IB BIOLOGY | A3.2 | HL

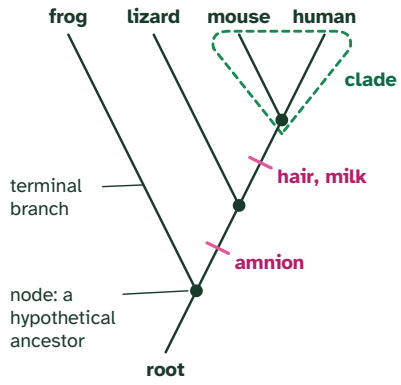
REVISION ON TWO PAGES

THE ONE IDEA

Group organisms by descent. A clade is one common ancestor and all its descendants, found most objectively from sequences.

Sorting life by *descent*

What to know, what to draw and what to say. Higher level only.



Draw it like this. A pink bar marks where a feature arose; every descendant inherits it.

A3.2.7 START HERE

Reading a *cladogram*

- The **root** is the base: the ancestor of everything on the tree. Each line out to a tip is a **terminal branch**.
- Each fork is a **node**: a **hypothetical common ancestor**. It must have existed to explain the split, but need not be a known fossil.
- To deduce how close two organisms are, trace both back until their lines meet. The **more recent that node**, the closer the relatives.
- A node and everything beyond it is a **clade**. Two groups from one node are **sister groups**. Only the branching order carries meaning.

THE PARTS OF A CLADOGRAM

Rabbits Nibble Tasty Carrots Slowly

R Root the base of the tree	**N** Node a hypothetical ancestor	**T** Terminal branch out to a tip	**C** Clade ancestor plus all descendants	**S** Sister groups share one node

A3.2.1

Why *classify*

- There are **too many species** to study one at a time: well over a million have been named.
- A group tells you where to look an organism up and what it is probably like.
- Once classified, a **broad range of further study** opens up: a new species' relatives say what to ask about it.
- Different rules give different groups, so the rule matters: the best one follows descent.

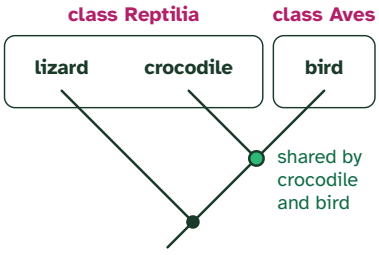
1m+ species named, many still unfound

3 domains hold all of life

A3.2.2 RANKS

When the *boxes* do not fit

- Traditional ranks: kingdom, phylum, class, order, family, genus, species (*King Philip Came Over For Good Soup*).
- Evolution makes branches, not boxes, so ranks **do not always match divergence**.
- **Nature of science:** ranks are **arbitrary**, as variation is gradual. Unranked clades replaced them: a **paradigm shift**.



A3.2.3 WHY DESCENT

Groups that *predict*

- The ideal classification **follows evolutionary relationships**: every member descends from one common ancestor.
- A feature that arose in that ancestor is shared across the clade, so **features can be predicted**: a newly found mammal will have hair and milk.
- Predictions reach biochemistry too: a useful plant chemical is first looked for in its relatives.
- A prediction is a good bet, not a promise: snakes lost the legs of their four-limbed ancestors.

A3.2.4

A *clade*: one ancestor, all its descendants

- A clade is a common ancestor and **all of its descendants**. Clades nest: birds are a clade, and so are birds with crocodiles.
- Leave out one descendant, or add one that is not a descendant, and the group is not a clade.

TEST 1
One ancestor
Do all the members share one common ancestor?

TEST 2
None left out
Are all of that ancestor's descendants in the group?

Sequences the most objective evidence
Base sequences of genes or **amino acid sequences of proteins**, compared position by position: anyone counting gets the same answer.

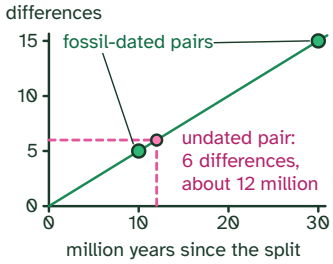
Morphology can also be used
Body structures can assign organisms to clades, but need a judgement on which traits count, and mislead when unrelated lines look alike.

