Control, Genome and Environment

Cellular Control & Variation

Cellular Control

*(a) state that **genes code for polypeptides, including enzymes;***

(b) explain the meaning of the term genetic code;

The sequence of the bases on a gene is a code with instructions for the construction of proteins. It has a number of characteristics:

It is a triplet code- three bases code of an amino acid

It is a degenerate code- All amino acids bar one have more than one code

Some codes don't code for amino acids but are 'stop' codons- they indicate the end of the polypeptide chain

It is widespread but not universal- Codons generally always code for the same amino acid in every organism, but this is not always the case.

(c) describe, with the aid of diagrams, the way in which a nucleotide sequence codes for the amino acid sequence in a polypeptide;

1. **Free RNA nucleotides are activated, two extra phosphoryl groups are added to make ATP, GTP, CTP and UTP.**
2. **The gene to be transcribed unwinds and unzips. To do this the length of DNA that makes up the gene dips into the nucleolus & the hydrogen bonds between the nucleotide bases break.**
3. **Activated RNA nucleotides binds, using Hydrogen Bonds, with their complementary exposed bases on the template strand. This is catalysed by RNA polymerase**
4. **The two extra phosphoryl are released, releasing energy for bonding two adjacent nucleotides The mRNA produced is complementary to the nucleotide base sequence on the template strand of DNA and therefore is a copy of the base sequence on the coding strand of DNA**
5. **The mRNA is released from the DNA and passes out of the nucleus through a pore in the nuclear envelope to a ribosome**

(d) describe, with the aid of diagrams, how the sequence of nucleotides within a gene is used to construct a polypeptide, including the roles of messenger RNA, transfer RNA and ribosomes;

1. **A molecule of mRNA binds to a ribosome. Two codons are attached to the small subunit of the ribosome and exposed to the large subunit. The first exposed mRNA codon is always AUG. Using ATP energy and an enzyme, a tRNA molecule with the amino acid methionine and the anticodon UAC forms hydrogen bonds with this codon**
2. **A seconds tRNA molecule, bearing a different amino acid, binds to the second exposed condon with its complementary anticodon**
3. **A peptide bonds forms between the two adjacent amino acids. This is catalysed by an enzyme in the small ribosomal sub unit**
4. **The ribosome now moves along the mRNA reading the next codon. A third tRNA brings another amino acid and a peptide bonds forms between it and the dipeptide. The first tRNA leaves and is able to collect and bring another of its amino acids.**
5. **The polypeptide chain grows until a stop codon is reached, for which there are no corresponding tRNAs and the polypeptide chain is complete**

*(e) state that **mutations cause changes to the sequence of nucleotides in DNA molecules;***

(f) explain how mutations can have beneficial, neutral or harmful effects on the way a protein functions;

Beneficial

The mutation changes the sequence of amino acids and therefore the phenotype, but this gives the organism an advantageous characteristic

E.g. Paler skin in more temperate climates absorbs more vitamin D

Neutral

It is a mutation in a non-coding region of the DNA

It is a silent mutation- although the base triplet has changed, it still codes for the same amino acid and so the protein is unchanged.

Harmful

The mutation changes the sequence of amino acids and therefore the phenotype, and the resulting characteristic is harmful

E.g. paler skin in a hotter climate burns more easily

*(g) state that **cyclic AMP activates proteins by altering their three-dimensional structure;***

(h) explain genetic control of protein production in a prokaryote using the lac operon;

E. coli grown in a culture medium with no lactose can be placed in a growth medium with lactose. At first they cannot metabolise the lactose because they only have tiny amounts of the enzymes needed to catalyse the reaction. A few minutes after the lactose is added, E. coli increases the rate of synthesis of these enzymes by about 1000 times, so lactose must trigger the production of them- it is the inducer.

When lactose is absent

1. **The regulator gene is expressed and the repressor protein is synthesised. It has two binding sites. One binds to lactose and one that binds to the operator region**
2. **In binding to the operator region, it covers part of the promoter region where RNA polymerase normally attaches**
3. **RNA polymerase cannot bind to the promoter region so the structural genes cannot be transcribed into mRNA**
4. **Without mRNA the genes cannot be translated and the enzymes cannot be synthesised**

When lactose is added

1. **Lactose binds to the other site on the repressor protein, causing the molecule to change shape. This prevents the other binding site from binding to the operator region. The repressor dissociates from the operator region**
2. **The leaves the promoter region unblocked. RNA polymerase can now bind to it and initiate the transcription of mRNA.**
3. **The operator- repressor- inducer system acts as a molecular switch. It allows synthesis of the structural genes**
4. **As a result, the bacteria can now use the lactose permease enzyme to take up lactose from the medium into their cells. They can then convert it to glucose and galactose using the β-galactosidase enzyme. These sugars can then be used for respiration**

(i) explain that the genes that control development of body plans are similar in plants, animals and fungi, with reference to homeobox sequences;

Homeotic genes are similar in plants, animals and fungi. These genes control the development of body plans and are expressed in specific patterns and in particular stages of development depending on when they are activated.

The homeobox is a sequence of DNA that codes for a region of 60 amino acids, and the resulting protein is found in most, if not all, eukaryotes. The region binds to DNA so that they can regulate transcription. In animals the homeobox is common in genes concerned with the control of developmental events, such as segmentation, the establishment of the anterior-posterior axis and the activation of genes coding for body parts such as limbs

(j) outline how apoptosis (programmed cell death) can act as a mechanism to change body plans.

Apoptosis is an integral part of plant and animal tissue development. It is a series of biochemical events that leads to an orderly and tidy cell death, in contrast to cell necrosis, which leads to the release of harmful hydrolytic enzymes. Apoptosis ensures that the rate of cells produced by mitosis is the same as the rate of cells dying, so the number of cells remains constant. No enough apoptosis leads to cancer.

Apoptosis causes the digits (toes and fingers) to separate from each other during development.

1. **Enzymes break down the cell cytoskeleton**
2. **The cytoplasm becomes dense with organelles tightly packed**
3. **The cell surface membrane changes and blebs form**
4. **The Chromatin condenses and the nuclear envelope breaks. DNA breaks into fragments**
5. **The cell breaks down into vesicles that are taken up by phagocytosis. The cellular debris is disposed of so that it does not damage other cells or tissue.**

Meiosis and Variation

*(a) describe, with the aid of diagrams and photographs, the behaviour of chromosomes during meiosis, and the associated behaviour of the nuclear envelope, cell membrane and centrioles. (Names of the main stages are expected, but **not** the subdivisions of prophase);*

Meiosis I

Prophase I

1. **The chromatin condenses and supercoils**
2. **The chromosomes come together in their homologous pairs to form a bivalent. Each member of the pair has the same genes at the same loci. Each pair consists of one maternal and one paternal chromosome**
3. **The non sister chromatids wrap around each other and attach at points called chiasmata**
4. **They may cross over and swap sections of chromatids with each other**
5. **The nucleolus disappears and the nuclear envelope breaks down**
6. **A spindle forms**

Metaphase I

1. **Bivalents line up across the equator of the spindle, attached to spindle fibres at the centromeres**
2. **The bivalents are arranged randomly (random assortment) with each member of the homologous pair facing opposite poles**

Anaphase I

1. **The homologous chromosomes in each bivalent are pulled by the spindle fibres to opposite poles**
2. **The centromeres do not divide**
3. **The chiasmata separate and the lengths of chromatid that have been crossed over remain with the chromatid to which they have become newly attached**

Telophase I

1. **In most animal cells two new nuclear envelopes form- one around each set of chromosomes at each pole and the cell divides by cytokenesis. There is a brief interphase and the chromosomes uncoil**
2. **In most plant cells the cell goes straight from Anaphase I to Meiosis II**

