KSQUARE CAREER INSTITUTE

MOLECULAR BASIS OF INHERITANCE

Class 12 Biology • Lecture: DNA Replication, Transcription & RNA • NEET Notes

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Lecture at a Glance

1. DNA replication — steps (activation of nucleotides → opening of helix → primer → synthesis → primer removal → ligation → proofreading)
2. Replication machinery — ori, replicon, replication fork, leading & lagging strands, Okazaki fragments
3. Enzymes of replication and their functions
4. Replication in prokaryotes vs eukaryotes
5. Transcription — introduction; types of RNA
6. Added: structure of DNA, semi-conservative replication (Meselson & Stahl), transcription unit, genetic code, translation, lac operon, HGP & DNA fingerprinting (overview), practice MCQs

DNA REPLICATION — STEPS

1. Activation of Nucleotides

- Deoxyribonucleoside monophosphates are converted to **triphosphates**: dAMP → **dATP**, dGMP → **dGTP**, dCMP → **dCTP**, dTMP → **dTTP** (activated).
- dNTPs have a **dual role**: they act as **substrates** and **provide energy** for polymerisation.

*Note: the class note writes "phosphorylase" for this step; phosphorylation of nucleotides is carried out by **kinase** enzymes.*

2. Opening of the DNA Helix

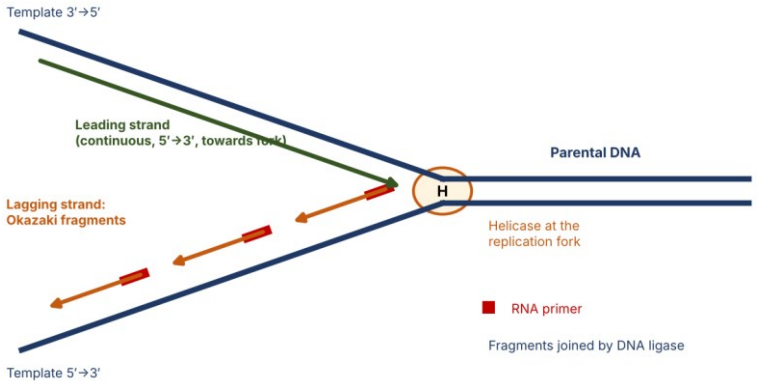
1. **Recognition of the origin (ori)** — replication begins at a definite point.
2. **Helicase** unwinds (opens) the DNA by breaking H-bonds.
3. **Topoisomerase** releases the tension caused by **supercoiling** ahead of the fork.
4. **Single-strand binding proteins (SSB)** keep the strands apart and **prevent re-formation of H-bonds**.

- Linear DNA forms a **replication fork**; circular DNA forms a **replication bubble**.

3. Primer Formation

- A short **RNA primer** is synthesised by **primase**; it provides a free **3'–OH** end, in front of which new nucleotides are added.
- New strand always grows **5' → 3'**.

4. Synthesis of New Strands



- Parent strand 3′ → 5′ is copied **continuously** — **leading strand**.
- The other strand is made **discontinuously** in short stretches — **Okazaki fragments** (lagging strand); each fragment needs its own primer.
- **DNA-dependent DNA polymerase (DNA pol III)** joins nucleotides to the primer, forming a polynucleotide chain.

5–7. Completion

1. **Removal of primers** by DNA polymerase (DNA pol I) and replacement with DNA nucleotides.
2. **Okazaki fragments are joined** by **DNA ligase**.
3. **Proofreading** followed by repair — DNA polymerase removes a wrongly inserted base.

REPLICATION MACHINERY

- Replication starts at **origin (ori)**; a unit of replication with one origin is a **replicon**.
- The two strands unwind and separate by breaking H-bonds in the presence of **helicase**; the Y-shaped region is the **replication fork**.
- Each separated strand acts as a **template**; DNA replicates in the **5′ → 3′ direction**.
- Replication is **bidirectional** from the origin and continues until the termini are reached.

Enzymes / Proteins of Replication

Protein	Function
Helicase	Unwinds the parental double helix at replication forks
Single-strand binding protein (SSB)	Binds to and stabilises single-stranded DNA until it is used as a template
Topoisomerase	Relieves ‘overwinding’ strain ahead of forks by breaking, swivelling and rejoining DNA strands
Primase	Synthesises an RNA primer at the 5′ end of the leading strand and of each Okazaki fragment
DNA pol III	Synthesises new DNA by adding nucleotides to the 3′ end of a pre-existing DNA strand or RNA primer; proofreading

Protein	Function
DNA pol I	Removes RNA primer nucleotides and replaces them with DNA nucleotides
DNA ligase	Joins Okazaki fragments (seals 3′ end of replacement DNA to the rest of the strand)

Prokaryotes vs Eukaryotes

Feature	Prokaryotes (E. coli)	Eukaryotes
Time	A few minutes — E. coli completes replication in ~**18 min** (avg. ~**2000 bp/s**)	A few hours
Origins	Single ori (circular DNA)	Many origins
When	Continuous	**S-phase** of the cell cycle

- Failure of cell division after DNA replication results in **polyploidy**.

NEET Point / PYQ Alert

Reiji Okazaki discovered the Okazaki fragments.

Replication requires the template, dNTPs (substrate + energy), and enzymes — and is semi-conservative (added below).

TRANSCRIPTION — INTRODUCTION

Transcription

The process of **copying genetic information from one strand of DNA into RNA** (heterocatalytic function of DNA: DNA → mRNA).

