CHEM1200
GENETICS

I. Cell Division and Reproduction

II. Nucleic Acid (DNA and RNA)

- Structure of DNA/RNA
- DNA Replication
- Flow of Genetic Information

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Title: Biology The Dynamic Science 3rd edition
by Russell Hertz McMillan

Ch. 10 Cell Division and Mitosis

Ch. 11 Meiosis: The Cellular Basis of Sexual Reproduction

Ch. 14 DNA structure, Replication, and Organization

Ch. 15 From DNA to protein

Learning Outcomes

Upon completion of this topic, you should be able to:

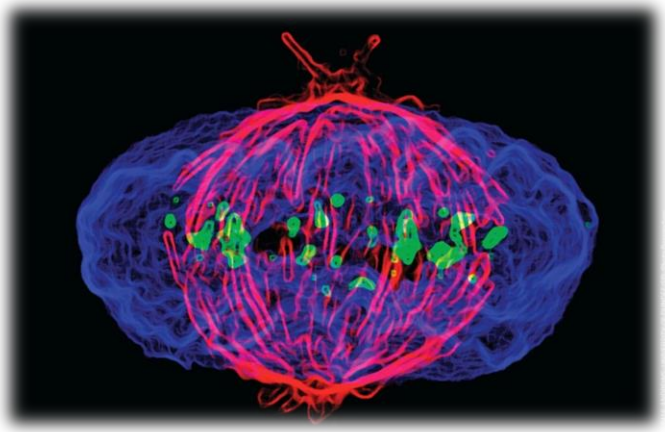
- **Briefly describe the purpose of cell division**
- **Describe briefly the activities of different stages of the cell cycle**
- **Distinguish between autosomes and sex chromosomes**
- **Distinguish between meiosis and mitosis**
- **Explain what is a karyotype**

Cell division plays many important roles in the lives of organisms

- **Reproduction of whole organisms, a key characteristic of life.**
- **Cell division**
  - **is reproduction at the cellular level,**
  - **requires the duplication of chromosomes, and**
  - **sorts new sets of chromosomes into the resulting pair of daughter cells.**

Cell division plays many important roles in the lives of organisms

- **Cell division is used:**
  - **for reproduction of single-celled organisms,**
  - **for growth of multicellular organisms from a fertilized egg into an adult,**
  - **for repair and replacement of cells, and**
  - **in sperm and egg production.**



A cell division by mitosis

Binary Fission of a Prokaryotic Cell (Cell division in prokaryotes)

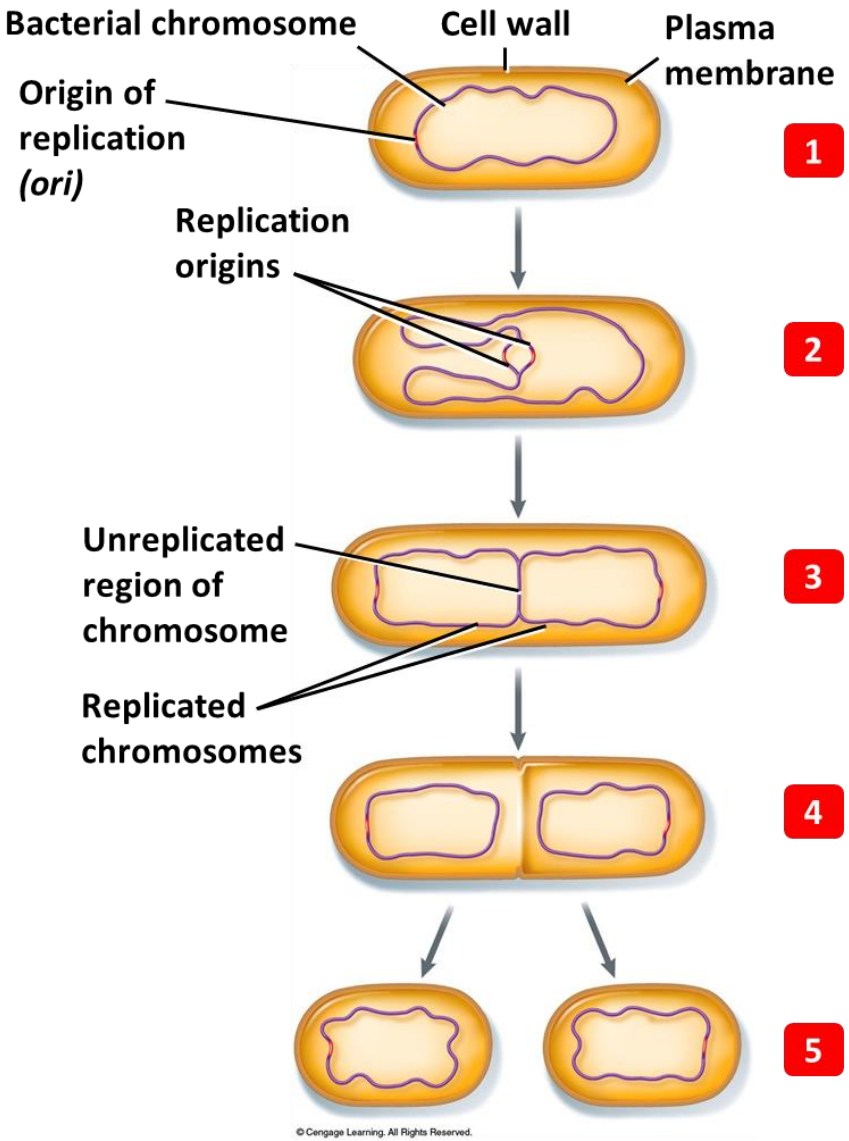
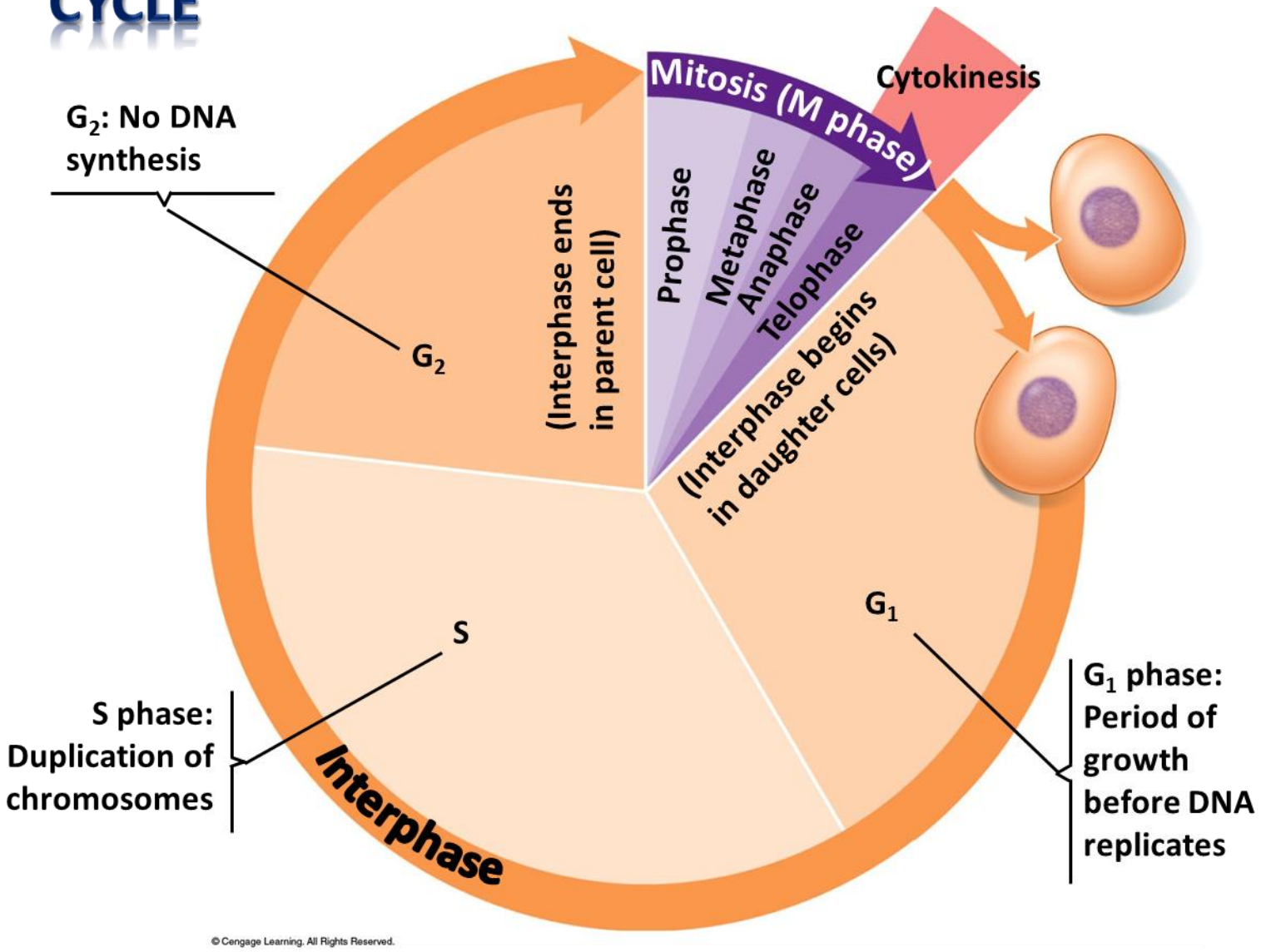


Figure 10-16 p221

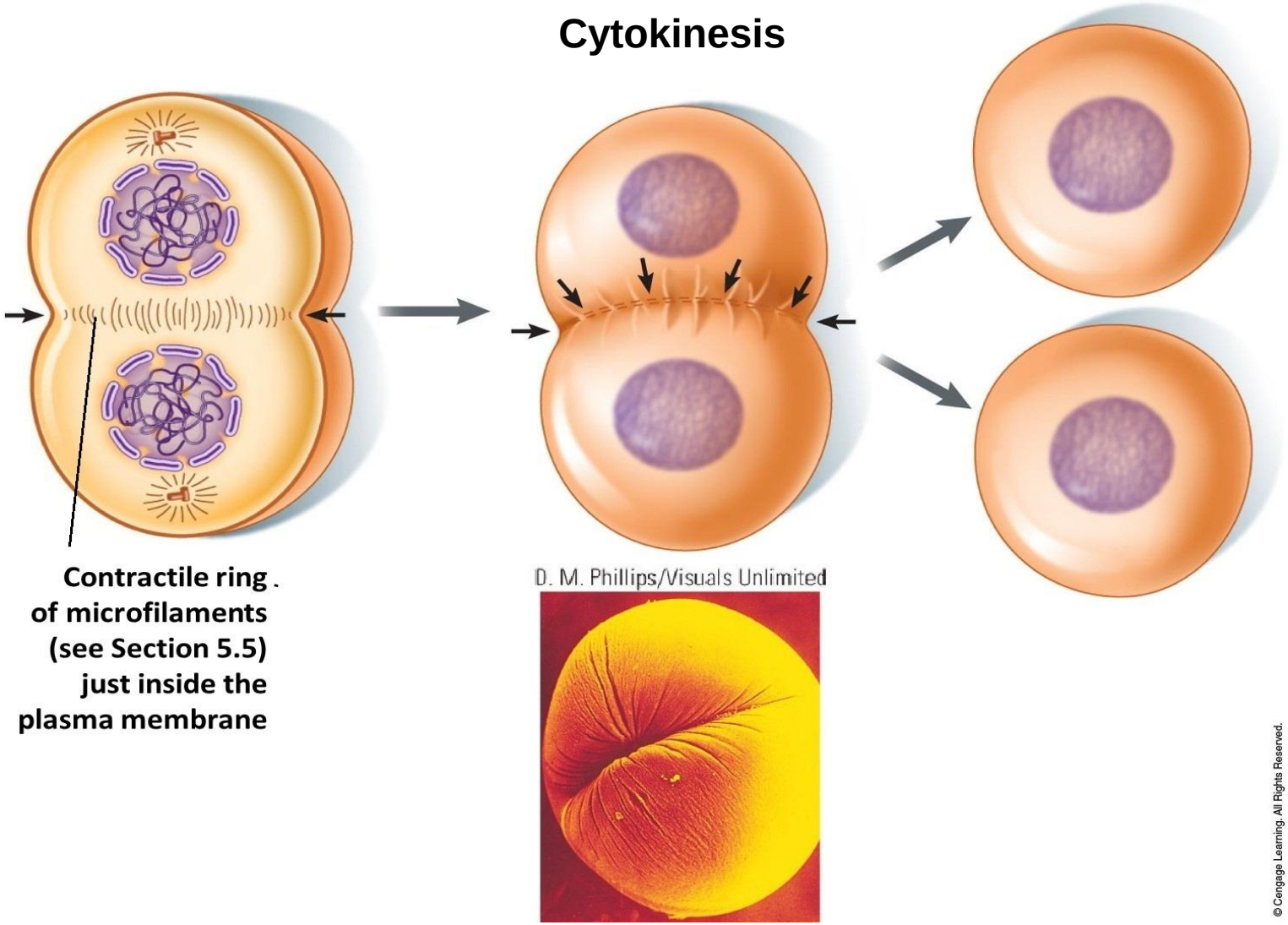
The Eukaryotic Cell Cycle (Cell division in eukaryotes)

- **The cell cycle consists of two stages:**
  1. ***Interphase*: duplication of cell contents**
     - **G_1—growth, increase in cytoplasm**
     - **S—duplication of chromosomes**
     - **G_2—growth, preparation for division**
  2. ***Mitotic phase*: division**
     - **Mitosis—division of the nucleus**
     - **Cytokinesis—division of cytoplasm**

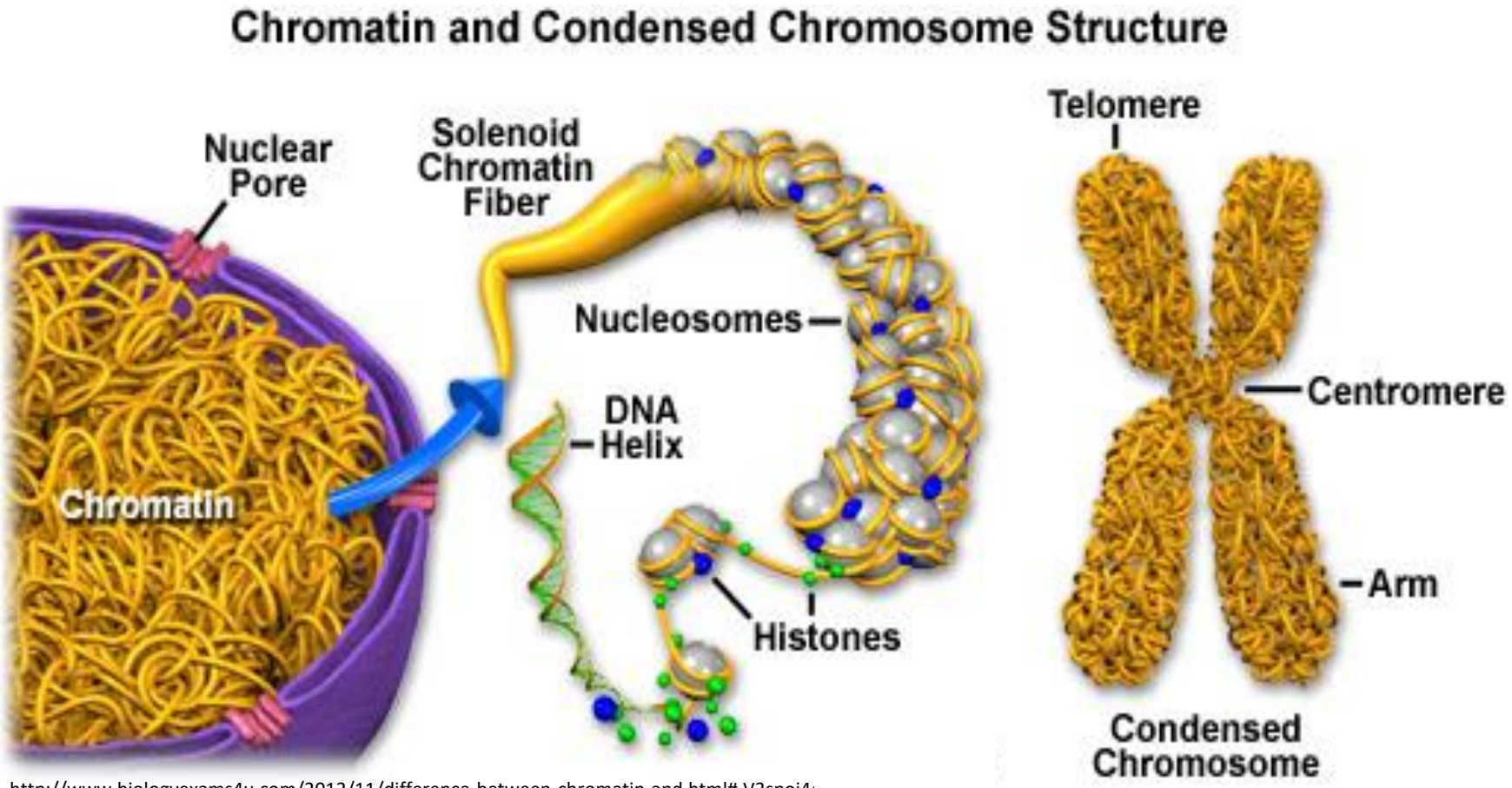
THE EUKARYOTIC CELL CYCLE



Cleavage of an animal cell (Mitosis)



