TOPIC 4:

BIODIVERSITY AND NATURAL RESOURCES

For the Edexcel Biology A Level (SNAB)

TOPICS COVERED

- Ecological Niches and Adaptation
- Evolution by Natural Selection
- Allopatric Speciation
- Hardy-Weinberg Equation
- Quantifying Biodiversity
- Classification
- Genetic Diversity within Populations
- Plant Cell Ultrastructure
- Cellulose and Starch
- Lignification, Transpiration and Translocation
- Use of Inorganic Ions by Plants
- Using Plant Fibres
- Drug Development and Clinical Trials
- Growing Bacteria and Aseptic Technique
- Using Seeds
- Sustainability: Seed Banks and Zoos

Edexcel Biology AS: Biodiversity and Natural Resources [Topic 4]

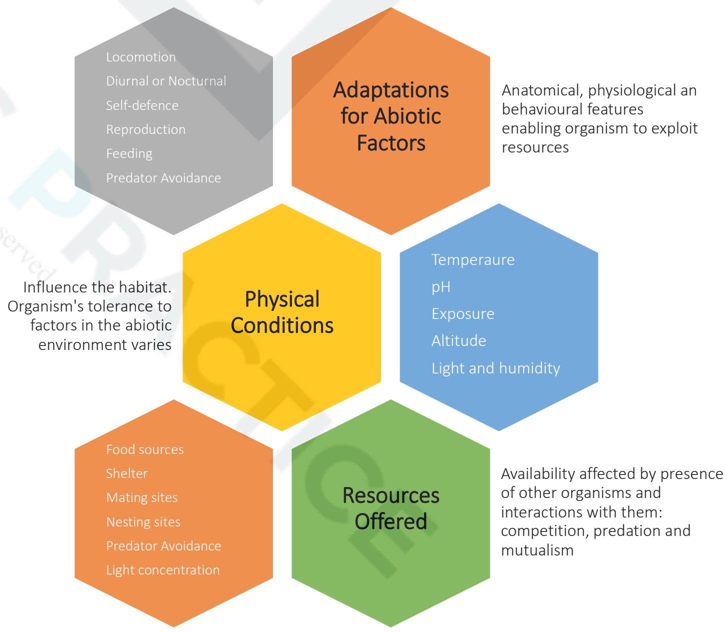
Ecological Niches and Adaptation

Key Terminology

Term	Definition
Niche	Precise description of all the physical, chemical and biological factors that a species needs to survive and reproduce. This includes the role of a species within an ecosystem, its location and function, its relationships with other organisms and its effect on the environment
Competitive Exclusion Principle	Two different species do not occupy the same niche simultaneously; one species will compete more efficiently and the weaker species will die out or adapt to another niche
Fundamental Niche	Potential niche of a population with a range of environmental conditions for a species to survive
Realised Niche	The actual niche occupies by the population
Intraspecific Competition	Competition for resources within a species
Interspecific Competition	Competition for resources between different species
Ecosystem	All the interdependent biotic and abiotic factors in a particular area with self-containing energy flow
Habitat	Geographical area occupied by an ecosystem
Community	All the biotic factors (organisms) in a particular habitat at one time
Population	All the members of one species in a habitat at one time
Behavioural Adaptation	Any actions by an organism which helps them to survive or reproduce
Physiological Adaptation	Features of the internal workings of organisms which help them to survive and reproduce
Anatomical Adaptation	Structures which can be seen by observation or dissection
Niche Partitioning	Species using different parts of fundamental niches to allow coexistence

Over time the variety of life has become extensive but is now being threatened by human activity.

Ecosystems contain many species, all of which have specific niches – a specific role each species plays, a suitable location and function, its relationships with other organisms and its effect on the environment. Whilst the fundamental niche for each species may be large, competition narrows the realised niche. Intraspecific competition broadens the niche as individuals relocate to different levels or locations within the habitat survive. Interspecific competition narrows the niche as it encourages niche differentiation – this is niche partitioning.



