(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.**

(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 for 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

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

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