Plant and animal responses to the environment

Scholarship Biology

Chapter 2

This chapter covers AS 91603 (Biology 3.3); candidates are expected to have background knowledge from AS 91158 (Biology 2.6).

AS 91604 (Biology 3.4) considers the ways in which animals (only) respond to maintain a stable internal environment despite fluctuations in the external (abiotic) environment – i.e. the process of *homeostasis.* Only *one* of five control systems (selected from body temperature, blood pressure, osmotic balance, level of blood glucose, levels and balances of respiratory gases) is analysed. While aspects of homeostatic control are generic, each of the control systems is unique in structure and function. In the considered opinion of the author, the content of AS 91604 (Biology 3.4) does not lend itself to the current format of the Scholarship Biology exam nor the emphasis of the Biology Performance Standard on concepts of ecology, genetics, evolution. Therefore, AS 91604 (Biology 3.4) has *not* been included in this book.

The *responses* of both plants and animals to their *external* environment include:

- orientation in space – tropisms and nastic movements (plants); taxes, kineses, homing (animals)
- orientation in time – annual, daily, lunar, tidal rhythms
- interspecific relationships – competition, mutualism, exploitation (herbivory, predation, parasitism)
- intraspecific relationships – competition, territoriality, hierarchical behaviour, co-operative interactions, reproductive behaviours.

The external environment includes both *biotic* and *abiotic factors*. It is essential that you know *how* and *why* a response occurs – essentially, this is explaining why the responses are *adaptations* to the organism's *ecological niche*. A thorough knowledge of important ecological concepts is required.

Essential exam notes

Biological communities and the ecological niche

Ecology studies the relationships between organisms and their environment (biotic and abiotic). An *organism* is any living thing. A *species* is a group of organisms that interbreed to produce fertile offspring. Members of a species belong to the same gene pool and are reproductively isolated from other species. A *population* is a group of individuals of the same species that live together in the same area at the same time. A *biological community* is all the organisms that live within a defined area (such as a lake, forest, beach, grassland) and their *inter-relationships* (biotic factors). An *ecosystem* consists of a biological community together with its *physical environment* (abiotic factors). A *managed ecosystem* is one that is *set up and controlled by humans*, usually in the form of a type of farm. The organisms in a natural ecosystem are subject to natural selection; the organisms in a managed ecosystem are *not* subject to natural selection, as humans control the external environmental factors (e.g. biological and chemical control of pests (using pesticides) and weeds (using herbicides); control of supply of water, nutrients, light intensity, temperature) and also control which organisms will breed.

The availability of food and the actions of herbivores and predators are important in determining the presence and abundance of organisms in a (natural) biological community. In particular, predation is an important factor in controlling the size and density of populations of prey species. Organisms can be classified as *producers*, *consumers*, *decomposers*. *Producers* are able to synthesise organic compounds ('food') from other chemicals using an energy source; most common are the green plants that use solar energy to combine carbon dioxide and water into carbohydrates in the process of *photosynthesis*. *Consumers* are unable to make their own food, so they depend on other organisms to supply their organic compounds. There are various groups of consumers, including herbivores, carnivores, omnivores, parasites, scavengers, carrion feeders, filter feeders, detritus feeders. *Decomposers* are also unable to make their own food; decomposers are certain species of fungi (includes moulds) and bacteria that feed on waste products and dead bodies, breaking them down (decomposition). This process releases the chemicals from the wastes and bodies into the soil which become nutrients for other life forms such as plants (nutrients obtained via the roots).

Producers start the *food chains* that exist in a biological community; producers are eaten by herbivores which in turn are eaten by carnivores. Food chains typically cross-link to form complex *food webs* within a community. Reduction in numbers or removal of a link in a food chain can have severe consequences on other organisms in the chain/web (e.g. food source removed or greatly reduced, predator reduced or removed). Similarly, the addition of a new organisms to the chain/link can have consequences for the rest of the chain (e.g. addition of a competitor, herbivore, predator). Chemicals entering the food chain can *accumulate* as they progress up the food chain/web. This occurs most obviously with toxins such as lead (Pb), and pesticides such as DDT, and neonicotinoids. It is the top carnivores/predators that accumulate the highest levels of those toxins in their tissues, and the effects can be very harmful, even lethal (refer to question on Californian condors (page ix) and question on honeybees (page 42)).

