

Science 9–10

Chapter 9 — Biological sciences C: evolution and biodiversity

This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/> or send a letter to Creative Commons, PO Box 1866, Mountain View, CA 94042, USA.

Attribution: Classbasics Pty Ltd, vwx.au

Aboriginal and Torres Strait Islander content has been excluded as accuracy cannot be guaranteed, and it is better to be respectful than cover the entire curriculum inaccurately.

Significant effort has been made to ensure this content is legal. Please send any areas of concern to admin@vwx.au with appropriate document/legal references so errors can be verified and changes be made.

Contents

Section	Page
Evolution by natural selection: variation, isolation, selection and adaptation	2
The evidence: fossil record, biogeography, comparative embryology — biodiversity and relatedness	20
Test A	37
Test B	40
Test A — Section A — Multiple choice	44
Test A — Section B — Short/structured response	46
Test B — Section A — Multiple choice	47
Test B — Section B — Short/structured response	49
Mark record — Test A	51
Mark record — Test B	52

Evolution by natural selection: variation, isolation, selection and adaptation

Chapter 9 — Biological sciences C: evolution and biodiversity (Science, Levels 9 and 10)

Subtopic 9A · VC2 Science Understanding — Biological sciences

CD code: VC2S10U05 (split delivery †; this subtopic owns the processes limb — the partner Subtopic 9B owns the evidence limb) **Content description (verbatim):** “the theory of evolution by natural selection includes the processes of variation, isolation and adaptation and is supported by evidence including the fossil record, biogeography and comparative embryology; the theory explains past and present biodiversity and demonstrates how all organisms have some degree of relatedness to each other” **This subtopic’s limb (TOC §4 clause split):** the processes of variation, isolation and adaptation — how the theory of evolution by natural selection works. The partner subtopic 9B delivers the other limb: the evidence (fossil record, biogeography, comparative embryology) and what the theory explains (past and present biodiversity, and the relatedness of all organisms). **Elaboration ids drawn on:** VC2S10U05.E01 · VC2S10U05.E04 · VC2S10U05.E05 (ids VC2S10U05.E02 · VC2S10U05.E03 · VC2S10U05.E07 are drawn on by Subtopic 9B; id VC2S10U05.E06 is withheld — not authored — under the TOC’s D10 ICIP decision) **Achievement standard (extract served):** “They describe the evidence supporting the theory of evolution by natural selection.” (The describing of evidence is assessed through Subtopic 9B; this subtopic builds the account of the *processes* that the evidence supports — variation, isolation, selection and adaptation.)

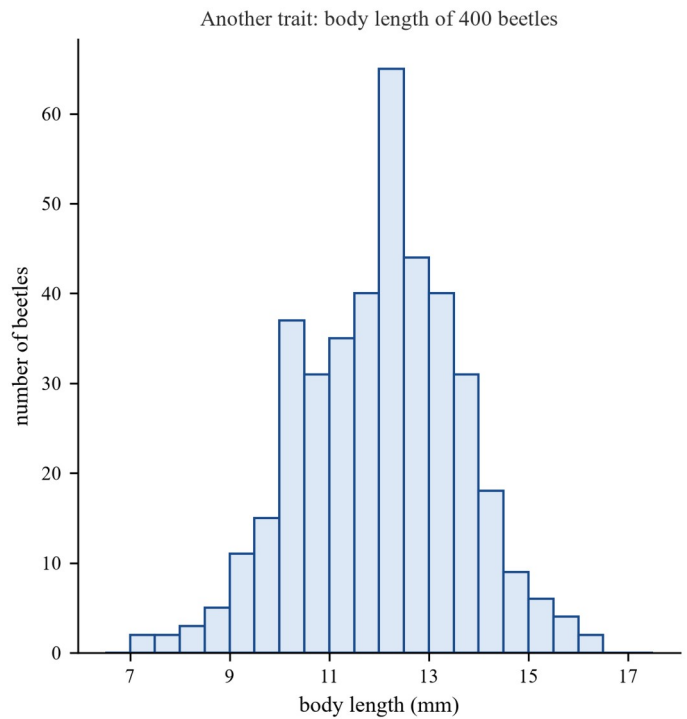
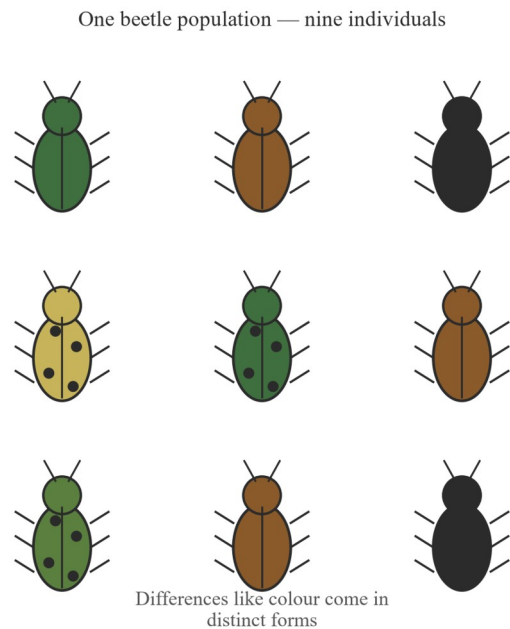
Theory

Life has a history, and species have changed along the way. The organisms alive today are not the same as the ones that lived thousands or millions of years ago, and every species is very well matched to its way of life — cacti to deserts, frogs to drying swamps, beetles to the bark they sit on. The theory that explains both facts is **evolution by natural selection**: species change over generations because the individuals whose inherited features suit their environment are the ones that survive and reproduce. This subtopic builds the theory from its four working parts — **variation, selection, inheritance and isolation** — and ends with the result of those parts working together: **adaptation**.

The words of this section. Several terms do most of the work here, so here they are up front. A **species** is a group of organisms that can interbreed with each other under natural conditions and produce fertile offspring. A **population** is the group of individuals of one species living in one area at one time. **Variation** is the differences between individuals of the same species. **Natural selection** is the process in which individuals with inherited features that suit their environment are more likely to survive and reproduce than individuals without those features. An **adaptation** is an inherited feature — in structure, behaviour or body function — that helps an organism survive and reproduce in its environment. **Evolution** is the change in the inherited features of a population over generations. (The Victorian Curriculum uses these terms without giving one fixed wording, so this subtopic works to those definitions, and every question here can be answered from them.)

Variation — the raw material (elaboration VC2S10U05.E01)

Look closely at any group of individuals of one species and you will see differences: size, colour, shape, blood group, disease resistance. These differences are **variation**, and variation is present in **every** natural population. It is the raw material that natural selection works on — without differences between individuals, there is nothing for selection to choose between.



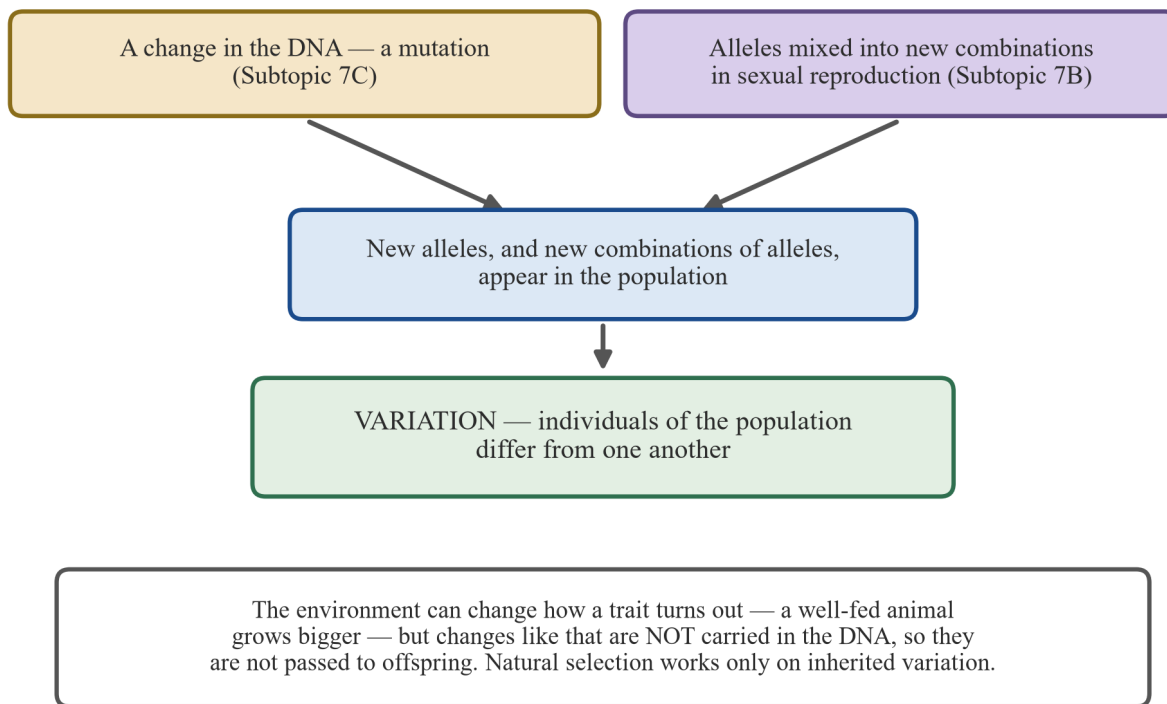
Variation: the differences between individuals of the same species.

Simulated illustrative data — most are near the middle, with a spread either side.

A panel of nine beetles of one species drawn in different colour forms, beside a histogram of 400 simulated body lengths from the same population — the bars form a smooth spread, tallest in the middle and shorter at both ends, showing that variation in a population is continuous.

Two kinds of variation matter here. **Inherited variation** is the difference in the instructions an organism is born with — the variation caused by the genes and alleles you met in Subtopic 7C. **Environmental variation** is the difference caused by conditions during life — extra food, training, a tan from the sun, a scar. Only **inherited** variation can be passed to offspring, so only inherited variation can cause a population to change over generations.

Where does inherited variation come from? Two sources do most of the work, and both are ideas you have already met in this band.

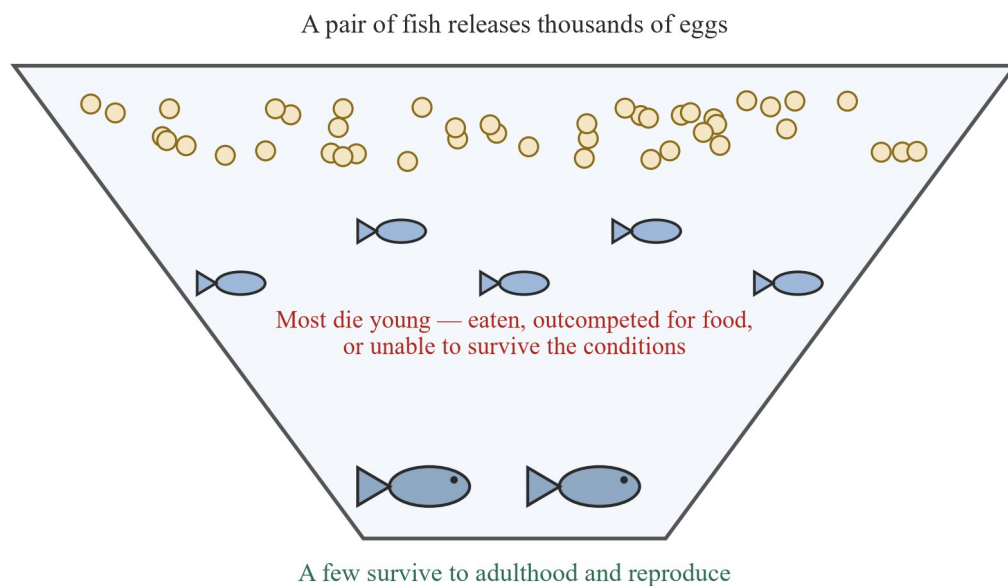


A concept map showing the two sources of inherited variation — mutation (from Subtopic 7C) making new alleles, and sexual reproduction (from Subtopic 7B) mixing and recombining the alleles each parent passes on — both feeding into variation in a population, with a note that changes caused by the environment during life are not inherited.

- **Mutation** (Subtopic 7C) — a change in the genetic instructions. Mutation makes *new* alleles, such as the allele for a new colour form. Most mutations are neutral or harmful, but occasionally one is useful in a given environment.
- **Mixing in sexual reproduction** (Subtopic 7B) — each parent passes on a half of their instructions, and the halves are shuffled into new combinations in every offspring. This is why brothers and sisters differ from each other even with the same two parents.

More offspring than can survive

Nearly every species produces more offspring than the environment can support. A single pair of beetles can leave hundreds of descendants in a few seasons; a fish releases thousands of eggs; a plant sheds thousands of seeds. Yet populations do not explode — year after year, the number of adults stays roughly the same. The reason is that **most offspring die young**, from hunger, predators, disease, drought or cold. Only a few of each generation live to reproduce. That gap — many born, few breeding — is the engine of natural selection, because *which* individuals make it through is not random: it depends on their inherited features.



Model: in every generation, more individuals are born than the environment can support.

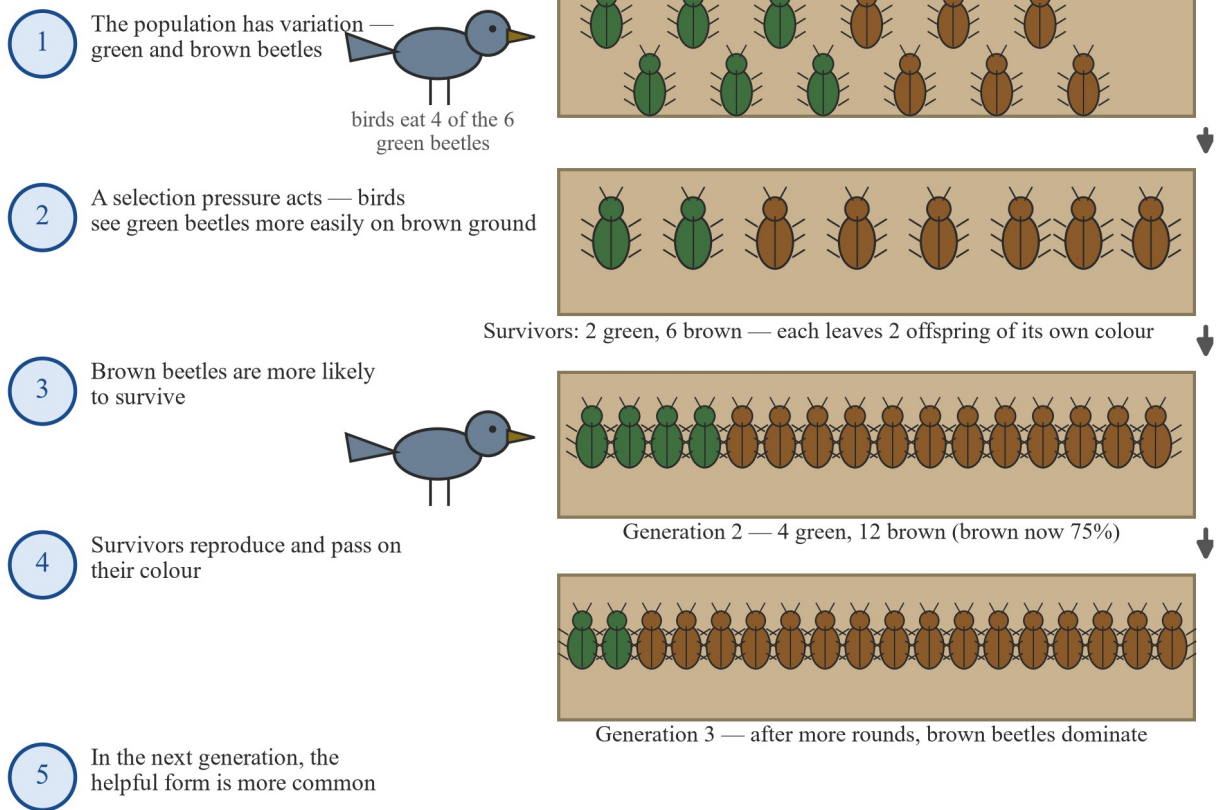
A funnel model of overproduction: a pair of beetles produces thousands of eggs; most offspring die young from predators, hunger, cold and disease; only a few survive to reproduce — the population size stays roughly steady from year to year.

Natural selection — five steps that sort variation (elaboration VC2S10U05.E05)

Put variation, inheritance and overproduction together and you get **natural selection**. Follow it in a model population of beetles that comes in two inherited colour forms, green and brown, living on brown bark.

1. **Variation.** The population contains different inherited forms — some beetles are green, some are brown.
2. **Overproduction.** More beetles are born than can survive, so most die before reproducing.
3. **Selection.** Birds hunt by sight. On brown bark, green beetles are easier to see, so brown beetles are **more likely to survive** — not because they are stronger, just because their inherited colour hides them.
4. **Inheritance.** Colour is inherited, so the survivors pass their colour on to their offspring.
5. **Change over generations.** The next generation starts with more brown parents, so it contains a higher share of brown beetles. Repeat the cycle and the population becomes browner and browner.

Natural selection, step by step — one beetle population



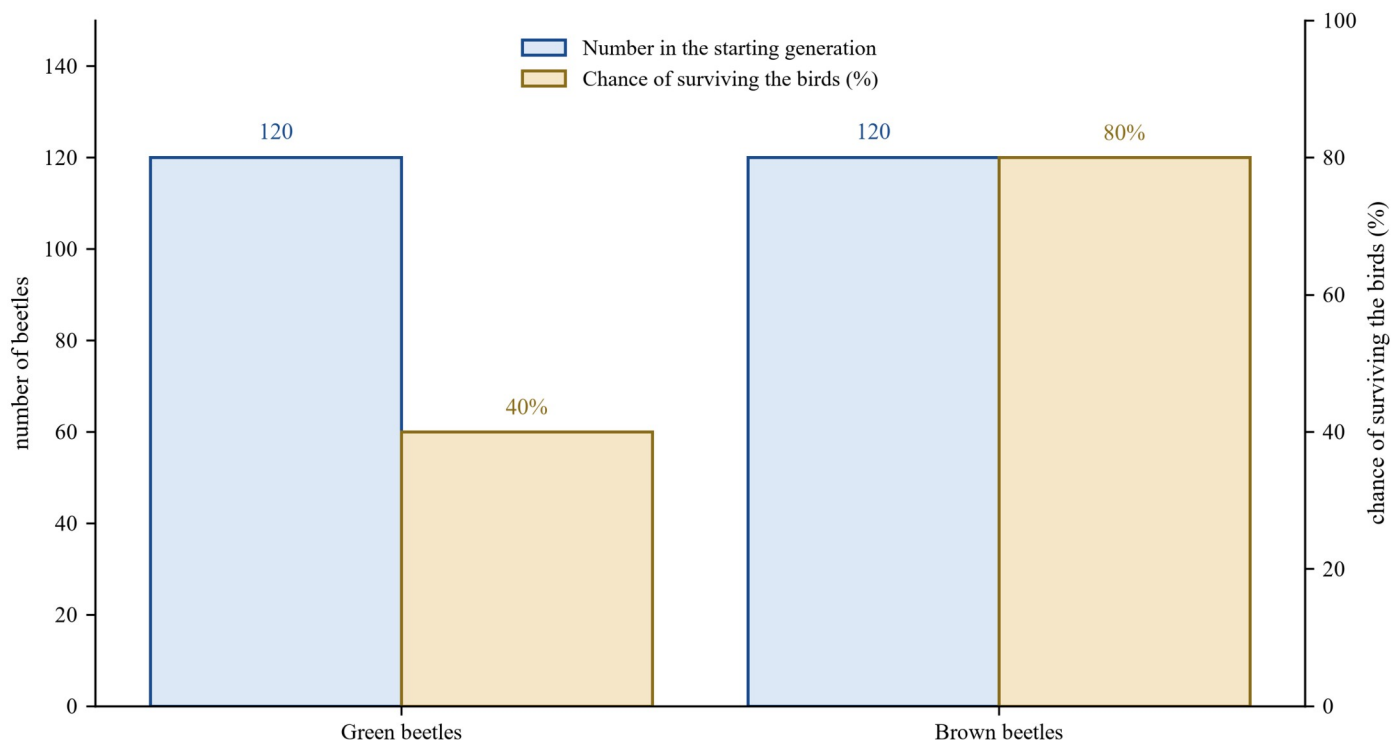
No beetle changed colour. What changed is which forms survived and reproduced — the population changed.

Model — one round of selection per generation.

The five-step model worked on a beetle population on brown bark: generation 1 has 6 green and 6 brown beetles; birds eat 4 of the 6 green; the 8 survivors (2 green, 6 brown) reproduce, giving generation 2 with 4 green and 12 brown; one more round gives generation 3 with 2 green and 16 brown. The caption notes that no beetle changed colour within its life — the population changed.

The single most important idea in this subtopic is in that last figure: **no beetle changed colour within its own lifetime**. Selection does not change individuals; it changes the *share* of each inherited form in the population, generation by generation. Evolution is something populations do, not something organisms do.

Here is a second, numbered model of the same process to work through yourself — the calculation it sets up is Worked Example 2.

