nursery. Improved growth of banana tissue culture plants in the nursery reduces the time occupied by the plants in these expensive structures allowing an increased turnover. The addition of specific bacteria to the soil enhance establishment and growth of banana tissue culture plants in the field and promote early flowering. This leads to a reduction in cycle time and increases yield per annum in banana. These findings promote the current approach of world-wide agriculture to rely more on biological processes and biotechnology applications.

A programme aimed at providing a range of improved banana varieties with durable disease resistance has been successful. Thirty-two banana cultivars and selections were imported, and 113 local banana selections have been made. These cultivars and selections were started, multiplied and evaluated for fungal (*Fusarium*) resistance in field trials. A further 126 variants were produced by mutation. Every variant was screened twice for *Fusarium* wilt resistance under quarantine conditions in the nursery. All surviving plants were kept, hardened-off and planted in the field. This programme has led to the identification of 7 *Fusarium* tolerant varieties that are currently being evaluated for their horticultural characteristics and the registration of two new banana cultivars.

Indigenous plants

The unit has initiated one of the largest indigenous plant breeding programmes in South Africa. The programme is currently working with 360 indigenous species and will expand to 500 by the end of the year. The aim of the project is to develop crops that are well suited to resource poor farmers in marginal agricultural areas. It is hoped that the crops used in the programme will enable resource poor farmers to exploit their traditional knowledge and develop into commercial farmers.

Medicinal plants

Siphonochilus aethiopicus, or wild ginger, is a rare and endangered plant species that is extremely high in demand on both the local informal medicinal plant markets as well as on the international markets. In order to prevent the unnecessary plundering of the remaining wild populations of the species, this programme investigated the feasibility of setting up a gene bank and commercial production facility for planting material to encourage homestead cultivation of the species. The tissue culture techniques were developed to make this possible. Plants are multiplied and supplied to the conservation authorities to ensure the continued survival and use of this valued medicinal plant. The project has initiated test programmes to protect indigenous knowledge and ensure the flow of royalties back to the communities.

With regards to the forestry industry the Institute developed a rejuvenation system for eucalyptus based on clonal propagation, and helped to establish the largest hardwood tissue culture laboratory in the southern hemisphere at the time, with a production potential of 30 000 trees a day. Commercial results indicated increases up to 400% in yields for clonal plants when compared to conventional seedling plants. In addition, the increase in vigour induced by the rejuvenation process and appropriate clone selections reduced harvest periods from the traditional 7-8 years to 4-5 years.

ARTICLE 3.

Jomo Kenyatta University of Agriculture and Technology (JKUAT)

kahangi@africaonline.co.ke

http://www.africancrops.net/Research/kahangi.htm 13 Oct 2003

Banana improvement project in Kenya

This project is aimed at understanding the banana agronomy in Kenya in order to better manage the germplasm, planting regimes and production levels in the area. Here the project leaders report on their progress to date.

Project Outputs

1. We have collected important information on banana production from over two thousand small-scale farmers in the Mt. Kenya region using Participatory Rural Appraisal (PRA) method;
2. We have trained about four hundred farmers on nursery management, banana agronomy and post harvest handling of bananas in the Mt Kenya region;
3. We have established six village nurseries and six demonstration plots in the region following participatory approach;
4. We have collected the local banana cultivars grown in the above region and initiated studies on their in vitro conservation and DNA characterization.

ARTICLE 4.

ORE[1] operates a small tissue culture laboratory to rapidly multiply improved disease free plant material.

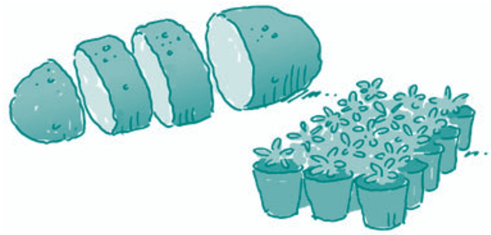
http://www.oreworld.org/tissue.htm

Tissue Culture

The tissue culture laboratory is used to produce healthy banana plantlets from selected commercial varieties for distribution to farmers using material selected from international and local sources. The program is working on reproducing commercial varieties of both cooking and eating bananas which are resistant to the Black Sigatoka. This deadly fungal disease, which has decimated production in many Caribbean, Central and South American and African countries, has been recently identified in the northwest of Haiti. Although banana represents an important source of revenue and nutrition to the rural population, production levels have steadily declined over the past decade. The plant material has degenerated in quality and has become infested with nematodes and diseases. Trials have shown that improved, disease-free plants from the lab generate approximately twice the revenue of traditional materials.

Tissue culture is the most rapid method of propagation of valuable disease-free material.

Minisetting



Minisetting is a rapid propagation techniques which is used to quickly and inexpensively produce plant material, whether it is banana plantlets or germinated seeds for yam production. Bananas produced in the laboratory can be rapidly multiplied using minisetting to make healthy plantlets available to farmers on a commercially significant scale.

[1] **Organization for the Rehabilitation of the Environment:** ORE was established in 1985 in the south of Haiti. They saw the potential economic and environmental benefits of grafted fruit trees for Haitian farmers and set out to introduce high value fruit trees as a permanent feature of the Haitian agricultural system. The organization was started off with a grant by the Canadian Embassy to produce 16 000 grafted fruit trees. At the time this was the first large scale grafting of fruit trees to be attempted in Haiti. The project was a success and was quickly followed by a larger program funded by USAID to produce over 100 000 trees.

Activity 3.4.4

Genetically Modified Tea

Tea is grown in many parts of the world, including South Africa. It was originally grown for its use as a refreshing drink in the east but, as travel around the world increased and more people shared their culture, tea became a sought after beverage for almost everyone around the globe.

One problem with tea however is that it contains caffeine, a common ingredient in many of our beverages that has an effect on the human body. Some people cannot drink tea at night because the caffeine in it can keep them awake. Also, the sports fraternity sees caffeine as a stimulant. Many athletes are not allowed to drink any beverage containing caffeine for fear of being excluded from their sporting events because of drug testing.

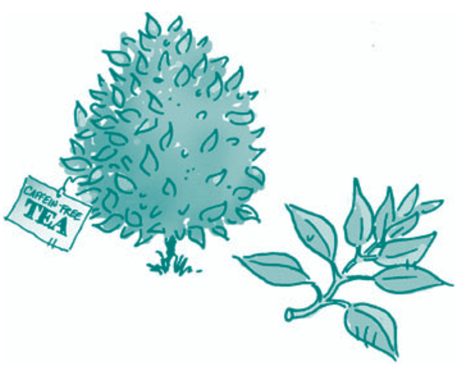
Scientists are attempting to produce genetically modified tea plants that are more disease resistant and can grow in a wider variety of climates. Plants that can produce superior quality tea and reduced caffeine content are also being created using transgenic (gene transfer between species carried out in a laboratory) techniques.

Read the following article and answer the questions that follow.

http://gray-seddon-tea.com/archive.shtml

GM Tea

Naturally decaffeinated tea may soon be grown
[The Tea Business September 2000]



British and Japanese researchers have tracked down the genetic source of caffeine in tea. Over the past few months the world's press have reported on the tea cloning research carried out at the University of Glasgow, Scotland and Ochanomizu University in Japan. Having previously identified one of the key enzymes involved in the mechanism, the researchers have gone on to clone (isolate) a gene in tea responsible for caffeine biosynthesis. Most *Camillia sinensis* (or *C. assamica*) varieties grown contain about 2 to 3% (dry mass) of caffeine. There have also been varieties of tea propagated with naturally lower caffeine. However, the development of genetically-modified tea plants would give rise to a cup of tea completely, and 'naturally' free of the substance. Caffeine is cited as the prime cause of many ailments, including irregular heart rhythms, gastro-intestinal irritation, anxiety, insomnia and increased blood pressure. The news of naturally decaffeinated tea is thought to be welcomed by many tea drinkers who are sensitive to caffeine, or would prefer to limit intake. Improvements in food processing to strip the tea-leaf of its caffeine have tried to satisfy the 'decaf' tea drinkers. Unfortunately, all attempts to decaffeinate the leaf have also altered flavour and aroma, and the beverage comes a poor second to the original. Years of plant breeding programmes in Africa, India, China and Japan have uncovered many new tea clones which have steadily improved the qualities of the tea beverage. Most new varieties of tea have been propagated in rich nations like Japan. Such producers have managed their tea stocks by a programme of continued investment in research. If tea drinkers accept the caffeine-free GM teas which are sure to follow, then growers would be forced to re-stock their gardens with the new caffeine-free clone. At a time when most tea gardens and plantations lack very basic investment, the costs associated with the mass re-plantings necessary to meet supply would be a daunting prospect, and one the tea industry could not afford.

1. Why is the genetically modified tea considered 'naturally' free of caffeine?
2. What is the difference between the way someone who is pro GM and another who is against GM would describe the term "natural"?
3. Why would GM caffeine free tea be considered better by tea lovers than teas that have had the caffeine removed after harvesting?
4. What are some of the effects of caffeine on the human body?
5. Do all people suffer from these side effects? Explain your answer.
6. Give two reasons why you think 'Joko' and 'Five Roses' do not contain GM teas at present.

Activity 3.4.5

Transgenic Flowers

The cut flower market has been transgenically creating new varieties for some time now without much resistance from the public. The lack of resistance is probably because the flower industry does not produce anything humans will eat and therefore possibly be harmed by.

The following article tells of the development of a genetically modified orchid. Orchids are sought after for their beautiful flowers and are generally very expensive. Orchid breeders put a lot of effort into trying to breed more unusual and more beautiful orchid flowers. Read about how Professor Chia Tet Fatt went about creating a novel orchid in Singapore…

World's First and Only Geneticall Engineered Bioluminescent Orchid Up For Auction

http://www.hybridorchids.com/FullMeRe.html (Adapted)

Researcher demonstrates how his orchid hybrids can be used for new educational and business opportunities

9 November, Singapore - The world's first and only genetically modified bioluminescent orchid has been successfully developed by Prof. Chia Tet Fatt from the National Institute of Education (NIE). In line with the government's technopreneurship thrust, Prof. Chia has teamed up with a home-grown start up, InterAuct! Pte Ltd, to create novel business opportunities for this original hybrid orchid. The rights to name and grow this unique orchid will be put up for auction to the public, through the Internet. Spurred on by his scientific success, Prof. Chia has ventured on to pioneering scientific learning and understanding for primary and secondary school students, through project work related to orchids.

Creating a "Glow-in-the-dark" Orchid

To create the bioluminescent orchid, Prof. Chia transformed tissues from orchids (the Dendrobium genus) using the firefly luciferase gene. Using a method called "particle bombardment", biologically active DNA from the firefly gene was delivered into orchid tissues. Transformed cells were identified by their bioluminescence trait. These transformed tissues were propagated and used to generate transgenic plants (plants with a foreign gene incorporated into every cell). This process was repeated several times, and the bioluminescent trait was present in all transgenic plants. This confirms that the firefly luciferase gene has been integrated into the orchid.

Unlike fluorescent traits which store and re-emit light energy, the bioluminescent trait of the orchid uses its own energy to create light. These bioluminescent orchids will produce constant light, visible to the human eye, for up to 5 hours at a stretch. This greenish-white light is emitted from the whole orchid, including roots, stem, leaves and petals. The intensity of light produced varies across the different parts, ranging from 5,000 to 30,000 photons per second.

Genetic transformation can help supplement traditional breeding of orchids to create orchids with desirable traits, such as novel colours, longer shelf life and increased resistance to pests and diseases. It is also possible that this procedure can be used for the transformation of other species.

