IB BIOLOGY | D1.1 | SL AND HL

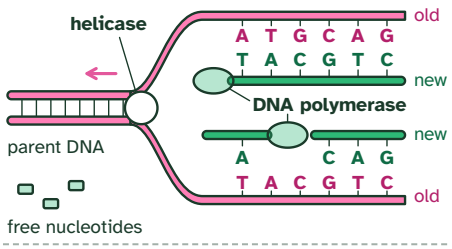
REVISION ON TWO PAGES

How DNA is *copied*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Each old strand is a template. Base pairing makes every new strand its exact complement, so both copies keep the original sequence.



Draw it like this. Old strands pink, new strands green; each new base pairs with the base opposite it.

D1.1.2, D1.1.3 START HERE

Unzip, pair, build: *semi-conservative*

- **Helicase unwinds the double helix** and **breaks the hydrogen bonds** between the bases, so the two strands part at the replication fork.
- Each old strand is a **template**. Free nucleotides line up by **complementary base pairing**: A with T, C with G, and nothing else fits.
- **DNA polymerase joins the free nucleotides** into a new strand, each matched to the template. One works on each strand.
- **Semi-conservative**: each daughter molecule is **one whole old strand and one whole new strand**. Only one base fits each template base, so the copy is **highly accurate**.

D1.1.1

An *exact* copy

- Replication copies a DNA molecule with an **identical base sequence**: the same bases in the same order.
- It is needed for **reproduction** (a bacterium splits in two), **growth** and **tissue replacement** (skin, gut lining, blood cells).
- A change that slips through is a **mutation**, which is why the copy must be exact.

Replication copies the DNA
The whole molecule, not one gene, before every division.

Cell division comes after
Each new cell gets one full copy.

D1.1.4 AMPLIFYING DNA

PCR: a *millionfold* copy

- The **polymerase chain reaction** copies one chosen stretch of DNA: it **amplifies** a tiny sample.
- **Primers:** two short single strands of DNA, one for **each end of the target**. They give the polymerase a start and choose what is copied.
- **Taq polymerase**, from *Thermus aquaticus* of hot springs, is **not denatured at 95 °C**, so it survives every cycle.
- Each cycle **doubles the copies**: up to 2^n after n cycles, a billion after 30.

ONE CYCLE IN A THERMAL CYCLER

Dragons Always Exhale

D **Denaturation**
about 95 °C: hydrogen bonds break, strands separate

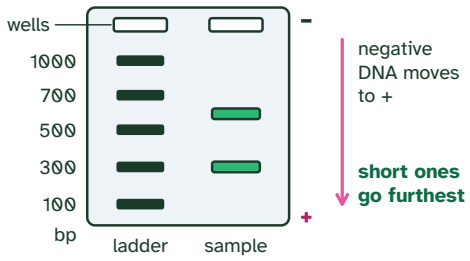
A **Annealing**
about 55 °C: primers bind to each end

E **Extension**
about 72 °C: Taq builds the new strands

D1.1.4 SEPARATING DNA

Gel electrophoresis: sorted by *size*

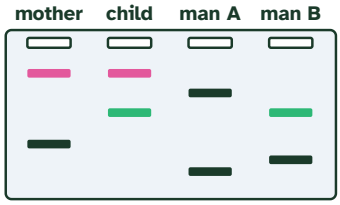
- Phosphates give DNA a **negative charge**, so it moves **towards the positive electrode**.
- The gel is a mesh: **long fragments are held back more**, so **short ones travel furthest**.
- A **DNA ladder** of known sizes gives the scale, in base pairs (bp). To size a band, find the ladder band level with it.
- Each band is millions of fragments of one length, which is why PCR comes first.



D1.1.5 APPLICATIONS

DNA *profiling*

- PCR copies **short tandem repeats** (STRs) at several markers; people differ in the number of repeats. The gel sorts them by length.
- **Forensic:** a match at every marker is strong evidence; **one clear mismatch excludes**. **Paternity:** a child's band that the mother lacks **must come from the father**.
- **Nature of science:** reliability rises with more measurements: **more markers, fewer false matches**.
- **Other uses:** diagnosing infections (the COVID-19 test), inherited conditions, identifying species, ancient DNA.



