

Cambridge AS & A Level · Biology 9700 · Notes

Classification, biodiversity and conservation

A2

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Read first: [Cell structure](#), [Selection and evolution](#)

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What you need to know

By the end of this topic you should be able to:

1. **Discuss the biological, morphological and ecological species concepts.**
2. **Describe the three domains:** Archaea, Bacteria and Eukarya.
3. **State that Archaea and Bacteria are both prokaryotes** and that they differ in their membrane lipids, ribosomal RNA and cell walls.
4. **Describe the taxonomic hierarchy** used for eukaryotes: kingdom, phylum, class, order, family, genus, species.
5. **Outline the features of the four eukaryote kingdoms:** Protocista, Fungi, Plantae and Animalia.
6. **Outline how viruses are classified:** DNA or RNA, single- or double-stranded.
7. **Define ecosystem and niche.**
8. **Explain the three levels of biodiversity:** ecosystems and habitats; species and their relative abundance; genetic variation within each species.
9. **Explain why sampling must be random.**
10. **Describe and use frame quadrats, line transects, belt transects and mark-release-recapture** (Lincoln index given).
11. **Use Spearman's rank and Pearson's linear correlation** to test a link between two variables, such as an abiotic factor and a species' abundance (formulae given).
12. **Use Simpson's index of diversity (D)** and say what its value means (formula given).
13. **Explain how climate change, competition, hunting by humans and habitat loss or degradation** can make populations and species extinct.
14. **Outline why biodiversity should be maintained.**
15. **Outline the roles of zoos, botanic gardens, conserved areas (national and marine parks), frozen zoos and seed banks.**
16. **Describe IVF, embryo transfer and surrogacy** in conserving endangered mammals.
17. **Explain why invasive alien species are controlled.**
18. **Outline the roles of the IUCN and CITES.**

Understand it

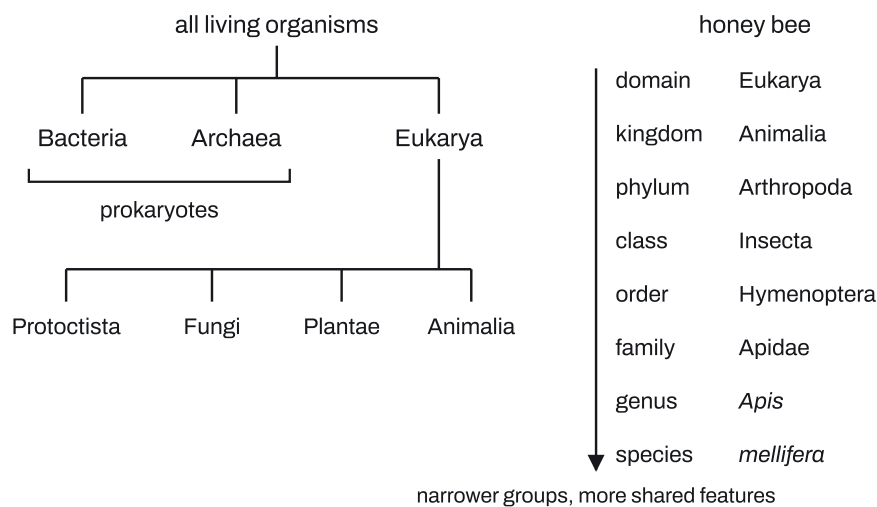
What is a species?

No one definition fits every organism, so there are three **species concepts**:

- **Biological species concept**: a group of organisms that can **interbreed to produce fertile offspring** and are **reproductively isolated** from other groups. It cannot be tested on fossils, on organisms that reproduce asexually, or when breeding cannot be observed.
- **Morphological species concept**: organisms that **look alike**, sharing observable features (shape, size, colour, structure). It works for fossils, dead specimens and asexual organisms, but males and females can look very different, and unrelated species can look alike.
- **Ecological species concept**: organisms that share the **same niche**, adapted to the same way of life.

The concepts can disagree: two populations that differ in colour, size and diet but produce fertile hybrids are two species by the morphological and ecological concepts, one by the biological concept.

