Molecular biology, DNA

IMBB 2014

What is Molecular Biology?

Molecular biology is the study of biology at a molecular level, especially DNA and RNA

Molecular biology is the study of molecular underpinnings of the processes of replication, transcription, translation, and cell function. The central dogma of molecular biology where genetic material is transcribed into RNA and then translated into protein, despite being an oversimplified picture of molecular biology, still provides a good starting point for understanding the field.

Molecular biology chiefly concerns the understanding of the interactions between the various systems of a cell.

Molecular biology overlaps with other areas of biology and chemistry, particularly genetics (effect of genetic differences on organisms) and biochemistry (chemical substances and vital processes occurring in living organisms).

Molecular biology is the convergence of various, previously distinct biological and physical disciplines: biochemistry, genetics, cell biology, microbiology, virology and physics.
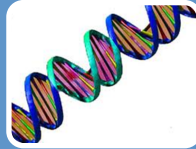
Molecular biology is the branch of biology that deals with the manipulation of DNA or RNA so that it can be sequenced, detected, modified, or expressed.

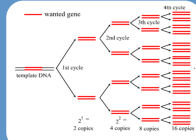The techniques of molecular biology are applied to many fields

- Genomics
- Cell biology
- Microbiology
- Biotechnology
- Diagnostics
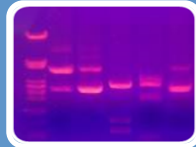- Therapeutics
- Forensics
- Agriculture
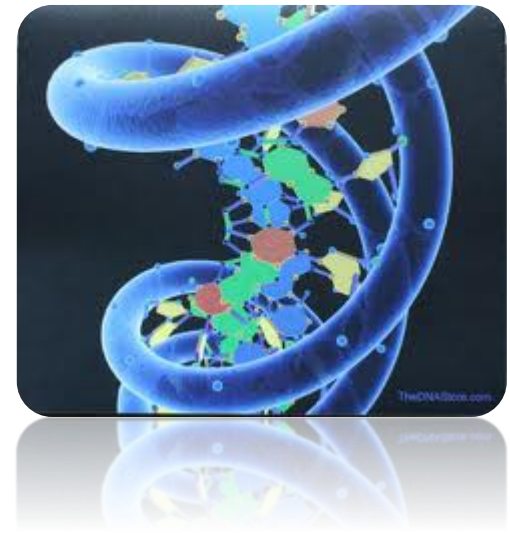
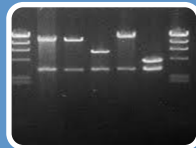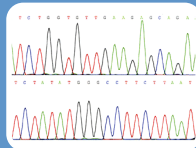# Some core tools of molecular biology
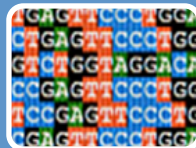

DNA purification

Polymerase chain reaction

Gel electrophoresis
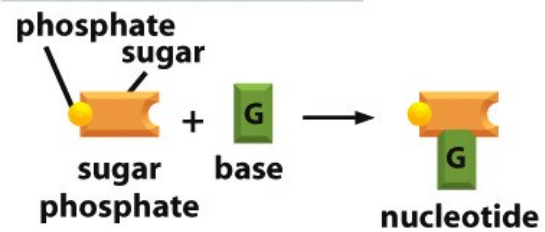

Restriction analysis

DNA sequencing

Bioinformatics

DNA structure and replication

DNA

- **Deoxyribonucleic acid**

- Macromolecule (average human chromosome has 5 cm of DNA)

- Contains genetic instructions for development and functioning of all known living organisms (with the exception of RNA viruses)

- Long-term storage of information

- Contains the instructions needed to construct RNA molecules and proteins

- DNA segments that carry this genetic information are called genes

- Other DNA sequences have structural purposes, or are involved in regulating the use of the genetic information.