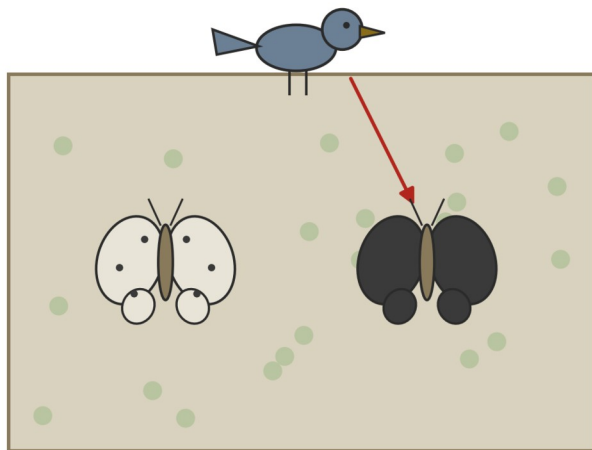


*Simulated data for practice. Rule of the model: each survivor leaves two offspring of its own colour:
Work out the next generation yourself — that is Worked Example 2.*

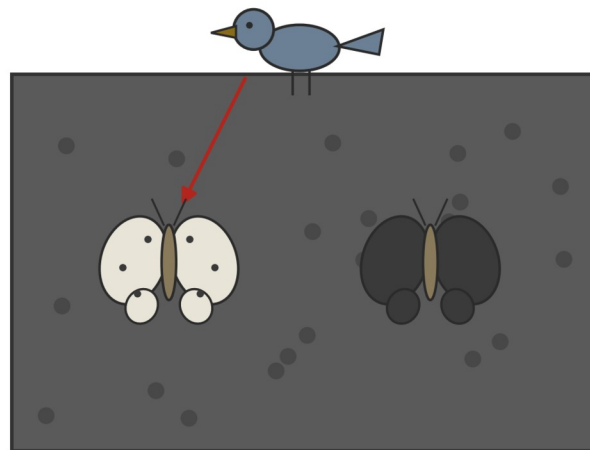
A twin-axis bar chart of the practice model: the starting generation has 120 green and 120 brown beetles; on brown bark the green beetles' chance of surviving the birds is 40% and the brown beetles' is 80%; the caption notes the data are simulated and that each survivor leaves two offspring of its own colour, so the next generation can be worked out.

Selection seen in real life — the peppered moth

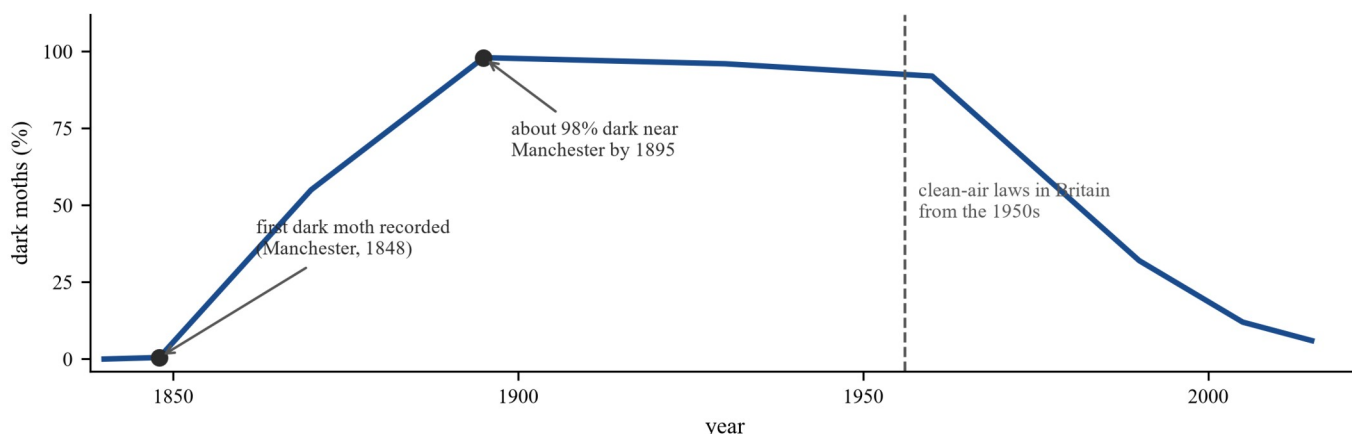
The beetle model is not just a model. The peppered moth of Britain comes in a pale speckled form and a dark form, and the difference is inherited. On tree bark covered with pale lichens, the pale form is camouflaged and the dark form is picked off by birds. In soot-covered industrial areas the lichens die and the bark darkens — and then the dark form is the hidden one.



Clean trunk with lichen — the dark moth stands out



Trunk darkened by soot — the pale moth stands out



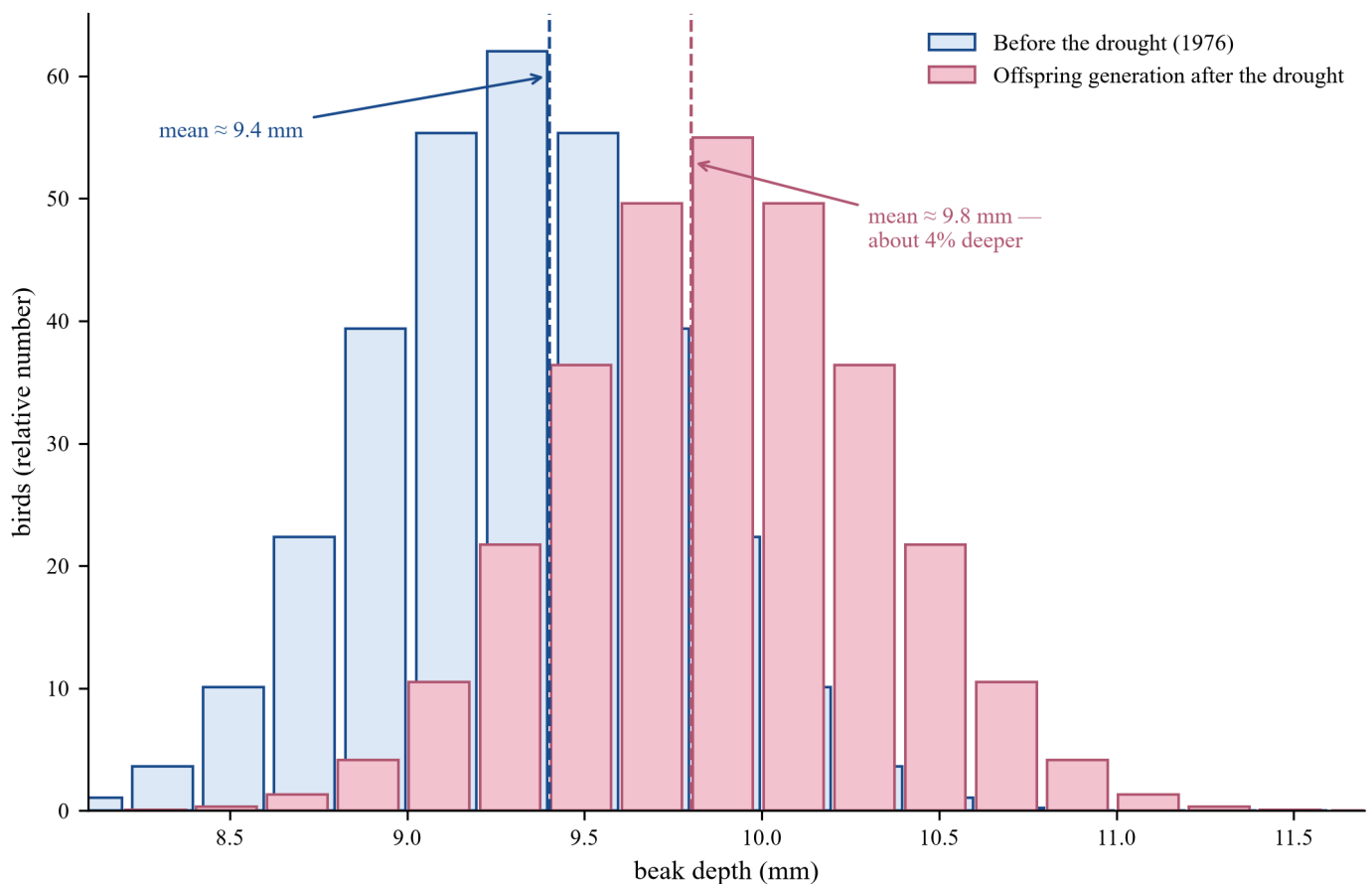
Schematic curve — anchor values from the published record (see source in the text).

Two panels of moths resting on tree trunks with birds hunting: on a pale lichen-covered trunk the pale moth is camouflaged and the dark moth is seen and eaten; on a soot-darkened trunk the situation reverses. Below, a schematic frequency curve shows the dark form rising from about half a percent of moths recorded in 1848 to about 98% by 1895 in industrial areas, then declining after clean-air laws from the 1950s.

The dark form was first recorded in 1848, and by 1895 about 98% of the moths in some industrial areas were dark — selection had shifted the population in under fifty years. When clean-air laws from the 1950s cleared the soot and the lichens returned, the change ran backwards and the pale form became common again. *Source: Wikipedia, “Peppered moth” — first dark form recorded 1848; about 98% dark in industrial areas by 1895; decline after clean-air laws from the 1950s; retrieved 2026-08-21.* This is natural selection observed within a human lifetime, in both directions.

Selection seen in real life — finches on Daphne Major

On the Galápagos island of Daphne Major, Peter and Rosemary Grant measured every beak of every ground finch on the island for years. The severe drought of 1977 killed most of the plants’ small, soft seeds, leaving mostly large, hard seeds. Birds with **deeper beaks** could crack those seeds and survived better; most of the small-beaked birds died. The survivors bred, and because beak depth is inherited, the **offspring generation had a mean beak depth about 4% deeper** than the generation before the drought.



*Approximate values drawn to the published account of the 1977 drought on Daphne Major, Galápagos (Boag & Grant 1981).
The drought left mostly large, hard seeds — birds with deeper beaks survived better.*

Paired histograms of ground finch beak depth on Daphne Major: the generation before the 1977 drought (mean about 9.4 mm) and the offspring generation after it (mean about 9.8 mm, about 4% deeper), showing the whole distribution shifted toward deeper beaks.

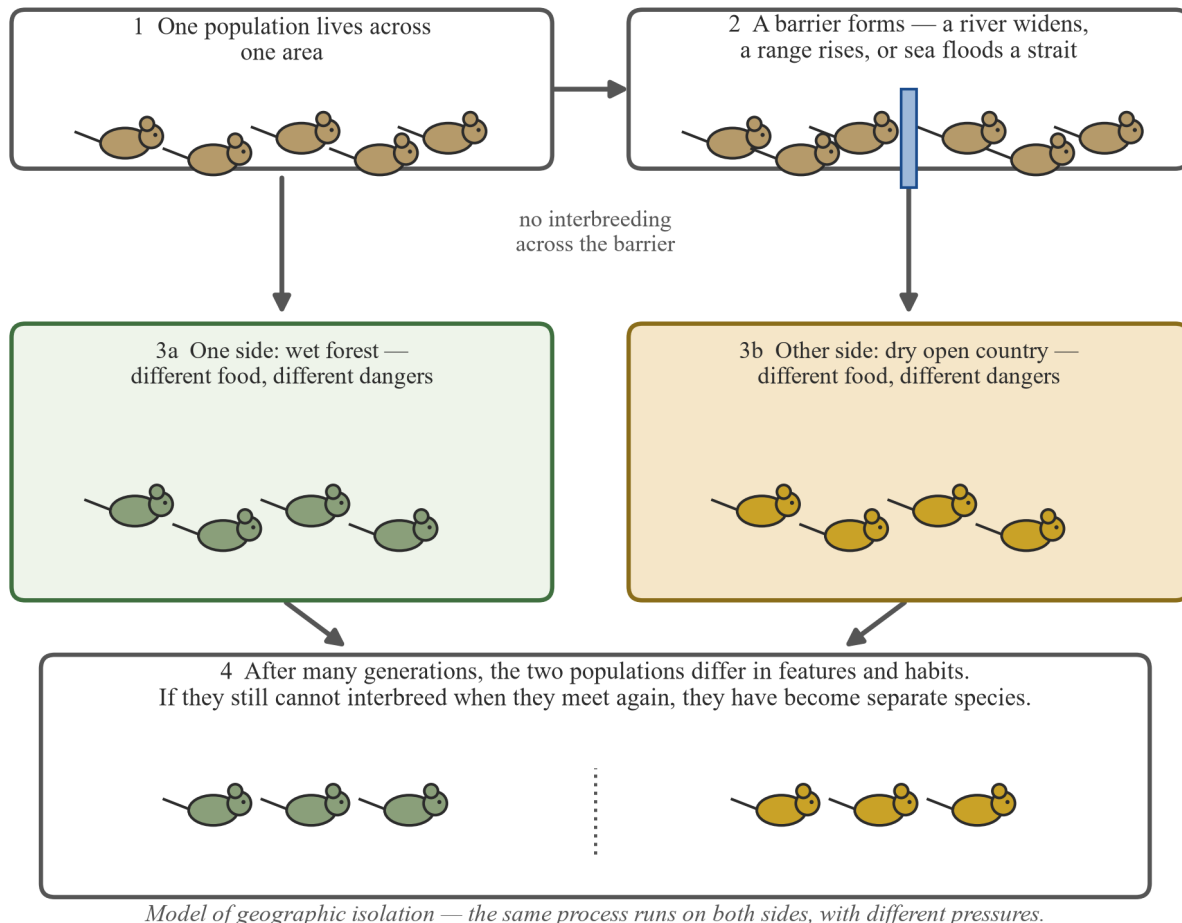
Source: Boag, P. T. and Grant P. R. (1981), “Intense natural selection in a population of Darwin’s finches (Geospizinae) on Daphne Major, Galápagos”, Science 214(4516): 82–84, doi:10.1126/science.214.4516.82 — values as plotted are approximate; retrieved 2026-08-21. One drought, one measured generation, one clear shift: natural selection in the wild, written down as data.

Selection seen in real life — bacteria and antibiotics

When the antibiotic methicillin began to be used in hospitals in 1959, almost every *Staphylococcus* bacterium it met died. But variation existed: a few bacteria carried inherited resistance. The first resistant bacteria (MRSA) were found in 1961. Where the antibiotic was used, the non-resistant bacteria died and the resistant ones survived and reproduced, passing the resistance on — exactly the five steps. Within decades, resistant strains went from rare to common: in UK hospital samples, about 22% of *Staphylococcus* were MRSA by 1995 and about half by 1997. *Source: Wikipedia, “Methicillin-resistant Staphylococcus aureus” — first MRSA isolates 1961; share of UK samples 22% in 1995 and about 50% in 1997; retrieved 2026-08-21.* This is why antibiotics are a resource to be used carefully: every course of treatment is a round of selection.

Isolation — one population becomes two

Variation and selection explain change — but how does one species become **two**? The usual first step is **isolation**: a barrier splits one population into two groups that no longer interbreed. A river widens, a mountain range rises, a sea floods a strait. From that moment, the two groups are on separate paths, because no variation or alleles move between them.



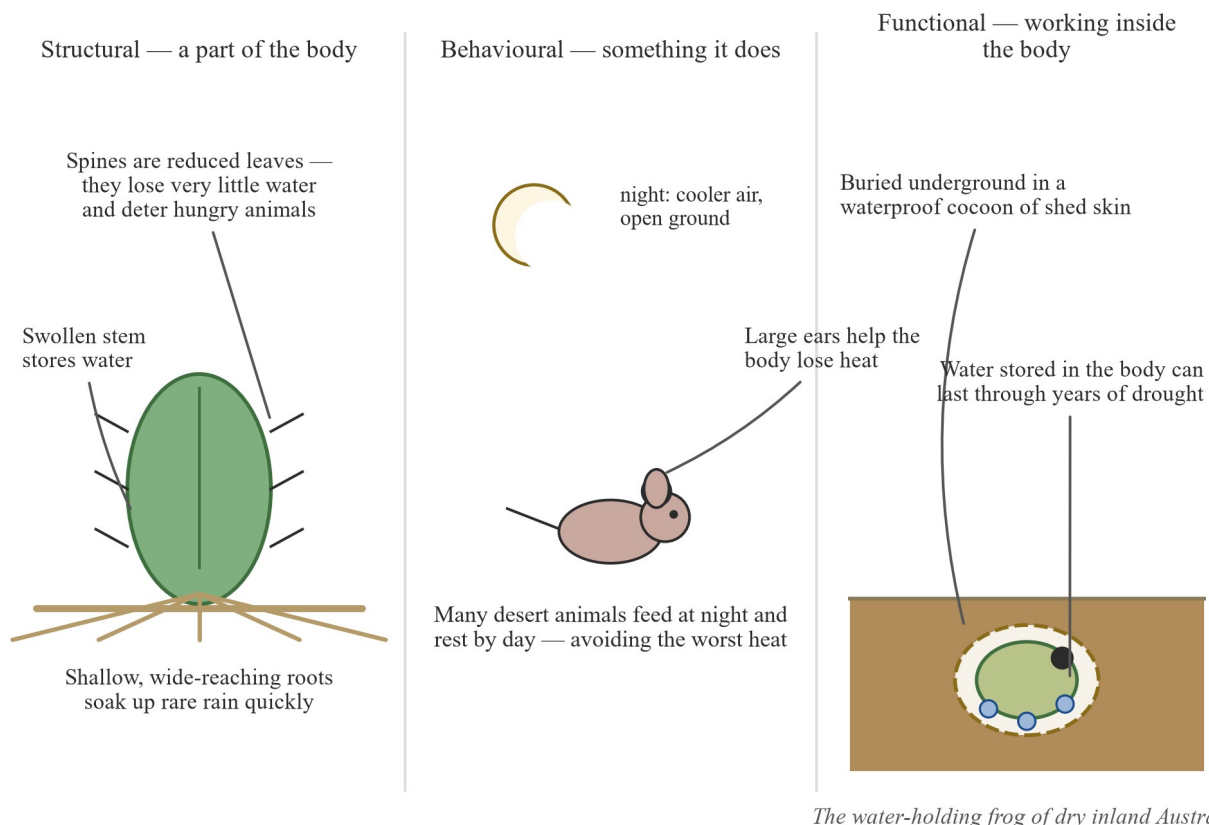
Model of geographic isolation — the same process runs on both sides, with different pressures.

A four-stage model of geographic isolation: 1, one population lives across one area; 2, a barrier forms — a river widens, a range rises, or sea floods a strait — with no interbreeding across the barrier; 3a and 3b, each side faces different food and different dangers, so selection favours different inherited features on each side; 4, after many generations the two populations differ in features and habits, and if they still cannot interbreed when they meet again, they have become separate species.

Once isolated, the two groups usually face **different conditions** — different food, different predators, different climate — so natural selection pulls each group in a different direction, and each accumulates its own inherited changes. After many generations the groups can differ so much in features and habits that, even if the barrier disappears, they can no longer interbreed. At that point they are **two species**. Isolation is what lets two populations drift apart; selection is what drives them apart.

Adaptation — three kinds of match (elaboration VC2S10U05.E04)

Run variation, selection and inheritance for long enough and the result is **adaptation** — inherited features that suit an organism to its environment. Adaptations come in three kinds, and one organism usually carries several at once.



Three panels showing the three kinds of adaptation: structural — a cactus with spines instead of leaves, a swollen water-storing stem and wide shallow roots; behavioural — a desert mouse that is active at night and rests in a burrow by day; functional — the water-holding frog buried underground in a waterproof cocoon with water stored in its body through years of drought.

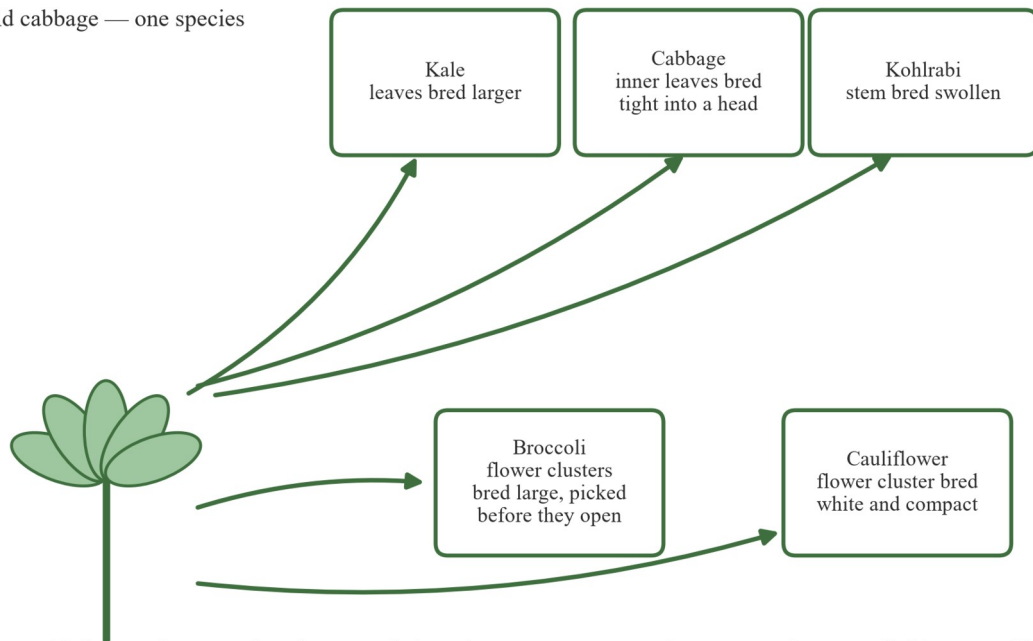
- **Structural adaptations** — features of body structure. A cactus carries spines instead of broad leaves (less surface to lose water, and protection from animals), a swollen stem that stores water, and wide shallow roots that catch rare rain.
- **Behavioural adaptations** — things an organism *does*. A desert mouse avoids the heat by resting in its burrow by day and feeding at night.
- **Functional adaptations** — processes inside the body. The water-holding frog of dry inland Australia burrows underground, forms a waterproof cocoon of shed skin, and lives on water stored in its body for years until rain returns. *Source: Wikipedia, “Water-holding frog” — waterproof cocoon, water stored in the body, survival underground for up to five years; retrieved 2026-08-21.*

Each adaptation is the product of selection on inherited variation in the past: the individuals whose bodies, behaviour or functions suited the desert left more offspring, and their features became the normal ones in the population.