Prof. Chia commenced his research on this project, while at the Institute of Molecular and Cell Biology (IMCB), a leading research institute in Asia, and continued with the research when he took up a teaching position in NIE. "This breakthrough of creating the world's first bioluminescent orchid after 9 years of research has been immensely rewarding for me and my team. We hope that this research will help further boost Singapore's reputation as the Life Sciences hub in Asia," said Prof. Chia Tet Fatt, Natural Science Academic Group, National Institute of Education, Nanyang Technological University.

Answer the following questions about the article:

1. Where did the gene come from that was inserted into the orchid to create the 'glow-in-the-dark' plant?

2. How do you feel about inserting animal genes into plants of plant genes into animals? Justify your answer.

3. Find out where the insulin comes from that diabetics use today. Write down which organism the insulin producing genes come from and what organism produces the insulin. How do you feel about the mix of species here?

4. What process do you think is more difficult: Inserting an animal gene into a plant, or inserting a plant colour gene from one plant into another plant? Justify your answer.

Excerpt from "Brave new rose"

http://journals.iranscience.net:800/www.newscientist.com/www.newscientist.com/hottopics/gm/gm.jsp@id=21584800

It's 2020. You're lying on a lemon scented lawn. The roses are blue...

TURNING a rose blue. In an era when researchers can clone mammals and insert genes into plants to ward off crop-devouring insects, you would think this would be easy. But it isn't.

Ask Edwina Cornish. Years ago, this Australian biotechnologist and her colleagues began a quest to create in the lab what cannot be created by breeding. They founded a company, Florigene in Collingwood, Victoria. They raised money for the research. They cloned the gene that enables petunias to produce the blue pigment that roses lack. But when they inserted the gene into rose cells, the resulting flower was no bluer than, well, a rose.

You get the picture. Plant biochemistry is turning out to be more unpredictable, and harder to tame, than researchers had thought. Even the researchers say so. "In the early days it was easy to be optimistic," says Cornish. "We might have underestimated how long things would take and the complexity of the pathways we were trying to manipulate."

But here's the rub. Hard to tame does not mean impossible to tame. Slowly but surely, researchers like Cornish and Sederoff are getting to grips with the complexities of engineering plants. Slowly they are laying the foundations for a world where the initials "GM" will come to prefix far more than just genetically manipulated tomato puree and soya beans.

It might take five years, it might take twenty, but we will have genetically modified roses that are blue, along perhaps with GM geraniums that smell of roses, GM orchids that glow when they need watering, GM leylandii hedges that stop growing at a reasonable height, GM lawns that (almost) never need mowing, and GM bin liners made from plastics synthesised in plants. Not to mention GM newspapers and wallpaper.

If this sounds silly, think what has been achieved so far. Fifteen years ago, there was just one technique, based on the crown gall bacterium, for ferrying genes across the thick walls of plant cells. Now there are several, including two types of gun for propelling DNA into cells at high speed. A decade ago, researchers knew almost nothing about the genes that control the shapes, sizes and flowering characteristics of plants. Now dozens of such genes have been identified and a project to sequence the entire genome of a flowering plant, a weed called *Arabidopsis thaliana*, is complete.

Already efforts are well under way to engineer potatoes to double up as vaccines; to create transgenic "smart" plants that will use a fluorescent "SOS" protein to give farmers or growers early warning of drought or disease; to equip oilseed rape with bacterial genes for producing biodegradable plastic; and to engineer cotton plants to produce wrinkle-free fibres.

Researchers elsewhere are experimenting with genes that may boost the growth of trees during winter months or curb the height of fruit trees so they take up less space and their fruit is easier to harvest. Mini cherry trees small enough for the tiniest city garden could be just a few years away. In labs like Sederoff's, meanwhile, efforts are under way to identify genes that affect wood strength and density. Where will it all lead? "A short, fat, fast-growing tree" might be the thing of the future, says Ellis, only half in jest. "With no taper so you don't waste space on the logging trucks."

And with technicoloured timber perhaps? For there's nothing about the biology of plant pigments that means grass has to be green or that wood has to be a yellowy brown. Polka dot button hole flowers to match your tie or scarf are some way off, but already a couple of transgenic carnations that are mauve rather than the usual pink, yellow, white or red are being sold by florists in the EU, Australia, Japan and the US.

The carnations owe their strange hue to the pigment gene Cornish and her colleagues cloned from petunias-the one that has so far failed to turn roses blue. Why the gene works in carnations (up to a point) but not in roses isn't entirely clear. But the researchers suspect petal acidity is a major factor. The gene encodes an enzyme needed to synthesise blue pigment molecules called delphinidins, which are lacking in both roses and carnations. The problem for roses is that these molecules are only blue at high pH, and the cellular cavities, or vacuoles, that hold petal pigments in roses are acidic.

To solve the problem, Cornish and her colleagues are pinning their hopes on one of two options-finding a conventional rose variety that is less acidic, or cloning the genes that control petal pH so that they can alter conditions in the vacuoles. Even then, there remains a risk that the rose's natural pigment molecules, the red cyanadins and orangy perlagonidins, will drown out the added blue.

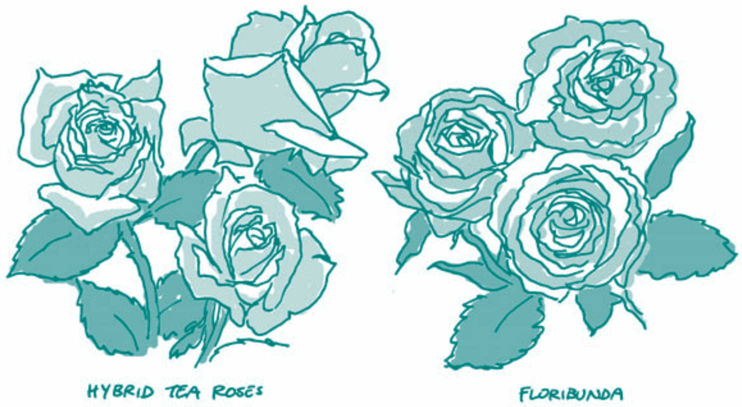
One reason why turning grass blue or red might be easier than it sounds is that any biochemical changes might only need to be skin deep. For instance, genetic engineers could use a pigment gene hooked up to a piece of DNA that keeps the gene switched off in all but the outer layer of cells.

Another approach might be to make use of silent and unused pigment genes. After all, the green stems and leaves of ornamental flowers have the same genes as the petals. "The genes are there," explains Cornish, "but they are expressed in the flowers, not the leaves." In theory, genetic engineers could rouse these pigment genes from their slumber, producing leaves and stems awash with floral pigments.

So, when blue roses do finally begin to emerge from labs, perhaps some them will have the chance to express their native pinkness in their leaves.

Some might also have the chance to smell of lemons. "Some people find sweet roses overwhelming, and most cut roses have almost no odour at all," says Michael Dobres.

Two years ago, in Philadelphia, Dobres helped found a company called NovaFlora that aims to remedy this sorry state of affairs. One of their projects involves inserting a gene into roses that would enable their petals to produce lemon fragrance molecules. The gene encodes an enzyme called limonene synthase, which citrus plants use to synthesise scent molecules known as monoterpenes. The researchers have already given the gene to petunias and are waiting for their first crop of what they hope will be a lemon scented transgenic flower.



Limonene synthase is only one way to perk up scentless plants. "There are hundreds of different monoterpenes out there, synthesised by different enyzymes," says

Dobres. Not to mention two other major types of plant fragrance molecule. In future, predicts Dobres, genetic engineers will be able to create finely-tuned fragrances to order in almost any plant. Among the many possibilities would be lemon scented golf courses and GM camomile lawns that are much easier to maintain than the traditional kind. And as for the idea of Calvin Klein scented GM roses. "That would be dynamite," says Dobres. "That's something we definitely aspire to."

Of course, achieving all this won't be easy. The scent molecules that transgenic plants make will be produced in vain if they remain trapped inside their tissues. One reason many commercial cut flowers are so odourless in the first place is that breeders select for tough petals with waxy coats. Then again, perhaps genetic engineering could be used to make these coats permeable to scent molecules.

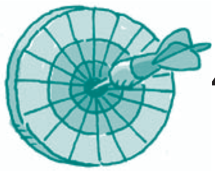
Genetic modification can certainly be used to alter the shape, form and number of flowers that a plant produces. Knowledge of the gene code which specifies the physical arrangement of a flower's sepals, petals, stamens and carpels is so advanced that it is already possible to design "fantasy flowers" that have any of these organs in any position in the flower. And genetic engineers can also alter when a plant flowers.

At the University of Leicester, Garry Whitelam and his colleagues have engineered asters so that they flower in the middle of winter, not just in summer. Growing conventional cut flowers in greenhouses in winter is expensive because of the extra lighting needed to make them flower. In a bid to cut costs, the researchers manipulated an aster gene so that it would produce higher than normal levels of a phytochrome protein that enables plants to sense changes in day length. The GM asters required only 6 hours of daylight to flower compared with the usual 14.

Questions

1. In a table, write down all the transgenic plants mentioned in the article that have already been created. Show the genetic modification they have undergone as well as the success or lack thereof from the genetic modification.
2. Think about an organism that you would like to create using the transgenic procedures. Write down which genes you would insert into which creature and what the benefit would be. After you have listed the benefits, criticize your own creation by stating what possible problems could arise from your GM creature.

Unit Four - Moving Genes



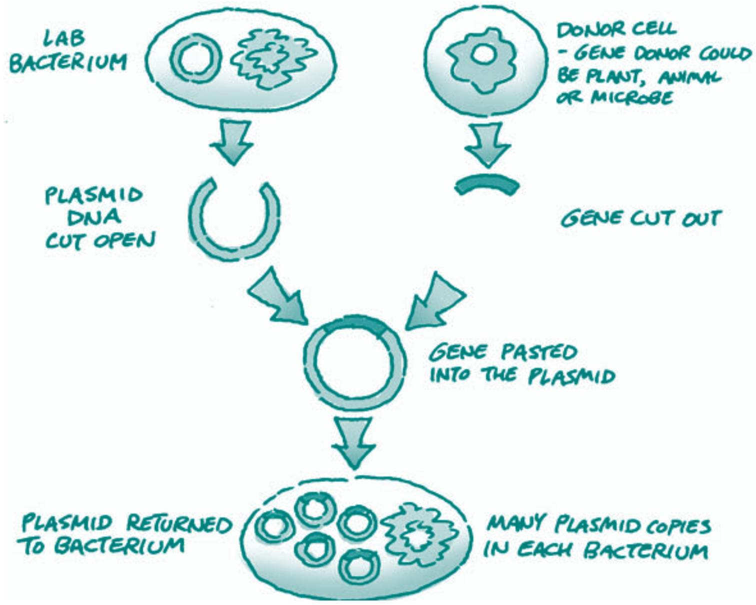
4.1 Objectives

Based on the activities and discussion in this unit, you will be able to:

Learning Outcome	Description of activity to achieve outcome
1 – Scientific enquiry and problem solving skills: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using enquiry, problem solving, critical thinking and other skills.	Learners create a model to illustrate genetic modification. In addition they gather data on current research regarding cotton resistance to bollworm.
2 – Construction and application of Life Sciences knowledge: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.	Construction of knowledge regarding gene spicing, bacterial DNA (plasmid), restriction enzymes and gene modification. Learners become familiar with the concept of pest resistant crops.
3– Life Sciences, technology, environment and society: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.	Learners create their own imaginary genetically modified organism and investigate the impact of pest-resistant crops on biodiversity. Learners interpret and construct arguments for and against genetic modification, and investigate the role of animal activists.

