DP Biology – A4.1

Evolution and speciation

- What evidence supports evolution?
- What do analogous and homologous structures show about what organisms share and how they differ?

SL statements A4.1.1–7. Textbook pp. 138–150.

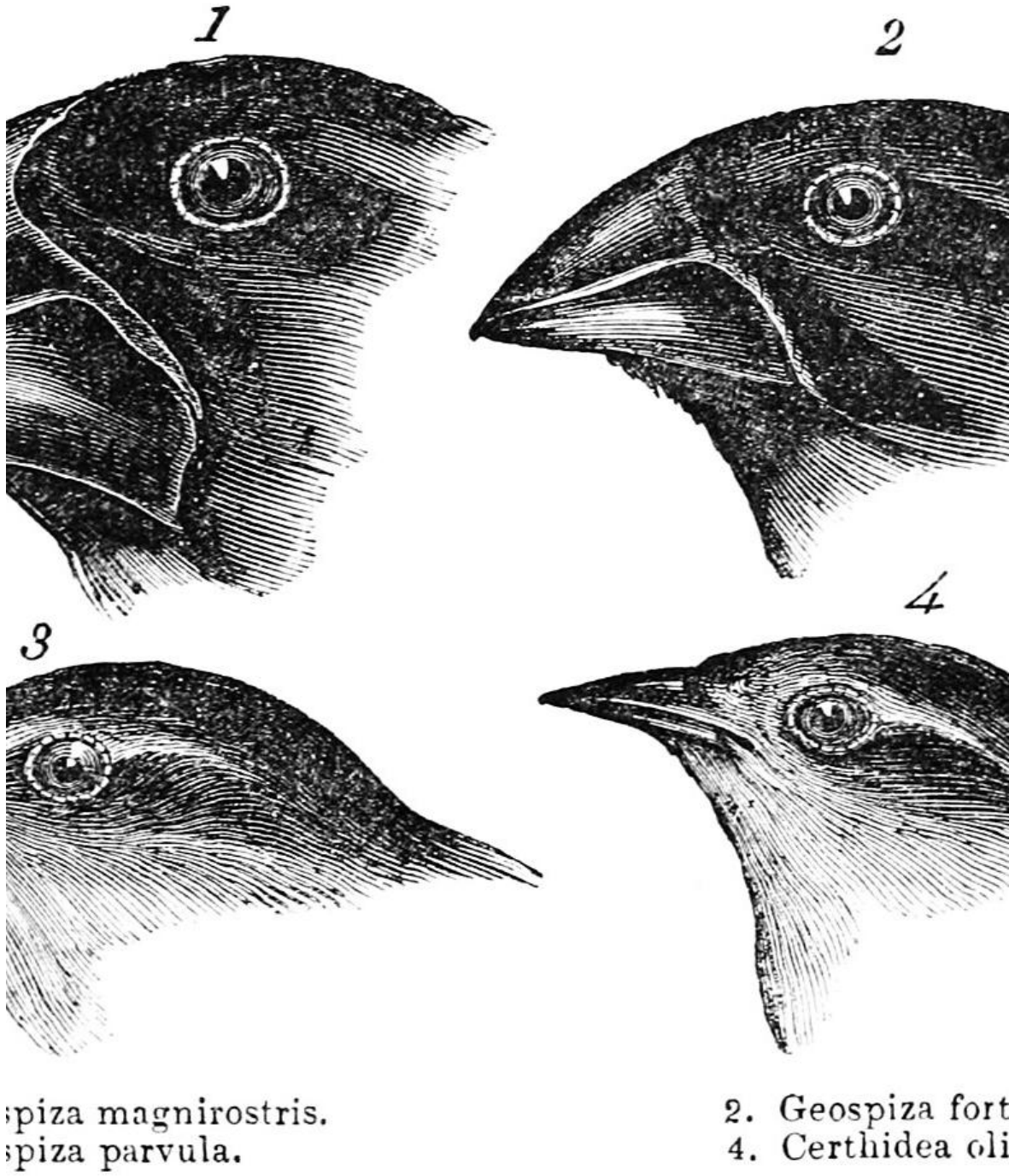


Image: Galapagos finches, drawn by John Gould. Public domain.

