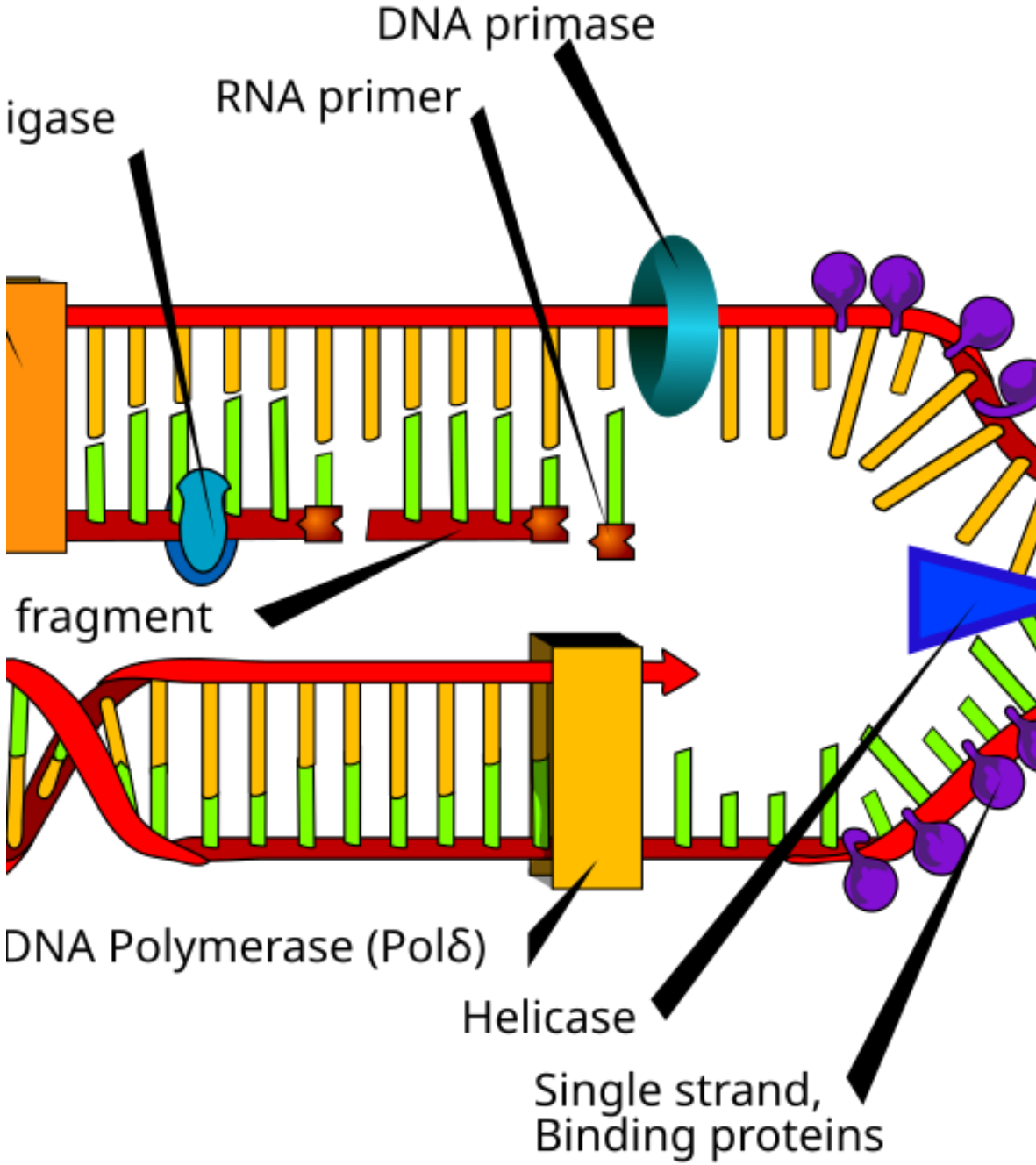
DP Biology – D1.1 (HL extension)

Inside DNA replication

- How do cells make new DNA?
- What biotechnology has understanding DNA replication made possible?