4.2 Background Information

As our understanding of the structure and functions of DNA and genes improved, the possibility of moving a gene for a specific required characteristic from one organism to another has become possible, thus avoiding the problems with hybridization[1] and mutation[2]. Essentially, a required gene is cut from the DNA of the one organism and then 'pasted' into the DNA of the organism one wants the characteristic to be expressed in. Very simply put, we can now cut genes we want out of the DNA of an organism that has them naturally. We can then paste them into the DNA of a different organism that we want to see that gene expressed in. This process of *cutting* and *pasting* is called gene splicing.

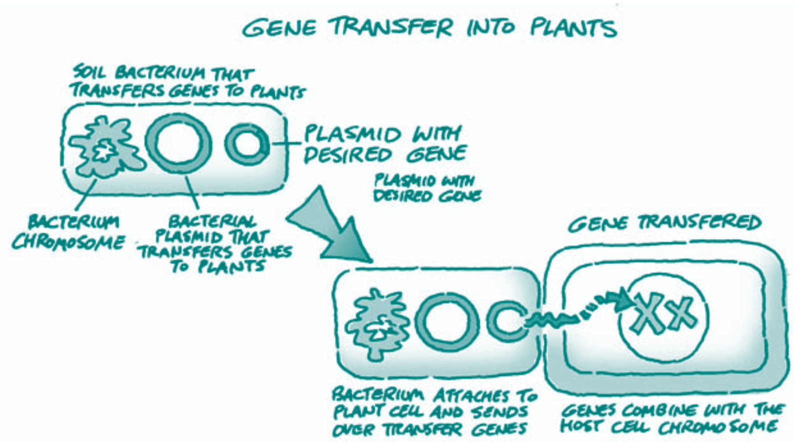


In the last unit we looked at some applications of gene splicing, now we will look at it in a bit more detail. It is relatively easy to understand gene splicing if one thinks of it as a mere cutting and pasting process.

The process of gene splicing happens at a molecular level… too small for us to see and do ourselves under even the strongest microscopes. We therefore need help and employ special bacteria to do splicing for us. The DNA of a bacterial cell is a simple circle that we call a plasmid. (The DNA of plants and animals is more complex, with strands wound onto chromosomes.)

The first stage in the gene splicing process is to get the bacterial plasmid and the DNA with the gene we want into the same cell. The gene is cut out of the donor organism's DNA with a restriction enzyme. The circular plasmid is cut open, giving two ends. The gene is spliced into the cut plasmid and the circle reformed. The plasmid is used to carry the gene to another cell. It is now called a recombinant plasmid, i.e. it has a gene recombined into the plasmid.

A **restriction enzyme** is a protein that cuts DNA at a specific sequence. Cells use restriction enzymes to recognise 'foreign DNA' and chop it up – i.e. for protection. Scientists use restriction enzymes to cut DNA at specific points to isolate genes for splicing.



In order to ensure that lots of copies of the plasmid and gene are made, the bacteria are allowed to reproduce in a nutrient medium. Because bacteria reproduce by division, the resulting cells are all clones and all have the new gene in the plasmid. This way we can be certain that all the plasmids carry the identical gene from the donor organism.

The recombinant plasmid now has to place the gene near the DNA of the

[1] *Genes not present in the species or difficult to locate*

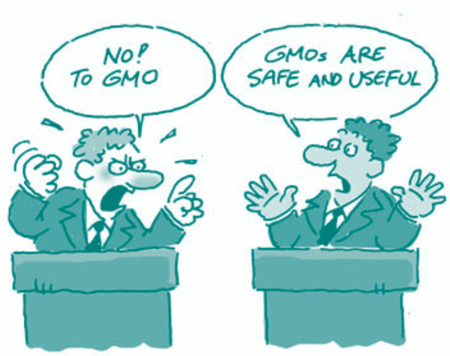
[2] *Many random mutations means many failures before a success is identified*

recipient organism. To do this the recombinant plasmids move into the recipient cells. The gene is pasted into the DNA of the recipient organism. Now the recipient organism has the gene and is genetically modified.

Gene splicing applications have received mixed responses from people all over the world. An organism that has undergone gene splicing is called genetically modified. There are groups of people who are enthusiastic about genetically modifying organisms and others who are vehemently opposed. Each side has valid arguments that can be re-argued over and over again. What is important is that each person should know enough about genetic modification to make up his or her own mind about how they feel about this technology.

We may find some genetically modified organisms easy to accept and others easy to reject. Consider vitamin A–enriched rice to help prevent childhood blindness in poor Asian communities? Consider blue eye genes for human embryos? Importantly, the value, acceptability and safety of each genetically modified organism is individually assessed in South Africa and in most countries in the world today.

Activity 4.4.1



It is often argued that gene-splicing is an extension of conventional breeding by scientists producing new GM (genetically modified) seed. However, anti-GM groups have been known to call this statement 'a myth'.

If you were asked how conventional breeding differs from genetic modification through gene-splicing, what would you say?

The following article looks at three differences. They are the scope of genetic material transferred, location of the genetic insertions, and use of DNA vectors designed to move and express genes across species barriers.

The article can be accessed at *http://www.netlink.de/gen/diskussion1.html.* It is reproduced here in a shortened and adapted form. From the article, discuss what the author's arguments are. Discuss these in groups and then try and provide valid counter-arguments.

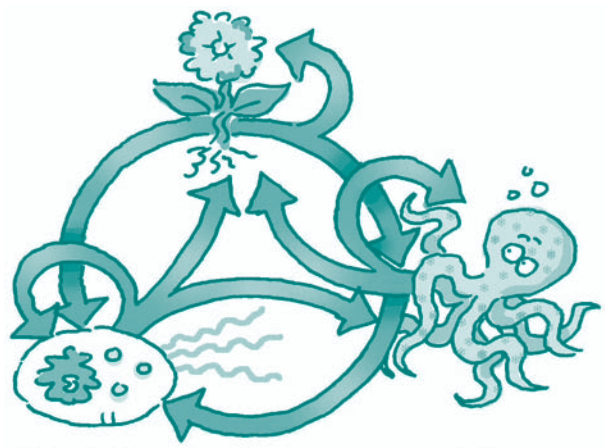
"Genetic Engineering is not an Extension of Conventional Plant Breeding:

How genetic engineering differs from conventional breeding, hybridization, wide crosses[3] and horizontal gene transfer[4]"

Michael K. Hansen, Research Associate, Consumer Policy Institute/Consumers Union. January, 2000

Scope of Gene Transfers

For the scope of genetic material transferred, genetic engineering (GE) allows the movement of genetic material from any organism to any other organism. It also offers the ability to create genetic material, and expression products of that material, that have never existed before.



GENE TRANSFER CAN MOVE GENES FROM ANY DONOR TO ANY RECIPIENT

This radically differs from traditional breeding, which merely permits the movement of genetic material between different varieties within species, between closely related species, or closely related genera. Even hybridization and wide crosses cannot move genetic material much beyond these limits. Thus, hybrid corn is simply the crossing of two pure corn varieties to produce a mixed line. In a sense wide crosses represent a stretching of these boundaries by inches compared to miles with GE. After all, with GE, one can mix genes not only from widely different plant

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[3] *Wide crosses are forced across natural reproductive barriers, such as the grasses crossed to make wheat.*

[4] *Horizontal gene transfer is the very rare crossing of DNA from one organism to another without sexual reproduction. Usually visualised as DNA that is released into the environment and taken up by other cells.*

families, one can move genes from any organism on earth, or can create genes which have not existed before and put them into plants

The view that genetic engineering may be more prone to unexpected outcomes because it creates profound disruption in the normal interactions of genes is supported by differences in the success rate in producing viable stable offspring for genetic engineering versus conventional breeding. In nature, most offspring are viable[5]; the vast majority of seeds germinate and produce organisms that survive and reproduce. In conventional breeding, scientists grow many plants and keep only a few with the most desirable traits; however the ones they discard are still almost always normal examples of the species[6]. This is not true for products of genetic engineering. In the early days of GE, although one could select cells which contained and expressed the desired trait, it was necessary to grow the engineered cells into whole plants to determine the overall impact of the GE. A very large percentage of the transformed cells either were not viable, were grossly deformed, or failed to stably incorporate the desired gene, i.e. failed to produce the gene product in the plant in successive generations. Some of the malformations may be due to difficulties with tissue culture of the transformed cells; however unexpected genetic effects also appear to be a causative factor. In fact, only one in thousands (or tens of thousands or in some cases even millions) of attempts achieves the desired results in terms of a seed that incorporates the desired traits, and expresses them in a useful fashion generation after generation, and doesn't have undesirable side effects. Assertions that genetic engineering is a highly precise process therefore seem misleading.

Location of Gene Insertion

GE can control relatively precisely the trait that is being inserted into a host plant genome. However it cannot yet control the location where the trait is inserted into the genome with any precision, nor guarantee stable expression of the transgene[7]. The process of insertion of genes into the host plant genome and the expression of such material is called transformation or gene transfer. Gene transfer is currently accomplished through several relatively crude methods which are relatively random in where the genes end up. One transformation method frequently uses a bacterium called, *Agrobacterium*. These bacteria are among the few known which can transfer their genetic material to another kingdom or phyla of organisms. These bacteria cause a disease in plants by attaching to the plants, transferring bacterial DNA into the plant cells and getting that DNA incorporated into the host plant genome. *Agrobacterium*-mediated gene transfer involves engineering the *Agrobacterium* by deleting the disease-causing genes and inserting the new genes to be transferred in their place. This engineered *Agrobacterium* is mixed with the recipient plant cells and allowed to transfer the genes to them. The use of *Agrobacterium*-mediated gene transfer occurs mostly with vegetable crops and is difficult to do with cereals.

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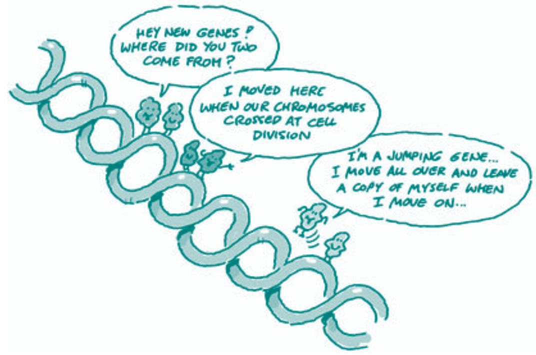
5 *Is this true?*
6 *Is this true?*
7 *A transgene is a gene transferred into a new host*

The effect of a gene on the whole organism is significantly governed by its location. The lack of control over location may be a significant cause of unexpected effects. In terms of the location of genes in traditional breeding, since it occurs between organisms that share a recent evolutionary background, it involves the shuffling around of different versions of the same gene. Furthermore, these genes are usually fixed in their location on the chromosome by evolution. With GE, the gene insertion happens in unpredictable places which may lead to unpredictable effects. Thus, genetic engineering is more random than conventional breeding.



Unintended gene transfer

A third important way genetic engineering differs from conventional breeding is in its use of genes that may move and cause expression of desired traits.

Traditional (or conventional) breeding involves mixing of genetic material from species that are sexually compatible[8]. Sexually compatible species already contain elements to help gene transfer occur. The same is not true with GE, which uses non-sexual means of transfer and usually entails the movement of a gene between species that could rarely, or never, exchange genes in natural conditions. To help this process, GE makes use of plasmids specifically designed to move genes across species barriers. These plasmids come from natural microbes, plants or animals specifically designed to smuggle genes into cells that would otherwise exclude them and to get the genes inserted into the genome of the host plant.

