St. Ambrose College

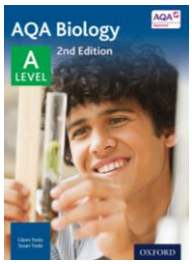
A Level Biology (Year 12)

Knowledge Organiser: Unit 4 Genetic information, variation and relationship between organisms (4.4-4.7)

4.4 Genetic diversity and adaptation
4.5 Species and taxonomy
4.6 Biodiversity within a community
4.7 Investigating diversity

For every 1 hour A Level Biology lesson you are expected to spend at least 1 hour independently reviewing the subject content. The following resources should be referred to regularly to support your independent work.

You have been provided with a printed copy of the full subject specification (also available on the AQA website https://www.aqa.org.uk/subjects/science/as-and-a-level/biology-7401-7402/specification-at-a-glance). Use this to follow the learning in lessons…track your progress and be aware of what is still to come.



kerboodle

Use the textbook on www.kerboodle.com after every lesson to develop your understanding. Read the relevant pages, add detail to your class notes and complete the summary tasks. Create your own summary notes/flashcards for future use in the run up to exams.

Unit 4 Genes and Variation on pages

SENECA
www.senecalearning.com

Use regularly between lessons to review basic content and to become more familiar with key terminology. https://senecalearning.com/en-GB/

PMT
resources • tuition • courses

Access detailed revision notes, key definitions, flash cards, past paper questions and mark schemes.
https://www.physicsandmathstutor.com/biology-revision/a-level-aqa/

As an A Level student you are expected to take a proactive approach to your studies; arrive to lessons fully equipped and prepared for what you will be learning about (read ahead in the specification/textbook), focus and participate in lessons, ask for help/clarification when you are unsure and spend time after the lesson consolidating/embedding new learning.

4.4 Genetic diversity and adaptation

Genetic diversity = Number of different alleles of a gene in a population
(Population – group of interbreeding individuals of the same species)

EVOLUTION means **change in <u>allele frequency</u> over time**

The principles of natural selection in the evolution of populations

1. Variation of alleles exists in population due to **random DNA mutations**
   e.g. some bacteria contain gene for antibiotic resistance due to a mutation
2. **Selection pressure** / change in environment
   e.g. antibiotic introduced
3. Those with advantageous allele have increased chance of survival and reproduction –**differential survival/reproductive success**
   e.g. bacteria with gene for resistance survive and reproduce whilst those without it die
4. Those surviving / reproducing **pass advantageous allele to offspring**
5. **Frequency of advantageous allele** (and [named] characteristic) **increases** in the population
6. Over **many generations** / long period of time

Directional selection e.g. antibiotic resistance in bacteria

- *Change to the environment*
- Selection pressure acts one side of the mean *(selecting for one extreme)*
- One extreme phenotype more likely to survive and produce

eg. Bacteria with gene for antibiotic resistance

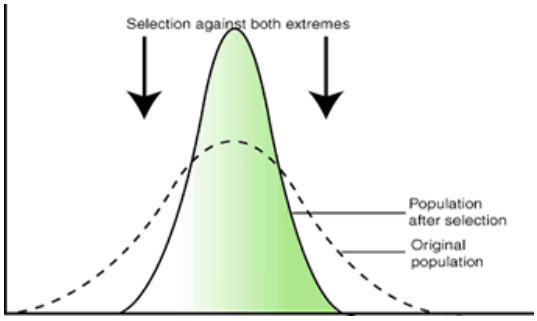
- Mean phenotype shifts towards the extreme

Stabilising selection e.g. human birth weights

- *Stable environment*
- Selection pressure acts both sides of the mean (selecting against both extremes, favouring the mean)
- Both extremes of phenotype less likely to survive and reproduce

eg. human birth weight. Very small or very large babies less likely to survive

- Mean phenotype remains the same



Natural selection results in better adapted species

Adaptations increase an organism's probability of survival (and/or reproduction). Adaptations can be categorised as;

Anatomical

- Structural features of organisms body / observed structures
- *E.g. whales thick layer of blubber helps keep warm in cold sea*

Physiological

- Processes inside the body
- *E.g. brown bears hibernate in the winter, lower metabolism to conserve energy so they don't need to look for food when its scarce*

Behavioural

- Ways an organism acts
- *E.g. possum plays dead if they're being threatened by a predator, to escape attack*

Example Exam Question

Snow geese fly north to the Arctic in the spring and form breeding colonies. Different colonies form at different latitudes. The greater the latitude, the further north is the colony. The further north a breeding colony forms, the colder the temperature and the greater the risk of snow.

