Applications of Biology

Contents List

INTRODUCTION

Too often the study of Biology at A-level can seem like a disorganised collection of facts. The problem is that to understand many of the ways in which Biological knowledge, understanding, skill and technology is used to enhance our lives, we need to understand the basic principles of Biology. This is one of the purposes of the core sections of the biology syllabus, and takes time and effort. Students who are approaching the end of their A level studies have acquired a better understanding of the way Biology works and can thus look at applications of Biology in a more meaningful way.

This booklet is designed to support teaching and learning in 9700 Biology A Level, in the Applications of Biology section of the syllabus which is a feature of the 2007 syllabus and those that follow. This material replaces the former options. All students are expected to study all sections of the Applications of Biology syllabus.

This section of the syllabus examines some of the important areas in which facts, understanding, skills and technology obtained from biological science research and studied in the core syllabus can be applied to making life better. The topics include biodiversity and conservation, gene technology, biotechnology, crops plants and aspects of human reproduction.

Chapter 1: Biodiversity and Conservation investigates the variety and classification of organisms and the potential and actual advantages of such biodiversity. Through the study of the African elephant as an example, the reasons that organisms become endangered are considered. The role of zoos, botanic gardens, national parks and seed banks are considered in relation to conservation of biodiversity.

Chapter 2: Gene Technology takes a structured look at the process known as genetic engineering or genetic manipulation and the creation of recombinant DNA and its implications. Electrophoresis is used as a context to consider genetic fingerprinting and DNA sequencing. Cystic fibrosis is investigated as a genetic condition which gene technology has the potential to improve.

Chapter 3: Biotechnology is about the variety of industrial applications of microorganisms and cultured cells. It includes bio-extraction from heavy-metal ores, culture of microorganisms focussing on penicillin, enzyme immobilisation, application of such enzymes in dip-sticks and biosensors for glucose detection and monoclonal antibodies.

Chapter 4: Crop Plants takes a look at the variety of techniques that are used to enhance the crop plants that feed the world. Aspects of the biology and reproduction of crop plants are considered as well as some of their adaptations and use of hybridisation and genetic manipulation to improve them.

Chapter 5: Aspects of Human Reproduction reviews human gametogenesis and the role of hormones in controlling the menstrual cycle. The role of hormones and synthetic hormones in controlling fertility is exemplified by the combined contraceptive pill and IVF, looking both at how they work and also their implications.

Each topic lays out the key objectives, stating concisely the intended learning outcomes of the chapter, which are detailed in the syllabus, to which reference should also be made. It has key definitions that include any hard-to-define terminology in the syllabus section. These are followed by the main text, termed Key Ideas. At the end of each chapter are self-assessment questions to help students to check their understanding as they work through the material.

The book is designed so that it can be used by teachers, alongside the Applications of Biology syllabus and the Scheme of Work that can be found on the CIE Teacher Support Website (contact international@cie.org.uk to find out how to gain access to this learning resource). The book should help teachers to design effective learning programmes to teach this material, which makes up 16% of the total assessment at A level and should thus make up just over 30% of the total teaching time available during the A2 part of the course.

The book is also designed so that it can be used by students, to promote their own learning, and for this purpose contains, as well as a lot of detailed and carefully chosen information, self-assessment questions for students to use in helping to determine how effective has been their learning.

Throughout the book are given website addresses. All of these have been tested and are working at the time of writing, but such sites are notoriously quick to change their url addresses, so by the time that you get to try and use them, they may well be found not to work. The author strongly recommends that a good search engine such as google or yahoo, or a meta-search engine such as copernic, be used to seek up-to-date websites for information on each of the topics on the syllabus. Make use of the ability of these sites to search for definitions of terms (e.g. search for ‘biodiversity definition’), specific information (e.g. searching for ‘five kingdom classification’ in google produces over 10 million hits, of which every site on the first page is relevant and useful) and images (e.g. search for ‘maize leaf’ in the image tab on google currently gives 446 hits, on the first page of which are eight useful images).

BIODIVERSITY AND CONSERVATION

Key Objectives

- To be able to outline the five kingdom classification of living organisms
- To be able to define the term *biodiversity* and discuss its meaning
- To understand why *biodiversity* is declining and the need fore it to be maintained
- To understand the reasons why one named species has become endangered
- To understand the ways in which endangered species may be protected and prevented from becoming extinct

Key Definitions

- *Biodiversity* – this is the total number of different species living in a defined area, ecosystem or biome. It is also possible to consider the biodiversity of the earth.
- *Endangered species* – any species whose numbers have become so low that they are unlikely to be maintained by normal rates of reproduction and are in danger of becoming extinct.

