New Jersey Center for Teaching and Learning

Progressive Science Initiative

Click to go to website:
www.njctl.org

AP BIOLOGY

Big Idea 3
Part A

November 2012

www.njctl.org

Big Idea 3:

Living systems store, retrieve, transmit and respond to information essential to life processes.

Big Idea 3

The following is the AP's explanation of the second Big Idea:

"Genetic information provides for continuity of life and, in most cases, this information is passed from parent to offspring via DNA. The double-stranded structure of DNA provides a simple and elegant solution for the transmission of heritable information to the next generation; by using each strand as a template, existing information can be preserved and duplicated with high fidelity within the replication process. However, the process of replication is imperfect, and errors occur through chemical instability and environmental impacts...

Big Idea 3

"Random changes in DNA nucleotide sequences lead to heritable mutations if they are not repaired. To protect against changes in the original sequence, cells have multiple mechanisms to correct errors. Despite the action of repair enzymes, some mutations are not corrected and are passed to subsequent generations. Changes in a nucleotide sequence, if present in a protein-coding region, can change the amino acid sequence of the polypeptide. In other cases, mutations can alter levels of gene expression or simply be silent. In order for information in DNA to direct cellular processes, information must be transcribed (DNA→RNA) and translated(RNA→protein). The products of transcription and translation play an important role in determining metabolism, i.e., cellular activities and phenotypes. Biotechnology makes it possible to directly engineer heritable changes in cells to yield novel protein products."

Big Idea 3: Part A

Click on the topic to go to that section

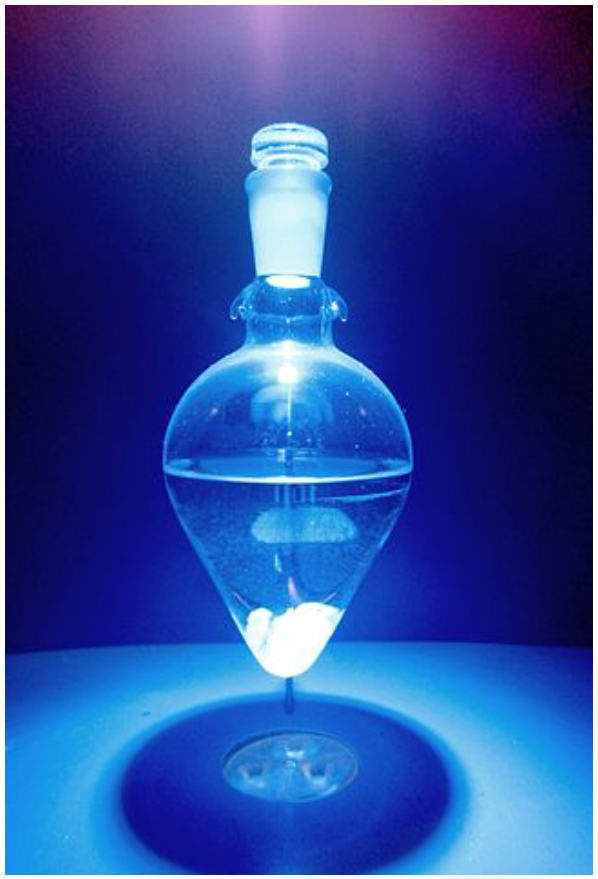
The Discovery of Genes

Return to Table of Contents

Nucleic Acid

The precipitate at the bottom of this flask is Deoxyribose Nucleic Acid. This chemical is the informational basis for all life.

Its properties allow for the storage of instructions to build living things.

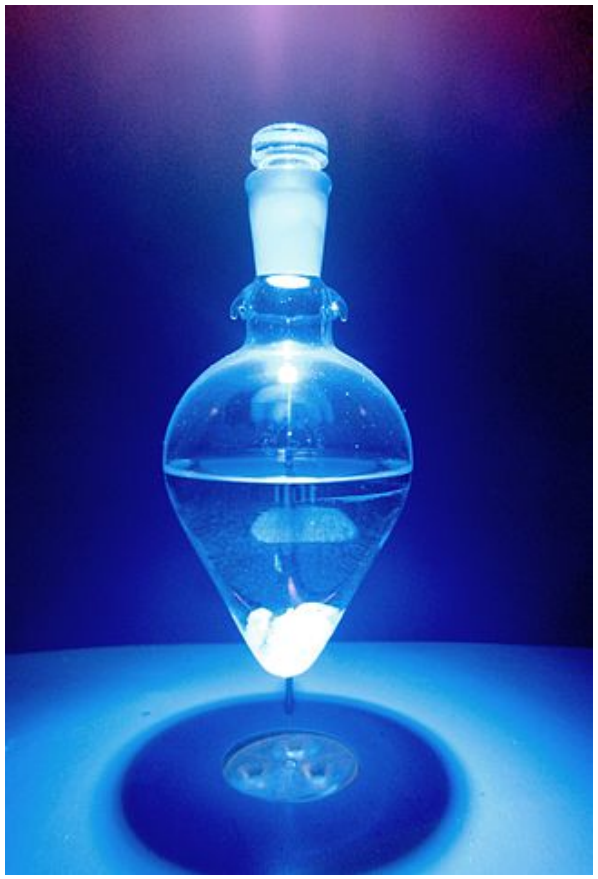


Nucleic Acid

Every molecule, organelle, cell, organ, organ system, organism and population is built by this molecule.

It is the building block of the **genes** that control how bodies are shaped and how organisms react to environmental factors.

This molecule is evolution.



The Selfish Gene

"Individuals are not stable things, they are fleeting. Chromosomes too are shuffled into oblivion, like hands of cards soon after they are dealt. But the cards themselves survive the shuffling. The cards are the genes. They merely change partners and march on.

They are the replicators and we are their survival machines. When we have served our purpose we are cast aside. But genes are denizens of geological time: genes are forever."

Richard Dawkins, Evolutionary Biologist and Oxford University professor.

Genes Live Beyond Individuals

As an example, blue eyes are a **phenotype;** a physical trait, controlled by a single gene.

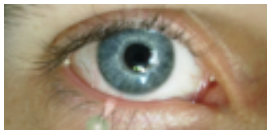
A recent study showed that a mutation in one individual's OCA2 gene, which produces the pigment that gives color to eyes, created a gene for blue eyes. This occurred 8,000 years ago and the new gene was passed generation to generation.

Genes live beyond individuals





Today approximately 560,000,000 people have blue eyes. Each individual carries 2 copies of the original mutation. The gene has long outlived the human that it originated in.




"Standing on the Shoulders of Giants"

The proof that DNA is the carrier of genetic information involved a number of important historical experiments. These include:

Griffith Transformation Experiment

Avery-Macleod-McCarty Experiment

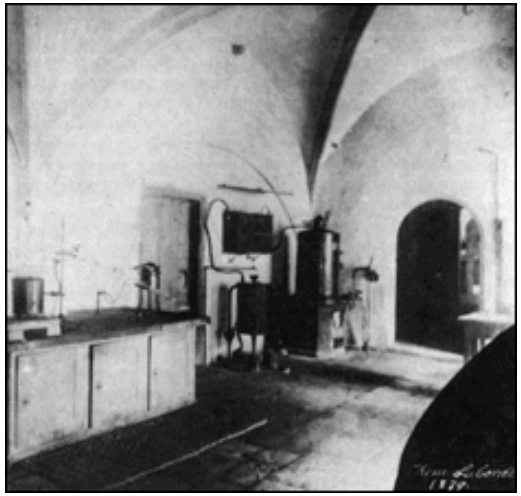
Hershy-Chase Experiment

Contributions of Watson, Crick, Wilkins, and Franklin

Primary Discovery

Nucleic acids were first isolated by the Swiss physician Friedrich Miescher who, in 1869, discovered a microscopic substance in the pus of discarded surgical bandages.

At the time it was an unknown cellular substance and was not considered important until many years later.



Miescher's Lab where he discovered nucleic acid

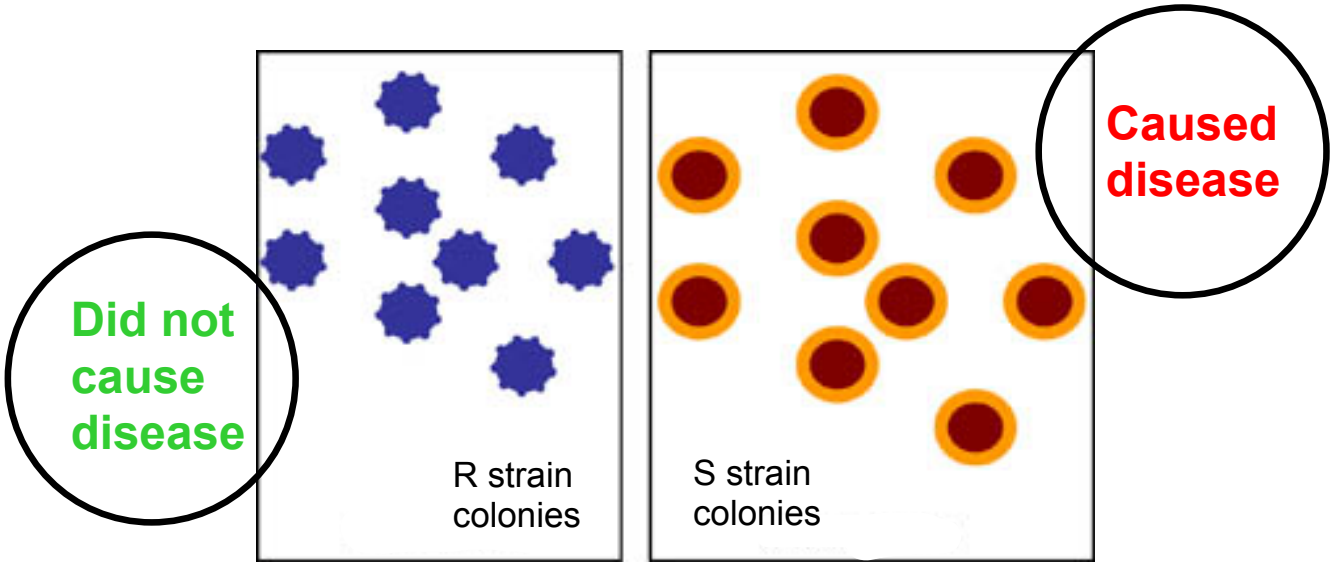
Griffith and Transformation

In 1928 British Scientist Frederick Griffith was conducting experiments with mice to determine how bacteria made people sick.

Griffith isolated two different strains of pneumonia bacteria from mice and grew the bacteria on petri dishes in the lab.

Griffith's Colonies

One strain grew in rough colonies and did not cause disease.
The other strain grew in smooth colonies and caused disease.



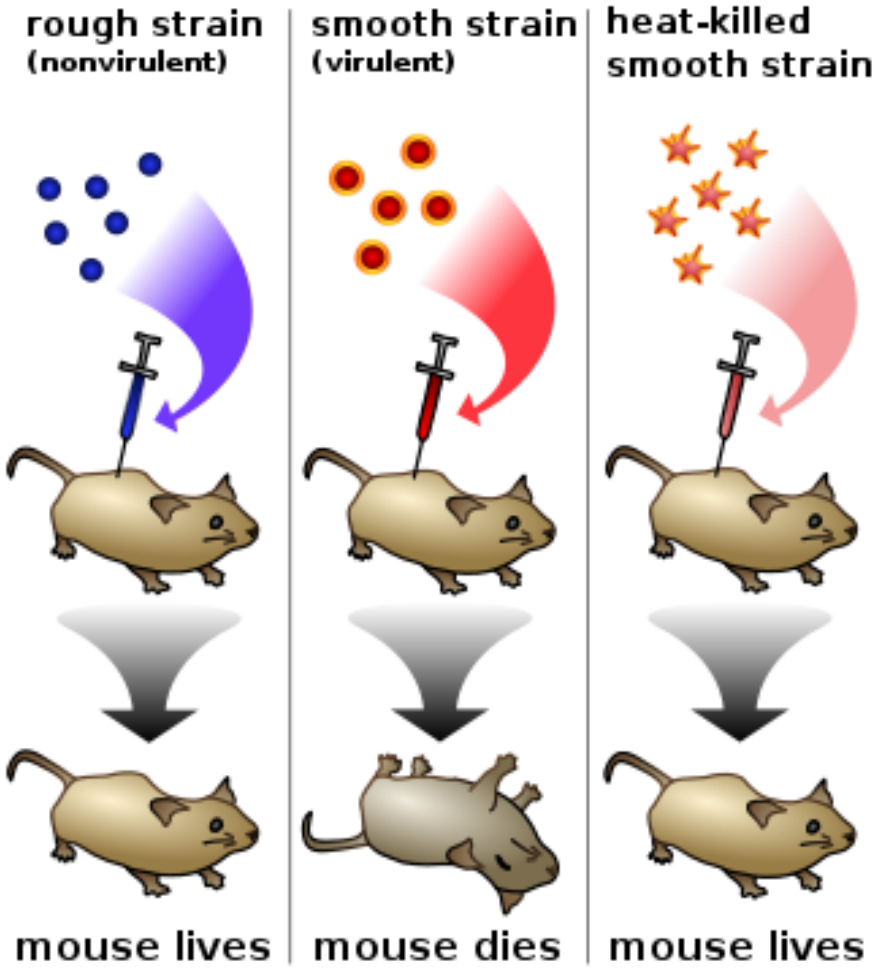
Mice and the 2 strains

When he injected the mice with the rough (R) strain, they lived.
When he injected the mice with the smooth (S) strain, they died.

However, when he heated the S strain of bacteria, killing them, and then injected the heat-killed S strain bacteria into the mice, they did not die.

Mouse Mortality

Heating the S strain killed the bacteria and prevented them from passing disease to the mice.