Three domains



The largest groups are the three **domains**. **Bacteria** and **Archaea** are both **prokaryotes**: no nucleus, no membrane-bound organelles, circular DNA and 70S ribosomes. They differ in three ways:

	Bacteria	Archaea
Membrane lipids	fatty acids joined to glycerol by ester links; unbranched chains	chains joined by ether links; branched chains
Ribosomal RNA	its own base sequences	different base sequences, closer to those of eukaryotes
Cell wall	contains peptidoglycan	no peptidoglycan (other polysaccharides or proteins)

Mark schemes have also credited histone proteins with the DNA of Archaea but not Bacteria. **Eukarya** have cells with a nucleus and membrane-bound organelles.

The taxonomic hierarchy

After the domain, eukaryotes are sorted into ranks: **kingdom, phylum, class, order, family, genus, species**. Large groups are divided into smaller ones, and the lower the rank, the more features the members share. The **genus** and **species** form the scientific name (binomial), in italics with a capital letter only for the genus: *Apis mellifera*, genus *Apis*.

The four eukaryote kingdoms

	Protocista	Fungi	Plantae	Animalia
Cells	eukaryotic; unicellular or multicellular (seaweeds)	eukaryotic; unicellular (yeasts) or multicellular	eukaryotic; multicellular	eukaryotic; multicellular
Cell wall	some (often cellulose), some none	chitin	cellulose	none
Nutrition	some autotrophic (algae, with chloroplasts), some heterotrophic	heterotrophic : saprotrophic or parasitic; no chlorophyll	autotrophic : chloroplasts, photosynthesis	heterotrophic : ingest food
Other features	very varied: any eukaryote that is not a fungus, plant or animal; no specialised organs	hyphae forming a mycelium , often multinucleate ; spores ; store glycogen	specialised tissues and organs; large vacuole; store starch	specialised tissues and organs; nervous system ; usually motile ; some cells with cilia or flagella; store glycogen

Viruses

Viruses are not cells, so they are outside the three domains. They are grouped by their genetic material: **DNA or RNA**, and **single-stranded or double-stranded**. HIV has single-stranded RNA; herpes viruses have double-stranded DNA.

Ecosystems, niches and biodiversity

- An **ecosystem** is a self-contained unit made of a **community** of populations of different species, the **biotic and abiotic** factors around them, and the **interactions** between them, linked by **energy flow** and **nutrient cycling**.
- A **niche** is the **role of a species in its ecosystem**: where it lives, what it feeds on, what feeds on it and how it interacts with its surroundings.

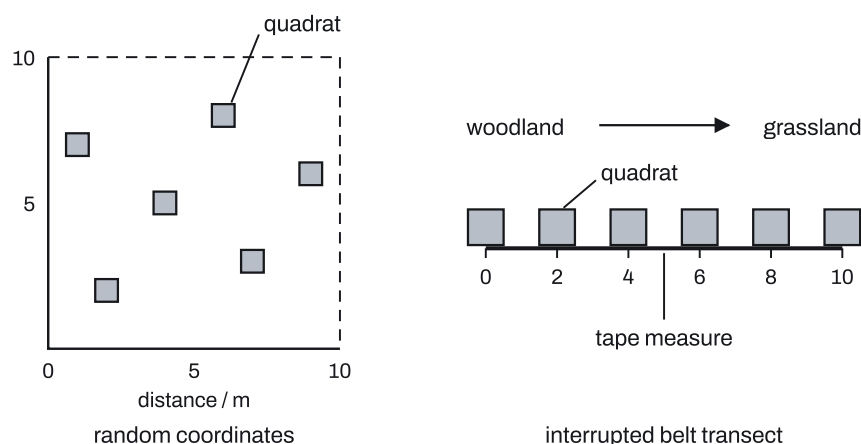
Biodiversity is assessed at three levels:

1. **Ecosystem (habitat) diversity**: the number and range of different ecosystems and habitats in an area.
2. **Species diversity**: the **number of species** (species richness) **and their relative abundance**.
3. **Genetic diversity**: the variation in **alleles** within each species. Individuals share the same genes but have different alleles. More diversity means some may survive a new disease or climate: the species can **adapt**.