Environmental factors may be divided into *abiotic* (non-living or *physical* factors) and *biotic* (*living*) factors. *Abiotic* factors include temperature, light intensity, humidity, oxygen, carbon dioxide, minerals/nutrients, substrate, salinity, wind speed, pH, water. For any organism, certain abiotic factors play a more important role than others in its survival, and members of a species can only inhabit areas where the abiotic factors are within the range of *physiological tolerance* of the organisms. *Biotic* factors are the influences and interactions with other living organisms. These include competition (both intraspecific and interspecific), exploitation (herbivory, predation, parasitism), mutualism.

To be successful, all organisms need to survive and reproduce, contributing their alleles to the gene pool. The *responses* of plants and animals are *adaptations* for survival and reproduction, through:

- finding favourable conditions and avoiding unfavourable conditions
- ensuring supplies of oxygen, water, nutrients, energy, warmth
- reducing competition (both intraspecific and interspecific)
- avoiding predators / reducing herbivory
- finding a mate of the same species.

Organisms occupy an **ecological niche**. The niche is a *combination* of *where* the organism lives (its *habitat*) and *how* it lives there (its *adaptations* – structural, behavioural, physiological, life cycle). The niche reflects the role that the organism performs in the biological community that it is a member of. *Each species has a unique niche.*

- The *fundamental niche* for an organism is the niche that it would occupy if all the necessary environmental factors were present. The limits to the fundamental niche are set by *the limits of an organism's physiological tolerance to the abiotic factors* (e.g. temperature, pH, salinity, type of substrate, light intensity, nutrient levels) of the environment.

- The *realised niche* is the actual niche that the organism occupies. It is not as extensive as the fundamental niche, with *boundaries typically set by the biotic factors* (e.g. predation, interspecific competition) of the environment. (Refer to question on barnacles page 26.)

Where different species overlap, *interspecific competition* occurs. The greater the overlap, the greater the competition. If the niches are sufficiently similar, *Gause's competitive exclusion principle* applies *in which one species outcompetes and so eliminates the other species.* Such competition provides *strong selection pressures for individuals to adapt to occupy slightly different niches, enhancing survival.*

The niche may change during an organism's life cycle (e.g. in the case of insects and amphibians that undergo metamorphosis such that the adult lives in a different habitat, has a different form, eats different food, display different adaptations from the juvenile form (e.g. butterfly and caterpillar; frog and tadpole)). This decreases intraspecific competition.

When different species live in geographic isolation in different parts of the world but occupy similar habitats exposed to similar environmental factors, they are subject to similar selection pressures (i.e. natural selection), so evolve to occupy similar niches. Such species are known as *ecological equivalents* (and display parallel or convergent evolution).

Empty or *vacant niches* – refers to the situation when an organism moves into a new environment and niches are 'available', or when existing organisms become extinct so their niches are now available to be 'filled'. The habitat offers new opportunities to organisms moving in; natural selection will operate to adapt the organisms to the habitat. Organisms evolve to 'fill' these niches as they adapt to the environment (through natural selection) and the opportunities (e.g. new food sources) the new environment offers. (Refer to question on New Zealand bats page 16.) When humans introduce a species into a new country or area, the species may fill empty niches by exploiting opportunities (e.g. new food sources) not available in its original country. In doing so, the species often becomes a pest (e.g. possums, stoats in New Zealand).

Scholarship Question

Both the following question and all other questions in this chapter are from Scholarship exams.

For each question, analyse both the resource material and what the question asks of you. Then plan your answer in the space provided. In your plan, use relevant biological concepts to briefly (e.g. bullet points, table, flow chart, or similar) explain the relevant aspects of the resource material/topic. Arrange your bullet points, or table, etc. into a logical order that will best address the question. Discuss your plan with your classmates and/or teacher then use your own paper to write an extended scientific essay using your plan, turning it into a discussion that links descriptions and explanations to form a comprehensive, logical answer. Use examples from the resource material and your own biological knowledge to support your explanations. Your essay is likely to take 4 or 5 sides of A4 paper. Give your completed essay to your teacher for their feedback.