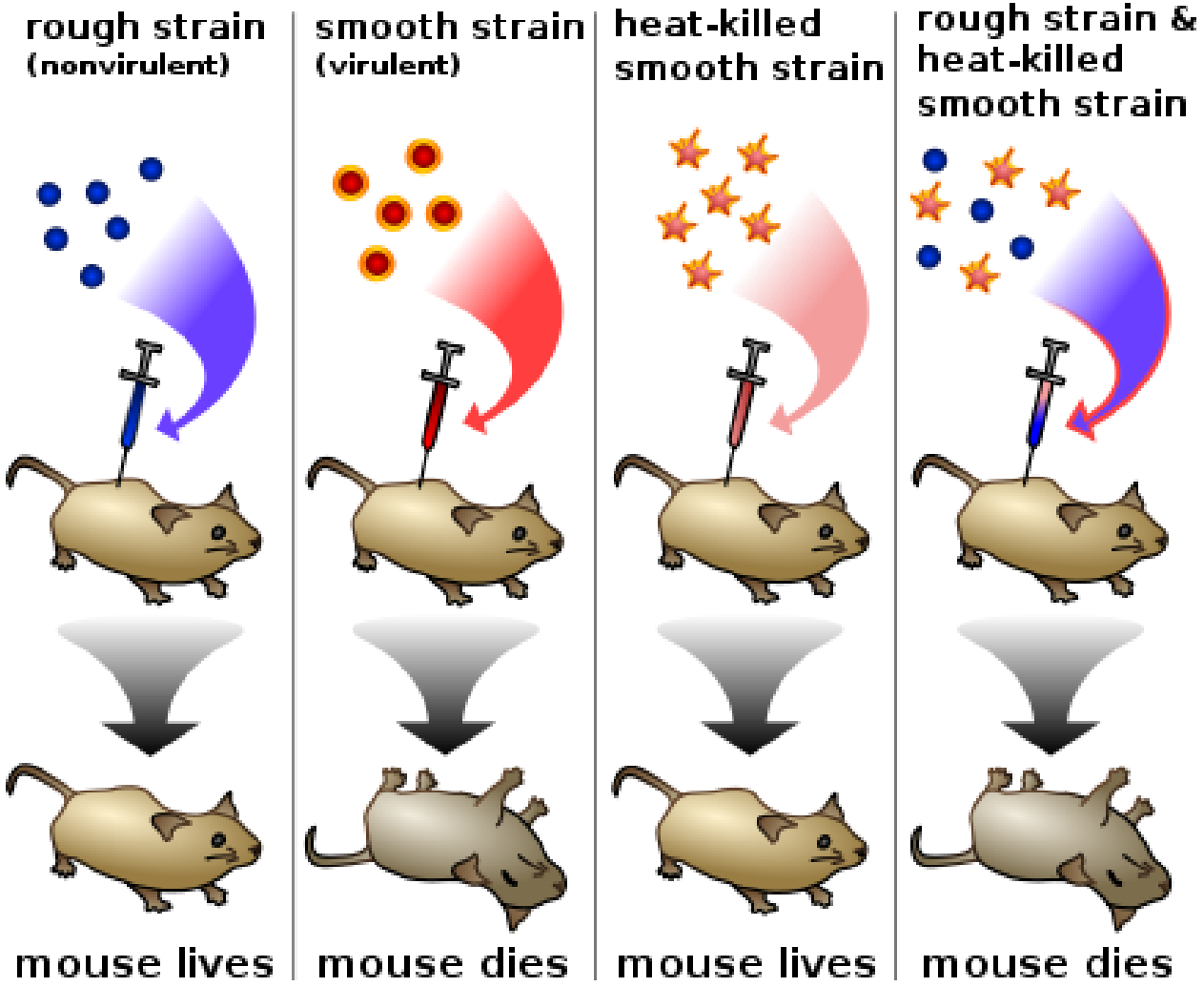


Griffith Experiment Part 2

Griffith then mixed heat-killed disease-causing S strain bacteria with live, harmless R strain bacteria and injected this mixture into mice.

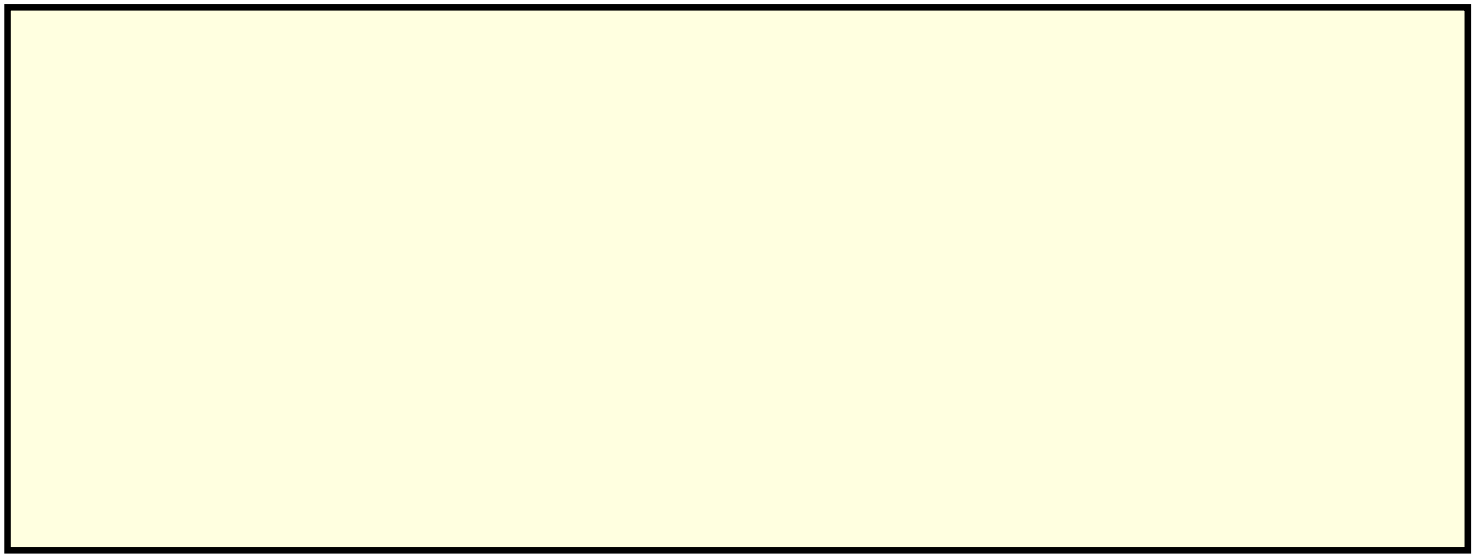
Before neither heat-killed S strain or live R strain bacteria made the mice sick, but the mixture of the two caused the mice to develop pneumonia and die.

Griffith: Part 2



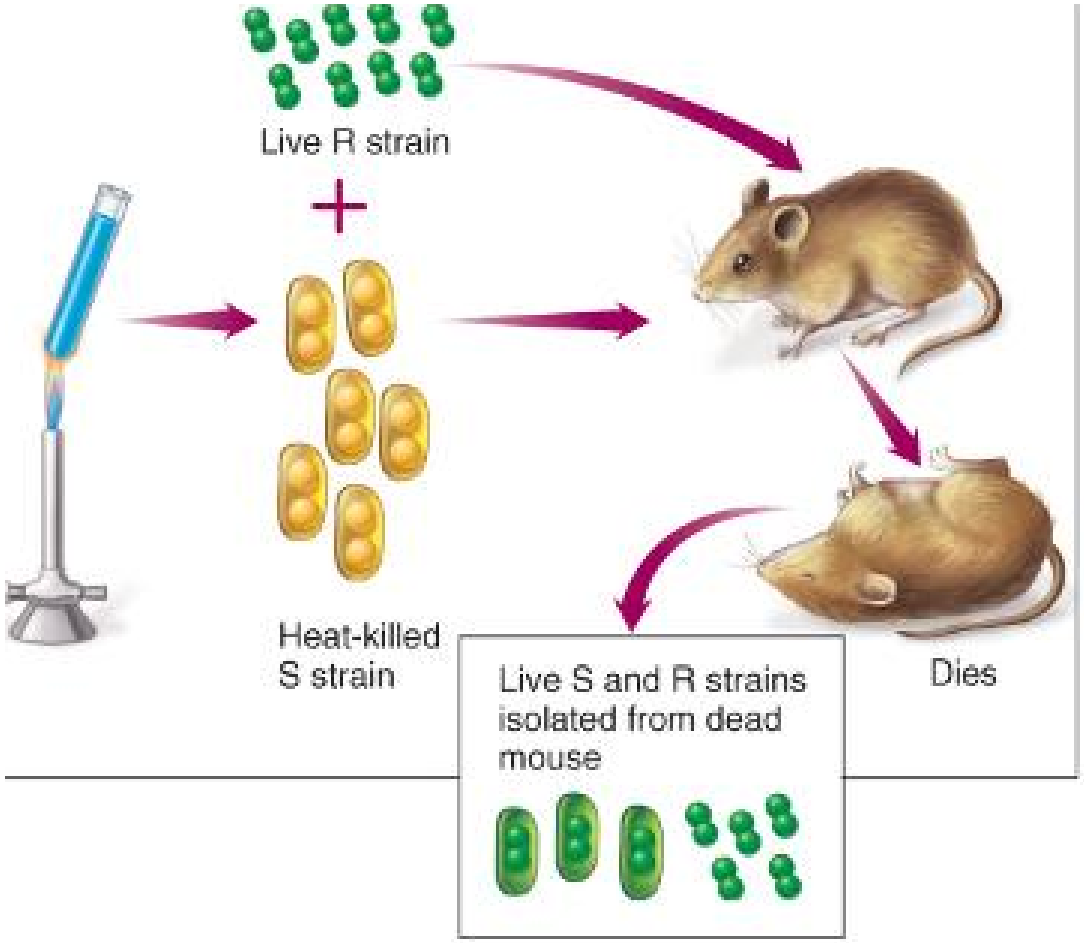
The Search for Genes

In Griffith's experiment why does the dead mouse contain living S strain when only dead S strain was injected? Theorize what may be happening.



What was the chemical factor?

He also noted this factor was passed on as the bacteria reproduced.



1 What is bacterial transformation?

- A The inheritance of genetic material
- B The exchange of genetic material between strains of bacteria
- C The interaction between strains of bacteria
- D The passage of genetic material from parent to offpsring

2 Why was Griffith's experiment significant?

A It showed that a chemical factor transformed R strain bacteria into S strain bacteria

B It proved dead bacteria could still transmit disease directly to mice

C It indicated proteins were the source of genetic material

D None of the above

Closing in on the Genetic Material

After Griffith's experiment most scientists believed that the molecule transforming bacteria was a protein, not a nucleic acid.

In the early 1940s experiments performed by Oswald T. Avery and his colleagues at the Rockefeller Institute for Medical Research challenged that assumption.

Closing in on the Genetic Material

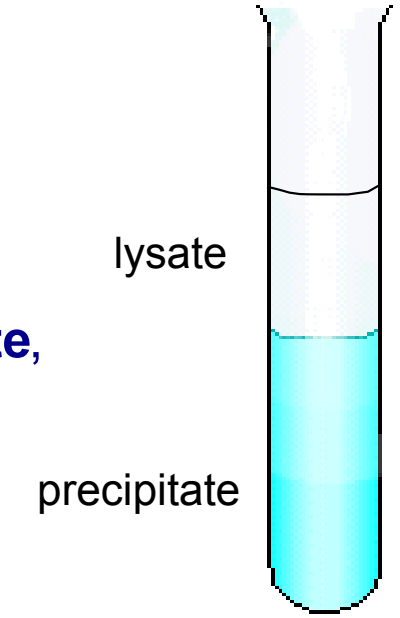
Avery used a **test tube assay.** This is when a scientist compares differences in test tubes after treating each differently. The benefit is that you can discover more specific reactions.

This approach will lead to more information than dead or living mice can provide.

Closing in on the Genetic Material

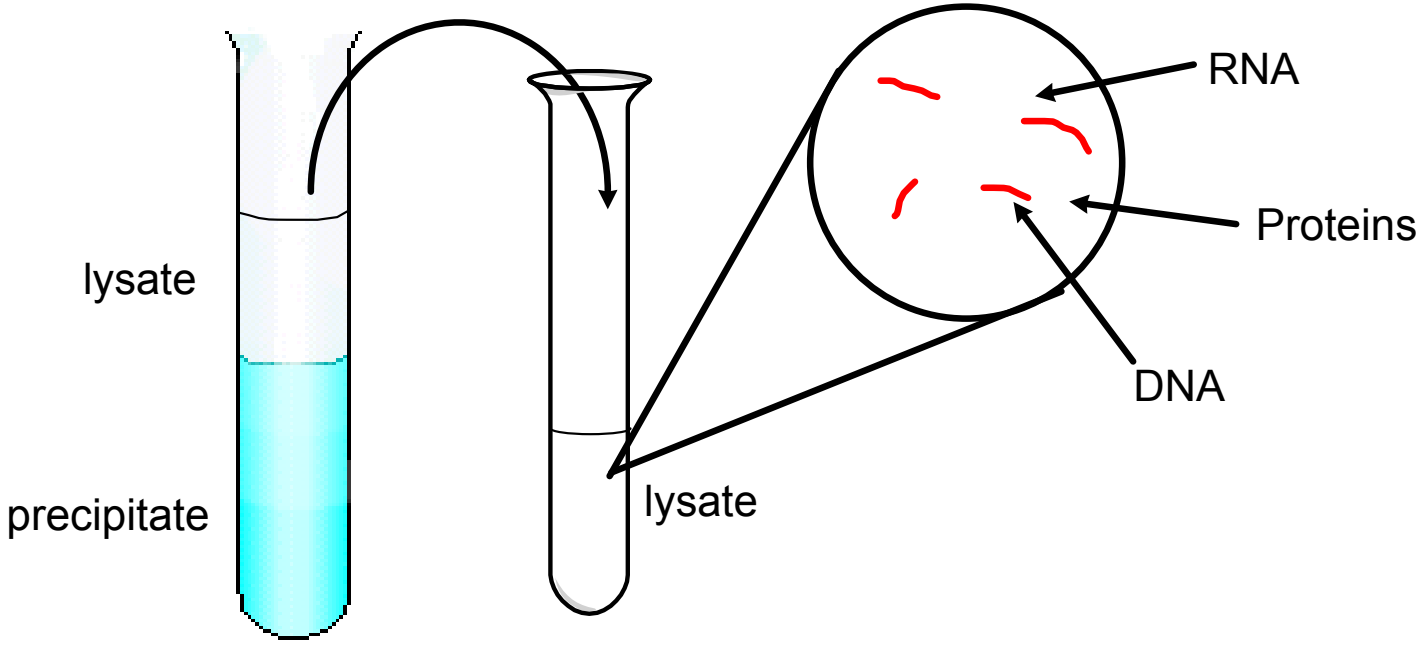
First he heat-killed the S strain bacteria and mixed it with detergent. This caused the bacterial cells to break apart. Their membranes lysed and spilled out the cell's contents.