Conclusion

Genetic engineering clearly differs from conventional breeding in several ways. Conventional breeding relies primarily on selection, using natural processes of sexual and asexual reproduction. Genetic engineering uses a process of insertion of genes, via direct gene introduction methods, or by specially designed plasmids adapted from nature. Genetic engineering can insert genes from any life form into any other; conventional breeding generally can only work within a species, or within closely related genera, as done for wide crosses. Conventional breeding relies on mixing characteristics from different populations within a species and then selecting the best suited genes from a plant's natural complement of genes. However genetic engineering relies on inserting genes into random locations, which may disrupt complex gene interactions. The products may exhibit unexpected effects.

Genetically engineered plants often contain viral or bacterial gene 'switches' and in some cases a

[8] *Commonly share genes through sex.*

bacterial antibiotic marker gene. These, though naturally occurring in or around crops, are never deliberately introduced in products of conventional breeding.

There are thus identifiable differences between genetic engineering and conventional breeding, both in the process, and in the genetic makeup of the product. Indeed, wherever DNA is recoverable, the presence of engineered DNA can be identified in the product, because of these identifiable pieces of inserted DNA.

Whether these differences are "significant" or "insignificant", however, is a value question and a philosophical question, not a scientific question[9]. We see genetic engineering as a quantum leap from conventional breeding as different from it as nuclear power generation is from a coal-fired plant. In our view traditional breeding is humankind's attempt to manipulate natural breeding processes for our own benefit. But this attempt, while wildly successful in one sense (the creation of all the major food plants and animals from wild relatives), has only mildly pushed the barriers of gene transfer. GE, on the other hand, does away with all such barriers in the natural world, permitting scientists to manipulate genes in a way that was inconceivable before.

A number of scientists, particularly ecologists, see the differences as we do. However, other scientists maintain it is a continuum. In the end, it is a matter of values, judgment and opinion as to who is correct. Indeed, it can well be argued that there is no one right answer as to whether this difference is "significant" or not.

Answer the following questions:

1. Read the following pararaph:

   '…only one in thousands (or tens of thousands or in some cases even millions) of attempts achieves the desired results in terms of a seed that incorporates the desired traits, and expresses them in a useful fashion generation after generation, and doesn't have undesirable side effects. Assertions that genetic engineering is a highly precise process therefore seem misleading.'

   Do you think a genetic engineer would deny that the above process takes place whereby many progeny are not viable after genetic engineering?

2. What do you think a genetic engineer would mean when s/he says that genetic engineering is highly precise?

3. Would you say that the argument used by genetic engineers is misleading?

4. If science is expected to 'inform' the argument for genetic modification/ engineering (see last paragraph of the article), who should inform the argument against genetic modification/ engineering.

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[9] *Is this true? Is safety or ecological impact a scientific or philosophical question?*

Activity 4.4.2

Create your own GMO[10]

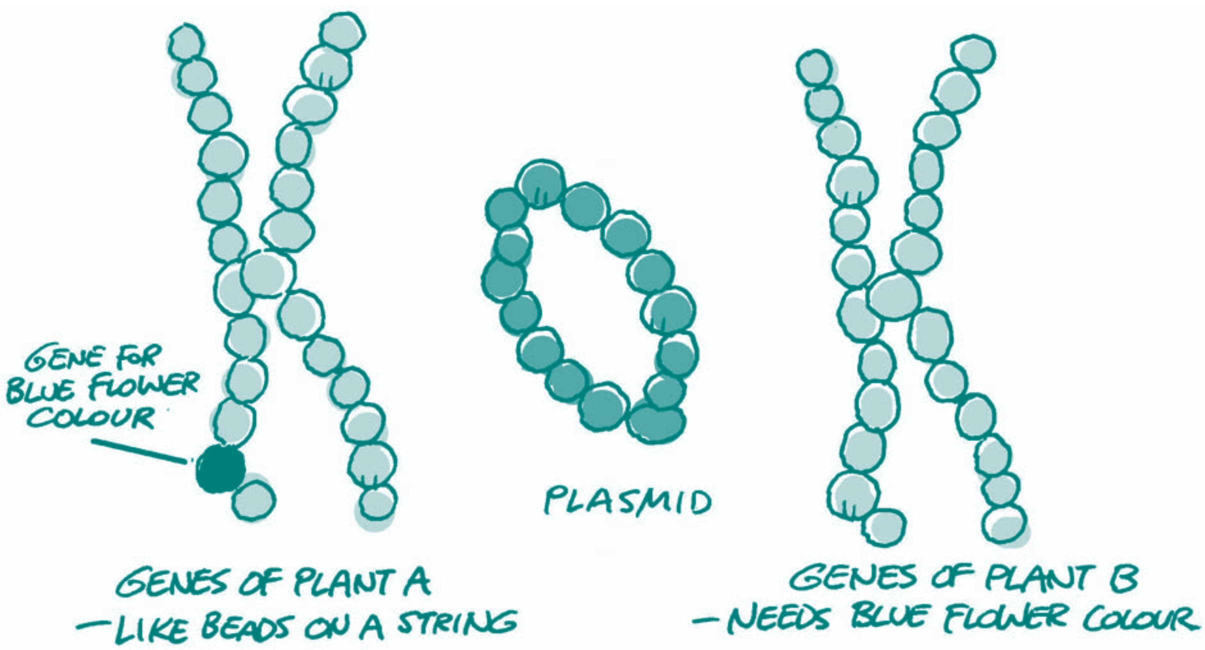
In pairs or groups, imagine that you are a team of geneticists who can create any genetically modified organism you could imagine. It could be a Christmas tree with a firefly gene that flashes bioluminescence or a cow that makes chocolate flavoured milk.

Take any creature you know of (animal, plant or microbe) and think how you could improve it for human use through genetic modification.

- What properties will you provide it with?
- Where would you get the genes for these characteristics?
- Why will you produce it, i.e. what are the benefits?
- What will it look like? Draw it.
- What will you call it?

[10] *GMO = genetically modified organism.*

Activity 4.4.3



Here is the DNA of a plant that contains the gene for blue flowers (plant A), a plasmid, and a plant that normally has white flowers (plant B), but we want them to be blue.

Cut out the DNA for each organism.

1. Remove the DNA for blue pigment from plant A. Describe in scientific terms what you are doing.
2. Insert the 'blue' gene into the plasmid DNA. Describe in scientific terms what you are doing.
3. Cut plant B DNA and insert the 'blue' gene it into. Describe in scientific terms what you are doing.

A more complex exercise can be accessed at:
http://www.accessexcellence.org/AE/AEPC/WWC/1994/simulation_gene_splicing.html

Activity 4.4.4

Read the article below and work through the questions.

Chinese Farmers Laud GM Cotton

He Sheng, China Daily 31 Aug 2001. Shortened.

Life was hard for Guo Chuanyou, a farmer from Lujiang in East China's Anhui Province, during the summer of 1998. He remembers it as a time of extensive flooding and the relentless pests. The heaviest rainfalls in half a century held the province hostage for months. Young men and women volunteered in large numbers to help reinforce the riverbanks, while the elderly, like 61-year-old Guo, were left to take care of the crops. The farmers faced an outbreak of bollworm, a major threat to cotton growth.

"The pesticides seemed to fail," said Guo. "There were so many bollworm that we had to get rid of them by hand each day." Guo's was not the only family that suffered great losses that year. But things started looking better beginning last year, when Guo and other farmers began growing a new type of cotton called transgenic anti-pest cotton. Guo used seeds bred with genetic engineering technology that introduces a pest-resistant toxin from the bacterium Bacillus thuringiensis (Bt) into the cotton cells. The introduced toxin enables cotton to produce its own toxin against bollworms while causing no harm to human beings, the environment or other insects.

"I feel much more relaxed now about taking care of my cotton, even though my two sons have left and now have their own families," Guo said, pointing to his small cotton field. Guo said he still uses pesticide sometimes, either to kill other pests or simply to feel safe, but far less than before. Guo's feelings are probably shared by the millions of cotton-growing farmers in Anhui, who have long been plagued by bollworms. Ever since its introduction in Anhui in the mid-1990s, the pest-resistant cotton seeds have gained favour with farmers at a startling speed.

Across the country, the growing acreage of this cotton type has skyrocketed from less than 10 000 hectares in 1998 to almost 1 million in 2000, or from 2.2 per cent of the country's total cotton fields to 28 per cent. "The number is sure to rise sharply this year," said Du Min, a research fellow at the Research Centre for Rural Economy (RCRE) under the Ministry of Agriculture. It has been described by seed producers as one that benefits all but pesticide producers. Du and her colleagues have followed the research and development of pest-resistant transgenic cotton from the very beginning, and have conducted field investigations and case studies in major growing areas like Anhui. Their research has suggested that this cotton type has become one of the most successful in terms of acceptance by farmers and the financial benefits it has brought. The two most important factors in its success are lower labour costs and reduced expenditures on pesticides.

"Some farmers like to call it "cotton for the lazy", said Zhao Deping, general manager of Andai Seed company in Anhui. Yet the creation of the cotton seed itself was time-consuming and a drain on funds.

China formally launched research and development of transgenic pest-resistant cotton in the early 1990s and became the second country in the world to successfully breed such cotton in 1994. In 1996, Chinese scientists synthesized a cotton resistant to both bollworm and budworm.

Questions

1. Why do the farmers still use pesticide sometimes if the cotton plants are protected against the bollworm pest?

2. Why do you think farmers call the genetically modified crop 'cotton for the lazy'?

3. The farmers think the cotton is better. What impact would this cotton have on the biodiversity of insects in and around the cotton fields, compared to conventional crops sprayed with insecticide?

4. Many small scale cotton farmers and commercial farmers in South Africa agree with this article. Can you find out any information about this crop in this country and the farmers who use it? You may want to do an Internet search for Cotton SA (012 804 1462) or AfricaBio (012 667 2689). Alternatively, you could phone them in Pretoria. Prepare a poster of your findings

Activity 4.4.5

Read the following article carefully. Look for any possible biases and note whether the author substantiates his opinions with true facts.

The ethics of gene splicing

by Andrew Boardman

Over recent history, mankind has exploded into new fields of research and discovery, raising our knowledge of our surroundings exponentially.

From rudimentary knowledge in such fields as chemistry, physics, and biology, scientists have made discoveries which have lead to the curing of large numbers of diseases and infections, and have raised not only the life expectancy all over the world, but have increased the standard of living also. However, this is only the basework, these fields were already known for centuries upon centuries and early discoverers had done work on them long before us, which turns my attention on the newer fields. There are a number of fields of science, be it biological or industrial, which have been "discovered" only in recent history, some are as young as a few decades, and some are just over a century or two old, which are in practice almost brand new to humankind. One of these is genetic engineering.

Genetic engineering is, in years, not new to humankind, the principals of the field were discovered in the 1860's by Gregor Mendle, however, in practice, researchers are almost brand new to the field. Although they have had over 120 years, short-sightedness and scepticism at least halves the time humankind has been actively researching this field. As with all new things, it has been treated with care and many have been frightened of it, not knowing its potential, either malicious or benign.

The genetic researcher's view is this: in a brand new field, and even in some old ones, the potential for that field is not known until the field is fully understood. Assuming the worst just causes a panic which cannot help either side of the issue. The genetic researcher is trying to help mankind by the same basic methods as all industry and other fields of science: do work which will make life simpler for humankind. They are not crazed lunatics attempting to take over the world with mutated animals. By inserting the human gene for insulin into an E. coli (a bacterium), many thousands of lives have been saved and costs for both the government and the patients suffering from diabetes have been cut extremely drastically. In the researcher's opinion, this example shows the unbelievable promise that this field shows for helping mankind.