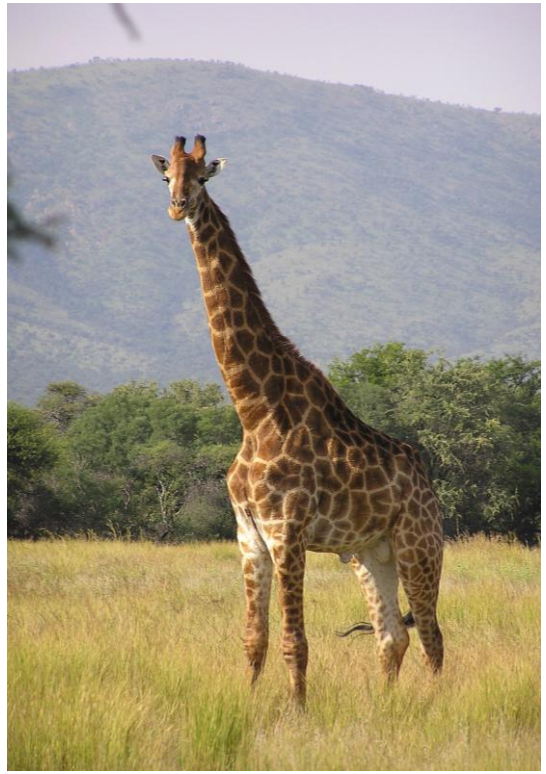
Objectives for each class

Class	Statements	By the end of the class, you can...
1	A4.1.1–2	Define evolution, separate it from inheritance of acquired traits, and use sequence data as evidence
2	A4.1.3–4	Explain how selective breeding and homologous structures give evidence for evolution
3	A4.1.5	Distinguish analogous from homologous structures, and explain convergent evolution
4	A4.1.6–7	Explain speciation, using reproductive isolation and differential selection

What is evolution?

A4.1.1

- **Evolution** is a change in the **inherited characteristics** of a population
- Traits must be passed on through genes to count
- Changes acquired during a lifetime are not evolution



	Lamarck	Darwin
Idea	Traits acquired in life are passed on	Variation already exists, and selection acts on it
Giraffe	Stretching lengthens necks, and offspring inherit this	Those with longer necks feed better and leave more offspring

Example

Trees bent by the wind grow in that shape throughout life, yet their seedlings grow upright.
Giraffe: M. Duchacek, CC BY-SA 3.0.

Evidence from sequences

A4.1.2

- DNA and RNA base sequences, and protein amino acid sequences, can be compared between species
- Mutations accumulate over time, so close relatives have more similar sequences
- The more differences there are, the longer ago two groups split

Species	Made-up section of a gene
1	A A T C G C C G A A G C T T T G C A T T T G C A A
2	A A T C G C A G A A G C T T T G C A T T T T C A A
3	A A T C A A C G A A G C T A T G C A T T T G C A A
4	A A T C A C C G A A G C T A T G C A T T T G C A A

Activity

Count the differences between each pair of sequences. Which two species are most closely related? Which two are most distant?

Why sequence evidence is so strong

A4.1.2

- All organisms use the same genetic code and the same 20 amino acids in proteins
- Some genes are found across widely different organisms: for example, Pax6 controls eye development in animals as different as flies and humans
- Sequences provide objective data, and the differences can be counted
- Evidence from sequences largely agrees with evidence from anatomy and fossils

Key idea

These similarities are hard to explain unless organisms share common ancestors. Independent lines of evidence all point to the same relationships, and this agreement is part of why scientists accept evolution.

Evidence from selective breeding

A4.1.3



Teosinte and maize. John Doebley, CC BY 3.0.