The upper portion of the test tube, the **lysate**, contains less dense materials like proteins, enzymes, and nucleic acids.



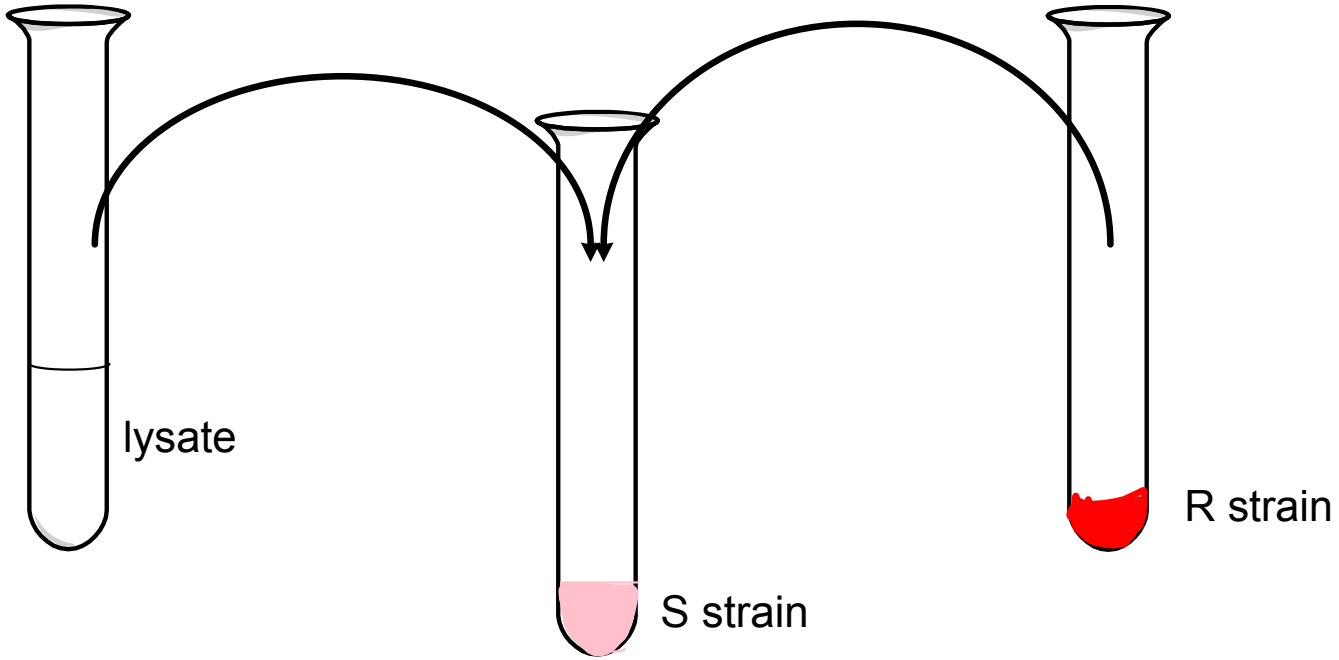
Closing in on the Genetic Material

The precipitate contained the large organelles and proteins of the cell. Avery isolated the lysate to use because it contained smaller molecules that were more likely to be the genetic material.



Closing in on the Genetic Material

To be sure he took the S strain lysate and mixed it with R strain to see if it would transform the bacteria to S strain and it worked.



Closing in on the Genetic Material

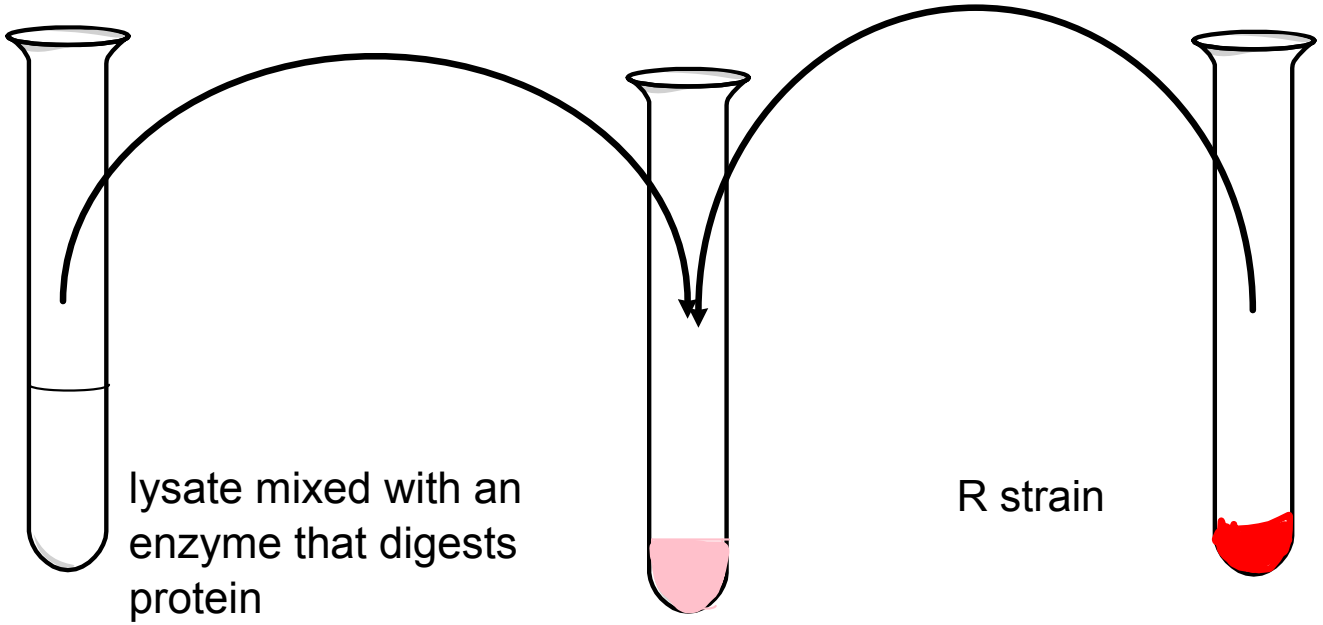
It is easy to tell the difference from R and S because they look different when grown on a petri dish. (R for rough edge; S for smooth edge).

S strain

R strain

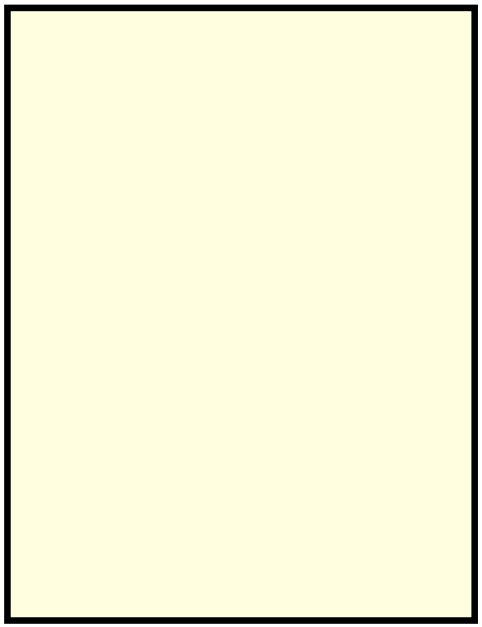
Closing in on the Genetic Material

Next Avery put in an enzyme that digests proteins into the lysate and did the same experiment. What do you suspect is the result and why?



Closing in on the Genetic Material

Next Avery put in an enzyme that digests proteins into the lysate and did the same experiment. What do you suspect is the result and why?



Closing in on the Genetic Material

What could you do to confirm this result? In other words what would be another way to treat the lysate that would give usable data?

Closing in on the Genetic Material

Avery and his team devised a technique that used alcohol to isolate and purify nucleic acids from solution.

In a later experiment they mixed the purified nucleic acid from S strain with R strain bacteria. What is the expected result?

3 Avery's experiments provide proof that the molecule responsible for transforming bacteria was

A protein
B nucleic acid

The Definitive Proof

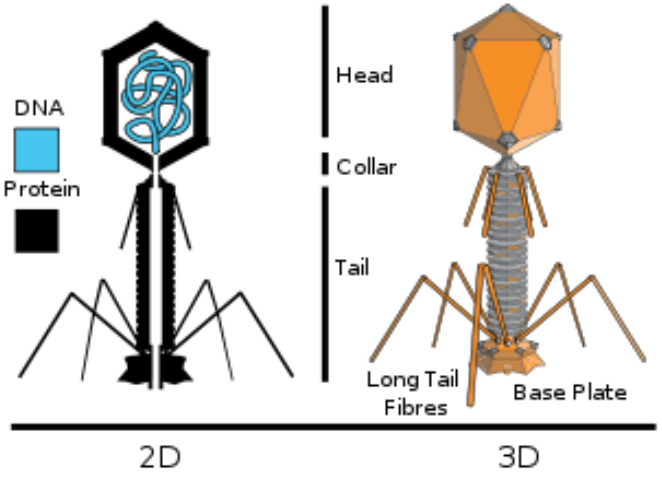
The Hershey–Chase experiments were a series of experiments conducted in 1952 by Alfred Hershey and Martha Chase that confirmed DNA was the genetic material.

By this time many new discoveries allowed these scientists to go beyond what others had been able to discover about nucleic acids.

The Definitive Proof

Most importantly, intense research on viruses at the time expanded the knowledge of these tiny particles.

Hershey and Chase concentrated on bacteriophages. These viruses that infected and killed bacteria were known to only be composed of 2 things: proteins and DNA



4 Viruses are considered non-living because

I. They cannot reproduce on their own

II. Their nucleic acid does not code for protein

III. They are not made of cells

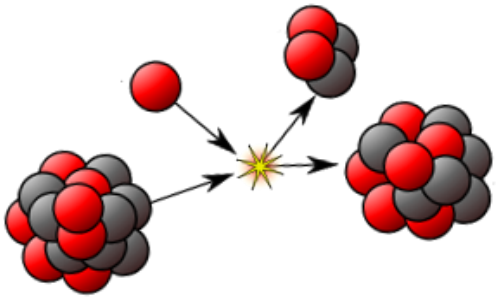
A III only
B II and III
C I, II, and III
D I and III

5 When a virus infects a bacteria cell, what part of the virus enters the bacteria?

- A Only the nucleic acid
- B The nucleic acid and the virus head it is contained in
- C Only the tail fibers
- D Only the head

The Definitive Proof

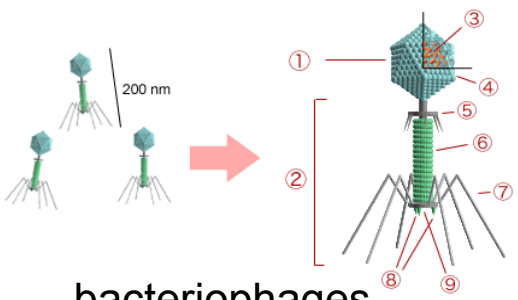
Secondly, a lot was being learned about radioactivity. Since they could not see the viruses, Hershey and Chase used a novel approach that took advantage of a new technique called **radioactive labeling**. This allowed them to track different parts of the virus by looking for radiation.



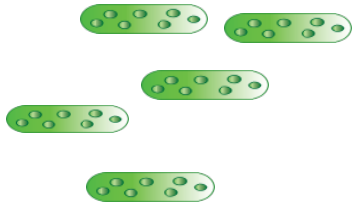
A geiger counter can find and measure radioactive particles

The Definitive Proof

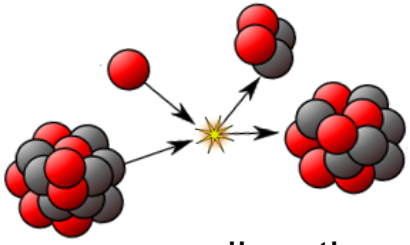
Hershey and Chase began by creating 2 kinds of radioactive viruses using a labeling technique. Below is how they made virus A.



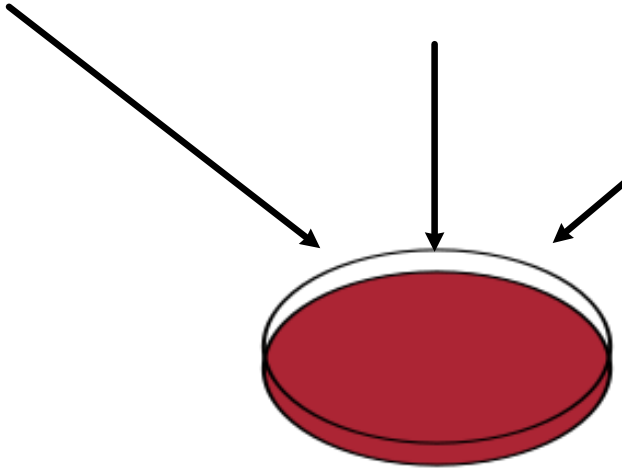
bacteriophages



bacteria



radioactive
SULFUR



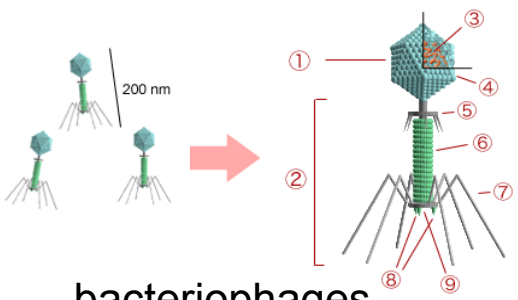
Viruses grow via lytic cycle. When they make proteins they must use the radioactive sulfur.

6 In the lytic cycle of phages

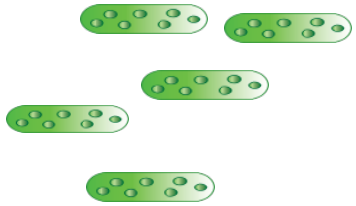
- A Phage DNA is incorporated into the host cell's genome
- B The viral capsid is assembled according to the genetic information of the capsid
- C The entire phage is taken into the bacterium
- D The cell typically dies, releasing many copies of the virus

The Definitive Proof

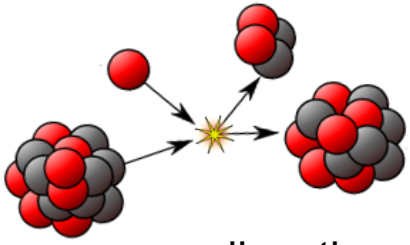
The procedure is repeated to make virus B with a change in the radioactive material.