A species has certain adaptations which allows it to exploit the resources available in its niche: these can be behavioural, the actions which helps the organism to survive, physiological, internal features, or anatomical, visible structures.

Example of a Niche and Adaptations of the Organism: Acacia Tree

Producer found in the Savannah biome in the Sahel region of Africa.

- Anatomical Adaptation: long tap roots reaching ground water stores, fire resistant
- Physiological Adaptation: secretion of toxin in leaves to deter herbivorous giraffes
- Behavioural Adaptation: releases cloud of ethylene gas to warn other nearby trees to produce toxin in leaves

Evolution by Natural Selection and Allele Frequencies

Key Terminology

Term	Definition
Evolution	Change in allele frequency in a population over time
Natural Selection	Process by which organisms with an adaptation favouring a selection pressure are able to survive and reproduce, eventually leading to evolution
Gene Pool	All the alleles of all the genes present in a population
Microevolution	Small changes in allele frequency
Macroevolution	Long-term changes leading to evolution and eventual speciation
Speciation	The formation of new species which are reproductively isolated
Sympatric Speciation	Evolution of new species which live in the same habitat
Allopatric Speciation	Evolution of new species due to geographical isolation and exposure to different selection pressures

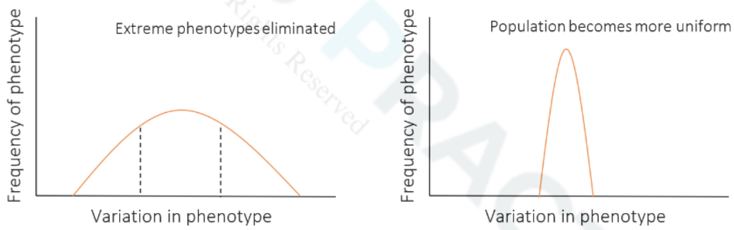
Evolution is the process by which there is a gradual change in the gene pool of a species over time. Natural selection is the continuously occurring process which usually drives evolution. If the environment remains stable, organisms may simply become better adapted to existing niches.

Darwin's Theory of Evolution by Natural Selection:

1. A population has natural-occurring genetic variation with new alleles created by mutation
2. A change on the environment causes a change in selection pressures acting on the population
3. An allele which was previously of no particular advantage now becomes favourable
4. Organisms with this allele are more likely to survive and reproduce
5. Offspring are more likely to inherit the allele so it becomes more common in the population

Evolution can be driven by five processes:

- Population Size: a decrease in population size leads to some alleles being lost by chance
- Mate Selection: selecting mates based on phenotypes leads to changing allele frequencies
- Mutation: new alleles are created and therefore proportion of alleles must change
- Movement: migration causes gene flow and changes in genetic diversity
- Natural Selection: individuals with advantageous alleles are more likely to survive and pass these alleles on to further generations



The above graphs depict stabilising selection – natural selection favours the average individuals in a population, favouring the majority of the population that is well adapted to the environment

Directional selection favours an extreme phenotype, whilst disruptive selection favours extreme values for a trait over intermediate values, dividing the population into two groups and increasing variance.

The ability of a population to adapt to new conditions depends on the strength of the selection pressure, the size of the gene pool and the reproductive rate of the organism. Organisms can never be perfectly adapted to an environment due to the time lag between environment change and adaptation.

The gene pool consists of all the alleles of all the genes present in a population. Populations with a larger gene pool are said to have greater genetic diversity. New alleles are produced continuously by mutation of existing alleles but this is a slow and random process.