Human Chromosomes

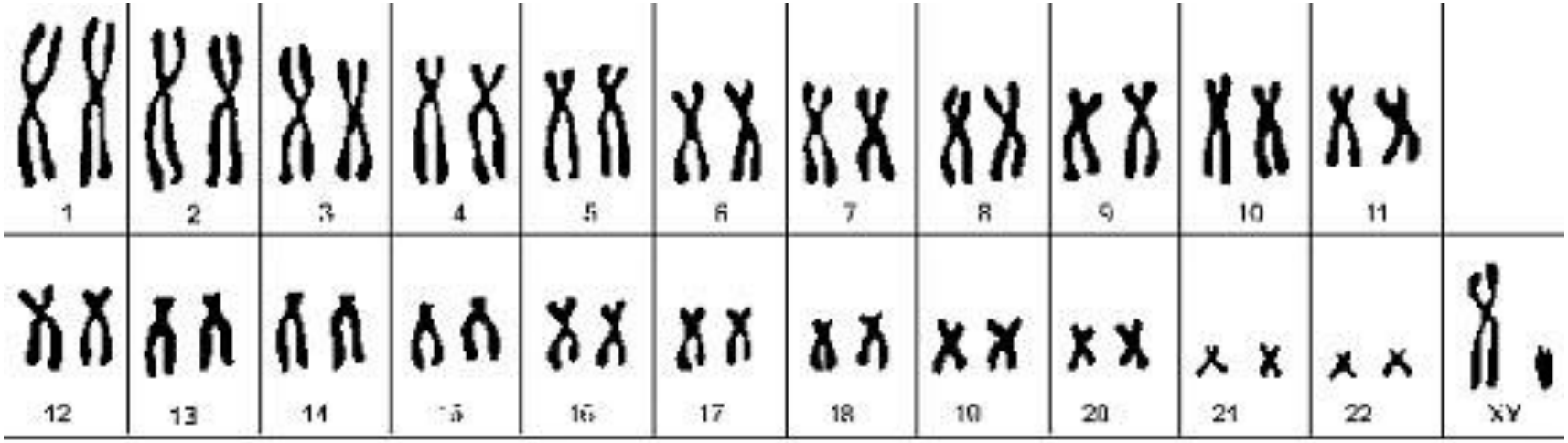


http://www.biologyexams4u.com/2012/11/difference-between-chromatin-and.html#.V3spoj4

Chromosomes are matched in homologous pairs in somatic cells

- **In humans, somatic cells have**
  - **23 pairs of homologous chromosomes; with one member of each pair from each parent.**
- **Possess a pair of sex chromosomes X and Y which differ in size and genetic composition.**
- **And carry 22 pairs of autosomes (non-sex chromosomes), each pair of the same size and genetic composition.**

23 pairs of Chromosomes



revisionworld

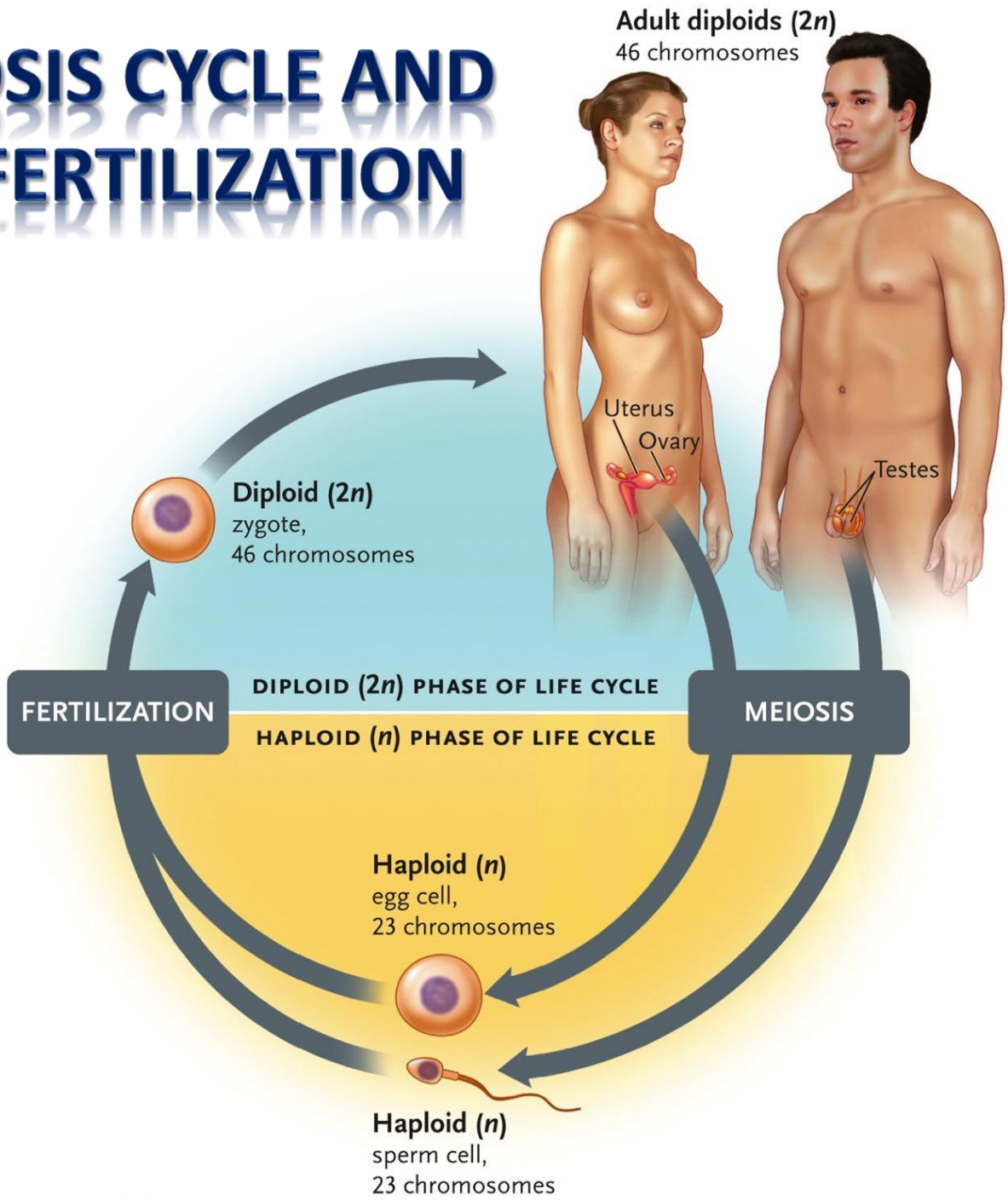
http://revisionworld.com/a2-level-level-revision/biology/genes-genetic-engineering/chromosomes-alleles

THE MEIOSIS CYCLE AND SEXUAL FERTILIZATION

Gonads
(sexual organs)

↓

Gametes
(sperm or eggs)



Gametes (germ cells) have a single set of chromosomes

- An organism's life cycle is the sequence of stages leading
  - from the adult stage of one generation to the adult stage of the next.
- Humans and many animals and plants are diploid, with body cells that have
  - two sets of chromosomes,
  - one from each parent.

Gametes (germ cells) have a single set of chromosomes

- **Meiosis** is a process that converts **diploid** nuclei to **haploid** nuclei.
  - **Diploid cells** have two homologous sets of chromosomes.
  - **Haploid cells** have one set of chromosomes.
  - Meiosis occurs in the sex organs (**gonads**), producing gametes—**sperm** and **eggs**.
- **Fertilization** is the union of sperm and egg.
- The **zygote** has a diploid chromosome number, one set from each parent.

Gametes have a single set of chromosomes (Meiosis)

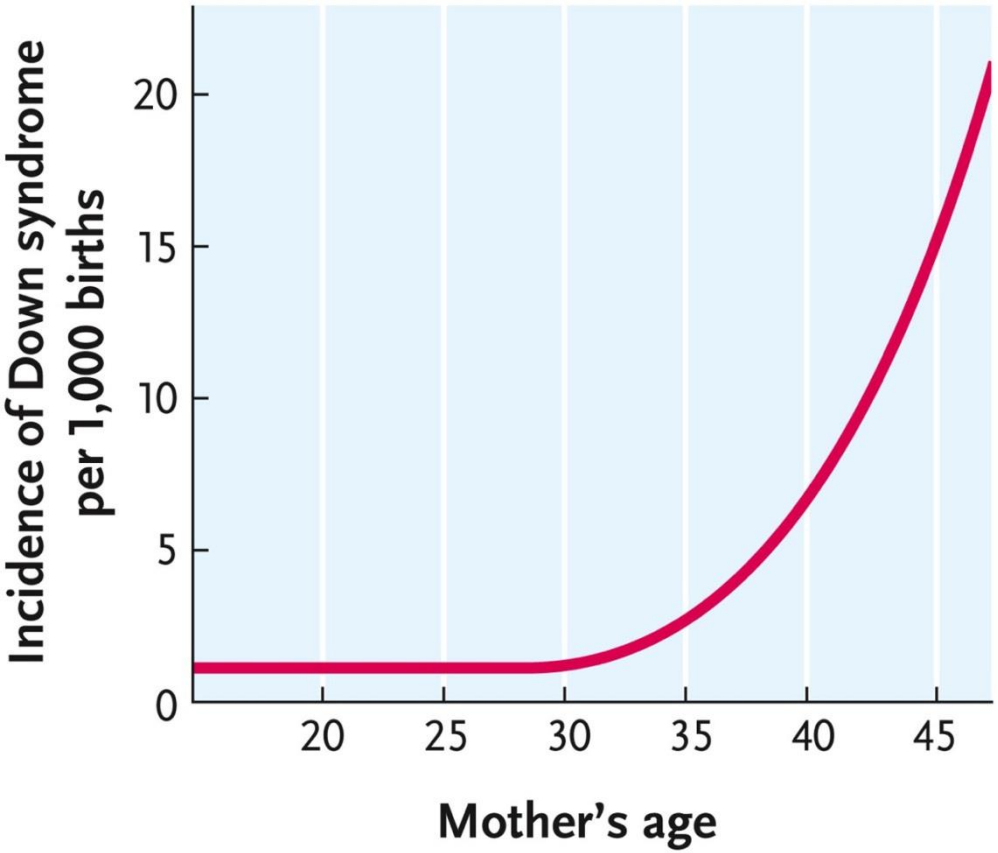
- **All sexual life cycles include an alternation between**
  - **a diploid stage and**
  - **a haploid stage.**
- **Producing haploid gametes prevents the chromosome number from doubling in every subsequent generation.**

An extra copy of chromosome 21 causes Down syndrome

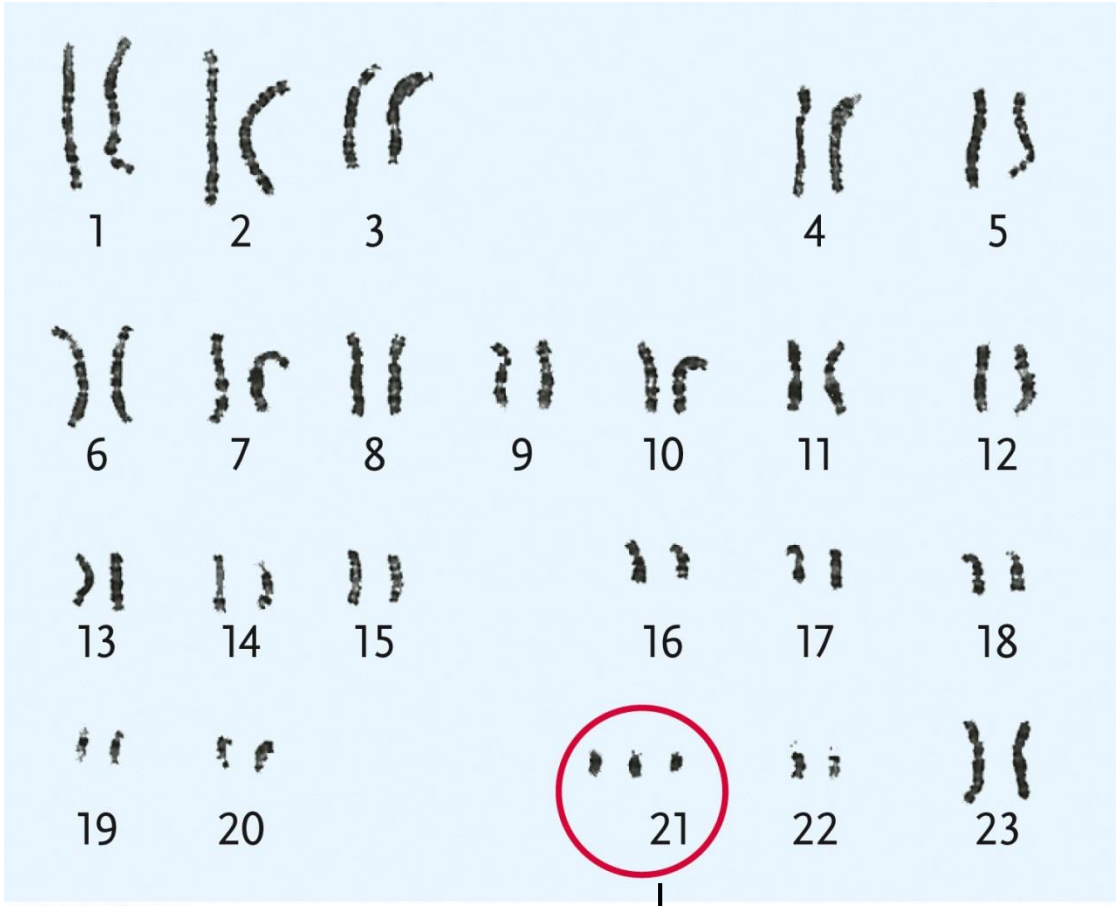
- **Trisomy 21 (presence of a full or partial extra copy of chromosome)**
- **produces a characteristic set of symptoms, which include:**
  - **mental retardation,**
  - **characteristic facial features,**
  - **heart defects,**
  - **susceptibility to respiratory infections, leukemia, and Alzheimer's disease, and**
  - **shortened life span.**
- **The incidence increases with mother's age.**

Maternal Age and Incidence of Down Syndrome

B. The increase in the incidence of Down syndrome with increasing age of the mother, from a study conducted in Victoria, Australia, between 1942 and 1957.