Artificial selection — people as the selector

The process is easier to see when the selector is a person. **Artificial selection** is breeding in which *people* choose which individuals reproduce. All the ordinary vegetables below were bred from one wild cabbage species by choosing, generation after generation, the plants with the part the breeder wanted, and growing on their seed.

Wild cabbage — one species



Breeders selected the plants with the part they wanted, and grew on their seed — over many generations, one species was pulled into very different varieties.

A wild cabbage plant at left with arrows to five boxes: kale (leaves bred larger), cabbage (inner leaves bred tight into a head), a form with a swollen stem, broccoli (flower clusters bred large, picked before they open) and cauliflower (flower cluster bred white and compact) — one species pulled into very different varieties by breeders' choice.

Compare the two selectors side by side.

Feature	Artificial selection	Natural selection
Who does the selecting?	People — farmers and breeders choose which individuals reproduce	The environment — conditions decide who is more likely to survive and reproduce
Which forms are favoured?	The ones with features people want (more wool, bigger heads, tamer behaviour)	The ones with inherited features that help survival and reproduction in that environment
How fast is the change?	Often fast — breeders apply strong, steady choice every generation	Depends on the strength of the pressure and the generation time — from years to thousands of years
What is the outcome?	Breeds and varieties suited to people's needs	Populations better matched to their environment — adaptations

Same three ingredients in both — variation, selection and inheritance — but a different selector.

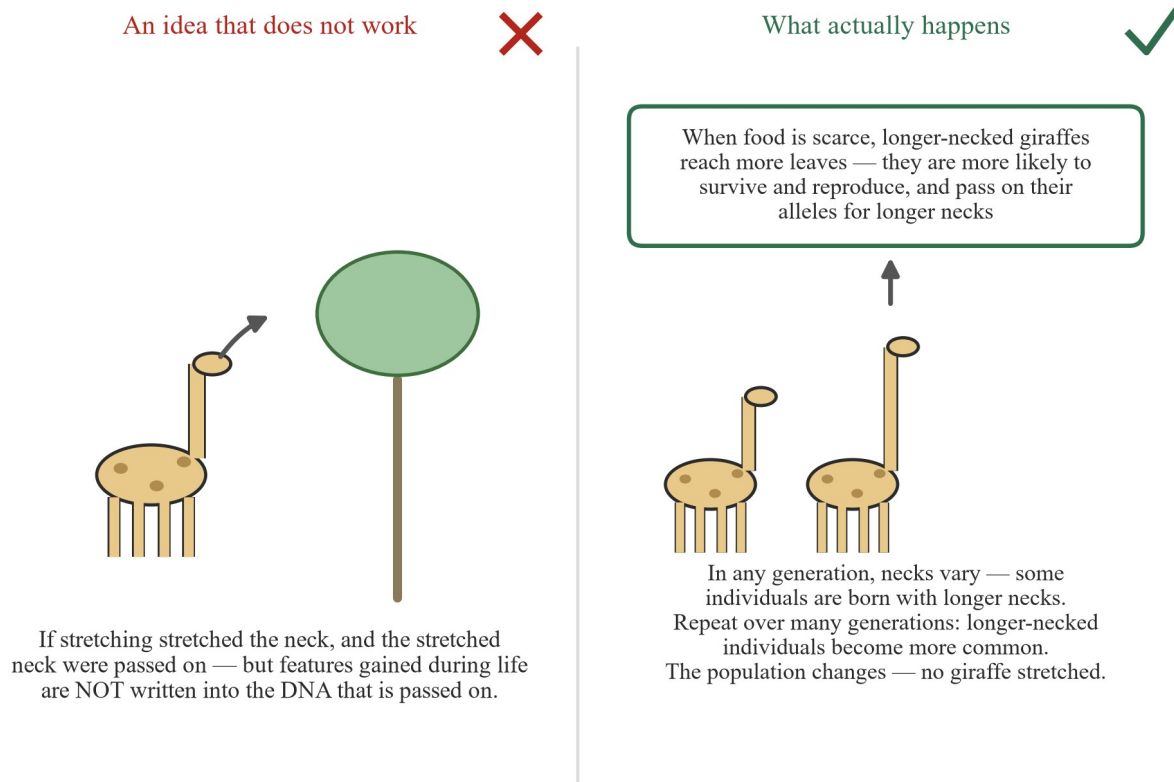
A four-row comparison table of artificial and natural selection: who does the selecting (people, versus the environment); which forms are favoured (features people want, versus inherited features that help survival and

reproduction); how fast the change is (often fast under steady choice, versus years to thousands of years); and the outcome (breeds and varieties for people's needs, versus populations better matched to their environment — adaptations).

The two processes share the same three ingredients — **variation, selection and inheritance** — and differ only in *who selects*. Darwin used exactly this comparison: if choice can reshape a cabbage in a few centuries, then nature, choosing every generation for millions of years, can reshape a species into something new.

A misconception to avoid

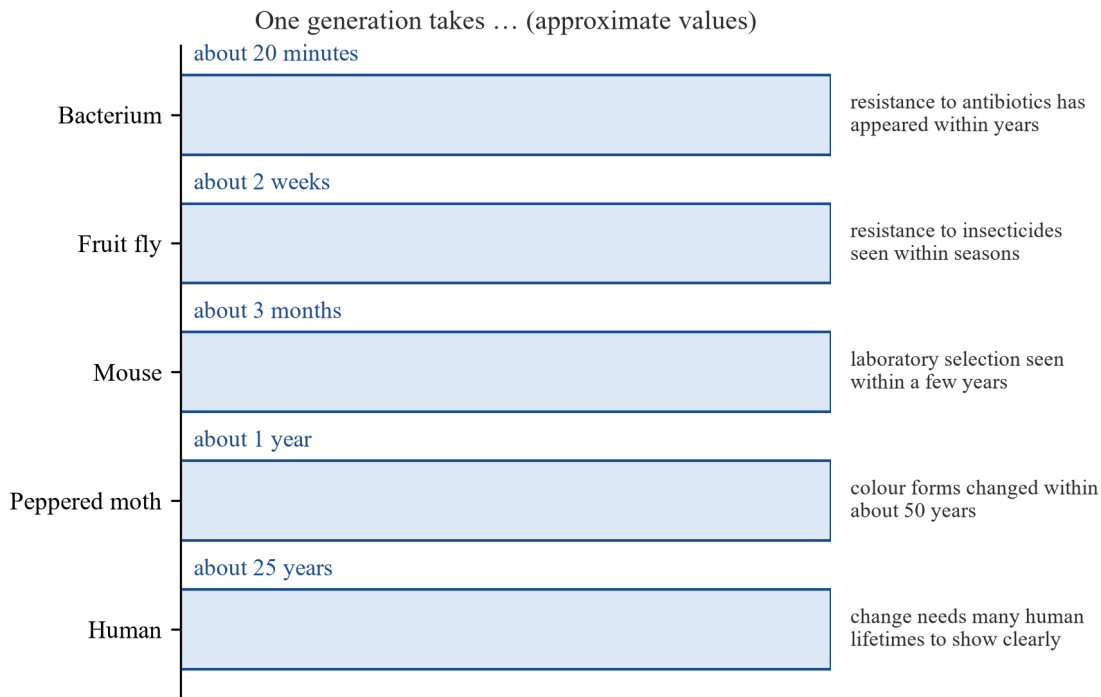
The classic error is to say that organisms *change themselves* by trying or straining, and pass that change on — giraffes stretching their necks, then passing on stretched necks. Features gained during life are not written into the DNA that is passed on, so they cannot be inherited. The working account is the one on the right of the figure: necks vary in every generation; when food is scarce, longer-necked individuals reach more leaves, survive and reproduce more, and pass on their alleles for longer necks; repeat over many generations and the population's necks lengthen — with no giraffe ever having stretched.



Two panels: left, a giraffe stretching toward a tree under a cross mark — the idea that stretched necks are passed on does not work, because features gained during life are not written into the DNA; right, under a tick mark, two giraffes born with different neck lengths, and a box explaining that when food is scarce the longer-necked one is more likely to survive and reproduce, so over many generations the population changes without any giraffe stretching.

How fast can change be seen?

Selection acts every generation, so the speed of visible change depends on how fast the generations come.



*The bars are equal-length rows, not a scale — compare the written times.
The faster the generations, the sooner a change caused by selection can be observed.*

Equal-length rows (not a scale — the written times are the data) for five organisms: bacterium about 20 minutes a generation, fruit fly about 2 weeks, mouse about 3 months, peppered moth about 1 year, human about 25 years; notes beside each row say resistance to antibiotics has appeared within years, resistance to insecticides within seasons, laboratory selection in mice within a few years, moth colour change within about 50 years, while change in humans needs many lifetimes to show clearly.

That is why antibiotic resistance and insect resistance appear within years, while change in long-lived species is usually seen only in the fossil or historical record. The process is the same in every case — only the clock is different.

Activities

Activity 1 — Measuring variation in the class (elaboration VC2S10U05 .E01; graphing skills from Subtopic 4C). Work in pairs. Measure the hand span (thumb tip to little-finger tip, hand flat and stretched) of every student who volunteers, to the nearest half centimetre, and record the results in a class table. Then draw a histogram of the data with bin widths of 1 cm. (i) Describe the shape of the spread in one sentence. (ii) State whether hand span shows variation in this population, and how you can tell from the histogram. (iii) Give one **environmental** factor that could affect hand span, and one reason the variation is also partly **inherited**. (iv) Explain why this variation could not, by itself, cause evolution by natural selection in the class.

Activity 2 — The beetle hunt (elaboration VC2S10U05 .E05). Cut 20 small “beetles” from green paper and 20 from brown paper. Spread a sheet of brown paper as the “bark” and scatter the 40 beetles on it. One student is the bird: in 10 seconds they pick up as many beetles as they can see, one at a time. Count the survivors by colour and record them. Each survivor now “leaves two offspring of its own colour”: rebuild the population from the survivor counts (survivors $\times$ 2 of each colour) and repeat the hunt for two more generations. (i) Tabulate the number and the share of each colour in generations 1, 2 and 3. (ii) State which form was favoured and why. (iii) Swap the bark to green paper and predict what would happen over three generations, giving your reasoning in terms of the five steps.

Activity 3 — Breed a better crop (artificial selection). A “field” of 30 paper plants is provided, each with a seed-head of a different size (drawn as a circle 1–4 cm across). You are the breeder, and your market wants the biggest seed-heads. Generation 1: measure and rank the seed-heads, keep only the 6 largest, and “breed” the next generation by drawing 30 new plants whose seed-heads vary around the mean of your 6 chosen parents (your teacher will give the breeding rule). Repeat for three generations. (i) Record the mean seed-head size in each generation. (ii) State what

has changed in the population. (iii) Name the selector in your crop and the selector in natural selection, and give one way the two processes are alike and one way they differ.

Worked examples

Example 1 — scaffolded

The beetle population on brown bark starts (generation 1) with 6 green and 6 brown beetles. Birds eat 4 of the 6 green beetles, and each survivor leaves two offspring of its own colour. Work out generation 2, and the share of brown beetles in each generation.

Working	Comment
Survivors: green $6 - 4 = 2$; brown $6 - 0 = 6$.	Selection acts on the inherited colour: on brown bark the green form is seen and eaten first.
Generation 2: green $2 \times 2 = 4$; brown $6 \times 2 = 12$; total 16.	Each survivor leaves two offspring of its own colour — colour is inherited.
Share brown, generation 1: $6/12 = 50\%$.	Start from the shares, not just the counts.
Share brown, generation 2: $12/16 = 75\%$.	The share of the favoured form has risen in a single generation.
The population has become browner; no beetle changed its own colour.	This is evolution by natural selection: the population changed, generation by generation.

Example 2 — scaffolded

A model population has 120 green and 120 brown beetles on brown bark. In one round of bird hunting, each green beetle has a 40% chance of surviving and each brown beetle an 80% chance. Each survivor leaves two offspring of its own colour. Work out the next generation.

Working	Comment
Green survivors: 40% of 120 = 48.	The survival chance is the selection pressure acting on the green form.
Brown survivors: 80% of 120 = 96.	The brown form is better hidden on brown bark, so more survive.
Next generation: green $48 \times 2 = 96$; brown $96 \times 2 = 192$.	Inheritance: offspring match their parent's colour.
Share green falls from $120/240 = 50\%$ to $96/288 \approx 33\%$.	One round of selection shifted the shares; repeated rounds would shift them further.

Example 3 — unscaffolded

In an industrial area of Britain in 1850, tree bark was dark with soot and the pale form of the peppered moth was common early in the century, yet by 1895 about 98% of moths there were dark. Explain this change using the ideas of variation, selection and inheritance. (3 marks)

The population showed **variation** — an inherited pale form and a dark form existed. On soot-darkened bark the pale moths were easy for birds to see and eat, while the dark moths were camouflaged, so the dark form was **selected**: dark individuals were more likely to **survive and reproduce**. Colour is **inherited**, so the survivors passed the dark form to their offspring, and over generations the share of dark moths rose to about 98%. $\therefore$ the population changed because selection acted on inherited variation — no moth changed its own colour.

Example 4 — unscaffolded

Mice of one species live on both sides of a narrow land bridge. The sea rises and floods the bridge, so no mouse can cross for thousands of generations. The left side is wet forest and the right side is dry open country. Explain, step by step, how the two groups could end up as two species. (4 marks)

The rising sea **isolates** the population into two groups with **no interbreeding**, so no alleles move between them. The two sides have **different conditions** — different food and different predators — so **natural selection favours**

different inherited features on each side, and each group also accumulates its own variation over time. After many generations the groups **differ so much** in features and habits that, even if the sea fell again, they **could no longer interbreed** — and at that point they are **two species**. ∴ isolation splits the population, and selection drives the two halves apart.

Practice questions

Scaffolded questions

Question 1 The vocabulary of this subtopic. Define each of the following: (a) species; (b) population; (c) variation; (d) natural selection; (e) adaptation; (f) evolution.

Question 2 The five steps. The statements below are the five steps of natural selection, out of order. Rewrite them in the correct order, numbering them 1–5. (a) Survivors pass their inherited features to their offspring. (b) A population contains inherited variation. (c) The share of the favoured form rises in the next generation. (d) More offspring are born than can survive. (e) Individuals with features that suit the environment are more likely to survive and reproduce.

Question 3 Kinds of adaptation. Sort each feature into *structural*, *behavioural* or *functional*: (a) cactus spines; (b) a desert mouse feeding at night; (c) the water-holding frog's waterproof cocoon; (d) a cactus's swollen water-storing stem; (e) a bird hiding from predators in thick scrub at midday. Then add one example of your own for each kind.

Question 4 Reading the finch data. Use the paired histograms of beak depth on Daphne Major. (a) State the mean beak depth of the generation before the 1977 drought. (b) State the mean beak depth of the offspring generation. (c) Calculate the difference in mm. (d) State which inherited form — deeper or shallower beaks — survived the drought better, and give the evidence from the graphs.

Question 5 The beetle model. Use the model figure with 120 green and 120 brown beetles and survival chances of 40% and 80%. (a) Calculate the number of green survivors and of brown survivors. (b) If each survivor leaves two offspring of its own colour, calculate the number of green and brown beetles in the next generation. (c) State the share of green beetles before selection and in the next generation.

Question 6 Artificial versus natural selection. Copy and complete the table.

Feature	Artificial selection	Natural selection
---------	----------------------	-------------------

Who does the selecting?

Which forms are favoured?

What is the outcome?

Unscaffolded questions

Question 7 A bodybuilder's children are not born strong, and a tan is not inherited. Explain why changes like these, gained during life, cannot cause evolution by natural selection. (2 marks)

Question 8 In the beetle model on brown bark, the share of brown beetles rose from 50% to 75% in one generation of bird hunting. If the same hunting continues for many more generations, state what will happen to the share of the green form, and explain why the green form does not disappear in a single generation. (2 marks)

Question 9 "Giraffes got long necks because they stretched to reach leaves, and passed the longer necks on." Explain why this account does not work, and replace it with the selection account in two or three sentences. (2 marks)

Question 10 Two populations of mice live on either side of a mountain range and look slightly different. State what must be shown to be true before they can be called two separate species, and name the process that first allowed the two populations to differ. (2 marks)

Question 11 MRSA bacteria were first found in 1961, soon after methicillin began to be used, and in UK hospital samples the resistant share rose from about 22% in 1995 to about half by 1997. Explain this rise using the five steps of natural selection. (2 marks)

Question 12 Resistance to insecticides has appeared in fruit flies within seasons, while visible selection-driven change in humans needs many lifetimes. Explain the difference. (2 marks)

Question 13 After the 1977 drought on Daphne Major, the offspring generation of ground finches had a mean beak depth about 4% deeper than the generation before the drought. Explain how a drought — which kills birds rather than changing their beaks — produced that shift. (3 marks)

Question 14 Kale and cauliflower were both bred from wild cabbage, yet they look nothing alike. (a) Name the process and the selector that produced them. (b) Explain why all the varieties shown are still counted as one species. (3 marks)

Question 15 A population of beetles lives on bark that becomes darkened by soot, as in industrial Britain. Predict which inherited colour form will become more common, and justify your prediction with the five steps. (4 marks)

Question 16 “Natural selection has no goal — it only sorts the variation that already exists.” Explain this statement, using one example from this subtopic to show what selection can do and one reason it cannot produce a feature “on purpose”. (4 marks)

Answers

Question 1 (a) a group of organisms that can interbreed under natural conditions and produce fertile offspring; (b) the individuals of one species living in one area at one time; (c) the differences between individuals of the same species; (d) the process in which individuals with inherited features that suit the environment are more likely to survive and reproduce; (e) an inherited feature — structure, behaviour or body function — that helps an organism survive and reproduce in its environment; (f) the change in the inherited features of a population over generations. **Question 2** 1 = (b); 2 = (d); 3 = (e); 4 = (a); 5 = (c). **Question 3** (a) structural; (b) behavioural; (c) functional; (d) structural; (e) behavioural; own examples vary. **Question 4** (a) about 9.4 mm; (b) about 9.8 mm; (c) about 0.4 mm; (d) deeper beaks — the whole distribution, and the mean, shifted toward deeper beaks after the drought. **Question 5** (a) green 48, brown 96; (b) green 96, brown 192; (c) 50% before, about 33% after. **Question 6** Artificial: people (farmers, breeders); the forms with features people want; breeds and varieties suited to people's needs. Natural: the environment (conditions); the forms with inherited features that help survival and reproduction; populations better matched to their environment — adaptations. **Question 7** see solution. **Question 8** see solution. **Question 9** see solution. **Question 10** see solution. **Question 11** see solution. **Question 12** see solution. **Question 13** see solution. **Question 14** see solution. **Question 15** see solution. **Question 16** see solution.

Fully-worked solutions

Question 7 Features gained during life — bigger muscles, a tan — are **not written into the DNA** of the sex cells, so they are **not inherited** by offspring. Evolution by natural selection needs **inherited** variation to act on; without inheritance of the feature, the next generation does not change. $\therefore$ only inherited differences can cause evolution. (1 mark each: *changes gained during life are not in the DNA / not inherited; selection can only act on inherited variation, so the population cannot change from such features.*)

Question 8 The share of the green form would **keep falling generation by generation**, approaching very low values while the brown form rises. It does not disappear in one generation because green survivors **still reproduce and pass the green form on** — selection changes the *shares* of the forms each round, it does not remove a form in a single step. (1 mark each: *share of green keeps falling over generations; green survivors still pass the form on, so the change is gradual.*)

Question 9 The stretching account fails because a neck stretched during life is **not written into the DNA** and so **cannot be inherited**. The working account: necks **vary** in every generation; when food is scarce, longer-necked individuals reach more leaves, so they **survive and reproduce more** and **pass on their alleles** for longer necks; repeated over many generations, the **population's** necks lengthen — no giraffe stretched. (1 mark: *stretched features are not inherited; 1 mark: the selection account with variation, survival/reproduction and inheritance across generations.*)

Question 10 It must be shown that, when they meet again, the two groups **can no longer interbreed** (and produce fertile offspring) under natural conditions — that is what makes them two species. The process that first allowed them to differ is **isolation**: the barrier stopped interbreeding, so each group accumulated its own inherited changes under its own selection pressures. (1 mark each: *cannot interbreed when they meet; isolation stopped the gene mixing first.*)

Question 11 **Variation** existed — a few bacteria carried inherited **resistance**. Where methicillin was used, non-resistant bacteria died while resistant ones **survived and reproduced** (selection), and resistance was **inherited**, so over generations the resistant share rose from rare to about half of samples. (1 mark: *variation plus selection by the antibiotic; 1 mark: resistance inherited, so the resistant share rose over generations.*)

Question 12 Selection acts **once per generation**, so change appears as fast as the generations come. Fruit flies breed in about two weeks, so many rounds of selection fit inside one season; humans take about 25 years per generation, so the same number of rounds needs many lifetimes. (1 mark each: *selection works per generation; fly generations are weeks while human generations are decades.*)

Question 13 The drought changed the **food supply**, leaving mostly large hard seeds. Birds with **deeper beaks** could crack them, so they **survived better** and most shallow-beaked birds died (selection on existing variation — the drought killed birds, it did not stretch beaks). Beak depth is **inherited**, so the surviving deep-beaked birds passed

deeper beaks on, and the offspring generation's mean was about 4% deeper. (1 mark each: deep beaks favoured by the new food; survivors reproduced; depth inherited, shifting the offspring generation.)