Meiosis II

This occurs at right angles to Meiosis I

Prophase II

1. **If a nuclear envelope has reformed, it breaks down again**
2. **The nucleolus disappears, chromosomes condense and spindles form**

Metaphase II

1. **The chromosomes arrange themselves on the equator of the spindle. They are attached to spindle fibres at the centromeres**
2. **The chromatids of each chromosome are randomly assorted**

Anaphase II

1. **The centromeres divide and the chromatids are pulled to opposite poles by the spindle fibres. The chromatids randomly segregate**

Telophase II

1. **Nuclear envelopes reform around the haploid daughter nuclei**
2. **In animals, the two cells now divide to give four daughter cells**
3. **In plants, a tetrad of four haploid cells if formed**

(b) explain the terms

allele

An alternative version of a gene

locus

Specific position on a chromosome, occupied by a specific gene

phenotype

Observable characteristics of an organism

genotype

Alleles present within cells of an individual, for a particular trait/characteristic

dominant

Characteristic in which the allele responsible is expressed in the phenotype, even in those with heterozygous genotypes

codominant

A characteristic where both alleles contribute to the phenotype

recessive

Characteristic in which the allele responsible is only expressed in the phenotype is there is no dominant allele present

(c) explain the terms

linkage

Genes for different characteristics that are present at different loci on the same chromosome are linked

crossing-over

Where non-sister chromatids exchange alleles during prophase I of meiosis

(d) explain how meiosis and fertilisation can lead to variation through the independent assortment of alleles;

Meiosis:

Crossing over 'shuffles' alleles

Random distribution and subsequent segregation of maternal and paternal chromosomes in the homologous pairs during meiosis I leads to genetic reassortment

Random distribution and segregation of the chromatids at meiosis II leads to genetic reassortment

Random mutations

Fertilisation

Randomly combining two sets of chromosomes, one from each of two genetically unrelated individuals

(e) use genetic diagrams to solve problems involving sex linkage and codominance;

Sex linkage

e.g. Haemophilia

Parental Phenotypes	Carrier Mother		Normal Father	
Parental Genotypes	X^HX^h		X^HY	
Gametes	X^H	X^h	X^H	Y

	Male Gametes	
Female Gametes	X^H	Y
X^H	X^HX^H Normal female	X^HY Normal male
X^h	X^HX^h Carrier female	X^hY Haemophilliac male

The gene for haemophilia is carried on the X chromosome. Male offspring only have one copy of the X chromosome, so if they have the allele for Haemophilia, they will be affected

Codominance

e.g. Blood type

Parental Phenotypes	A Mother		B Father	
Parental Genotypes	B^AB^O		B^BB^O	
Gametes	B^A	B^O	B^B	B^O

	Male Gametes	
Female Gametes	B^B	B^O
B^A	B^AB^B AB Blood	B^AB^O A Blood
B^O	B^BB^O B Blood	B^OB^O O Blood

If both the A and the B alleles are present in the genotype, the phenotype will be AB- they are co-dominant. The O allele is recessive, so it will not be expressed in the phenotype unless the alleles A or B are not present

*(f) describe the interactions between loci (epistasis). (Production of genetic diagrams is **not** required);*

Epistasis is the interaction of different gene loci so that one gene locus makes or suppresses the expression of another gene locus.

Recessive Epistasis

The homozygous presence of a recessive allele prevents the expression of another allele at a second locus

E.g. flower colour in Salvia

The alleles for purple (B) and pink (b) can only be expressed in the presence of the allele A. When the genotype is aa-- the phenotype is white

Dominant Epistasis

A dominant allele at one gene locus masks the expression of alleles at the second gene locus

E.g. feather colour in poultry

If the dominant allele A is present, the chickens will be white; even if the dominant allele of the second gene, B/b is present. The genotype must be aaB- for any colour to be expressed

(g) predict phenotypic ratios in problems involving epistasis;

Recessive epistasis in Salvia

9:3:4

Dominant epistasis in Poultry

13:3

(h) use the chi-squared (χ^2) test to test the significance of the difference between observed and expected results. (The formula for the chi-squared test will be provided);

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

O is observed

E is expected

The smaller the value of χ^2, the more certain we can be that that difference between observed and expected data is due to chance and is therefore not a significant difference.

To calculate how significant the χ^2 value is, a χ^2 table is used. Using n-1 (where n= number of classes) degrees of freedom, and a 5% critical value, we can see if the value is due to chance.

If the value is smaller than the value on the table, the null hypothesis can be accepted- any difference is due to chance and therefore not significant. If the value is larger than the value on the table then the null hypothesis is rejected- any difference is significant and not due to chanche.

(i) describe the differences between continuous and discontinuous variation;

Discontinuous variation describes qualitative differences between phenotypes- they fall into clearly distinguishable categories with no intermediates.

E.g. blood type is either A, B, AB or O

Continuous variation is quantitative differences between phenotypes- there is a wide range of variation within the population with no distinct catagories

E.g. height

(j) explain the basis of continuous and discontinuous variation by reference to the number of genes which influence the variation;

Discontinuous variation

Different alleles at a single gene locus have large effects on the phenotype.

Different gene loci have different effects on the trait

Continuous variation

Different alleles at the same gene locus have small effects

Different gene loci have the same, often additive effect on the trait

A large number of gene loci may have a combined effect on the trait

*(k) explain that both genotype and environment contribute to phenotypic variation. (**No** calculations of heritability will be expected);*

While an organism may have the genetic potential to achieve a certain characteristic, e.g. length of corn cob, the environment also has an influence. The corn cob may have the genetic potential to be 12cm long, but the plant may be short of water, light or certain minerals, meaning that the cob is shorter, as the environmental factors have limited the expression of the genes.

(l) explain why variation is essential in selection;

So that when the environment changes, there will be individuals that are better adapted, so they will survive and reproduce passing on the advantageous alleles to their offspring and allowing the species to continue

(m) use the Hardy–Weinberg principle to calculate allele frequencies in populations;

p is the frequency of the dominant allele A

q is the frequency of the recessive allele a

∴ p+q = 1 as everyone in the population has the alleles

q^2 is the frequency of the homozygous recessive genotype aa

p^2 is the frequency of the homozygous dominiant genotype AA

2pq is the frequency of the heterozygous genotype Aa

∴ $1= p^2+2pq+q^2$ as everyone in the population has one of the genotypes

The frequency of aa can be measured. Suppose that the incidence is 1%.

If $q^2= 0.01$ then $q = \sqrt{0.01} = 0.1$

$p+0.1=1$

∴ $p= 0.9$

So, $p^2 = 0.9^2= 0.81$

$0.81+2pq+0.01 = 1$

So $2pq = 1- (0.01 + 0.81)$

$= 0.18$

So, 18% of the population are heterozygous Aa

(n) *explain, with examples, how environmental factors can act as stabilising or evolutionary forces of natural selection;*

In unchanging conditions, stabilising selection maintains existing adaptations and so maintains existing allele frequencies.

In changing conditions, directional selection alters allele frequencies.

A mutation may be disadvantageous in existing conditions, and so is removed in stabilising selection, but if the conditions change, the mutation might be advantageous and selected for, meaning that selection becomes an evolutionary force

(o) *explain how genetic drift can cause large changes in small populations;*

Genetic drift is a change in allele frequency that occurs by chance because only some of the organisms in each generation reproduce. It is particularly noticeable when a small number of individuals are separated from the rest of the large population. They form a small sample of the original population and so are unlikely to be representative of the large population's gene pool. Genetic drift will alter the allele frequency still further.