A Karyotype showing Trisomy 21



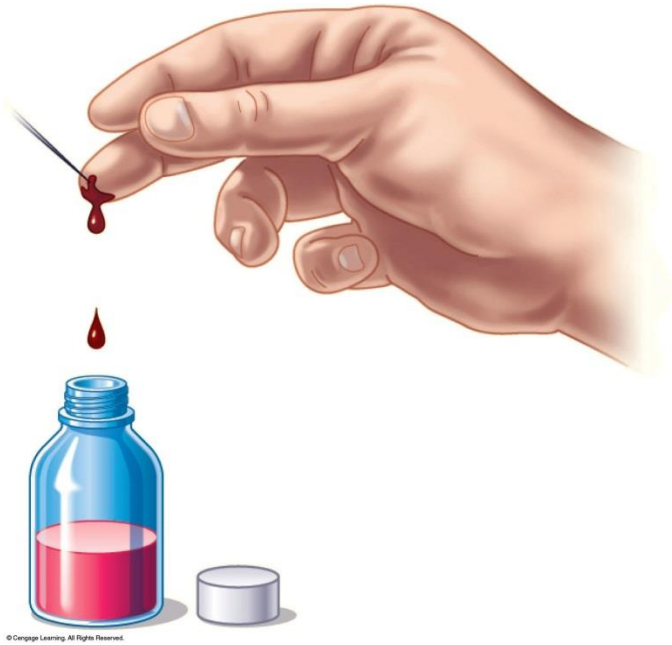
Trisomy 21

R. Gino Santa Maria/Shutterstock.com

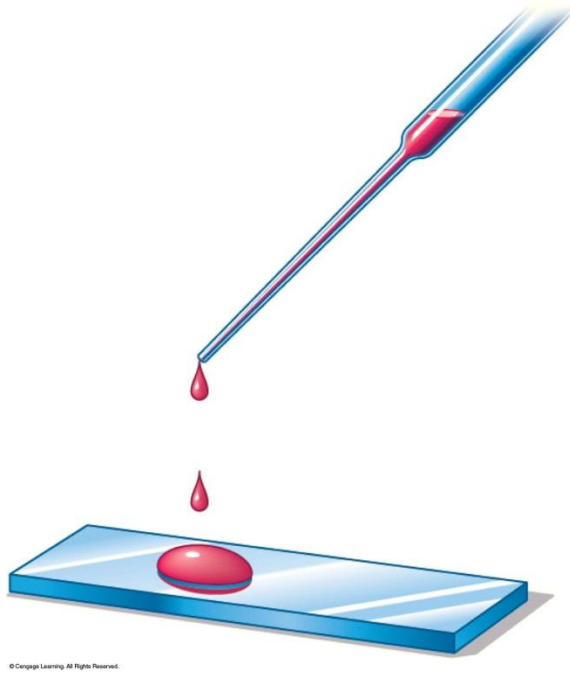
A karyotype is a photographic inventory of an individual's chromosomes

- **A karyotype is an ordered display of magnified images of an individual's chromosomes arranged in pairs.**
- **Karyotypes**
  - **are often produced from dividing cells arrested at metaphase of mitosis and**
  - **allow for the observation of**
    - **homologous chromosome pairs,**
    - **chromosome number, and**
    - **chromosome structure.**

Preparation of a Karyotype from a Blood Sample

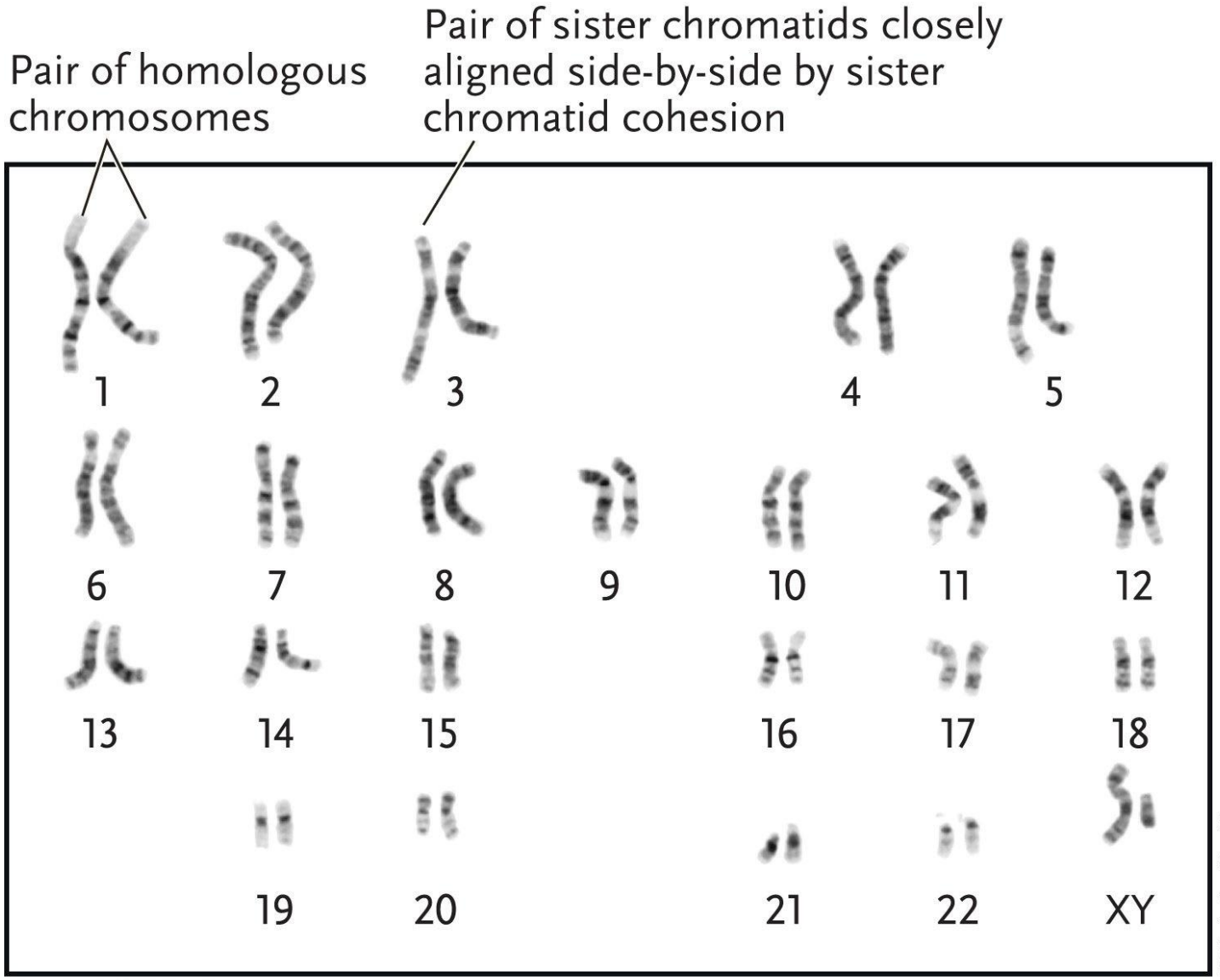


Add sample to culture media that has stimulator for growth and division of cell. Addition of colchicine will interrupt mitosis.



Stain the cell for distinguishing the chromosomes.

Resulting Display of a Karyotype



II. Nucleic Acid (DNA and RNA)

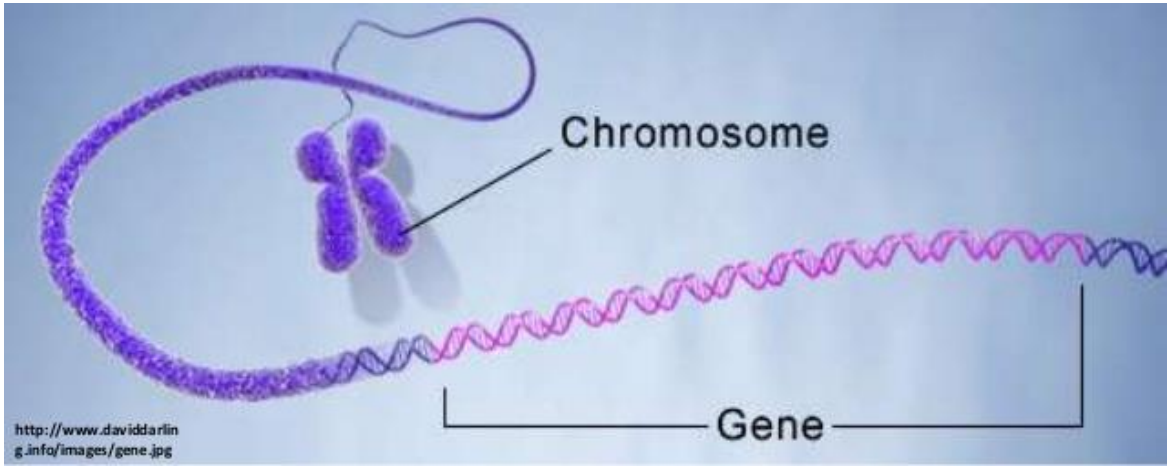
A. Structure of Genetic Material (DNA)
B. DNA Replication
C. Flow of Genetic Information from DNA to RNA to Protein

(*Chapter 14 & 15 of Cengage Learning*)

How big is the Human Genome?

The total DNA length of all 23 pairs of chromosomes in ONE diploid cell

= 2 m or ~ 6 feet



https://genographic.nationalgeographic.com/science-behind/genetics-overview/

Total DNA length from 100 trillion cells in a human body

= 113 billion miles (i.e. to the sun and back 610 times)

A. Structure of Genetic Material

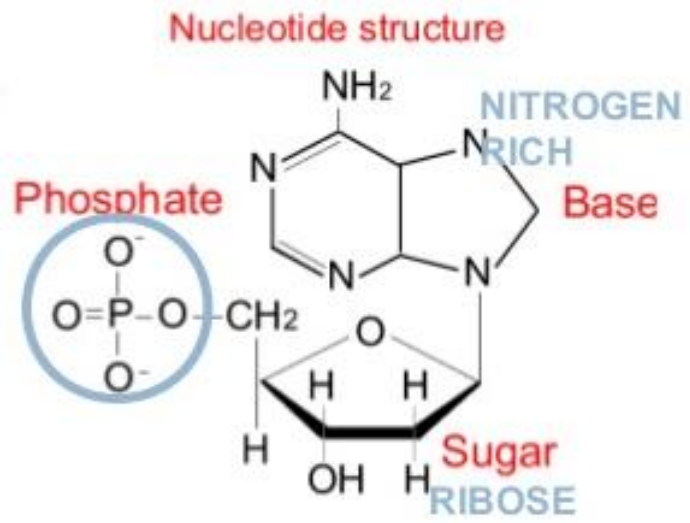
Learning Outcome

Upon completion of this topic, you should be able to:

- **Describe the structure of DNA and RNA**

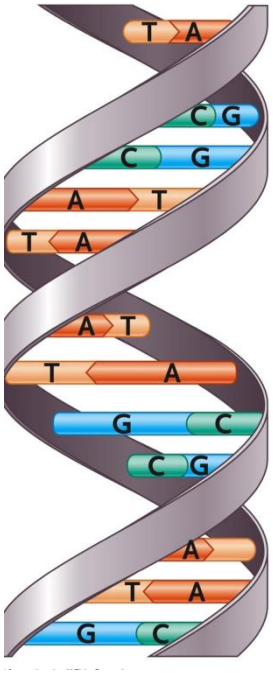
DNA and RNA are polymers of nucleotides

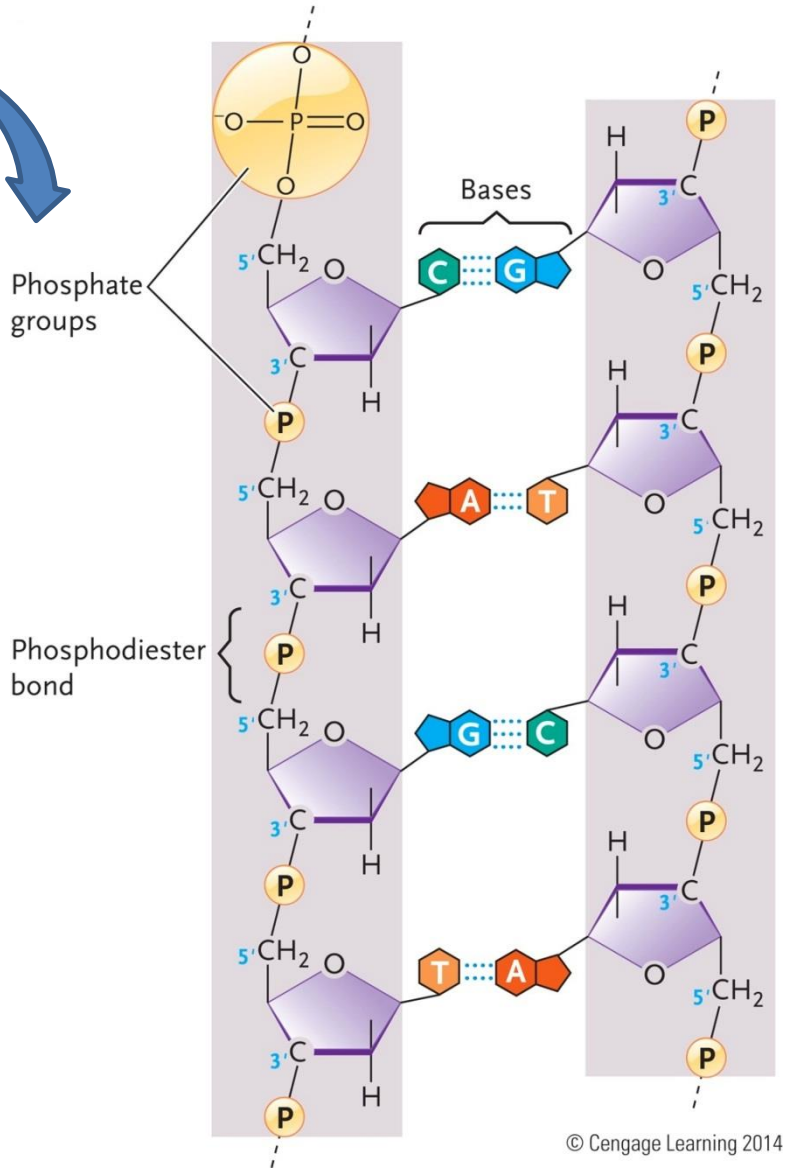
- DNA and RNA are nucleic acids.
- DNA is a polynucleotide i.e. a nucleotide polymer (chain).
- A nucleotide is composed of a
  - nitrogenous base,
  - five-carbon sugar, and
  - phosphate group.
- The nucleotides are joined to one another by a sugar-phosphate backbone.