Question 14 (a) The process is **artificial selection** and the selector is **people** (breeders choosing which plants reproduce). (b) The varieties can still **interbreed and produce fertile offspring**, so by the definition of a **species** they remain one species — they are varieties, not separate species. (1 mark: artificial selection / people as selector; 2 marks: interbreeding with fertile offspring means one species.)

Question 15 The **darker** form will become more common. Steps: the population shows inherited **colour variation**; on sooty bark the **pale beetles are seen and eaten** while dark beetles are camouflaged, so dark beetles are **more likely to survive and reproduce**; colour is **inherited**, so survivors pass the dark form on; and over generations the **share of the dark form rises** — the population changes without any beetle changing its own colour. (1 mark each across the steps: variation; selection by birds on sooty bark; inheritance; change in the population's shares.)

Question 16 Selection can only **sort the inherited variation already present** in the population — it cannot call new features into being. Example of what it can do: on brown bark, birds sorted the existing green/brown variation and the population became browner. Reason it cannot work “on purpose”: if no allele for a useful feature **exists** (variation arises only by mutation and the mixing of alleles, without direction), selection has nothing to favour, so the feature cannot appear because it would be useful. ∴ the direction comes from the environment's filter, not from a goal. (1 mark: selection sorts existing variation, with a correct example; 1 mark: new variation arises undirected by need; 1 mark each: explaining why a needed-but-absent feature cannot appear, and a concluding statement.)

Where this leads: the processes built here — variation, selection, inheritance, isolation and adaptation — are assumed by VCE Biology Unit 2, Area of Study 2 (“How do inherited adaptations impact on diversity?”), which extends them into biodiversity and the history of life — reference-only for this book. The **evidence** for the theory — the fossil record, biogeography and comparative embryology, and what the theory explains about biodiversity and relatedness — is taught in this band by Subtopic 9B, the partner half of this content description; the genetic machinery behind the variation (DNA, genes, alleles, mutation) is taught by Subtopic 7C, and reproduction and its mixing of instructions by Subtopic 7B.

The evidence: fossil record, biogeography, comparative embryology — biodiversity and relatedness

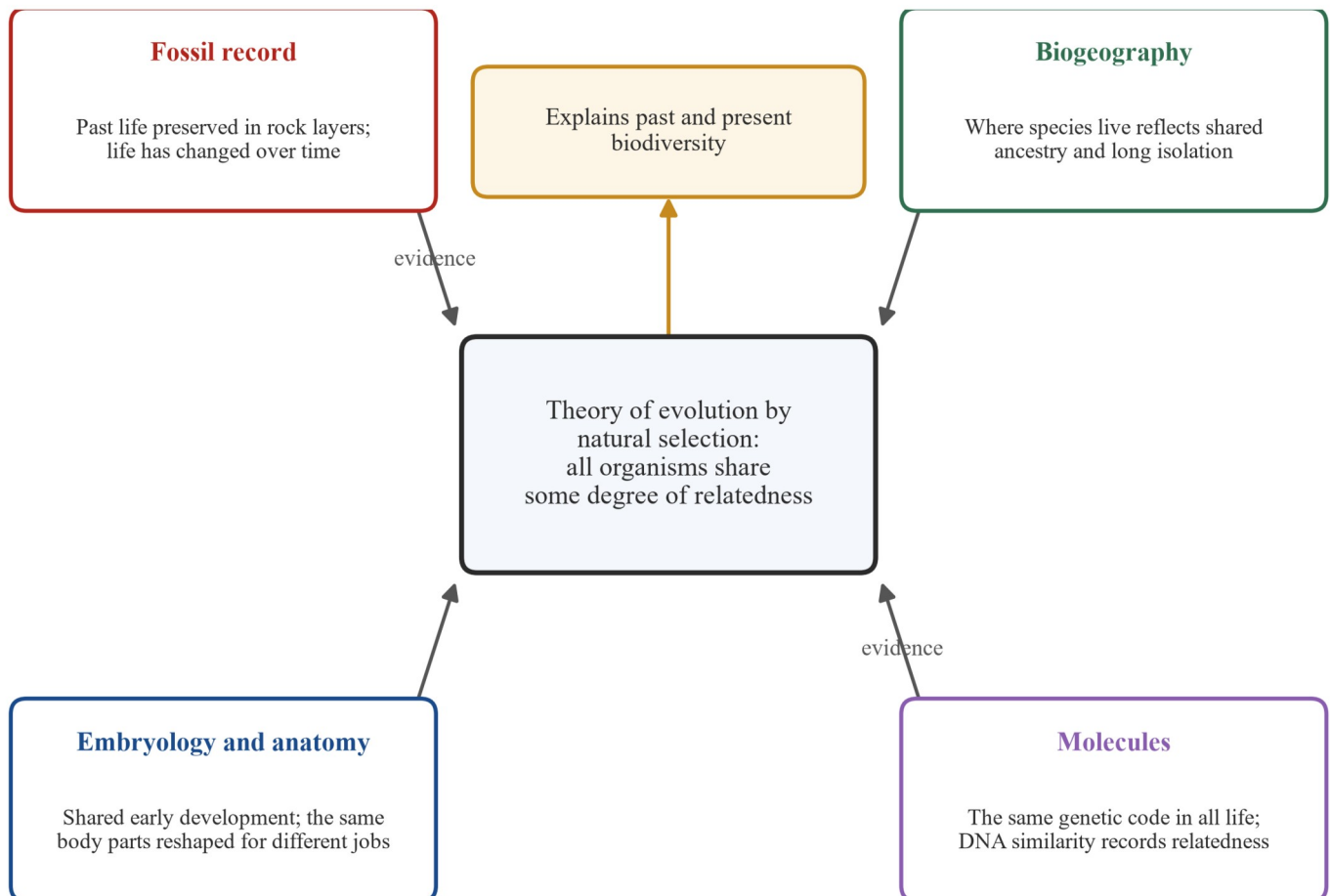
Chapter 9 — Biological sciences C: evolution and biodiversity (Science, Levels 9 and 10)

Subtopic 9B · VC2 Science Understanding — Biological sciences

CD code: VC2S10U05 (split delivery †; this subtopic is the partner, not the accountable owner) **Content description (verbatim):** “the theory of evolution by natural selection includes the processes of variation, isolation and adaptation and is supported by evidence including the fossil record, biogeography and comparative embryology; the theory explains past and present biodiversity and demonstrates how all organisms have some degree of relatedness to each other” **This subtopic’s limb (TOC §4 clause split):** the fossil record, biogeography and comparative embryology — the evidence supporting the theory — and what the theory explains about past and present biodiversity and the relatedness of all organisms. The accountable owner 9A delivers the other limb: the processes of variation, isolation, selection and adaptation. **Elaboration ids drawn on:** VC2S10U05.E02 · VC2S10U05.E03 · VC2S10U05.E07 (id VC2S10U05.E06 is withheld — not authored — under the TOC’s D10 ICIP decision; ids VC2S10U05.E01 · VC2S10U05.E04 · VC2S10U05.E05 are drawn on by Subtopic 9A.) **Achievement standard (extract served):** “They describe the evidence supporting the theory of evolution by natural selection.” (This CD carries a single standard sentence; 9B serves the evidence half of it and 9A the processes half — TOC D6.) **Maths interlock (D11):** VC2M9M02 — scientific notation for very large measurements and timescales, used here for the deep-time axis of the fossil record.

Theory

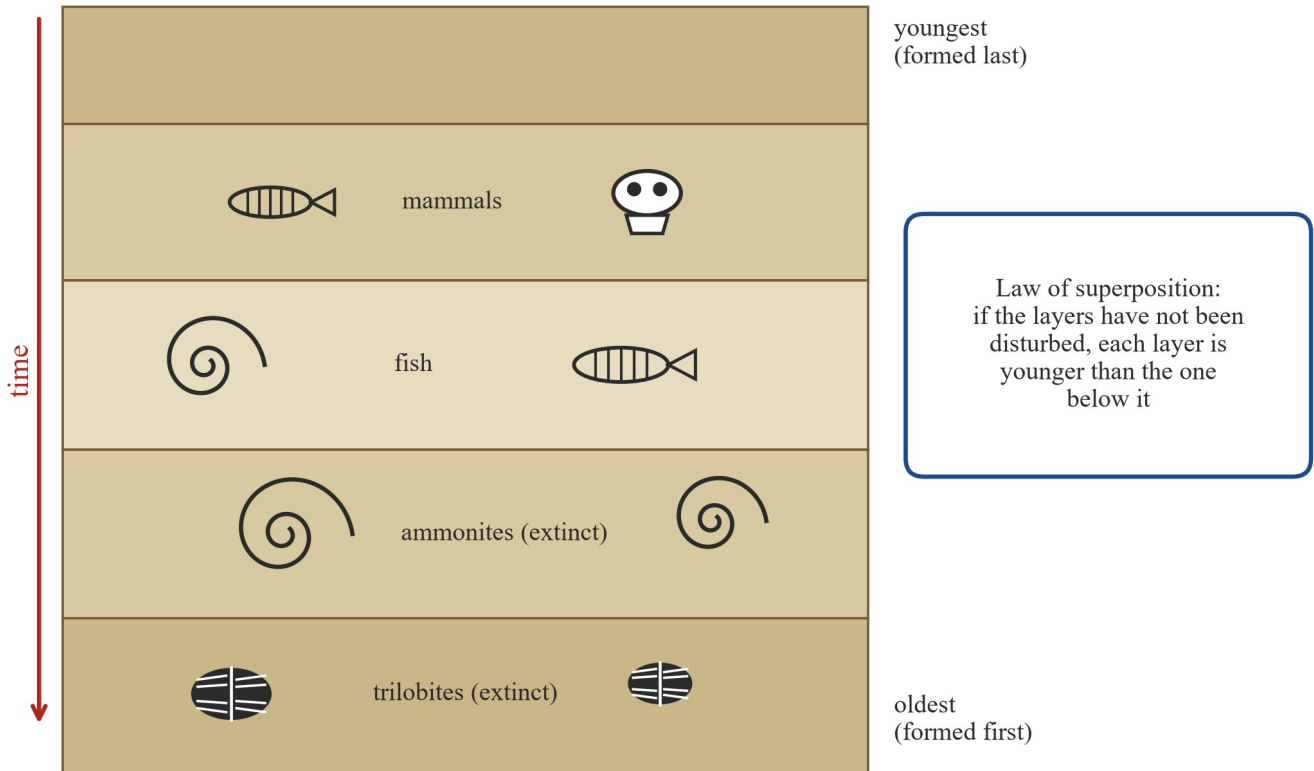
What this subtopic does. Subtopic 9A taught the *process* of evolution by natural selection: within a population there is variation; in a given environment some variants survive and leave more young; and isolated populations can adapt, generation by generation. This subtopic asks the next question: *how do we know the process really ran over the whole history of life?* A scientific theory earns acceptance when many independent lines of evidence all point the same way. Four lines are examined here — the fossil record, biogeography, comparative embryology together with anatomy, and the molecules of life — and then the theory is used to explain biodiversity and relatedness, and to frame a live scientific debate about Australia’s megafauna.



Summary map with the theory of evolution by natural selection at the centre and four evidence cards pointing to it: fossil record (past life preserved in rock layers; life has changed over time), biogeography (where species live reflects shared ancestry and long isolation), embryology and anatomy (shared early development; the same body parts reshaped for different jobs), and molecules (the same genetic code in all life; DNA similarity records relatedness); an arrow from the theory points to a box reading “explains past and present biodiversity”

Line 1 — the fossil record. A **fossil** is the preserved remain or trace of a once-living organism. Most fossils form in **sedimentary rock** — rock built up from layers of sand and mud (sediment) laid down over time. In a stack of layers that has not been disturbed, each layer is younger than the one below it; that rule is the **law of superposition**. So the fossils in a lower layer are older than the fossils in a higher layer, and the stack reads like the pages of a history book, oldest at the bottom.

Sedimentary rock layers keep fossils in time order



Five horizontal sedimentary rock layers stacked from oldest at the bottom to youngest at the top: trilobite fossils (labelled extinct) only in the lowest layer, ammonites (labelled extinct) in the next layers, fish fossils above them and a mammal skull in the top layer; a red arrow up the left side marks time, and a box states the law of superposition

The pattern the layers show is exactly what evolution predicts. The oldest layers hold the remains of simple organisms and of whole groups not alive today, such as **trilobites** (armoured sea animals) and **ammonites** (coiled-shell relatives of squid). Higher, younger layers hold fishes, and higher still, mammals. Life preserved in rock has changed over time in a steady order, and no layer ever holds an organism below the layers holding its ancestors.

The oldest Australian fossils. The oldest fossils found in Australia are **stromatolites** — layered, dome-shaped mounds built up by mats of microbes (mostly cyanobacteria, the light-using microbes that also form pond scum) trapping new sediment, layer on layer. In the Pilbara of Western Australia such structures occur in rock about 3.5 billion years old, among the oldest signs of life anywhere; and at Shark Bay, Western Australia, stromatolites are still forming today, so the mound-building process can be watched alive.

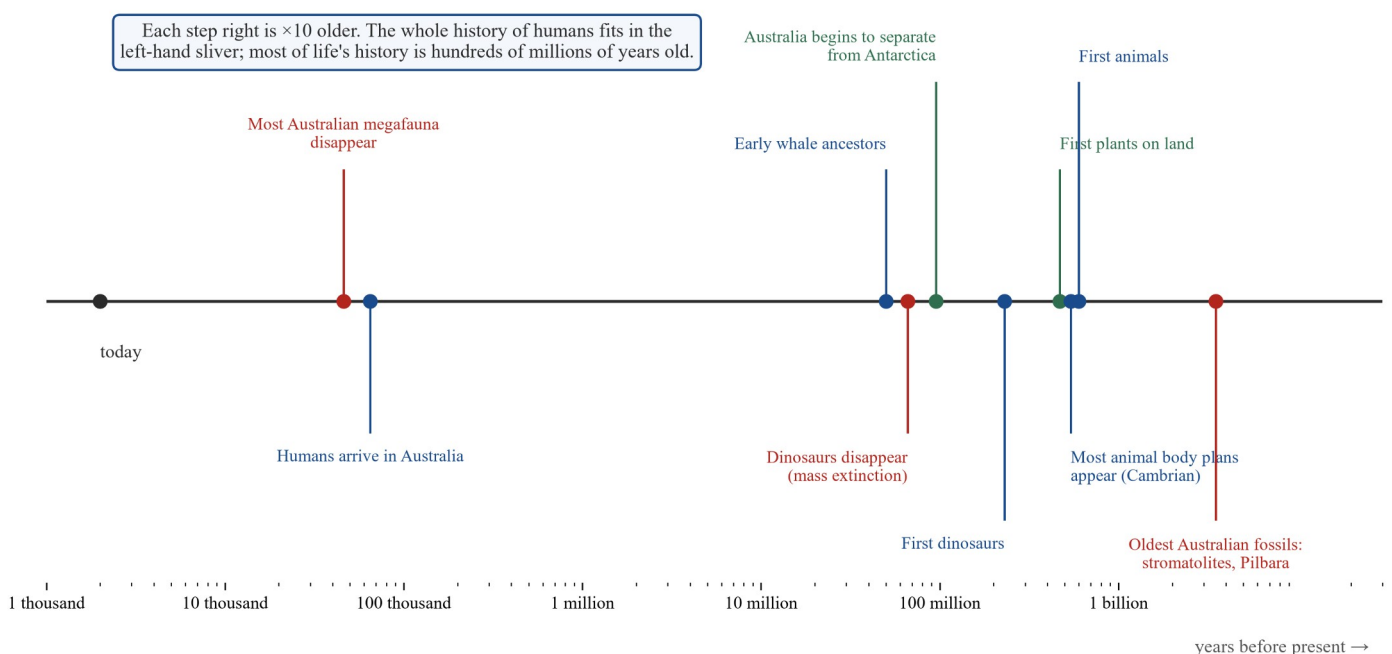


Two panels: left, a fossil stromatolite drawn as a dome of curved layered bands in a rock layer, labelled “fossil form — Pilbara, Western Australia, rocks about 3.5 billion years old”; right, living stromatolites as layered domes in shallow seawater at Shark Bay with green microbes growing on top, and a close-up inset of alternating green microbial and pale sediment layers

Source: Djokic et al., “Earliest signs of life on land preserved in ca. 3.5 Ga hot spring deposits”, *Nature Communications* 8, 2017. <https://doi.org/10.1038/ncomms15263> — retrieved 2026-08-21.

Source: Geoscience Australia, “Algae to Zooxanthellae | Geoscience Australia”, n.d. <https://www.ga.gov.au/education/algae-to-zooxanthellae-life-in-the-rock-record> — retrieved 2026-08-21.

Deep time. The history of life is measured on a scale that is hard to feel, so it is written in scientific notation (VC2M9M02): 65 000 = 6.5×10^4 , and 3.5 billion = 3.5×10^9 . The timeline below uses a multiplying scale: each step to the right is ten times older.



A log-scale timeline of years before present running from 1 thousand to beyond 1 billion, with labelled events: most Australian megafauna disappear at about 46 000 years, humans arrive in Australia at about 65 000 years, early whale ancestors at about 50 million years, dinosaurs disappear (mass extinction) at 66 million years, Australia begins to separate from Antarctica at about 95 million years, first dinosaurs at about 230 million years, first plants on land at about 470 million years, most animal body plans appear (Cambrian) at about 540 million years, first animals at

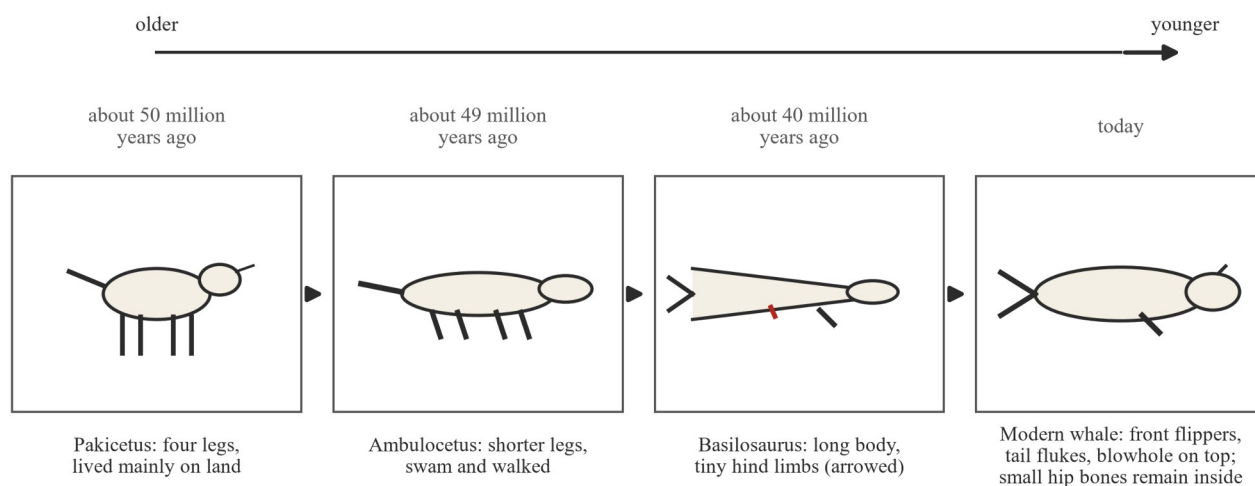
about 600 million years, and the oldest Australian fossils (stromatolites, Pilbara) at about 3.5 billion years; a box notes that each step right is ten times older and that human history fits in the left-hand sliver

Two things to notice. First, the whole history of humans sits in the sliver at the left: humans arrived in Australia about 65 000 years ago, and most of Australia's megafauna disappeared not long after, inside the window about 40 000–50 000 years ago. Second, the ordering of events matches the law of superposition: whale ancestors appear in rocks younger than the first dinosaurs, and animals with backbones appear only after the Cambrian spread of animal body plans (about 5.4×10^8 years ago). (How a rock is given a number of years — dating with unstable atoms and half-lives — is taught in subtopic 10B; here the order comes from superposition, and the ages quoted are the published ones below.)

Source: Clarkson et al., “Human occupation of northern Australia by 65,000 years ago”, *Nature* 547, 2017. <https://doi.org/10.1038/nature22968> — retrieved 2026-08-21.

Source: Roberts et al., “New Ages for the Last Australian Megafauna: Continent-Wide Extinction About 46,000 Years Ago”, *Science* 292, 2001. <https://doi.org/10.1126/science.1060264> — retrieved 2026-08-21.