Now the animal rights activist: s/he is a person affected by animals, probably has one or more in his life, who sees the humanitarian reasons for stopping cruelty to animals. S/he has an empathy with the animal world, considering himself a part of that, which causes them to try to get others to treat animals as they do; as a brother. They do not believe that any person has any right to mistreat an animal, because it is just the same morally as mistreating a human being, and since the mistreating of a human being is illegal, so should be the mistreating of an animal, whether at home or in the research lab.

An animal activist may see the good that may stem from genetic engineering, but they also see, and more clearly see, the potential for harm to the environment, to humankind, and to the animal kingdom. The potential is there, there is no doubt about that, a "bad" gene could be spliced into an E.coli, for instance, escape from the lab, and before anything could be done to stop it that strain of intestinal bacterium could destroy billions of humans and possibly other animals. They see the possibilities for an "evil" scientist to work for a government and produce genetic warfare materials that could send the Earth into the third world war as predicted by Star Trek. They see the possibilities of taking an already deadly virus such as AIDS and altering it so that it is more easily contracted.

Gene splicing consists of the transfer of the DNA of one organism, through a virus, being embedded into the DNA of another organism. There are limitless possibilities for this kind of research, including the prenatal curing of certain genetic diseases before they affect the infant, like Down's syndrome, Tay-Sachs disease, sickle-cell anaemia and Spina bifida. All of these conditions can currently be spotted in the womb, but with further research a spliced gene could be substituted in the embryo for the malfunctioned gene, and the baby could be cured of these diseases. Those are not the only diseases, over 250 more can be identified in the womb.

Another benefit can come from the development of new animals from splicing. These animals, for instance the first animal which was a mouse that had no immune system, can further research that may not have been able to continue without the specialized animal. The new research will help out mankind and the animal word, and could possibly lead to the cure for cancer, or AIDS, or any future epidemic.

However, much of the research happening today is torturous and extremely cruel to animals. For information of head injuries, scientists at the Head Injury Laboratory at the University of Pennsylvania actually had a rhesus monkey in a tank with its head being slammed into a machine (OMNI November 1986). That laboratory, by the way, was broken into by a extremist animals group called ALF (Animal Liberation Front), where they ransacked the laboratory, and dozens of video tapes showing explicit torture were stolen by the group.

Industrial (mass production) farm animals suffer too, if they are ill kept, being quartered in overcrowded and unsanitary conditions, and are mistreated.Chickens, for instance, are debeaked by the millions and put into crowded and poorly kept cages for either egg production or fattening for slaughter, and veal calves are chained in cramped cages and fed iron-deficient diets which can cause anaemia (ALDF Newsletter Fall 1987). If genetically produced animals are put on the market, a bigger pig that requires less food, or a chicken that lays more eggs, conditions are bound to get worse, and certainly won't get any better for them.

My personal opinion follows almost the same lines as this paper. I have lots of sympathy for both sides. I can see the limitless possibilities for genetic engineering, the idea of curing genetic diseases, of making life easier, and maybe of even creating creatures that till then were only mythical. I can't say I'm not tempted by the idea of actually seeing a live Centaur. However, I do love animals, and I don't like to know that they suffer, and I am nearly positive, in my youthful ignorance, that there has got to be a better way, maybe not an easier way, but a better way to find out the effects of head injuries with slamming an innocent monkey against a wall and taking notes, I find that extremely disgusting.

I can see genetic engineering having a vast future, but I believe that there will always have to be an opposing side just to keep them on their toes and make sure that the scientists don't get out of hand. Unless someone is intending to start a holocaust, mankind has a long future in front of him, and patience is a wise lab rule of thumb.

Task

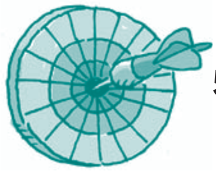
1. Do you think the author is totally unbiased? Give reasons for your answer.

2. Was the head bashing monkey an example of genetic engineering research? Why do you think he used this example in his essay on the ethics of gene splicing?

3. Just as the author above has outlined some facts about genetic modification and given his opinion, write your own opinions about genetic modification and substantiate them with facts.

4. What animal cruelty do you think might result from gene transfer?

Unit Five - Safeguarding Biodiversity through Biotechnology



5.1 Objectives

Based on the activities and discussion in this unit, you will be able to:

Learning Outcome	Description of activity to achieve outcome
1 – Scientific enquiry and problem solving skills: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using enquiry, problem solving, critical thinking and other skills.	Learners are supplied with articles, which enable them to extract and interpret data to criticise the validity of the quagga breeding programme and to extrapolate the data to other extinct species. Learners research a plant that is extinct in the wild but thrives in nurseries and home gardens as an example of biochemical techniques applied to threatened plants.
2 – Construction and application of Life Sciences knowledge: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.	Learners are supplied with texts and structured questions to familiarise them with the following terms: genotype, phenotype, biodiversity, mitochondrial DNA vs nuclear DNA, species, subspecies, clines and populations. They are made aware of several threatened plants and of the existence of gene banks.
3– Life Sciences, technology, environment and society: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.	Learners appreciate the value of preserving threatened plants and animals and the consequences of the extinction of a species. Learners research threatened plants and the roles that biotechnology plays in conservation of threatened species.

5.2 Background Information

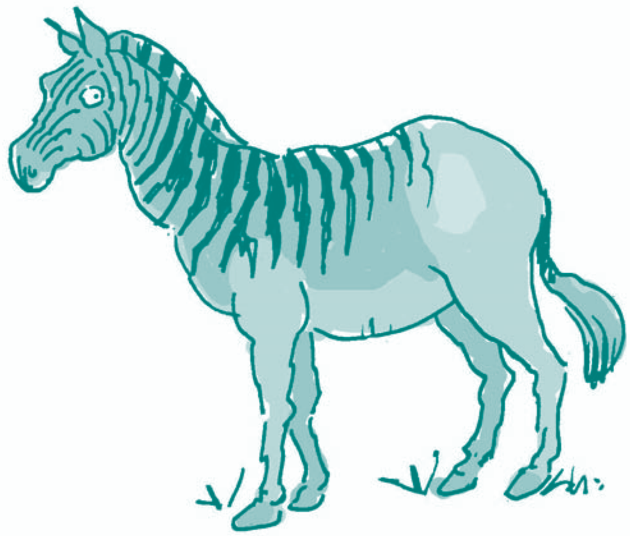
As the pool of genes has diversified through time it has created an enormous body of biodiversity. Biodiversity is eroded away through over-exploitation by humans, including destruction of habitats, as well as through natural changes in the environment. Biotechnology provides several tools that can help preserve biodiversity and diminish the amount of biodiversity lost in these ways.

When the last woolly mammoth died out several thousand years ago, the end of the species was definite. It was irreversible because there were no more breeding pairs left. Today biotechnologists are working on bring back the woolly mammoth. Woolly mammoth carcasses have been found in the ice packs of northern Russia that have very well preserved DNA. Live cells are required for cloning, so right now it is not possible to clone the mammoth, but by using that DNA it may be possible in a decade or so to create another mammoth. This is only possible where the DNA has been preserved.

In the case of the woolly mammoth nature itself preserved the DNA. As species are being depleted today, biotechnology can provide more certain ways of preserving germplasm that otherwise may be lost forever. The first step in preserving biodiversity is documenting what we have and what is most at risk. The following tasks look at various methods that have been applied to save or recreate germplasm that potentially could be lost.

Germplasm describes all the different varieties of a single organism.

Activity 5.4.1



As settlers moved through southern Africa with herds of cattle, sheep and goats, they exterminated wildlife that competed for grazing. It was this indiscriminate hunting that saw to the extinction of the quagga in the Karoo and southern Free State.

In 1883, the last quagga died in a zoo in Amsterdam. Today there are twenty-three preserved specimens left in museums throughout the world. Only mitochondrial DNA has been found and what is interesting is that it is identical to the mitochondrial DNA of all other living zebra species. One can infer thus that the quagga is very closely related to all other zebras; in fact it is likely to belong to the same species, being merely a sub-species.

Mitochondrial DNA is found in the mitochondria of plant and animal cells. Because it is outside of the nucleus and chromosomes, it is called 'extrachromosomal DNA'. Interestingly, only female mitochondrial DNA is passed to offspring during sexual reproduction.

Up until the 1980's it was thought that the quagga was so completely different looking to all other zebras that it would have had to be a separate species altogether. With this 'knowledge' the thought of using surviving species to re-create the quagga through breeding was not considered. However, with the technologies able to show that the mitochondrial DNA of the quagga is the same as for other zebras, the realization was made that the quagga may have been phenotypically distinct, but less so genotypically.

Phenotypic differences are those visible in the organism, like hair or eye colour in humans, while geneotypic differences are only seen in the genetic code, like intelligence and susceptibility to disease.

In the latter half of the 1980's scientists got together to re-breed the quagga from existing zebra species. Nine zebras from Etosha were selected and captured to begin the program. The first foal was born within a year of capture and foals have been reared and bred with others in order to increase the appearance of a quagga (the phenotypic difference). More germplasm has been added from Etosha and Zululand over the years of the project. The foals in the program being born today are beginning to resemble the quagga quite remarkably.

For more information refer to the Quagga Breeding Project website at http://www.museums.org.za/sam/quaga

Answer the following questions:

1. The quagga breeding project team claims that they are going to breed a true quagga. Given that the only genetic information we have from the quagga is the mitochondrial DNA, do you think that this is a valid claim? Explain your argument.
2. Biotechnology has contributed to the quagga-rebreeding project. Explain where and how this has happened.
3. Why is the quagga being recreated through selective breeding and not through cloning?
4. The scientists involved in this project are not considering cloning at this point. What effect do you think the technology of cloning could play in this project?
5. Can the same technique for re-creating extinct species be applied to recreate a Tyrannosaurus rex? Explain your answer.
6. What are the conditions for success in rebreeding and extinct species?
7. In terms of germplasm preservation, has the quagga germplasm been preserved?
8. In terms of loss of biodiversity, what has this project achieved?

The following information has been taken off the website:
www.museums.org.za/sam/quagga

These passages provide more information.
Read them in order to answer the above questions in more depth.

The Quagga Project

What is a species or subspecies?

A population, however large or small, in which all individuals share basic genetic characteristics, and therefore produce fertile offspring, constitutes a species.

If a species occurs over a wide geographical area, as for example, the Plains zebra, (north-east Africa to South Africa), populations in different parts of the distribution area, especially at the opposite ends, may look quite different from each other. Yet, when members of those populations are mated, they produce fertile offspring; that is, these offspring are able to reproduce. If various populations within a huge distribution area do differ from each other in appearance, they are considered different subspecies. If there are no geographical barriers which separate such populations or subspecies , the change in appearance is gradual and is referred to as 'cline'. If however, there are geographical barriers which separate populations that were formerly part of a unified distribution, such isolated populations or subspecies could differ from others more markedly. Depending on how long they have been isolated, they may be on the verge of becoming separate species, as there is no more exchange of genes between these and other subspecies.

A variety of zebra, known as the 'Quagga', inhabited the Karoo and southern Free State of South Africa well into the second half of the 19th century, when it became extinct. It differed from other zebras mainly in having been striped on the head, neck and front portion of its body only, and in having been brownish, rather than white, in its upper parts. The belly and legs were not striped and whitish.

How was the quagga related to other zebras?

There has never been unanimous agreement between zoologists regarding the Quagga's relationship to other members of the horse family. Some regarded the Quagga as a full zebra species, while others treated it as the southern-most subspecies of the widely distributed Plains zebra (often referred to as Burchell's zebra). While most scientists accept the Quagga as belonging to the zebras, in 1980 one researcher did suggest that the Quagga was more closely related to the horse than to the zebra. It was thought that this question about the Quagga's relationship to other Equids, would probably never be answered, as the Quagga had long since become extinct, thus precluding the study of the living animal.