Speciation is the formation of new species and occurs using the following steps:

1. Groups are geographically isolated by a physical barrier, such as mountains, water or glaciers
2. In these different locations, groups must occupy different niches and the different biotic and abiotic factors cause different selection pressures
3. Some organisms possess favourable alleles giving a selective advantage, making these individuals more likely to survive, reproduce and pass on favourable genes
4. Over time, evolution causes the groups to become reproductively isolated and, by definition, different species: this process is allopatric speciation. Reproductive isolation can occur due to: habitat isolation, no sexual attraction, structural differences, gametic isolation or hybrid sterility

Hardy-Weinberg Equation

$p^2 + 2pq + q^2 = 1$ where p = frequency of dominant allele and q = frequency of recessive allele

The Hardy-Weinberg Equation is used to calculate the relative frequencies of the dominant and recessive alleles, the frequency of each phenotype and the frequency of each genotype.

The equation can only be used assuming:

- population large enough to avoid genetic drift
- no mutations
- random mating with respect to genotype
- no natural selection
- no gene flow due to migration

Quantifying Biodiversity

Key Terminology

Term	Definition
Biodiversity	Variety of species that belong to every different group of organisms living in a habitat. Biodiversity also refers to the diversity within a species, between species and of ecosystems
Species	A group of organisms with similar morphology, physiology and behaviour, which are reproductively isolated from other species
Reproductive Isolation	Individuals from the same species can reproduce to create fertile offspring
Endemic	Native and restricted to a specific place, cannot be found naturally elsewhere
Binomial System	Naming system using genus and species. The name is italicised and the genus is capitalised e.g. *Homo sapiens*
Artificial Classification	Classification based on properties of interest. Useful to focus on properties of species and stable/observable traits
Natural Classification	Classification based on evolutionary relationships to link related species
Classification	Grouping of organisms into categories based on features
Phylogeny	Study of evolutionary relationships between organisms
Taxonomy	Study of the principles of classification
Peer Review	Evaluation of scientific, academic, or professional work by others working in the same field
Species Richness	Number of species in a habitat
Species Evenness	Measure of how close in abundance each species in a habitat is
Genetic Diversity	Number of alleles in a species, measured by heterozygosity index

Classification

Organisms are classed using the following hierarchy: Kingdom → Phylum → Class → Order → Family → Genus → Species. The last two parts are used in the binomial system of naming.

The Five Kingdom Classification System categorised organisms according to cell structure

Kingdom	Description
Animalia	Multicellular, cells have nuclei, motile, heterotrophic nutrition
Plantae	Multicellular, photosynthetic, cellulose cell walls, autotrophic, non-motile
Fungi	Multicellular (except yeast), chitin cell walls, feed off dead matter
Protists	Mostly unicellular, cells have nuclei and some have cell walls
Prokaryote	Unicellular, no nucleus, flexible cell wall

The Three Domain System was determined using molecular phylogeny. RNA from different organisms was sequenced, comparing proteins and enzymes by comparing amino acid sequences, in order to determine differences between Eukarya, Archaea and Bacteria. It was discovered that unicellular Archaea shared more genetic similarities with Eukarya than Bacteria, hence the new system

Characteristic	Bacteria	Archaea	Eukarya
True Nucleus	No	No	Yes
Mitochondria	No	No	Yes
Ribosome Size	70S	70S	80S
Sensitive to antibiotics	Yes	No	No
Cell walls contain peptidoglycan	Yes	No	No
Lipids in cell membranes contain ester bonds	Yes	No	No

The process by which the scientific community critically evaluates new theories is called peer review. Individual scientists or research groups publish their findings in scientific journals. Other scientists then comment on the method and interpretations, in addition to checking the data and statistical evidence in relation to the conclusion made. This process of peer review tests for validity – precise, accurate and reliable results which support conclusions made

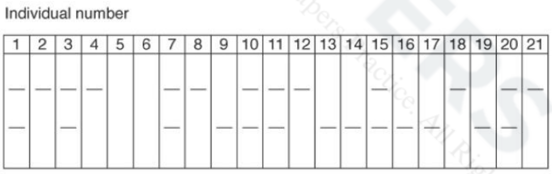
Genetic Diversity in Populations

Genetic diversity within a species in introduced during:

- Gene Mutations – alterations to the DNA base sequence, often arising during DNA replication
- Chromosome Mutations – sections of chromosomes may be altered during meiosis
- Independent Assortment – random arrangement of chromosomes from a homologous pair
- Crossing Over – exchange of alleles between non-sister chromatids
- Mate Selection – different allele combinations depend on which parents reproduce
- Random Fertilisation – different allele combinations depending on which gametes fuse

Genetic diversity can be measured by recording the alleles present in a sample. These alleles can be found by electrophoresis – different alleles produce fragments of different lengths – or by DNA sequencing.