building blocks of DNA

phosphate
sugar

sugar
phosphate + base → nucleotide

DNA strand

5′ G C A T 3′

double-stranded DNA

3′ 5′

C G
A T
T A
T A
G C
C G
C G
A T
G C
T A

sugar-phosphate
backbone

5′ 3′
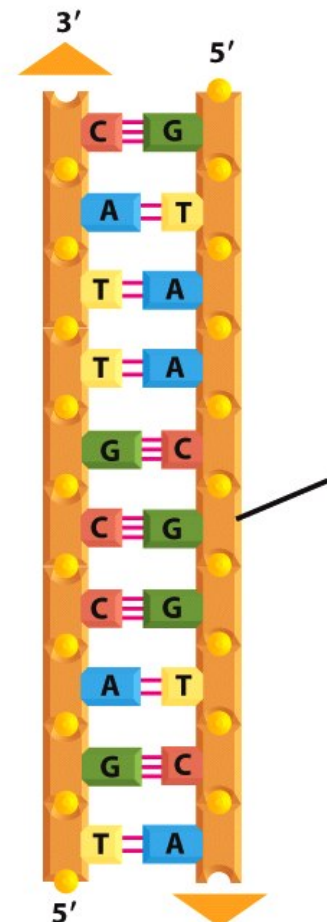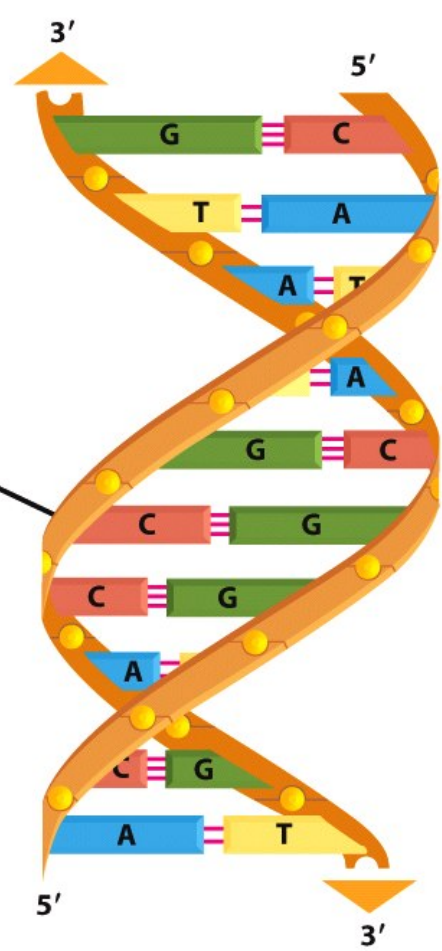
hydrogen-bonded
base pairs

DNA double helix

3′ 5′

G C
T A
A T
A
G C
C G
C G
A
C G
A T

sugar-phosphate
backbone

5′ 3′

Figure 4-3 *Molecular Biology of the Cell* (© Garland Science 2008)

- DNA is normally double stranded

- Two strands held together by H bonds between bases

- A single strand of DNA has an orientation ($5' \rightarrow 3'$)