http://www.slideshare.net/thelawofscience/historical-experiments-related-to-dna

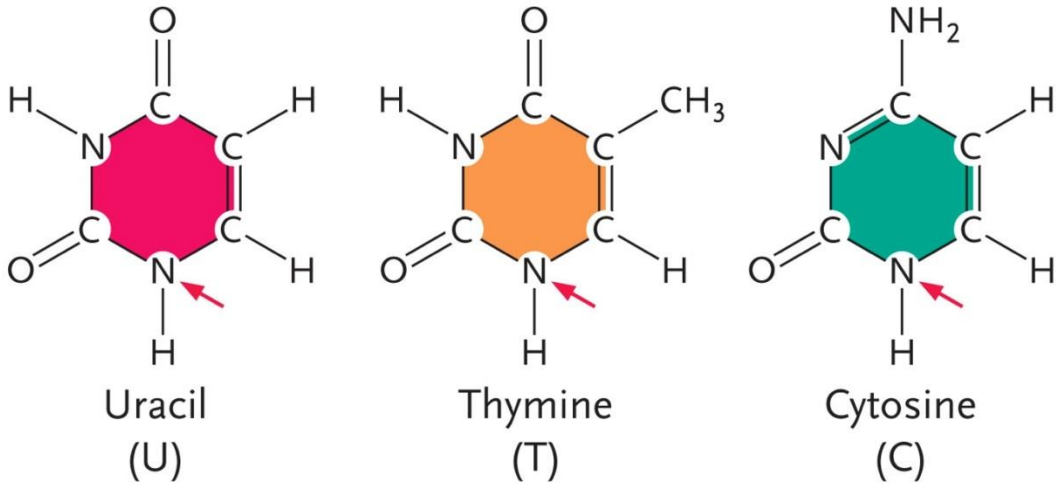
Structure of the DNA Polynucleotide



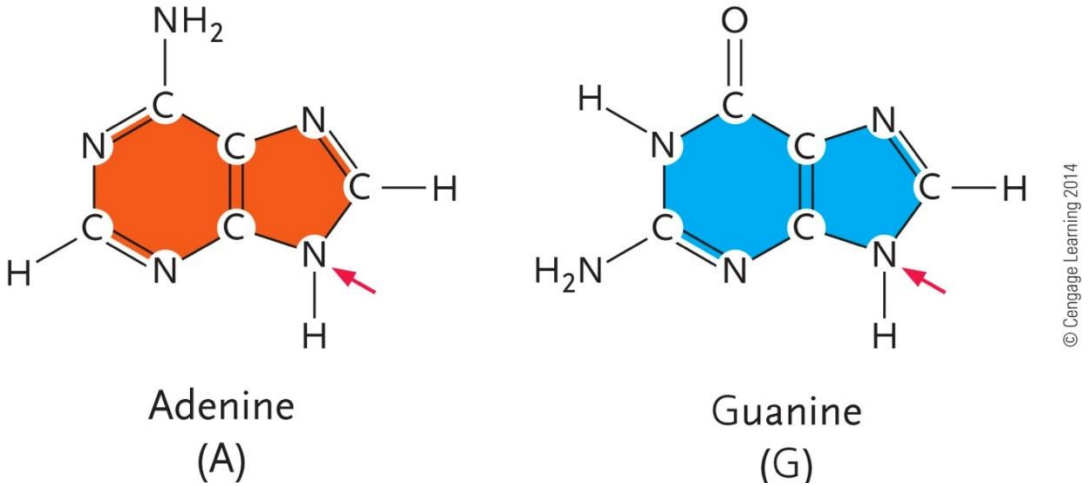


Nitrogenous Bases of nucleic acid

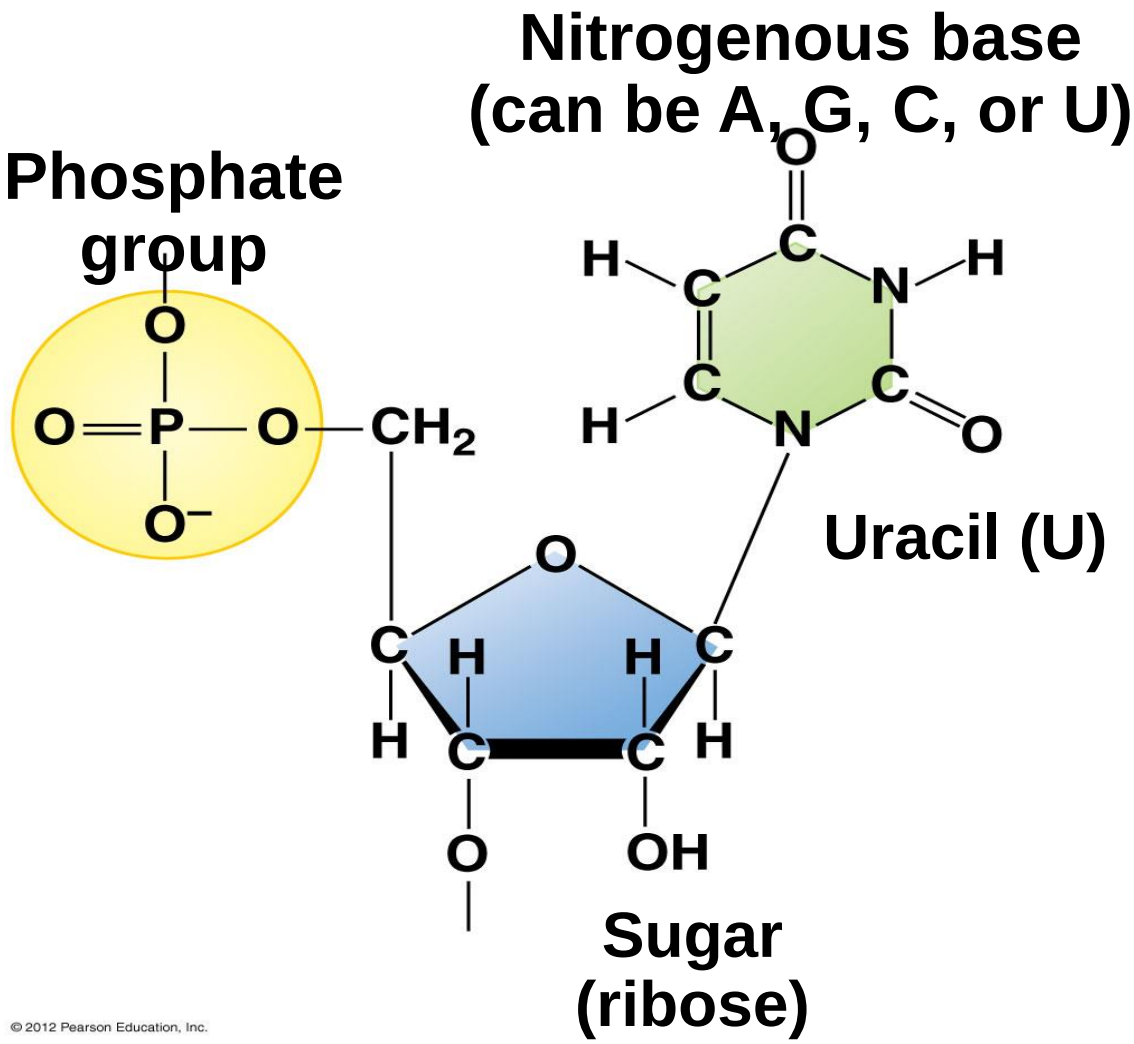
Pyrimidines



Purines



An RNA Nucleotide



Retrieved from Chapter 3 The Molecules of Cells (P.82) of Campbell Biology: Concepts and Connections, 7th edition. Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

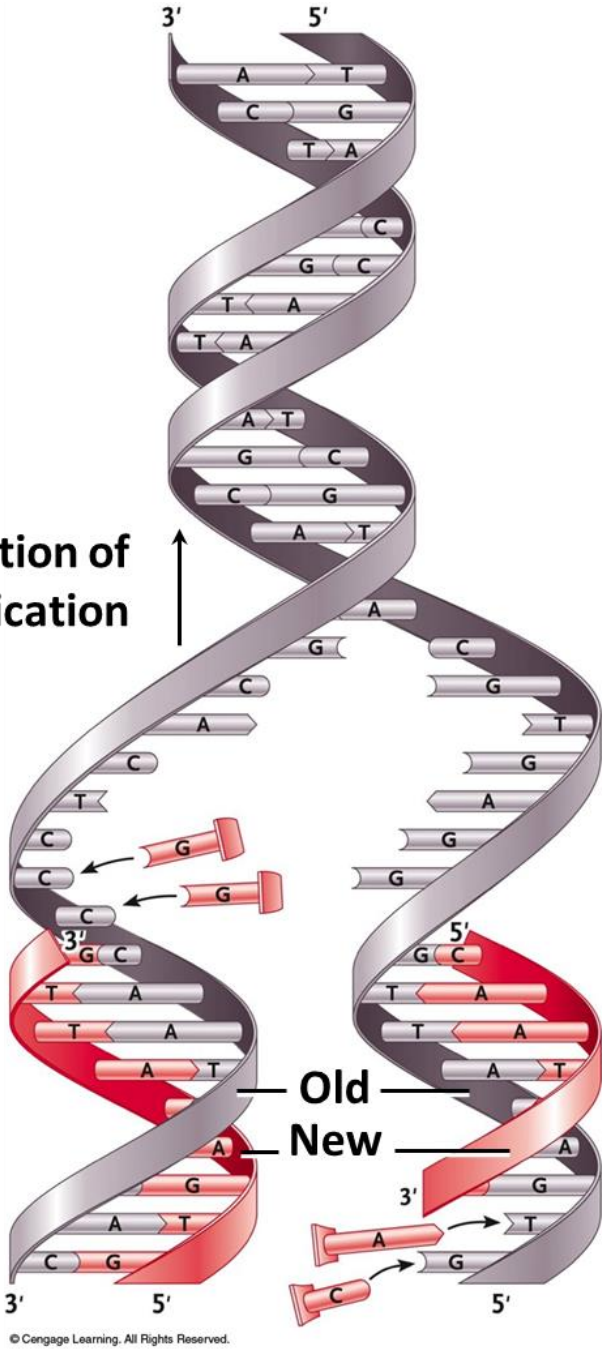
B. DNA REPLICATION

Learning Outcome

Upon completion of this topic, you should be able to:

- **List the steps in DNA replication**

THE UNTWISTING AND DNA REPLICATION



Complementary base pairing in the DNA double helix: A pairs with T, G pairs with C.

The two chains unwind and separate.

Each "old" strand is a template for the addition of bases according to the base-pairing rules.

The result is two DNA helices that are exact copies of the parental DNA molecule with one "old" strand and one "new" strand.

Figure 14-7, p. 292

DNA replication proceeds in two directions at many sites simultaneously

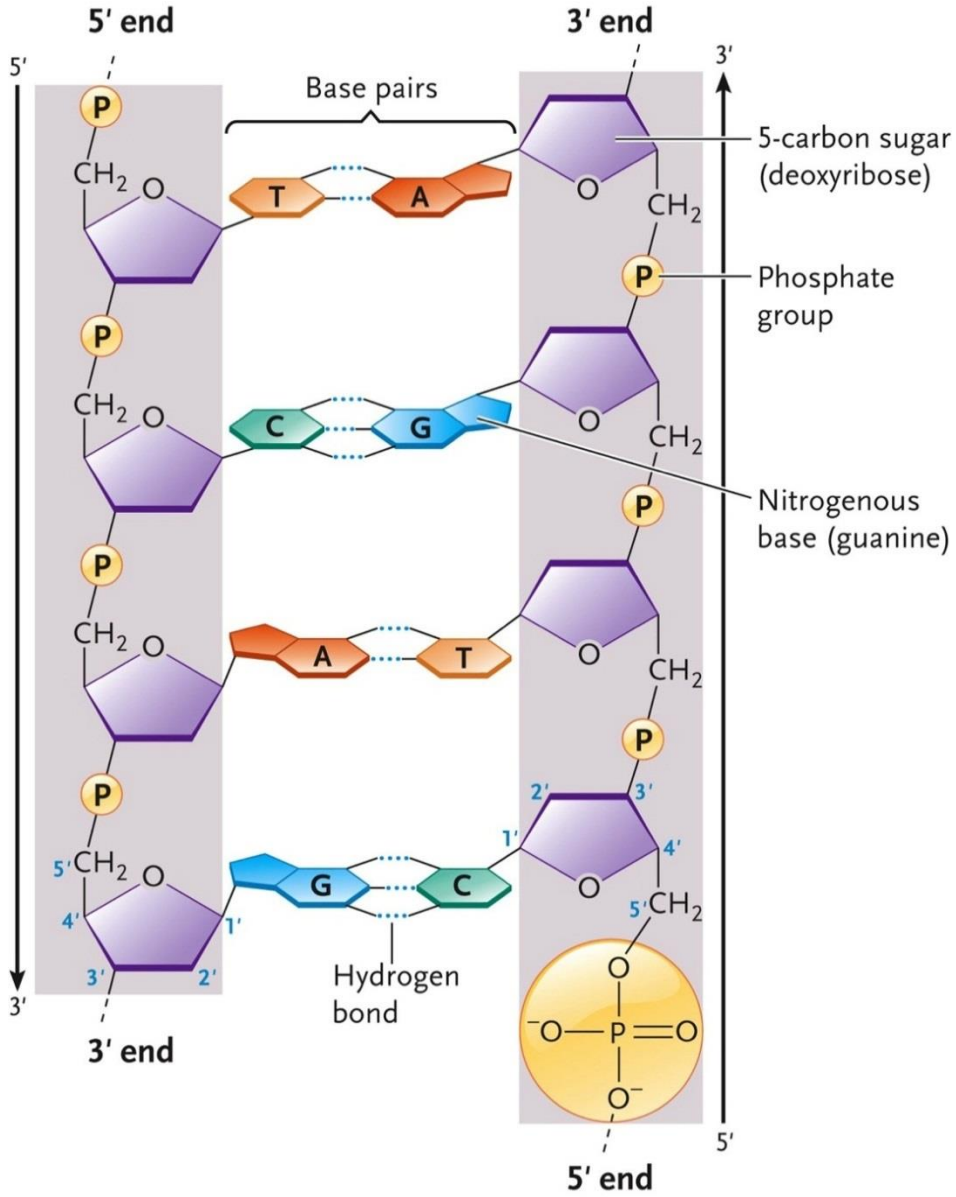
- DNA replication (synthesis of new DNA) begins at the origins of replication where
  - DNA unwinds at the origin to produce a "bubble"
  - replication proceeds in both directions from the origin, and
  - replication is based on the A = T and C = G base-pairing rule
- DNA replication occurs in the 5′ to 3′ direction.
  - Replication is continuous on the 3′ to 5′ template.
  - Replication is discontinuous on the 5′ to 3′ template, forming short segments.

The opposite orientations of DNA strands

Anti-parallel Strands of DNA

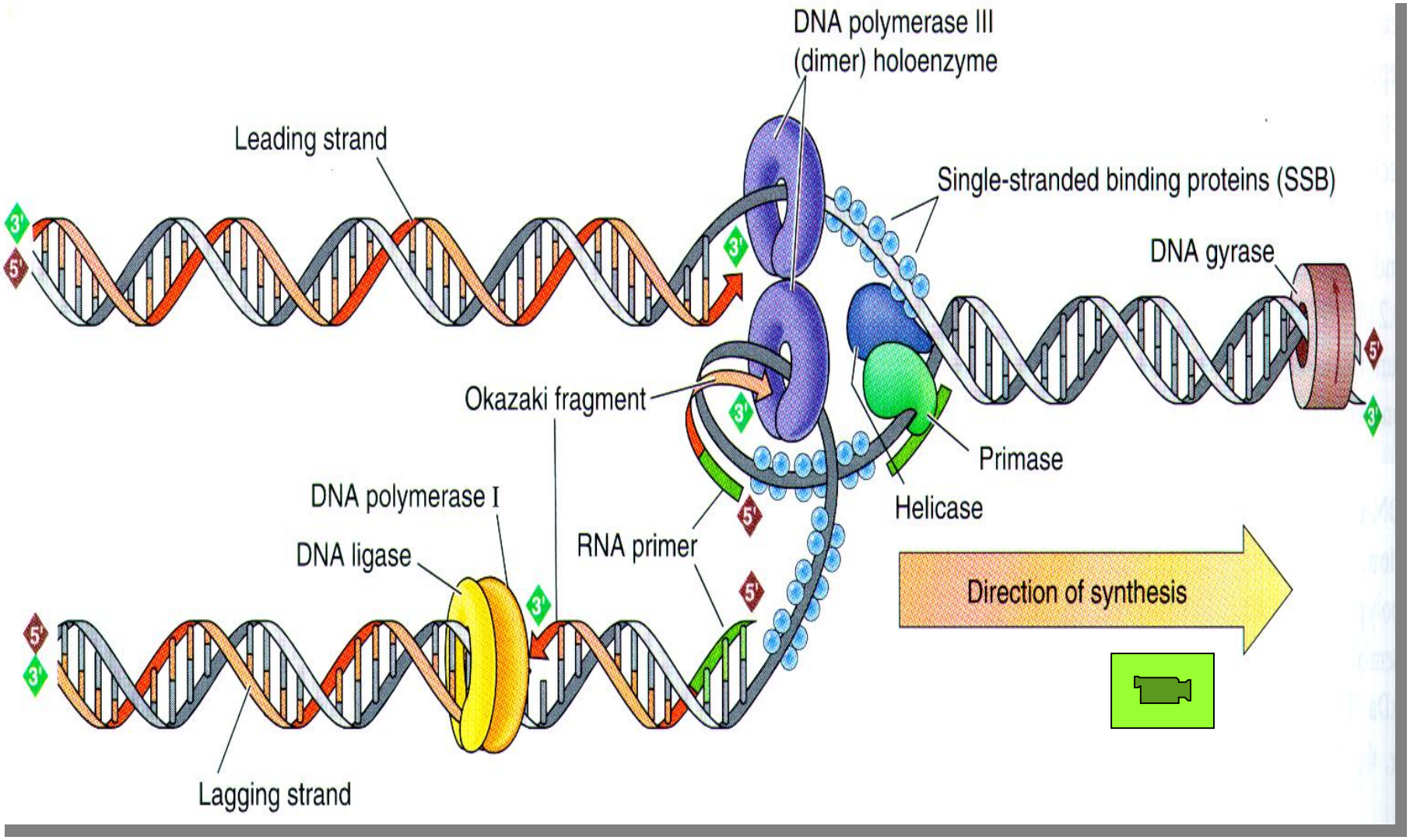
5’ ——— 3’

