

Classification and biodiversity

Revision notes · The species concept, three-domain classification, biodiversity and endemism, and measuring biodiversity with species richness, heterozygosity and D.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Classification and biodiversity Spec 4.14–4.18

Classification and the three-domain system Spec 4.14

Classification is a way of organising the variety of life into groups, based on the relationships between organisms. Organisms that are more closely related share more similarities in their **phenotypes** (observable features such as anatomy, physiology and behaviour) and in their **genotypes** (DNA base sequences, which can also be compared indirectly through the amino acid sequences of the proteins they code for).

The species concept and hierarchy

The basic unit of classification is the **species**: a group of organisms with similar characteristics that can interbreed to produce fertile offspring. Species are placed in a hierarchy of groups, each contained in the next: domain, kingdom, phylum, class, order, family, genus, species. Each species has a two-part name, the binomial (for example *Homo sapiens*), written with the genus first (capital letter) and the species second.

Exam tip: The species concept has limits: it does not apply to organisms that reproduce only asexually (including bacteria), or to fossils, and some different species can interbreed to produce hybrids.

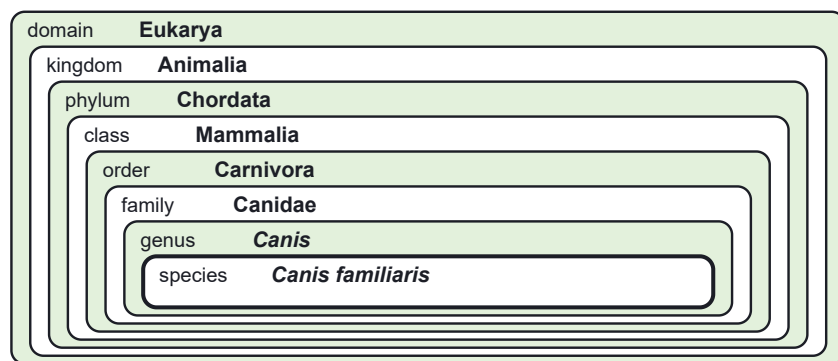
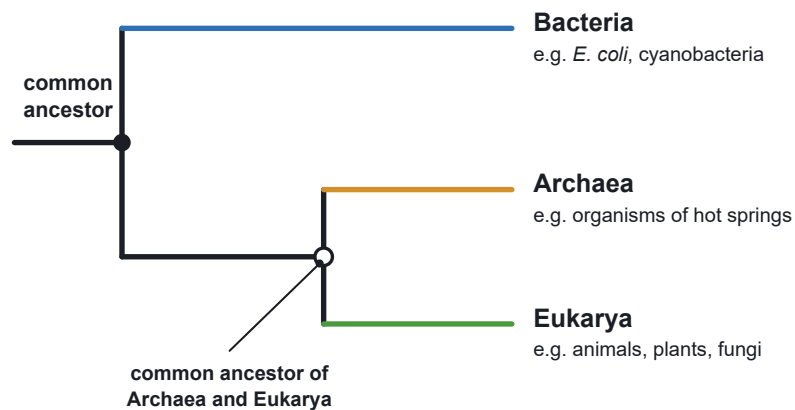
Molecular evidence

Early classification used mainly physical features, which can mislead because unrelated organisms may look similar. Comparing DNA base sequences, the amino acid sequences of proteins and RNA sequences gives more objective evidence of how closely organisms are related. The more similar the sequences, the more recently the species shared a common ancestor.

Critical evaluation and the three domains

New data are critically evaluated by the scientific community. Before publication in a scientific journal, other experts check the methods, data and conclusions (peer review). After publication and presentation at conferences, other scientists discuss the findings and try to repeat the work, often with new data. Only if the evidence is supported do the taxonomic groupings change, which keeps classification reliable. Molecular evidence showed that the prokaryotes used to be considered a single kingdom contain two very different groups, and led to the **three-domain system** in which all organisms are placed into Archaea, Bacteria or Eukarya.

Features of the three domains			
Feature	Bacteria	Archaea	Eukarya
Nucleus	Absent	Absent	Present
Cell wall	Peptidoglycan	No peptidoglycan	Cellulose (plants), chitin (fungi), none in animals
Membrane lipids	Ester-linked	Ether-linked	Ester-linked
Ribosomes	70S	70S	80S
DNA	Circular, no histones	Circular; in many species associated with histones	Linear, associated with histones
Examples	<i>Escherichia coli</i>	Methane-producing and many extreme-environment species	Plants, animals, fungi, protoctists



The three domains of life, and the taxonomic hierarchy using the domestic dog as an example.

Biodiversity, endemism and human threats Spec 4.15, 4.16

Biodiversity	The variety of living organisms in a given area or on Earth, measured as the number and abundance of species (species diversity), the genetic variation within species (genetic diversity) and the range of habitats (habitat diversity).
Endemism	A species being found in only one geographical region, and nowhere else in the world. Such a species is called endemic. Examples: lemurs in Madagascar; many species on isolated islands such as the Galápagos or Hawaii.