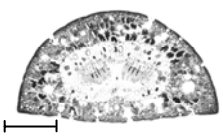
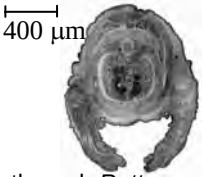
Key Ideas

The Five Kingdom Classification

To understand the five kingdom classification, pupils will need to be familiar with Syllabus section A, especially c, e and g – the structure of plant and animal cells and the differences between prokaryotes and eukaryotes.

Early classifications suggested that organisms could best be organised into two kingdoms, those having no cell walls, whilst being motile and heterotrophic (animals) and the rest (plants). It was realised that this did not work very well as some of the organisms in the 'plant' kingdom were very different, for example prokaryotic bacteria and highly differentiated eukaryotic flowering plants. Various alternative classifications have been proposed, most recently a three-domain classification in which prokaryotes are divided into two domains (bacteria and archaea) with eukaryotes as a third. http://en.wikipedia.org/wiki/Three-domain_system The working classification used by many biologists, and featured in the 9700 biology syllabus has five kingdoms and is considered below. http://en.wikipedia.org/wiki/Five-kingdom_system

This five kingdom classification divides the living world into five Kingdoms. The diagnostic features of each of these kingdoms is summarised in the table on the following page.

Prokaryotae (prokaryotes)	**Protoctista** (protoctists)	**Fungi**	**Plantae** (plants)	**Animalia** (animals)
single-celled or groups of cells cells are prokaryotic i.e. • have no nucleus or membrane-bound organelles, • circular DNA with no associated histone proteins • small circles of DNA (plasmids) often present • small (70s) ribosomes	single-celled or not differentiated into tissues – any eukaryote not in one of the other three eukaryote kingdoms cells are eukaryotic i.e. • have a nucleus and various membrane-bound organelles, • DNA in form of linear chromosomes with histone proteins in a nucleus • larger (80s) ribosomes diverse, some have cell walls, some don't, some autotrophic, some heterotrophic	most are multicellular but not differentiated into tissues, yeasts are single-celled never motile (self-propelled) cells are eukaryotic i.e. • have a nucleus and various membrane-bound organelles, • DNA in form of linear chromosomes with histone proteins in a nucleus • larger (80s) ribosomes cell walls of chitin heterotrophic body made of hyphae, reproduce by spores	multicellular and differentiated into tissues motile male gametes in mosses and ferns cells are eukaryotic i.e. • have a nucleus and various membrane-bound organelles, • DNA in form of linear chromosomes with histone proteins in a nucleus • larger (80s) ribosomes cell walls of cellulose autotrophic (feed by photo-synthesis)	multicellular and differentiated into tissues often motile cells are eukaryotic i.e. • have a nucleus and various membrane-bound organelles, • DNA in form of linear chromosomes with histone proteins in a nucleus • larger (80s) ribosomes no cell walls heterotrophic
bacteria archeobacteria cyanobacteria	algae protozoa slime moulds	yeasts moulds mushrooms	mosses ferns conifers flowering plants	worms arthropods chordates
 Single bacterium showing flagellae, cell wall & lack of nucleus	 Part of *Spirogyra* showing cell wall nucleus & chloroplast	 Part of *Pencillium* showing cell walls, nuclei and spores	t.s. through *Pinus* leaf showing various differentiated tissues 	 t.s. through *Rattus* thorax showing various differentiated tissues

Biodiversity

The biodiversity of the planet is the result of evolution. In any ecosystem, there is a huge interdependence between species and it is clear that biodiversity is essential to maintain ecological balance and stability.

Another part of biodiversity is the extent of genetic diversity with species and populations. Such genetic diversity is also essential for the stability and survival of a species.

The Need to maintain Biodiversity

Biodiversity is in decline – mostly as a result of a variety of man's activities. It is now well understood that it is important to try and halt this decline – indeed, conservation measures are needed, not only to halt the decline, but to try and restore as much biodiversity as possible.

The need to maintain biodiversity may be considered in terms of biological reasons or reasons from a human perspective :

Biological reasons

As mentioned above, it is essential that biodiversity is maintained if ecosystems (and the whole planet) are to remain ecologically balanced and stable.

In addition, evolution has resulted in diverse gene pools within populations – the maintenance of these gene pools and the genetic diversity of species is extremely important if species are to be prevented from becoming extinct.

Human reasons

Other species of animals and plants provide an important resource for humans. These may be

- For use in agriculture, either as potential food supplies or to be crossed with existing agricultural species to improve features, such as yield, hardiness or disease resistance.
- To provide possible medicines
- To encourage tourism in some countries - ecotourism
- From an ethical point of view, if human activity has been largely responsible for the decline in biodiversity, then humans have an obligation to reverse this decline. Equally, it is important to try and maintain the current level of biodiversity for future generations.