3’ ——— 5’



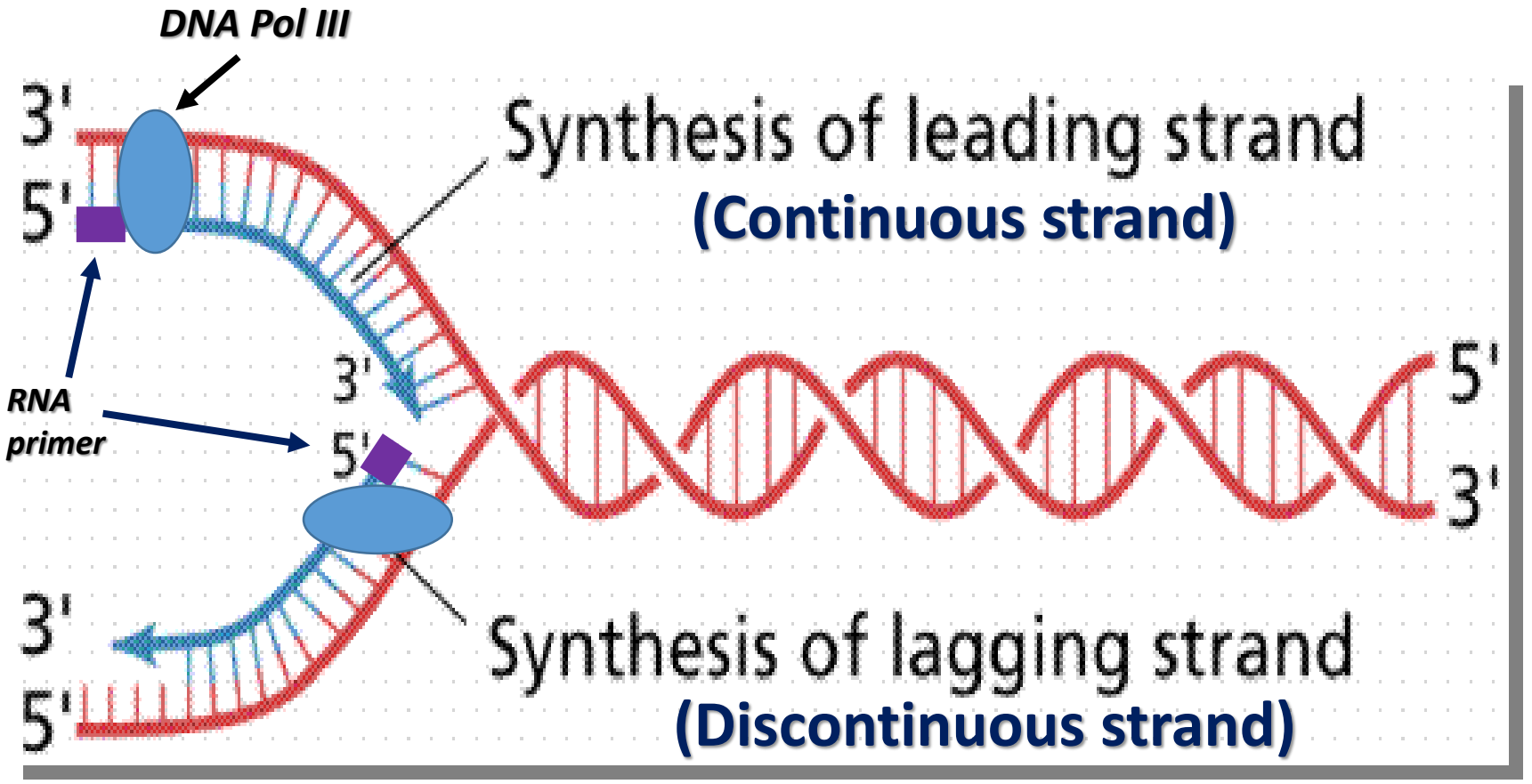
DNA replication proceeds in two directions at many sites simultaneously

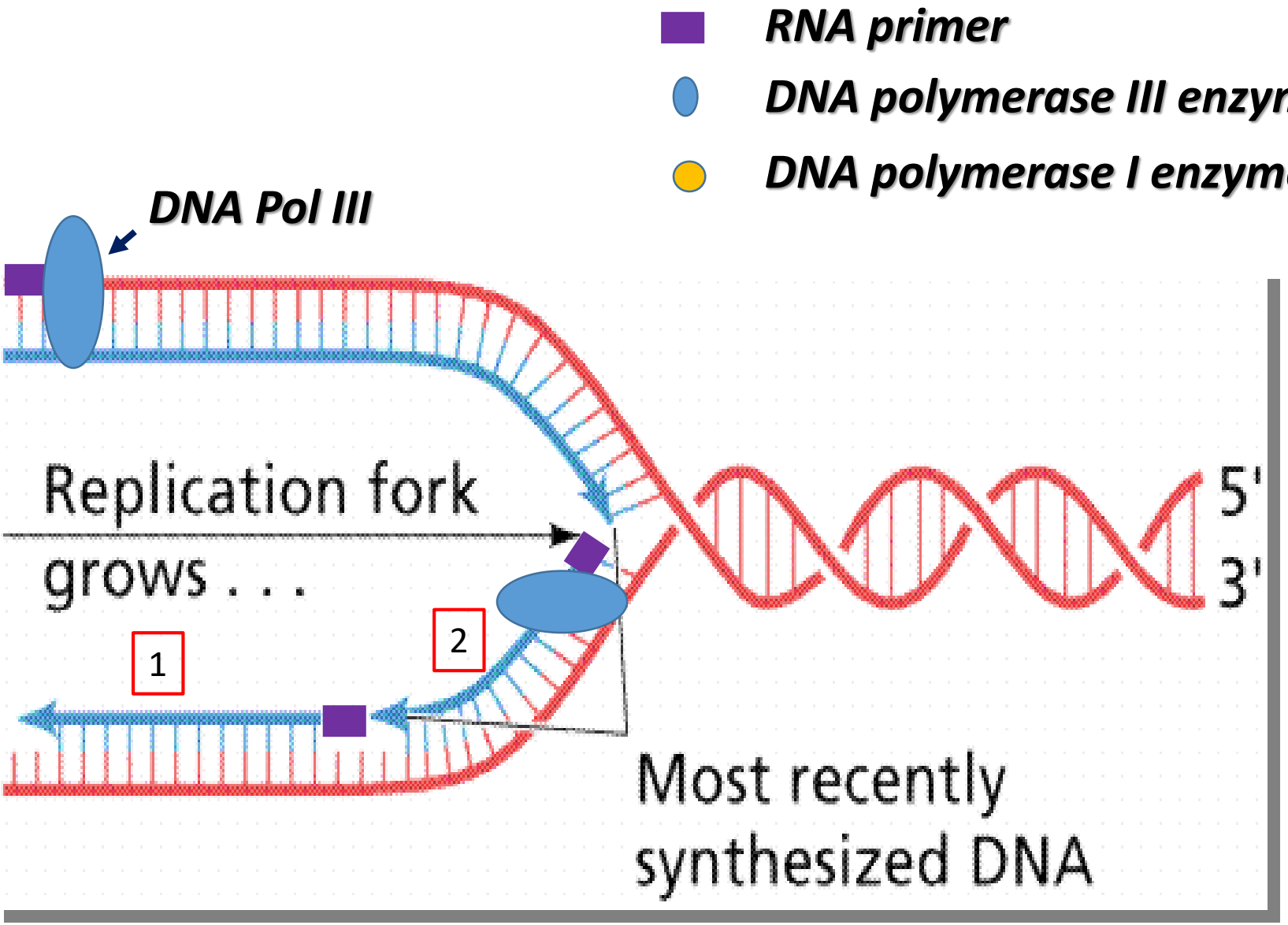
- **Two key proteins are involved in DNA replication.**
  1. **DNA ligase joins small fragments into a continuous chain.**
  2. **DNA polymerase**
     - **adds nucleotides to a growing chain and**
     - **proofreads and corrects improper base pairings.**

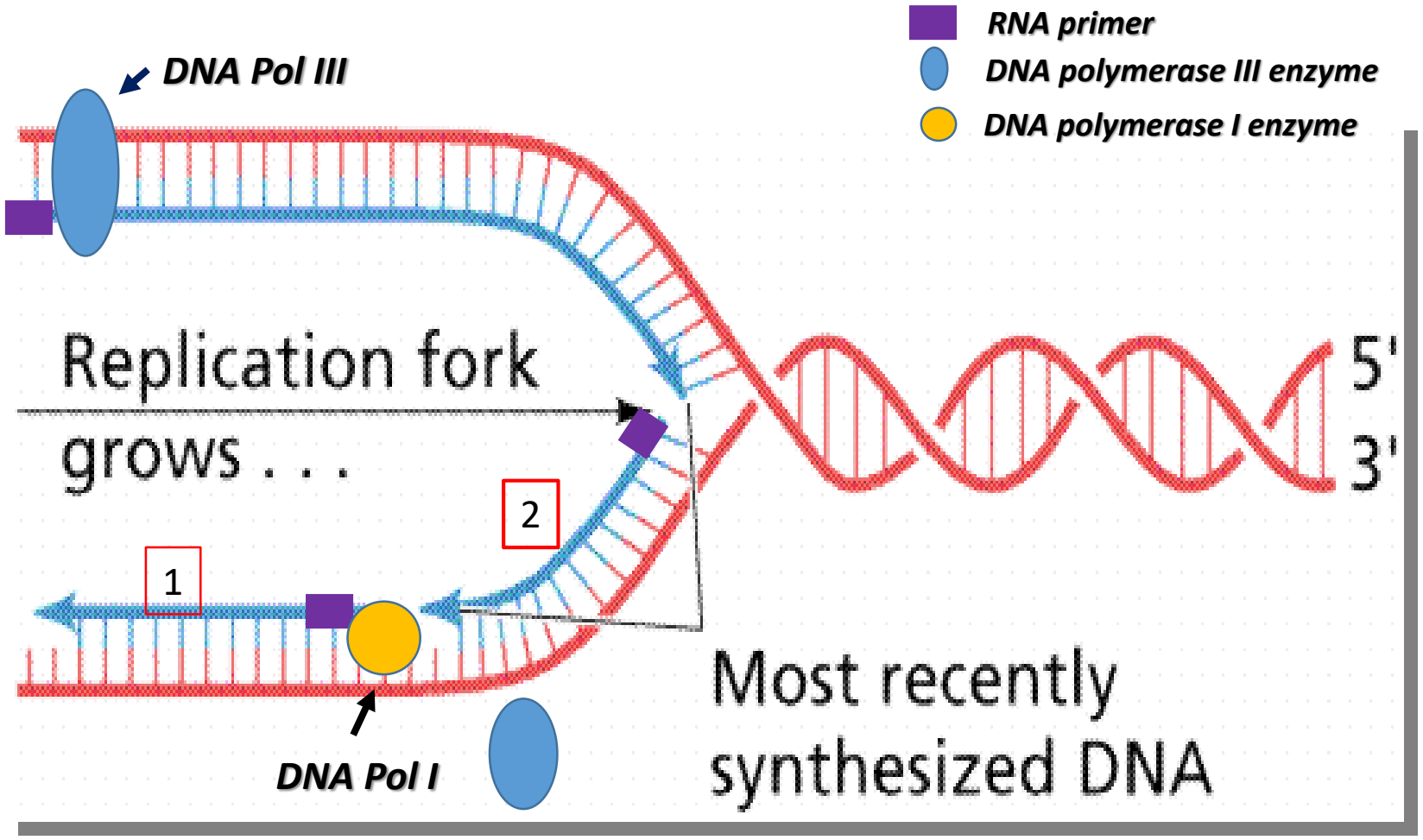

DNA polymerase III
(dimer) holoenzyme
Leading strand
Single-stranded binding proteins (SSB)
DNA gyrase
Okazaki fragment
Primase
Helicase
DNA polymerase I
DNA ligase
RNA primer
Direction of synthesis
Lagging strand

DNA Replication Fork

DNA polymerase III
+
dATP, dCTP, dGTP and dTTP



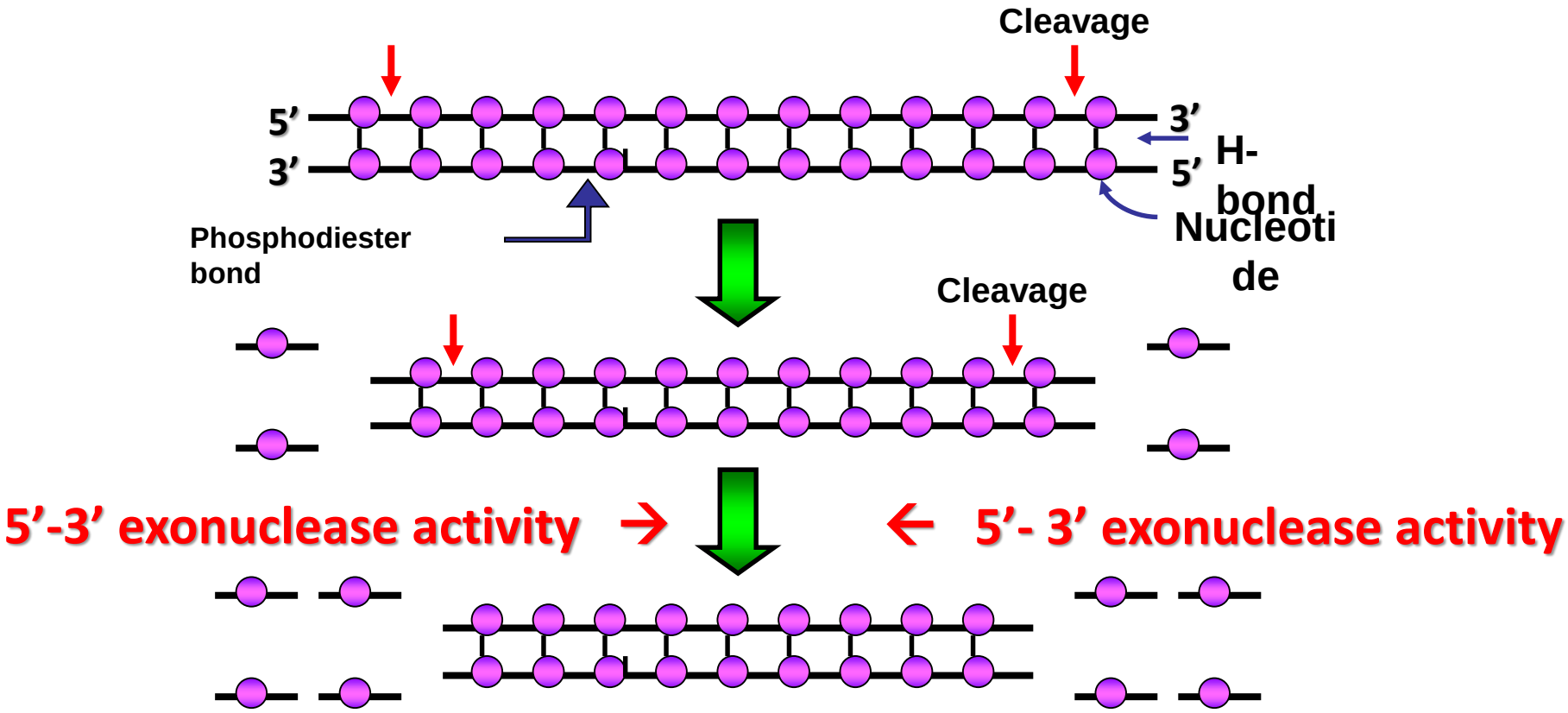

RNA primer
DNA polymerase III enzyme
DNA polymerase I enzyme
DNA Pol III
Replication fork
grows . . .
1
2
5'
3'
Most recently
synthesized DNA