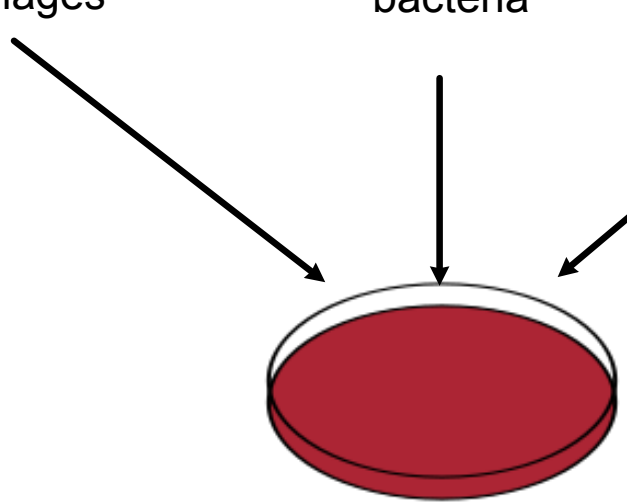
bacteriophages



bacteria



radioactive
PHOSPHORUS



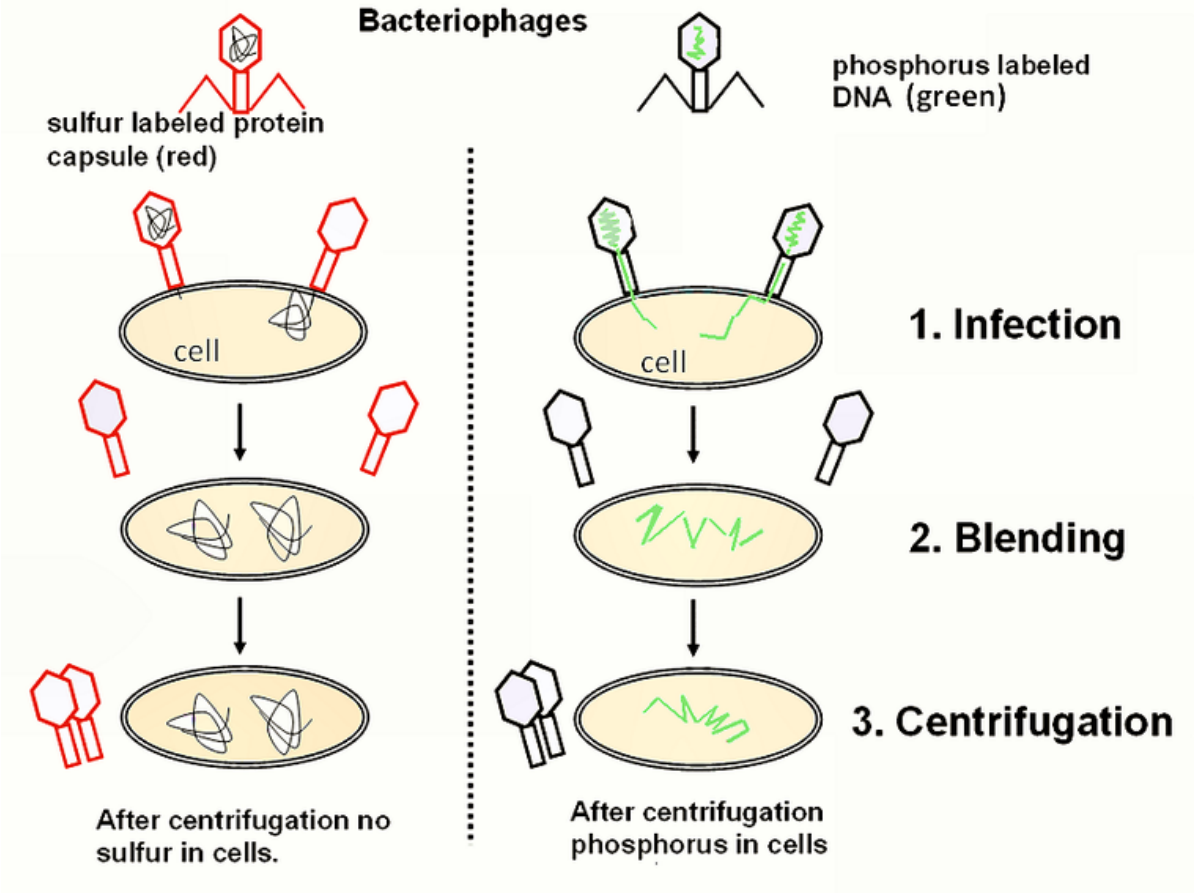
Viruses grow via lytic cycle. When they make DNA they must use the radioactive phosphorus.

7 In Hershey's and Chase's experiment, the viruses' DNA will contain _____ and protein will contain _____.

- A sulfur, phosphorus
- B phosphorus, sulfur

The Definitive Proof

Summary of Hershey Chase experiments:



The Double Helix

With the data collected by Hershey and Chase the focus of the scientific community shifted to nucleic acids. DNA in particular became the focus of scientists looking to make the next big discovery.

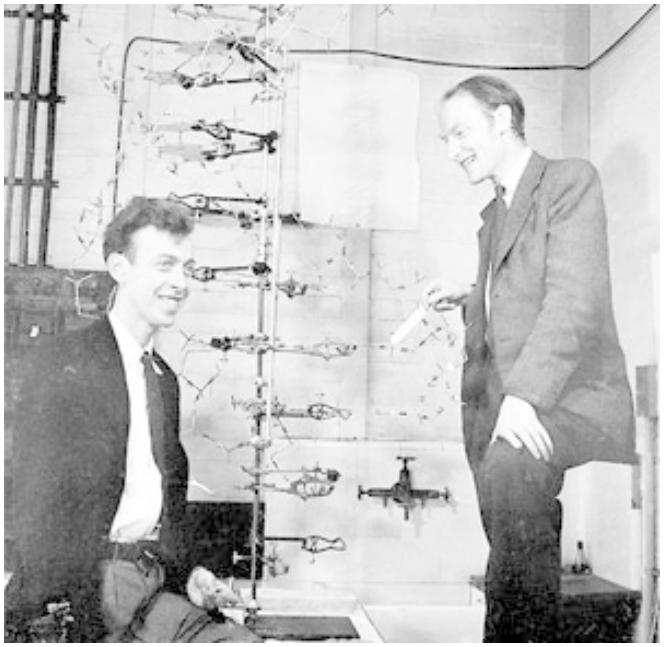
Two pairs of scientists working in the same facility ultimately made the discoveries about DNA that led to the modern understanding of the genetic material.

The Double Helix

Watson and Crick deciphered from the photo that DNA was a double helix. They began to build models of the structure so they could speculate on how DNA can:

1) Self replicate

2) Code for all the traits of living things



The discoverers of the DNA structure, James Watson, left, and Francis Crick, with their model of a DNA molecule. (A. Barrington Brown/Photo Researchers, Inc.)

DNA and Modern Medicine

The discovery of the structure and function of DNA has led to astounding leaps in understanding of biology, heredity, and modern medicine.

"It's impossible to overstate the importance of knowing the structure of DNA."
- Francis Collins, Director of the Human Genome Project

Click Here to see a DNA timeline

8 The scientists associated with the discovery of the structure of DNA were:

- A Hershey and Chase
- B Watson, Crick, Wilkins, and Franklin
- C Avery, MacLeod, and McCarty

9 These scientists showed that DNA was at the root of bacterial transformation.

- A Hershey and Chase
- B Watson, Crick, Wilkins, and Franklin
- C Avery, MacLeod, and McCarty

10 Four of the following terms all involve the experiment of Hershey and Chase. Choose the one which does not belong.

- A helix structure
- B DNA
- C virus
- D host
- E bacteriophage

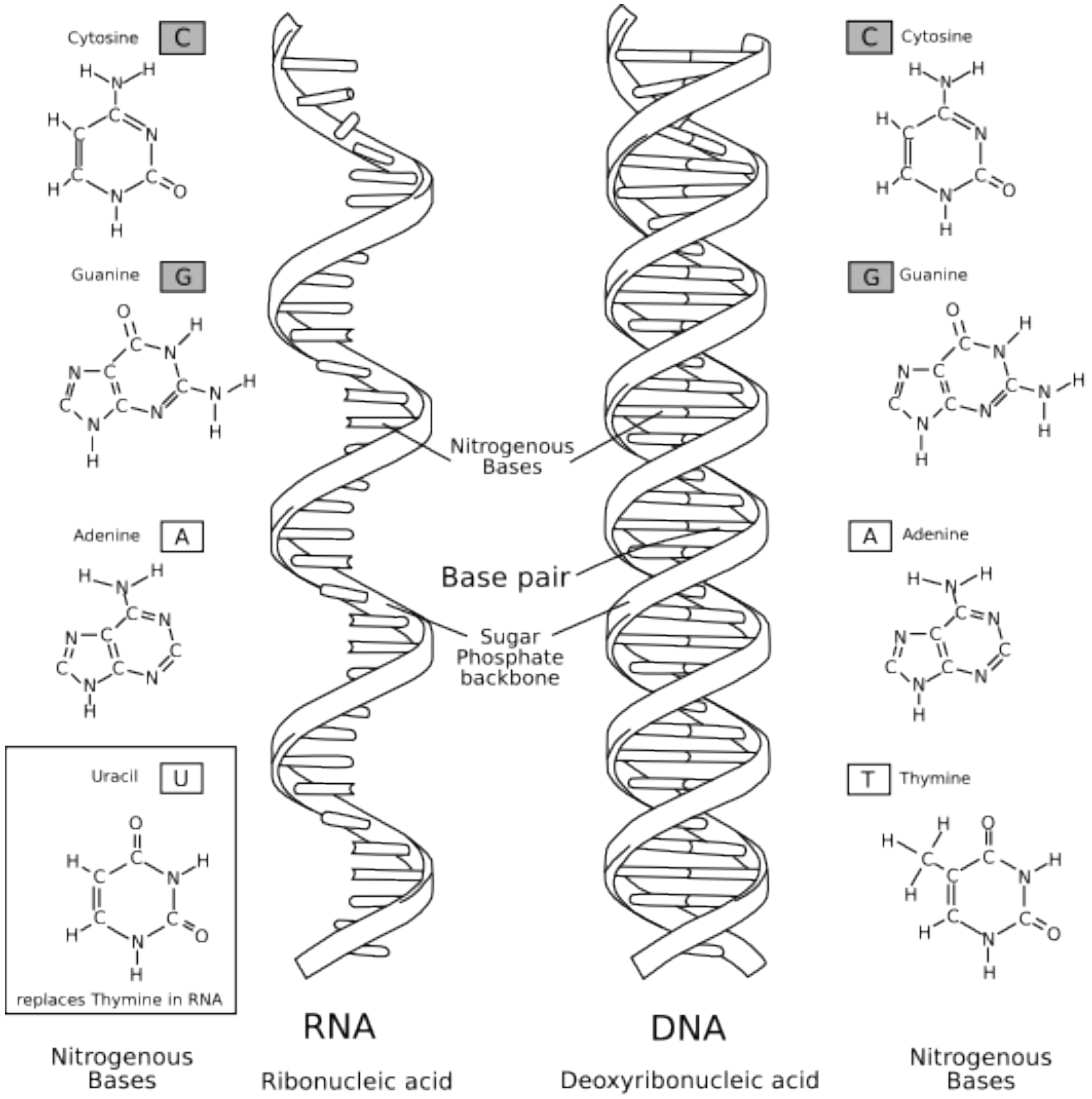
Chemistry of Nucleic Acids

Return to Table of Contents

RNA and DNA

RNA and DNA are the 2 nucleic acids necessary for living organisms.

This diagram reviews the major differences in structure



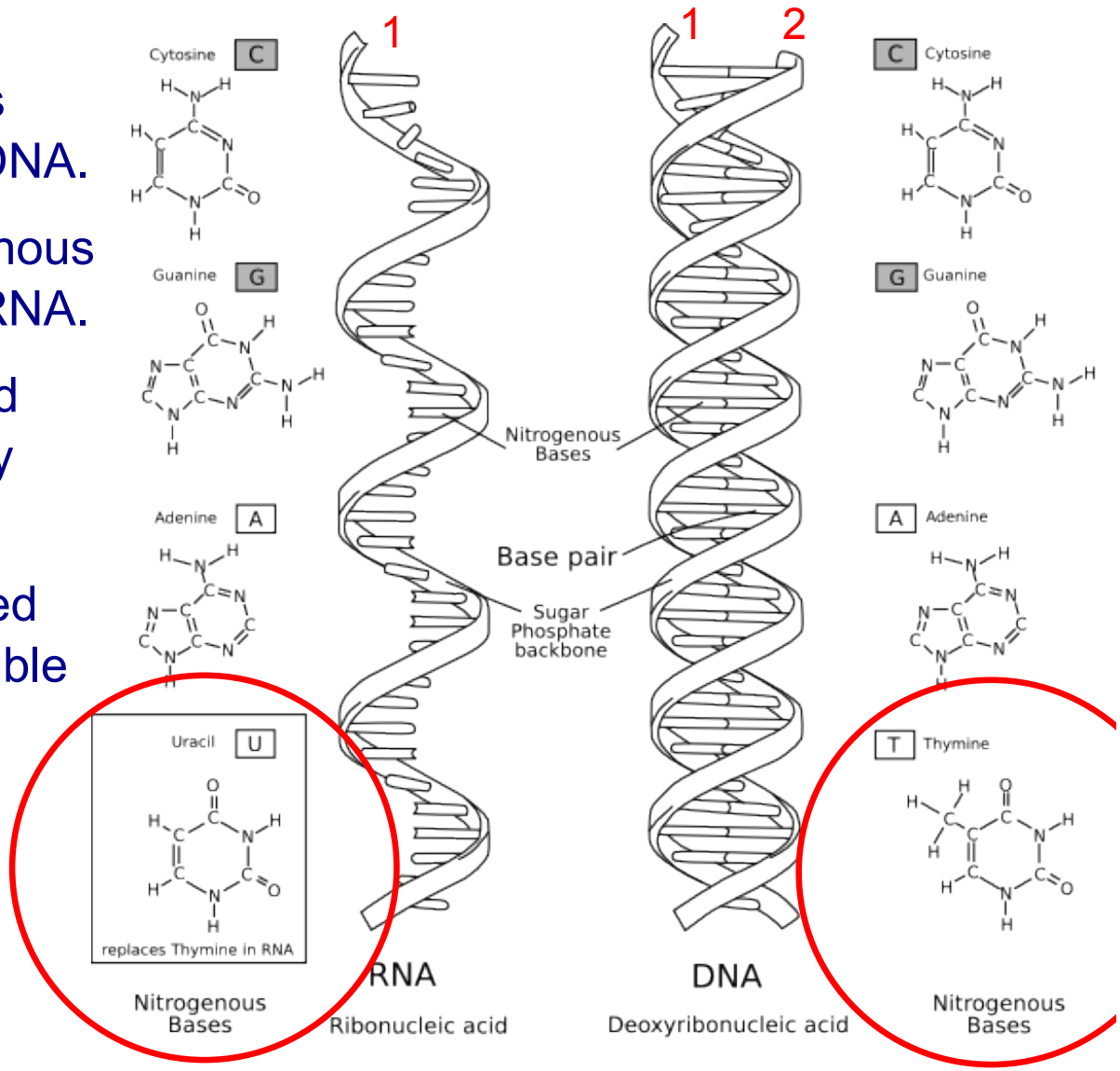
RNA and DNA

Uracil is a nitrogenous base in RNA but not DNA.