Against all expectations, the question of the taxonomic status of the Quagga was answered in 1984. Three groups of scientists from the University of California undertook molecular studies on dried flesh and blood samples that had been removed from Quagga skins during re-mounting of four old museum specimens in 1969/70 and 1980/81. The biochemists obtained protein and DNA fragments from the samples. The DNA fragments were successfully cloned. Both the protein and the DNA confirmed the status of the Quagga as a subspecies of the Plains zebra.

How many different zebras are there?

There is a lot of confusion about Burchell's Zebra, Quagga and other zebras, despite there being only three zebra species.

The reason for this is in the history of zebra descriptions and naming. Whenever an early explorer took a zebra skin from Africa to Europe, it did not match any of those in collections, so, it "needed a name".

That there is enormous individual variation in, especially, the Plains Zebra (which is often refered to as Burchell's Zebra), had not been expected nor realized until the early 1900s. By then, the Quagga, which had been described and named in 1788, had become extinct. The Burchell's Zebra, described and named in 1824, was still around.

Gradually, further north, somewhat more extensively-striped zebra populations were described. It was noticed that they were very similar to Burchell's Zebra, and they were described and named as subspecies of Burchell's Zebra. These subspecies were usually given names of explorers, like Chapman, Wahlberg, Selous, Grant, Boehm, etc. Eventually the zebra population from which William Burchell had taken a skin to the British Museum, had been wiped out, but "Burchell's zebra subspecies" continue to exist in many areas of Africa.

Now I must explain why I prefer to speak of Plains Zebra, rather than Burchell's Zebra, as is often done. The original Burchell's Zebra (sometimes refered to as the "true" Burchell's Zebra) is, or rather was, one of the subspecies of the species under discussion. Consequently, all the other subspecies (with explorers' names) should be called Chapman's Burchell's Zebra, Wahlberg's Burchell's Zebra, Selous's Burchell's Zebra, and the "extinct" subspecies *burchelli* should be called Burchell's.

CAPE MOUNTAIN ZEBRA

BURCHELL'S ZEBRA

Activity 5.4.2

Read the following article accessed at KZN Wildlife - Biodiversity Research Programmes, Threatened Plant Conservation Unit.

BIODIVERSITY RESEARCH PROGRAMME
THREATENED PLANT CONSERVATION UNIT

" Because we are city dwellers we are obsessed with human problems....We are so alienated from the world of nature that few of us can name the wild flowers and insects of our locality or notice the rapidity of their extinction." James Lovelock (1988)

Introduction

Plants are intimately entwined in the life histories of virtually all other living organisms. People depend on plants for food, shelter, clothing, fuel, medicines and cosmetics. Therefore in order to sustain the resource that probably most contributes to man's survival, man has to embrace preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment.

Plants maintain environmental stability through diversity of systems and species and through complexity. Loss of any one species in a complex ecosystem can have a cascading effect and cause the demise of other species. It is therefore imperative that all plant species and ecosystems are identified and managed for there preservation.

Extinction is irreversible, and prevents future options for use and continued evolution.

Of the 6000 plant species found in KwaZulu-Natal, 682 are threatened, rare or endemic. Four are known to be *extinct* in the wild and six are *critically endangered*. With large scale habitat destruction through change in land-use, indiscriminate harvesting and alien infestation these disturbing figures are set to increase unless a concerted effort is made to prevent this.

The Threatened Plant Conservation Unit aims to alleviate some of this pressure by co-ordinating and implementing measures to prevent human induced extinction of endangered indigenous plants. This is done primarily through the development and co-ordination of

Threatened Plant Recovery Plans. These Recovery plans identify and prioritise actions required to improve the conservation status of a species.

The role of the Threatened Plant Conservation Unit

The role of The Threatened Plant Conservation Unit includes:

- maintaining a list of priority species requiring recovery plans
- selection of recovery team leaders
- the responsibility of ensuring recovery plans are prepared in a consistent manner and circulated
- maintaining an updated register of all recovery plans in progress
- *ex-situ* (away from their natural habitat) production of threatened plants for restoration projects (Biotechnology: tissue culture; plant propagation)
- determining suitable methods of propagation and growth requirements
- increase understanding of reproductive biology, pollinators and natural enemies
- assistance with identification of suitable reintroduction sites
- assistance with monitoring and management of natural and reintroduced populations (Biotechnology: DNA fingerprinting)
- establishment of live genebanks of threatened plants (Biotechnology: tissue culture, seed banks, cryopreservation, cell culture; DNA sequence banks)
- maintaining an updated list of all *ex-situ* populations of endangered plants with recovery plans (Biotechnology: DNA fingerprinting)

Major Current Activities

- Threatened Plant Recovery Plans:
  - *Aloe saundersiae* - Endangered
  - *Dahlgrenodendron natalensis* - Endangered
  - *Encephalartos cerinus* - Critically Endangered
  - *Encephalartos msinganus* - Endangered
  - *Gerbera aurantiaca* - Endangered
  - *Kniphofia latifolia* - Endangered
  - *Kniphofia leucocephala* - Critically Endangered
  - *Kniphofia pauciflora* - Extinct in the wild
  - *Leucospermum gerrardii* - Locally Endangered
  - *Protea comptonii* - Vulnerable
  - *Warburgia salutaris* - Endangered

- Establishment of genebanks of threatened plants.
- Propagation of and the relevant research into threatened plants.

Programme leader: **Ms B. Church** (Horticulturist, Biodiversity Division.)

Answer the following questions:

1. The writer gives two consequences of extinction. What are these?

2. *Kniphofia pauciflora* is extinct in the wild. How could this extinction affect the future of humanity?

3. What are possible causes for the extinction in the wild of *K. pauciflora*?

4. Is *K. pauciflora* extinct?

5. Do an internet search to find a picture of *K. pauciflora*.

6. What percentage of plants in KwaZulu Natal are endangered?

7. The role of The Threatened Plant Conservation Unit includes several activities where biotechnology can be applied. Select three roles and say what biotechnology techniques can be applied to them.

OR, chose any of the other plants in the 'threatened recovery plan' list and answer the above questions for that one.

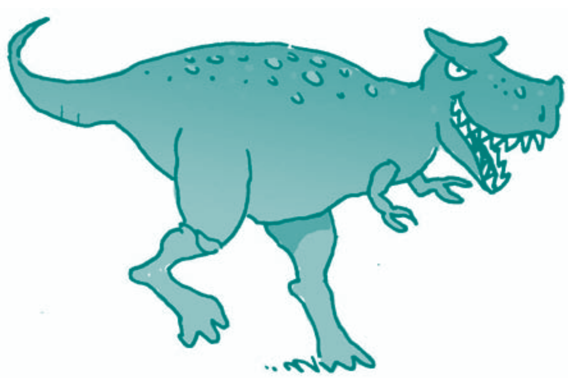
The following exercise has been adapted from
"Saving the Bilby – why bother" from the Biotechnology Australia worksheets.

Read the following letter and then follow the tasks below:

Dear Ms Church

There is nothing to be gained by saving plants in the wild. Some people may get some thrill out of saving endangered species and may even get a university degree for their efforts, but I have never seen a *Kniphofia pauciflora* in my life and I don't think I have suffered any loss because of that. I bet there are fewer people in South Africa who know what it is than there are people with doctors' degrees anyway. And anyway, horticulturists are growing loads of them now for botanical gardens and the like where they will be protected. I don't know anyone who goes off on a trip to a game reserve in the hope of seeing a *K. pauciflora*. What is it? An insignificant little green plant that flowers for a couple of days a year!

The reason I have this gripe with preserving plants that don't seem to be that important anyway is the cost. The new biotechnology techniques you propose to use to save the most obscure of plants are very expensive. Your laboratory must cost hundreds of thousands to run. Looking at your roles you have stated, it seems a lot of money is going into this work. And as for the cloning of plants…is this a science fiction world we live in? I mean, wouldn't the money be better spent where we need it? On roads, schools, hospitals and job creation? I am not against conservation at all. I believe it is important to save the cheetah and the rhino and all that but the *K. pauciflora*? If you have to save something why not save something that helps with tourism or something? Anyway, it is natural for things to become extinct. I mean look at the dinosaurs! Man was not even around when they became extinct! Losing a couple of plants can't really be much of a deal, there are so many of them anyway. Your project should be stopped and the funding better spent elsewhere.



Citizen Activist

1. Working on your own, read the letter and then list the arguments the writer uses to support his/her argument. Highlight those arguments based on incorrect assumptions.

2. Work in groups of 4 to 6 and discuss all the points you have extracted from above question.

3. In your groups discuss whether it matters whether some people consider a species more important than others do. Is there something other than "opinion from different points of view" that could be more important in deciding the importance of a species?

4. Anthropocentrism (human centredness) is an attitude taken where all things are considered in the light of the relationship they have with man only. This means that the importance of plants and animals is seen only in the light of value to man. As an example, a plant may not seem as important if it does not have any direct economic benefit to man such as providing food or medicine. Do you think the author of the letter is anthropocentric? Support your argument with quotes from the letter.

5. Table an argument from each of the following points of view for and against the conservation of endangered species;
   a. economic,
   b. scientific,
   c. cultural,
   d. ethical,
   e. environmental, other.

   You may look specifically at the quagga and *K. pauciflora*, but you can choose other species too.

6. Respond to the writer of the letter setting out your views on conservation and the roles biotechnology can play in conservation.

Activity 5.4.3

The following is a list of collections of potato germplasm in Europe and the Americas (taken from Major Potato Collection.htm).

Major collections of wild and/or primitive potato species

Europe

- The Dutch-German Potato Collection, the Netherlands.
- The Commonwealth Potato Collection (CPC), United Kingdom.
- The Groß Lüsewitz Potato Collecion (GLKS), Germany.
- The Potato Collection of the Vavilov Institute (VIR), Russia
- Many European potato variety collections are in the participant list of the EU project on potato genetic resources.

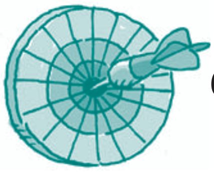
Americas

- The US Potato Genebank (NRSP-6), USA.
- The Potato Collection of the International Potato Center (CIP), Peru.
- The Potato Collection of the University of Cusco, Peru.
- The Potato Collection of the Proyecto de Investigation de la Papa (PROINPA), Bolivia.
- The Potato Collection of INTA-Balcarce, Argentina.
- The Potato Collection of CORPOICA, Colombia.

Answer the following questions:

1. Why do you think there are so many potato germplasm collections worldwide?
2. Are there germplasm banks for other plants? You may have to use the internet to source information to answer this question.
3. What are the benefits of having local potato germplasm collections?
4. What are the benefits of having international cooperation between the different potato collections?