Adenine pairs with uracil instead of thymine. Enzyme: **RNA polymerase**.

- Template strand (3′→5′) is copied; the other strand is the **coding strand** (same sequence as RNA, with T in place of U).

Types of RNA

- RNA is a **single chain of polynucleotide** — except **reovirus (dsRNA)**.
- **Genomic / genetic RNA:** in some viruses RNA is the genetic material — e.g. **TMV**.
- **Non-genetic RNA:** rRNA, mRNA, tRNA.

RNA	Function	% of total RNA (class note)
mRNA (messenger)	Provides the **template for translation**	2–5%
rRNA (ribosomal)	**Structural & catalytic** role during translation — e.g. **23S rRNA** in bacteria acts as a **ribozyme**	~80%

RNA	Function	% of total RNA (class note)
tRNA (transfer / soluble)	Brings **amino acids** and **reads the genetic code**	~15%

BEYOND THE LECTURE — KEY CHAPTER POINTS (ADDITIONAL TOPIC)

Topic	Key facts
DNA structure	Double helix — **Watson & Crick (1953)** using X-ray data of **Wilkins & Franklin**; antiparallel strands; A=T (2 H-bonds), G≡C (3 H-bonds); **Chargaff's rule**: A = T, G = C; pitch 3.4 nm, 10 bp per turn, 0.34 nm between bp
Packaging	Prokaryotes: nucleoid (polyamines); eukaryotes: **histone octamer** + 200 bp DNA = **nucleosome** ('beads on string') → chromatin; euchromatin (active, loose) vs heterochromatin (dense, inactive)
Search for genetic material	Griffith (transforming principle, Streptococcus pneumoniae); Avery, MacLeod & McCarty (DNA); **Hershey & Chase** (radioactive $^{32}P/^{35}S$ bacteriophage — DNA is genetic material)
Semi-conservative replication	Proved by **Meselson & Stahl (1958)** using ^{15}N and CsCl density gradient in E. coli; Taylor (Vicia faba)
Transcription unit	Promoter (upstream), structural gene, terminator; RNA pol + σ (initiation) and ρ (termination) in bacteria; eukaryotes: RNA pol I (rRNA), II (hnRNA → mRNA), III (tRNA, 5S rRNA, snRNA); **splicing** (remove introns), **capping** (5' methyl G) and **tailing** (3' poly-A)
Genetic code	Triplet, 64 codons (61 code amino acids), **AUG** start (Met), **UAA, UAG, UGA** stop; unambiguous, degenerate, universal, comma-less
Translation	On ribosomes; tRNA (cloverleaf; anticodon loop, amino-acid acceptor end); aminoacylation; initiation, elongation, termination; UTRs
Lac operon (Jacob & Monod)	Inducible; i gene → repressor; z (β-galactosidase), y (permease), a (transacetylase); **lactose (allolactose) is the inducer**
HGP & DNA fingerprinting	HGP (1990–2003): ~3×10^9 bp, ~20,000–25,000 genes, < 2% codes proteins; ESTs, sequence annotation. Fingerprinting (Alec Jeffreys) uses **VNTRs**, Southern blotting

PRACTICE MCQS

Q1. The enzyme that unwinds the DNA double helix is

(a) Primase
(b) Helicase
(c) Ligase
(d) Topoisomerase

Answer: (b)

Q2. Okazaki fragments are joined by

(a) DNA polymerase III

(b) Primase
(c) DNA ligase
(d) Helicase

Answer: (c)

Q3. Which enzyme relieves supercoiling tension ahead of the replication fork?

(a) Topoisomerase
(b) SSB
(c) DNA pol I
(d) RNA polymerase

Answer: (a)

Q4. dNTPs in replication act as

(a) only substrate
(b) only energy source
(c) both substrate and energy source
(d) primers

Answer: (c)

Q5. The RNA primer is synthesised by

(a) DNA polymerase I
(b) Primase
(c) RNA polymerase II
(d) Ligase

Answer: (b)

Q6. In eukaryotes DNA replication occurs in

(a) G_1 phase
(b) S phase
(c) G_2 phase
(d) M phase

Answer: (b)

Q7. The ribozyme in bacteria is

(a) 16S rRNA
(b) 23S rRNA
(c) 5S rRNA
(d) tRNA

Answer: (b)

Q8. Which virus has double-stranded RNA?

(a) TMV
(b) Reovirus
(c) Bacteriophage T4
(d) HIV

Answer: (b)

Q9. During transcription, adenine of DNA pairs with

(a) Thymine
(b) Uracil
(c) Cytosine

(d) Guanine

Answer: (b)

Q10. Semi-conservative replication was experimentally proved by

(a) Watson and Crick
(b) Meselson and Stahl
(c) Hershey and Chase
(d) Griffith

Answer: (b)

QUICK REVISION

- Steps: dNMP → dNTP; ori recognised; helicase opens; topoisomerase removes supercoils; SSB stabilises; primase → RNA primer; DNA pol III synthesises 5′→3′; DNA pol I removes primers; ligase joins Okazaki fragments; proofreading.
- Leading strand continuous; lagging strand discontinuous (Okazaki fragments).
- E. coli: ~18 min (2000 bp/s); eukaryotes: S-phase, hours; failure of division → polyploidy.
- Transcription: DNA → RNA by RNA polymerase; A pairs with U.
- RNA single-stranded (except reovirus); TMV — RNA genome; mRNA (template), rRNA (structural/catalytic, 23S ribozyme), tRNA (adaptor).