Thyamine is a nitrogenous base in DNA but not RNA.

RNA is single stranded and can fold into many shapes.

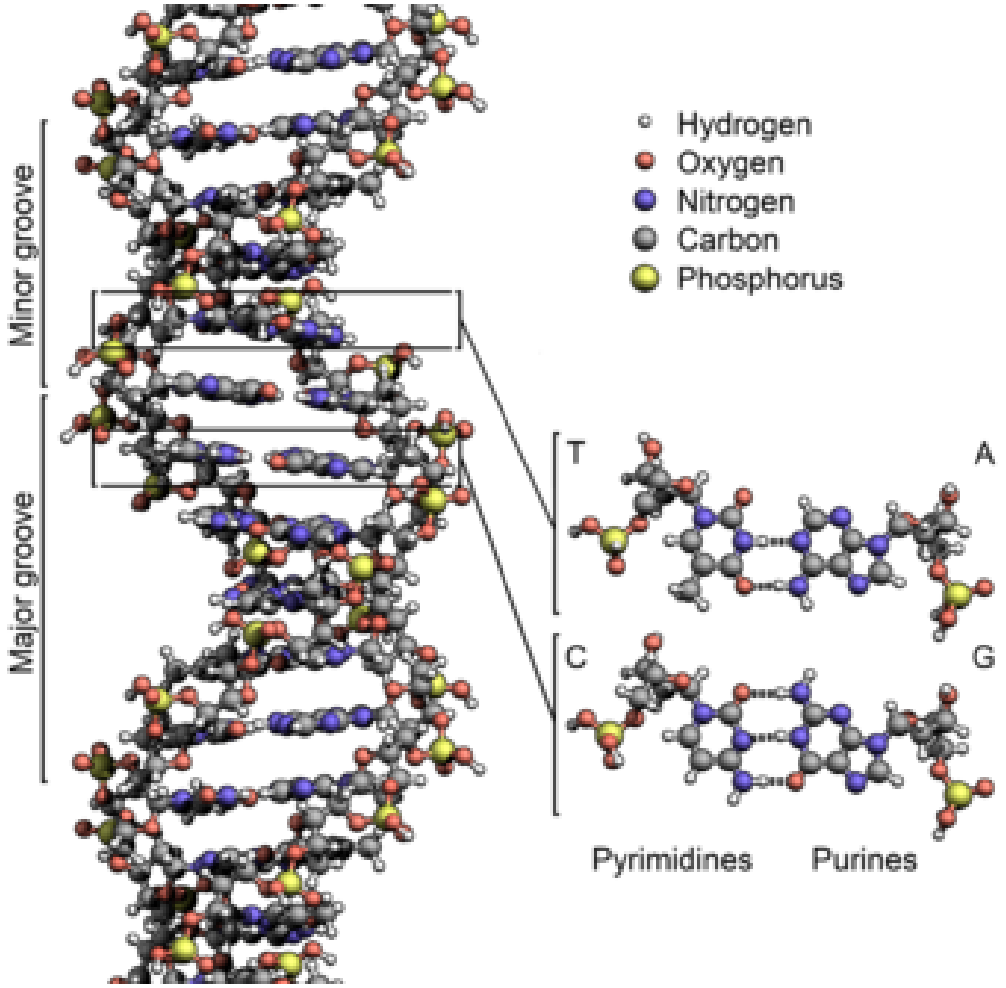
DNA is double stranded and can only be a double helix.



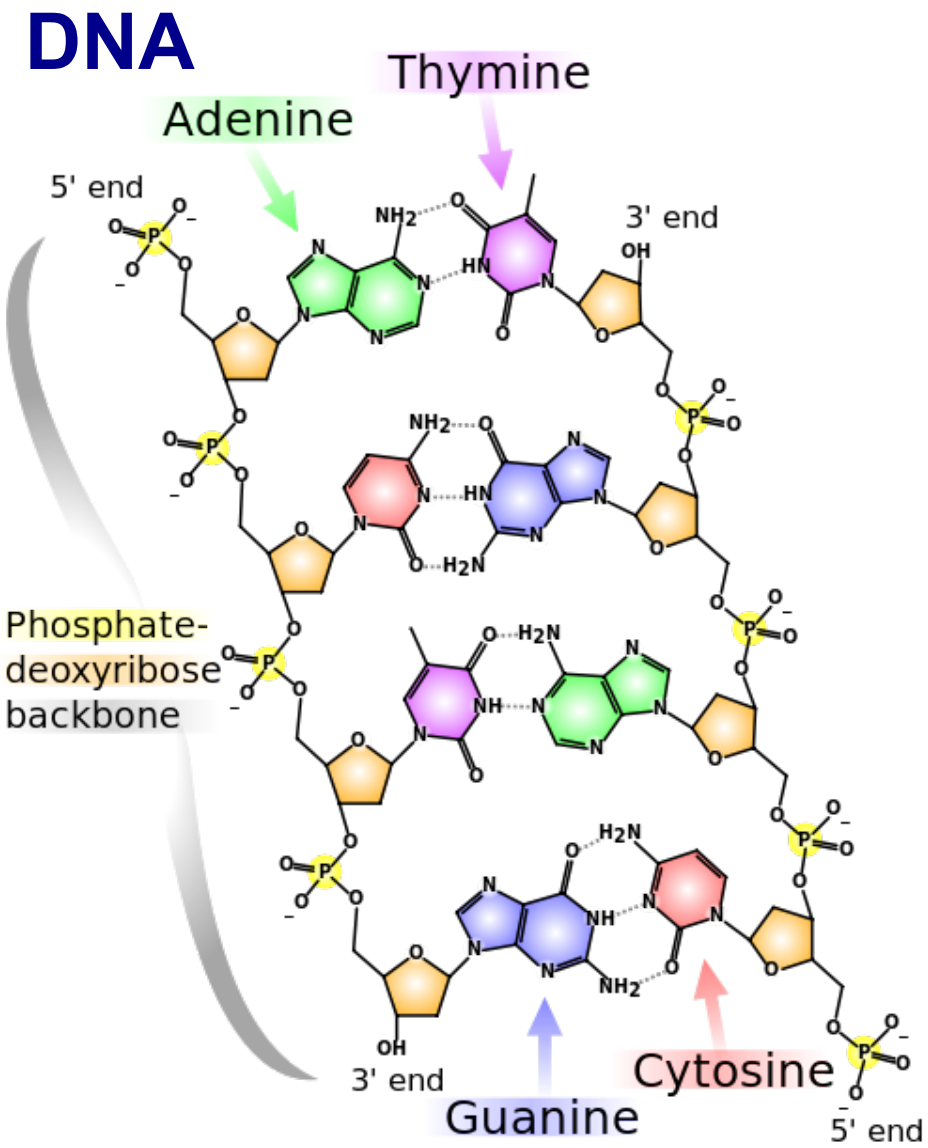
DNA

DNA is an informational molecule encoding the genetic instructions used in the development and functioning of all known living organisms

This diagram highlights the major chemical features.

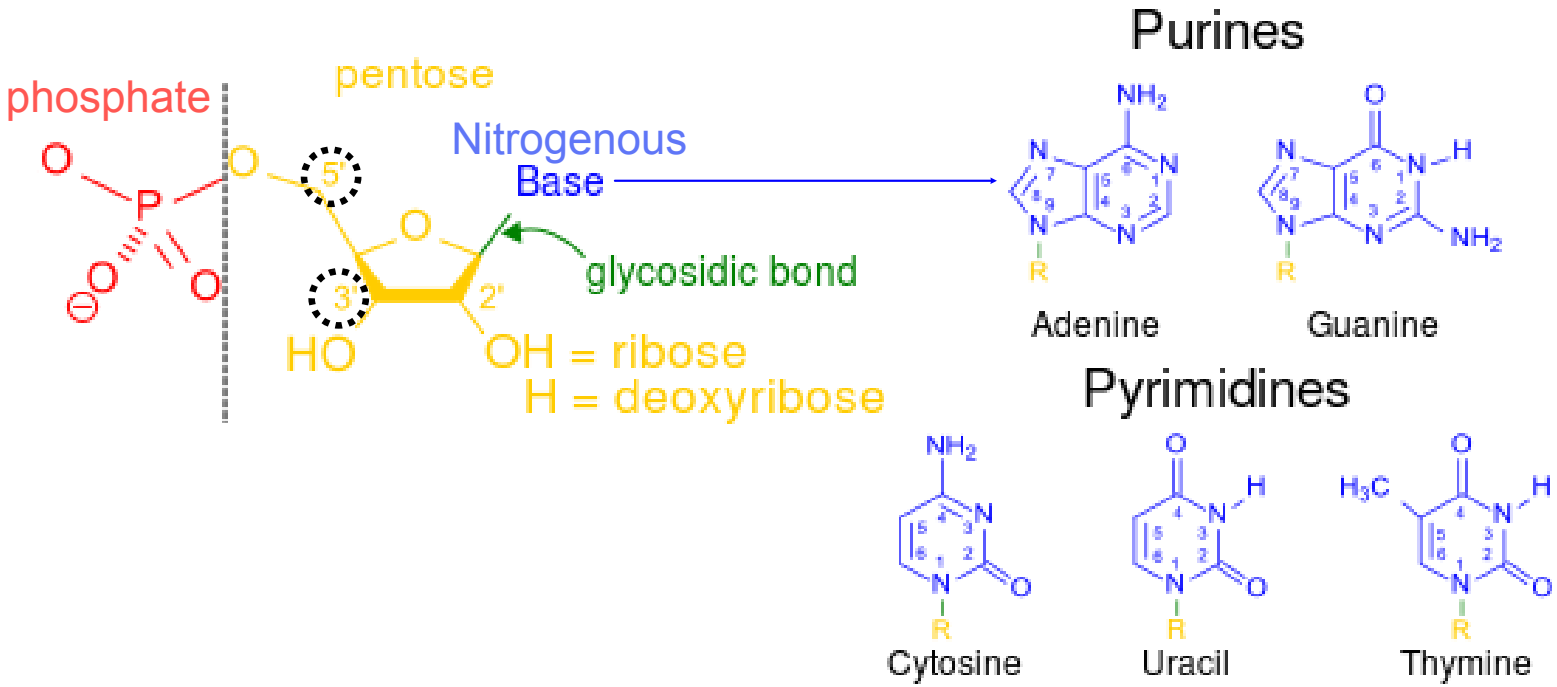


The two strands run in opposite directions to each other and are therefore **anti-parallel**, one backbone being 3' (three prime) and the other 5' (five prime). This refers to the direction the 3rd and 5th carbon on the sugar molecule is facing.



DNA

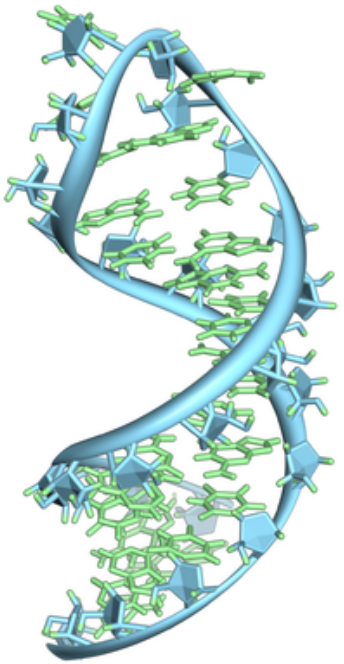
Nucleotides are the monomers that build the polymer strands



RNA

Nucleotides also build the single stranded polymer of RNA molecules. The single strandedness of the RNA allows it to fold on itself making many shapes.

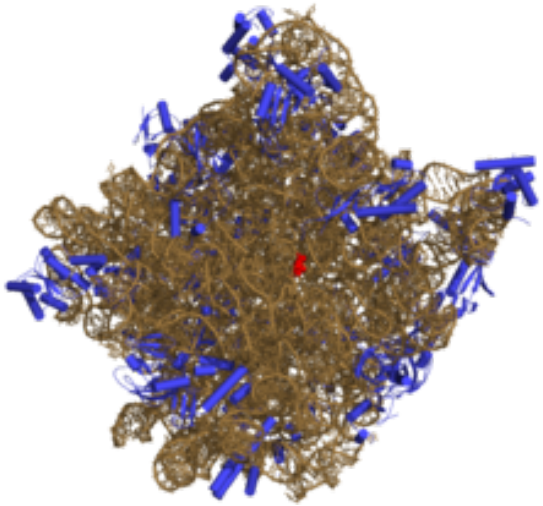
The shape of the molecule is dictated by the sequence of nucleotides.



A hairpin loop form of RNA. Highlighted are the nucleobases (green) and the ribose-phosphate backbone (blue).

RNA

RNA makes the molecular machinery necessary for the function of DNA. It plays a major role in the replication of DNA and the reading of the information stored in DNA.



Three- dimensional representation of the small ribosomal subunit. RNA is in brown, protein in blue. The active site is in the middle (red). This molecule reads the genetic code.