- In double stranded DNA, the two strands have opposite orientation

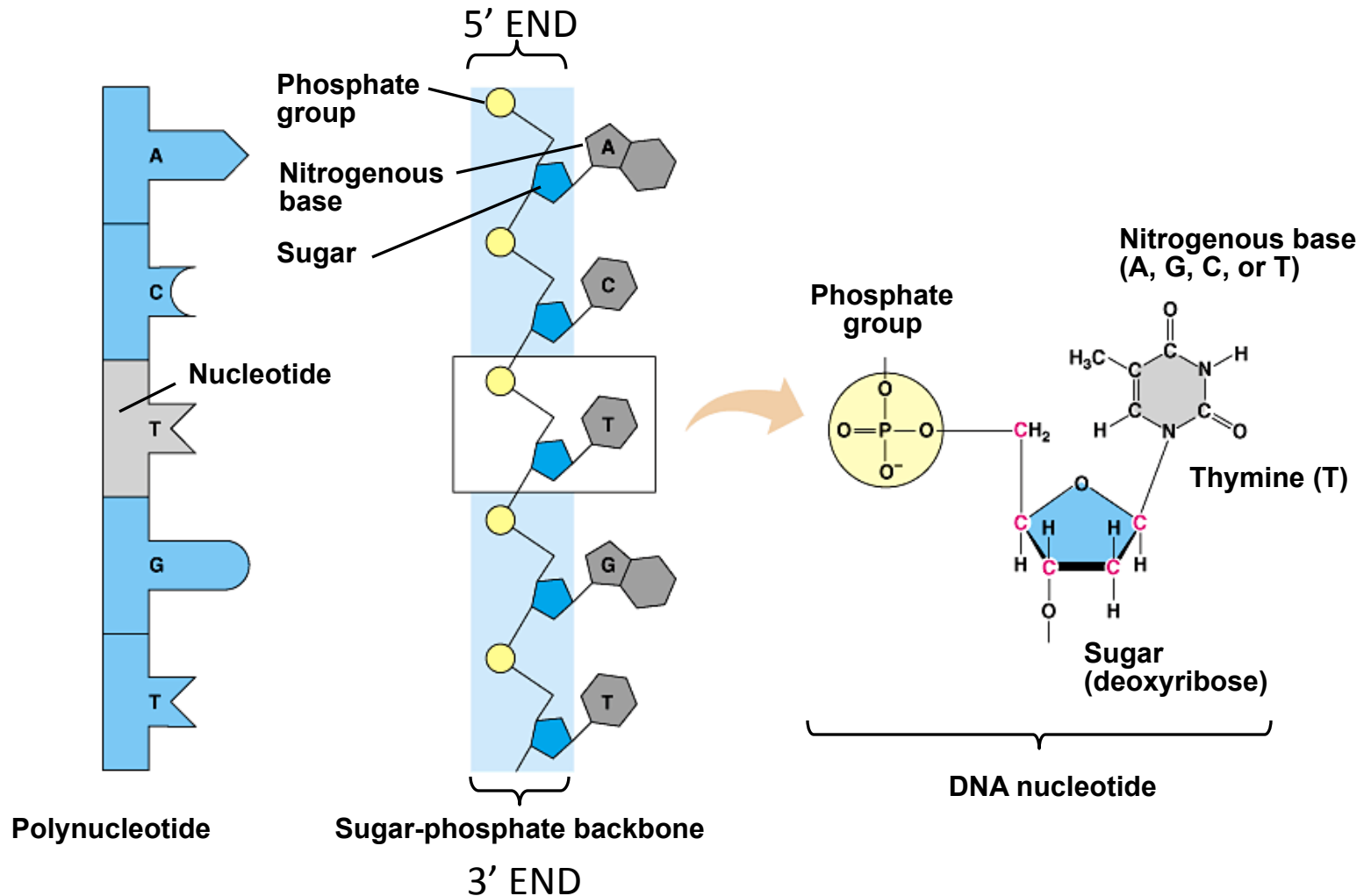- There are four bases A (adenine), C (cytosine), G (guanine), T (thymine)

- Specific base pairing
    - Base A always pairs with T
    - Base C always pairs with G

- The sequence of one strand defines the sequence of the second strand. The two strands are said to be 'complimentary'

- Information is stored in the sequence of bases

- Double stranded DNA resembles a ladder
    - Rails = sugar/phosphate
    - Rungs = base pairs (bp)

- DNA building blocks = 4 nucleotides (phosphate/sugar/base)