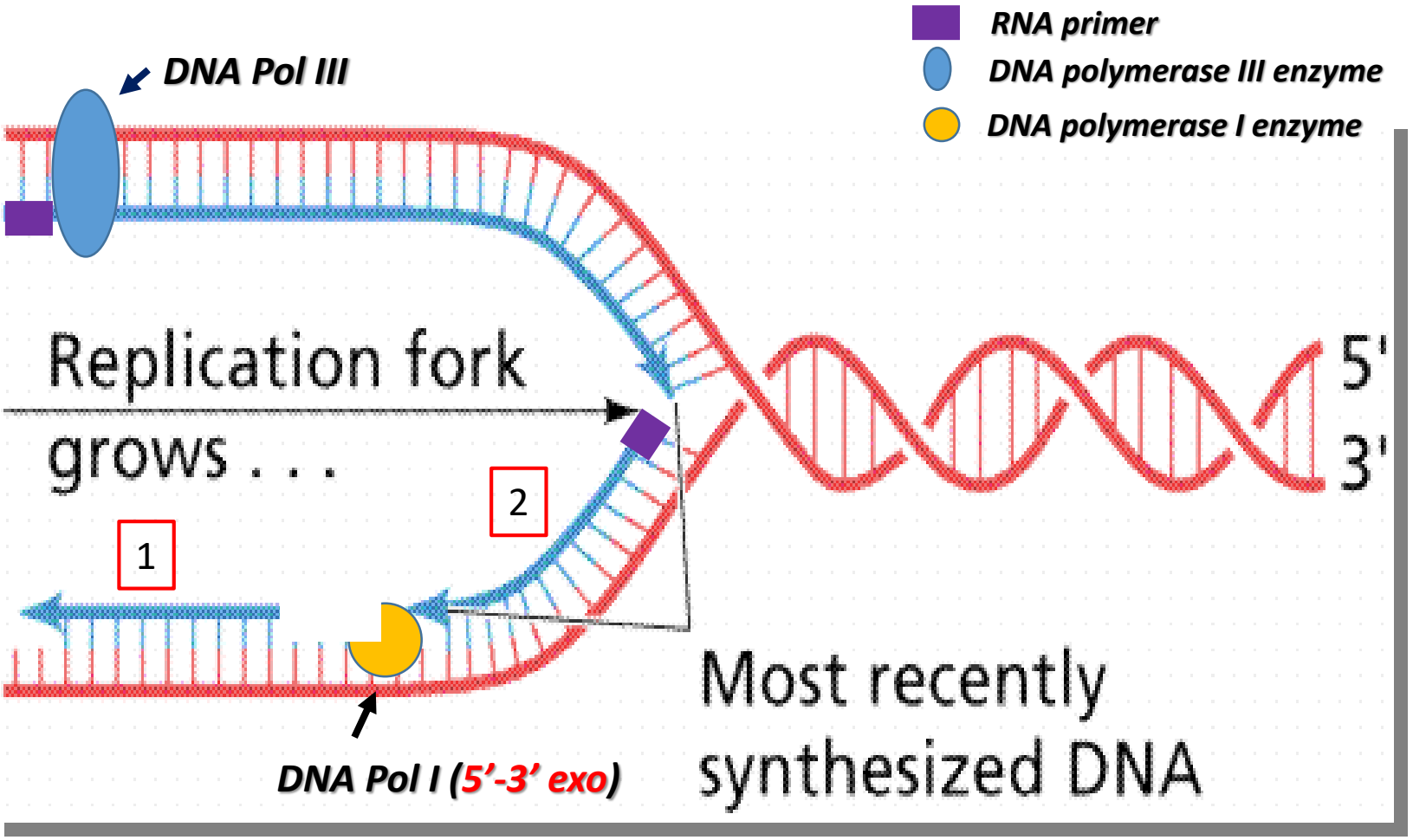

RNA primer
DNA polymerase III enzyme
DNA polymerase I enzyme
DNA Pol III
Replication fork grows . . .
5'
3'
2
1
DNA Pol I
Most recently synthesized DNA

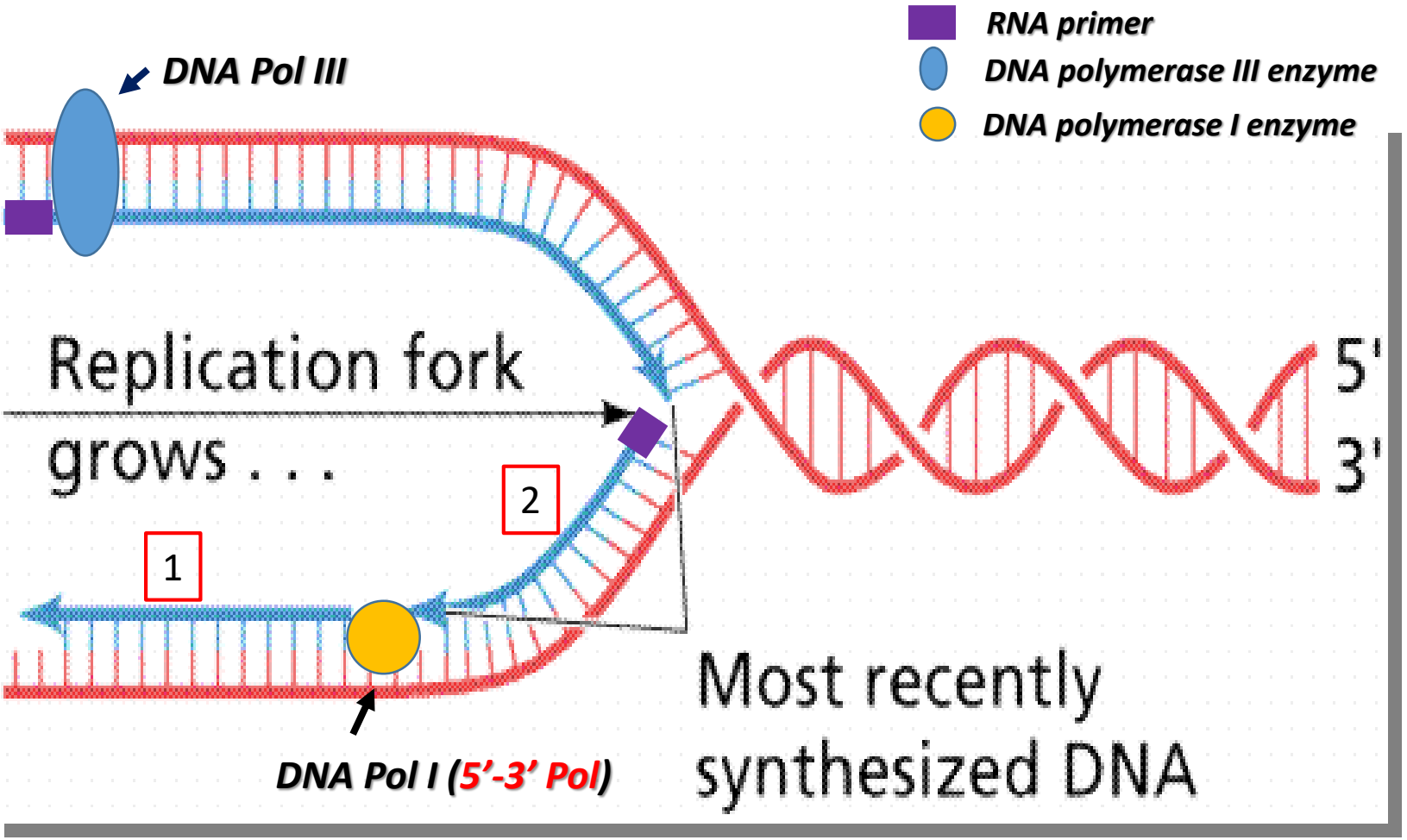
DNA Polymerase I

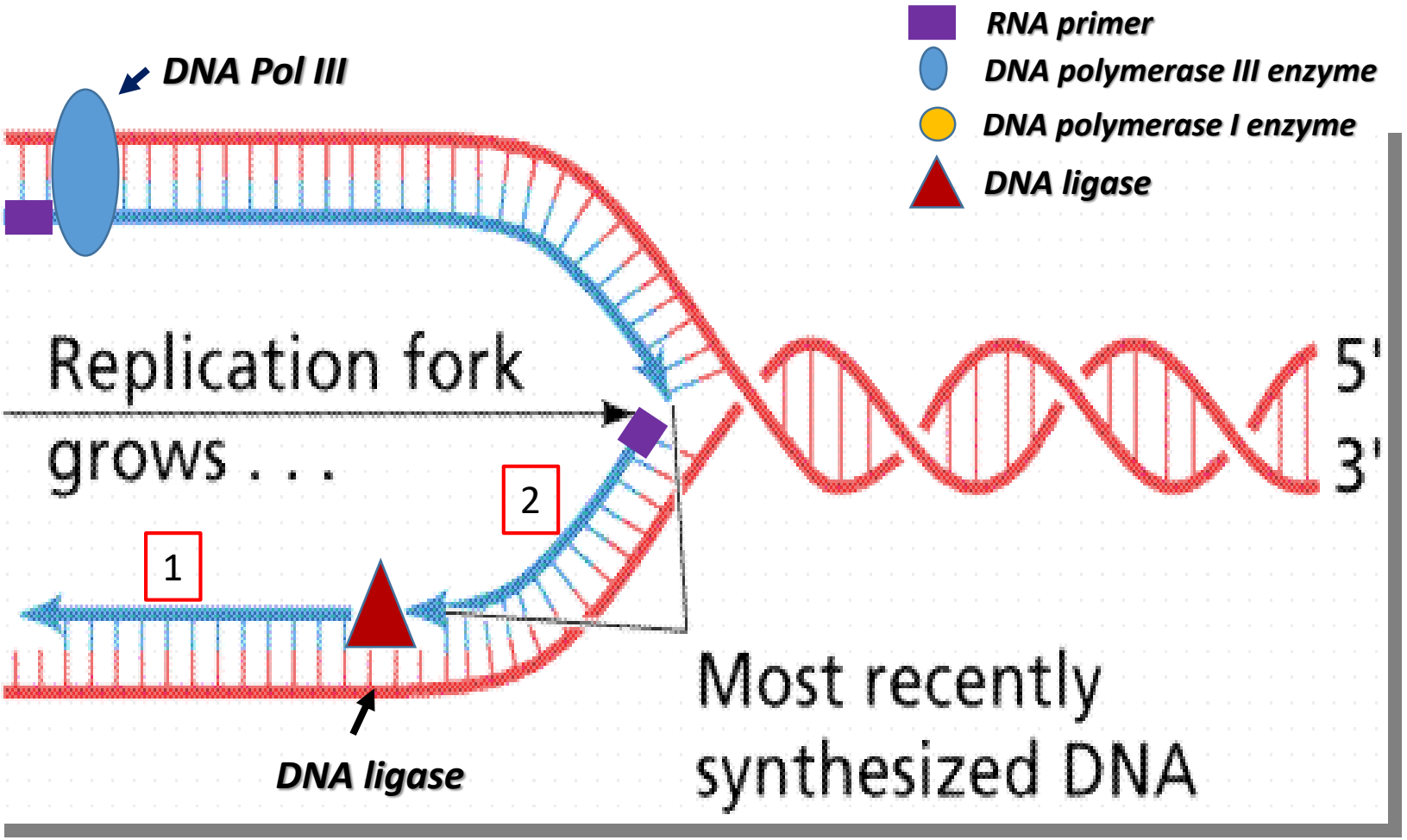
- **5’- 3’ DNA polymerase activity**
- **5’- 3’ exonuclease activity**
- **3’- 5’ exonuclese activity**