Transitional forms: the whale series. Evolution predicts *transitional forms* — organisms with a mix of features from an older group and a younger one — and the fossil record supplies them. The sequence of whale ancestors, found in Eocene rocks of Pakistan, is one of the best:



Schematic drawings. From left to right the body becomes longer and more streamlined, the front limbs become flippers, and the hind limbs shrink until only small hip bones remain — a sequence of transitional forms from land to sea.

Four schematic drawings in a row from older to younger: Pakicetus, a four-legged mammal that lived mainly on land about 50 million years ago; Ambulocetus with shorter legs, which swam and walked, about 49 million years ago; Basilosaurus, a long-bodied fully aquatic form with tiny hind limbs (arrowed), about 40 million years ago; and a modern whale with front flippers, tail flukes and a blowhole, with small hip bones remaining inside; a caption notes the body becomes longer and more streamlined, the front limbs become flippers, and the hind limbs shrink until only small hip bones remain

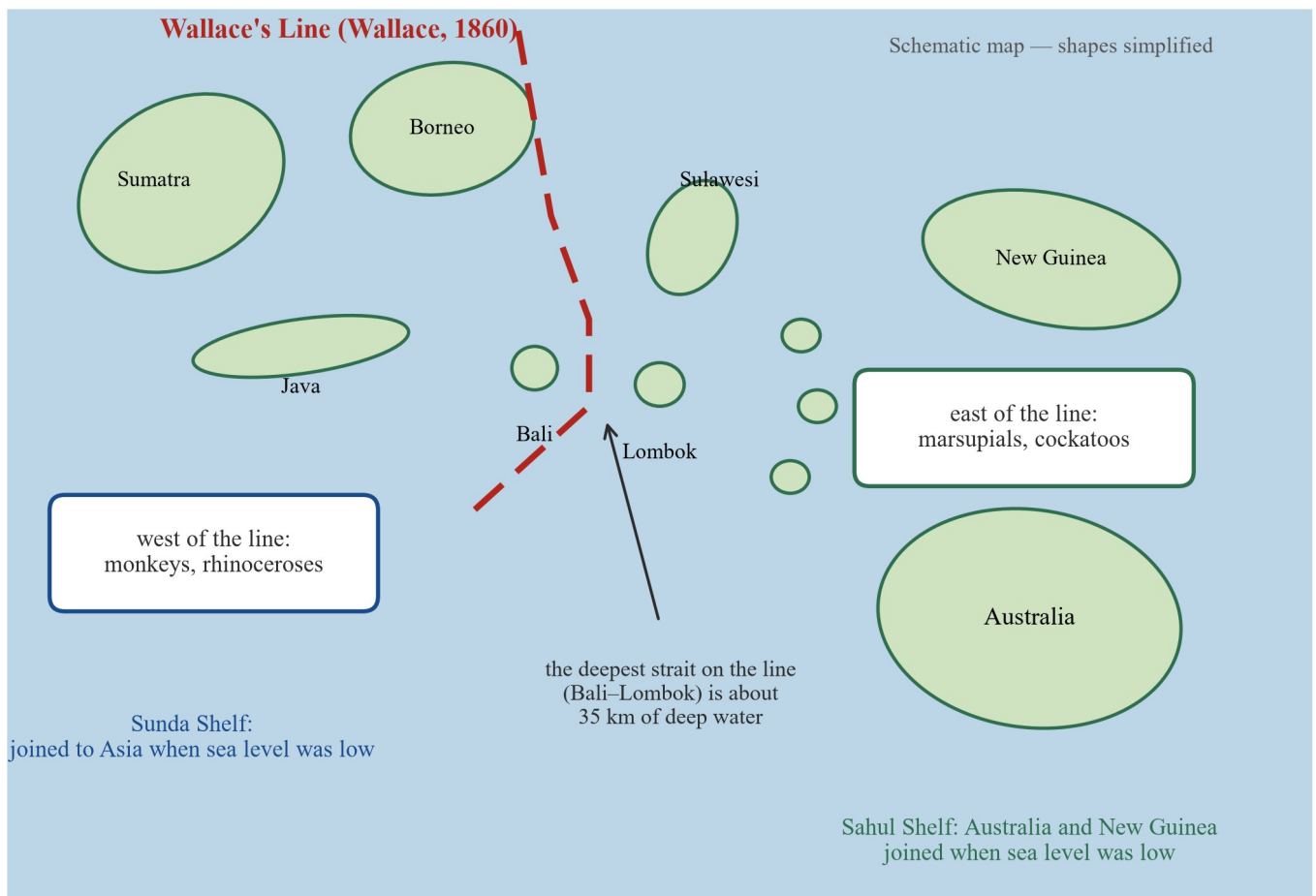
From left to right the body becomes longer and more streamlined, the front limbs become flippers, and the hind limbs shrink until only small hip bones remain inside the body — hip bones that no longer support walking. Each stage is found in rock layers of the right age, older stages in older layers. A land mammal that became fully aquatic left exactly the trail of in-between forms the theory says it should.

Source: Thewissen, Williams, Roe & Hussain, “Skeletons of terrestrial cetaceans and the relationship of whales to artiodactyls”, *Nature* 413, 2001. <https://doi.org/10.1038/35095005> — retrieved 2026-08-21.

Source: Thewissen, Hussain & Arif, “Fossil Evidence for the Origin of Aquatic Locomotion in Archaeocete Whales”, *Science* 263, 1994. <https://doi.org/10.1126/science.263.5144.210> — retrieved 2026-08-21.

Source: Gingerich et al., “New whale from the Eocene of Pakistan and the origin of cetacean swimming”, *Nature* 368, 1994. <https://doi.org/10.1038/368844a0> — retrieved 2026-08-21.

Line 2 — biogeography. **Biogeography** is the study of where species live and why. In an 1860 paper on the zoological geography of the Malay Archipelago (the island group of South-East Asia), Alfred Russel Wallace drew a line through the islands between Asia and Australia: west of the line the animals are Asian (monkeys, rhinoceroses), east of it they are Australian (marsupials, cockatoos) — even though the islands either side look alike and sit close together. The line runs through a deep-water strait that stayed open even when falling sea level joined the other islands into two great shelves, so animals could not cross it.



Schematic map of the islands between Asia and Australia with Wallace's Line drawn as a red dashed line through the deep strait between Bali and Lombok: on the Sunda Shelf west of the line (Sumatra, Java, Borneo, joined to Asia when sea level was low) the animals are monkeys and rhinoceroses; on the Sahul Shelf east of the line (Australia and New Guinea, joined when sea level was low) they are marsupials and cockatoos; shapes simplified

Source: Wallace, "On the Zoological Geography of the Malay Archipelago", Journal of the Proceedings of the Linnean Society of London. Zoology, 1860. <https://doi.org/10.1111/j.1096-3642.1860.tb00090.x> — retrieved 2026-08-21.

The same pattern holds at continent scale. Australia's native large land mammals are almost all **marsupials** — mammals whose young are born very undeveloped and finish growing in a pouch: kangaroos, koalas, wombats, possums, quolls, the Tasmanian devil. On the other continents the native large land mammals are almost all **placental** mammals, which grow their young longer inside the body before birth.

The same kind of animal on different continents: marsupials in Australia, placental mammals elsewhere

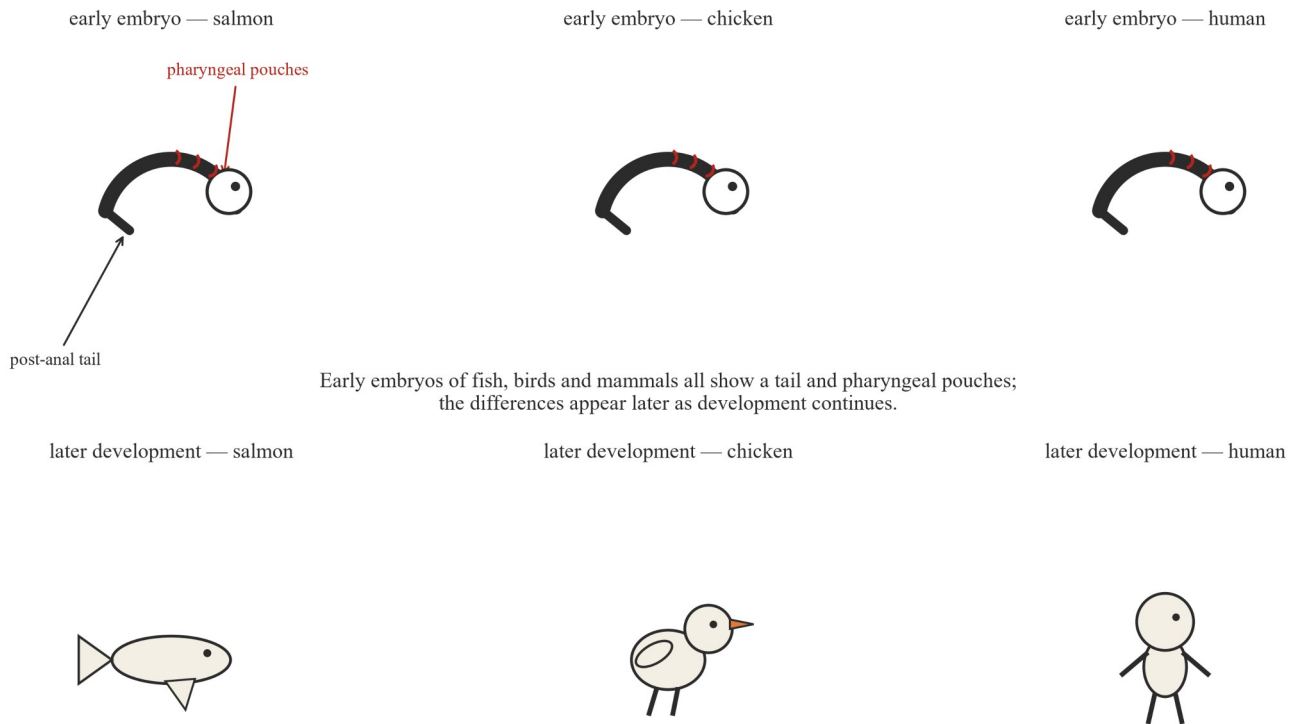
Australia	South America	Africa, Asia and Europe
red kangaroo	opossums (marsupials)	no native marsupials
koala	deer, cats, mice, monkeys ...	lions, deer, mice, monkeys ...
common wombat		
brush-tail possum		
quoll		
Tasmanian devil		
Native large land mammals: almost all marsupials	A few marsupials survive, but placental mammals dominate	Native mammals are almost all placental

Three panels comparing native large land mammals: Australia, where almost all are marsupials (red kangaroo, koala, common wombat, brush-tail possum, quoll, Tasmanian devil); South America, where a few marsupials such as opossums survive but placental mammals (deer, cats, mice, monkeys) dominate; and Africa, Asia and Europe, where there are no native marsupials and mammals are almost all placental

Why the difference? Not because one kind suits Australia's climate better — it is history. Australia began to separate from Antarctica about 95 million years ago and drifted north as an island continent, so the mammals on it evolved in isolation from the rest of the world for tens of millions of years. Where land stayed joined (as Asia and Europe are, and as South America mostly was), placental mammals spread and came to dominate. Isolation plus shared descent predicts exactly this: nearby species look alike because they share ancestors, and long-separated regions carry different branches of the same family tree.

*Source: Veevers & Eittreim, "Reconstruction of Antarctica and Australia at breakup (95 ± 5 Ma) and before rifting (160 Ma)", *Australian Journal of Earth Sciences* 35, 1988. <https://doi.org/10.1080/08120098808729453> — retrieved 2026-08-21.*

Line 3 — comparative embryology and anatomy. An **embryo** is an organism in its early stages of development, before birth or hatching. **Comparative embryology** compares those early stages across species. The early embryos of a fish, a bird and a human look very alike: each shows a tail beyond the body (a **post-anal tail**) and a series of pouches in the neck region (**pharyngeal pouches**). In a fish the pouches develop into gills; in chicks and humans they are rebuilt into parts of the jaw, ear and throat. The differences between the groups appear later, as development continues.



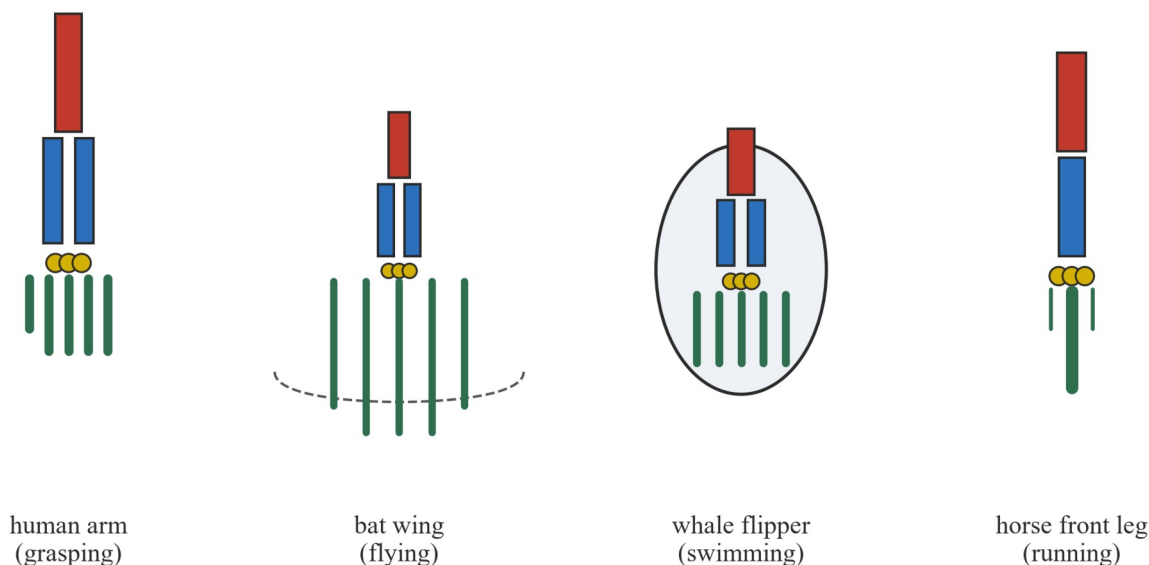
Schematic drawings — not to scale.

Two rows of schematic drawings: the top row shows the early embryos of a salmon, a chicken and a human, each with a tail and pharyngeal pouches labelled on the first panel; the bottom row shows the later development of each into a fish with fins, a chick with a wing and beak, and a human with arms and legs; a caption notes that the differences appear later as development continues

Shared starting points are evidence of shared ancestry: unrelated groups would be unlikely to build the same early body, with the same pouches and tail, unless they inherited the plan from a common ancestor.

Anatomy says the same thing. The human arm, the bat's wing, the whale's flipper and the horse's front leg do different jobs, but inside they are built from the same bones in the same order: one upper bone, two lower bones, wrist bones, and digits. A limb built on five digits is called the **pentadactyl limb**, and body parts that share the same underlying build but do different jobs are called **homologous** structures. The simplest explanation is inheritance with reshaping: one limb plan, laid down in a common ancestor, modified for grasping, flying, swimming and running.

one upper bone (humerus)
 two lower bones (radius, ulna)
 wrist bones (carpals)
 digits (fingers/toes)



Same bones, same order, different jobs — the pentadactyl (five-digit) limb plan, schematic and not to scale

Four schematic limb diagrams with bones colour-coded the same way in each: one upper bone (humerus), two lower bones (radius, ulna), wrist bones (carpals) and digits; the human arm grasps, the bat wing flies, the whale flipper swims and the horse front leg runs; the caption reads “same bones, same order, different jobs — the pentadactyl (five-digit) limb plan”

Line 4 — molecules. All known life stores its instructions in DNA, using the same four bases (A, T, G and C) read by the same **genetic code** — the chemical dictionary that turns a DNA sequence into a body (DNA itself is taught in subtopic 7C). The universal code is itself evidence that all life shares a common ancestor; and once the code is shared, the same gene can be compared position by position between species. The pattern is simple: the fewer the differences between two species’ copies of a gene, the more recently they share a common ancestor.

The same 24-base gene compared position by position

Species A	A	C	G	T	T	C	A	G	A	A	G	C	G	C	G	C	A	C	T	G	T	A	C
Species B	A	C	G	A	T	C	A	G	A	A	G	C	G	C	G	C	G	C	T	G	T	A	C
Species C	A	G	G	T	T	C	C	G	A	C	G	C	G	C	T	C	G	A	C	T	T	C	C

Differences in the same gene: A–B: 2 of 24 A–C: 6 of 24 B–C: 8 of 24

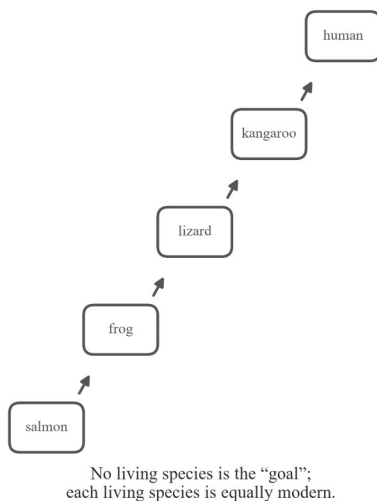
Fewer differences = more recent common ancestor: A and B are the closest pair.
Simulated data for practice.

The same 24-base gene written as three rows of A, T, G and C boxes for species A, B and C, with the differing positions ringed in red: A and B differ at 2 of 24 positions, A and C at 6 of 24, and B and C at 8 of 24; a caption notes that fewer differences means a more recent common ancestor, and labels the data as simulated data for practice

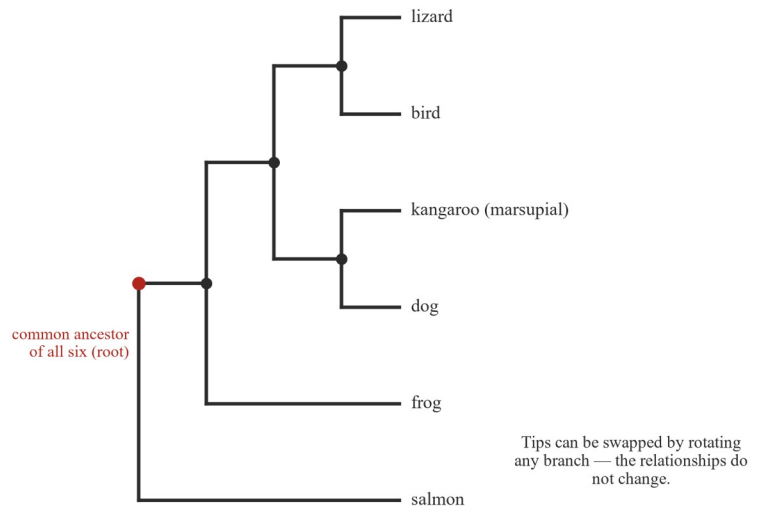
(The figure is simulated data for practice; real comparisons use genes hundreds to thousands of bases long, and they give the same nested pattern as the fossils, the embryos and the geography.)

Relatedness: a tree, not a ladder. Put the four lines together and they agree on one picture: all organisms have some degree of relatedness to each other. The right way to draw that relatedness is a branching tree. Each branch point is a common ancestor; the tips are living species. Rotate any branch and the relationships do not change — which shows why the old picture of a *ladder of progress*, with a fish “becoming” a frog, a frog “becoming” a lizard and so on up to a human, is wrong. No living species is the ancestor of another living species; every species alive today is equally modern, and each sits at its own tip of the tree.

WRONG: a ladder of progress



RIGHT: a branching tree of descent

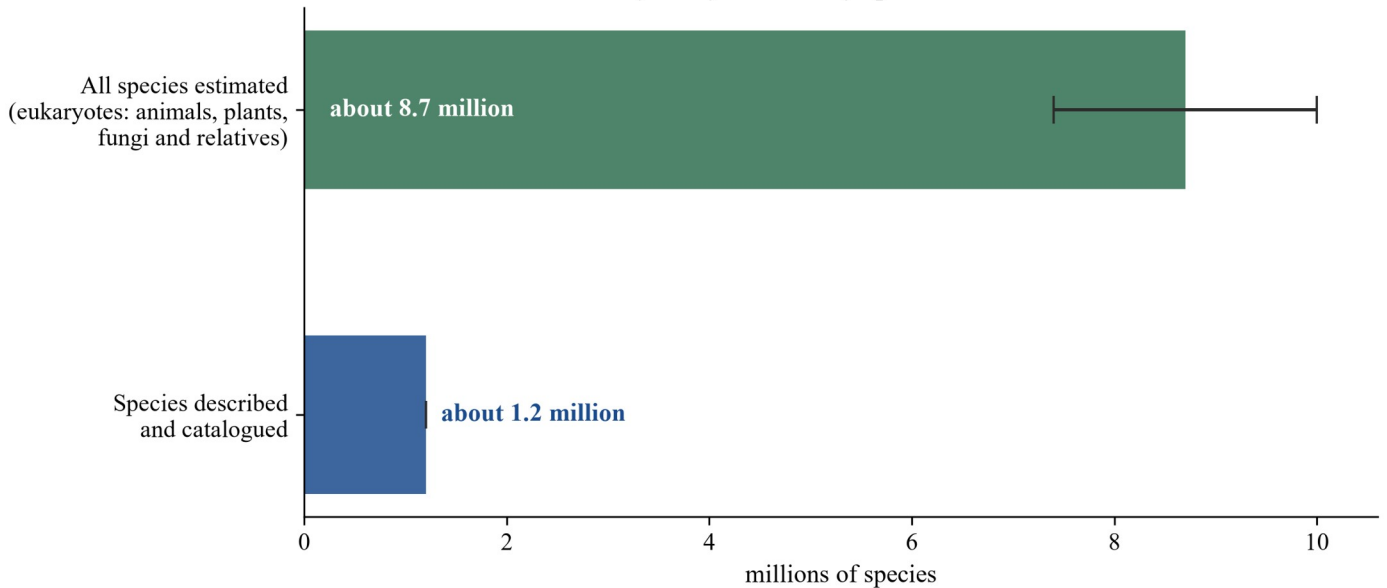


Two panels: left, crossed out as wrong, a ladder of progress climbing through salmon, frog, lizard, kangaroo and human, with a note that no living species is the goal and each living species is equally modern; right, a branching tree of descent for salmon, frog, lizard, bird, kangaroo (marsupial) and dog, with branch points marked as common ancestors, the root labelled as the common ancestor of all six, and a note that tips can be swapped by rotating any branch without changing the relationships

Biodiversity as a product of evolution. Biodiversity — the variety of life — is large beyond counting. About 1.2 million species have been described and named, and the total number of species of animals, plants, fungi and their relatives on Earth today has been estimated at about 8.7 million (± 1.3 million): most species alive today are still unknown to science.