(a) There is a positive correlation between the size of snow geese and how far north they breed. A large size results in snow geese being adapted for breeding in colder conditions. **Explain how. (2 marks)**

- ✓ Small surface area to volume ratio / more fat
- ✓ Lose less heat (to the environment) / for insulation
- ✓ When they are sitting on eggs

(b) Snow geese are either white or blue in colour. The table shows the percentage of white snow geese in colonies at different latitudes at different times over a 40-year period. *The blank cells in the table are years for which no figures are available.*

Colony	Latitude in degrees north	Percentage of white snow geese each year			
		1930	1950	1960	1970
A	72	100		100	100
B	71		>99	>99	>99
C	66	95	85	76	
D	63	86	75	67	65
E	55		62		28

(i) **Describe how the percentage of white snow geese varies with distance north. (1 mark)**

- ✓ The further north/higher the latitude, the higher the percentage of white snow geese

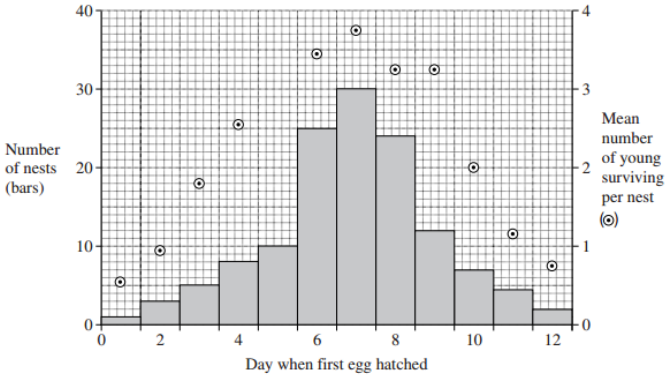
(ii) The further north, the greater the risk of snow. **Use this information to explain how natural selection might have accounted for the effect of latitude on the percentage of white snow geese. (3 marks)**

- ✓ Snow lying longer / melts slower further north / at greater latitudes
- ✓ White geese better camouflaged (further north)
- ✓ Predation linked to survival / reproductive success

(c) The percentage of white snow geese in these colonies changed over the period shown in the table. **Use your knowledge of climate change to suggest an explanation. (2 marks)**

- ✓ Snow melts earlier / snow melts further north / less snow
- ✓ White geese decreasing as less well camouflaged / at disadvantage / blue geese increasing as better camouflaged / at an advantage

(ci) Snow geese breed in large colonies. Scientists studied the nests in one colony. For each nest, they recorded the day on which the first egg hatched. They also recorded the number of young that survived from the nest. They used the data to plot a graph.



(i) **What type of natural selection is shown in the graph? (1 mark)**

- ✓ Stabilising

(ii) **Describe the evidence for your answer. (1 mark)**

- ✓ Few geese survive at the extremes / most survive from the middle of the range

4.5 Species and Taxonomy

Species

- If two organisms belong to the same species they are able to produce **fertile** offspring
- Offspring from 2 different species mating may occur, however infertile hybrid offspring will be produced.

offspring will have an odd number of chromosomes so can't perform meiosis to produce (haploid) gametes.

Example exam question

The red panda is native to South East Asia. There are two populations that are separated by a deep river gorge. These populations are very different from each other in appearance.

How could scientists show that the two populations are the same species? (2 marks)

- ✓ *Breed together red pandas from different areas*
- ✓ *If fertile offspring, then still same species*

Courtship behaviour

- Courtship behaviour is a necessary precursor to successful mating.
- The role of courtship in species recognition (recognition of members of the same species because courtship behaviour is species specific... therefore production of fertile offspring)
- Indication of sexual maturity
- Recognition/attraction of opposite sex
- Stimulate release of gametes
- Establishes a pair bond to raise young
- Synchronise mating → maximum probability that sperm will fertilise ovum

Example exam question

Male field crickets produce a courtship song by vibrating their wings. The natural song contains seven low-pitched 'chirps' followed by two high-pitched 'ticks'.