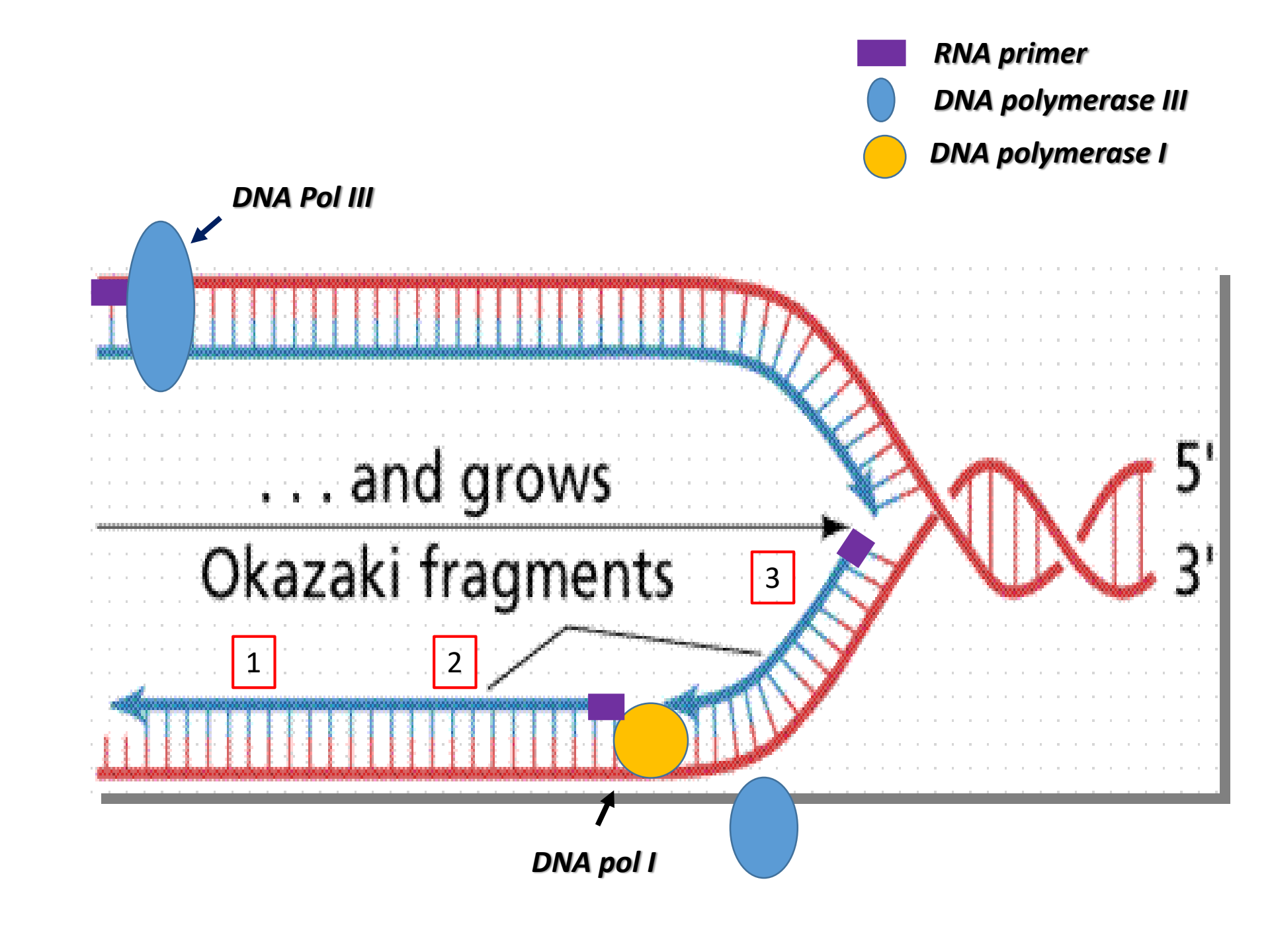
Exonuclease Activity

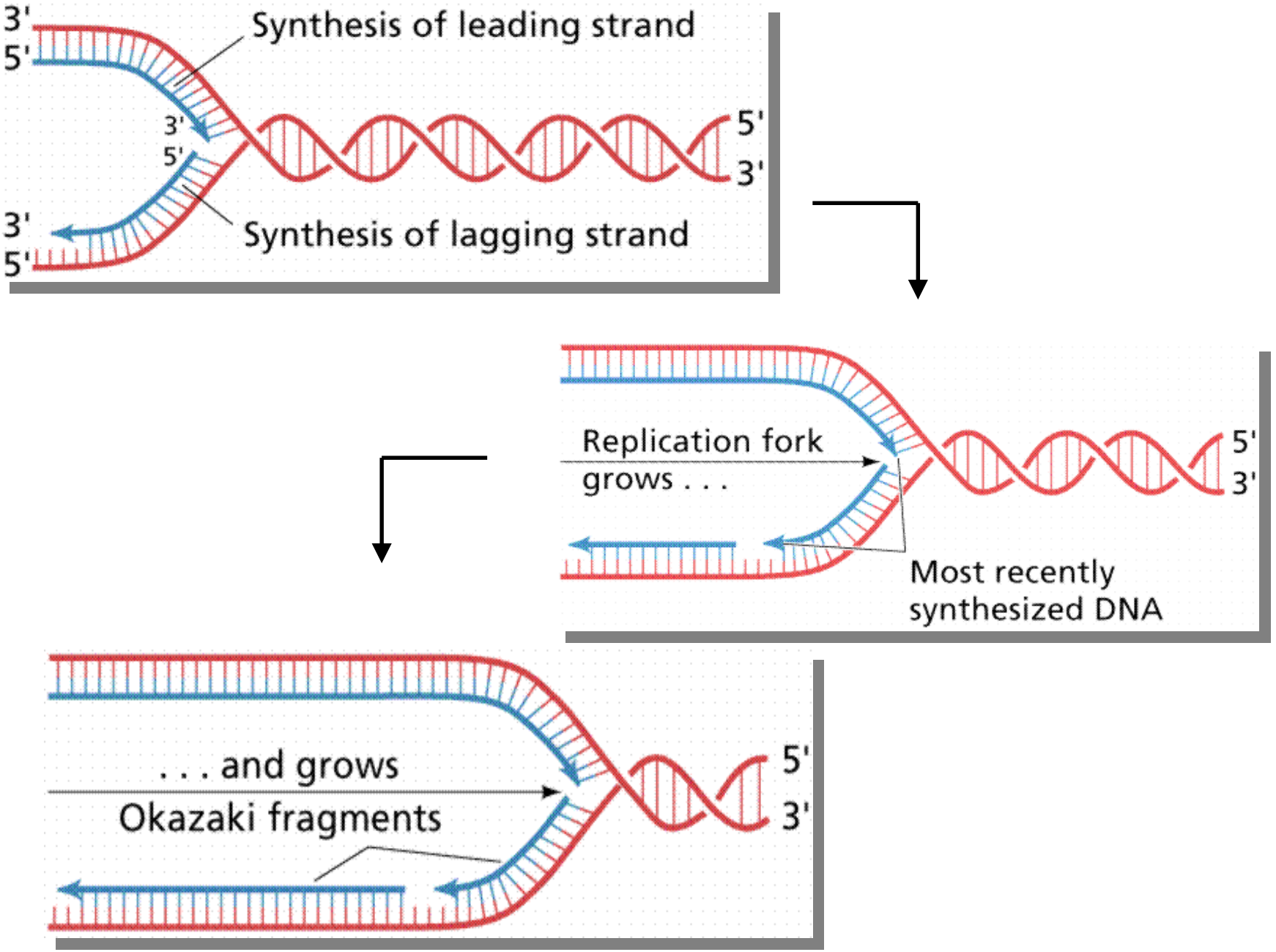



RNA primer
DNA polymerase III enzyme
DNA polymerase I enzyme
DNA Pol III
Replication fork grows . . .
5'
3'
2
1
Most recently synthesized DNA
DNA Pol I (5'-3' exo)


RNA primer
DNA polymerase III enzyme
DNA polymerase I enzyme
DNA Pol III
Replication fork
grows . . .
1
2
5'
3'
Most recently
synthesized DNA
DNA Pol I (5'-3' Pol)


RNA primer
DNA polymerase III enzyme
DNA polymerase I enzyme
DNA ligase
DNA Pol III
Replication fork
grows . . .
1
2
5'
3'
DNA ligase
Most recently
synthesized DNA

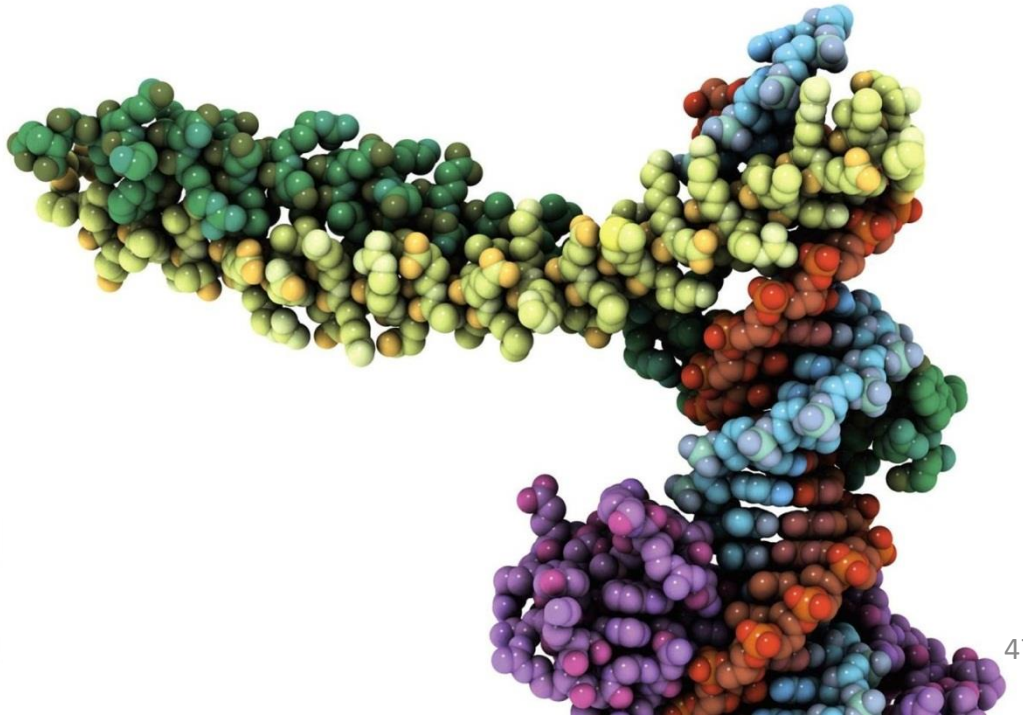

RNA primer
DNA polymerase III
DNA polymerase I
DNA Pol III
. . . and grows
Okazaki fragments
1
2
3
5'
3'
DNA pol I


3'
5'
Synthesis of leading strand
3'
5'
5'
3'
3'
5'
Synthesis of lagging strand
Replication fork
grows . . .
5'
3'
Most recently
synthesized DNA
. . . and grows
Okazaki fragments
5'
3'

Summary

- DNA synthesis requires a single-stranded DNA template, deoxyribonucleoside triphosphates (dNTPS), a growing nucleotide strand, and enzymes (DNA polymerase I, DNA polymerase III, DNA ligase, etc.)
- All DNA synthesis proceeds in the 5’-> 3’ direction meaning a new dNTP is always added to the 3’ end of the growing DNA strand
- At each replication fork, synthesis of the leading strand proceeds continuously and that of the lagging strand proceeds discontinuously

Ch. 15 From DNA to Protein
(Gene Expression)

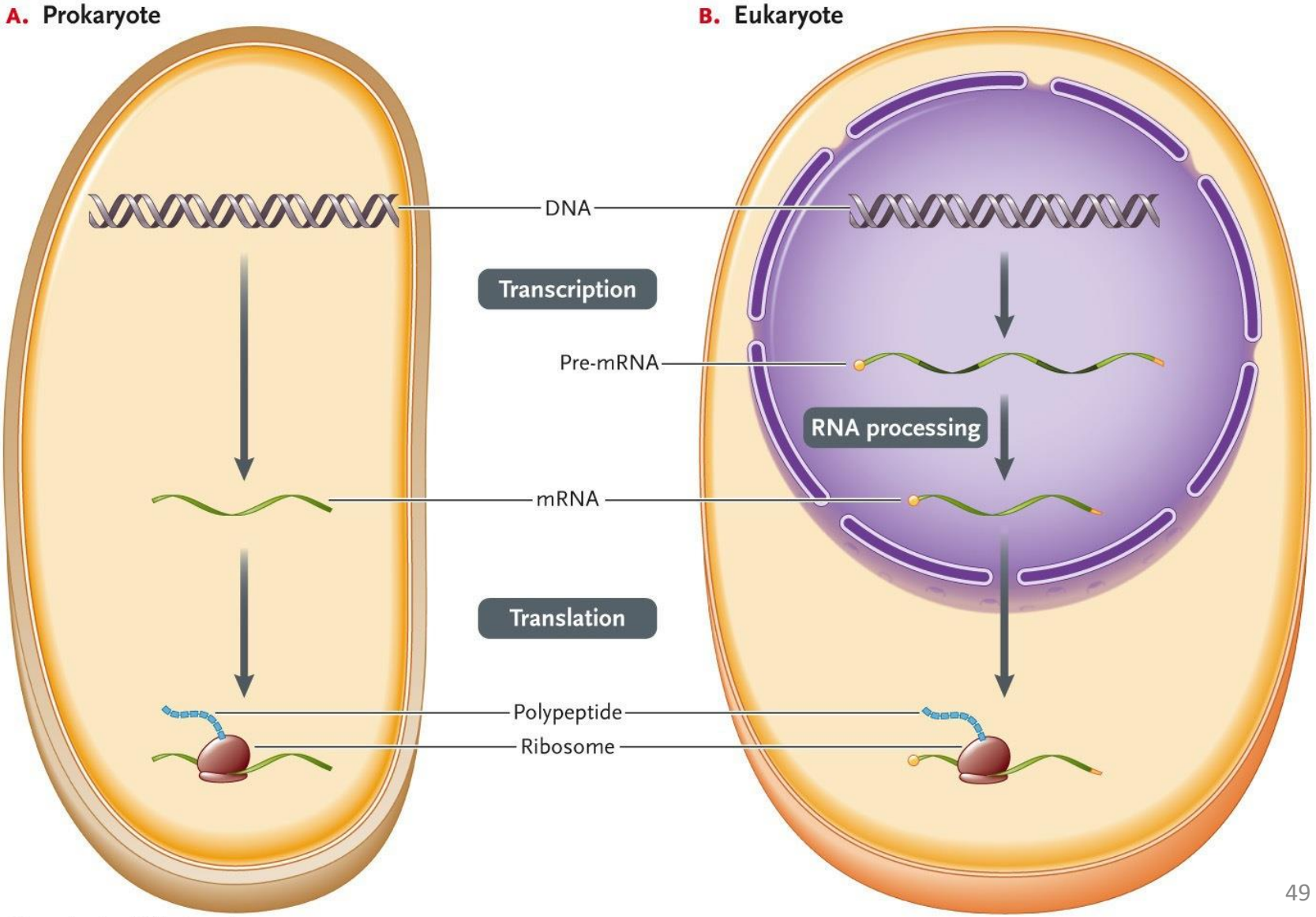


Learning Outcomes

Upon completion of this topic, you should be able to:

- **List the key steps in gene expression**
- **Explain the main features of the genetic code**
- **Describe the process of transcription**
- **Describe the process of translation**

C. THE FLOW OF GENETIC INFORMATION FROM DNA TO RNA TO PROTEIN



Deciphering the genetic information in DNA

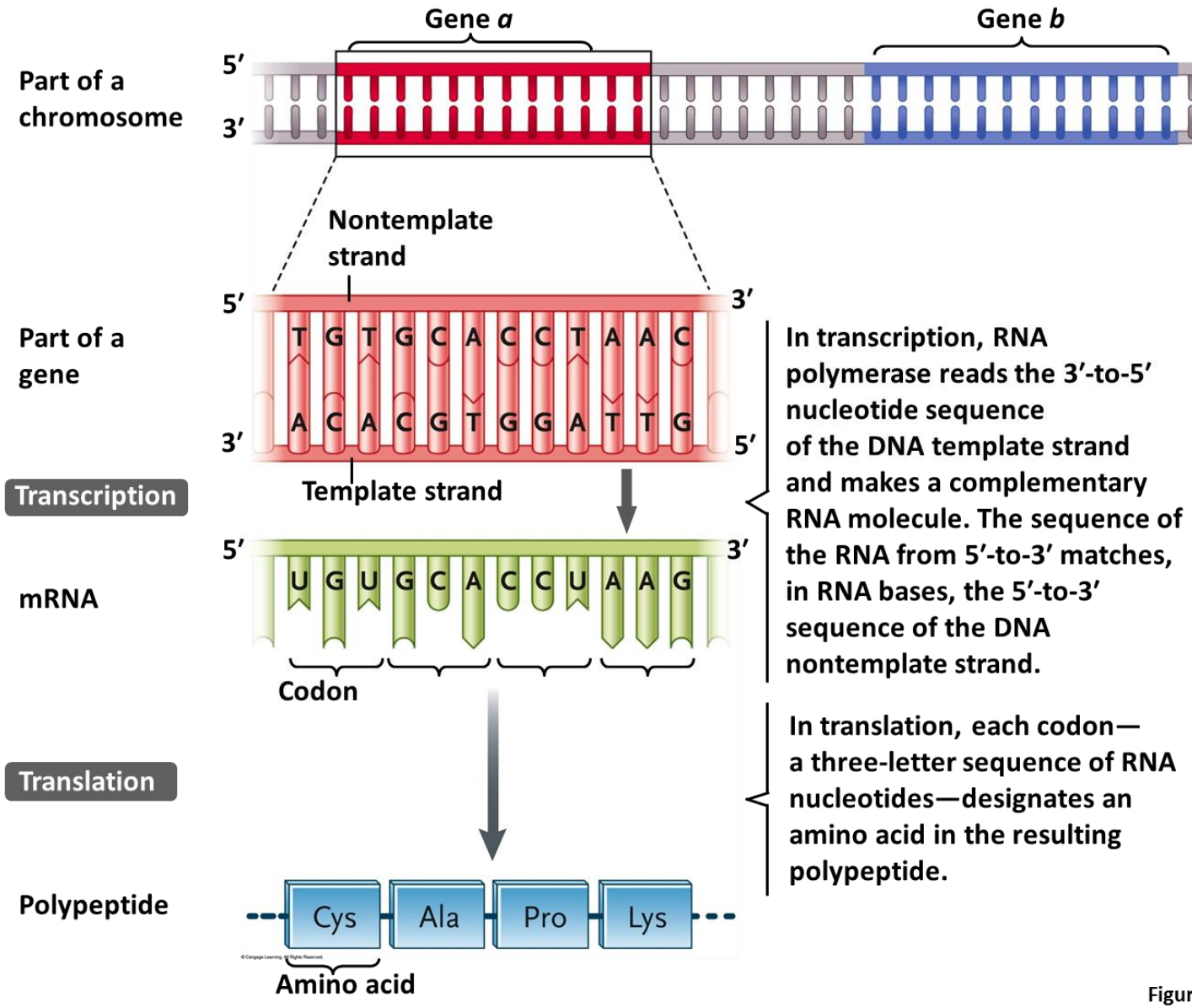
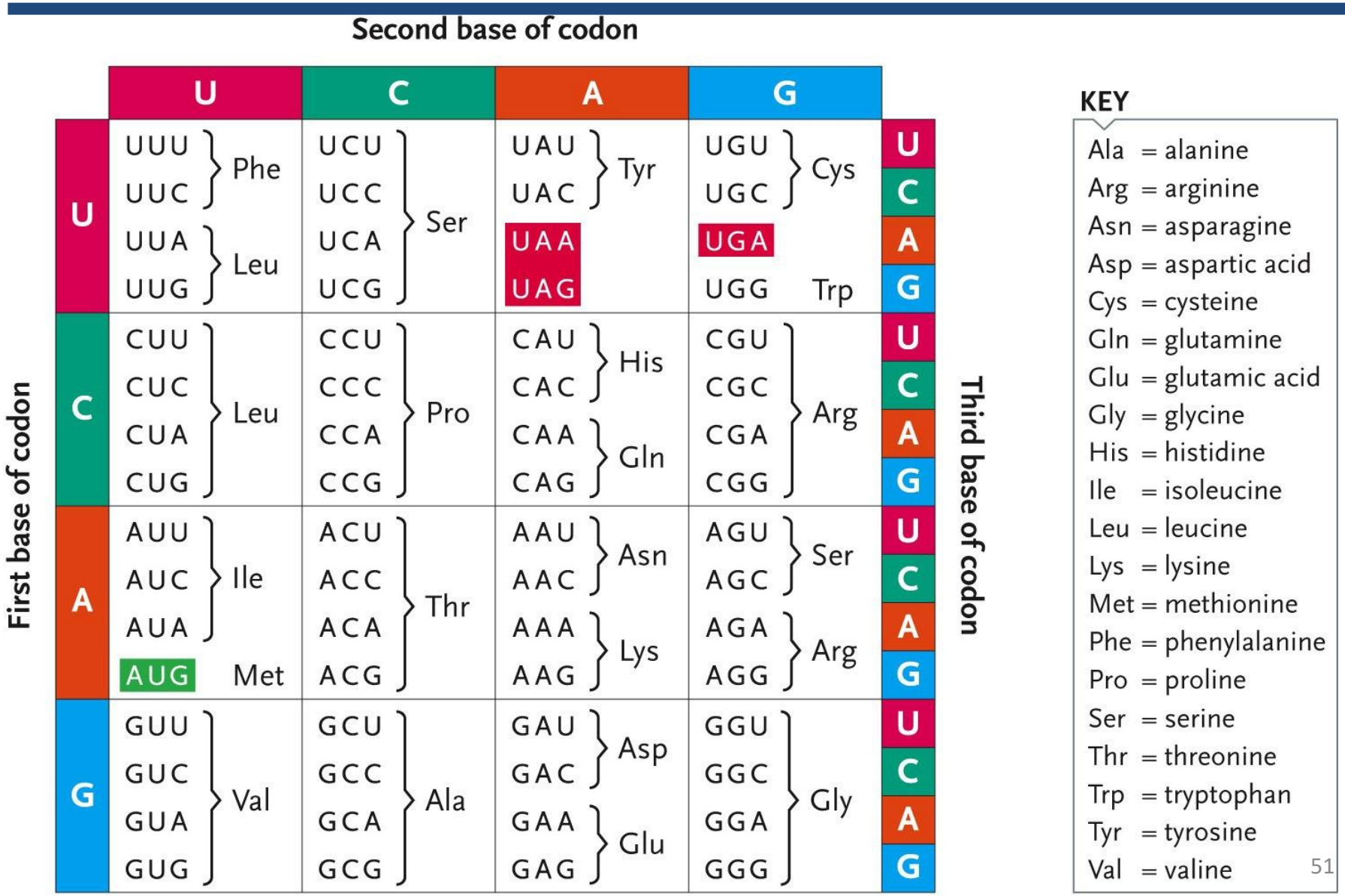