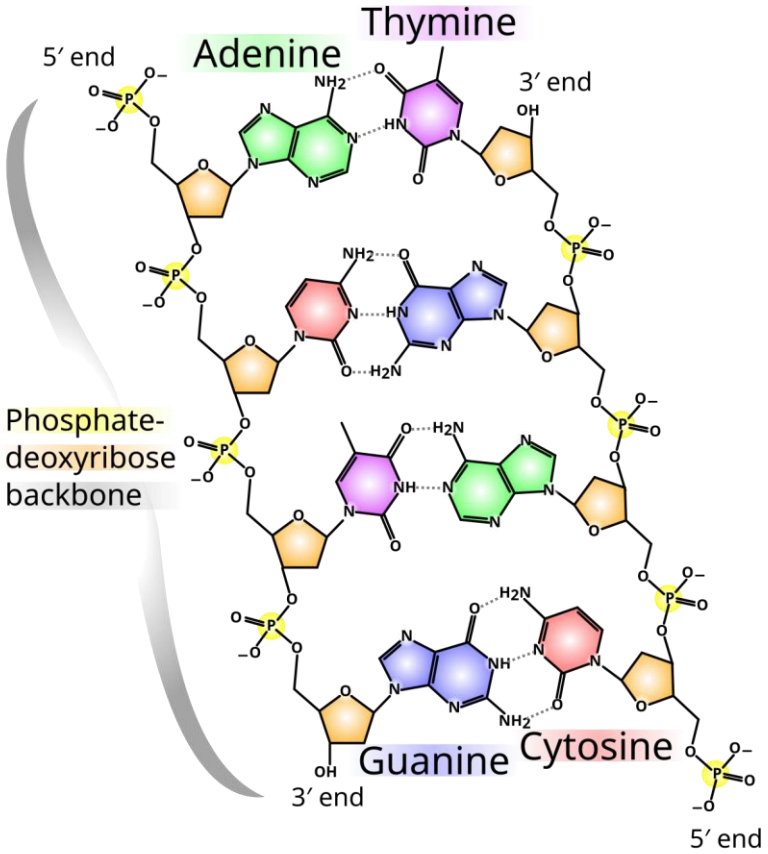
HL statements D1.1.6–9. Textbook pp. 604–614.
Image: DNA replication. Mariana Ruiz Villarreal, public domain.

Objectives for each class

Class	Statements	By the end of the class, you can...
1	D1.1.6	Explain why DNA polymerases can only build DNA in the 5′ to 3′ direction
2	D1.1.7–8	Compare the leading and lagging strands, and explain the roles of primase, DNA polymerases I and III, and ligase
3	D1.1.9	Explain how DNA polymerase III proofreads, and why this matters

DNA polymerase works in one direction

D1.1.6



DNA strands are antiparallel. CC BY-SA 3.0.

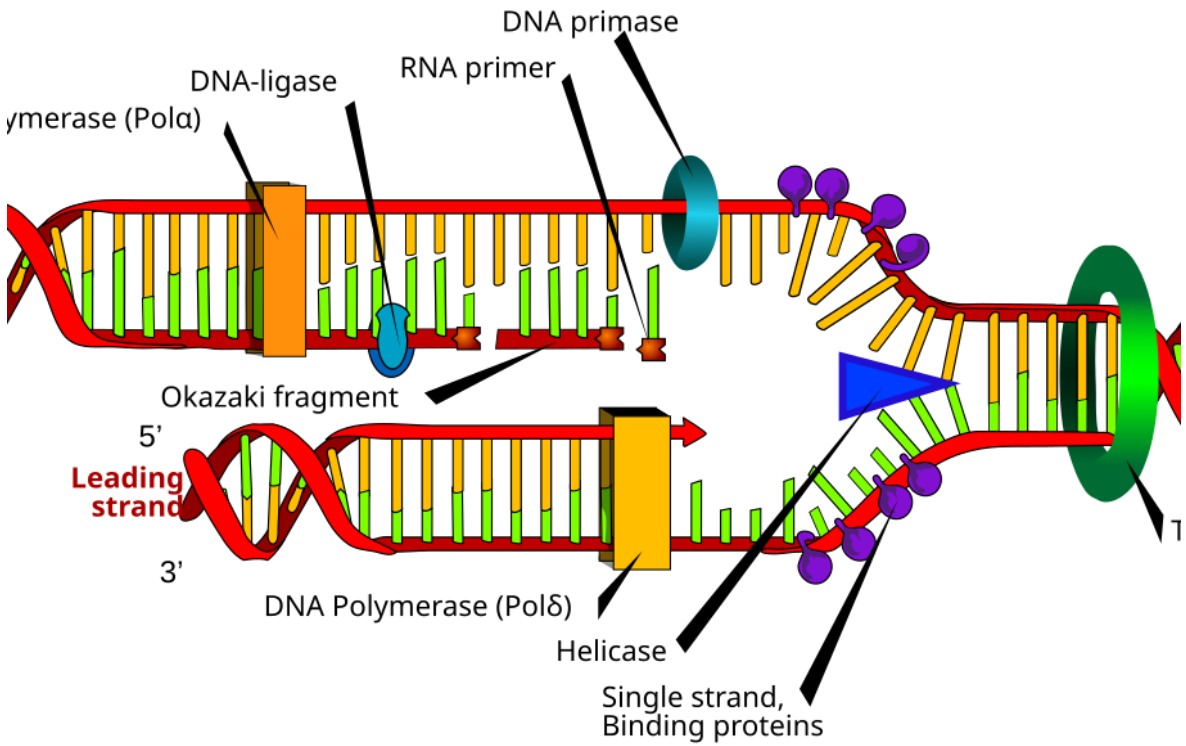
- A free nucleotide arrives as a nucleoside triphosphate
- DNA polymerase links its 5′ phosphate to the free 3′ -OH at the end of the growing strand
- Two phosphates are released, providing the energy
- So the new strand always grows **5′ to 3′**, and the template is read 3′ to 5′
- DNA polymerase cannot start a new strand: it needs an existing 3′ end