The variety of life over time

Over millions of years evolution by natural selection and speciation has produced an extensive variety of life, with millions of species, most of them not yet described. Biodiversity has been reduced in the past by mass extinctions.

The threat from human activity

The variety of life is now being reduced faster than before, and human activity is the main cause. Endemic species are especially vulnerable because they live in small areas and cannot move elsewhere if their habitat is changed.

Human threats to biodiversity	
Threat	How it reduces biodiversity
Habitat loss and fragmentation	Clearing land for agriculture, housing and roads destroys habitats or divides them into small patches
Climate change	Warming changes rainfall and temperature, so species may no longer be adapted to their habitat
Pollution	Fertilisers, pesticides and plastics harm organisms or alter habitats
Overexploitation	Hunting, fishing and harvesting faster than populations can recover
Introduced (invasive) species	Compete with, prey on or bring disease to native species

Exam tip: Always say how the threat reduces biodiversity (for example "habitat destruction reduces the number of species that can live there"), not only name it.

Measuring biodiversity: species richness and heterozygosity index Spec 4.17

Species richness

Species richness is the number of different species in a habitat. It is found by sampling (for example with quadrats, transects or pitfall traps), identifying each species and counting how many species there are. It is simple, but it takes no account of how many individuals there are in each species. A habitat with 10 species of which 99% of individuals are one species has the same richness as one where the 10 species are equally common.

Genetic diversity: heterozygosity index

Genetic diversity is the variety of alleles within a species. One measure is the **heterozygosity index**, which uses the proportion of individuals in a population that are heterozygous for a gene.

heterozygosity index = number of heterozygotes ÷ number of individuals in the population

The value is between 0 and 1. A value near 1 means many individuals are heterozygous and the population has high genetic diversity. A small isolated population, in which alleles are lost and relatives interbreed, has a low index.

Calculating a heterozygosity index

A sample of 80 beetles was genotyped for one gene. 30 beetles were AA, 36 were Aa and 14 were aa. Calculate the heterozygosity index.

1. Heterozygotes (Aa) = 36
2. Individuals in the population sample = 80
3. $36 \div 80$

Answer: 0.45

Maths skill: Heterozygotes are individuals with two different alleles (Aa). Do not include homozygous individuals (AA or aa) in the top line.



Illustrative data: the small isolated population has a much lower heterozygosity index, so less genetic diversity.

Comparing habitats: index of diversity (D) Spec 4.18

Species richness does not tell us how evenly individuals are spread among species. The index of diversity (D) uses both the number of species and their relative abundance.

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

- N = total number of organisms of all species
- n = total number of organisms of each species
- Σ = sum of

A habitat with many species with similar numbers of individuals has a high D. A habitat dominated by one species has a low D, as does one with few species. D has a minimum of 1 for a single species.

Calculating D for a habitat

A quadrat survey of woodland A recorded five species: 12, 8, 5, 3 and 2 individuals. Calculate the index of diversity.

1. $N = 12 + 8 + 5 + 3 + 2 = 30$

2. $N(N - 1) = 30 \times 29 = 870$

3. $\sum n(n - 1) = (12 \times 11) + (8 \times 7) + (5 \times 4) + (3 \times 2) + (2 \times 1) = 132 + 56 + 20 + 6 + 2 = 216$

4. $D = 870 \div 216$

Answer: 4.0 (to 2 significant figures)

If a second woodland, B, has 30 individuals in three species (25, 3 and 2), $\sum n(n - 1) = 600 + 6 + 2 = 608$ and $D = 870 \div 608 = 1.4$. Woodland A is more diverse than woodland B, even though B also has several species, because B is dominated by one species.

Interpreting and evaluating D

- A high D means the habitat is more diverse, which often indicates a stable habitat with many niches.
- A low D suggests a habitat dominated by a few species, which may indicate pollution or disturbance.
- Results depend on sampling: use random sampling, with enough samples, from habitats of comparable area, at the same time of year.
- D uses numbers only, so it does not show how different the species are from one another, and it gives only a snapshot at one time.

Exam tip: Show N , $N(N - 1)$, the sum $\sum n(n - 1)$ and the division. A final answer with no working often loses marks.

Maths skill: $n(n - 1)$ for a species with 1 individual is 0, so single individuals do not add to the bottom line but are still counted in N .

Quick check

1. Name the three domains of life.
2. What type of evidence led to the three-domain system?
3. Define endemism.
4. What is species richness?
5. In $D = N(N - 1) \div \sum n(n - 1)$, what does n stand for?

Quick check answers

Classification and biodiversity

1. Archaea, Bacteria and Eukarya.
2. Molecular evidence, such as differences in rRNA and other nucleotide or protein sequences.
3. A species being found in only one geographical region and nowhere else.
4. The number of different species in a habitat.
5. The total number of organisms of each species.