Random sampling

You cannot count every organism, so you take **samples**. Choosing the spots yourself brings **bias**. Random sampling gives every point an equal chance, so the sample is **representative** and statistical tests can be used. Take **many** samples.

Frame quadrats and transects



Frame quadrat (a square frame of known area), for plants and slow-moving animals:

1. Mark out the area with two tape measures at right angles as axes.
2. Use a **random number generator** for the coordinates of each quadrat.
3. Identify each species with a **key**.
4. Record each species' abundance: **count** individuals (species density), estimate **percentage cover** (grasses, mosses) or use the **ACFOR** scale (abundant, common, frequent, occasional, rare).
5. Use many quadrats (20 or more), find the means, and work out Simpson's index.

Transects show a **change across an area**, such as woodland into grassland; the line is placed on purpose across the change.

- **Line transect**: a tape stretched across the area; record every organism touching the line at regular intervals.
- **Belt transect**: quadrats along the line, next to each other (continuous) or at regular intervals (**interrupted**). It gives abundance, not just presence. Measure abiotic factors (light, soil water, pH) at each quadrat too.

Mark-release-recapture

For mobile animals (beetles, snails, fish, frogs):

1. Catch a sample, count it (n_1), and **mark** each animal harmlessly (a paint dot, a tag, a clipped patch of fur).
2. **Release** them where they were caught and allow time to **mix** back into the population.
3. Catch a second sample, count all of them (n_2) and count the marked ones (m).
4. Estimate the population with the **Lincoln index**: $N = \frac{n_1 \times n_2}{m}$. Repeat for reliability.

The estimate is valid only if the **marks do not harm** the animal, make it easier for predators to see, or **wear off**; marked animals **mix** fully; there are **no births, deaths, immigration or emigration** between samples (so keep the gap short); and every animal has an **equal chance** of being caught. It fails for animals with huge territories or that are dangerous to catch: too few are recaptured.

Correlation

A **correlation** is a link between two variables, such as a species' abundance and an abiotic factor. It does not prove **cause**.

- **Pearson's linear correlation** (r): continuous, **normally distributed** data, a scatter graph that looks like a **straight line**, and at least 5 pairs.
- **Spearman's rank correlation** (r_s): data that are **not normally distributed** but can be **ranked**, a scatter graph that rises or falls (not necessarily in a straight line), and more than 5 pairs, sampled at random.

Both run from -1 (perfect negative) through 0 (none) to $+1$ (perfect positive). The **null hypothesis** is "there is no correlation between X and Y". If the size of your value (ignore the sign) is **greater** than the **critical value** at $p = 0.05$ for your number of pairs, reject it: the correlation is significant, less than 5% likely to be due to chance.

Simpson's index of diversity

$$D = 1 - \sum \left(\frac{n}{N} \right)^2$$

n is the number of individuals of each species and N the total of all individuals. D runs from 0 to 1. A value **near 1** means **high diversity**: many species, none dominating. A value **near 0** means low diversity: few species, or one species dominating. It uses relative abundance, so it says more than a count of species.

Why species become extinct

- **Climate change**: higher temperatures, changed rainfall, rising sea level and ocean acidification change habitats faster than species can adapt or move; food may disappear.
- **Competition**: a species that shares a niche with a more successful one (often an introduced species) loses food, space or nest sites.
- **Hunting by humans**: for food, fur, horns or the pet trade (poaching), or to protect livestock.

- **Degradation and loss of habitat:** forests cleared for farms, plantations, roads and towns; pollution; wetlands drained.

Low genetic diversity

A **bottleneck** (a population crash) or a very small population leaves a **small gene pool**. The consequences: **inbreeding**, so harmful **recessive alleles** are more often **homozygous** and expressed (**inbreeding depression**: lower fertility, weaker offspring, less disease resistance); little variation for **natural selection** to act on, so the species is **less able to adapt** to new diseases or climate; so a **higher risk of extinction**. Adding wild-caught animals to a captive group brings in new alleles.