(p) *explain the role of isolating mechanisms in the evolution of new species, with reference to ecological (geographic), seasonal (temporal) and reproductive mechanisms;*

If two sub-populations are separated from each other, they will evolve differently as they have different selection pressures, so different alleles will be eliminated or increased within each sub population. Eventually the sub populations will not be able to interbreed and so will be different species.

The sub populations may be split by various isolating mechanisms

Geographical barriers e.g. rivers or mountains

Seasonal barriers e.g. climate change throughout the year

Reproductive mechanisms e.g. their genitals, breeding seasons or courtship rituals may be different

(q) *explain the significance of the various concepts of the species, with reference to the biological species concept and the phylogenetic (cladistic/evolutionary) species concept;*

(r) *explain the significance of the various concepts of the species, with reference to the biological species concept and the phylogenetic (cladistic/evolutionary) species concept;*

The biological species concept

A species is 'a group of similar organisms that can interbreed and produce fertile offspring and it reproductively isolated from such other groups'

But

Not all organisms reproduce sexually

Members of the same species can look very different to each other

Males can look different to females

Isolated populations may appear to be very different from each other

The phylogenetic species concept

A species is 'a group of organisms that have similar morphology, physiology, embryology and behaviour, and occupy the same ecological niche'. This classification shows the evolutionary relationships, or phylogeny. The phylogenetic linage is called a clade.

(s) *compare and contrast natural selection and artificial selection;*

Natural selection

The organisms best adapted for their environment are more likely to survive and pass on the favourable characteristics to their offspring

Artificial selection

Humans select the organisms with the useful characteristics

Humans allow those with useful characteristics to breed and prevent the ones without the characteristics from breeding

Thus, humans have a significant impact on the evolution of these populations or species

(s) describe how artificial selection has been used to produce the modern dairy cow and to produce bread wheat (Triticum aestivum)

Dairy cow

Each cow's milk yield is measured and recorded

The progeny of bulls is tested to find out which bulls have produced daughters with high milk yields

Only a few good-quality bulls need to be kept are the semen from one bull can be used to artificially inseminate many cows

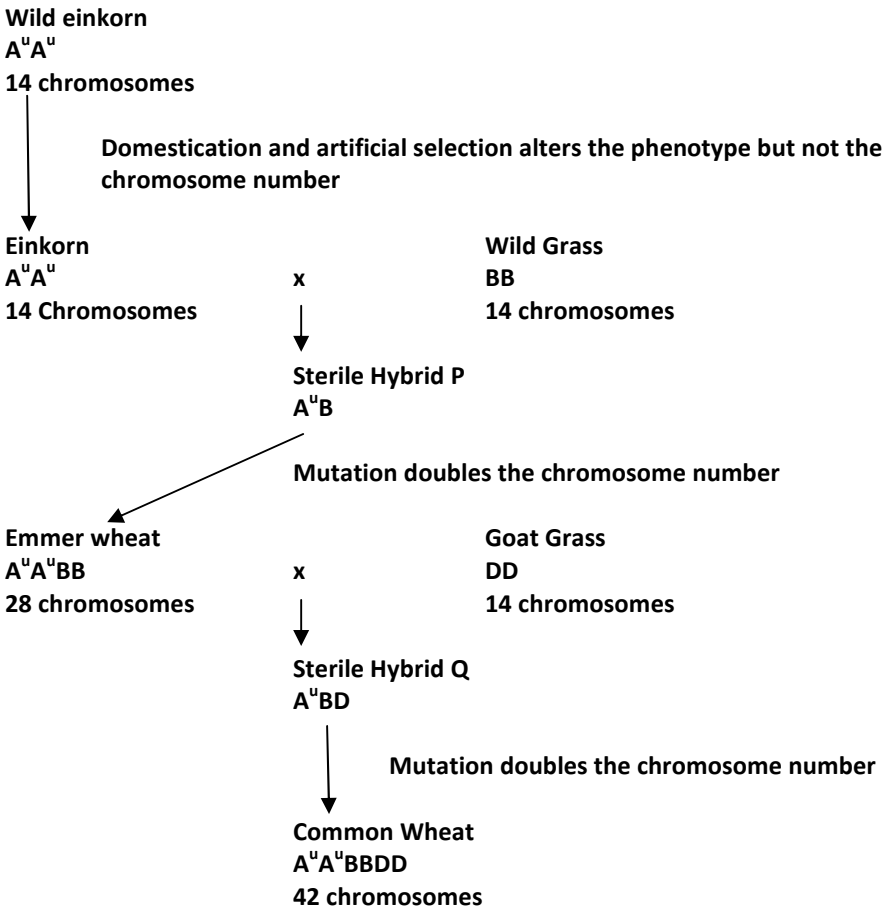
Some elite cows are given hormones so they produce many eggs

The eggs are fertilized in vitro and the embryos are implanted into surrogate mothers

These embryos could also be clones and divided into many more identical embryos

Bread wheat

Wheat can undergo polyplody- the nuclei can contain more than one diploid set of chromosomes. Modern bread wheat is hexaploid, having 42 chromosomes in the nucleus of each cell, meaning that the cells are bigger.



Control, Genome and Environment

Biotechnology and Gene Technologies

Cloning in Plants and Animals

(a) outline the differences between reproductive and non-reproductive cloning;

Reproductive cloning is the production of offspring which are genetically identical to either the mother (nuclear transfer), or the other offspring (splitting embryos)

Non-reproductive cloning is the use of stem cells in order to generate replacement cells, tissues or organs which may be used to treat particular diseases or conditions of humans

(b) describe the production of natural clones in plants using the example of vegetative propagation in elm trees;

The English Elm is adapted to reproduce asexually following damage to the parent plant.

New growth in the form of basal sprouts appears within two months of the destruction of the main trunk

These suckers grow from meristem tissue in the trunk close to the ground where the least damage is likely to have occured

(c) describe the production of artificial clones of plants from tissue culture;

A small piece of tissue is taken from the plant to be cloned, usually from the shoot tip- this is called the explant

The explant is placed on a nutrient growth medium

Cells in the tissue divide but do not differentiate. Instead they form a mass of undifferentiated cells called a callus

After a few weeks, single callus cells can be removed from the mass and placed on a growing medium containing plant hormones that encourage shoot growth

After a further few weeks, the growing shoots are transferred onto a different growing medium that encourages root growth

The growing plants are then transferred to a greenhouse to be acclimatised and grown further before they are planted outside

(d) discuss the advantages and disadvantages of plant cloning in agriculture;

Advantages	**Disadvantages**
Very many genetically identical plants can be produced from one original plant	Because all of the plants are genetically identical, they are all susceptible to a newly mutated pathogen or pest, or to changing environmental conditions
Plants can be produced at any time of the year and air-freighted around the world	The process is labour intensive- it is more difficult to plant plantlets than to sow seed
Callus can be genetically engineered	

(e) describe how artificial clones of animals can be produced;

Nuclear transfer

A nucleus from an adult differentiated cell is placed in an enucleated egg cell. The egg then goes through the stages of development using the genetic information from the inserted nucleus

Splitting embryos

Cells from a developing embryo are separated out, with each one going on to produce a separate, genetically identical organism

(f) discuss the advantages and disadvantages of cloning animals

Advantages	**Disadvantages**
High value animals, e.g. cows giving a high milk yield, can be cloned in high numbers	High value animals are not necessarily produced with animal welfare in mind. Some strains of meat producing chickens jave been developed that are unable to walk
Rare animals can be cloned to preserve the species	As with plants, excessive genetic uniformity in a species makes it unlikely to be able to cope with, or adapt to, changes in the environment
Genetically modified animals- e.g. sheep that produce pharmaceutical chemicals in their milk- can be quickly reproduced	It is still unclear whether animals cloned using the nuclear material of adult cells will remain healthy in the long term