Unit Six - Biotechnology Tools to Help Conserve Biodiversity



6.1 Objectives

Based on the activities and discussion in this unit, you will be able to:

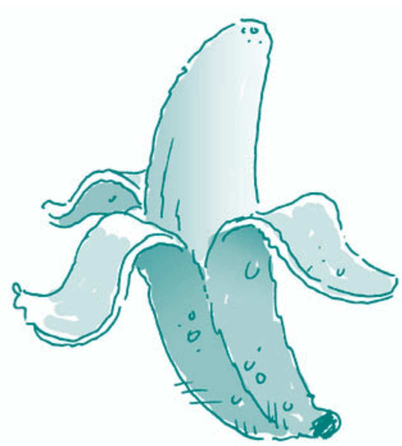
Learning Outcome	Description of activity to achieve outcome
1 – Scientific enquiry and problem solving skills: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using enquiry, problem solving, critical thinking and other skills.	Learners research and summarise the laws surrounding genetically modified organisms and critically discuss the example of floriculture in Nepal.
2 – Construction and application of Life Sciences knowledge: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.	Learners are introduced to various laws governing genetic modification of organisms. The investigate techniques to determine, document, conserving biodiversity and sustainable use thereof.
3– Life Sciences, technology, environment and society: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.	Learners discuss how animal cloning can enhance and/or deplete biodiversity. They weigh up the merits of cloning different types of organisms for different purposes. Learners are introduced to the controversy of the human gene bank in Britain, to the conflict between pressure groups and scientists and the laws protecting biodiversity and the responsible use thereof.

6.2 Background Information

As man has strengthened his position for survival on our planet, so biodiversity equilibriums have changed. In the past, the main consequence of man's dominance has been a general threat to biodiversity. There is no doubt that man impacts on biodiversity. Today we understand the dynamics of life on our earth better and are more equipped to take more responsible care of the environment. Biotechnology offers many tools that can assist us as custodians of biodiversity in determining the extent of biodiversity, documenting it, conserving it and finding ways to use it sustainably. The following table shows where some biotechnology tools are used in our study of biodiversity.

Role in our study of biodiversity	Tools	Role in conserving biodiversity
Determining Biodiversity	Genomic mapping	Allows us to see how much living organisms differ at the chromosomal level
	Phylogenetic trees	Allows a glimpse of evolutionary history of organisms – who their ancestors were
Documenting biodiversity	DNA fingerprinting	Allows molecular comparison between individuals
	Genome sequencing	Allows the identification of rare and useful genes
	Bioinformatics	Provides mechanisms for storing huge amounts of information and making it easily accessible
Conserving biodiversity	Sperm banks	Preserving and keeping male germplasm
	Egg banks	Preserving and keeping female germplasm
	Gene banks	Various parts of plants or animals are stored for possible use later. These can be frozen seed in the seedstore, meristems (mini plants) in test tubes, or genes held in clonal archives.
Sustainable use of biodiversity	Tissue culture;	Production of thousands of plants from a few mother plants and establishment of medicinal nurseries and gardens.
	Cell suspension cultures	Production of useful products without need to harvest wild plants.

Throughout the units in this series on biotechnology and biodiversity, we have seen that various human practices have increased biodiversity and others have threatened it. Some people see only the positive impacts humans have had and others see only the negative. This ambiguity in human attitude has provided a forum for a polar debate on man's input in the changes that occur in biodiversity. There are extremists who attack biotechnology in principle and those who support it in principle without looking carefully at what is being proposed with implementation of new technologies. It is the responsibility of each citizen to become well informed for wise citizenship. Being familiar with the arguments for extreme views and knowing the real science behind biotechnological methods will put us in a better position to make an informed decision about whether to allow ourselves, our family, our community, or the environment to be exposed to a biotechnology. Are you well enough informed to answer the question, "Will you eat this GM banana?"



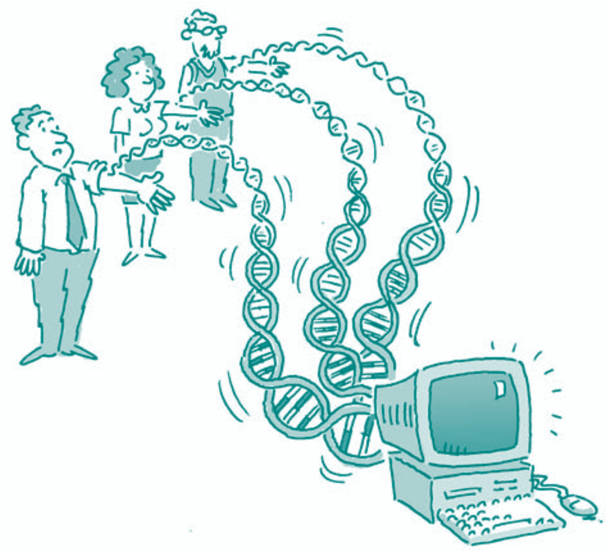
Activity 6.4.1

Read the following news release and the answer the questions that follow.

BBC News

Gene bank to recruit soon

Story from BBC NEWS: http://news.bbc.co.uk/go/pr/fr/-/2/hi/health/2923871.stm
Published: 2003/04/07 08:51:09 GMT. © BBC MMIV



A ground-breaking gene bank which will pool the DNA and medical histories of thousands of people in Britain plans to start recruiting volunteers in 18 months' time.

The controversial UK Biobank is an ambitious project designed to produce a mass database to help in tackling many diseases such as cancer, heart disease and Parkinson's. The organisers expect to begin looking for a representative sample of 500 000 middle-aged people aged 45-69 to volunteer a DNA sample and confidential health information next year. These people will then be tracked for up to 30 years.

Project director Dr John Newton will spell out plans for the project to a meeting of MPs, academics and industrial leaders in London on Monday. The Commons Science and Technology Committee has expressed doubts about the wisdom of the project, claiming it may drain scarce resources away from other research for no guaranteed gain.

And the pressure group GeneWatch UK has called for an independent review of the project. Dr Newton told the BBC: "It will give us a profound insight into the relative roles of environment, lifestyle and inherited factors in the course of all the important causes of disease which will help us to plan public health strategies for the next century."

'Good value'

The project will cost £45m over the first seven years. However, Dr Newton, former director of research at the John Radcliffe Hospital in Oxford, stressed that it would never cost more than approximately 1% of the total UK budget for medical research.

He said: "We think the benefits will be way out of proportion to the amount of funding. "It will have different benefits at different stages of its lifecycle. Even as we start collecting the data the information will provide a tremendous insight into the patterns of health and disease for our UK population. "But the really important benefits will come some 10-20 years down the line."

Dr Newton stressed that all volunteers would be free to withdraw from the project at any point.

"Information provided by them will be confidential and samples and data will be held in an anonymised form and stored in accordance with the highest possible security and encryption standards. "Samples and DNA will be stored centrally under the control of Biobank at all times. "They will not be released to third parties, and will only be used for the stated purposes of the project: that is, for biomedical research and the public interest."

Answer the following questions:

1. Why do you think the project is controversial?
2. Why are people from 45 to 69 only going to be asked to participate in the study?
3. The "Commons" are the members of the British Parliament who have been elected by the public to government. What is your opinion about the comments made by the Commons Science and Technology Committee? Think about 'informed' decision-making mentioned in the background information.
4. What is £45 million in South African rand?
5. Find out about GeneWatch UK and comment on their role in the debate.
6. Who provides the balancing view in the debate?
7. Write down what you think the benefits and the problems of the proposed project are.
8. Do you think you are adequately informed to make a decision about your parents (for example) participation in this project? Do you want to review your answer to question 3 above?

Activity 6.4.2

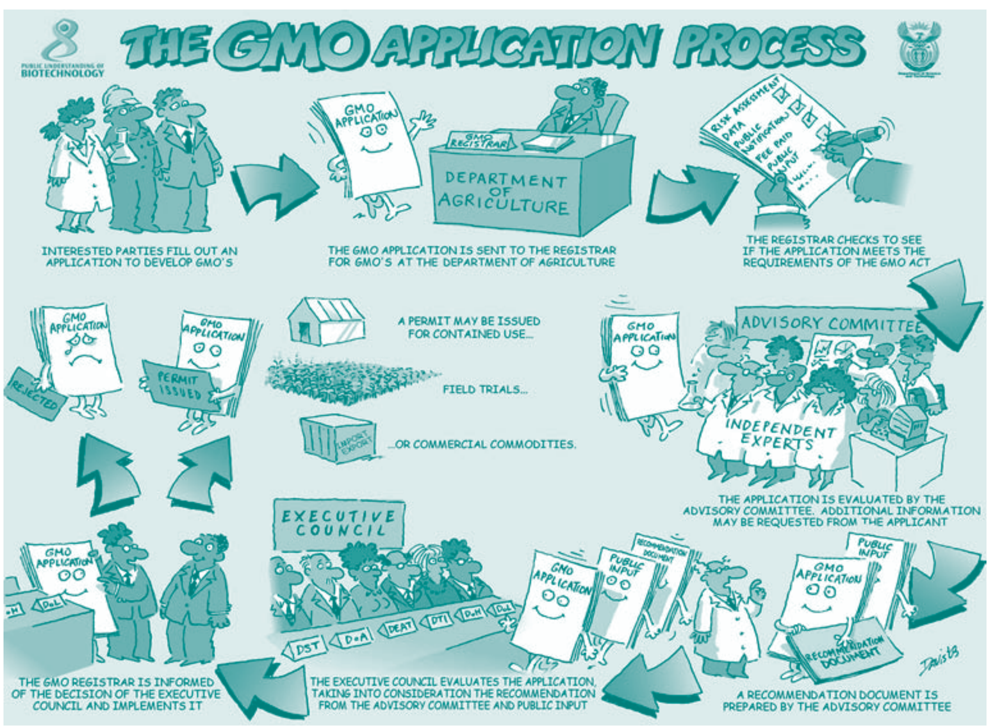
Laws to protect biodiversity and ensure the responsible use biotechnology

South Africa is a Party to an international convention negotiated in 1992 to help conserve the world's dwindling biodiversity – the Convention on Biological Diversity. (You may remember the big World Summit for Sustainable Development held in Johannesburg in 2002. This was a 10-year review of the Convention). This Convention requires Parties to put into place laws to protect threatened biodiversity. In response to the Convention, South Africa has developed a Biodiversity Act that requires all activities that may adversely affect biodiversity to get government approval.

The Convention also requires countries to investigate technology, including biotechnology, which could help document, conserve and allow sustainable use of biodiversity. South Africa includes this in the country's National Biotechnology Strategy. But, finally, the Convention asks countries to ensure that genetically modified organisms, improved by biotechnology, will not be so strong that they will displace vulnerable biodiversity. To this end, the country has implemented a GMO Act, which requires that all activities with GMOs are documented and obtain prior permission from government.

To assess the potential impact of GMOs, each one must undergo a risk assessment. This is undertaken by scientists who use their knowledge to predict and understand what impact new GMOs may have on health, the environment and social and economic aspects of life in this country. The risk assessment helps the decision makers decide what GMOs are safe enough to proceed with and which ones need to be made safer before they can be used. This process is illustrated in the following poster.

Study the poster of the GMO Act process and answer the following questions:



1. The GMO Act requires all applicants to apply for activities with GMOs. Can you spot what GMO activities require a permit?

2. The process requires a risk assessment, a call for public input, an independent scientific review of the risk assessment and a decision making committee. Can you find each of these components in the poster?

3. Which government department receives all applications on GMOs and issues the final permit?

4. Which government departments participate in the decision making?

5. In a table, match which of the following impacts each of the government departments might assess before making a decision. Positive and negative impact on:

   - Labour;
   - Biodiversity of agricultural crops;
   - Trade into and out of the country;
   - Industrial growth;
   - Natural biodiversity;
   - Human health;
   - Animal health;
   - Food safety;
   - Feed safety;
   - Commercial and small-farmer agriculture;
   - Ethics;
   - Public acceptance;
   - Traditional practices;
   - Science policy;
   - Environmental impact.

6. Do you think the GMO Act allows the government to make an informed decision? Support your answer with aspects of the application review process.

7. Knowing that each and every GMO on the market in South Africa passes through this safety review process, would you say that GM products are safe to eat? Justify your answer.

Activity 6.4.3

The following article has been cut to provide only parts relevant to the questions.