Question One: Ecological niche of barnacles

Year 2007
Ans. p. 96

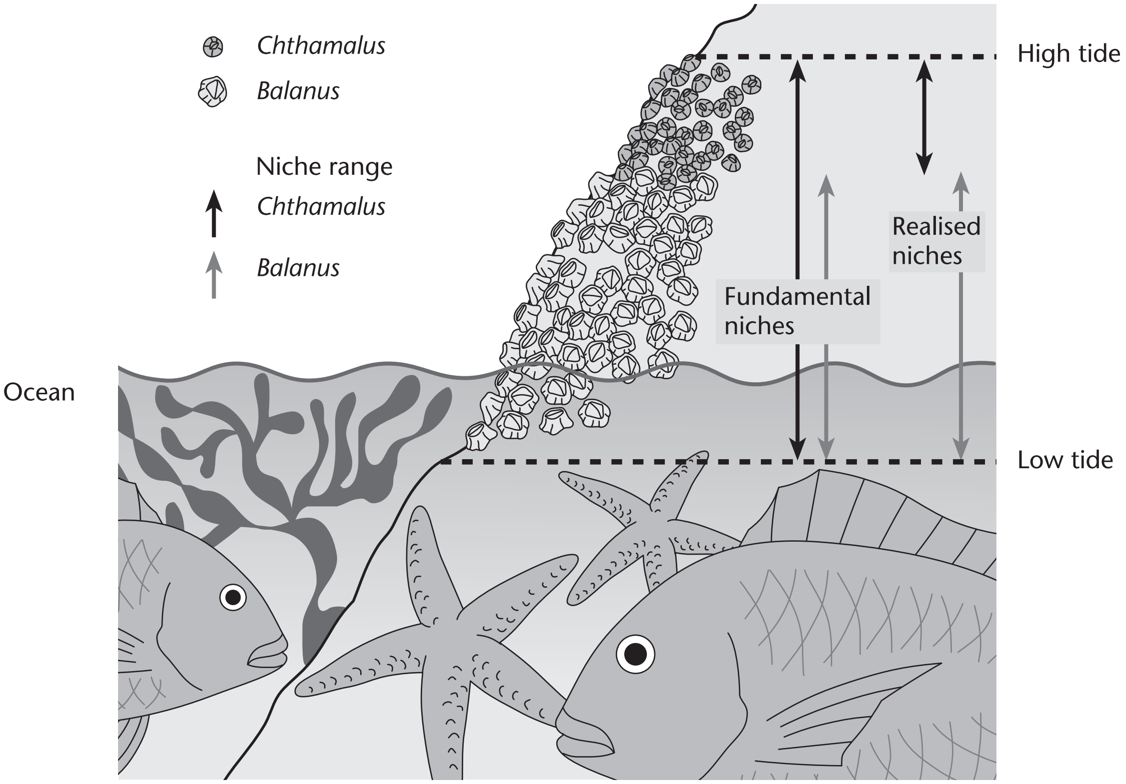
Barnacles are filter feeders that populate the coastlines of countries around the world. Fertilisation is external, and microscopic larvae develop. The larvae live for a time as plankton in the surface layer of the sea before settling and cementing onto rocks, where they metamorphose into the sessile adults.

The adults of two species of barnacle, *Chthamalus stellatus* and *Balanus balanoides*, are found on rocks in the inter-tidal zone of exposed shores in Scotland. *Chthamalus*, the smaller of the two barnacle species, is found in the upper tidal zone, whilst the larger *Balanus* extends to the low-tide mark. If *Balanus* is absent, *Chthamalus* can grow throughout the inter-tidal zone.

Predators of the adult barnacles are found throughout and below the inter-tidal zone. Predatory starfish are predominantly found below the low-tide mark, whilst predatory whelks and fish may feed in the intertidal zone.

Algae are dominant below the low-tide mark.

Discuss how different **biotic and abiotic factors** act to **determine the fundamental and realised niches** of these two species, *Chthamalus stellatus* and *Balanus balanoides*.



Planning page

Scholarship Biology

Chapter 3

Gene expression and genetic manipulation

This chapter covers AS 91607 (Biology 3.7); candidates are expected to have background knowledge from AS 91157 (Biology 2.5) and from AS 91159 (Biology 2.7).