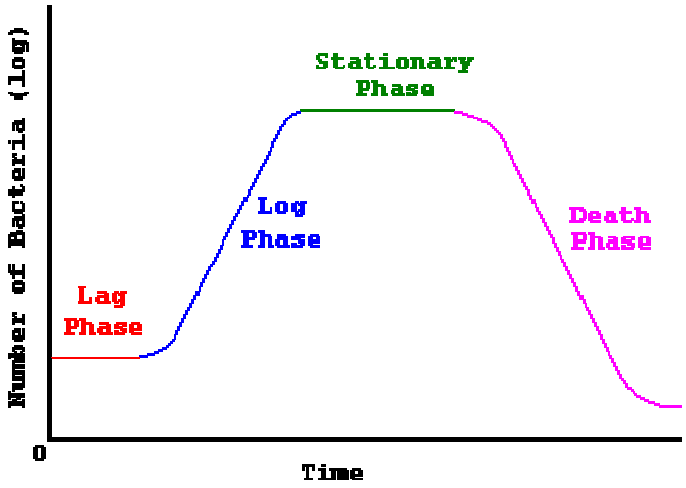
Biotechnology

(a) state that ***biotechnology is the industrial use of living organisms (or parts of living organisms) to produce food, drugs or other products;***

(b) explain why microorganisms are often used in biotechnological processes;

Grow rapidly in favourable conditions, with a generation time of as little as 30 minutes
Often produce proteins or chemicals that are given out into the surrounding medium and can be harvested
Can be genetically engineered to produce specific products
Grow well are relatively low temperatures, much lower than those required in the chemical engineering of similar processes
Can be grown anywhere in the world and are not dependent on climate
Tend to generate products that are in a more pure form than those generated via chemical processes
Can often be grown using nutrient materials that would otherwise be useless or even toxic to humans

(c) describe, with the aid of diagrams, and explain the standard growth curve of a microorganism in a closed culture;



Lag phase

Organisms are adjusting to the surrounding conditions. This may mean taking in water, cell expansion, activating specific genes and synthesising specific enzymes. The cells are active but not reproducing so population remains fairly constant. The length of this period depends on the growing conditions

Log phase

The population size doubles each generation as each individual has enough space and nutrients to reproduce. In some bacteria the population can double every 20-30 mins. The length of this phase depends on how quickly the organisms reproduce and take up the available space and nutrients

Stationary phase

Nutrient levels decrease and waste products like Carbon Dioxide and other metabolites build up. Individual organisms die at the same rate at which new individuals are being produced. In an open system this would be the carrying capaciry

Death phase

Nutrient exhaustion and increased levels of toxic waste products and metabolites leads to the death rate increasing above the reproduction rate. Eventually all of the organisms will die in a close system

(d) describe how enzymes can be immobilised;

Adsorption

Enzyme molecules are mixed with the immobilising support and bind to it due to a combination of hydrophobic interactions and ionic links.

Covalent bonding

Enzyme molecules are covalently bonded to a support, often by covalently linking enzymes together and to an insoluble material using a cross-linking agent

Entrapment

Enzymes are trapped, for example in a gel bead or network of cellulose fibres. Substrate and product molecules can pass through the material to the enzyme, but the enzyme cannot pass through to the solution

Membrane separation

Enzymes are physically separated from the substrate mixture by a partially permeable membrane. The substrate and product molecules can pass through the membrane, but the enzymes cannot

(e) explain why immobilised enzymes are used in large-scale production;

Enzymes can be recovered easily and used many times

The product is not contaminated by the enzyme

Protection by the immobilising material means the enzyme is more stable in changing temperatures or pH

Enzyme activity can be controlled more easily

(f) compare and contrast the processes of continuous culture and batch culture;

Batch Culture	**Continuous Culture**
Growth rate is slower because nutrient level declines with time	Growth rate is higher as nutrients are continuously added to the fermentation tank
Easy to set up and maintain	Set up is more difficult, maintenance of required growing conditions can be difficult to achieve
If contamination occurs, only one batch is lost	If contamination occurs, huge volumes of product may be lost
Less efficient- fermenter is not in operation all of the time	More efficient- fermenter operates continuously
Very useful for processes involving the production of secondary metabolites	Very useful for processes involving the production of primary metabolites

(g) describe the differences between primary and secondary metabolites;

Primary metabolites are substances produced by an organism as part of its normal growth. The production of primary metabolites matches the growth in population of the organism

Secondary metabolites are substances produced by an organism that are not part of its normal growth. The production of secondary metabolites usually begins after the main growth period of the organism and so does not match the growth in population of the organism

(h) explain the importance of manipulating the growing conditions in a fermentation vessel in order to maximise the yield of product required;

The growing conditions can be manipulated and controlled in order to ensure that the microorganism is growing in its optimum conditions, and so the yield can be maximised

Temperature

Too hot and enzymes will be denatured, too cold and growth will be slowed

Type and addition of nutrient

This depends on whether the product is a primary or a secondary metabolite

Oxygen concentration

Most organisms are grown under aerobic conditions so there must be a sufficient supply of oxygen to prevent the unwanted products of anaerobic respiration and a reduction in growth rate

pH

Chances in pH can reduce the activity of enzymes and therefore reduce growth rates

(i) explain the importance of asepsis in the manipulation of microorganisms.

Asepsis is the absence of unwanted microorganisms which could:

Compete with the culture microorganisms for nutrients and space

Reduce the yield of useful products from the culture microorganisms

Cause spoilage of the product

Produce toxic chemicals

Destroy the culture microorganisms and their products

Control, Genome and Environment

Genomes and Gene Technologies

(a) outline the steps involved in sequencing the genome of an organism;

Genomes are mapped to identify which part of the genome that they come from. Information that is already known is used, such as the location of microsatellites

Samples of the genome are mechanically sheared into smaller sections of around 100,000 base pairs

These sections are places in separate Bacterial Artificial Chromosomes (BACs) and transferred to E. coli cells. As the cells are grown in culture, many copies of the sections are produced- referred to as Clone Libraries

Cells containing specific BACs are taking and cultured. The DNA is extracted from the cells and restriction enzymes used to cut it into smaller fragments. The use of different restriction enzymes on a number of samples gives different fragment types

The fragments are separated using electrophoresis

The many copies of the fragments are put in a reaction mixture containing DNA polymerase, free DNA nucleotides and primers, with some of the nucleotides containing a florescent marker.

The primer anneals to the 3' end of the template strand, allowing DNA polymerase to attach

DNA polymerase adds free nucleotides

If a modified nucleotide is added, the polymerase enzyme is thrown off and the reaction stops on that template strand

As the reaction proceeds, many molecules of DNA are made. The fragments generally differ in size, as different numbers of nucleotides will have been added

As the strands run through a machine, a laser reads the colour sequence. The sequence of colours, and therefore the sequence of bases can then be displayed

(b) outline how gene sequencing allows for genome-wide comparisons between individuals and between species;

The identification of genes for proteins found in all or many living organisms gives clues to the relative importance of such genes to life

Comparing the DNA of different species shows evolutionary relationships

Modelling the effects of changing DNA can be carried out

Comparing genomes from pathogenic and similar but non-pathogenic organisms can be used to identify the genes or base-pair sequences that are more important in causing the disease, so more effective drugs can be developed

The DNA of individuals can be analysed to reveal the presence of alleles associated with particular diseases

(c) define the term recombinant DNA;

A section of DNA, often in the form of a plasmid, which is formed by joining DNA sections from two different sources

(d) explain that genetic engineering involves the extraction of genes from one organism, or the manufacture of genes, in order to place them in another organism (often of a different species) such that the receiving organism expresses the gene product;

The required gene is obtained

A copy of the gene is placed in a vector

The vector carries the gene to the recipient cell

The recipient expressed the gene through protein synthesis

(e) describe how sections of DNA containing a desired gene can be extracted from a donor organism using restriction enzymes;

A DNA probe can be used to locate the gene on DNA fragments and the gene can be cut from a DNA fragment using a restriction enzyme

Restriction enzymes cut through DNA at specific points, only where a specific base sequence occurs, normally about 10 base pairs long.