Why maintain biodiversity?

- **Ecological:** species depend on each other in **food webs**; losing one (a top predator, a pollinator) disrupts the ecosystem. Ecosystems give **services**: pollination, soil stability, clean water and air, nutrient recycling.
- **Practical:** food, wood, fibres, new **medicines**, wild alleles for crops, **ecotourism**.
- **Genetic:** a large gene pool keeps alleles for future use.
- **Scientific:** research and education.
- **Ethical, aesthetic and cultural** reasons.

Conservation

In the wild:

- **Conserved areas** (national parks, reserves, **marine parks**): the habitat is protected by law; hunting, logging, building and fishing are restricted and patrolled; damaged habitat is restored. This protects every species in it.
- **Legal protection:** hunting and trade bans with fines; monitoring with surveys or tracking collars.

Outside the wild:

- **Zoos:** **captive breeding**, swapping animals between zoos using breeding records so mates are unrelated; **reintroduction** into protected habitat; **research** (diet, behaviour, reproduction, disease); **education** and raising funds; veterinary care; safety from poachers. Captive animals may be stressed, refuse to mate or lack suitable mates.
- **Botanic gardens:** grow endangered plants in controlled conditions, propagate them (cuttings, tissue culture, hand pollination), research, educate and reintroduce plants to the wild.
- **Seed banks:** seeds are dried and stored cold (about -20°C), staying alive for many years. Samples are germinated regularly to test **viability** and restocked when it falls. They keep the **genetic diversity** of many species in a small space, for research and replanting.
- **Frozen zoos:** sperm, eggs, embryos and tissue stored in **liquid nitrogen** (-196°C), keeping alleles (even of dead animals) for later IVF or embryo transfer.

Assisted reproduction

- **IVF**: the female is given **hormones** (such as FSH) so several oocytes mature; the oocytes are **collected** with a fine needle; **sperm** from an unrelated male (fresh or frozen) is added; the zygotes grow into embryos in a **culture medium**; a healthy embryo is placed in the **uterus**. Spare embryos can be frozen.
- **Embryo transfer**: an embryo (from IVF, or flushed out of a mated female) is placed in the uterus of **another** female.
- **Surrogacy**: the female carrying the embryo is not its genetic mother. She can be of a related, common species (a domestic camel carrying a wild camel embryo), so the rare female can give eggs again instead of spending months pregnant.

Invasive alien species

An **alien species** is one moved by humans outside its natural range. It is **invasive** when it spreads fast and harms the ecosystem, often because it has **no natural predators** there and **breeds quickly**. It may **compete** with natives for food, space or the same niche; **prey on** natives that have no defences; bring **new diseases**; **disrupt food webs** and the habitat, lowering biodiversity and causing **extinctions**; and harm **farming**, tourism or health (toxins). So they are removed, trapped or poisoned, and border checks stop new arrivals. When an invasive predator is removed, its prey recover, which changes the numbers of what the prey eat.

The IUCN and CITES

- The **IUCN** (International Union for Conservation of Nature) is a worldwide organisation that collects data and **assesses the conservation status** of species, publishing the **Red List of Threatened Species**. The categories, in increasing risk: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW), Extinct (EX). This **identifies and prioritises** species most at risk, **advises governments** and scientists so that action is taken, and raises awareness.
- **CITES** (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an agreement between governments that **controls international trade** in wild species and their products (ivory, skins, pets). Species are listed in **appendices**: trade in the most threatened is **banned**; for others it needs **permits**. This cuts illegal trade and poaching, even for species with no Red List status, and listing a species publicises its threat, **raising awareness** among governments, traders and the public.

Key facts and formulas

"Given" means it is printed on the paper when needed. "Learn it" means you must remember it.