DNA is a polymer of nucleotides

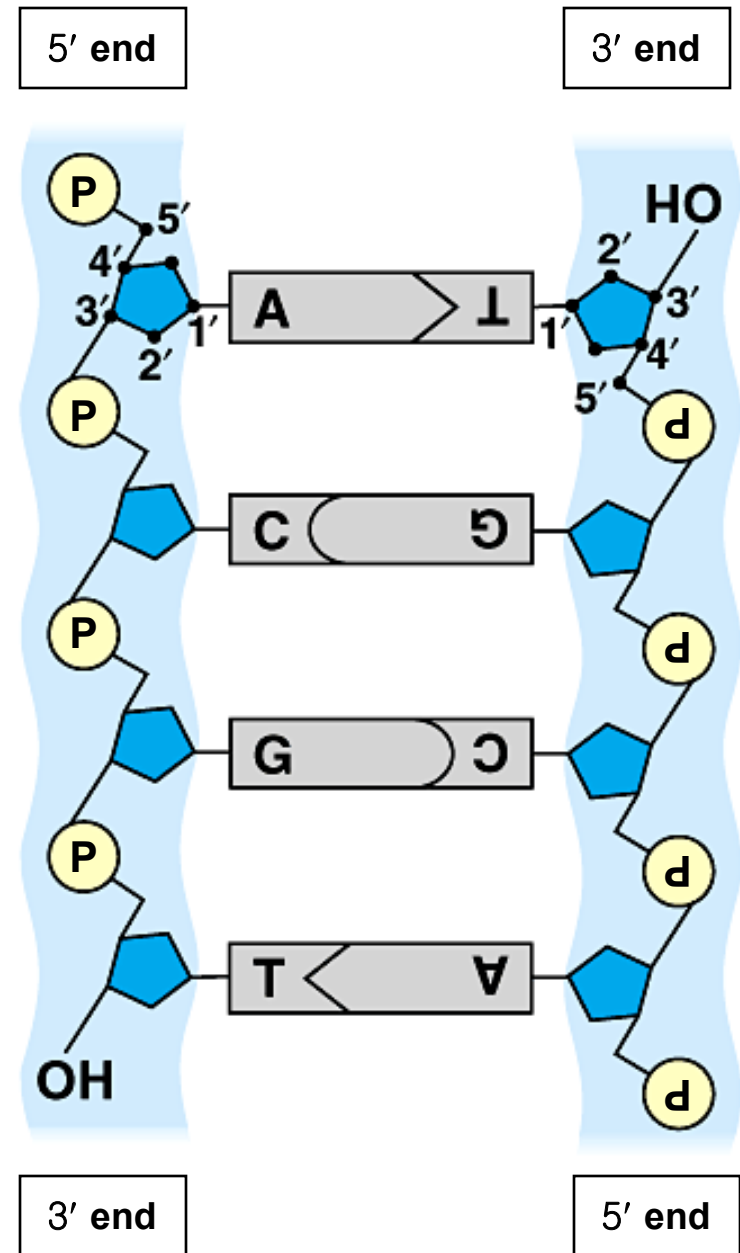- DNA is a nucleic acid, made of long chains of nucleotides

Campbell et al. (2003) BIOLOGY concepts and connections.
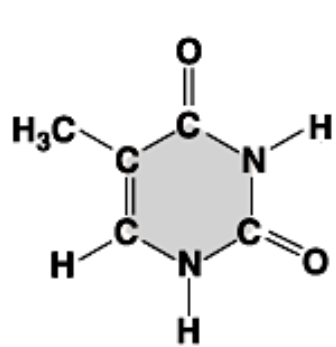
3' and 5' ends of DNA movie