Essential exam notes

Background

Genes are the units of inheritance, found on the **chromosomes** and made of the molecule **DNA**. Chromosomes exist as *homologous pairs*. Genes found at the same *locus* on a homologous pair of chromosomes have the genetic code (the *sequence of bases on the DNA molecule*) for the same characteristic. **Alleles** *are different forms of a gene* (have slightly different base sequences of DNA) and determine the particular traits or variations of the characteristic. *A gene is that length of DNA that has the code for a particular protein* (or polypeptide), with a sequence of three bases (a *triplet*) coding for an *amino acid.* The code is *transcribed* onto *mRNA* (*codons* match triplets) in the nucleus of the cell then *translated* into polypeptide chains of proteins by the *ribosomes* and *tRNA* (*anticodons* of tRNA match *codons* of mRNA at the ribosomes) in the cytoplasm of the cell. Translation ends when one of the three 'stop' codons occurs on the mRNA strand and the complete polypeptide chain becomes (part of) an actual protein.

Enzymes are an essential group of proteins which act as *biological catalysts* controlling each and every step in **metabolic pathways**. Enzymes are *specific* in their action – i.e. each enzyme catalyses only one type of reaction. A metabolic pathway is a series of enzyme-controlled steps in which a reactant (or substrate) is converted into a product which becomes the reactant for the next step in the pathway until an end product is reached. For example, part of the metabolic pathway for the synthesis of the essential amino acid phenylalanine is as follows:

	Enzyme 1		*Enzyme 2*		*Enzyme 3*	
Chorismate	➡	Prephenate	➡	Phenylpyruvate	➡	Phenylalanine

Metabolic pathways are linked into networks through shared substrates; there are many complex pathways for carbohydrate, lipid and protein metabolism. *Each reaction in a pathway is controlled by a specific enzyme which is the product of an expressed gene.*

Gene mutations occur randomly in DNA during replication with a base in a triplet being deleted, inserted, or substituted for another base (whole triplets may be deleted or duplicated too). *Substitution* is usually the least harmful of the gene mutations, as it may not cause a change in the amino acid sequence (from code degeneracy), or a different amino acid may not affect the biological function of the protein (e.g. for an enzyme, the active site for catalysis is unaffected). However, the different amino acid may result in the protein not being able to carry out its biological function (e.g. if the active site of the enzyme is affected). Deletion and insertion are typically the most damaging mutations, as they produce a reading frameshift, so that all triplets, hence all amino acids, after the site of the mutation are affected – with the usual outcome being early termination (if a 'stop' codon results) and therefore typically no functional protein is formed. If the protein is an enzyme which has a catalytic function damaged by the mutation, then the metabolic pathway it operates in will cease at this step and the product prior to the step will accumulate while the product(s) after the step will not be formed, resulting in a deficiency. For example, in the preceding metabolic pathway for the production of phenylalanine, if Enzyme 1 is not produced or not functional as a result of a mutation in the gene that encodes it, then the substrate chorismate will accumulate while there will be a deficiency of prephenate, phenylpyruvate, and phenylalanine.

Gene mutations form new alleles so provide the raw material for evolution. To be inherited, a gene mutation must occur *during the formation of the gametes* (not *in* the gamete), and that gamete must be fertilised and form a zygote – the new allele now becomes *subject to natural selection.* Beneficial/favourable mutations expressed in the genotype (i.e. produce adaptations that enhance fitness) will be selected for, so will increase in frequency in the gene pool while harmful/unfavourable mutations expressed in the genotype will be selected against and will not become established in the gene pool. Neutral (or 'silent') mutations will not be selected either for or against, and their frequency in the gene pool will be determined by chance / genetic drift. While mutated alleles are typically recessive, they can be dominant (see question on Munchkin cats page 63); dominant alleles are always expressed in the phenotype when present in the genotype. Mutated recessive alleles may be 'carried' in heterozygous phenotypes and not expressed until occurring together in the homozygous genotype (see question on condors, page ix).

DNA in the **genome** can be recognised as *coding* or *non-coding.* Coding DNA is that part that has the genes which code for proteins (humans have about 30 000 genes), while non-coding DNA is that part that has the 'switches' which turn genes 'on' or 'off' (this part of DNA has previously been called 'junk' DNA); i.e. non-coding DNA *determines which genes are expressed* ('turned on') *or not expressed* ('turned off') *at any one time.* Gene mutations can occur in both coding and non-coding regions; those occurring in non-coding regions may alter gene expression by causing a change in the 'switches'. For example, a mutation in the non-coding region of DNA associated with switching off the gene that codes for the enzyme lactase (which catalyses the breakdown of lactose – the sugar in milk) when a baby is weaned has resulted in the production of lactase into adulthood (the gene is still expressed), allowing adults to digest the lactose in milk throughout their lives (see question on Lactase persistence, page 88).