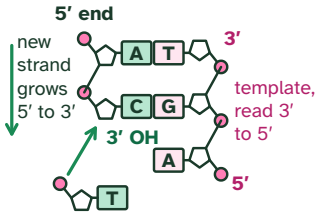
Pink: from the mother. Green: from the father (man B, not man A).

The fork in *detail*: direction, fragments, proofreading

D1.1.6 HIGHER LEVEL

Only ever at the *3′ end*

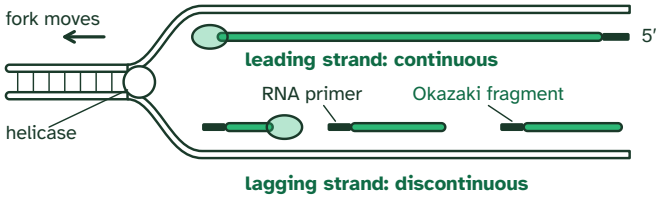
- A strand has a **5′ terminal** (free phosphate) and a **3′ terminal** (free OH on a 3′ carbon).
- DNA polymerase joins a new nucleotide's **5′ phosphate to the 3′ OH**: new strands **grow 5′ to 3′**.
- The template is **antiparallel**: it is read 3′ to 5′.



D1.1.7 HIGHER LEVEL

Leading and *lagging* strands

- The **leading strand** grows towards the fork: made **continuously**.
- The **lagging strand** grows away from the fork, so it is made **discontinuously**, in short **Okazaki fragments**.
- An **RNA primer** starts every new piece: **once on the leading strand**, but **once per Okazaki fragment** on the lagging strand.



D1.1.8 HIGHER LEVEL

The enzymes at the *fork*, in order

THE PROKARYOTIC SYSTEM

Hungry Pandas Prefer Plain Lettuce

H	**Helicase**	unwinds, breaks hydrogen bonds (D1.1.3)
P	**Primase**	makes each short RNA primer
P	**Polymerase III**	extends primers 5′ to 3′; builds most DNA
P	**Polymerase I**	removes RNA primers, puts DNA in their place
L	**Ligase**	seals each nick in the backbone

- Primers are RNA, so **polymerase I swaps them for DNA**; **ligase** then makes the last covalent bond where fragments meet.

D1.1.9 HIGHER LEVEL

DNA *proofreading*

- **DNA polymerase III** checks the nucleotide it has just added: it **checks as it builds**.

1 in 10^5 wrong without proofreading

1 in 10^7 with it

STEP 1
Mismatch
A base that does not pair with the template is added.

STEP 2
Remove
Polymerase III removes it from the **3′ terminal**.

STEP 3
Replace
It adds a **correctly matched** nucleotide.

WATCH OUT

Six mistakes that *cost marks*

- ✕ **Semi-conservative is about the molecule.** Each strand is wholly old or wholly new.
- ✕ **Helicase breaks hydrogen bonds between bases.** The sugar and phosphate backbone stays whole.
- ✕ **DNA polymerase does not make bases.** It joins whole nucleotides, already made.
- ✕ **Long fragments travel less far.** The gel holds them back; they are not "heavier".
- ✕ **Polymerase I removes primers, not polymerase III.** Ligase adds no nucleotides.
- ✕ **The lagging strand is not copied later.** Both strands are made at the same time.

COVER THE SHEET

Can you *answer these?*

1. State three reasons why cells replicate their DNA.
2. Explain how base pairing makes replication accurate.
3. Outline the roles of helicase and DNA polymerase.
4. Describe one cycle of PCR, with its temperatures.
5. Explain why DNA fragments separate by size in a gel.
6. Explain how a profile can exclude a man as a father.
7. Explain why a new strand grows only 5′ to 3′. HL
8. Distinguish the leading from the lagging strand. HL
9. State the functions of DNA polymerase I and ligase. HL
10. Describe how DNA polymerase III proofreads. HL

IN THE EXAM

Name the enzyme and the bond: helicase breaks **hydrogen bonds**; DNA polymerase makes **covalent bonds**. For PCR, give each step its temperature and its purpose.

GO FURTHER

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