Only about 1 in 7 of the estimated species had been described when this estimate was made (Mora et al., 2011) — most species are still unknown.

Biodiversity today: how many species are there on Earth?

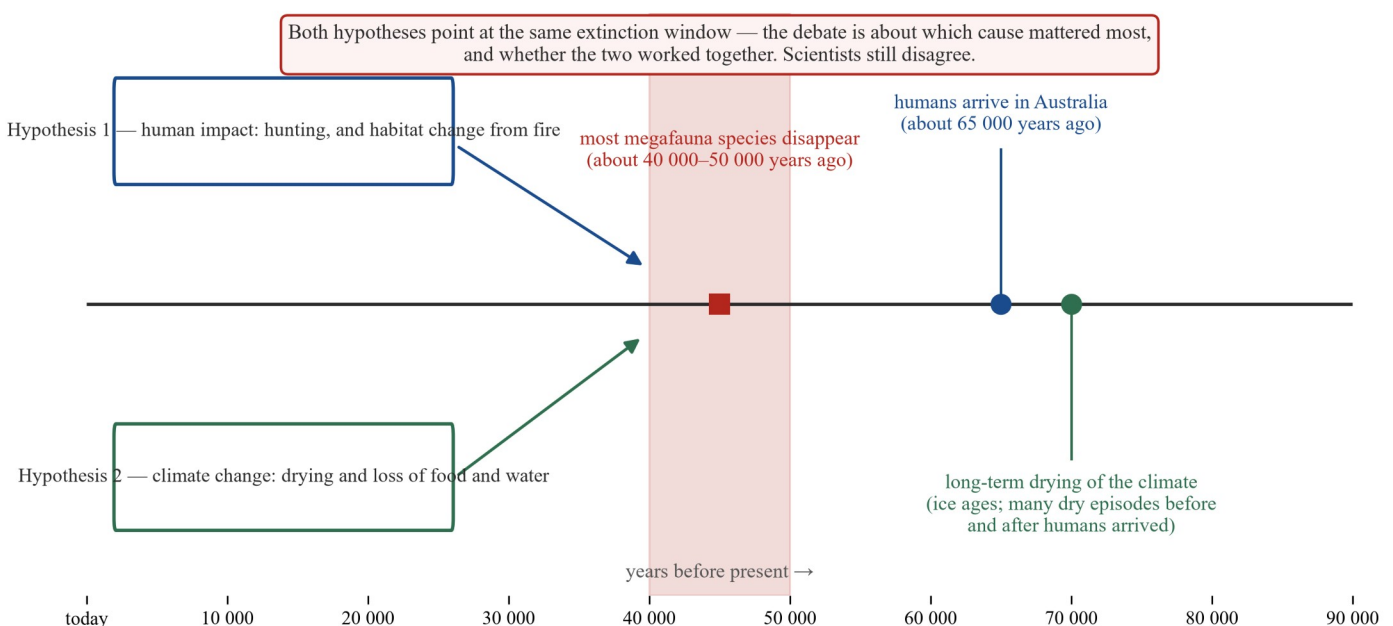


Horizontal bar chart in millions of species: about 1.2 million species described and catalogued, against about 8.7 million (error bar ± 1.3 million) estimated species of animals, plants, fungi and relatives; a note says only about 1 in 7 of the estimated species had been described, so most species are still unknown

Source: Mora et al., “How Many Species Are There on Earth and in the Ocean?”, *PLoS Biology* 9(8), 2011.
<https://doi.org/10.1371/journal.pbio.1001127> — retrieved 2026-08-21.

Evolution explains both the size of that number and its pattern. Branching descent, repeated over hundreds of millions of years, filling new ways of life and split by isolation, produces many species from few; and extinction — most of all the great mass extinctions marked on the deep-time axis — prunes the tree and opens room for new branches. Past and present biodiversity is the outcome of the same process 9A taught, running over deep time.

A live debate: Australia’s megafauna. Until about 50 000 years ago Australia carried **megafauna** — giant versions of more familiar animals, such as *Diprotodon* (a plant-eating relative of wombats the size of a hippopotamus), giant short-faced kangaroos, and *Genyornis*, a heavy flightless bird. Most of these species disappear from the fossil record inside the window about 40 000–50 000 years ago. Why? Two hypotheses are in debate, and both are serious.



A timeline from today back to 90 000 years before present showing: humans arriving in Australia at about 65 000 years, a shaded extinction window at about 40 000–50 000 years in which most megafauna species disappear, and

long-term drying of the climate (ice ages, with dry episodes before and after humans arrived); two boxes state hypothesis 1, human impact through hunting and habitat change from fire, and hypothesis 2, climate change through drying and loss of food and water; a note says both hypotheses point at the same extinction window and scientists still disagree

Hypothesis 1 — human impact. Humans arrived by about 65 000 years ago, and the extinctions follow within some tens of thousands of years. Hunting, egg-collecting and habitat change (for example more burning of the landscape) could have driven slow-breeding giant animals to extinction even without heavy hunting. Evidence cited for this side: Roberts et al. (2001) dated the last megafauna across the continent to about 46 000 years ago, after human arrival; and Miller et al. (1999) read the burnt and collected eggshells of *Genyornis* as a sign of human hunting.

Hypothesis 2 — climate change. The Pleistocene — the ice-age period covering the last few million years — was a time of long-term drying in Australia, with many dry swings before and after humans arrived. On this view the megafauna were already stressed by the loss of water and food plants, and some may have been rare or gone before 65 000 years ago, so the overlap with humans is thinner than it looks. Evidence cited for this side: Wroe & Field (2006) reviewed the fossil sites and argued that the direct evidence for human hunting is thin, and that climate change alone remains a sufficient cause.

Both hypotheses point at the same extinction window; they disagree about which cause mattered most, and the two may have worked together. The debate is live and properly scientific: the fossil record for those tens of thousands of years is thin, and each side tests the other's dates and sites. That is the process of science — the same process described in Chapters 1 and 5 — working on an incomplete record.

Source: Miller et al., "Pleistocene Extinction of *Genyornis newtoni*: Human Impact on Australian Megafauna", *Science* 283, 1999. <https://doi.org/10.1126/science.283.5399.205> — retrieved 2026-08-21.

Source: Wroe & Field, "A review of the evidence for a human role in the extinction of Australian megafauna and an alternative interpretation", *Quaternary Science Reviews* 25, 2006. <https://doi.org/10.1016/j.quascirev.2006.03.005> — retrieved 2026-08-21.

Activities

Activity 1 — Deep-time cards and $\times 10$ steps. Copy the ten events of the deep-time figure onto cards, each with its age written in scientific notation (for example humans arrive: 6.5×10^4 years). Shuffle the cards, deal them to a partner, and race to rebuild the timeline from today backwards. Then, for each pair of neighbours on your rebuilt line, work out the age ratio (for example the first dinosaurs, 2.3×10^8 years, and the disappearance of the dinosaurs, 6.6×10^7 years, are neighbours; their ratio is about 3.5, less than one $\times 10$ step). Which gap between neighbours is the biggest jump in $\times 10$ steps?

Activity 2 — Sort the evidence. Sort each statement below under the line of evidence it belongs to (fossil record / biogeography / embryology and anatomy / molecules), and for one of them write a sentence saying *why* it supports evolution: (i) a whale's body carries small hip bones that no longer support walking; (ii) the lower a rock layer, the older its fossils; (iii) human embryos show a tail and pharyngeal pouches; (iv) Australia's native large mammals are mostly marsupials, while Africa's are not; (v) a human gene and a chimpanzee gene differ at only a few positions in every hundred; (vi) *Ambulocetus* had legs for walking and a body built for swimming.

Activity 3 — The megafauna debate, argued fairly. Work in pairs: one of you takes Hypothesis 1 (human impact), the other Hypothesis 2 (climate change). Each writes the two strongest pieces of evidence for their side from this subtopic, and one question their side cannot yet answer. Then, together, write a list of what *both* hypotheses agree about. A hypothesis argued at its strongest, and tested against the other side's evidence, is how science treats a live debate.

Worked examples

Data in this section are quoted to the significant figures shown (two to four), and final answers match the precision of the given data unless the arithmetic is exact.

Example 1 — scaffolded

- (a) Write 65 000 years and 3.5 billion years in scientific notation.
(b) How many times older are the Pilbara stromatolite rocks than the first human arrival in Australia?

Working	Comment
$65\,000 = 6.5 \times 10^4$ years	A number between 1 and 10 (6.5) multiplied by a power of ten; the decimal point moves 4 places.
$3.5 \text{ billion} = 3\,500\,000\,000 = 3.5 \times 10^9$ years	One billion is 10^9 .
$(b) (3.5 \times 10^9) \div (6.5 \times 10^4) = 0.54 \times 10^5$ $= 5.4 \times 10^4$, about 54 000 times older	Divide the front numbers ($3.5 \div 6.5 \approx 0.54$) and subtract the powers ($10^9 \div 10^4 = 10^5$). Rewrite in standard scientific notation. Humans are a very recent arrival on the deep-time axis.

Example 2 — scaffolded

Use the molecular figure (simulated data): species A and B differ at 2 of 24 positions, A and C at 6 of 24, and B and C at 8 of 24. (a) Which two species share the most recent common ancestor? (b) Show that the B–C count is consistent with the A–B and A–C counts. (c) What shared feature of all life makes this comparison possible at all?

Working	Comment
(a) A and B	Fewest differences (2 of 24) → most recent common ancestor.
(b) $2 + 6 = 8$	Each difference arose on one branch after the species split, so the two A–B differences plus the six A–C differences also appear when B is compared with C.
(c) the same genetic code	All life reads DNA the same way, so the same gene can be lined up position by position in any two species.

Example 3 — unscaffolded

Three undisturbed sedimentary layers. Layer X holds only trilobite-type fossils; layer Y, above it, holds trilobites and fishes; layer Z, above Y, holds fishes and mammals. Layer X is dated at 5.0×10^8 years and layer Z at 1.0×10^8 years (the dating method is subtopic 10B's). (a) Put the layers in order from oldest to youngest, naming the rule you used. (b) Does that rule tell you how many years passed between layer X and layer Y? Explain. (c) How many times older is layer X than layer Z?

The rule is the law of superposition: undisturbed layers lie oldest at the bottom. The fossil order agrees (trilobites alone → trilobites + fishes → fishes + mammals), so the order is **X, then Y, then Z**.

- (b) No. Superposition gives *order*, not *duration*: it says X is older than Y but not by how much. A number of years needs a dating method (10B).
(c) Divide the older age by the younger:

$$\frac{5.0 \times 10^8}{1.0 \times 10^8} = 5.0.$$

Layer X is **5 times** older than layer Z.

Example 4 — unscaffolded

The first dinosaurs appear about 2.3×10^8 years ago; humans arrive in Australia 6.5×10^4 years ago. (a) Calculate how many times older the first dinosaurs are than the first human arrival. (b) The deep-time axis says each step to the right is $\times 10$ older. How many $\times 10$ steps apart are these two events?

- (a) Divide the older age by the younger:

$$\frac{2.3 \times 10^8}{6.5 \times 10^4} = 0.35 \times 10^4 = 3.5 \times 10^3.$$

The first dinosaurs are about **3 500 times** older than the first human arrival.

- (b) The ratio from (a) is about 3.5×10^3 , which sits between 10^3 and 10^4 , so the two events are **between three and four $\times 10$ steps apart — about three and a half**. Check: three $\times 10$ steps up from 6.5×10^4 reach 6.5×10^7 , and a fourth step would reach 6.5×10^8 , which overshoots 2.3×10^8 .
-

Practice questions

Scaffolded questions

Question 1 About the fossil-layers figure: (a) Which layer is oldest — the one holding trilobites or the one holding mammals? (b) Name the rule that lets you decide. (c) A new fossil is found in the layer directly below the fish layer. Is it older or younger than the fish?

Question 2 Using the deep-time figure: (a) Write 65 000 years in scientific notation. (b) Write 3.5 billion years in scientific notation. (c) Of humans arriving, the dinosaurs disappearing and the first animals, which event is oldest?

Question 3 About the whale series figure: (a) State one trend you can see from left to right. (b) What could *Ambulocetus* do that a modern whale cannot? (c) What do the tiny hind limbs of *Basilosaurus* suggest about its ancestors?

Question 4 About Wallace's Line: (a) Which side of the line has marsupials as the native mammals? (b) Why did the deep strait on the line stop animals crossing, even when sea level fell? (c) What does the line show about isolation and shared descent?

Question 5 About the embryo figure: (a) Name the two features the early embryos of a fish, a bird and a human share. (b) When do the differences between the three appear? (c) What does shared early development suggest about the three groups?

Question 6 About the molecular figure (simulated data): (a) Which pair of species is the most closely related? (b) How many of the 24 positions differ between A and C? (c) Why can the same gene be compared across species at all?

Un scaffolded questions

Question 7 Define *biogeography* and give one example from this subtopic that supports evolution by natural selection.

Question 8 Define *homologous structures*, using the pentadactyl limb as your example.

Question 9 Explain how the fossil record supports the theory of evolution by natural selection. Refer to both the order of fossils in rock layers and transitional forms.

Question 10 Australia's native large mammals are almost all marsupials, while Europe's are almost all placental mammals. Explain why, using the ideas of isolation and shared descent.

Question 11 Outline the human-impact hypothesis for the megafauna extinctions, with one piece of evidence cited for it in this subtopic. Name the researchers.

Question 12 Outline the climate-change hypothesis for the megafauna extinctions, with one piece of evidence cited for it in this subtopic. Name the researchers.

Question 13 The two megafauna hypotheses disagree, yet they agree on one key fact. State it, and state one reason the debate is still open.

Question 14 (a) From the biodiversity figure, state the described and the estimated number of species. (b) Hence state, as a fraction, roughly how many of the estimated species had been described. (c) Explain how evolution by natural selection accounts for so large a number of species.

Question 15 About the relatedness figure: (a) which two of the six species share the most recent common ancestor on the tree? (b) Explain why the ladder of progress is a wrong picture of the same relationships.

Question 16 Pick two different lines of evidence from this subtopic and, for each, explain in one or two sentences how it independently supports the idea that all organisms have some degree of relatedness.

Answers

Question 1 (a) the trilobite layer; (b) the law of superposition; (c) older. **Question 2** (a) 6.5×10^4 years; (b) 3.5×10^9 years; (c) the first animals. **Question 3** (a) see solution; (b) walk on land; (c) see solution. **Question 4** (a) the east; (b) see solution; (c) see solution. **Question 5** (a) a post-anal tail and pharyngeal pouches; (b) later, as development continues; (c) see solution. **Question 6** (a) A and B; (b) 6 of 24; (c) see solution. **Question 7** See solution. **Question 8** See solution. **Question 9** See solution. **Question 10** See solution. **Question 11** See solution. **Question 12** See solution. **Question 13** They agree on the extinction window (about 40 000–50 000 years ago); the record for those years is thin, so the cause is still debated. **Question 14** (a) about 1.2 million described; about 8.7 million estimated; (b) about 1 in 7; (c) see solution. **Question 15** (a) see solution; (b) see solution. **Question 16** See solution.

Fully-worked solutions

Question 1 (a) The **trilobite layer** is oldest — it lies lowest in the stack. (b) The **law of superposition**: in undisturbed sedimentary rock, each layer is younger than the one below it. (c) **Older** — a layer directly below the fish layer was laid down before it.

Question 2 (a) $65\,000 = 6.5 \times 10^4$ years. (b) 3.5 billion = 3.5×10^9 years. (c) **The first animals** (about 6×10^8 years ago), then the dinosaurs disappearing (6.6×10^7), then humans arriving (6.5×10^4).

Question 3 (a) Any visible trend: the body becomes longer and more streamlined; the front limbs become flippers; the hind limbs shrink until only small hip bones remain. (b) *Ambulocetus* could **walk on land** as well as swim. (c) The tiny, useless-for-walking hind limbs suggest *Basilosaurus* **descended from four-legged, walking ancestors** — limbs inherited from them but no longer needed.

Question 4 (a) The **east** side (Australia, New Guinea and the islands towards them). (b) The strait held **deep water that never dried up**, even when falling sea level joined the other islands into shelves, so land animals could not cross. (c) Groups kept apart by a barrier **evolve separately**, so each side carries the descendants of its own ancestors — isolation plus shared descent makes neighbouring regions different.

Question 5 (a) A **post-anal tail** and **pharyngeal pouches**. (b) **Later**, as development continues — the adult fish, chick and human look very different. (c) That fish, birds and mammals **inherited the same early body plan from a common ancestor** — shared development is evidence of shared ancestry.

Question 6 (a) **A and B** — only 2 of 24 differences, the fewest. (b) **6 of 24**. (c) Because **all life uses the same genetic code** (the same four DNA bases read the same way), so one gene can be lined up position by position in any two species.

Question 7 Biogeography is the study of where species live and why. Example: Australia's mammals are mostly marsupials while other continents' are mostly placental, because Australia separated early and its mammals evolved in isolation — distribution matching shared descent, as evolution predicts. (Wallace's Line is an equally acceptable example.)

Question 8 Homologous structures are body parts in different species that share the same underlying build but do different jobs. The **pentadactyl limb** — one upper bone, two lower bones, wrist bones and digits — is built the same way in the human arm (grasping), the bat wing (flying), the whale flipper (swimming) and the horse leg (running): one inherited plan, reshaped for different jobs.

Question 9 The **order** of fossils matches descent with change: simple forms in the oldest layers, then fishes, then mammals, with no organism appearing below the layers holding its ancestors (law of superposition). **Transitional forms**, such as the whale series, show in-between stages in the right order — land mammal to fully aquatic whale, hind limbs shrinking to hip bones. Both patterns are what evolution by natural selection predicts and what no alternative explains as simply.

Question 10 Australia **began to separate from Antarctica about 95 million years ago** and drifted as an island continent. Its mammals were **isolated**, so the marsupial branch already present on it diversified without competition from the placental mammals that spread across the joined continents. Both faunas share deep ancestry (they are all

mammals), but **isolation let the two branches go different ways** — exactly the pattern biogeography predicts under evolution.

Question 11 The human-impact hypothesis: after humans arrived (by about 65 000 years ago), hunting, egg-collecting and habitat change drove the slow-breeding megafauna to extinction inside the window about 40 000–50 000 years ago. Evidence: **Roberts et al. (2001)** dated the continent-wide disappearance to about 46 000 years ago, after human arrival; **Miller et al. (1999)** read burnt and collected *Genyornis* eggshells as a sign of human hunting.

Question 12 The climate-change hypothesis: Pleistocene ice ages brought long-term drying to Australia, stressing the megafauna's water and food supply, so climate alone could have caused the extinctions. Evidence: **Wroe & Field (2006)** reviewed the fossil sites, found the direct evidence for human hunting thin, and argued that some megafauna may have been rare or gone before humans arrived.

Question 13 Both hypotheses agree that **most megafauna species disappear inside the window about 40 000–50 000 years ago**. The debate stays open because **the fossil record for those tens of thousands of years is thin** — few dated sites — so the timing of the last megafauna against the timing of human arrival and of dry swings is still being tested by both sides.

Question 14 (a) Described: **about 1.2 million**; estimated: **about 8.7 million (± 1.3 million)**. (b) $1.2 \div 8.7 \approx 0.14$, i.e. **about 1 in 7** of the estimated species. (c) Branching descent over deep time repeatedly splits populations — by isolation and adaptation (9A) — into new species, filling many ways of life; extinction prunes branches and opens room for new ones. Repeated splitting over hundreds of millions of years yields millions of species.

Question 15 (a) Any pair joined at the nearest branch point: **lizard and bird**, or **kangaroo and dog** (either pair is correct — on this tree both pairs are joined at the branch points nearest the tips). (b) On the tree, **every tip is a living, equally modern species**, and no tip sits “above” another — rotate a branch and the relationships are unchanged. The ladder pretends one living species is an ancestor or a “higher” version of another (salmon $\rightarrow$ frog $\rightarrow$... $\rightarrow$ human), which the branching pattern of common ancestors contradicts.