Formula	Status
Lincoln index: $N = \frac{n_1 \times n_2}{m}$	Given
Simpson's index: $D = 1 - \sum \left(\frac{n}{N} \right)^2$	Given

Formula	Status
Spearman's rank: $r_s = 1 - \frac{6 \times \sum D^2}{n^3 - n}$, D = difference in rank of each pair, n = number of pairs	Given
Pearson's: $r = \frac{\sum xy - n\bar{x}\bar{y}}{(n-1)s_x s_y}$	Given
D near 1: high diversity; near 0: low diversity	Learn it
Correlation value (ignoring sign) > critical value at $p = 0.05$: significant, reject the null hypothesis	Learn it
Mean rate of change = $\frac{\text{change in value}}{\text{time taken}}$	Learn it
Percentage change = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$	Learn it

How to do it

We have tagged 51 Paper 4 questions for this topic, 2021–2025 (45 different: 6 are repeated on Paper 41). One, **9700/41/M/J/24 Q4**, uses crayfish only as the setting for a gene technology question, so the table counts the other 44; 36 of those mix types, so the counts add up to more than 44.

Question type	Questions
Explain why a species became endangered or extinct	14
Outline ways to conserve an endangered species	11
Outline or compare the features of the eukaryote kingdoms	11
Calculate a rate or percentage change, or describe a graph	10
The IUCN, CITES and Red List categories	8
Place an organism in the taxonomic hierarchy	8
Apply the species concepts	6
Give reasons to maintain biodiversity	6
Effects of invasive alien species	6
Compare Archaea and Bacteria	5
The levels of biodiversity	5
Describe a sampling method	5
IVF, embryo transfer and surrogacy	5
Mark-release-recapture	4
Effects of low genetic diversity	3
Define ecosystem and niche	3
Simpson's index of diversity	3

Question type	Questions
Spearman's or Pearson's correlation	3
How viruses are classified	1

1. Explain why a species became endangered or extinct (14 questions)

1. Read the stem for clues (range, diet, land use, introduced animals).
2. Give one point per mark: habitat loss or degradation (with its cause), hunting, poaching or the pet trade, climate change (with its effect), competition, introduced predators, disease, pollution.
3. Tie each point to the organism: "forest cleared for oil palm removes its food trees".

Variations: effects of rising carbon dioxide on biodiversity (warming, rising sea level, habitat change, disrupted food webs, extinctions); factors to monitor for a newly recognised species (habitat, hunting, food supply, genetic diversity, range).

2. Outline ways to conserve an endangered species (11 questions)

Give one point from each group: **protect the habitat** (parks, reserves, replanting, sustainable farming); **stop killing and trade** (bans, enforcement, CITES); **breed and store** (captive breeding and release, frozen zoos, seed banks, IVF); **support** (monitoring and tracking, research, education).

Variations: zoos' roles **other than** captive breeding; ideal features of a reserve (no humans or predators, food, places to hide or nest); problems with captive breeding (stress, refusal to mate, few mates, inbreeding, cost) and why wild animals are added (new alleles); methods for plants (botanic gardens, seed banks with storage and viability testing, replanting).

3. Outline or compare the features of the eukaryote kingdoms (11 questions)

Start with "eukaryotic", then use the kingdom table. For a comparison, pair each point: "Fungi have chitin walls, whereas plants have cellulose walls."

Variations: a yes/no table (unicellular? walls? autotrophic?): Animalia no, no, no; Fungi yes, yes, no; Plantae no, yes, yes; Protocista yes, yes, yes. The Protocista features a seaweed shows (eukaryotic, photosynthetic, cellulose walls, multicellular without specialised tissues).

4. Calculate a rate or percentage change, or describe a graph (10 questions)

1. Read both values carefully off the graph or table (check the scale).
2. **Rate** = $\frac{\text{change}}{\text{number of years}}$, with units such as "per year". **Percentage change** = $\frac{\text{change}}{\text{original}} \times 100$.
3. Show the working and give the accuracy asked.

For example, a population falling from 820 in 1995 to 310 in 2020 decreased at $\frac{820-310}{25} = 20.4$ animals per year, a fall of $\frac{510}{820} \times 100 = 62.2\%$.