Heterozygosity Index is measured by $\frac{\text{Number of Heterozygotes}}{\text{Number of Individuals in Sample}}$. The average heterozygosity is the mean heterozygosity of all the genes investigated. Using DNA fingerprints, two lines indicated heterozygosity.



e.g. $H = \frac{\text{Number of Heterozygotes}}{\text{Number of Individuals in Sample}}$

$= \frac{7}{2}$ $= 0.333$

Comparing Biodiversity

Species Richness is simply the total number of species present in a given habitat – however, this does not take into account the population size of each species. Species Evenness measures how close together the percentage abundance of each species within a habitat – the more even the abundances, the more diverse the habitat is. A good way of quantifying this is by finding the standard deviation of each.

Some species are endemic – native and restricted to a specific place.

The diversity index compares the number of individual organisms found in an area with the number of species found there.

$D = \frac{N(N-1)}{\sum n(n-1)}$ where N = total number of organisms of all species and n = number of individuals in each species.

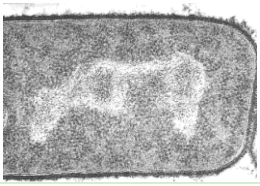
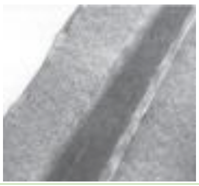
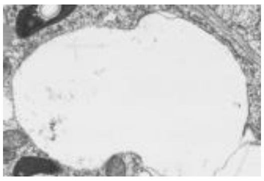
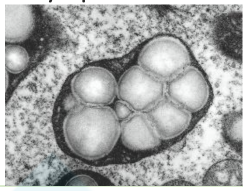
e.g. Habitat A has 4 individuals of Species W, 10 of Species X, 5 of Species Y and 5 of Species Z

$$D = \frac{N(N-1)}{\sum n(n-1)} = \frac{24 \times 23}{(4\times3) + (10\times9) + 2(5\times4)}$$

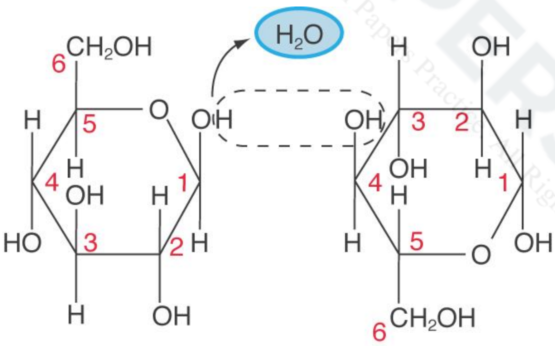
$$= 3.887$$

Plant Structures

Plant Cell Structures

Name and Image	Structure and Function	Name and Image	Structure and Function
Cell Wall 	A protective, semi-permeable outer layer of a plant cell made of cellulose used for strength and structure, and to filter molecules movement	**Middle Lamella** 	Intercellular space made of calcium pectate, holding adjacent cells together and cellulose microfibrils and microfibres
Vacuole and Tonoplast 	The vacuole controls turgidity in the cell by changing water levels in the organelle, bound by a membrane called the tonoplast.	**Amyloplast** 	Glucose produced during photosynthesis is stored in cells as starch in amyloplasts. When energy demand increases, starch is hydrolysed for respiration
Chloroplast 	Containing green pigment chlorophyll, chloroplasts use light energy for the process of photosynthesis, converting carbon dioxide and water into oxygen and glucose	**Plasmodesmata** 	Narrow fluid-filled channels crossing cell walls, joining the cytoplasm of neighbouring cells for rapid diffusion of substances
		Pits 	Thin cell wall due to only one layer of cellulose, aiding rapid movement of substances

Cellulose and Starch



Cellulose is formed from β-glucose molecules. 1,4 glycosidic bonds form between β-glucose molecules when every other glucose monomer is rotated 180° and the molecules undergo condensation reactions.