Scientists recorded this song and used a computer program to change the number of chirps and ticks. Different versions of the song were then played back continuously to females in the presence of a male. This male had previously had one wing removed so he could not produce a courtship song. The scientists determined the percentage of females that showed courtship behaviour within 5 minutes of hearing each recorded song.

Table 3 shows the results of the scientists' playback experiments.

Table 3

Version of recorded song played	Number of chirps	Number of ticks	Percentage of females that showed courtship behaviour within 5 minutes
K	No song played		30
L (natural)	7	2	83
M	7	0	70
N	0	2	65
O	7	1	83
P	7	4	82

(a) The scientists wanted to know if the recorded natural song was less effective than the natural song in stimulating courtship behaviour. **Suggest how the scientists could determine if the recorded natural song (L) was less effective than the natural song. (2 marks)**

- ✓ *Use a (real) male (with intact wings/no wing removed)*
- ✓ *Determine (percentage) response (of females compared with L) (accept: compare results with L)*

(b) A student concluded from Table 3 that the number of chirps and ticks is essential for successfully stimulating courtship behaviour. **Do these data support this conclusion? Explain your answer (4 marks)**

- ✓ *Lowest/only 30% courtship with no song/K/ (or) courtship still occurred when no song played/K*
- ✓ *Reduced courtship when no ticks/M / there is some courtship when no ticks/M*
- ✓ *Reduced courtship when no chirps/N / there is some courtship when no chirps/N*
- ✓ *(So) courtship must involve a visual stimulus/other factor involved*
- ✓ *Chirps more important as lowest courtship when none/N / ticks less important as similar courtship when changed/M*
- ✓ *Data only show presence and absence of chirps/0 and 7 chirps*

Taxonomy = (from Ancient Greek τάξις (taxis) 'arrangement', and -νομία (-nomia) 'method') is the scientific study of naming, defining and classifying (grouping) biological organisms based on shared characteristics. *Each group = taxon*

Phylogenetic classification system

- Species arranged into groups based on their evolutionary origins (common ancestors) and relationships
- Uses a hierarchy
    - Smaller groups placed within larger groups
    - No overlap between each group

Linnaean system hierarchy comprises the taxa:

- Domain *(drunken)*
- Kingdom *(kangaroos)*
- Phylum *(punch)*
- Class *(children)*
- Order *(on)*
- Family *(family)*
- Genus *(game)*
- Species *(shows)*

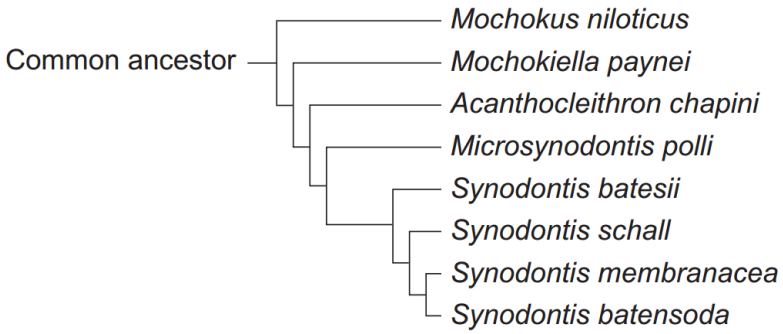
Each species is universally identified by a binomial (two-part name) consisting of the name of its genus and species

Genus e.g. homo + Species e.g. sapien
= Homo sapien

Advantage – universal; no confusion as many organisms have more than one common name

Example exam question

There are over 200 species of catfish. All catfish evolved from a common ancestor. The diagram shows how some species of catfish are classified. This diagram is based on the evolutionary links between these species.



(a) **Which species of catfish is most closely related to Synodontis membranacea? (1 mark)**

✓ *Synodontis batensoda*

(b) **Which species of catfish is most distantly related to Synodontis membranacea? (1 mark)**

✓ *Mochokus niloticus*

(c) **How many different genera are shown in this diagram? (1 mark)**

✓ *5*

Modern methods of classification

Traditional methods for classification relied on morphological and behavioural comparisons. More recently, technological advances in genome sequencing and protein analysis/immunology have enabled scientistis to clarify evolutionary relationships between organisms.