http://www.youtube.com/watch?v=p835L4HWH68

- Each strand of the double helix is oriented in the opposite direction

- DNA has four kinds of bases, A, T, C, and G
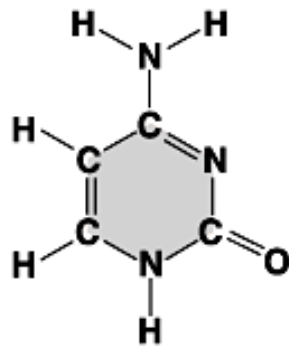
Thymine (T) **Cytosine (C)** **Adenine (A)** **Guanine (G)**
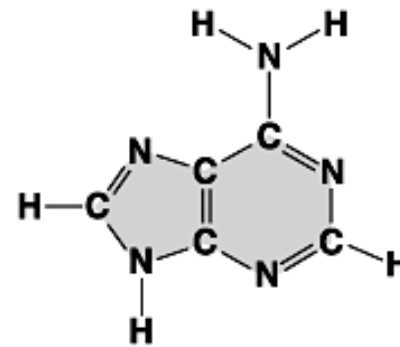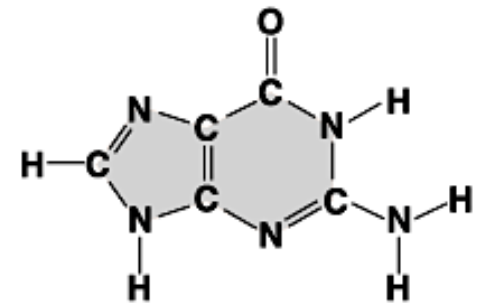
Pyrimidines **Purines**

DNA REPLICATION

DNA replication depends on specific base pairing

- In DNA replication, the strands separate
  - An enzyme (polymerase) use each strand as a template to assemble the new strands

Parental molecule of DNA

Both parental strands serve as templates

Nucleotides

Two identical daughter molecules of DNA
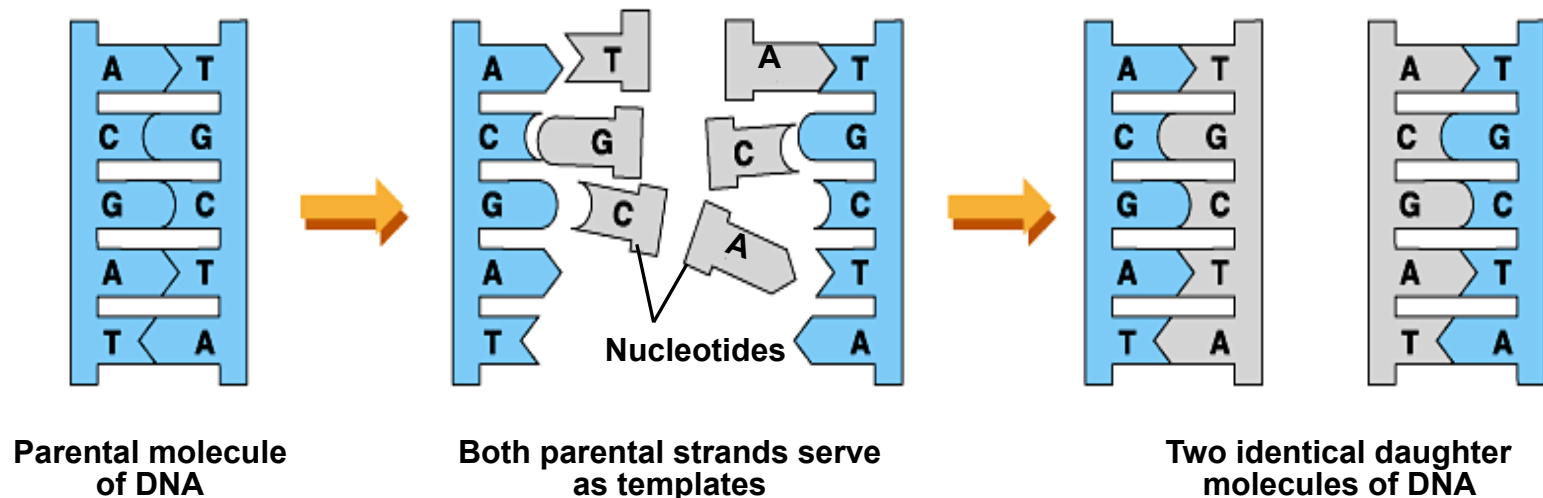
■ Figure 1-9 Simultaneous replication of both strands of the double helix. Both strands are read in the 3′ to 5′ direction. The lagging strand is read discontinuously, with the polymerase skipping ahead and reading back toward the replication fork on the lagging strand.