Describing a graph: the trend, any change in it (a steep rise, then a plateau), and a data quote: two values with their years and units.

5. The IUCN, CITES and Red List categories (8 questions)

Give the roles from "Understand it". The IUCN **assesses**, CITES **controls trade** (bans, permits) and a listing **raises awareness**; neither runs reserves. **Variations:** a species Endangered in one region but Near Threatened overall is less abundant and at higher risk there; testing a predicted link between genetic diversity and status against data (look for species that break the pattern).

6. Place an organism in the taxonomic hierarchy (8 questions)

Write the ranks in order and fill the gaps: rank names (phylum, order) or groups (Eukarya, Animalia; the genus is the first word of the binomial). **Variation:** "the principles of classification": large groups divided into smaller ones, shared features, the ranks in order, the binomial, the domain and kingdoms involved.

7. Apply the species concepts (6 questions)

State each concept, then **apply** it to the data with a verdict: "They produce fertile hybrids, so by the biological concept they are one species; they differ in colour and size, so by the morphological concept they are two." **Variations:** when the morphological concept is more useful (fossils, asexual organisms); how to test whether two forms are one species (breed them and test the offspring's fertility; compare DNA).

8. Give reasons to maintain biodiversity (6 questions)

Give **different** reasons, one per mark, fitted to the context: for plants add wood, fibres, crops and soil stability; for lichens, pioneer species and air-quality indicators; for a top predator, its prey would increase and overgraze.

9. Effects of invasive alien species (6 questions)

Use the stem's clues (fast breeding, spread, toxins, no predators) and give the effects. **Variation:** explain the recovery after an invasive predator was removed, using data (its prey recovered, then what the prey ate fell).

10. Compare Archaea and Bacteria (5 questions)

Name both domains, then pair the differences from the table. Similarities: prokaryotic, circular DNA, 70S ribosomes, binary fission. **Variation:** an essay comparing Eukarya with Bacteria: nucleus vs none; linear DNA with histones vs circular without; membrane-bound organelles vs none; 80S vs 70S ribosomes; walls sometimes (cellulose or chitin) vs always (peptidoglycan); mitosis vs binary fission; can be multicellular vs unicellular.

11. The levels of biodiversity (5 questions)

Name the three levels. **Variations:** which levels a survey measured (counting species in quadrats measures species abundance, not habitat or genetic diversity); matching pictures to levels.

12. Describe a sampling method (5 questions)

Frame quadrat: the five steps in "Understand it". **Variations:** name a belt transect from a description; sampling insects (sweep nets, pitfall traps, pooters; mark-release-recapture); why the abundance of lichens that cannot survive sulfur dioxide shows air pollution.

13. IVF, embryo transfer and surrogacy (5 questions)

Write the steps in order: hormones → oocytes collected → sperm added → zygote cultured → embryo checked → placed in the uterus of the same female or a surrogate, or frozen. **Variations:** order lettered steps; fill boxes on a flow chart.

14. Mark-release-recapture (4 questions)

Give N as a **whole number**, and the four assumptions. **Variation:** why it fails for wide-ranging predators (hard and dangerous to catch, huge territories, few recaptured).

15. Effects of low genetic diversity (3 questions)

Small gene pool → inbreeding depression → harmful recessive alleles expressed → less able to adapt → higher extinction risk. **Variation:** why computers and databases compare DNA sequences (store and align many sequences, process large data fast, share data).

16. Define ecosystem and niche (3 questions)

Use the definitions in "Understand it": ecosystem needs community, biotic and abiotic, and interactions; niche is the role.

17. Simpson's index of diversity (3 questions)

1. Work out $\frac{n}{N}$ and $\left(\frac{n}{N}\right)^2$ for each species, to the decimal places the table uses.
2. Add the squares, then $D = 1 - \text{sum}$.
3. Interpret: near 1 is high diversity; compare two values.