Question 16 Any two of: - **Fossil record** — transitional forms such as the whale series link older and younger groups in the right layer order, so living groups descend from shared earlier forms. - **Biogeography** — nearby regions carry similar species (and long-separated regions carry different branches of the same groups), as inheritance from local common ancestors predicts. - **Embryology and anatomy** — vertebrate embryos share a tail and pharyngeal pouches, and the pentadactyl limb is one bone plan reshaped for many jobs: shared build from shared ancestry. - **Molecules** — all life uses the same genetic code, and the number of DNA differences between species matches the closeness of their relatedness seen in the other lines.

Where this leads: within this book, the processes limb of VC2S10U05 — variation, isolation, selection and adaptation — is owned by subtopic 9A, and the methods that put numbers on the deep-time axis (unstable atoms and half-lives) are taught in subtopic 10B. Beyond school, the destination is VCE Biology Units 3 and 4, the Area of Study “*How are species related over time?*”, and VCE Environmental Science Unit 3, on the value of maintaining biodiversity (TOC §5, reference-only, D12). What carries forward from here is the habit of reading relatedness as a nested branching tree and never as a ladder of progress — the wrong idea VCE meets most often in this topic — together with deep-time skill in scientific notation (VC2M9M02). No VCE content is pre-taught here (TOC D9).

Test A

Topic test 3 — Biological sciences

Biological sciences · Chapters 7–9 · Subtopics 7A, 7B, 7C, 7D, 8A, 8B, 8C, 8D, 9A and 9B · Codes VC2S10U01, VC2S10U02, VC2S10U03, VC2S10U04 and VC2S10U05

Total: 40 marks · Section A (multiple choice): 10 marks · Section B (short/structured response): 30 marks, including one Punnett square item

8 of the 40 marks are inquiry-strand marks — Question 16 applies inquiry skills to the ruler-drop test of Subtopic 8A.

Planned for about 50 minutes. This paper is untimed — there is no time to beat.

This is a school-designed paper. It is a school-based assessment instrument of this book's own design — it is not a VCAA instrument, and it is not a VCAA examination. Levels 9 and 10 carry no external assessment; achievement at Levels 9 and 10 is reported against the Victorian Curriculum achievement standard on teacher judgement, and the marks here are one source of evidence towards that judgement.

Conditions

- Completion is **untimed**. The 50 minutes is planning guidance only; take as long as you need.
- **Reading support** is permitted. Your teacher may read any question out to you if you need it. Reading is not what is being looked at, and your teacher will not help with the answer.
- **No calculator is permitted on this paper.** A scientific calculator is permitted for Topic tests 4, 5 and 6 only, and nothing on this paper needs one anyway. No formula sheet. No reading time.
- Answer every question. For multiple-choice questions, circle the letter of the best answer. There is only one best answer for each question.

In this test you will:

- relate the structures of reproductive cells and organs to their functions, and compare sexual and asexual reproduction (Q1, Q6, Q12)
- explain how the nervous and endocrine systems coordinate responses and use negative feedback to maintain homeostasis, and apply inquiry skills to the ruler-drop test (Q2, Q7, Q13, Q16)
- distinguish infectious from non-infectious disease, and match control measures to the link of the chain of infection they break (Q3, Q8, Q14)
- explain inheritance — genes, alleles, chromosomes and meiosis — and predict the outcome of a monohybrid cross with a Punnett square (Q4, Q9, Q11)
- explain natural selection and describe the evidence for evolution (Q5, Q10, Q15)

Section A — Multiple choice (10 marks)

Each question is worth 1 mark. Circle the letter of the best answer.

Q1 (1 mark · VC2S10U01) Which organ produces sperm in human males?

A. Bladder B. Pancreas C. Testes D. Liver

Q2 (1 mark · VC2S10U02) Pupil constriction in bright light is a:

A. A conscious decision B. A reflex (rapid, automatic) C. An endocrine response only D. Random response

Q3 (1 mark · VC2S10U03) Tuberculosis is caused by a:

A. Bacterium B. Virus C. Fungus D. Parasite

Q4 (1 mark · VC2S10U04) A gene is a:

A. A whole chromosome B. A protein produced by the cell C. A feature of the organism that you can observe D. A stretch of DNA that carries one set of instructions

Q5 (1 mark · VC2S10U05) Natural selection requires:

A. Identical individuals with no variation B. Variation in heritable traits C. An unchanging environment D. Only asexual reproduction

Q6 (1 mark · VC2S10U01) Egg cells are typically much LARGER than sperm because:

A. They contain cytoplasm with a food store to support early development B. They carry many more chromosomes than sperm cells C. They need to be visible to the unaided eye D. They must swim faster than sperm cells

Q7 (1 mark · VC2S10U02) Why are nervous responses FASTER than endocrine responses?

A. Hormones travel directly along nerve fibres at the same speed B. Endocrine signals are faster because hormone molecules are smaller than nerve impulses C. Both systems respond at exactly the same speed because they use the same chemical messengers D. Electrical signals through neurons are faster than hormones carried by the blood

Q8 (1 mark · VC2S10U03) Why do antibiotics not work on viral infections?

A. Viruses replicate too quickly for any drug to reach them B. Antibiotics only act in acidic conditions inside the stomach C. Antibiotics target bacterial structures (such as cell walls) that viruses lack D. Viruses are physically larger than antibiotic molecules

Q9 (1 mark · VC2S10U04) How many chromosomes does a typical human body cell have?

A. 46 (23 pairs) B. 23 C. 92 D. 100

Q10 (1 mark · VC2S10U05) Individuals best adapted to local conditions are MORE likely to:

A. Die before reproducing B. Survive and reproduce, passing on traits C. Develop new traits during their lifetime D. Migrate away from the habitat

Section B — Short/structured response (30 marks)

Q11 (6 marks · VC2S10U04) Cystic fibrosis is a recessive condition. The dominant allele *C* gives the unaffected phenotype; the recessive allele *c* causes cystic fibrosis when no *C* is present. Two unaffected parents are both carriers, *Cc*.

- (a) State the meaning of the term *carrier*. (1 mark)
- (b) Complete a Punnett square for the cross $Cc \times Cc$. Write one parent's gamete alleles along the top and the other parent's down the side, and write the offspring genotype in each of the four cells. (2 marks)
- (c) State the probability that a child of these parents has cystic fibrosis. Give your answer as a fraction. (1 mark)
- (d) The parents' first child has cystic fibrosis. They say: "Now that our first child has it, the next child is less likely to have it." Evaluate this claim. (2 marks)

Q12 (4 marks · VC2S10U01)

- (a) State **two** differences between sexual reproduction and asexual reproduction. (2 marks)
- (b) A strawberry plant sends out runners, and new plants grow at points along the runner. State the name for offspring that are genetically identical to the parent. (1 mark)
- (c) Explain why variation within a species helps its survival when the environment changes. (1 mark)

Q13 (4 marks · VC2S10U02) On a hot afternoon, a student's core body temperature rises above the set point of about 37 °C.

- (a) Name the part of the brain that acts as the control centre of this loop. (1 mark)
- (b) State **two** responses that cool the body, and for each say how it removes heat. (2 marks)
- (c) Explain why this loop is an example of negative feedback. (1 mark)

Q14 (4 marks · VC2S10U03) A student sorts two diseases: influenza and scurvy.

- (a) Classify each disease as infectious or non-infectious, and state the cause of each. (2 marks)

- (b) A person with a cold coughs into their hand and then shares a water bottle with a friend. Name the link of the chain of infection broken by coughing into the elbow instead, and the link broken by not sharing the bottle. (2 marks)

Q15 (4 marks · VC2S10U05) Methicillin is an antibiotic first used in hospitals in 1959. The first resistant *Staphylococcus* bacteria (MRSA) were found in 1961, and by 1997 about half of *Staphylococcus* samples in UK hospitals were MRSA.

Source: Wikipedia, “Methicillin-resistant *Staphylococcus aureus*”, 2026. https://en.wikipedia.org/wiki/Methicillin-resistant_Staphylococcus_aureus — retrieved 2026-08-21.

Explain this rise using the five steps of natural selection: variation, overproduction, selection, inheritance, and change over generations. (4 marks)

Q16 (8 marks · VC2S10U02 · inquiry) A pair of students uses the ruler-drop test to measure reaction time. They then plan an extension: does a distraction (a phone) slow reaction time? (All data in this question are simulated data for practice.)

- (a) In the extension investigation, name the independent variable and the dependent variable. (2 marks)
- (b) State **two** variables the pair must keep the same between the distracted and the undistracted tests. (2 marks)
- (c) Each student does five trials in each condition. Explain why five trials and a mean are more reliable than a single trial. (1 mark)
- (d) The test’s scale gives: a fall of 4.9 cm = 0.10 s; a fall of 19.6 cm = 0.20 s. One student’s best trial is a fall of 4.9 cm and their worst trial a fall of 19.6 cm. State the reaction time for each catch. (1 mark)
- (e) In the simulated data, the distracted curve lies above the undistracted curve at every trial, and both curves fall with practice. One student says: “Maybe the distraction slows the eye.” Use the pattern in the data to explain why the distraction is more likely to slow the control centre than the eye or the muscle. (2 marks)

Test B

Topic test 3 — Biological sciences

Biological sciences · Chapters 7–9 · Subtopics 7A, 7B, 7C, 7D, 8A, 8B, 8C, 8D, 9A and 9B · Codes VC2S10U01, VC2S10U02, VC2S10U03, VC2S10U04 and VC2S10U05

Total: 40 marks · Section A (multiple choice): 10 marks · Section B (short/structured response): 30 marks, including one pedigree item

8 of the 40 marks are inquiry-strand marks — Question 16 applies inquiry skills to the handwashing agar-plate investigation of Subtopic 8D.

Planned for about 50 minutes. This paper is untimed — there is no time to beat.

This is a school-designed paper. It is a school-based assessment instrument of this book's own design — it is not a VCAA instrument, and it is not a VCAA examination. Levels 9 and 10 carry no external assessment; achievement at Levels 9 and 10 is reported against the Victorian Curriculum achievement standard on teacher judgement, and the marks here are one source of evidence towards that judgement.

Conditions

- Completion is **untimed**. The 50 minutes is planning guidance only; take as long as you need.
- **Reading support** is permitted. Your teacher may read any question out to you if you need it. Reading is not what is being looked at, and your teacher will not help with the answer.
- **No calculator is permitted on this paper**. A scientific calculator is permitted for Topic tests 4, 5 and 6 only, and nothing on this paper needs one anyway. No formula sheet. No reading time.
- Answer every question. For multiple-choice questions, circle the letter of the best answer. There is only one best answer for each question.

In this test you will:

- relate the structures of reproductive cells to their functions, and explain why internal fertilisation suits life on land (Q1, Q6, Q12)
- explain how the body keeps blood glucose and body temperature near their set points through negative feedback (Q2, Q7, Q13)
- distinguish between pathogens, match diseases to their treatments, and explain why antibiotics do not cure viral diseases (Q3, Q8, Q14)
- explain inheritance — meiosis, gametes and variation — and read a simple pedigree (Q4, Q9, Q11)
- explain why biodiversity is a consequence of evolution, using biogeography and one other line of evidence (Q5, Q10, Q15)
- plan and read the handwashing agar-plate investigation (Q16)

Section A — Multiple choice (10 marks)

Each question is worth 1 mark. Circle the letter of the best answer.

Q1 (1 mark · VC2S10U01) Sperm have a tail specialised for:

A. Producing energy through photosynthesis B. Movement toward the egg C. Storing additional genetic material D. Digesting nutrients from the surrounding fluid

Q2 (1 mark · VC2S10U02) Sweating helps maintain:

A. Blood sugar level B. Heart rate C. Lung capacity D. Body temperature (cooling)

Q3 (1 mark · VC2S10U03) In a handwashing experiment, the **DEPENDENT** variable is:

A. The number of bacterial colonies on agar B. The soap brand C. The time of day D. The subject's age

Q4 (1 mark · VC2S10U04) Meiosis produces gametes with:

A. The same chromosome number as the parent cell B. Double the chromosome number of the parent cell C. Half the chromosome number of the parent cell D. A different chromosome number each time, with no fixed pattern

Q5 (1 mark · VC2S10U05) Biodiversity is largely a consequence of:

A. A single common ancestor that never changed B. Evolutionary divergence and adaptation C. Identical environments across all habitats D. Only recent human activity

Q6 (1 mark · VC2S10U01) Which organ produces ova in human females?

A. Ovaries B. Uterus C. Pancreas D. Liver

Q7 (1 mark · VC2S10U02) Why is negative feedback central to homeostasis?

A. It amplifies any change away from the set point so responses are stronger B. It replaces the need for any hormonal control of the body C. It only operates during exercise and shuts off at rest D. The response acts in the opposite direction to the change, bringing the condition back toward the set point

Q8 (1 mark · VC2S10U03) In a handwashing experiment, a control sample (no handwashing) is needed to:

A. Show which soap brand is the strongest B. Demonstrate the effect of warm water on its own C. Establish a starting point of bacterial load for comparison D. Reduce the number of trials that need to be repeated

Q9 (1 mark · VC2S10U04) What makes the gametes produced by meiosis all different?

A. Mitosis B. The random mixing of chromosomes as the matched pairs separate C. The DNA copying itself before the cell divides D. Producing clones of the parent cell

Q10 (1 mark · VC2S10U05) Why might an island ecosystem develop unique species?

A. Isolation allows populations to change separately into forms found nowhere else B. Islands always contain more nutrients than mainlands C. Island species stop reproducing sexually D. Ocean currents prevent any evolutionary change

Section B — Short/structured response (30 marks)

Q11 (6 marks · VC2S10U04) Cystic fibrosis is a recessive condition. The dominant allele *C* gives the unaffected phenotype; the recessive allele *c* causes cystic fibrosis when no *C* is present. The pedigree of one family is described below.

- Generation I: two partners, neither of whom has cystic fibrosis.
- Generation II: their three children, oldest first — a son with cystic fibrosis, an unaffected daughter, and an unaffected son.

Use the pedigree conventions of Subtopic 7D: square = male, circle = female, filled shape = a person with the condition.

- The parents in generation I do not have cystic fibrosis, but their son does. Explain, using alleles, why this shows that both parents are carriers. (2 marks)
- The unaffected daughter marries a man who has cystic fibrosis (*cc*). The daughter is a carrier (*Cc*). Complete a Punnett square for the cross $Cc \times cc$. (2 marks)
- State the probability that a child of this couple has cystic fibrosis. Give your answer as a fraction. (1 mark)
- The couple's first child has cystic fibrosis. State the probability that their next child also has it, and give the reason. (1 mark)

Q12 (4 marks · VC2S10U01)

- State **two** structural differences between a sperm cell and an egg cell, and for each link the structure to its function. (2 marks)
- State where fertilisation happens in the human female reproductive system. (1 mark)
- State one reason internal fertilisation suits animals that live on land. (1 mark)

Q13 (4 marks · VC2S10U02) After a meal rich in carbohydrate, a person's blood glucose rises above the set point (roughly 4 to 7 mmol/L through the day).

- (a) Name the organ that acts as both the receptor and the control centre of this loop. (1 mark)
- (b) Name the hormone released, and state what it tells the liver and muscle cells to do. (2 marks)
- (c) People with type 1 diabetes inject insulin; they never take it as a swallowed tablet. Explain why insulin must be injected. (1 mark)

Q14 (4 marks · VC2S10U03)

- (a) State **two** differences between a bacterium and a virus. (2 marks)
- (b) Match each disease to the type of medicine used to treat it. Choose from *antibiotic*, *antiviral* and *antifungal*: candidiasis (a yeast infection); tuberculosis (a bacterial infection). (1 mark)
- (c) A person with influenza asks their doctor for antibiotics. Explain why an antibiotic will not cure influenza, and state one harm of using antibiotics when they cannot help. (1 mark)

Q15 (4 marks · VC2S10U05) Australia's native large land mammals — kangaroos, koalas, wombats, quolls and the Tasmanian devil — are almost all marsupials: mammals whose young are born very undeveloped and finish growing in a pouch. On most other continents, the large native mammals are almost all placental mammals. Australia began to separate from Antarctica about 95 million years ago and drifted north as an island continent.

Source: Veevers & Eittreim, "Reconstruction of Antarctica and Australia at breakup (95 ± 5 Ma) and before rifting (160 Ma)", *Australian Journal of Earth Sciences* 35, 1988. <https://doi.org/10.1080/08120098808729453> — retrieved 2026-08-21.

- (a) Explain why Australia's mammals evolved separately from the mammals of other continents for tens of millions of years. (2 marks)
- (b) Give one **other** line of evidence that supports the theory of evolution — from the fossil record, comparative embryology, or molecules — and state why it supports the theory. (2 marks)

Q16 (8 marks · VC2S10U03 · inquiry) A group plans the handwashing agar-plate investigation: fingertips are pressed onto agar before and after different handwashing treatments, the plates are incubated, and the bacterial colonies that grow are counted. (All counts in this question are simulated data for practice.)

- (a) Write a hypothesis comparing washing with water only against washing with soap for 30 seconds, then drying. (1 mark)
- (b) Name the independent variable and the dependent variable in this investigation. (2 marks)
- (c) State **two** variables the group must keep the same across all plates. (2 marks)
- (d) Explain why plate A — fingertips pressed before any washing — matters. (1 mark)
- (e) Give one safety rule for the plates once colonies have grown, and give the reason for it. (1 mark)
- (f) The simulated results are: unwashed 120; water only 74; soap for 10 s 32; soap for 30 s then dried 8 (mean colonies per plate). Identify the treatment that removes the most microbes, and support your answer by quoting two values. (1 mark)

Marking guide

This guide is written for a teacher marker — no specialist science background beyond Chapters 7–9 of this book is needed. Award a mark when the student’s answer matches an acceptable response below or says the same idea in other words. Do not award half marks. The marks are a record that evidence was seen; they are not used to rank students.

Test A — Section A — Multiple choice

Q	Answer	Code	Source
Q1	C	VC2S10U01	bank item VC2S10U01.E01.S01.D1.V01
Q2	B	VC2S10U02	bank item VC2S10U02.E01.S01.D1.V01
Q3	A	VC2S10U03	bank item VC2S10U03.E01.S01.D1.V01
Q4	D	VC2S10U04	bank item VC2S10U04.E01.S01.D1.V01 (options in the book's words)
Q5	B	VC2S10U05	bank item VC2S10U05.E01.S01.D1.V01
Q6	A	VC2S10U01	bank item VC2S10U01.E02.S01.D2.V01
Q7	D	VC2S10U02	bank item VC2S10U02.E01.S01.D3.V01
Q8	C	VC2S10U03	bank item VC2S10U03.E01.S01.D3.V01
Q9	A	VC2S10U04	bank item VC2S10U04.E01.S01.D2.V01
Q10	B	VC2S10U05	bank item VC2S10U05.E01.S01.D2.V01

All ten items are drawn from the MCQ bank (mcq-system/data/output/questions/L9-10_Science.csv, six items keyed to each of VC2S10U01–VC2S10U05) under the codes assessed on this paper; none is drawn from a neighbouring code. Items mix easy (D1), medium (D2) and hard (D3) bank difficulties. Items are printed with their stem and options word for word except where noted in the table above, and the positions of the options have been changed for this paper so that the correct answers are spread across A, B, C and D (the printed positions are $A \times 3$, $B \times 3$, $C \times 2$, $D \times 2$). In Q4, the bank's *codes for a function (often a protein)* option is rewritten in the book's own definition (Subtopic 7C: a gene is one stretch of DNA that carries one set of instructions), and the bank's *short RNA molecule* option is replaced with *a feature of the organism that you can observe* — RNA is not taught at this level (TOC D9), and the replacement tests the same gene-versus-trait confusion. The two unused VC2S10U02 bank items (VC2S10U02.E01.S01.D2.V01, which names the sympathetic nervous system, and VC2S10U02.E02.S01.D1.V01, which names glucagon) are not drawn on either paper: both terms are VCE-only and are not taught in this book (TOC D9).

Why each answer is correct, in brief:

- **Q1 C** — the testes produce sperm (Subtopic 7A); the bladder stores urine, the pancreas releases insulin, and the liver processes blood.
- **Q2 B** — the pupil reflex is a fast, automatic response to a change in light (Subtopic 8A); it is not decided consciously and is not hormonal.

- **Q3 A** — tuberculosis is caused by a bacterium (Subtopic 8C); influenza is viral, candidiasis is fungal, and a tapeworm is parasitic.
- **Q4 D** — a gene is one stretch of DNA carrying one set of instructions (Subtopic 7C); it is not a whole chromosome, not a protein, and not the observable feature itself (that is the phenotype).
- **Q5 B** — natural selection acts on heritable variation within a population (Subtopic 9A); identical individuals, an unchanging environment or asexual reproduction alone give selection nothing to sort.
- **Q6 A** — the egg is large because its cytoplasm holds a food store for early development (Subtopic 7A); it carries the same 23 chromosomes as a sperm and does not swim.
- **Q7 D** — nervous messages are electrical impulses along neurons (up to about 120 m/s); hormones travel in the blood, carried by blood flow, so they arrive in seconds to minutes (Subtopic 8A).
- **Q8 C** — bacteria are cells with structures such as cell walls; a virus is genetic material in a protein coat with no cell parts, so an antibiotic has nothing to attack (Subtopics 8C and 8D).
- **Q9 A** — a human body cell has 46 chromosomes in 23 matched pairs (Subtopic 7C); 23 is the gamete number.
- **Q10 B** — individuals with inherited features that suit their environment are more likely to survive and reproduce and pass those features on (Subtopic 9A); individuals do not develop new traits within their lifetime.