- Genome sequencing
    - Compare the order of base sequence of whole genome of different species
        - Higher % match = more closely related [more recent common ancestor]
        - e.g. humans and chimps = 98%
- Immunology
    - DNA → mRNA → sequence of amino acids in polypeptide
    - So tertiary structure of protein tells us about sequence of DNA
        - If same antibody binds to a specific antigen then it is closely related

4.6 Biodiversity within a community

"É Ï ÄÉÖÅÒÓÉÔÙ ©: the variety of living organisms in an area. It can be investigated by measuring:

- **Species diversity** – the number of different species and the number of individuals of each species within a community
- **Genetic diversity** - the number of different alleles for genes between individuals
- **Ecosystem diversity** - the number of different habitats and niches available within an ecosystem

Biodiversity can be considered at different levels

- Local biodiversity → the variety of species living in a small habitat e.g. pond / meadow
- Global biodiversity → the variety of species living on Earth

Quantifying species diversity

- Species richness
  - The number of different species in a community
- Index of diversity
  - Describes the relationship between the number of species in a community and the number of individuals in each species
  - There are many different diversity indices that can be used *eg. Simpson's Index shown below.*

Simpson's index of diversity

$$\text{Index of diversity } D = \frac{N(N-1)}{\Sigma\, n(n-1)}$$

N = total number of organisms of all species present
n = total number of organisms of each individual species
Σ = sum of ...

- The greater the species richness and species evenness, the higher the number
- The larger the value of D, the greater the diversity

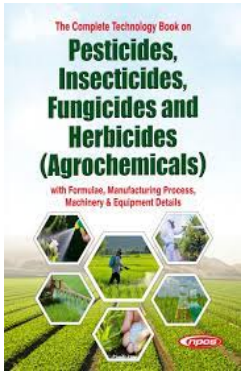
An alternative formula for Simpson's index is...

$$1-\left(\Sigma\left(\frac{n}{N}\right)^2\right)$$

- Index of diversity is a more useful measure of species diversity than species richness
  - As well as measuring the number of species, it also measures the number of individuals in a species (different proportions of species)
  - So takes account for the fact that some species may be present in low/high numbers

Farming techniques reduce biodiversity

- Removal of woodland and hedgerows
- Monoculture e.g. replace natural meadows with one cereal crop
- Use of pesticides, herbicides and inorganic fertilisers
- Crops better competitors for resources e.g. light / nutrients



Exam question example

(a) Farmers clear tropical forest and grow crops instead. **Explain how this causes the diversity of insects in the area to decrease. (3 marks)**

- ✓ Less variety of plants / lower diversity of plants (could now be monoculture)
- ✓ Fewer habitats / niches
- ✓ Less variety of food sources
- ✓ Aspect of agriculture kills insects e.g. pesticides

(b) The demand for increased food production has led to areas of heath being used to grow wheat.

(i) Explain the effect of this on the species diversity of plants (2 marks)

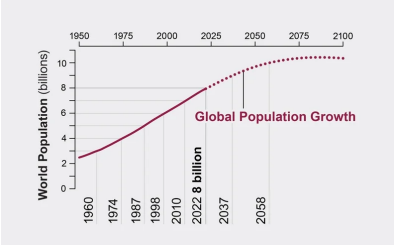
- ✓ Reduced as one species grown / other species removed
- ✓ Use of herbicides / weeding / ploughing
- ✓ Weat (better) competitor for named factor e.g. light / nutrients

(ii) Explain the effect of this on the species diversity of animals (2 marks)

- ✓ (Reduced) as less variety of food sources
- ✓ (Reduced) as fewer habitats/niches
- ✓ Reduced by pesticides / chemicals

The balance between conservation and farming

- Humans need to make a balanced judgement between the demands for increased food production due to a rapidly growing human population, and the need to conserve the environment



- Some conservation techniques can be applied that increase biodiversity without unduly raising food costs or lowering yields, for example…
  - Use crop rotation of nitrogen fixing crops instead of fertilisers
  - Maintain existing hedgerows and plant new hedges instead of using fences
  - Reduce the use of pesticides

- It is recognised that these practices will make food slightly more expensive to produce, so to encourage farmers there are a number of financial incentives e.g. from the Department for Environment, Food and Rural Affairs (DEFRA) and the European Union.