The enzyme catalyses a hydrolysis reaction which breaks the sugar phosphate backbone of the DNA at different places. The gives a staggered cut which leaving some exposed bases called sticky ends

(f) outline how DNA fragments can be separated by size using electrophoresis;

DNA samples are treated with restriction enzymes to cut them into fragments

The DNA samples are placed into cells cut into the negative electrode end of the gel

The gel is immersed in a tank of buffer solution and an electric current is passed through the solution for a fixed period of time, usually around two hours

DNA is negatively charged because of its phosphoryl groups. It is attracted to the positive electrode.

Shorter lengths of DNA move faster than longer lengths, so move further in the fixed time that current is passed through the gel

The position of the fragments can be shown by using a dye that stains DNA molecules

(g) describe how DNA probes can be used to identify fragments containing specific sequences;

A DNA probe is a short single-stranded section of DNA that is complementary to the section of DNA being investigated. The probe is labelled in one of two ways:

Using a radioactive marker so that the location can be revealed by exposure to photographic film

Using a fluorescent marker that emits a colour on exposure to UV light

Copies of the probe are added to a sample of DNA fragments and will anneal to any fragment where a complementary base strand is present

(h) outline how the polymerase chain reaction (PCR) can be used to make multiple copies of DNA fragments;

The DNA sample is mixed with a supply of DNA nucleotides and DNA polymerase

The mixture is heated to 95°C. This breaks the hydrogen bonds holding the strands together, so the samples are now single stranded

Primers (short lengths of single stranded DNA) are added

The temperature is reduced to 55°C to allow the primers to bind and form small sections of doubl stranded sections

DNA polymerase can bind to these double-stranded sections

The temperature is raised to 72°C. The enzyme extends the double stranded section by adding nucleotides to the unwound DNA

When the DNA polymerase reaches the other end of the DNA, a new, double stranded DNA molecule is generated

The whole process can be repeated many times so the amount of DNA increase exponentially

(i) explain how isolated DNA fragments can be placed in plasmids, with reference to the role of ligase;

The plasmids and the fragments are both cut with the same restriction enzyme so they have complementary sticky ends

The base pairs anneal and DNA ligase joins together the phosphate sugar backbones to form recombinant DNA

(j) state other vectors into which fragments of DNA may be incorporated;

Liposomes

Viral DNA e.g. bacteriophages

Hybrid vectors with the propertied of both plasmids and bacteriophages

(k) explain how plasmids may be taken up by bacterial cells in order to produce a transgenic microorganism that can express a desired gene product;

Large quantities of the plasmid are mixed with bacterial cells

Calcium salts are added, and the temperature of the culture is lowered to freezing before the being quickly raised to 40°C.

This increases the rate at which plasmids are taken up by bacterial cells to around 0.25%

(l) describe the advantage to microorganisms of the capacity to take up plasmid DNA from the environment;

Genetic variation

In the case of antibiotic resistance genes, survival in the presence of these chemicals

(m) outline how genetic markers in plasmids can be used to identify the bacteria that have taken up a recombinant plasmid;

Not all bacteria take up the plasmid.

Some of the bacteria take up a plasmid that has not seals with a copy of the gene, but just sealed up on itself to reform the original plasmid

A plasmid is used which carries genes which make any bacteria receiving them resistance to two different antibiotics. The resistance genes are known as genetic markers

The plasmids are cut by an enzyme which has its resistance site in the middle of one of the resistance genes (G1), so that if the required gene is taken up, the resistance gene for one of the antibiotics does not work, but it other (G2) does

The DNA is placed in the plasmids, and the plasmids in bacteria cells

The bacteria are grown on an agar plate to produce a colony

Some cells from the colonies are transferred onto agar that has been made from the antibiotic that remains intact, meaning that all bacteria that have taken up a plasmid will grow.

Some cells are transferred onto agar that has been made from the second antibiotic. Only the bacteria which have taken up a plasmid that is not recombinant will grow.

By keeping track of which colonies are which, we now know that any bacteria which grow on the agar containing the first antibiotic, but not on the agar containing the second antibiotic must have taken up the recombinant plasmid

The required colonies can now be identified and be grown on a large scale

(n) outline the process involved in the genetic engineering of bacteria to produce human insulin;

1. **mRNA from human insulin is extracted from pancreas cells**
2. **Reverse transcriptase uses mRNA as a template to make single stranded cDNA, and this is made double stranded by DNA polymerase**
3. **A single sequence of nucleotides (GGG) is added to each end of the DNA to make sticky ends**
4. **Plasmids are cut open when a restriction enzyme**
5. **Cut plasmids have a single sequence of nucleotides (CCC) asses to each to make sticky ends**
6. **Plasmids and the insulin gene are mixed so that sticky ends form base pairs**
7. **DNA ligase links sugar-phosphate backbones of plasmid and insulin gene**
8. **Plasmids are mixed with bacteria in the presence of calcium ions**
9. **Bacteria take up plasmids and multiply to form a clone**
10. **Genetically engineered bacteria transcribe and translate the human gene to make human insulin**

(o) outline the process involved in the genetic engineering of 'Golden Rice™';

Two genes from the Daffodil and one from the bacterium *Erwina urefovora* were inserted into TI plasmids and taken up by the bacterium *Agrobacterium tumefaciens*. This introduced the genes into rice embryos

The resulting rice plants produced seeds with β-carotene in the endosperm, which is yellow.

Vitamin A is produced in our bodies from β-carotene

(p) outline how animals can be genetically engineered for xenotransplantation;

Pigs have been engineered to lack the enzyme α-1,3-transferase, which is a key trigger for rejection of organs in humans

The human nucleotidase enzyme has been grafted into pig cells in culture. It reduces the number of immune cell activities involved in xenotransplant rejection

(q) explain the term gene therapy;

Any therapeutic technique where the functioning allele of a particular gene is placed in the cells of an individual lacking the functioning alleles of that particular gene. Can be used to treat some recessive conditions, but not dominant conditions

(r) explain the differences between somatic cell gene therapy and germ line cell gene therapy;

Somatic cell gene therapy	**Germline cell gene therapy**
The functioning allele of the gene is introduced into target cells- ∴ techniques are needed to get the gene to the target location, or the specific cells must be removed, treated and then replaced	The functioning allele of the gene is introduced into germline cells- delivery techniques are more straightforward
Introduction into somatic cells means that any treatment is short-lived and has to be repeated regularly. The specialised cells containing the gene will not divide to pass on the allele	Introduction into germline cells means that all cells derived from the germline cells will contain a copy of the functioning allele. The offspring may also contain the allele
There are difficulties in getting the allele into the genome in a functioning state. Genetically	Although more straightforward, it is considered unethical to engineer human embryos. It is not

modified viruses have been tried, but the host becomes immune to them so cells will not accept the vector on second and subsequent treatments. Liposomes are used but these may be inefficient	possible to know whether the allele has been successfully introduced without any unintentional changes to it which may damage the embryo
Genetic manipulations are restricted to the actual patient	Genetic manipulations could be passed on to the patient's children

(s) discuss the ethical concerns raised by the genetic manipulation of animals (including humans), plants and microorganisms

Religious objections
Objections to tampering with an organism's natural genotype
Fears of unforeseen effects of the gene
Fears of the consequences of escape into the wild
Growing GM plants might damage the environment
Eating GM plants might be bad for health