18. Spearman's or Pearson's correlation (3 questions)

1. Substitute; n is the number of **pairs**. Keep the **sign**.

2. Compare the size of the value with the critical value for your n at $p = 0.05$; state the conclusion about the null hypothesis.

Variation: name the method (Simpson's index for diversity; Spearman's or Pearson's for a link).

19. How viruses are classified (1 question)

DNA or RNA; single- or double-stranded.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
 - **A1** accuracy mark: for a correct answer; it needs the M mark before it.
 - **B1** mark for a correct result on its own, with no method needed.
-

Example 1

The honey bee, *Apis mellifera*, is an insect.

(a) Complete the table to show the classification of the honey bee. **[3]**

taxonomic rank	name
domain	
kingdom	Animalia
phylum	Arthropoda
	Insecta
order	Hymenoptera
family	Apidae
genus	

(b) Some bacteria live in the gut of honey bees. Name the other domain of prokaryotes and state two differences between its members and bacteria. **[3]**

(a) Domain: **Eukarya**. **B1** The missing rank is **class**. **B1** Genus: **Apis**. **B1**

(b) Archaea. B1 Any two, **B1** each: Bacteria have peptidoglycan in their cell walls, Archaea do not; Bacteria have ester-linked membrane lipids with unbranched chains, Archaea have ether-linked lipids with branched chains; their ribosomal RNA has different base sequences.

Example 2

Students sampled ground beetles in two habitats using pitfall traps.

species	woodland	field margin
P	24	45
Q	12	3
R	8	2
S	4	0
T	2	0

(a) Calculate Simpson's index of diversity (D) for each habitat. Give your answers to 3 decimal places. **[3]**

(b) Compare the diversity of ground beetles in the two habitats. **[2]**

(a) Woodland: $N = 50$.

$$\sum \left(\frac{n}{N} \right)^2 = 0.48^2 + 0.24^2 + 0.16^2 + 0.08^2 + 0.04^2 = 0.3216$$

$$D = 1 - 0.3216 = 0.678. \text{ M1 A1}$$

Field margin: $N = 50$. $\sum \left(\frac{n}{N} \right)^2 = 0.9^2 + 0.06^2 + 0.04^2 = 0.8152$, so $D = 0.185$. **A1**

(b) The woodland has the higher diversity: its D is closer to 1. **B1** The field margin has fewer species and is dominated by species P (45 of the 50 beetles), so its D is close to 0. **B1**

Example 3

A student measured the percentage of water in the soil and counted moss plants in eight quadrats.

quadrat	1	2	3	4	5	6	7	8
soil water / %	12	18	25	31	36	44	52	60
number of moss plants	3	5	4	9	8	12	15	14

(a) Calculate Spearman's rank correlation coefficient, r_s . **[3]**

(b) The critical value for 8 pairs at $p = 0.05$ is 0.738. State what the student can conclude. **[2]**

(a) Rank each variable from lowest to highest. Soil water is already in order, ranks 1 to 8. Moss ranks: 1, 3, 2, 5, 4, 6, 8, 7. So $D = 0, -1, 1, -1, 1, 0, -1, 1$ and $D^2 = 0, 1, 1, 1, 1, 0, 1, 1$. **M1** for ranking both variables. $\sum D^2 = 6$. **M1**

$$r_s = 1 - \frac{6 \times 6}{8^3 - 8} = 1 - \frac{36}{504} = 0.929$$

A1

(b) $0.929 > 0.738$, so reject the null hypothesis: there is a **significant positive correlation** between soil water and the number of moss plants, with less than a 5% probability that it is due to chance. **B1 B1** It does not prove that the water causes the moss to grow.

Example 4

A small forest deer lives only on one island. Its forest is being cleared for farms, and it is hunted for meat. The IUCN classes it as Critically Endangered, and only 60 remain in the wild.

(a) Suggest why the small population is at greater risk of extinction than its numbers alone suggest. **[3]**

(b) A zoo holds eight of the deer. Outline how IVF and surrogacy could be used to increase the captive population. **[4]**

(a) Any three, **B1** each: a small gene pool (low genetic diversity); inbreeding, so harmful recessive alleles are expressed (lower fertility and disease resistance); little variation for natural selection, so it cannot adapt to a new disease or change; one outbreak or disaster could kill them all.