Alleles for a gene may display **complete dominance**, **co-dominance**, **incomplete dominance**. The **genotype** is determined by which two alleles are present at the locus of the gene; their expression results in the **phenotype**. If both alleles are the same, the individual has a **homozygous** genotype; if the two alleles are different, the individual has a **heterozygous** genotype. Individuals which are homozygous are **pure breeders** as they can only pass on the one type of allele to their offspring; individuals which are heterozygous are **non-pure breeders** as they can pass on either (and different) alleles to their offspring.

- **Complete dominance** occurs when the presence of one allele (the dominant allele) in the genotype masks the presence of the other allele (the **recessive** allele), so that the dominant allele is always expressed when present in the genotype. For example, in a cross between red × white, all the offspring would be red if red was the dominant allele (and vice versa).
- **Incomplete dominance** occurs when neither allele is dominant, therefore both contribute information to the offspring which tends to be an *intermediate* (or blend) between the two parents. For example, in a cross between red × white, all the offspring would be pink, the intermediate colour between red and white.
- **Co-dominance** occurs when both alleles are dominant so that both are expressed in the offspring. For example, in a cross between red × white, all the offspring would be red and white (broken colour or patches of both colours).

Multiple alleles occurs when there are *more than two* possible alleles for any particular gene (e.g. the ABO inheritance of human blood groups has three alleles I^A, I^B and i, in which I^A and I^B are co-dominant while i is recessive to both I^A and I^B). **Lethal alleles** occur when an individual inherits a (typically) homozygous recessive genotype resulting in a phenotype that means that the individual does not survive, usually dying as an embryo or in the early years of the life (see the chondrodystrophy allele/genotype in the question on condors on page ix).

Genetically modified organisms (**GMOs**) are organisms that have had their genetic material modified in some specific way by humans to meet our needs and demands – e.g. inserting a foreign gene (from another species) into the genome of an individual in *transgenesis.*

Genetic manipulation refers to the different ways/techniques that humans may use to *deliberately alter the genetic composition of organisms to produce organisms with characteristics that we desire.* Specifically, AS 91607 (Biology 3.7) considers the manipulations of **selective breeding**, **transgenesis**, **whole organism cloning**, and various ways in which we can manipulate the **expression of genes**. Each of these manipulations (dependent on the case study) may have *specific biological implications* (often negative) in any/all of the following areas:

- ecosystems
- genetic diversity
- health and survival of populations
- evolution of populations.

When discussing biological implications, you need to take into account that humans selectively breed organisms for our purposes and they are contained within *managed ecosystems*. We control the environment in managed ecosystems, so remove (natural) selection pressures from acting on the plants and animals we are breeding and cultivating. Therefore, evolution is being controlled by humans – in contrast to *natural ecosystems*, in which organisms remain subject to natural selection.

Modification of expression of existing genes

Each cell switches on, or *expresses*, only a fraction of its genes. Genes are switched on and off during development of the individual – e.g. a stem cell becomes a functional muscle cell instead of a functional neuron. Gene regulation most commonly occurs at the level of *transcription. Methylation* of DNA (adding the methyl group, CH_3) is a common method of switching a gene off (the gene is not transcribed, so is *silenced*) so that it is not expressed in the genotype. The extent of methylation (heavy methylation will switch off a gene) is a factor in **epigenetics** – the regulation of gene expression by factors in the internal environment such as levels of nutrients (from diet), hormones, temperature. Scientists can therefore modify the internal environment of an organism and switch off a gene, preventing it being expressed (also known as *gene knockdown*) – e.g. New Zealand AgResearch scientists have been able to 'knockdown' the gene in cows that produces the protein BLG, resulting in milk that lacks this protein (BLG provokes an allergic reaction in some babies).