Why only one way?

The energy-carrying phosphates are on the incoming nucleotide's 5′ end. Adding to the 5′ end of the strand would need the energy to be on the strand instead, which would be lost every time a wrong base was removed.

Leading and lagging strands

D1.1.7



	Leading	Lagging
Synthesis	Continuous	Discontinuous
Direction	Towards the fork	Away from the fork
Primers	One	Many, one per fragment
Pieces	One long strand	Okazaki fragments

Replication fork, with eukaryotic enzyme names (Pol). Public domain.

Why?

Both new strands grow 5′ to 3′. The strands are antiparallel, so as the fork opens one new strand can follow it, while the other must be made backwards in short pieces.

The enzymes of replication

D1.1.8

Enzyme	Role (prokaryotes)
Helicase	Unwinds the helix and separates the strands by breaking hydrogen bonds
DNA primase	Makes a short RNA primer, giving a 3′ end to build on
DNA polymerase III	Adds DNA nucleotides to the primer, 5′ to 3′, by complementary base pairing
DNA polymerase I	Removes the RNA primers and replaces them with DNA
DNA ligase	Joins the sugar-phosphate backbones of adjacent fragments

Order on the lagging strand

Primase, then polymerase III, then polymerase I, then ligase.

Build a replication fork

D1.1.7–8

1. In pairs, draw a replication fork with both template strands labelled 5′ and 3′. Add each enzyme where it acts.
2. **Predict** what would happen on each strand if a bacterium had no working primase.
3. **Predict** what would be found in a cell with no working ligase.
4. **Explain** why the lagging strand needs many primers but the leading strand only one.

Hint

Without ligase, look for many short pieces. Without primase, look at what DNA polymerase needs to begin.

Proofreading by DNA polymerase III

D1.1.9

A wrong nucleotide is added at the 3′ end → The mismatch distorts the helix → **Polymerase III moves back and removes the wrong nucleotide** → It adds the correct one and carries on

Stage	Errors per base, roughly
Base pairing alone	1 in 100 000
After proofreading	1 in 10 million
After later repair	1 in a billion

Why it matters

A bacterial genome has about 5 million bases, a human cell 6 billion. Without proofreading, every replication would add many mutations. Taq polymerase, used in PCR, does not proofread, so PCR copies can contain errors.

Prokaryotes and eukaryotes

D1.1.6–9

	Prokaryotes	Eukaryotes
Origins of replication	One per circular chromosome	Many per chromosome
Replication forks	Two, moving in opposite directions	Many
Enzymes	Polymerases I and III, primase, ligase	More polymerases, but the same principles

Why many origins?

A human chromosome is far longer than a bacterial chromosome. With only one origin, copying it would take weeks; many origins let the whole genome be copied in a few hours.

Check that you can explain

1. Why new DNA is always made 5′ to 3′
2. Why DNA polymerase needs a primer
3. How replication differs on the leading and lagging strands
4. What Okazaki fragments are
5. The roles of helicase, primase, DNA polymerases I and III and ligase
6. How DNA polymerase III proofreads

Exit activity: 5 minutes

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

1. State the direction in which new DNA is synthesized.
2. Explain why the lagging strand is made as Okazaki fragments.
3. Outline the role of DNA polymerase I.

Image credits

DNA replication en.svg – LadyofHats Mariana Ruiz – Public domain

DNA chemical structure.svg – Madprime – CC BY-SA 3.0

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