(b) Any four, **B1** each: the female is given hormones (FSH) so several oocytes mature; the oocytes are collected; sperm from an unrelated male is added (fertilisation); zygotes are cultured into embryos, which are checked; each embryo is placed in the uterus of a surrogate, possibly of a common related deer species; spare embryos are frozen.

Common mistakes

- **Defining ecosystem too loosely.** "All the living things in an area" is a community. An ecosystem includes the abiotic factors and the interactions; "abiotic organisms" is wrong.
- **Confusing the IUCN and CITES with each other, or with zoos and charities.** The IUCN assesses and lists species; CITES controls trade.
- **Mixing up Protocista and prokaryotes.** Protocista are eukaryotes; so are Fungi, which are not plants.
- **Answering the wrong question.** "Other than captive breeding" or "animal biodiversity" means those points earn nothing; "effects of removing" a species needs the change, not the effects of its presence.
- **Simpson's slips:** rounding the fractions too early, forgetting "1—", or giving the wrong number of significant figures.
- **Mark-release-recapture:** leaving out a step (count, mark, release, recapture, count marked), or giving N as a decimal.
- **Correlation:** a wrong n (count the pairs), losing the minus sign, and claiming the correlation proves cause.
- **IVF:** forgetting that the embryos are checked, or that they can be frozen or placed in a surrogate.

How to get the marks

- **"Outline"** and **"suggest"** answers are marked "any three (or four) from" a list: give more short, **different** points than the marks, each linked to the organism in the stem.
- **"Compare"**: both sides in one sentence ("...", whereas ...").
- **"Discuss"**: both sides, then a conclusion; for species concepts, each concept with a verdict.
- **"Describe" data**: the trend plus a data quote with units.
- **Calculations**: show working (it earns a mark if the answer is wrong); give the accuracy asked; whole numbers for population estimates; units such as "per year".
- **"Define"**: the key words the mark scheme looks for (community, biotic and abiotic, interactions; role).

Quick check

1. A student marked 40 snails and released them. A day later she caught 50 snails, of which 8 were marked. Estimate the population, and give two assumptions she made.
2. The number of a bird species in a reserve fell from 3200 in 2000 to 1850 in 2025. Calculate the mean rate of decrease per year and the percentage decrease.
3. Name the kingdom of each organism: (a) a multicellular organism with chitin walls that feeds on dead leaves; (b) a single-celled organism with a cellulose wall and chloroplasts.
4. A virus has one strand of RNA. How is it classified?
5. Give three ways in which a seed bank helps conserve endangered plants.

Answers

1. $N = \frac{40 \times 50}{8} = 250$ snails. Any two: the paint marks don't harm the snails or make them easier for predators to see; the marks don't wear off; the marked snails mixed fully with the population; no births, deaths or migration in the day between; every snail had an equal chance of capture.
2. Rate = $\frac{3200 - 1850}{25} = \frac{1350}{25} = 54$ birds per year. Percentage decrease = $\frac{1350}{3200} \times 100 = 42.2\%$.
3. (a) **Fungi** (chitin walls; saprotrophic). (b) **Protoctista**: it has a cellulose wall and chloroplasts but is unicellular, and all plants are multicellular.
4. By its nucleic acid: an **RNA** virus that is **single-stranded**.
5. Any three: it stores seeds of many species and individuals in a small space, keeping **genetic diversity**; dried, cold seeds stay alive for years; samples are germinated to check viability; seeds can be grown for reintroduction or research.

Past questions to try

- [9700/41/M/J/25 Q9](#): Archaea against Bacteria, and classifying the tiger.
- [9700/42/M/J/25 Q9](#): using a frame quadrat, then Spearman's rank correlation.
- [9700/42/O/N/24 Q9](#): why a lemur is endangered, and captive breeding.
- [9700/42/M/J/24 Q9](#): an invasive toad, and IVF.