Biological implications may include:

- (unexpected) results from the effects on the **expression of other genes** – these effects may be harmful or beneficial to the individuals (e.g. milk with higher than normal casein levels produced by 'knockdown' cows may have a positive effect on their calves if the milk is more nutritious so the calves grow faster/bigger or are healthier than other calves (or the opposite if the higher casein levels have a negative effect on the calves))
- effects on **biodiversity** from presence of these organisms in natural ecosystems is likely to be similar to those from the presence of selectively bred and/or transgenic organisms (see the sections that follow for more information on this).

Selective breeding

In *natural selection*, environmental factor(s) determine which phenotype(s) will be successful, breed and pass on their successful alleles to the next generation (these are the *fittest* individuals). These successful alleles increase in frequency in the gene pool (at the expense of the unsuccessful alleles, which decrease). In *artificial selection*, humans select the phenotypes of individuals that will breed, and it is the alleles from these individuals that will increase in frequency in the gene pool – commonly known as **selective breeding**.

Individuals with desirable traits are bred together to increase the chance of the offspring having the same desirable traits. *Homozygous genotypes* are developed by *inbreeding* and *test crossing* to produce *pure breeders*. As a result, most domestic species of animal (e.g. cattle, sheep, horses, cats, dogs) have many different breeds. Selective breeding can be carried out by anyone, without specialised equipment, but it involves trial and error so takes (a long) time (and money) and the outcome is not guaranteed. **Genome analysis** (which involves determining the locus and base sequence of all an individual's genes) is now being used as a tool in selective breeding to identify individuals with desirable traits, which are then bred together. This *greatly increases the success rate* of producing offspring with the desirable alleles/traits. Both **artificial insemination** (**AI**) and **embryo transfer** are also used to facilitate selective breeding programmes.

Biological implications may include the following.

- **Inbreeding** increases the chances of bringing together harmful recessive alleles (e.g. from gene mutations), reducing the fitness of the species/breed/variety/cultivar (i.e. has a *genetic disorder*). In contrast, selective **outbreeding** may result in **hybrid vigour**, where the fitness of the (hybrid) offspring is greater than that of the parents.
- Reduction in *genetic diversity* – as the range of alleles in the gene pool is reduced, the species/breed is more at risk of the spread of disease; increased chance of extinction, especially in *monocultures* (e.g. Cavendish bananas).
- Selectively bred organisms, if released (by accident or design) from managed ecosystems into natural ecosystems, may **outcompete** wild types, so reducing the biodiversity of ecosystems with flow-on effects through food chains.
- Selectively bred organisms in managed ecosystems have their **evolution controlled by humans** and not by natural selection. Their evolution can be much *faster* than in nature – e.g. large number of different breeds within animal species, large number of varieties/cultivars within plant species (especially when combined with modern genetic manipulations such as genome analysis (embryos) and transgenesis).
- Selectively bred and managed organisms are typically much *healthier* and live longer (greater breeding opportunities) than those in natural ecosystems, as they are supplied with all nutrients needed, predators and pests are controlled, shelter provided.

Scholarship Question

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Question One: Selective breeding of bananas

Year 2009
Ans. p. 102

'Banana' is the common name for the plants and the fruit of the genus *Musa*. It is the fourth most important food crop in the world after rice, maize and wheat. Banana plants reproduce asexually by sprouts or suckers. The fruit of the modern-day banana are seedless, but 'wild' banana species produce seeds.

Many different species of banana exist today, all of which are descended from one or other of the 'wild' Asian species:

Musa acuminata (AA: 2n = 22)

Musa balbisiana (BB: 2n = 22)

both of which can reproduce sexually and asexually.

Fruits of 'wild' bananas have numerous large, hard seeds.

Today there are a number of different banana cultivars (cultivated varieties) within each different species.

Examples of modern-day cultivars found in six different species of banana

Species Genome	Cultivars
AA	Sucrier
	Jari Buaya
AAA	Gros Michel
	Grande Naine
	Cavendish
BB	Abuhon
	Chuoi Hot Qua Lep
AB	Njalipoovan
ABB	Awak
	Pelipita
AABB	Kluai Ngoen

Cultivars of banana species showing variation in size and colours when ripe.

Export bananas are popular, partly because they are produced all year round and can be picked when unripe. Ripening of fruit is stimulated by ethylene gas, which is produced in, and released from, the cells of the fruit. When unripe bananas reach their destination, they are placed in special airtight rooms, which are then filled with ethylene gas to induce ripening.