- Humans choose which individuals breed
- Over generations, varieties become very different
- Modern breeds can differ greatly from their wild ancestors
- Most can still interbreed with those ancestors

Key idea

Selective breeding shows how rapidly heritable characteristics can change under selection, over a few thousand years or less. It does not prove that evolution happens in nature, but it shows that selection can produce large changes.

Examples of selective breeding

A4.1.3



Wild cabbage. MPF, CC BY 2.5.



Belgian Blue. Eric Forget, CC BY 2.0.

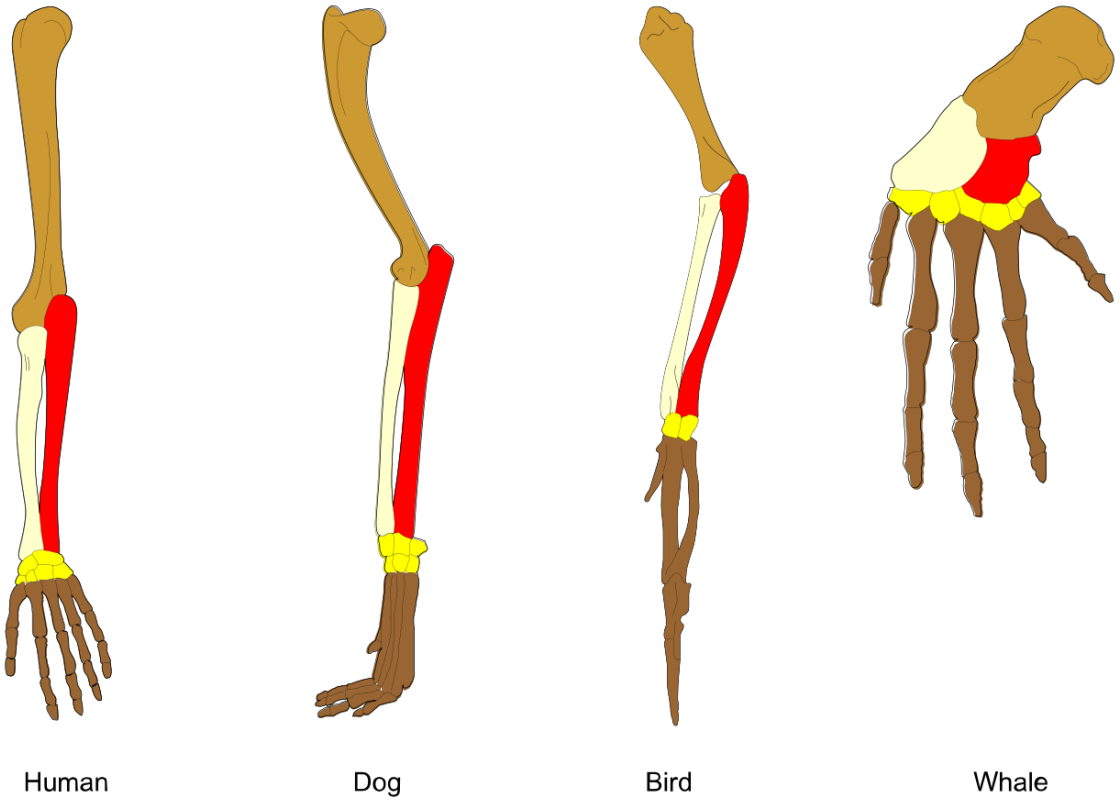
- Cabbage, kale, broccoli and cauliflower all come from one wild plant
- Belgian Blue cattle were bred for muscle

Activity

Choose a crop or a domesticated animal. Find the wild species it most resembles, and list three traits that differ. Explain what farmers must have done each generation to bring about these changes.

Evidence from homologous structures

A4.1.4



Homologous limb bones. Own work on Commons, CC BY-SA 4.0.

- **Homologous** structures have a similar basic structure, but can have different functions
- They suggest descent from a common ancestor
- This pattern is called **divergent** evolution

Example

Whale flippers, bat wings and human arms have the same arrangement of bones.