Dating splits, building trees and the *three domains*

A3.2.5 DATING A SPLIT

The *molecular clock*

- After a split, each line gathers its own mutations, so **sequence differences accumulate gradually**.
- **Calibrate:** plot differences against time for pairs whose split is **dated by fossils**, then read an undated pair off the line.
- It gives **only an estimate** of when clades diverged, because the rate of change varies.



WHAT SHIFTS IT

Gerbils Play Sports

- **G** **Generation time** — more copies a year
- **P** **Population size** — chance spreads changes
- **S** **Selection** — removes some changes

A3.2.6 MADE-UP DATA

Building a cladogram by *parsimony*

- Line up the same gene, or protein, from each species and compare it **position by position**.
- An **outgroup**, which split off earlier, shows the older state. A difference from it is a change.
- **Parsimony**: choose the tree that explains the differences with the **fewest changes**, since mutations are rare.
- **Nature of science:** different criteria can give different trees, so a cladogram is a hypothesis.

site	1	2	3	4	5	6
orangutan (out)	T	A	C	G	G	A
human	C	G	T	A	G	A
chimpanzee	C	G	T	G	T	A
gorilla	T	A	C	G	T	C

tree joins	changes
human, chimp	**7**
chimp, gorilla	9
human, gorilla	10

Sites 4 and 6 differ in one species only: they cost one change on every tree, so they cannot decide.

A3.2.8 CASE STUDY

Testing a *classification*

- If a group is real, its members should form a clade. Cladistics can test it.

By flower structure the old view
The figwort family (Scrophulariaceae) was a large family, grouped mostly by look-alike flowers.

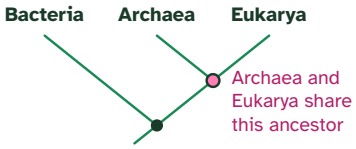
By chloroplast DNA the test
Its members fell into several clades. Many moved to other families, leaving a much smaller figwort family.

- The flowers were alike by **convergent evolution**, not common ancestry, so the old grouping was false.
- **Nature of science:** knowledge claims can be **falsified** by new evidence, so a classification stays open to testing.
- Learn the story, not the plant names. Either the common or the scientific name is accepted.

A3.2.9 RRNA EVIDENCE

The *three domains*

- In 1977, Woese and Fox compared **rRNA base sequences**. Every cell has ribosomes, so rRNA can be compared across all life.
- Prokaryotes were not one group. Life falls into three **domains**: Bacteria, Archaea and Eukarya.
- Archaea look like bacteria, but share a **more recent ancestor with Eukarya**.
- A new level **above the kingdoms**: animals, plants and fungi all sit in Eukarya.



WATCH OUT

Five mistakes that *cost marks*

- ✕ **A node is a hypothetical ancestor, not a living species.** Humans did not evolve from chimpanzees.
- ✕ **Tip order and height mean nothing.** Nodes can be spun; only the branching order counts.
- ✕ **A clade holds every descendant.** Reptilia leaves out the birds, so it is not a clade.
- ✕ **The clock gives estimates, not dates.** Its rate varies with generation time, population size and selection.
- ✕ **"Prokaryote" is not a clade.** Archaea are closer to Eukarya than to Bacteria.

COVER THE SHEET

Can you *answer these?*

1. Outline two reasons for classifying organisms.
2. Explain why the class Reptilia is not a clade.
3. Explain how clades let features be predicted.
4. State the most objective evidence for a clade.
5. Outline why the molecular clock is only an estimate.
6. Describe how parsimony selects a cladogram.
7. Draw a cladogram; label a root, node and terminal branch.
8. Explain what the figwort family case shows.
9. Outline the evidence for three domains.

IN THE EXAM

To deduce a relationship, **trace both tips back to the node where they meet**, then say they "share a more recent common ancestor", never that one evolved from the other.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.