Ripened Cavendish bananas in a New Zealand grocery store.

Discuss the following.

- The **sequence of events and processes** that have resulted in the three different **species** of banana with the following genomes, arising from the original 'wild' species of banana:

  AAA

  AB

  ABB

  Use annotated flow diagrams to support your answers.
- The **genetic processes** that could have occurred to produce the different **cultivars** of Gros Michel, Grande Naine and Cavendish within the one species of the AAA genome.

Answers and explanations

Chapter 1: Evolutionary patterns and processes

Self-check Questions

p. 8

1. *Environmental factors*
   - Geographical isolation – stopping gene flow/isolating gene pool.
   - Changing environment so new **selection pressures**.
   - Different adaptations selected for.
   - **Micro-evolution** occurs as gene/allele frequencies change in the gene pool.

   Biological factors

   Changes in organisms' structures/physiology/behaviour lead to **reproductive isolation**, as breeding is no longer possible with the ancestral population / other populations of the species.
   - Behavioural changes mean no longer able to recognise mating partners / courtship is no longer possible/successful.
   - Structural changes stop successful mating.
   - Physiological changes mean no longer compatible in body chemistry or processes, such that fertilisation is no longer possible / zygote not viable / chromosomes can't pair up – infertility may result.

   Reproductive isolation means no **gene flow** between populations, so the **gene pool** is now isolated from all others. Breeding between genetically related populations is no longer possible so no production of fertile offspring; so, by definition, a new species has come into existence.

   Speciation has occurred.
2. - **Natural selection** is operating on the phenotypes.
   - Similar environments favour similar **phenotypes/ adaptations**.
   - In colder climates, reduced SA:Vol ratios are advantageous in retaining body heat; therefore, shorter legs / larger bodies are adaptations to reducing heat loss in the cooler regions of the USA and Europe.
   - **Parallel evolution** in operation.

   Could also suggest a **founder effect** based on the small initial population of sparrows in America and a probable reduced genetic biodiversity compared with the European sparrows.
3. - Amphibians produce large numbers of eggs/offspring annually; cane toads are particularly prolific.
   - Large numbers of toads and no natural predators suggests **intraspecific competition** for resources, especially food.
   - **Migration** to new areas is a strategy for reducing competition; first migrants to arrive in a new environment are the first to access resources/food it offers – gives them competitive advantage.
   - Toads able to move/migrate faster (i.e. more powerful legs) will occur through **natural selection**. These toads are the **fittest**, so will contribute more to the gene pool, passing on their genes for the powerful legs – the **frequency of the alleles** for this will increase.
   - As there are large numbers of toads and a high rate of reproduction, evolution will be rapid.
4. - Sexual selection is a special type of natural selection; the female (typically) acts as the selecting agent in that she selects the male with whom she will mate. The supply-and-demand economics of sperm and egg production means that it is almost always the female who does the selecting.
   - Selection is made on the basis of the male that is most showy/beautiful, strongest/biggest, has the best song/call, occupies the best/biggest territory.
   - Such males are the best providers – healthiest, strongest, best adapted, have the 'best' genes.
   - Such males can therefore provide the female with the most care and protection, the best resources, the healthiest offspring, most help in raising offspring. They are therefore the fittest.
   - All these attributes enhance the survival of the female and her offspring – this is 'what she wants'.
   - Mutations arise through changes in the DNA which create new alleles. Those that occur in the production of gametes will enter the gene pool. Alleles which enhance sexual selection through changes in colour/length/size/song/strength/etc. will be selected for and so increase in frequency in the gene pool.
   - Evolution through sexual selection is *rapid* compared with other selecting agents, especially in species where a few males each breeding season get to mate with most of the females (e.g. birds with leks). Their alleles will dominate the gene pool of the next generation. Because of this, sexual selection can be an important factor in the (micro)evolution of a species.
   - However, sexual selection can decrease the fitness of males if their size/colour/length/etc. makes it more difficult for them to move/fly/feed/escape predators/etc. – this will restrict the possible range of phenotype(s).
5. - **Founder effect** – alleles present in this small group are unlikely to be representative of the country of origin (England), so allele frequency will differ and some alleles may not be present in this small gene pool.