Cellulose forms straight chains with projecting -OH groups from each side. Hydrogen bonds form between -OH groups in neighbouring cellulose chains, forming microfibril bundles, which are held together by short, branched polysaccharides called hemicelluloses and pectins.

This arrangement of cellulose microfibrils in a matrix of hemicelluloses and pectins strengthens cell walls and allows plant cells to be rigid in shape.

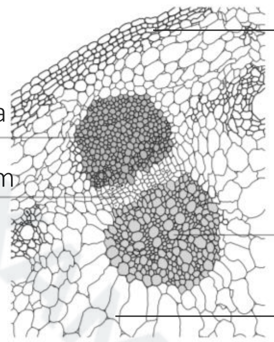
By contrast, starch is formed between α-glucose molecules and forms helical amylose or branched amylopectin due to the presence of 1,6 glycosidic bonds. In plants, starch is the storage molecule for glucose and can be hydrolysed to provide the substrate glucose for respiration

Plant Tissues and Transport

Key Terminology

Term	Definition
Vascular Bundle	Cross-sections of plant matter containing vascular tissue
Xylem Vessel	Plant tissue that transports water and mineral ions to the leaves
Phloem Tissue	Plant tissue that transports sucrose, amino acids and oxygen, consisting of a system of tubes which takes these molecules from the leaves to sink cells.
Sclerenchyma Fibres	Strengthening tissue in a plant, formed from cells with lignified walls

Lignin	Polymer found in some plant cell walls of sclerenchyma fibres and xylem vessels, making the walls stronger and more able to resist the forces on them
Autolysis	Self-destruction of cells
Diffusion Gradient	Difference in concentration of a substance causing passive movement of particles to areas of low concentration in attempt to reach equilibrium
Transpiration	Evaporation of water from the leaves of plants due to movement through the xylem vessels
Transpiration Stream	Stream of water molecules passing through a plant
Cohesion-Tension Theory	Hydrogen bonding between water molecules causes cohesion, causing water to stich tightly together in vessels. Water moves up the xylem as molecules linked by cohesion are pulled up under tension
Turgidity	Pressure a cell's contents exerts against the cell walls



The three basic types of tissue found within plants are the dermal tissue (epidermis), vascular tissue and ground tissue.

Each vascular bundle contains xylem vessels closer to the centre of the plant, with phloem sieve tubes further out. On the outside of each bundle is sclerenchyma fibre. This is surrounded by parenchyma tissue which forms the cortex. The outside of the stem is the epidermis.

Transpiration through the Xylem

Xylem vessels are formed of columns of large cells, with waterproofed and thickened cell walls. Lignin also forms rings in the matrix holding cellulose microfibrils together, strengthening the cell wall and allowing the vessel to withstand high water pressure. The tonoplast breaks down and autolysis occurs, with the breaking down of cell organelles, cytoplasm and plasma membrane, maximising carrying capacity of the vessel. Further adaptations include perforations in the end wall and pits allowing movement between vessels and the neighbouring phloem.

Water is significant to plants as a solvent, allowing dissolved chemicals to move through an aqueous environment, and enabling them to react, often using the water in hydrolysis or condensation reactions. Water is also a reactant in photosynthesis. Water has a high specific heat capacity, allowing the plants to maintain internal temperatures.