A pentadactyl limb has one upper bone, two lower bones, a group of wrist or ankle bones, and five digits.

The pentadactyl limb

A4.1.4

Region	Forelimb	Hindlimb
One upper bone	Humerus	Femur
Two lower bones	Radius and ulna	Tibia and fibula
Wrist or ankle	Carpals	Tarsals
Digits	Metacarpals and phalanges	Metatarsals and phalanges

Activity

Colour each type of bone on a diagram of a bat, a whale, a horse and a human limb. Then describe how each limb is adapted. Why is it unlikely that the same pattern would appear in all of them if they did not share an ancestor?

Convergent evolution and analogous structures

A4.1.5

- **Analogous** structures have the same function, but different evolutionary origins
- They arise by **convergent evolution**: similar selection pressures act on unrelated groups

	Homologous	Analogous
Basic structure	Similar	Different
Function	May differ	Similar
Ancestry	Common ancestor had it	Evolved separately
Example	Bat wing and whale flipper	Bird wing and insect wing

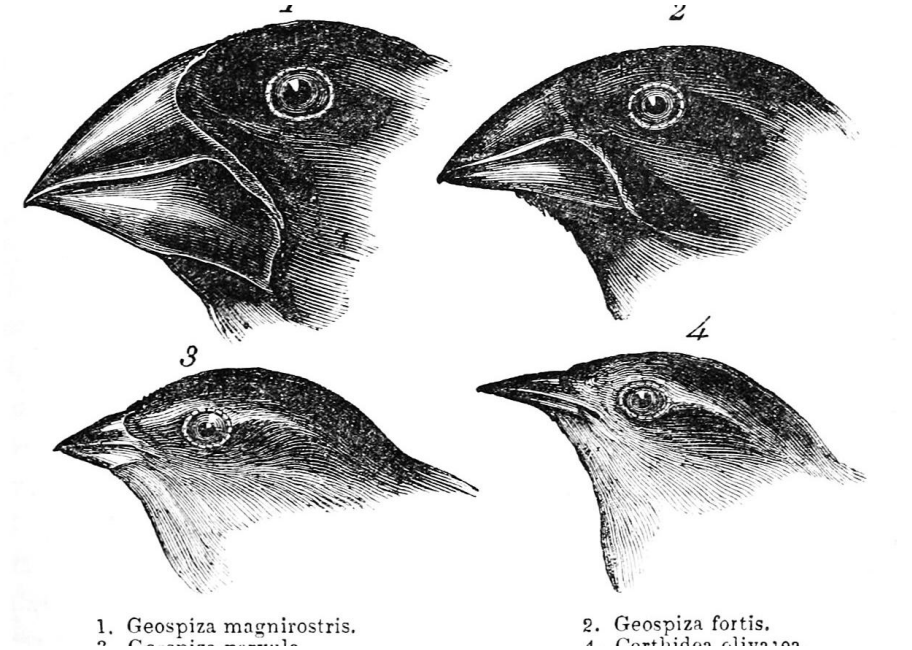
Key idea

Similar appearance can mislead, so DNA sequences are now used to classify organisms.

Speciation

A4.1.6

- **Speciation** is the splitting of one species into two or more
- It is the only way in which new species appear
- Speciation adds to the total of species alive, and extinction takes away from it



Galapagos finches. John Gould, public domain.

Example

Finches on the Galapagos Islands are thought to have descended from one ancestral species that reached the islands. Different populations became adapted to different foods, and beaks now differ in size and shape.