11 Four of the following are associated with DNA. Choose the one which is not.

- A uracil
- B thyamine
- C adenine
- D guanine
- E cytosine

12 If one strand of DNA is CGGTAC, the complementary strand would be:

- A GCCTAG
- B CGGTAC
- C TAACGT
- D GCCATG

13 If one strand of DNA is AGCTGA, the complementary strand would be:

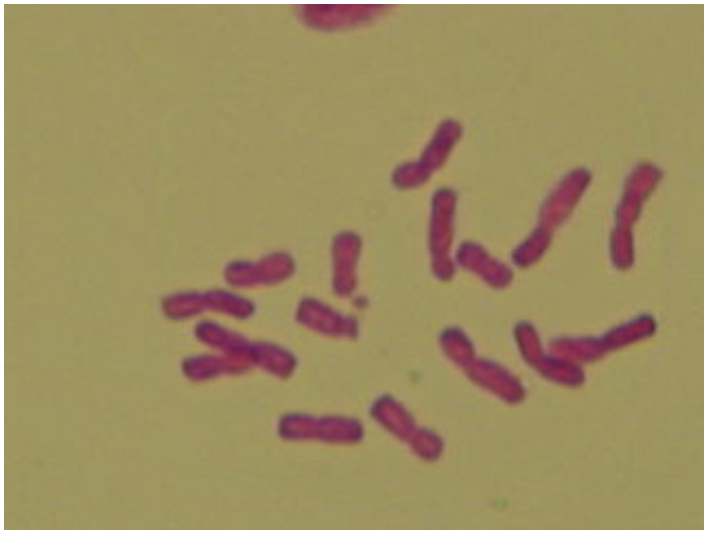
- A TCGACU
- B TCGACT
- C AGCTGA
- D AGTCGA

Chromosomes

Return to Table of Contents

Chromosomes Defined

A chromosome is an organized structure of **DNA and protein** found in cells. It is a single piece of coiled DNA containing **many genes.**

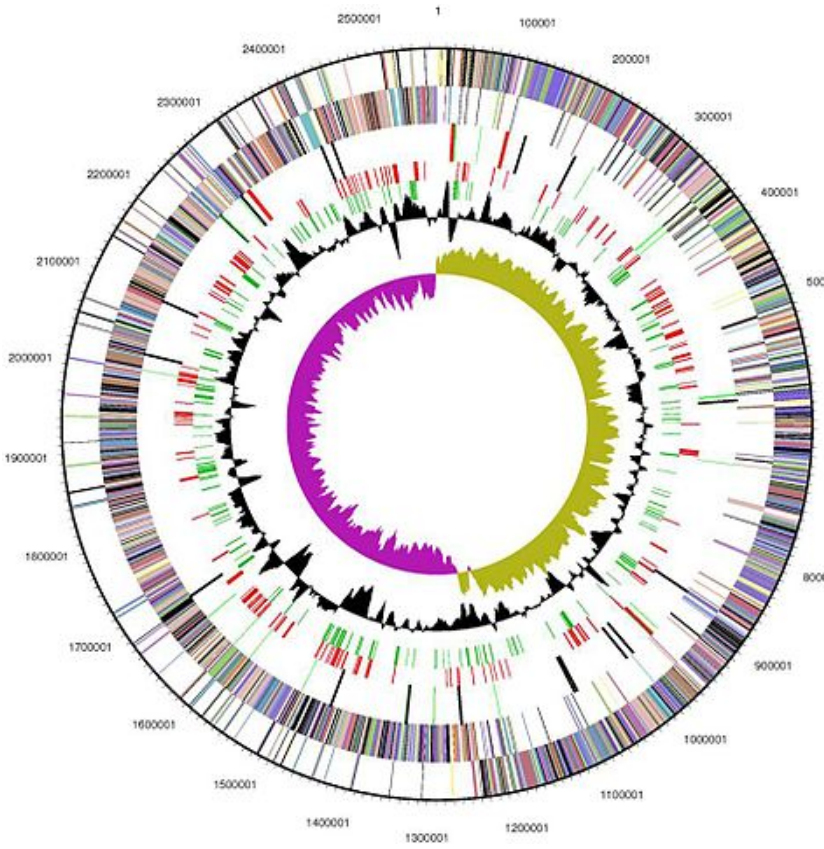


Chromosomes Defined

Chromosomes vary widely between different organisms. The DNA molecule may be circular or linear, and can be composed of 100,000 to over 3,750,000,000 nucleotides in a long chain.

Typically, eukaryotic cells have large linear chromosomes and prokaryotic cells have smaller circular chromosomes.

Prokaryotic Chromosomes



This is a chromosomal map of a bacteria, *H. orenii.*

Like all bacteria, this circular DNA molecule contains all the genes that are needed to make the entire organism.

This particular bacterial **genome** is made of ~2,500,000 nucleotides. Each different color in the outer circle represents another gene.

Eukaryotic Chromosomes

In eukaryotes, nuclear chromosomes are packaged by proteins into a condensed structure called **chromatin**. This allows the very long DNA molecules to fit into the cell nucleus.

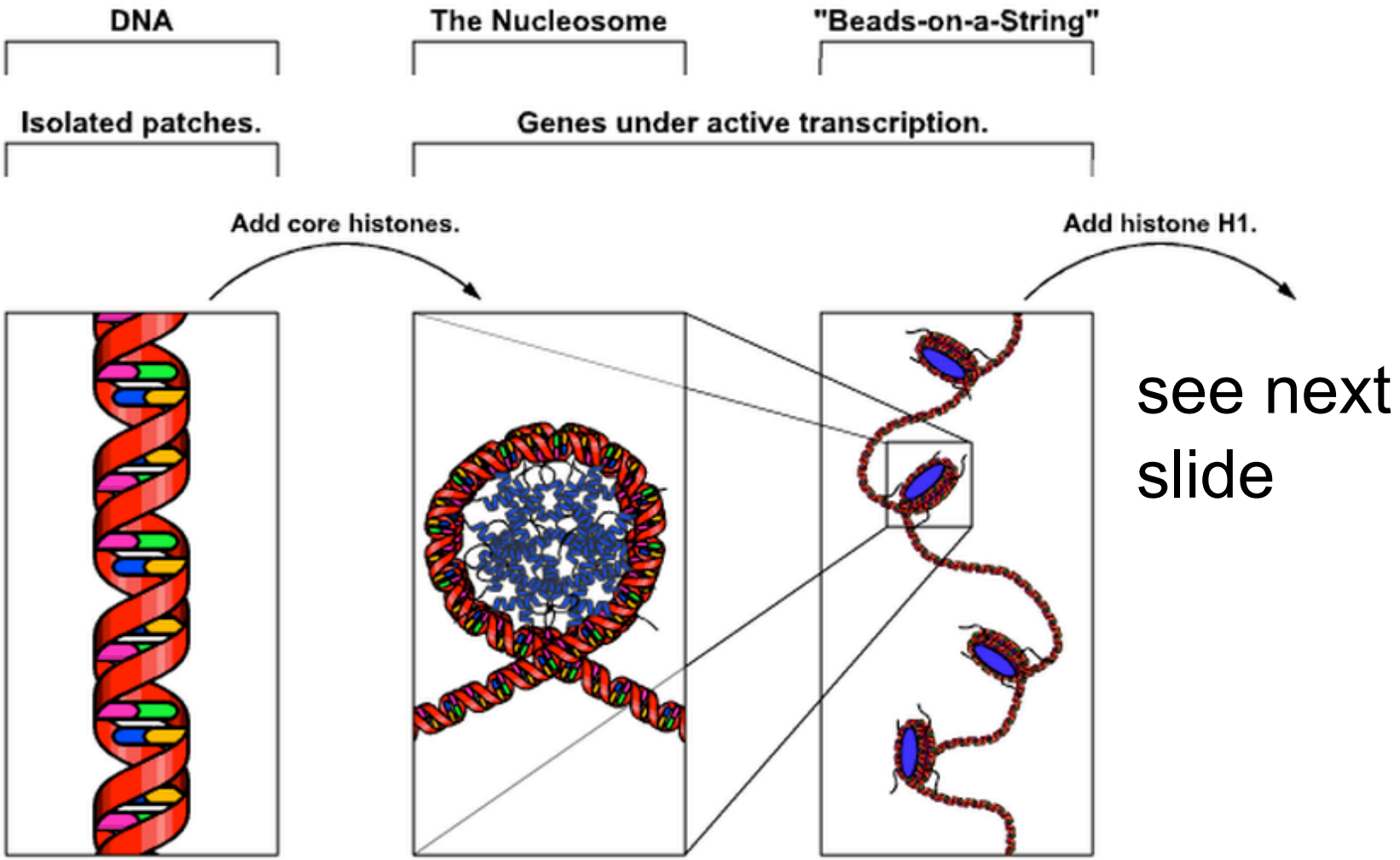
Chromosomes are the essential unit for cellular division and must be replicated, divided, and passed successfully to their daughter cells to ensure the genetic diversity and survival of offspring.

Eukaryotic Chromosomes

Since eukaryotes are larger and more complex, eukaryotic chromosomes are much larger and require more complex methods for storage of their numerous genes.

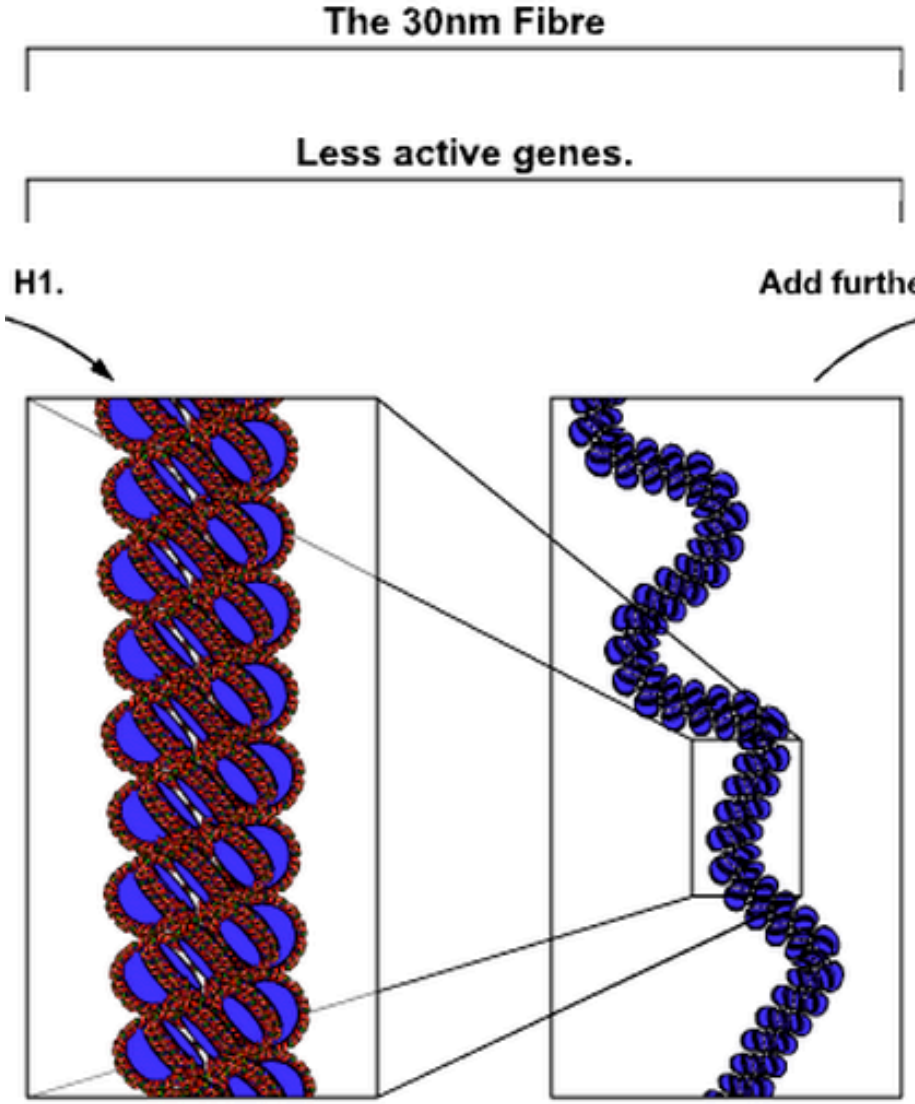
Special proteins called **histones** fold and pack the DNA strand into tight coils.