Water and mineral ions are transported through the xylem by transpiration:

1. Water diffuses out of plants from the spongy mesophyll cells then through stomata, down a diffusion gradient. Water constantly evaporates from the substomatal cavity
2. Loss of water sets up a water potential gradient, drawing water by capillary action, which is caused by surface tension
3. Water is drawn from the xylem, which causes the transpiration stream to be pulled through the stem up the stream exists due to cohesion between molecules formed by hydrogen bonds
4. Water uptake through the roots occurs by osmosis. Uptake of water dilutes the cytoplasm of root hair cells, creating a water potential gradient. Water moves through plasmodesmata in the cortex
5. Water movement in the xylem provides a mass flow system for the transport of inorganic ions, which are also crucial for growth.

If insufficient inorganic ions are absorbed, deficiency symptoms are seen.

Ion	Use in Plant	Deficiency Symptom
Nitrate	Used to make amino acids; after being converted to nitrogen, the atoms are combined with organic products of photosynthesis	Leaves become yellow due to lack of chlorophyll
Magnesium	Located in enzymes of chlorophyll molecules so vital for photosynthesis Used in the metabolism of carbohydrates and in cell membrane stabilization	Leaves become yellow without chlorophyll

Calcium	Calcium pectate binds cellulose in cell walls. Calcium is also used in activating certain enzymes and to send signals that coordinate certain cellular activities	Stunted growth, curled leaves, lack up upright structure
Phosphate	Component of DNA and of cell plasma membrane	Poor root growth, darker and fewer leaves

Sclerenchyma for Support

Lignin gives plants great tensile strength and stiffness, existing as rings in the vessel. Once lignified, sclerenchyma fibres die, leaving hollow fibres whose strength provides structural support to the plant. The strength of the fibres depends on their length and degree of lignification; the taller a plant grows, the stronger the stem must be and so greater lignification occurs. Tightly packed, turgid parenchyma cells maintain strength and structure, as turgor supports all cells in the plant

Translocation through the Phloem

The phloem tissue is highly specialised for translocation. The cells remain alive in this tissue, with a thin cytoplasm layer but disintegration of most organelles to maximise lumen diameter. The sieve tube elements have perforated end plates to allow rapid transfer of material. These are connected to transfer cells, which have highly folded walls to increase SA:V ratio and many mitochondria for active transport of sugars and amino acids into and out of the sieve tube. These companion cells are linked to the sieve tube by plasmodesmata and are absolutely interdependent.

1. Sucrose or amino acids enter transfer cell
2. Substance is loaded into sieve tube element by active transport
3. Increased solute concentration causes xylem to lose water to the phloem by osmosis
4. This increases hydrostatic pressure in the lumen
5. There is a low solute concentration in the sink, lowering concentration and causing water to re-enter the xylem
6. Hydrostatic pressure difference causes mass flow from source to sink

Using Plant Fibres

- Plant fibres are long, thin, flexible and strong, and hence are highly useful to humans in products such as clothing, rope and paper.
- To obtain the fibres, the fibres must be pulled out mechanically or surrounding tissue must be digested - cellulose is resistant to degradation, hence the fibres remain intact. The polysaccharides holding fibes together can then be dissolved away.
- To produce fibre pulp from trees, caustic alkali is used, whilst other plants are piles in heaps to allow microorganisms to break down the plants. This process is called retting
- Fibre mats are used to absorb heavy metals and hydrocarbons from polluted water. Plant fibres can form biocomposites; rapeseed fibres can be mixed with plastic to form a stronger material which is renewable, biodegradable and safer than artificial fibres.
- Many plants have chemical defences to repel or kill pests, producing toxins. Natural insecticides can be used by planting the plants which produce them alongside the crop as companion plants
- Plant fibres contain toxins which are antibacterials. These are typically found in the seed coat, fruit coat, bulb and roots. These toxins could be harnessed in new medicines
- Many medicines are derived from chemicals originally discovered in plants, such as aspirin and codeine

Using Plants in Modern Medicine

Drug Development

William Withering discovered a standard procedure to discover dosage of medication; he found that the most effective dose was just below that causing side effects.