Figure 15-4 p315

The Genetic Code dictates how codons are translated into amino acids



KEY

Ala = alanine
Arg = arginine
Asn = asparagine
Asp = aspartic acid
Cys = cysteine
Gln = glutamine
Glu = glutamic acid
Gly = glycine
His = histidine
Ile = isoleucine
Leu = leucine
Lys = lysine
Met = methionine
Phe = phenylalanine
Pro = proline
Ser = serine
Thr = threonine
Trp = tryptophan
Tyr = tyrosine
Val = valine

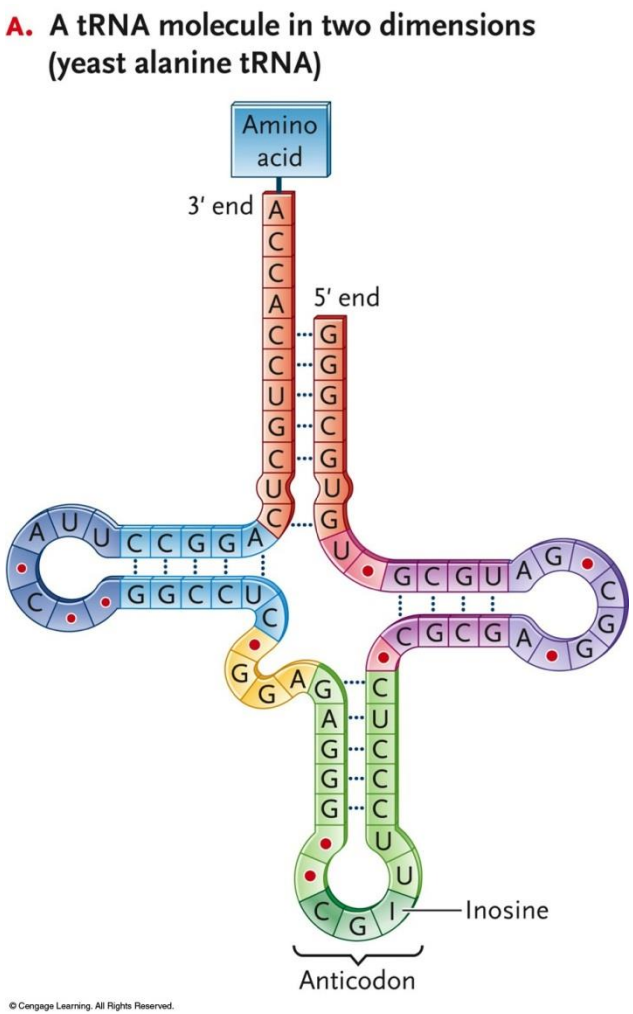
The Genetic Code dictates how codons are translated into amino acids

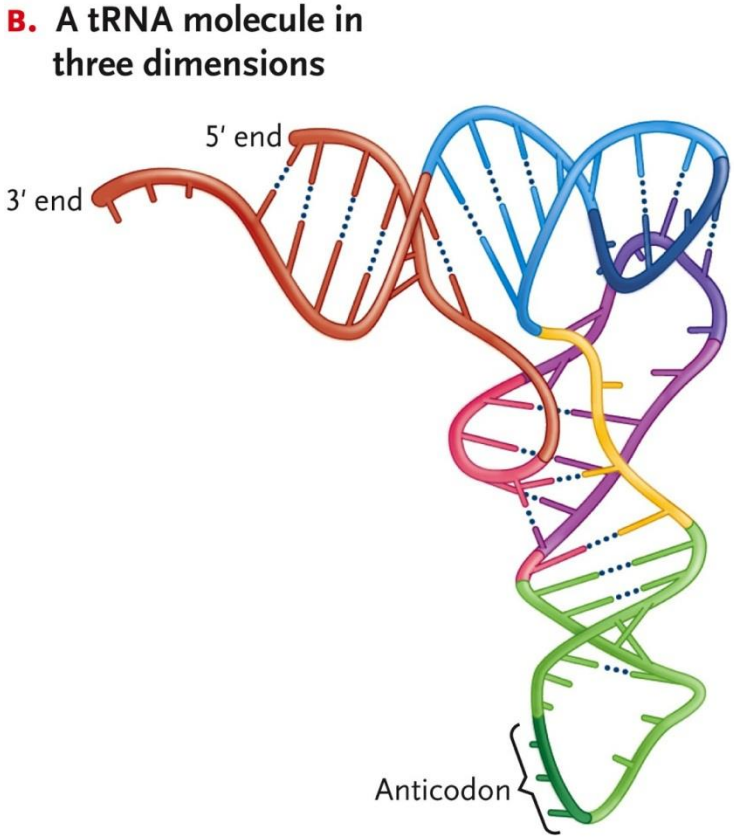
- **The genetic code is**
  - ***redundant*** **with more than one codon for some amino acids,**
  - ***unambiguous*** **in that any codon for one amino acid does not code for any other amino acid,**
  - ***nearly universal*****—the genetic code is shared by organisms from the simplest bacteria to the most complex plants and animals**

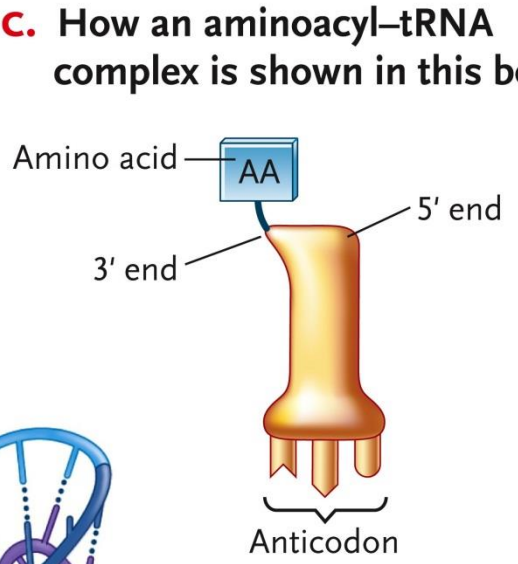
Transfer RNA molecules serve as interpreters during translation

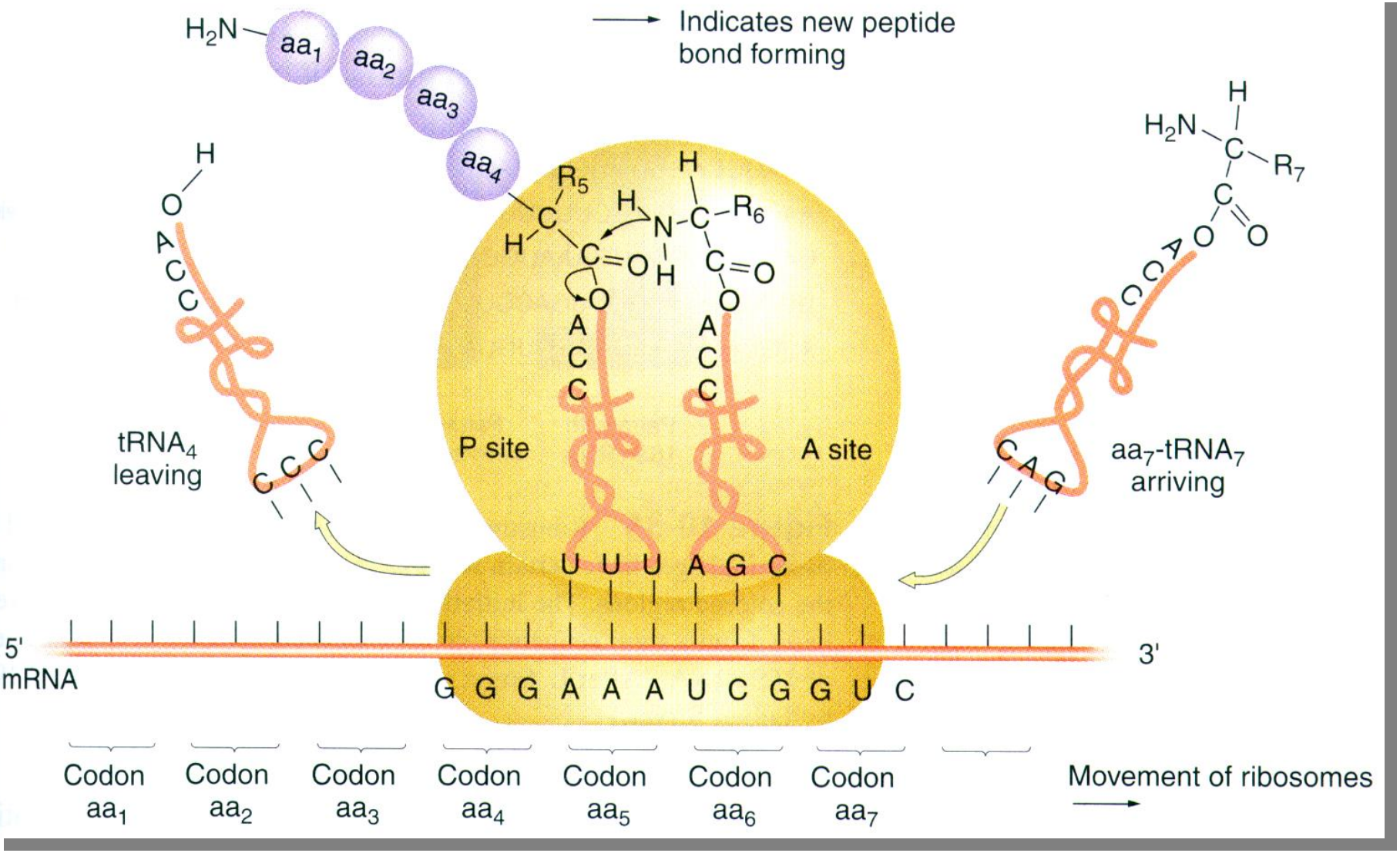
- **Transfer RNA (tRNA) molecules function as a language interpreter,**
  - **converting the genetic message of mRNA**
  - **into the language of proteins.**
- **Transfer RNA molecules perform this interpreter task by**
  - **picking up the appropriate amino acid and**
  - **using a special triplet of bases, called an anticodon, to recognize the appropriate codons in the mRNA.**

Structure of tRNA



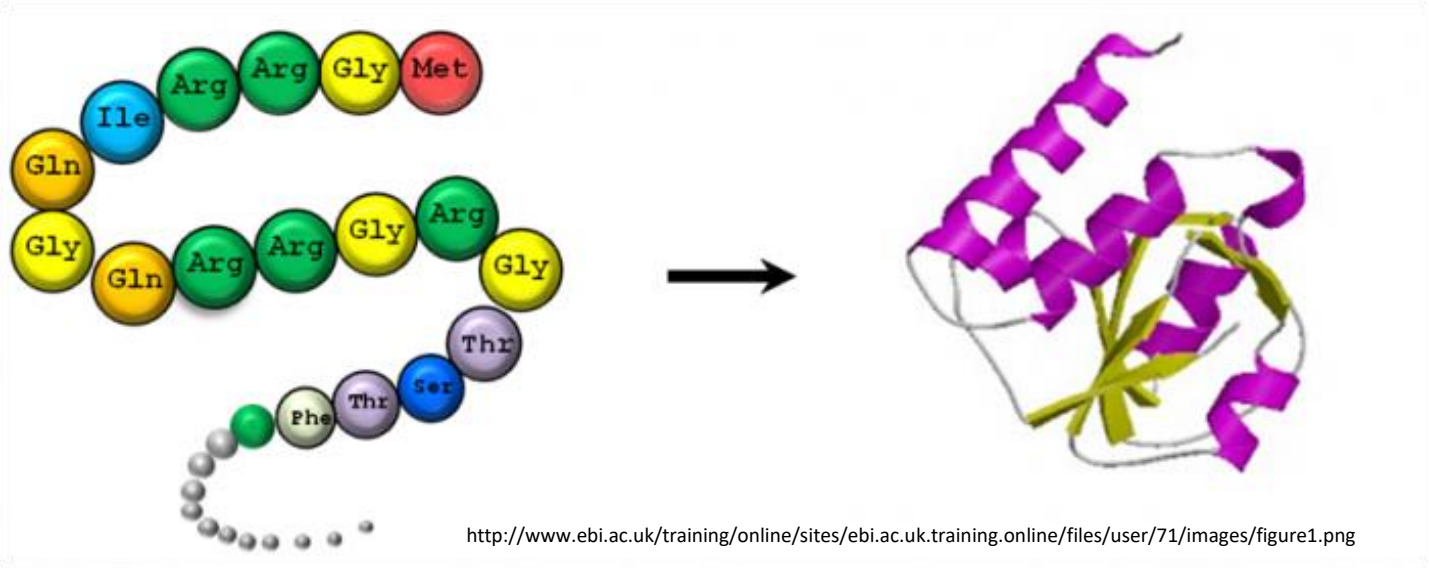






Addition of a single amino acid to the growing polypeptide chain in the course of translation of mRNA

Amino acid - Protein



http://www.ebi.ac.uk/training/online/sites/ebi.ac.uk.training.online/files/user/71/images/figure1.png

- are responsible for nearly every task of cellular life, including cell shape and inner organization, product manufacture and waste cleanup, and routine maintenance.
- Proteins also receive signals from outside the cell and mobilize intracellular response.

Can you ?

- Describe the purpose of cell division
- Describe the activities of different stages of the cell cycle
- Distinguish between autosomes and sex chromosomes
- Distinguish between meiosis and mitosis
- Explain what is a karyotype
- Explain the main features of the genetic code
- Describe the process of transcription
- Describe the process of translation