Control, Genome and Environment

Ecosystems and Sustainability

Ecosystems

(a) define the term ecosystem;

All living organisms and all the non-living components in a specific habitat, and their interactions

*(b) state that **ecosystems are dynamic systems**;*

(c) define the terms biotic factor and abiotic factor, using named examples;

Biotic factor

How living organisms affect each other

Food supply, predation, disease

Abiotic factor

The effect of non-living components of the ecosystem

pH, temperature, soil type

(d) define the terms

producer,

An organism that converts simple inorganic compounds into complex organic compounds

consumer

An organism that gains energy from complx organic matter

decomposer

An organism that feeds on waste from other organisms, or dead organisms

trophic level

Each feeding level in a food chain

(e) describe how energy is transferred though ecosystems;

Energy is transferred by organisms consuming each other. This is shown in a food web, with the arrows representing the flow of energy between organisms

(f) outline how energy transfers between trophic levels can be measured;

The energy content of samples of organisms from each trophic level is measured

Each sample is dried in an oven

The samples are weighed

The samples are burned in a bomb calorimeter

The energy produced passes to a known mass of water and the temperature rise of the water is measured

How much energy is released per gram is calculated

(g) discuss the efficiency of energy transfers between trophic levels;

Energy is lost between trophic levels because animals

Never eat all of the available food

Cannot digest all of the food they eat

Use energy to respire

Lose heat energy to the surroundings

Lose energy in urine and faeces

(h) explain how human activities can manipulate the flow of energy through ecosystems;

Replacing natural vegetation and fauna with crops and livestock

Deflecting natural succession to maintain grassland

Increasing productivity of producers through

Soil improvement

Irrigation

Fertilisers

Removal of

Competing weeds

Damaging pathogens and pests

Increasing productivity of producers and consumers through selective breeding or genetic engineering

Sheltering organisms from damaging environmental factors

(i) describe one example of primary succession resulting in a climax community;

A sand dune

Pioneer plants such as sea rocket colonies the sand just above the high water mark. These can tolerate salt water spray, lack of fresh water and unstable sand

Wind-blown sand builds up around the base of these plants, forming a 'mini' sand dune. As the plants die and decay, nutrients accumulate in this mini dune. As they dune gets bigger, plants like sea couch grass colonise it, which has underground stems to help stabilise the sand

With more stability and accumulation of more nutrients, plants like marram grass start to grow. Marram grass shoots trap windblown sand and, as the sand accumulated, the shoots grow taller to stay above the growing dune, thus trapping more sand.

As the sand dune and nutrients build up, other plants colonise the sand. Many are members of the bean family, which have nodules in their roots which contain bacteria which convert nitrogen to nitrates. With nitrates available, more species colonise the dunes, stabilising them further

Rock

Algae and lichens begin to living on the bare rock

Erosion of the rock and build up of dead and rotting organisms produces enough soil for larger plants, such as mosses and fern to grow

Larger plants succeed the small plants until the climax community is reached

(j) describe how the distribution and abundance of organisms can be measured, using

line transects,

On a line across the habitat and record every species touching the line, and their position.

belt transects,

Quadrats places sequentially along a line transect

quadrats

A square frame is placed at random in the habitat. Each species present is identified, and the abundance of each is estimated

point quadrats;

Frames with long pins. Lowered vertically at random. Each species which touches a pin is recoreded, along with the number of times it is touched

(k) describe the role of decomposers in the decomposition of organic material;

Decomposers feed on waste from other organisms. They recycle materials such as Carbon and Nitrogen. If they did not break down dead organisms, energy and valuable nutrients would remain in the dead organism

(l) describe how microorganisms recycle nitrogen within ecosystems. (Only Nitrosomonas, Nitrobacter and Rhizobium need to be identified by name).

$N_2 \rightarrow NH_4^+$

Nitrogen is fixed by bacteria such as Rhizobium that live in root nodules.

They have a mutalistic relationship with the plant- they fix the Nitrogen for the plant and the plant provides the bacteria with carbon compounds (glucose)

There are proteins which absorb oxygen, keeping conditions anaerobic, so that nitrogen reductase can reduce nitrogen gas to ammonium ions

$NH_4^+ \rightarrow NO_2^-$

Ammonium ions are released by bacteria in the putrefaction of proteins found in dead or waste organic matter

Nitrosomonas bacteria obtain their energy by oxidising Amonium ions to Nitrites under aerobic conditions

$NO_2^- \rightarrow NO_3^-$

Nitrobacter obtain their energy by oxidising Nitrites to Nitrates under aerobic conditions

$NO_3^- \rightarrow N_2 + N_2O$

Either plants absorb the Nitrates from the soil to make nucleotide bases.

Or denitrifying bacteria under anaerobic conditions use nitrates as a source of oxygen for respiration, producing nitrogen gas (N_2) and Nitrous Oxide (N_2O)

Control, Genome and Environment

Populations and sustainability

(a) explain the significance of limiting factors in determining the final size of a population;

A habitat cannot support a population large than its carry capacity because of limiting factors which place a limit on population size.

The limiting factors may include:

- **Resources**
  - **Food**
  - **Water**
  - **Light**
  - **Oxygen**
  - **Nesting sites**
  - **Shelter**
- **Effects of other species**
  - **Predators**
  - **Parasites**
- **Intensity of competition for resources**

(b) explain the meaning of the term carrying capacity;

The maximum population time that can be maintained over a period of time in a particular habitat

(c) describe predator–prey relationships and their possible effects on the population sizes of both the predator and the prey;

When the predator population gets bigger, more prey are eaten

The prey population then gets smaller, leaving less food for the predators

With less food, fewer predators can survive, and their population size decreases

With fewer predators, fewer prey are eaten, and their population size increases

With more prey, the predatory population gets bigger, and the cycle continues

(d) explain, with examples, the terms interspecific and intraspecific competition;

Interspecific competition

Competition between individual of different species can affect both the population size and the distribution of a species in an ecosystem as no two species can occupy the same niche

Red v Grey squirrel

The red squirrel outcompetes the grey in conifer forests, but the grey squirrel outcompetes the red in forests with less than 75% conifers

Intraspecific competition

Competition between individuals of the same species

If food supply becomes a limiting factor, the individuals best adapted to obtaining food will survive and reproduce, whereas those less well adapted will die out and fail to pass on their genes.

(e) distinguish between the terms conservation and preservation;

Conservation is the maintenance of biodiversity, but the area can still be sustainably exploited

Preservation protects species by leaving their habitat untouched

(f) explain how the management of an ecosystem can provide resources in a sustainable way, with reference to timber production in a temperate country;

Selective felling

Some mature trees, diseased trees and unwanted species are harvested, leaving other trees to develop and distribute seeds to fill the gaps

Strip felling

Small patches, or strips, of forest are cleared completely, leaving other patches untouched. Large areas are not felled at the same time, so loss of species and soil erosion are avoided

Coppicing

Trees are cut down, leaving stumps from which new shoot develop. These have a well developed root system and so grow fast. After a few years the shoots are cut and yield poles. Can be repeated indefinitely. Small strips or patches are cut in different years, providing a variety of habitats so producing high biodiversity

(g) explain that conservation is a dynamic process involving management and reclamation;

Maintaining biodiversity in dynamic ecosystems requires careful management to maintain a stable community or even reclaim an ecosystem by reversing the effects of human activity

Some management strategies may include:

- **Raising the carrying capacity by providing extra food**
- **Moving individuals to enlarge populations, or encouraging natural dispersion of individuals between fragmented habitats by developing dispersal corridors of appropriate habitat**
- **Restricting dispersal of individuals by fencing**
- **Controlling predators and poachers**
- **Vaccinating individuals against disease**
- **Preserving habitats by preventing pollution or disruption, or intervening to restrict the progress of succession**

(h) discuss the economic, social and ethical reasons for conservation of biological resources;

Economic

- **Many species provide a valuable food source**
- **Genetic diversity in wild strains of domesticated species may be needed in future for certain characteristics**
- **Natural environments are valuable sources of potentially beneficial resources**
  - **E.g. medicines**
- **Natural predators of pests can act as biological control agents**
- **Wild insect species pollinate crop plants**
- **Other organisms maintain water quality, protect soil and break down waste products.**
- **There is also evidence that reduced biodiversity may cause reduced climatic stability**

Social

- **Ecotourism relies on biodiversity, as does recreation**

Ethical

- **Every species has a value in its own right**
- **Every living thing has the right to survive**

(i) outline, with examples, the effects of human activities on the animal and plant populations in the Galapagos Islands

In 1980 the population of the Galapagos Islands was 5000, and about 4000 tourists visited every year. In 2005, the population was 28,000, and 100,000 tourists visited every year.