Reasons why species have become endangered

In African ecology, the elephant is regarded as a keystone species. In 1930 there were estimated to be 5 – 10 million African elephants. By 1979 the number was reduced to 1.3 million and when it was officially added to the endangered list in 1989,

the numbers had fallen to around 600,000 - less than 10% of its numbers earlier in the twentieth century.

http://www.panda.org/news_facts/education/high_school/species/herbivores/african_elephant/index.cfm
http://www.awf.org/wildlives/elephant.php http://www.save-the-elephants.org/

A number of factors contributed to this dramatic decline in numbers:

- *Habitat loss* – elephants eat a great deal and need a large amount of habitat. During the twentieth century, the human population of Africa has increased massively and, as a result, humans and elephants have become competitors for living space. The forest and savannah habitats of the elephant have been reduced as humans have used timber for fuel and building and land for growing crops and grazing livestock.
- When humans and elephants live in close proximity, various problems arise – elephants raid crops and, on occasion, will rampage through villages. Farmers and other residents regard them as something of a pest and shoot them.
- *Hunting* – this has been a major cause of the decline in elephant numbers. Elephants became prized trophies for big-game hunters and, more recently, they have been killed for their ivory tusks. Ivory is easily caved and regarded as a beautiful material – most of the ivory carving in the world takes place in Japan and other countries in Asia. At one stage, ivory was more expensive than gold – indeed, it became known as 'white gold'. Hunting continues for the global 'bushmeat' trade (see http://www.bushmeat.org/IMAP/species/L_africana.htm).
- *Poaching* – it is no longer legal to hunt elephants in most African countries. However, the high prices paid for ivory meant that elephants continued to be killed by poachers. At its peak, the poachers became highly organised, using automatic weapons, vehicles and even planes to herd and kill huge numbers at a time. The biggest elephants were usually targeted (because they have the largest tusks) which meant that it was generally the adults that were killed, leaving young elephants without any adults to learn from. As a result, the social structure of the elephant populations broke down and many of the elephant groups left were leaderless juveniles.

African elephants - summary

- IUCN Red list status = vulnerable
- CITES Listing Appendix I except Botswana, Namibia, South Africa and Zimbabwe, Appendix II
- Habitat loss – competition between humans and elephants for space, trees and grazing leading to loss and fragmentation of the elephant habitat
- Hunting and poaching – for trophies, ivory, protection of villages and for bushmeat

Other species which are endangered include the orangutan
http://www.un.org/works/environment/animalplanet/orangatang.html
http://www.panda.org/about_wwf/what_we_do/species/our_solutions/endangered_species/great_apes/orangutans/index.cfm
http://www.orangutan.org/facts/orangutanfacts.php

Methods of protecting endangered species

There are a variety of ways in which attempts are being made to protect endangered species and prevent them becoming extinct. The extent to which these attempts are successful is somewhat variable.

- **Zoos**

One way of protecting endangered species of animals is to capture some from the wild and place them in captivity. In this way, it is possible to make sure that they are well fed, protected from predators and disease and isolated from other potential problems which might be encountered in their natural habitat.

If such animals are simply placed in zoos, the zoo is really acting as an 'ark' and little is actually being achieved in terms of maintaining or increasing populations in the wild. If the animals will breed in captivity, then it is possible to maintain or even increase numbers. If such captive-bred individuals can be returned to their natural habitat, then it might be possible to increase numbers in the wild, thereby preventing the endangered from becoming extinct.

Captive breeding has a number of advantages:

- it is possible to monitor the health of the mother and the development of the fetus during the pregnancy.
- sperm and eggs can be obtained from the captive individuals
- these can be stored in a frozen form
- it allows the possibility of artificial insemination
- also in-vitro fertilisation
- fertilised embryos may be implanted in surrogate mothers (which might even be of different species)
- there is the possibility of international co-operation and the transfer of breeding individuals between different zoos
- it allows the keeping of breeding records and the genetic relatedness of captive individuals

Golden lion tamarin http://www.hrw.com/science/si-science/biology/animals/glt/index.html
http://nationalzoo.si.edu/ConservationAndScience/EndangeredSpecies/GLTProgram/
Arabian oryx http://www.arabian-oryx.com/

Although some species of animals have been bred successfully in captivity and released back into the wild, with other species this has not been straightforward and a number of problems have been encountered. It has been found that some species simply do not breed successfully in captivity, whilst, in some cases, there have been problems in releasing animals that have bred in captivity.