Eukaryotic Chromosomal Structure



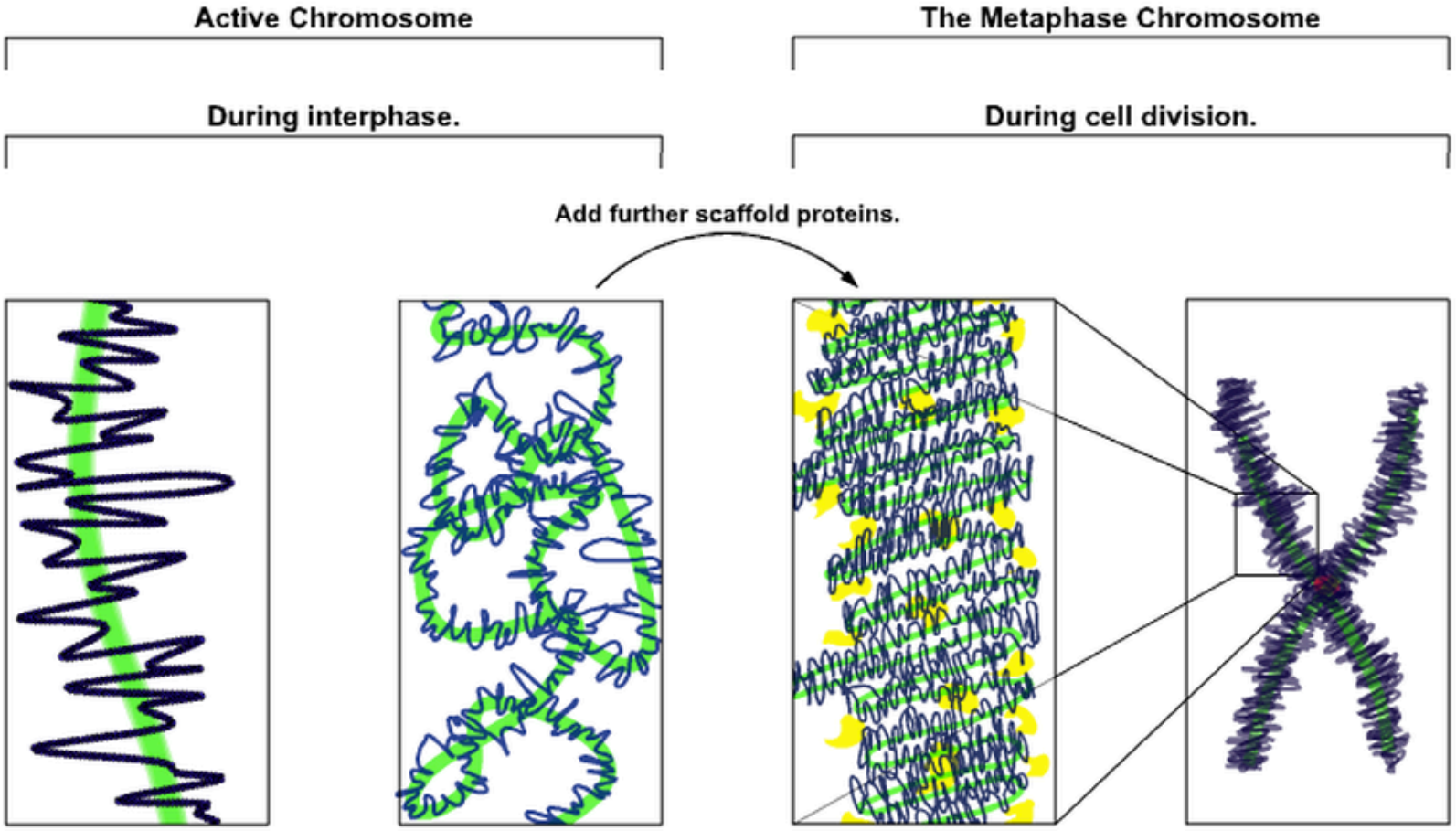
see next slide

Eukaryotic Chromosomal Structure

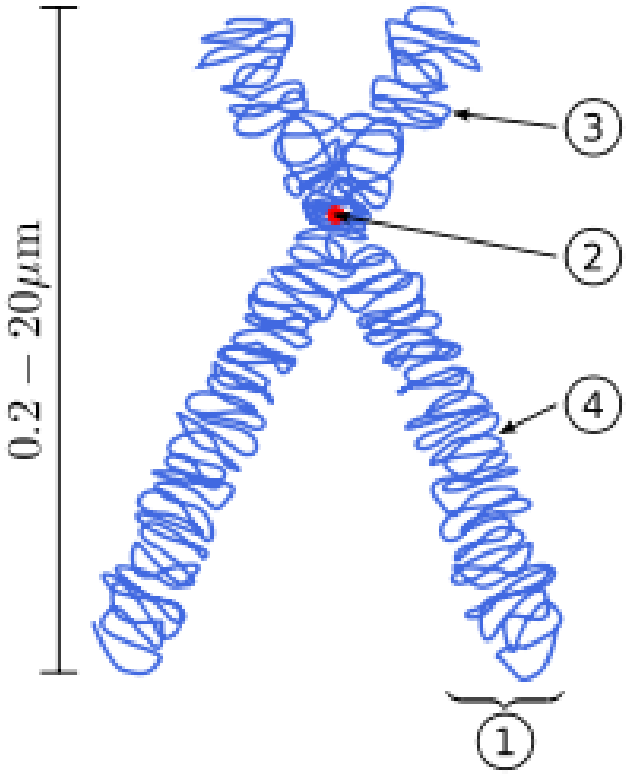


see next slide

Eukaryotic Chromosomal Structure



Eukaryotic Chromosomal Structure



This diagram represents a eukaryotic chromosome after replication has occurred.

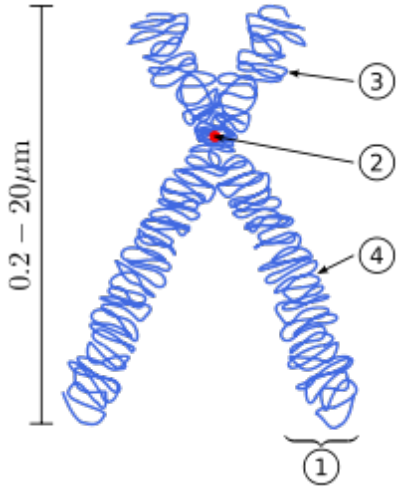
(1) **Chromatid** – one of the two identical copies of the chromosome.

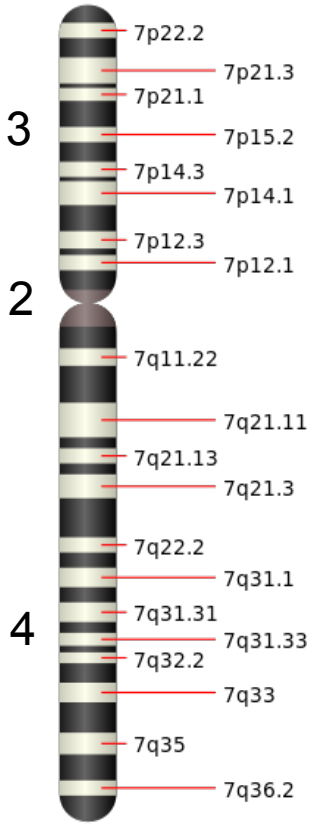
(2) **Centromere** – the point where the two chromatids touch, and where the microtubules attach during cell division.

(3) Short arm.

(4) Long arm.

Eukaryotic Chromosomal Structure

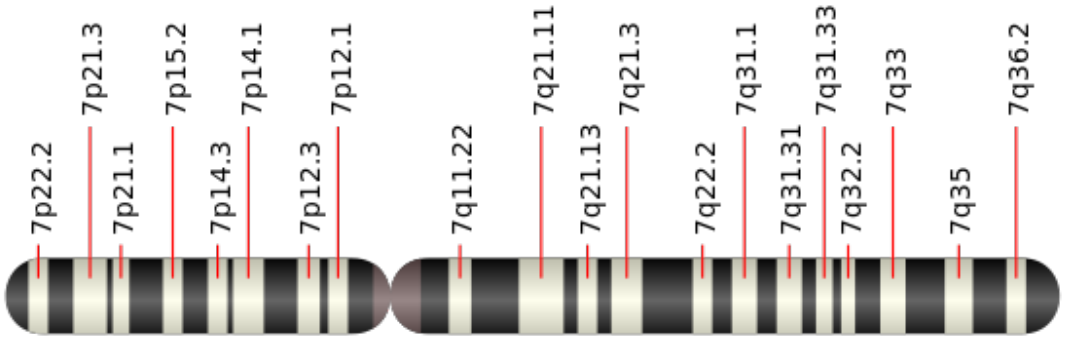




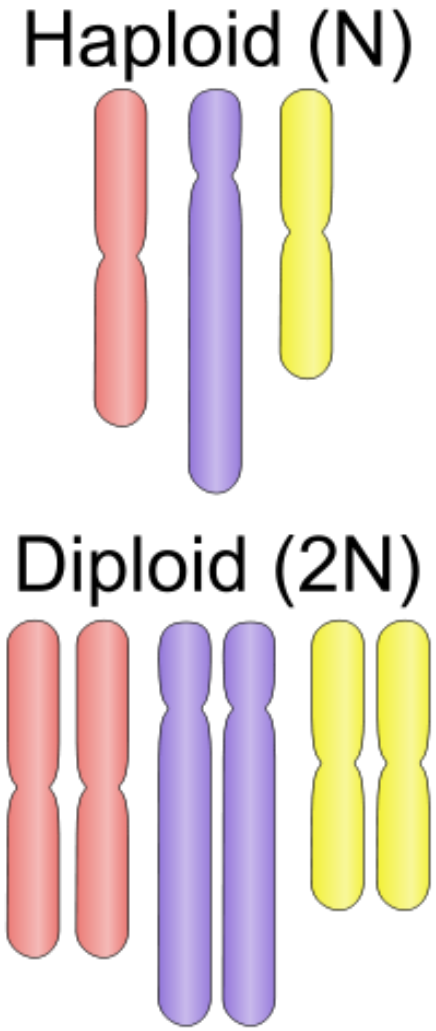
Chromosomes are often represented as genetic maps that show the loci of genes. This is a representation of human chromosome 7.

Human Chromosomes

Each band represents a gene or a group of genes that code for a phenotype of the human. Humans have 23 pairs of chromosomes in each of their cells that contain multiple copies of ~40,000 genes.



Eukaryotic Chromosomal Structure



Chromosomes can be **diploid**, 2 versions of each chromosome, or **haploid**, 1 version of each chromosome.

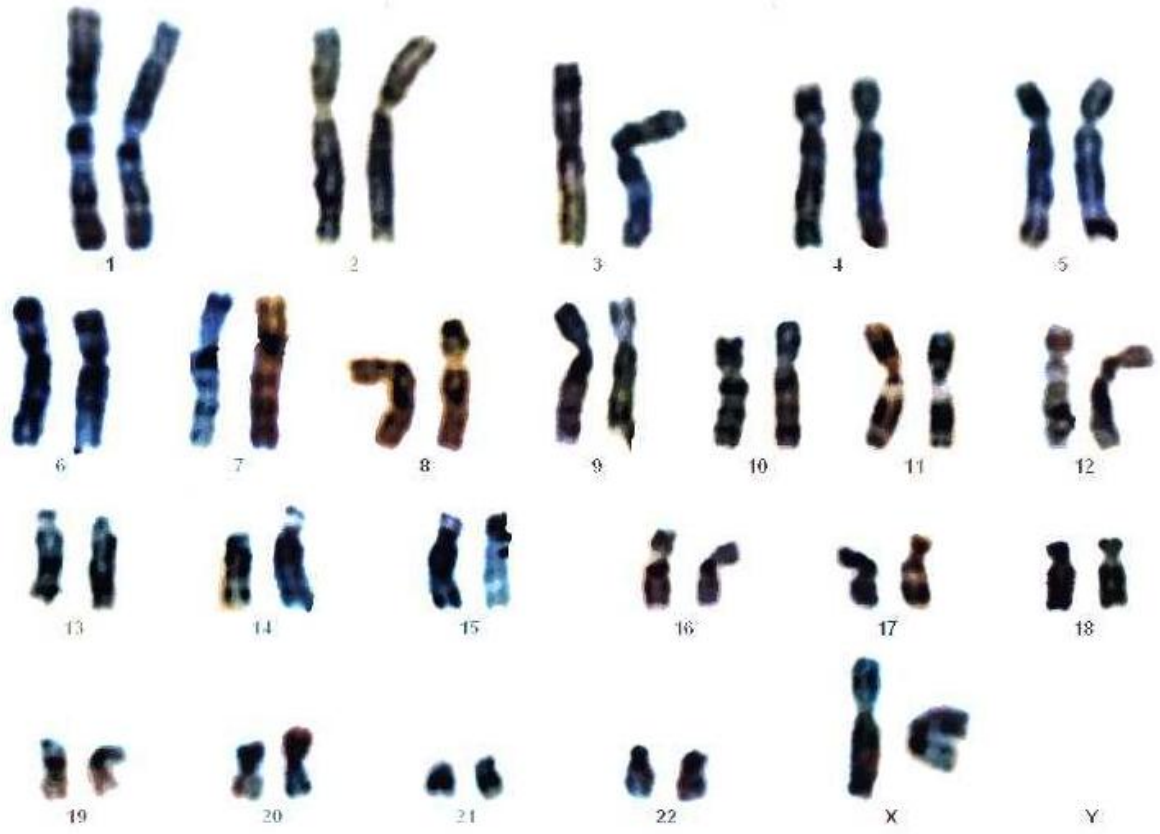
N= Number of chromatids

Human Karyotype

A karyotype is a photograph of the actual chromosomes of an individual human. A nucleus is isolated and the chromosomes are removed and arranged. They can be used to learn about possible chromosomal abnormalities.

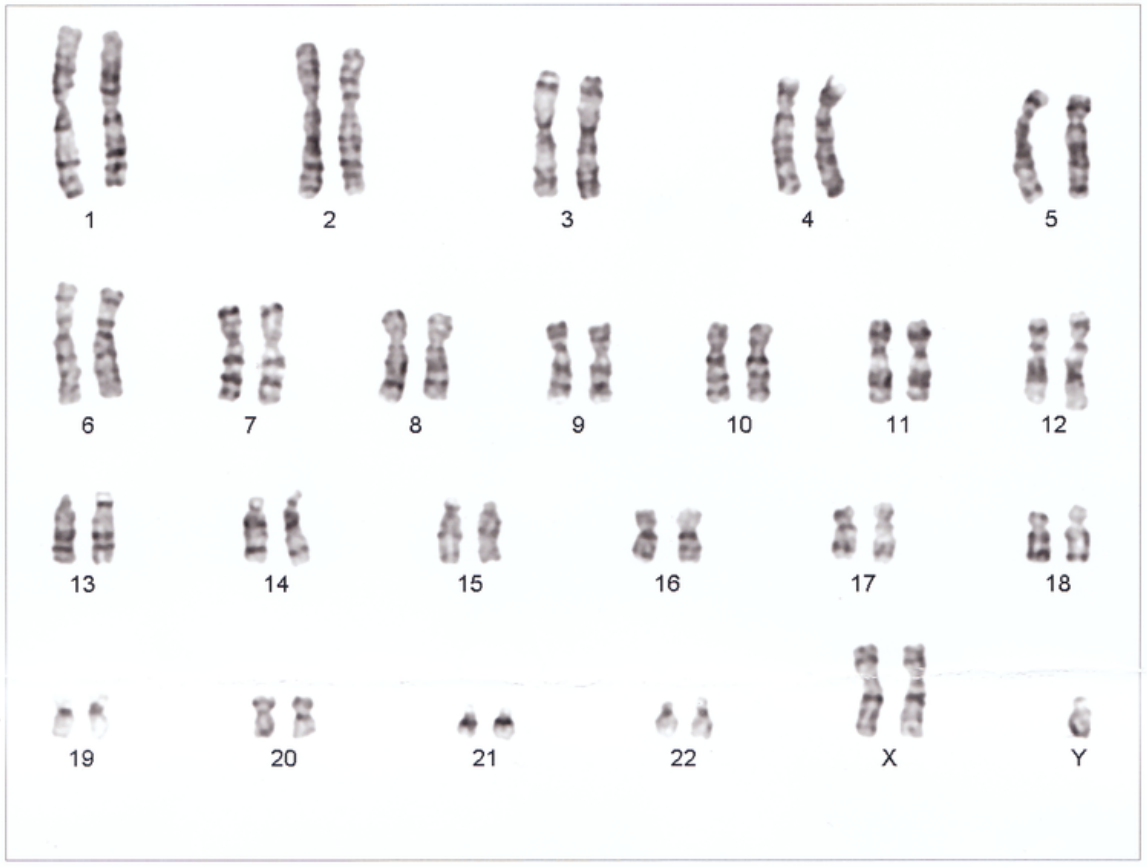
Human Karyotype

What can you learn about this individual from their chromosomes?