Nepalnews.com
NEWS FROM NEPAL AS IT HAPPENS

SPOTLIGHT
Vol. 20 :: No. 31
THE NATIONAL NEWSMAGAZINE
Feb 16 - Feb 22 , 2001.

Floriculture Development In Nepal

By Dr. Dibya Deo Bhatt

…The rich plant life of Nepal and existence of different bio-climatic zones allows growth of different flowering species, many of these being found in the Alpine zones. Thus far, about 6000 species of flowering plants have been catalogued by the British Museum (Natural History). There is an urgent need to preserve this rich biodiversity but unfortunately many plants because of over exploitation, including those which have been declared as endangered by the CITES and listed as protected are smuggled out of the country. This is especially the case of those which have high medicinal value. There is thus an urgent need to conserve such species and use new technologies (biotechnology) for their propagation. A conifer (Yew, Taxus baccata) which is found in East Nepal has been subjected to intense destruction as its leaves yield a drug which has been found highly useful in the treatment of certain types of cancer.

Hence, there is all the more need to make available plants raised by tissue culture methods. The Plant Research Division at Godavari has been successful in raising many plants, herbaceous as well as woody, in the laboratory through tissue culture. There is a compelling need to intensify this work.

In order to develop floriculture in Nepal, the government has to play an active role, especially through providing subsidies for the establishment of green houses, controlled temperature facilities at the airports, an efficient plant quarantine service and encouraging more research and development in this field. The role of the cooperative societies in promoting floriculture is considerable; in countries such as the Netherlands and Israel, which lead in exporting seeds, bulbs and other planting flowering materials, the government provides facilities for this.

The Botanical Gardens have an important role to play in the development of plant industry. Besides undertaking research on plants suitable for gardens, they should be able to fulfill the demand for plants, seeds and other material. Interest in flowers, both for home gardens and commercial purposes is now growing and the national Garden should be able to fulfill the needs of the growers, as well as home gardeners.

Task

In the above article, a biodiversity problem and proposed solution have been discussed. Discuss in your own words what the problem is and what biotechnological tools are mentioned in the article. Also propose some other biotechnology tools that could help alleviate the problem.

Activity 6.4.3

FEATURES

NATIONAL DAILY

THE RISING NEPAL

Kathmandu Jestha 29, 2059.

Bio-diversity Conservation

Biotechnology Essential

By Khilendra Basnyat

BIO-DIVERSITY is the term used to describe all kinds of living things on earth, together with their ways of life and the wild places in which they live. This term was used right after the Earth Summit Conference held in Rio de Janeiro, Brazil in June 1992.

Beneficial

At this conference, the leaders of over 150 countries' governments promised to protect the bio-diversity of their countries and to help poor countries do the same. They believed that humans have no right to destroy the world's living plants and wildlife. They also realised that any living plant and animals might be beneficial for humans either in helping to fight diseases or to produce new food crops.

The world's rapid population growth has led to widespread forest encroachment in order to feed the millions that come to this earth every year. Deforestation, along with other development activities, have put tremendous pressure on limited natural resources including land, water and forest.

The equilibrium between environment and development has been disturbed by human development activities over the past few decades. Hence, several national and international efforts have been made to generate awareness among the general people about the significance of environment, ecological balance and bio-diversity.

Due to its unique geographical location and geo-ecological variation, Nepal is considered to be one of the richest countries in the world in terms of bio-diversity. The wide geo-ecological variation has promoted a variety of ecosystems, thick forests with a wealth of flora and fauna. Some of these are endemic of Nepal.

In fact, the diversity of physical geography due to the latitudinal variation has made it possible to include almost all types of climate, of broadly tropical, temperate and alpine regions. This is why Nepal is prominent for its biological diversity and is called a naturalist's paradise.

Due to extended latitudinal climate and broad plant bio-diversity, Nepal possesses a huge potential of zoological realms. It is considered the house to about 850 species of wetland, aqua, migratory and residential birds, Apart from this, 155 species of Pisces, 43 species of mammals, 5055 species of other varieties of reptiles, and lesser invertebrates are found in this country.

Out of a total of 5000 plant species, 190 are indigenous to Nepal. About 700 of them are valuable medicinal plants, Rhododendron, the national flower of Nepal, adorns most of its hilly and mountainous areas. Equally enchanting are the seasonal flowers bearing significant cultural and religious importance.

The wild fowls found in Nepal's forests are the progenitors of the domesticated chickens. Wild bananas, wild mango and wild apples found in Nepal are said to have immense genetic value. They have great demand in agricultural research.

Due to high population growth, intense environmental pollution and extended economic crises, deforestation has accelerated in Nepal, Consequently, bio-diversity is threatened.

Since the past few years, a variety of symposiums, workshop seminars and conferences have been held with optimistic talks and policies. However, the situation regarding bio-diversity preservation remains rather dismal. In the last few years, billions of rupees were spent in the name of bio-diversity preservation. However, the expected objective is yet to be realised due to the lack of proper harmonised cultivation and its preservation.

The Ministry of Environment was established. Likewise, master plans of the forestry sector were launched with modifications to emphasise research and development regarding the environment and bio-diversity. However, till now, not much progress can be seen and the concerned authorities have not kept pace with the genuine needs.

In reality, the hallmark of the Eastern Himalayas is the immense diversity of landscape and a rich variety of biological life. Experts and policy-makers should assess gaps, opportunities and threats to bio-diversity and develop a long-term vision for conserving the rich bio-diversity of the eastern Himalayas.

Actually, a vision for the Eastern Himalayas requires a 20-year plan that leads to the conservation of the different animals and plants present within a well designed and well managed systems of protected areas.

For bio-diversity conservation, endeavours should be made to look forward to develop mechanisms for regional collaboration on information exchange and mutual support in scientific research. In addition, prevention of trade in wildlife products and an innovative institutional mechanism for future bio-diversity conservation are essential.

No doubt, the success of bio-diversity conservation depends on local community support. In order to meet their growing legitimate resource needs in a sustainable manner, areas adjacent to the protected areas should be designated buffer zones. This will help manage the resources in an effective way. Apart from this, consolidation of resources and updating the park management plan are of paramount importance to address the problems and challenges encountered by the local people of protected areas. Also a balance between bio-diversity conservation and judicious utilisation needs to be addressed for the longevity of our life support systems.

Since Nepal is a land of many villages, bio-diversity conservation is essential to boost household income in rural communities. In recent years, wild biological and genetic resources, plants, medicinal herbs, etc. have good market value. The annual income of medicinal herbs is about 10 million US dollars. However, about 90 per cent of the herbs are exported to India at low prices because of absence of processing facilities within the country.

In fact, destructive activities of humans in general and damaged habitats around the protected areas in particular have threatened Nepal's bio-diversity. It has been estimated that if Nepal were to lose its remaining humid tropical forests, ten species of valuable timber, six species of fiber, six species of fruit trees, four species of traditional medicinal herbs and about fifty species of little known trees and shrubs would be lost for ever.

What is more, several wildlife habitats for 200 species of birds, 40 species of mammals and 20 species of reptiles and amphibians would be greatly affected. It was in this regard that during the early 1970s, Nepal's protected areas were established totaling 21000 square kilometres, representing about 14 per cent of the country's total land area. This area includes eight national parks, four wildlife reserves, two conservation areas and one hunting reserve.

Nepal's wildlife resources outside the protected areas are threatened and virtually unprotected. In fact, the lists under the national parks and wildlife conservation act, (1973) fails to include some identified endangered species due to financial problems. The small gene bank established by the National Agricultural Research Council is also incomplete. It is due to scarce human and financial resources.

In reality, the government has realised the importance of bio-diversity conservation, especially since the treaty of the Convention on Biological Diversity was signed on June 12, 1992 during the Earth Summit in Rio de Janeiro. The priority areas in the environment and sustainable development have been identified in the Ninth Five-Year Plan.

The government has also drafted a Bio-diversity Trust Fund (BTF) to provide financial support for bio-diversity conservation. BTF focuses on the management of protected areas. The profile of BTF includes objectives, legal structure process/modus operandi, government or administrative mechanism, funding sources and criteria for funding capabilities. Likewise, the government has almost finalised the Bio-diversity Action plan, which will address the management planning, resources allocation and capacity building.

Need

Despite continuing efforts, Nepal has witnessed the fast depletion of its precious bio-diversity over the last few decades. Since biotechnology helps restore depleting bio-diversity, there is a need to adopt this technology as soon as possible.

TASK:

Design a 20 year conservation plan to help Nepal protect its biodiversity. Include animals and plants. Consider what areas need the most attention quickly and what biotechnology tools they could use to help document, conserve and use their biological resources sustainably. Are there ways that local communities could help conservation and get benefit from the biodiversity at the same time?

Activity 6.4.4

Read the following article and then do the task that follows:

Excerpt from: First cloned animal in Africa

http://www.saholstein.co.za/News/i_cloned.htm

"The *Embrio Plus Centre*, working in close collaboration with international embryologists, is now looking to the future to play a role in the cloning of animals," says Dr De la Rey, director of the centre.Dr De la Rey says the world-wide success rate of producing live cloned offspring from high-quality domestic livestock has improved in the past decade. The first cloned mammal was Dolly the sheep in Britain, which, before she died recently, had produced healthy lambs. "By cloning it is possible to reproduce the same attributes of known high-quality animals, thus eliminating the unknown factors that could result from normal breeding practices. There are of course, those who say that the downside of cloning is that it could narrow a breed's genetic base, with no further genetic improvement," he says.

"Because of its very high cost, cloning will not be economically viable in commercial agriculture. The implementation of the technique will initially be limited to biotechnology development, with the result that the genetic base of any breed will continue to be broadened by the existing conventional breeding practices. Cloning will probably be justified only when cells are taken from exceptionally high-producing and invaluable livestock. These animals must also have no prospect of generating offspring by the more conventional and cheaper assisted reproductive techniques," says Dr De la Rey.

The *Embrio Plus Centre*, specialising in embryos, has established a reputable name worldwide. In recent years the centre has exported about 12 000 embryos to many parts of the world, including Canada, the United States, Brazil, Argentina, Australia, and African countries. Last year it exported 3 000 embryos from South Africa's indigenous Bonsmara, Afrikaner, Nguni, Tuli, and Drakensberger cattle breeds and also breeds like Simmentaler, Brahman, Sussex, and Angus.

One of the possible benefits of animal cloning may be the influence it could have on the conservation of some critically endangered wildlife species. According to Dr Paul Bartels from the Endangered Wildlife Trust, wildlife species are facing greater threats to their survival than ever before, due mainly to human interference. Habitat protection remains the first priority in wildlife conservation. However, this may not be enough to save some wildlife species from extinction. It is prudent to use whatever techniques available, including cloning, so as not to lose further genetic diversity within wildlife populations," says Dr Bartels.

Cloning, he adds, has the potential to assist in the preservation of a species whose numbers are already critically low and from which tissue was previously collected when the species' numbers were still high. Theoretically then, one could clone one (only) animal from each cell line of previously banked tissue and so broaden the genetic diversity of the remaining population.

"Although cloning technology still has some way to go, this first calf holds great hopes for Africa's rare indigenous livestock and wildlife species as well as for agricultural science and biotechnology development."

Task:

Animal cloning can both enhance and deplete biodiversity.

Discuss these two extreme arguments and then apply your arguments to possible future cloning projects.

In your discussion weigh up the merits of cloning different types of organisms for different purposes. For example, should the same resources be ploughed into cloning cheetahs to raise their numbers as into cloning cows to produce medicinal milk that could vaccinate entire indigent populations without the use of syringes?

Notes