Test A — Section B — Short/structured response

Q11 (6 marks · VC2S10U04) (a) a person who is heterozygous for a recessive allele — carries one copy of it but does not show the condition. 1 mark Accept any response that captures carrying a recessive allele without showing the trait. (b) 2 marks — gametes *C* and *c* along the top and *C* and *c* down the side (or vice versa; 1 mark), and the four cells *CC*, *Cc*, *Cc*, *cc* (1 mark). Award the cell mark for all four genotypes correct; one error in the cells loses that mark only. (c) $\frac{1}{4}$ (accept 1 in 4, 25 %, 1 : 4 against 3). 1 mark (d) 2 marks — 1 mark for the judgement: the claim is wrong; 1 mark for the reason: each fertilisation is independent (the alleles are shuffled fresh each time), so the probability is still $\frac{1}{4}$ for every child. Do not accept “the probability drops” in any wording. Marker note: this is the required Punnett/pedigree item for this paper. The cross, the allele symbols and the carrier definition follow Subtopic 7D exactly; the scope is a monohybrid cross only — no dihybrid cross, no linkage (TOC D9).

Q12 (4 marks · VC2S10U01) (a) any two, one mark each: sexual reproduction needs two parents, asexual needs one; sexual reproduction involves the joining of gametes at fertilisation, asexual does not; sexual reproduction produces variation in the offspring, asexual produces clones. 2 marks Each difference must name both sides to earn the mark. (b) clones. 1 mark (c) any response that says a changing environment may suit some variants better than others, so at least some individuals are likely to survive and reproduce, whereas identical individuals could all be equally unsuited. 1 mark Accept “variation gives the species a better chance of surviving” only with that reason attached.

Q13 (4 marks · VC2S10U02) (a) the hypothalamus. 1 mark (b) any two response–link pairs, one mark each: sweat glands release sweat — as the sweat evaporates it removes heat from the skin; blood vessels near the skin surface widen — more heat escapes to the air; moving into shade or removing a layer (behaviour). 2 marks The response and how it removes heat must both be there; “sweating” alone, with no evaporation link, earns no mark for the link. (c) the response acts in the opposite direction to the change that started it — the body was too hot, and the responses bring the temperature back down toward the set point. 1 mark

Q14 (4 marks · VC2S10U03) (a) influenza — infectious, caused by a virus; scurvy — non-infectious, caused by a diet lacking vitamin C. 2 marks (1 mark each; the class and a matching cause must both be there). (b) coughing into the elbow breaks the **exit** link; not sharing the bottle breaks the **spread** link. 2 marks (1 mark each named link). Accept “passing it on”/“transmission” language only if the student clearly means the link between exit and entry; the taught six links are pathogen, source, exit, spread, entry, new host.

Q15 (4 marks · VC2S10U05) Any four of the five steps correctly applied to the MRSA scenario, one mark each: - **variation**: within any bacterial population, a few individuals are resistant to the antibiotic by chance; - **overproduction**: bacteria multiply fast, so far more are produced than can survive; - **selection**: the antibiotic kills the non-resistant bacteria and leaves the resistant ones alive; - **inheritance**: the survivors pass the resistance on to their offspring; - **change over generations**: the share of resistant bacteria in the population rises, course by course. 4 marks The step must be applied to the bacteria and the antibiotic — a recited step with no link to the scenario earns no mark. The MRSA dates in the stem are the real figures taught in Subtopic 9A (source line in the question).

Q16 (8 marks · VC2S10U02 · inquiry) (a) independent variable: whether or not there is a distraction (the phone); dependent variable: the reaction time (read from the distance the ruler fell). 2 marks (1 mark each; the name and the role must match). (b) any two, one mark each: the same person catching; the same ruler and the same starting position of the hand; the same drop height / the same release with no warning; the same time of day; the same number of trials. 2 marks (c) a single catch can be thrown off by chance (a fast or slow one); with five trials the high and low readings average out, so the mean is closer to the true reaction time. 1 mark Accept any response that says repeats let the scatter average out; do not accept “more accurate” with no reason. (d) best trial: 0.10 s; worst trial: 0.20 s. 1 mark Both needed. The values come from the scale taught in Subtopic 8A (a fall of 4.9 cm means 0.10 s; a fall of 19.6 cm means 0.20 s); no calculation is required and no calculator is needed. (e) 2 marks — 1 mark for the pattern: the distracted curve lies above the undistracted curve at every trial, yet both curves fall the same way with practice; 1 mark for the reasoning: the eye and the muscle are the same in both conditions, so a constant upward shift points to the part that differs — the attention given to the control centre. This is Activity 2 of Subtopic 8A, assessed here with its simulated data.

Test B — Section A — Multiple choice

Q	Answer	Code	Source
Q1	B	VC2S10U01	bank item VC2S10U01.E02.S01. D1.V01 (<i>flagellum</i> in the book's words)
Q2	D	VC2S10U02	bank item VC2S10U02.E02.S01. D2.V01
Q3	A	VC2S10U03	bank item VC2S10U03.E02.S01. D1.V01
Q4	C	VC2S10U04	bank item VC2S10U04.E02.S01. D1.V01
Q5	B	VC2S10U05	bank item VC2S10U05.E02.S01. D1.V01
Q6	A	VC2S10U01	bank item VC2S10U01.E01.S01. D2.V01
Q7	D	VC2S10U02	bank item VC2S10U02.E02.S01. D3.V01 (correct option in the book's words)
Q8	C	VC2S10U03	bank item VC2S10U03.E02.S01. D2.V01
Q9	B	VC2S10U04	bank item VC2S10U04.E02.S01. D2.V01 (stem and options in the book's words)
Q10	A	VC2S10U05	bank item VC2S10U05.E02.S01. D2.V01 (<i>endemic</i> in the book's words)

All ten items are drawn from the MCQ bank under the codes assessed on this paper; none is drawn from a neighbouring code, and no item is shared with Test A. Items mix easy (D1), medium (D2) and hard (D3) bank difficulties. Items are printed with their stem and options word for word except where noted in the table above, and the positions of the options have been changed for this paper so that the correct answers are spread across A, B, C and D (the printed positions are A × 3, B × 3, C × 2, D × 2). The rewrites, all of them, are: in Q1 the bank's *flagellum* becomes *tail* (the book's word, Subtopic 7A); in Q7 the correct option is put in the book's negative-feedback wording (Subtopic 8B: the response acts in the opposite direction to the change); in Q9 the bank's *crossing over and independent assortment* becomes *the random mixing of chromosomes as the matched pairs separate* and the *translation* option becomes *producing clones of the parent cell* — the bank's terms are VCE-only, and the rewrites test the same idea in the words of Subtopic 7C; in Q10 the bank's *endemic forms* becomes *forms found nowhere else*. The two unused VC2S10U02 bank items noted for Test A are likewise not drawn here.

Why each answer is correct, in brief:

- **Q1 B** — the tail whips from side to side and moves the sperm toward the egg (Subtopic 7A); the sperm's energy comes from mitochondria in the midpiece, never photosynthesis.
- **Q2 D** — sweating cools the body: as sweat evaporates it removes heat (Subtopic 8B). It does not regulate blood sugar, heart rate or lung capacity.
- **Q3 A** — the dependent variable is what is measured — the number of bacterial colonies counted on each plate after incubation (Subtopic 8D).
- **Q4 C** — meiosis halves the chromosome number: body cell 46, gamete 23, so that fertilisation restores 46 (Subtopic 7C).
- **Q5 B** — the theory of evolution by natural selection explains past and present biodiversity: populations diverge and adapt, branch by branch (Subtopic 9B).
- **Q6 A** — the ovaries produce ova (Subtopic 7A); the uterus is where the embryo develops.
- **Q7 D** — negative feedback is self-correcting: the response reverses the change that started it, keeping the condition near the set point (Subtopic 8B). It never amplifies the change.
- **Q8 C** — the unwashed plate is the starting point: it shows the bacterial load before any washing, so the washed plates have something to be compared with (Subtopic 8D, Activity 1).
- **Q9 B** — in meiosis the matched pairs separate at random, giving over 8 million possible mixes of chromosomes in one person's gametes (Subtopic 7C); mitosis and cloning make identical copies.
- **Q10 A** — isolation stops interbreeding and lets each population change separately; Australia's island history is the taught example (Subtopic 9B).

Test B — Section B — Short/structured response

Q11 (6 marks · VC2S10U04) (a) 2 marks — 1 mark: the affected son must have received a *c* allele from each parent (his genotype is *cc*); 1 mark: neither parent shows the condition, so each must also carry a *C* — both are *Cc*, carriers. (b) 2 marks — gametes *C* and *c* from the daughter on one side and *c* and *c* from the father on the other (1 mark), and the four cells *Cc*, *Cc*, *cc*, *cc* (1 mark). (c) $\frac{1}{2}$ (accept 1 in 2, 50 %). 1 mark (d) $\frac{1}{2}$ again; each fertilisation is independent, so the first child's genotype does not change the odds for the next. 1 mark Both the fraction and the reason needed. Marker note: this is the required Punnett/pedigree item for this paper. It stays within the simple recessive pattern taught in Subtopic 7D; no sex linkage is required here, no dihybrid cross, no linkage (TOC D9).

Q12 (4 marks · VC2S10U01) (a) any two structure–function pairs, one mark each: sperm has a long tail that whips — for swimming to the egg; egg is large and round with a food store in the cytoplasm — the size holds the food, and it does not need to travel; sperm has enzymes at the tip — to get through the egg's jelly coat; egg has a jelly coat — protection, and it changes after one sperm enters so no other can; sperm has a midpiece packed with mitochondria — energy for the swim. 2 marks The structure and a matching function must both be there. (b) in an oviduct (fallopian tube). 1 mark Do not accept “the uterus”. (c) any one: the gametes do not dry out on land; fertilisation does not need an outside body of water. 1 mark

Q13 (4 marks · VC2S10U02) (a) the pancreas. 1 mark (b) insulin; it tells the body's cells — especially liver and muscle cells — to take glucose out of the blood, and the liver stores the extra glucose as glycogen. 2 marks (1 mark for the hormone, 1 mark for what it tells the cells to do). (c) insulin is a protein: swallowed, it would be digested in the gut and broken down before it could reach the blood, so it must be injected. 1 mark The protein/digestion link must be there.

Q14 (4 marks · VC2S10U03) (a) any two, one mark each: a bacterium is a complete cell (with no nucleus) and a virus is not a cell — only genetic material in a protein coat; a bacterium can multiply on its own where conditions suit it, a virus can only multiply inside a living cell; a bacterium is about 1–5 μm long, a virus about 100 nm across. 2 marks (b) candidiasis — antifungal; tuberculosis — antibiotic. 1 mark Both needed. (c) influenza is caused by a virus, and antibiotics kill bacteria or stop them dividing — they do nothing to a virus; using them when they cannot help drives resistance. 1 mark Both the reason and the harm needed. Do not award the mark for any immune-mechanism explanation — the body's defences against pathogens are VCE-only and are not taught in this book (TOC D9).

Q15 (4 marks · VC2S10U05) (a) 2 marks — 1 mark: Australia separated from Antarctica about 95 million years ago and drifted north as an island continent; 1 mark: that isolation meant no interbreeding (no mixing) with the mammals of other continents, so selection acted on each population separately for tens of millions of years. (b) any one line of evidence with its why, 2 marks (1 mark each). Accept: fossil record — simpler organisms in older layers and transitional forms (such as *Ambulocetus*, which had legs for walking and a body built for swimming) link older groups to younger ones; comparative embryology — early embryos of fish, birds and humans share a post-anal tail and pouches in the neck region, pointing to shared ancestry; molecules — all life uses DNA with the same four bases and the same genetic code, and the fewer the differences between two species' copies of a gene, the more recently they share a common ancestor; comparative anatomy — the pentadactyl limb (one upper bone, two lower bones, wrist bones, digits) in a human arm, a bat wing and a whale flipper. All are taught in Subtopic 9B.

Q16 (8 marks · VC2S10U03 · inquiry) (a) any statement that names both treatments and predicts a direction, for example: washing with soap for 30 seconds then drying will leave fewer bacterial colonies than washing with water only. 1 mark A bare guess (“soap is better”) without the two treatments named earns no mark — a hypothesis names the variables and says how they change together. (b) independent variable: the handwashing treatment (water only / soap and time / none); dependent variable: the number of bacterial colonies counted on each plate after incubation. 2 marks (1 mark each; the name and the role must match). (c) any two, one mark each: the person pressing their fingertips; the pressure and area of the fingertip press; the incubation time and temperature; the type of agar and plates; when in the day the presses happen. 2 marks (d) it is the starting point: it shows the bacterial load before any washing, so the washed plates have something to be compared with. 1 mark (e) any one rule–reason pair: incubate plates sealed and upside-down, so condensation and colonies cannot fall out or leak; never open a grown plate, so grown microbes are not released or touched; wash hands before and after, so the investigation does not itself spread microbes; dispose of plates by the school's approved method. 1 mark The rule and a matching reason must both be there. These are the safety rules of Subtopic 8D, Activity 1. (f) soap for 30 seconds then drying — 8 colonies against

120 unwashed (or 74 water only, or 32 soap for 10 s). *1 mark* The treatment and two supporting values must both be there. The counts are the simulated data of Subtopic 8D, Activity 2, labelled as such in the question.

Tracing the items to the achievement standard

Every item traces to the achievement-standard extract of the subtopics that serve its code (§4.1 of the plan of record). Each of the five codes is split-delivered (†): U01 — 7A owner (structures) / 7B partner (processes and survival); U04 — 7C owner (DNA, chromosomes, genes, alleles, mitosis and meiosis) / 7D partner (Mendelian inheritance and pedigrees); U02 — 8A owner (coordinating responses to stimuli) / 8B partner (homeostasis and negative feedback); U03 — 8C owner (causes) / 8D partner (control measures); U05 — 9A owner (processes) / 9B partner (evidence). Each pair cites the same extract.

Code	Subtopics	Achievement-standard extract	Test A items	Test B items
VC2S10U01	7A and 7B	“Students describe how the processes of sexual and asexual reproduction enable survival of the species.”	Q1, Q6, Q12	Q1, Q6, Q12
VC2S10U02	8A and 8B	“They explain how the nervous and endocrine systems use negative feedback to support homeostasis in the body’s internal environment.”	Q2, Q7, Q13, Q16	Q2, Q7, Q13
VC2S10U03	8C and 8D	“They distinguish between infectious and non-infectious disease, and compare different infectious disease control measures.”	Q3, Q8, Q14	Q3, Q8, Q14, Q16
VC2S10U04	7C and 7D	“They explain the processes that underpin heredity and genetic diversity, and predict the outcomes of monohybrid crosses.”	Q4, Q9, Q11	Q4, Q9, Q11
VC2S10U05	9A and 9B	“They describe the evidence supporting the theory of evolution by natural selection.”	Q5, Q10, Q15	Q5, Q10, Q15

Inquiry weighting: 8 of the 40 marks on each paper are inquiry-strand marks — Question 16 of each test, which applies the inquiry skills built in Chapters 1–6 (variables, repeats and means, safety, reading data) to that chapter’s own practical work: the ruler-drop test of Subtopic 8A (Test A) and the handwashing agar-plate investigation of Subtopic 8D (Test B). This exceeds the required minimum of 6 inquiry-strand marks per topic test (D7).

Mark record — Test A

Question	Code	Worth	Given
Q1 — the organ that produces sperm	VC2S10U01	1	
Q2 — the pupil reflex	VC2S10U02	1	
Q3 — the cause of tuberculosis	VC2S10U03	1	
Q4 — what a gene is	VC2S10U04	1	
Q5 — what natural selection requires	VC2S10U05	1	
Q6 — why the egg is large	VC2S10U01	1	
Q7 — the nervous route is faster	VC2S10U02	1	
Q8 — antibiotics and viruses	VC2S10U03	1	
Q9 — the human chromosome number	VC2S10U04	1	
Q10 — survival of the best adapted	VC2S10U05	1	
Q11 — a monohybrid cross: cystic fibrosis	VC2S10U04	6	
Q12 — sexual and asexual reproduction	VC2S10U01	4	
Q13 — cooling the body: negative feedback	VC2S10U02	4	
Q14 — sorting disease, breaking the chain	VC2S10U03	4	
Q15 — MRSA and the five steps	VC2S10U05	4	
Q16 — the ruler-drop test (inquiry)	VC2S10U02	8	
Total		40	

Mark record — Test B

Question	Code	Worth	Given
Q1 — the sperm's tail	VC2S10U01	1	
Q2 — sweating and body temperature	VC2S10U02	1	
Q3 — the dependent variable	VC2S10U03	1	
Q4 — meiosis halves the number	VC2S10U04	1	
Q5 — biodiversity and evolution	VC2S10U05	1	
Q6 — the organ that produces ova	VC2S10U01	1	
Q7 — why negative feedback is central	VC2S10U02	1	
Q8 — the unwashed control plate	VC2S10U03	1	
Q9 — the random mix of meiosis	VC2S10U04	1	
Q10 — islands and unique species	VC2S10U05	1	
Q11 — reading a pedigree: cystic fibrosis	VC2S10U04	6	
Q12 — gametes and fertilisation	VC2S10U01	4	
Q13 — blood glucose after a meal	VC2S10U02	4	
Q14 — pathogens and treatments	VC2S10U03	4	
Q15 — marsupials and the evidence for evolution	VC2S10U05	4	
Q16 — the handwashing investigation (inquiry)	VC2S10U03	8	
Total		40	

Sources

- Victorian Curriculum F–10 Version 2.0, *Science, Levels 9 and 10*, content descriptions VC2S10U01, VC2S10U02, VC2S10U03, VC2S10U04 and VC2S10U05, their elaborations and the achievement standard. Victorian Curriculum and Assessment Authority, vcaa.vic.edu.au — retrieved 2026-08-21.
- Wikipedia, “Methicillin-resistant *Staphylococcus aureus*”, 2026. https://en.wikipedia.org/wiki/Methicillin-resistant_Staphylococcus_aureus — retrieved 2026-08-21.

- Veevers & Eittreim, “Reconstruction of Antarctica and Australia at breakup (95 ± 5 Ma) and before rifting (160 Ma)”, Australian Journal of Earth Sciences 35, 1988. <https://doi.org/10.1080/08120098808729453> — retrieved 2026-08-21.

The only real data on these papers are the MRSA dates in Test A Question 15 (first resistant isolates 1961; about half of UK hospital samples by 1997; Wikipedia, 2026, source line above) and the Australia–Antarctica separation of about 95 million years in Test B Question 15 (Veevers & Eittreim, 1988, source line above), each carrying its source line where it appears. Every other number on these papers — the ruler-drop falls and reaction times in Test A Question 16 and the colony counts in Test B Question 16 — is **simulated data for practice**, labelled as such wherever it appears. The cystic fibrosis families in Test A Question 11 and Test B Question 11 are original teaching scenarios of this book’s own design, in the allele conventions of Subtopic 7D.

Teacher-facing note

This note is written for an adult professional and is not student-facing text.

- **A school instrument, not a VCAA exam (D14).** Levels 9 and 10 carry no VCAA examination and no external assessment. These papers are school-based assessment instruments of this book’s own design, graded against the achievement-standard extracts above, and their marks are one source of evidence towards the on-balance teacher judgement.
- **Administration.** Completion is untimed despite the 50-minute suggested time; **no calculator is permitted** — scientific calculators are reserved for Topic tests 4, 5 and 6 (TOC §7); reading support is whatever the classroom normally provides. Award the marks exactly as set out in the guide — point-based, no holistic rubric, no half-marks, spelling and handwriting do not lose marks.
- **Inquiry coverage (D7).** Each paper carries 8 inquiry-strand marks — Question 16 of each test — attached to that chapter’s own practical work (the ruler-drop test, Subtopic 8A; the handwashing agar-plate investigation, Subtopic 8D), above the required minimum of 6. The inquiry marks sit on the content codes assessed by this test (VC2S10U02 and VC2S10U03), because the TOC’s §7 row for T3 assesses VC2S10U01–U05 only; the skills themselves are those built in Chapters 1–6.
- **Scope ceiling (D9).** No item asks for immune mechanism — antibodies, lymphocytes or the immune response — and vaccination is not assessed at all; Test B Question 14(c) explicitly bars immune-mechanism answers. The Punnett/pedigree items are monohybrid only: no dihybrid cross, no linkage, and pedigrees stay within the simple recessive pattern taught in Subtopic 7D. The blood-glucose loop is assessed without naming the second hormone (VCE-only). Two bank items were set aside for this reason: VC2S10U02.E01.S01.D2.V01 (names the sympathetic nervous system) and VC2S10U02.E02.S01.D1.V01 (names glucagon).
- **First Nations content (CONTENT_POLICY Rule 1).** These papers draw no Aboriginal or Torres Strait Islander content. The reserved elaborations VC2S10U03.E06 and VC2S10U05.E06 are not assessed here; elaborations are contexts, not scope (D12), so VC2S10U03 and VC2S10U05 are fully assessed through their non-First-Nations elaborations.