- **Dramatic increase in population size has placed huge demand on water, energy and sanitation services**
- **More waste and pollution have been produce**
- **The demand for oil has increased**
- **2001 oil spill had an adverse effect on marine and costal ecosystems**
- **Increased pollution, building and conversion of land for agriculture has caused destruction and fragmentation of habitats**
- **Species have been harvested faster than they could replenish themselves.**
  - **Giant tortoises were taken to be eaten on long voyages**
  - **Fishing for exotic species of fish has decimated the population**
  - **Depletion of sea cucumbers has had a drastic effect on under-water ecology**
  - **International market for Shark-fin has led to the deaths of around 150,000 sharks each year**
- **Humans have introduced many non-indigenous species**
  - **The red quinine tree spread rapidly and outcompetes the native species. Its presence has changed the landscape from mostly low scrub and grassland to a closed canopy forest. Many native animals have lost their nesting sites**
  - **Goats**
    - **eat species unique to the islands,**
    - **outcompete giant tortoises for grazing,**
    - **tramples on tortoise nesting sites**
    - **transforms forests into grassland, causing soil erosion**
  - **Cats hunt a number of indigenous species**

Control, Genome and Environment

Responding to the Environment

Plant Responses

(a) explain why plants need to respond to their environment in terms of the need to avoid predation and abiotic stress;

Plants respond to external stimuli as well as biotic and abiotic components of the environment to help the plant avoid stress, being eaten, and survive long enough to reproduce. These responses are coordinated by hormones

(b) define the term tropism;

A directional growth response in which the direction of the response is determined by the direction of the external stimulus

(c) explain how plant responses to environmental changes are co-ordinated by hormones, with reference to responding to changes in light direction;

The presence of auxin promotes the active transport of hydrogen ions through the ATPase enzyme, into the cell wall. This decreases the pH and allows optimum conditions for the wall loosening enzymes to work. These enzymes break bonds within the cellulose, so the walls become less rigid and can expand as the cells take in water.

A shoot bends towards a light source because auxin in transported to the tip o the shoot to the cells in the shade, allowing the cells to take up more water and elongate.

Because the cells elongate more on the shaded side than the side in the light, the shoot bends towards the light source

(d) evaluate the experimental evidence for the role of auxins in the control of apical dominance and gibberellin in the control of stem elongation;

Auxins

Apical dominance is when the growing apical bud at the tip of the shoot inhibits the growth of the lateral buds further down the shoot

Auxins are produced in the tip of the main shoot. They inhibit the growth of side shoots

When the tip of the main shoot is removed, or an auxin transport inhibitor is applied below the apex of the main shoot, the side shoots grow.

This shows that auxin is produced in the apex of the main shoot and transported to lateral buds to inhibit their growth. When there are low concentrations of auxin in the side shoots, their growth is not inhibited, and so they can grow.

This is also shown where, as the plant grows taller, the lateral buds at the bottom of the plants start to grow larger- they are further away from the main shoot, so there is a lower concentration of auxin and their growth is less inhibited

Gibberellins

If genetically dwarf plants are treated with Gibberellic acid, the stems elongate considerably

(e) outline the role of hormones in leaf loss in deciduous plants;

Cytokinins stop the leaves of deciduous trees senescing by making sure that the leaves act as a sink for phloem transport, so the leave is guaranteed a good supply of nutrients

If cytokinin production drops, the supply of nutrients dwindles and senescence begins

Senescence causes auxin production at the tip of the leaf to drop

This makes the cells in the abscission zone more sensitive to ethene

A drop in auxin concentration causes an increase in ethene production

This increases production of cellulase, which digests the walls of the cells in the abscission zone, eventually separating the petiole from the stem

(f) describe how plant hormones are used commercially

Synthetic auxins are used as growth stimulants when root cuttings are taken

A synthetic auxin is used as a selective weed killer

A form of abscisic acid what is not readily broken down by plants is used as an anti-transpirant as it closes stomata

Control, Genome and Environment

Animal Responses

(a) discuss why animals need to respond to their environment;

Animals need to respond to their environment to stay alive. This is done using nerves and hormones, to control responses ranging from muscle actions to run away from a predator, to fine control of balance, posture and temperature regulation.

(b) outline the organisation of the nervous system in terms of central and peripheral systems in humans;

Nervous system

- **Central Nervous System**
- **Peripheral Nervous System**
  - **Somatic Nervous System**
  - **Autonomic Nervous System**
    - **Sympathetic Nervous System**
    - **Parasympathetic Nervous System**

(c) outline the organisation and roles of the autonomic nervous system;

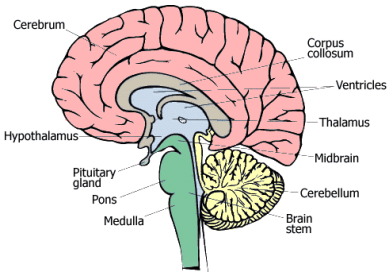
Sympathetic Nervous System

- **Most active in times of stress**
- **The neurones of a pathway are linked at a ganglion just outside of the spinal cord.**
- **Pre-ganglion neurones are very short**
- **Post-ganglion neurones secrete noradrenaline at the synapse between neurone and effector**
- **Effects of action include**
  - **Increased heart rate**
  - **Pupil dilation**
  - **Increased ventilation rate**
  - **Orgasm**

Parasympathetic Nervous System

- **Most active in sleep and relaxation**
- **The neurones of a pathway are linked at a ganglion within the target tissue, so pre-ganglion neurones vary in length**
- **Post ganglion neurones secrete acetylcholine as the neurotransmitter at the synapse between neurone and effector**
- **Effects of action include:**
  - **Decreased heart rate**
  - **Pupil dilation**
  - **Decreased ventilation rate**
  - **Sexual arousal**

(d) describe, with the aid of diagrams, the gross structure of the human brain, and outline the functions of the cerebrum, cerebellum, medulla oblongata and hypothalamus;



Cerebrum

- **Control of all higher order processes such as memory, language, emotions, thinking and planning**

Cerebellum

- **Control and coordination of movement and posture**

Medulla Oblongata

- **Control of breathing, heart rate and smooth muscle of the gut**

Hypothalamus

- **Control of the autonomic nervous system and some endocrine glands**

(e) describe the role of the brain and nervous system in the co-ordination of muscular movement;

The conscious decision to move voluntarily is initiated in the cerebellum. Neurones from the cerebellum carry impulses to the motor areas so that motor output to the effectors can be adjusted appropriately in these requirements

(f) describe how co-ordinated movement requires the action of skeletal muscles about joints, with reference to the movement of the elbow joint;