Captive Breeding

There are a number of reasons why animals do not always breed successfully when in captivity:

1 They are no longer living in their natural habitat

2 The conditions experienced in captivity can cause stress and behavioural changes
3 The stress can disrupt normal reproductive cycles and breeding behaviour
4 They often have little choice of mate and may reject the chosen mate

Release of captive-bred individuals into the wild

Problems which reduce the success rate of releasing captive-bred individuals include :

1 Habitat destruction (usually as a result of man's activities) might mean that there is very little suitable habitat available in which to release the animals
2 Having been in captivity, animals might not find it easy to move around in their natural habitat
3 It may not be easy for them to find enough food – especially if they have been used to being fed in captivity
4 They may not be able to communicate with other members of their species in the wild and may not integrate into social groups
5 They may be susceptible to diseases in the wild

Some of these problems are being overcome by making sure that conditions within zoos are as close to the natural habitat of the species as possible. Contact with humans is kept to an absolute minimum and individuals can be 'acclimatised' in cages before they are actually released into their natural habitat.

Cheetah http://nationalzoo.si.edu/ConservationAndScience/EndangeredSpecies/Cheetah/
Californian condor
http://bna.birds.cornell.edu/BNA/account/California_Condor/CONSERVATION_AND_MANAGEMENT.html
Detailed overall review of Captive Breeding and Reintroduction
http://darwin.bio.uci.edu/~sustain/bio65/lec23/b65lec23.htm

- **Botanic gardens**

Endangered species of plants can be grown in botanic gardens. Clearly, it is possible to create ideal growing conditions – either outdoors or in glasshouses, when it is possible to control very carefully the growing conditions. This applies to the availability of light, nutrients, water and the atmospheric conditions.

Within such botanic gardens, it is also possible to propagate endangered species – either by growing from seed or by some means of vegetative propagation, such as cuttings. Techniques of tissue culture also allow large numbers to be produced very quickly.

This allows the possibility of re-introducing endangered species of plants into their natural habitat.

Botanic Gardens Conservation International http://www.bgci.org.uk/
Varied links to botanic garden websites http://nature.ac.uk/browse/580.73.html
Royal Botanic Gardens, Kew, London, UK http://www.rbgkew.org.uk/conservation/index.html

- **Seed banks**

Many plants produce seeds which are very long-lived and large numbers can be stored in a relatively small space. Such a collection of seeds is referred to as a seed bank. The life span of such seeds can be extended if they are kept in carefully controlled conditions – especially in an atmosphere of low oxygen levels, moisture and temperature.

Given that the seeds will contain all the genetic material of any given species, it also means that the gene pool of that species is being maintained.

Clearly, if the seeds of endangered species are stored in this way, such seeds can be germinated at any time and plants can be grown in Botanic gardens or restored to the wild.

Some species produce seeds which have a limited longevity (e.g. cocoa, rubber, coconut) – keeping their seeds in seed banks is not possible. Such plants would need to be maintained in botanic gardens.

http://www-saps.plantsci.cam.ac.uk/osmos/os24.htm http://www.rbgkew.org.uk/msbp/

- **National Parks (and other protected areas)**

Many countries have designated areas, such as National Parks, which are set up to conserve rare / endangered species and maintain important habitats. Often, legislation is passed to ensure that such areas are protected under the law.

The ways in which National Parks protect their resident species include :

1. Wardens, rangers and volunteers can be used to patrol the parks
2. Access by humans can be restricted – often footpaths are created and maintained to avoid interference with wildlife habitats
3. Agricultural activities can be strictly controlled – traditional farming methods can be encouraged
4. Industrial activities and mining can be limited and controlled
5. The building of roads, dwellings and other developments can be strictly controlled
6. Visitor Centres can be established to educate the general public in the importance of conservation within the Park – and elsewhere
7. Wildlife can be protected directly e.g. 24 hour surveillance of nests / breeding sites

In addition to National Parks (which usually occupy large areas of land), different countries can also create other categories of conservation areas if they contain species or habitats which need some form of protection

http://www.wcmc.org.uk/protected_areas/data/sample/iucn_cat.htm http://www.unep-wcmc.org/protected_areas/index.html

Biodiversity and Conservation Self-Assessment Questions

SAQ 1 With reference to the five kingdom classification, outline the similarities and differences between :

(a) prokaryotes and protoctista

(b) fungi and plants

(c) plants and animals.

SAQ 2 Explain what is meant by the term *biodiversity* and give **three** reasons why it is important that it should be maintained.

SAQ 3 With reference to a **named** endangered species, explain why its numbers have declined to a level at which it had to be placed on the endangered list.

SAQ 4 Outline the roles of zoos and botanic gardens in the protection of endangered species.