Department
for Environment
Food & Rural Affairs

4.7 Investigating diversity

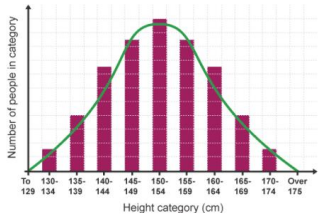
Variation

- Differences (in characteristics) between individuals, within a species (**intraspecific** variation) or between different species (**interspecific** variation)
- Variation within a species could be the result of…
    - Genetic factors i.e. different alleles
    - Environmental factors
    - Or a combination of both

Continuous variation

- Range of phenotypes (max to min, any value between)
- Data teds to be quantitative
- Controlled by many genes (polygenic)
- Strongly influenced by the environment

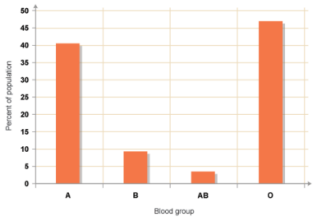
Example: height



Discontinuous variation

- Distinct, discrete categories
- Data tends to be qualitative
- Controlled by a single gene or a few genes
- Unaffected / not strongly influenced by the environment

Example: blood groups



Genetic diversity

- the number of different alleles in a population

- **traditionally genetic diversity was measured** by comparing the **frequency of measurable / observable characteristics**
  (the higher the variety of a characteristic, the higher the variety of alleles of that gene and hence the higher the genetic diversity)

  Limitations:
  Many observable characteristics coded for by more than one gene (polygenic) → vary continuously → difficult to distinguish one from another
  Characteristics could be modified by the environment so differences may be as a result of different environmental conditions rather than different alleles

- **Gene technologies** have made it possible to directly obtain DNA sequences. These technologies can be used to give **more accurate estimates of genetic diversity** within a population / species because:
  - Different alleles of the same gene have slightly different base sequences
  - Comparing DNA base sequences of same gene in different organisms in a population → find out how many alleles of that gene in a population
  - Different alleles transcribed into slightly different mRNA base sequences and may produce polypeptides with slightly different amino acid sequences which can also be compared

Quantitative investigations of variation within a species

- Taking a representative sample
  - **Random** sample → eliminates bias
    - Example of random sampling in a field:
      - Divide the area into a grid of numbered lines
      - Using random numbers from a table, obtain a series of coordinates
      - Take samples at the intersection of each pair of coordinates i.e. using quadrats
  - **Large** sample size
    - Minimise effects of chance (lower probability that chance will influence the data)
    - Anomalies have less influence and can be identified

- Calculating a **mean** of the collected data and the **standard deviation** of that mean
  - Mean = *measure of 'middleness'*
  - Standard deviation = measure of 'spreadoutness' around the mean
    - 68% of all measurements lie within ± 1 standard deviation of the mean
    - About 95% of all measurements lie within ± 2 standard deviations of the mean
      Note: this is only true if data shows a normal distribution i.e. when plotted as a graph it forms a bell-shaped curve

- Interpreting the mean values and their standard deviations
  - Mean → can show if there is variation / differences between samples
    - Useful for comparison, but provides no info about the range
  - Standard deviation
    - The higher the value standard deviation, the higher the variation
    - If standard deviations overlap, causing values of each set of data to be shared, any difference between the two may be due to chance
  - Mean and standard deviation can be shown in different ways, e.g.
    - 9 ± 3 mean = 9 and standard deviation = 3
    - Standard deviation can be plotted on graph / chart of mean values using error bars
      - Error bars extend one standard deviation above and one standard deviation below the mean

***** *Analyse results with a statistical test*
- *See if variation observed is or isn't due to chance*
- *choice of stats test depends on data collected (eg. t test, X^2 test and spearman's rank)*
- *always use p value <0.05 (less than 5% probability results due to random chance)*

Example:

Hypothesis: south facing leaves are smaller than north facing leaves.

Results: Surface area of south facing leaves 50mm² ± 14 and surface area of north facing leaves 70mm² ± 17

Interpretation: There is an overlap in standard deviations; the maximum size of the south leaves was 64 mm², whilst the minimum size of north leaves was 53mm²; so sometimes the south leaves are bigger than north leaves, so the difference in length may be due to chance