Coordinated and appropriate movement requires the controlled action of skeletal muscles about joints. This can be seen in the movement of the elbow joint

1. **Impulses arriving at the neuromuscular junction cause vesicles to fuse with the pre-synaptic membrane and to release acetylcholine into the gap**
2. **Acetylcholine binds to receptors on the muscle fibre membrane (sarcolemma) causing depolarisation**
3. **Depolarisation wave travels down tubules (T system)**
4. **T system depolarisation leads to Ca^{2+} release from stores in sarcoplasmic reticulum**
5. **Ca^{2+} binds to proteins in the muscle, which leads to contraction**
6. **Acetylcholinesterase in the gap rapidly breaks down acetylcholine so that contraction only occurs when impulses arrive continuously**

(g) explain, with the aid of diagrams and photographs, the sliding filament model of muscular contraction;

1. **Myosin head groups attach to the surrounding actin filaments forming a cross bridge**
2. **The head group then bends, forming the thin filament to be pulled along and so overlap more with the thick filament. This is the power stroke. ADP and P_i are released**
3. **The cross bridge is broken as new ATP attaches to the myosin head**
4. **The head group moves backwards as ATP is hydrolysed to ADP and P_i. It can then form a cross bridge with the thin filament along and bend again.**

(h) outline the role of ATP in muscular contraction, and how the supply of ATP is maintained in muscles;

Role

Energy from ATP is required to break the cross bridge connection and re-set the myosin head forwards

Maintenance

Aerobic respiration in mitochondria

Anaerobic respiration in sarcoplasm

Transfer of phosphate group from Creatine Phosphate to ADP in sarcoplasm

(i) compare and contrast the action of synapses and neuromuscular junctions;

Synapse	**Neuromuscular Junction**
Post synaptic membrane is the cell surface membrane of a neurone	Post synaptic membrane is the cell surface membrane of a muscle
Neurotransmitter may be ACh, noradrenaline, glutamate or another transmitter	Neurotransmitter is ACh
Depolarisation of the post synaptic membrane may be stimulatory or inhibitory	Depolarisation of post synaptic membrane is stimulatory
Neurotransmitter is secreted, diffuses across a cleft, binds to receptors in the postsynaptic membrane and is finally broken down	

(j) outline the structural and functional differences between voluntary, involuntary and cardiac muscle;

Voluntary	**Involuntary**	**Cardiac**
Striated	Unstriated	Semi-striated
Cylindrical cells are multinucleate	Spindle-shaped cells each have a single nucleus	Cylindrical cells, each with a single nucleus, branch and connect with other cells
Found attached to bone	Found in the walls of tubular structures, such as the gut, blood vessels and ducts	Found only in the heart
Controlled by the somatic nervous system	Controlled by the autonomic nervous system	Controlled by the autonomic nervous system
Contracts quickly; tires easily	Contracts slowly; fatigues slowly	Contracts spontaneously without fatigue

*(k) state that **responses to environmental stimuli in mammals are co-ordinated by nervous and endocrine systems;***

(l) explain how, in mammals, the 'fight or flight' response to environmental stimuli is co-ordinated by the nervous and endocrine systems.

Nervous

Sensory neurons from the somatic nervous system carry impulses from receptors to the sensory areas of the cerebrum of the brain, giving information about the danger in the environment

Nerve impulses pass to association areas in the cerebrum

Nerve impulses in sympathetic nerves of the autonomic nervous system, from the brain to the sinoatrial node of the heart, increase pulse rate and the stroke volume of the heart

Impulses in sympathetic nerves from the brain to the adrenal glands cause secretion of adrenaline from the adrenal medulla

Hormonal

Adrenaline is secreted into the blood then has a number of responses, including

- **Stimulation of the heart, increasing stroke volume and pulse rate**
- **Increase in blood pressure, by constriction of blood vessels in the skin and gut**
- **Increase in air flow to the lungs**
- **Increased breakdown of glycogen in the liver**
- **Decreased sensory threshold**
- **Increased mental awareness**

These responses provide an increased flow of oxygenated blood carrying glucose. This prepares the body for the needs of the muscles, which may work hard for the organisms to escape from, or cope with a source of danger.

A decision is then made about how to respond

Nerve impulses pass from the association areas in the frontal lobe of the cerebrum (concerned with planning actions and movements) to motor areas

From there, motor neurones of the somatic nervous system carry impulses to the muscles to produce the chosen action

Control, Genome and Environment

Animal Behaviour

(a) explain the advantages to organisms of innate behaviour;

It does not need to be learned

It has immediate survival value for a young, inexperienced animal in a dangerous situation

It is appropriated for invertebrates with a short live span that do not have time to learn

It required few neurones

It is likely to be appropriate for the animal's habitat, as the alleles controlling it will have been subject to natural selection

(b) describe escape reflexes, taxes and kineses as examples of genetically-determined innate behaviours;

Escape reflexes

A particular stimulus brings about an automatic response, the function of which is to avoid predators. Earthworms withdraw underground in response to vibrations in the ground

Taxes

A directional movement in response to an external stimulus. Woodlice move away from light to be less visible to predators and less liable to desiccation

Kineses

A movement in response to an external stimulus. The rate of movement is related to the intensity, but not the direction, of a stimulus. When woodlice are placed in dry/bright conditions, they will move around rapidly and randomly until they are in more suitable conditions

(c) explain the meaning of the term learned behaviour;

Animal responses that change or adapt with experience

(d) describe habituation, imprinting, classical and operant conditioning, latent and insight learning as examples of learned behaviours;

Habituation

Animals learn to ignore certain stimuli because repeated exposure to the stimulus results in neither reward or punishment. It avoids wasting energy in making escape responses to non-harmful stimuli

Imprinting

Young animals being associated with another organism, usually the parent. After that, they will only follow and learn from objects that look like the first objects. This helps the young learn skills from the parents

Classical conditioning

A form of adaptive learning in which the innate response is modified. The animal learns to respond to a stimulus that is different from the usual stimulus

Operant conditioning

A form of adaptive learning in which an animal learns to carry out a particular action in order to receive a reward or avoid an unpleasant experience.

Latent learning

Behaviour that is not directed towards a particular outcome. Animals explore new surrounding and learn information that has no apparent value at the time, but may be useful at some time.

Insight learning

A form of learning in which an animal integrates memories of two or more earlier actions to produce a new response or gain a reward. The organism has the ability to think and reason in order to solve problems or deal with situations that do not resemble simple fixed, reflex responses or the need for repeat trial and error

(e) describe, using one example, the advantages of social behaviour in primates;

In gorillas

- **Females give birth to only one (or very few) young at a time. The maternal care and group protection enhances the survival rate of the young. By the age of 12 months, the gorilla will only venture 5m from its mother**
- **The young learn through observation of, and play with, the other members of the group. Learned behaviour is vital to the survival of primates. By the age of two, juvenile gorillas play together and imitate the actions of the adults. From 3-6 the young play with the older male to learn new skills**
- **The final, relatively large brain size slows the maturity of primates. The security of a group enhances the survival and learning of the immature young**
- **Knowledge and protection of food sources is shared with the group**
- **Greater ability to detect and deter predators is achieved by groups of individuals working together**

(f) discuss how the links between a range of human behaviours and the dopamine receptor DRD4 may contribute to the understanding of human behaviour

There are a range of dopamine receptors in the brain. Depending on how effective the receptors are, there will be different levels of dopamine in the brain. The different levels are linked to a range of conditions, such as schizophrenia, ADHD and Parkinson's disease. The DRD4 receptor is one of the most variable receptors.

By studying the levels of Dopamine in the brain and the genotype of the individual, the alleles which may influence different conditions can be investigated, and different drugs for the conditions can be developed.