Withering believed that a substance in foxglove was a remedy for oedema. He created a digitalis soup, which reduced symptoms of the disease. Withering studied 163 patients, discovering and recording the side effects of the digitalis, including nausea, in addition to the sign of recovery – large volumes of urine production. He then used standard procedure to discover the effective dosage – increasing dose until vomiting, then dose was slightly reduced.

There are similarities to this procedure and current drugs testing steps: side effects of the drug are recorded before applying standard procedure to determine dosage. Indications of success were also observed. Results continue to be carefully recorded and analyse to determine effectiveness.

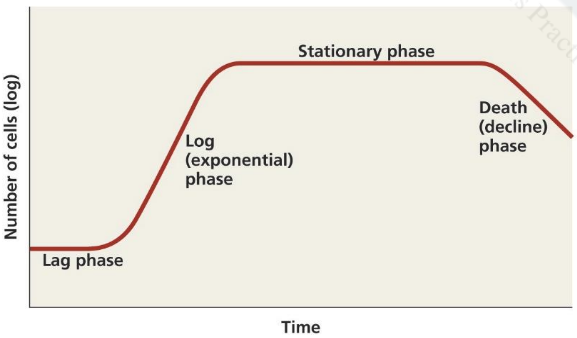
Stage	Description and Purpose
Pre-Clinical	Lab studies on isolated cells and tissue culture – *determine effectiveness and safety* Animal trials occur before MHRA approves Phase I
Phase I	Small group of healthy volunteers given varying doses – *tests the drug is absorbed, distributed and processed as expected.* Effects of different doses are measured
Phase II	Small group of volunteer patients with the disease are treated - *test effectiveness and determine doses*
Phase III	Large group of patients involved in a double-blind randomised control trial – neither doctors nor patients knows what drug they have- where some are given an inactive placebo **or the current standard treatment**, whilst others receive the new drug. If the results show a statistically significant improvement in patients receiving treatment, the drug can be licensed. *Side effects are also noted*
Phase IV	*Learn more about side effects, safety, long-term effects and wider application* through licensed use

Growing Bacteria

Aseptic technique must always be used when growing bacteria – using sterile techniques and equipment to prevent contamination with unwanted microbes. Techniques include disinfecting surfaces, flaming the neck of the culture, sterilising the inoculating loop by passing through a flame, sterilising glassware in an autoclave, working in the updraught of a flame and allowing condensation to collect under the culture.

Bacteria is only cultured at 20-30°C to reduce risk of culturing human pathogens.

Bacterial Population Growth Curve Model



- During the lag phase, enzymes and organelles for growth are synthesised and the bacteria acclimatises. Time is taken for the nutrients in the agar to be used
- During the exponential phase, there I low competition and high levels of oxygen and nutrients available for rapid population growth
- At the stationary phase, there is high competition and insufficient space for further growth of population
- In the death phase, there is high competition for scarce resources, and toxic waste products cause decrease

Seeds

Seeds are important as they: protect the plant embryo, aid dispersal and nourish the new plant.

Seeds contain an embryo plant, consisting of a root (radicle), shoot (plumule) and a seed leaf (cotyledons), together with a food source in the endosperm. During germination, the food source is used up to enable the radicle to grow into the soil, where it absorbs water and inorganic ions, and the plumule to grow towards light and begin photosynthesis.

The conditions for germination are: moisture, to enables enzyme mobilisation; warmth to allow enzyme-substrate collisions; and oxygen for aerobic respiration

Uses of Seeds

Starch from seeds is used in adhesives, textiles, conditioners and insulation.

- Thickening – when starch granules are heated in water they swell, absorb water and thicken thee liquid by gelatinisation

- Starch foam – starch can be used to make expanded foam structure. This process is used to make puffed wheat cereals and foam packaging. This material can also be used in place of polystyrene, polyethylene or other oil-based plastics
- Seeds are a rich source of oils which also have industrial uses as fuels – they can be used instead of petroleum-based oils for motor vehicles. Biodiesels today, made from vegetable oil or rapeseed, produce less SO_2 than diesel, and less CO_2 as the growth and use of plants is carbon neutral

Sustainability

Sustainability considers the preservation of resources and the environment for future generations.