How speciation happens

A4.1.7

Requirement	What it means
Reproductive isolation	Populations stop interbreeding, so no genes pass between them
Differential selection	Selection pressures differ, so traits diverge over time

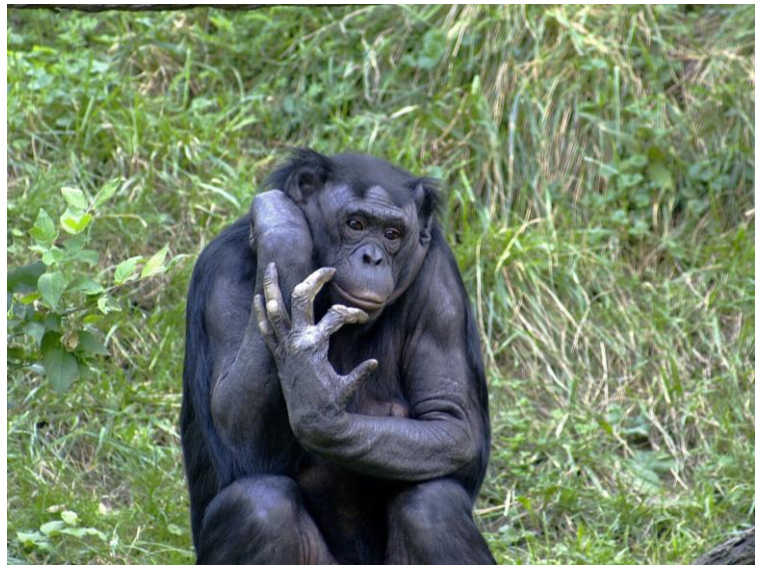
- A **geographical barrier**, such as a river or a mountain range, can isolate two populations
- With no gene flow, differences accumulate
- In time, they may no longer be able to interbreed

Common mistake

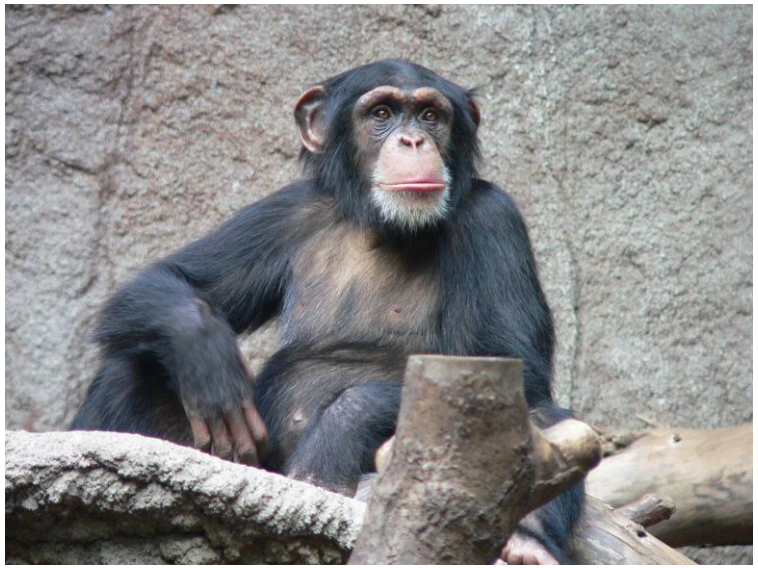
Isolation alone does not produce a new species. Selection or other changes must make the populations diverge. Both are required.

Example: bonobos and chimpanzees

A4.1.7



Bonobo. CC BY-SA 2.5.



Chimpanzee. Thomas Lersch, CC BY 2.5.

- Separated by the Congo River
- Neither swims
- Their ranges do not overlap

Differential selection

The river isolated two populations. Different conditions on each side are thought to have led to differences in diet and social behaviour. South of the river, bonobos face less competition for food, and their societies are led by females, whereas those of chimpanzees are led by males and are more aggressive.

Check that you can explain

1. The definition of evolution, and why acquired traits do not count
2. How sequence data are used as evidence
3. What selective breeding shows
4. Homologous structures and the pentadactyl limb
5. Analogous structures and convergent evolution
6. Speciation, reproductive isolation and differential selection, using bonobos and chimpanzees

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Define evolution.
2. Distinguish between homologous and analogous structures, with one example of each.
3. State the two processes required for speciation.

Image credits

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