DNA polymerase

3′

5′

Leading strand

Lagging strand

3′

5′

3′

5′

5′

3′

Replication fork

Okazaki fragments

Overall direction of replication
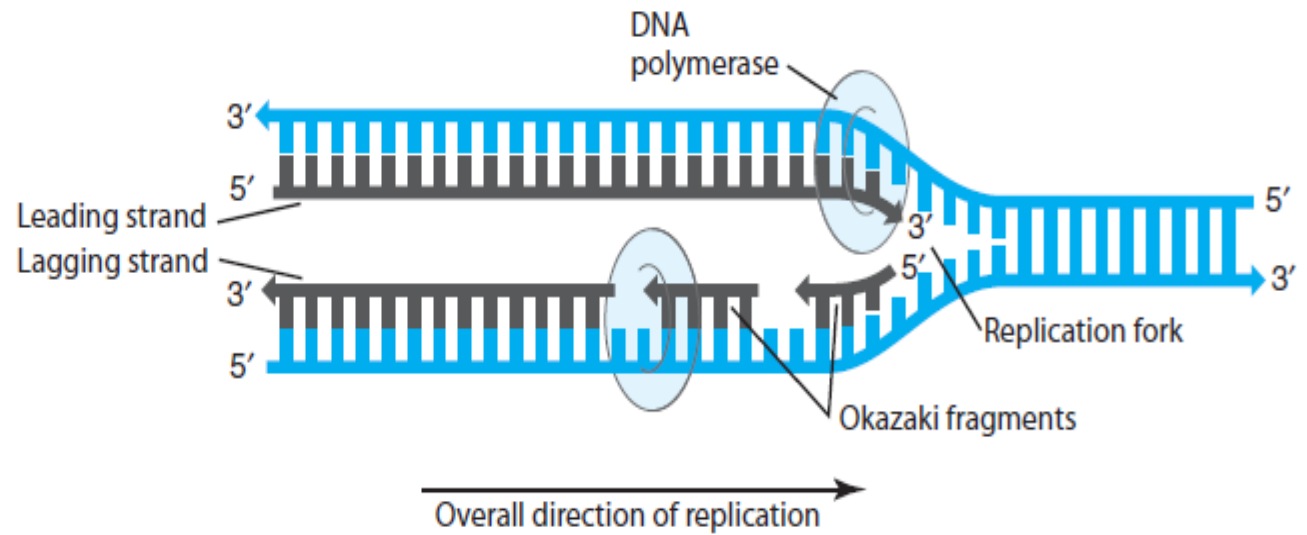
A SUMMARY OF DNA REPLICATION

❷ Single-strand binding proteins stabilize the unwound parental DNA.

❸ The leading strand is synthesized continuously in the 5′ → 3′ direction by DNA polymerase.

❶ Helicases unwind the parental double helix.