The use of oil-based plastics and fuels is not sustainable for several reasons:

- burning oil-based fossil fuels releases CO_2 , contributing to global warming
- oil reserves are indefinite
- plastics generate non-biodegradable waste, which cannot be broken down by microbial action, creating major disposal issues.

Using plant-based resources is carbon neutral as CO_2 is absorbed during growth by photosynthesis. In addition to this, the source of the plant, the energy used in transportation and packaging must be considered.

Although the use of plants appears entirely suitable, global use would pose these issues:

- insufficient space to cultivate large crops of plants
- rainforest must be conserved for wildlife and water conservation
- intensive agriculture (ploughing, harvesting, fertilising) is energy-demanding

Seed Banks

Seed banks conserve seed samples from threatened species of plants. This conserves the genetic diversity of plants, and protects plants from the impacts of natural disasters, drought, economic collapse and climate change. The plants stored may be useful in the future due to traits such as disease resistance or tolerance to changing environments, and preservation of crops ensures future food security.

Seed banks can be used to educate the public on the importance of conservation and the environment. They can also be used in research, testing whether reintroduction of seeds into different habitats is viable, in addition to uses of plants in medicine

Storing Seeds

Seeds are transported to seed banks from around the world. Upon arrival, their identity must be checked. After confirmation, seeds are dried, as germination is prevented by loss of water. Seeds are also kept very cold at -20°C to ensure that enzymes are frozen. After a month, a small sample is taken and germinated in agar to ensure the seed is viable. This is repeated every 10 years. When viability dips below 75%, the seeds are grown to collect a new sample which can then be stored

Zoos

Zoos are areas of confinement keeping samples of species alive under varying degrees of captivity. Academic research into the conservation of endangered species occurs here, with research into diet, behaviour and reproduction. Zoos acts as an attraction to visitors in order to generate revenue which keeps animals under optimum conditions, provide funding for research and stimulate interest and concern into conservation.

In Situ vs Ex Situ Conservation

In situ conservation is the protection of biodiversity in its natural habitat, and helping recovering populations to develop, for example national parks, biosphere reserves and wildlife sanctuaries

Ex situ conservation is the conservation of selected rare organisms outside their natural habitat. This prevents extinction of endangered populations, for example zoological parks, seed banks and botanical gardens.

Captive Breeding Programmes

Captive breeding programmes aim to increase the number of endangered species, maintain genetic diversity within the captive population and reintroduce animals into the wild where possible. In this process, zoologists improve understanding of reproductive physiology.

International species inventory system is used in the form of stud books. The studbook for a species shows the history and location of all captive animals of that species in places participating in the breeding programme. Zoologists then ensure that genetic diversity is maintained and represented equally in future generations, ensuring individuals have a similar fertility rate.

Genetic diversity can be lost by genetic drift. Genetic drift refers to the random changes in allele frequency that occur in populations over time. Changes are much more pronounced in smaller, captive populations, and alleles may be lost from the gene pool altogether.

Inbreeding Depression

In a small population, for example in captivity in a zoo or wild animal park, there is an increased chance that closely-related individuals will mate due to lack of mate choice. Inbreeding reduces the proportion of heterozygotes in the population, many recessive alleles, which have a higher rate of expression, have harmful effects on the phenotype, and an inbreeding depression results.

Evaluating the Role of Zoos

Arguments **For** Zoos and Captive Breeding	Arguments **Against** Zoos and Captive Breeding
• Preserves biodiversity and genetic diversity • Reduces impact of habitat degradation • Allows eventual return of species to the wild by reintroduction programmes • Vital for academic research into diet, behaviour and reproduction • Stimulates public concern	• Aggressive behaviour and pacing poses ethical concerns of keeping animals captive • In situ lets animals stay in the wild • Loss of innate behaviour in captivity • Very expensive • Low survival rate upon return to wild • Reinforces species bias