DNA polymerase

3′
5′

REPLICATION
FORK

RNA primer

❹ The lagging strand is synthesized discontinuously. Primase synthesizes a short RNA primer, which is extended by DNA polymerase to form an Okazaki fragment.
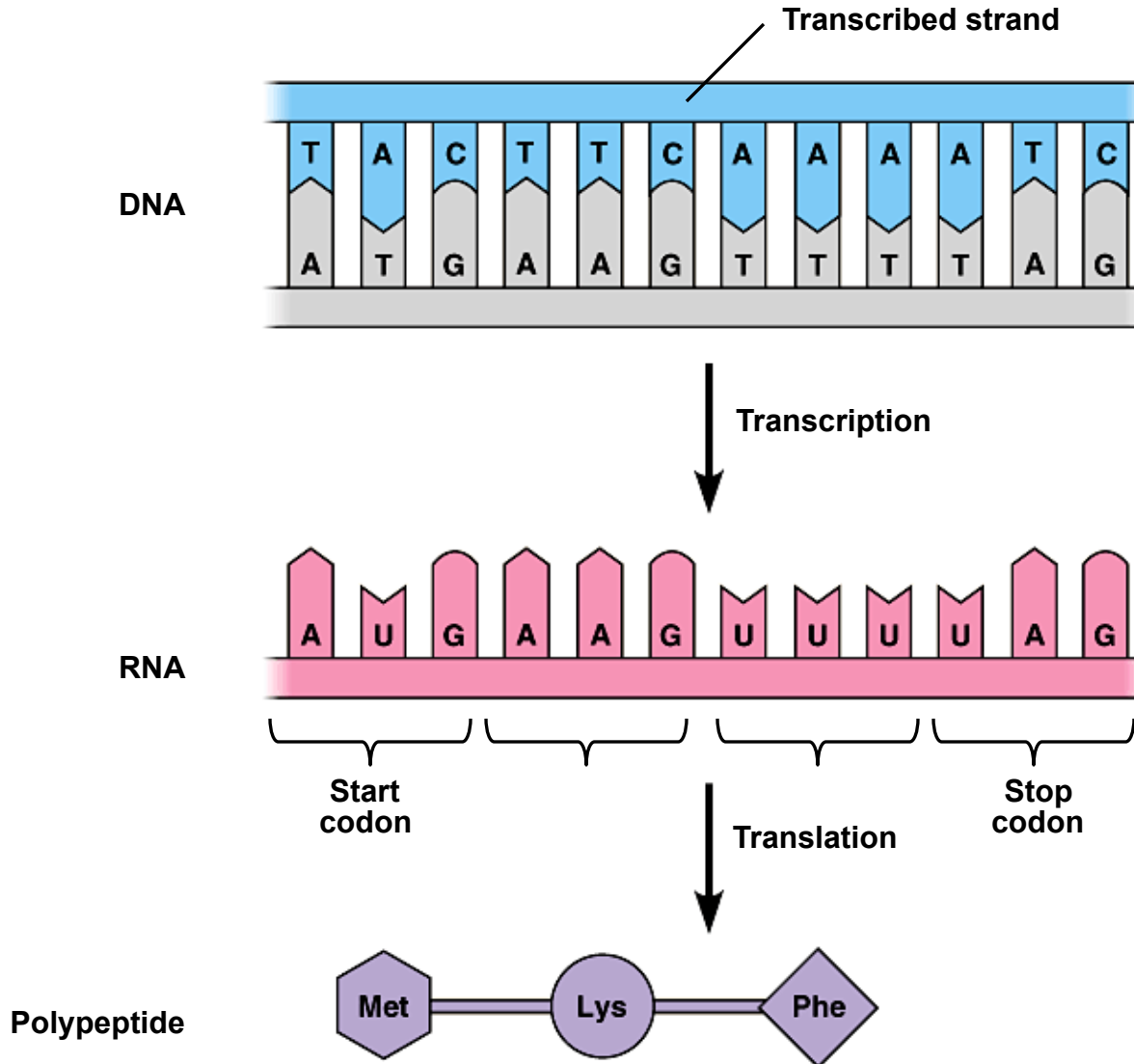
Primase

Okazaki fragment being made

5′
3′
Parental DNA

DNA polymerase

3′
5′

❺ After the RNA primer is replaced by DNA (by another DNA polymerase, not shown), DNA ligase joins the Okazaki fragment to the growing strand.

DNA ligase

← Overall direction of replication

http://www.tokresource.org/tok_classes/biobiobio/biomenu/dna_replication/index.htm

The DNA is transcribed into RNA, which is translated into the polypeptide

Thank you

- RNA is also a nucleic acid

  – RNA has a slightly different sugar

  – RNA has U instead of T

Phosphate group

Nitrogenous base (A, G, C, or U)

Uracil (U)

Sugar (ribose)

5′ end of chain

base

phosphodiester linkage

example: DNA

base

3′ end of chain