Human Karyotype

What can you learn about this individual from their chromosomes?

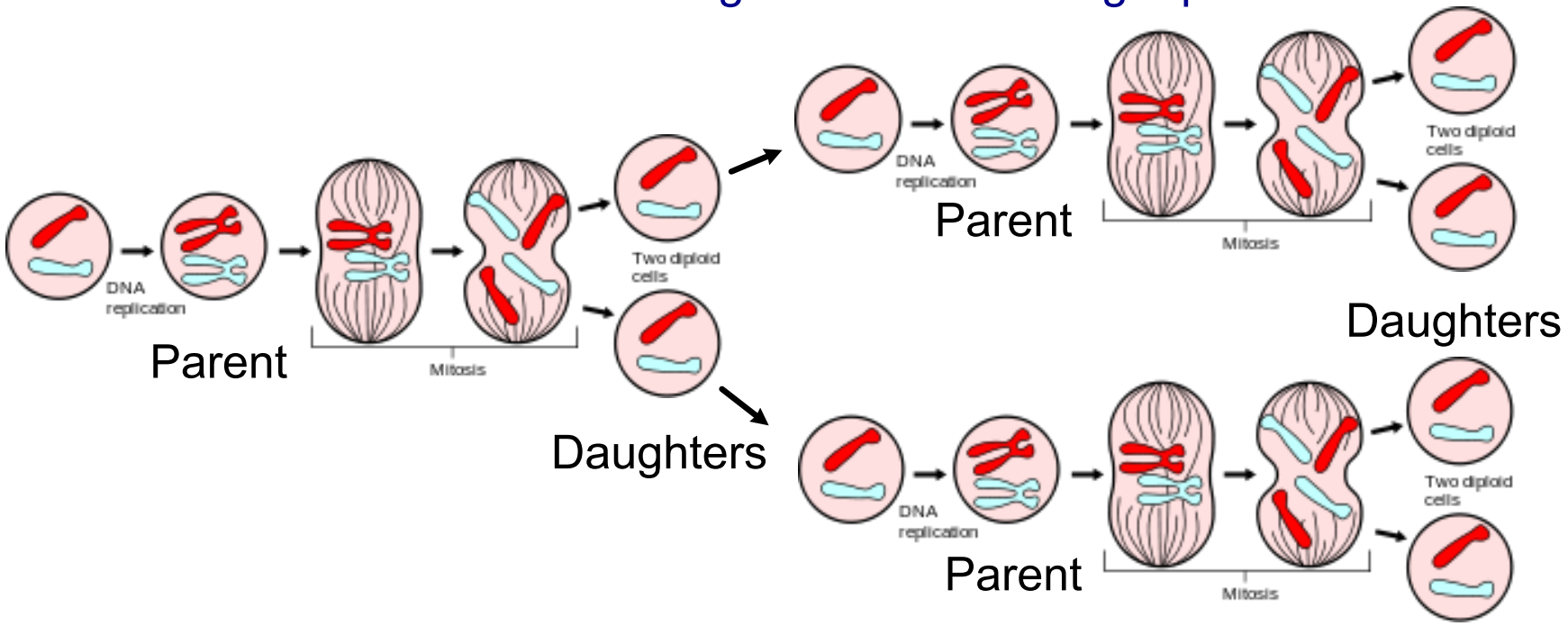


The Cell Cycle

Return to Table of Contents

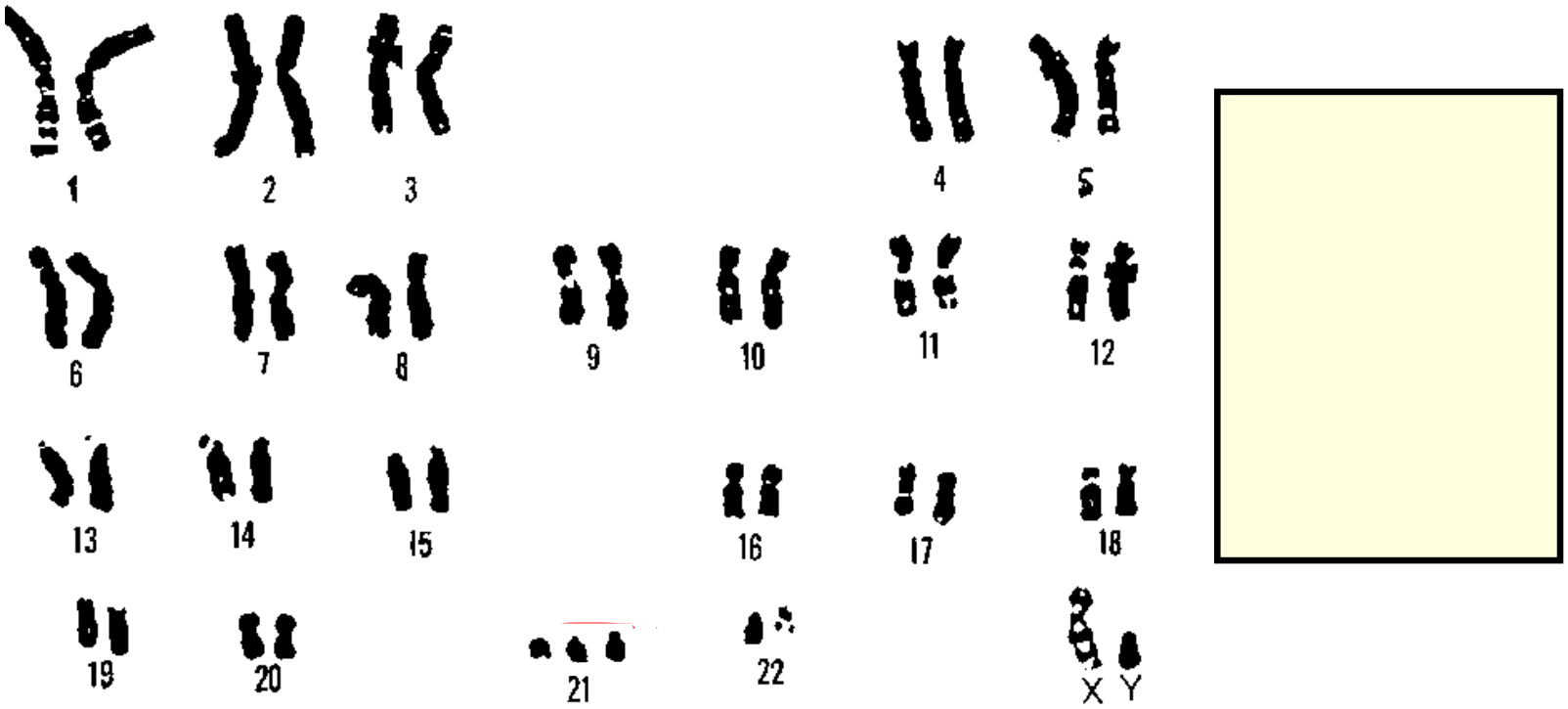
The Life of a Cell

The life of a eukaryotic cell can be defined by the time between cell divisions. When a **parent cell** divides (**mitosis**) it produces 2 **daughter cells**. Over time each daughter cell will go through a series of events that will lead to the daughter cell becoming a parent cell.



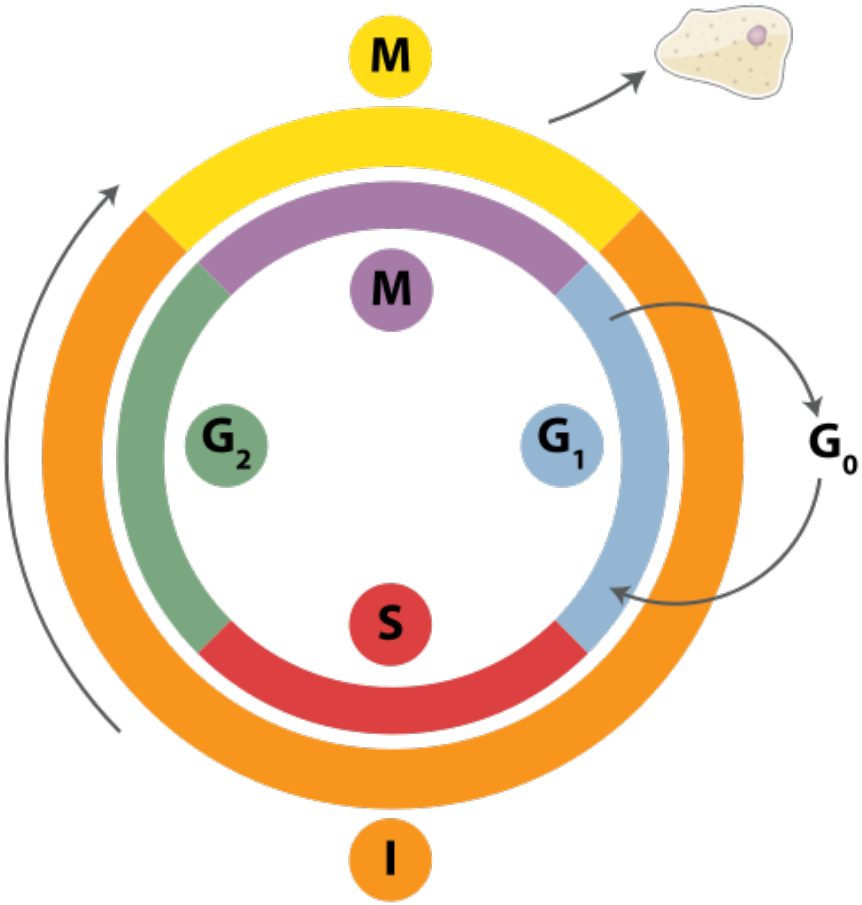
Human Karyotype

What can you learn about this individual from their chromosomes?



The Life of a Cell

The **cell cycle** is the stages a cell goes through from division to division.



M = Miotic phase

I = Interphase

G1 = Gap Phase1

S = DNA synthesis Phase

G2 = Gap Phase 2

G0 = Gap Phase 0

Interphase

Most cells spend more than 90% of the total time of their life cycle in interphase.

There are 3 distinct sub-phases to interphase:

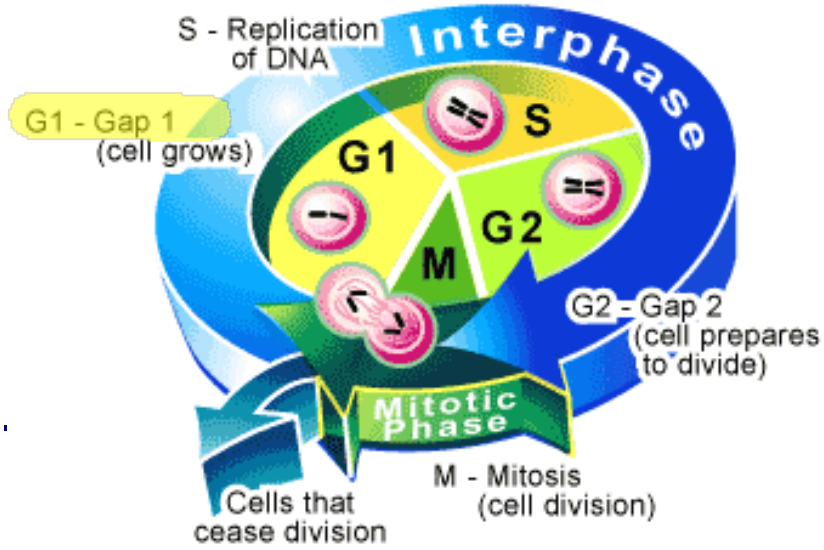
- Gap 1 (G_1)
- Synthesis (S Phase)
- Gap 2 (G_2)

Gap 1 (G_1 phase)

The cell increases in size.

The cell increases its supply of proteins, particularly those used in the duplication process.

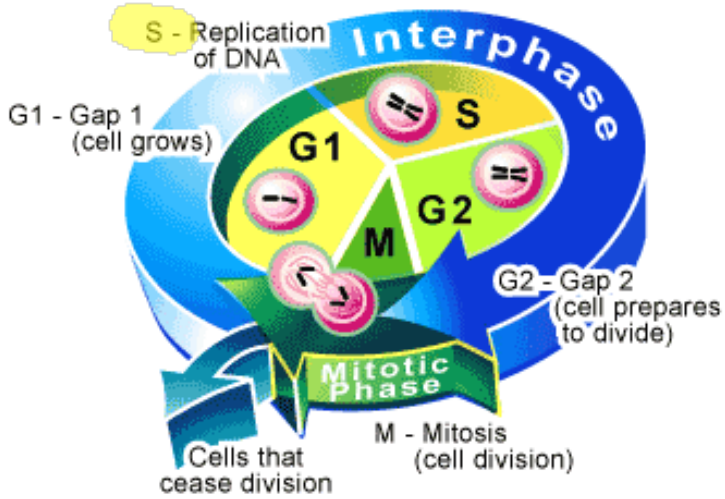
Duplication of organelles occurs.

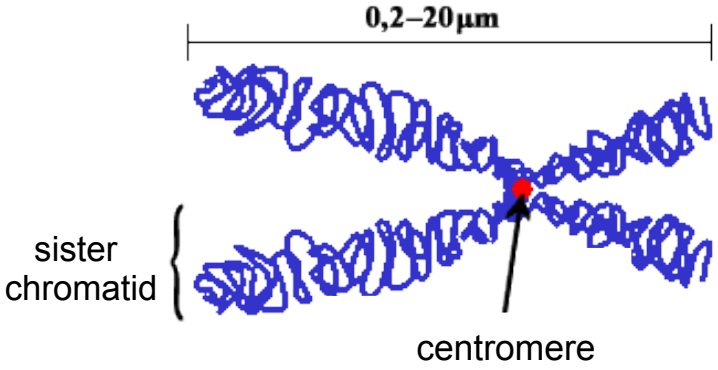


Synthesis (S-phase)

DNA replication occurs.

At the end of this sub-phase, each chromosome in the cell has doubled. The two copies of a chromosome remain attached at a central point called a **centromere**. Each copy is then know as a **sister chromatid.**

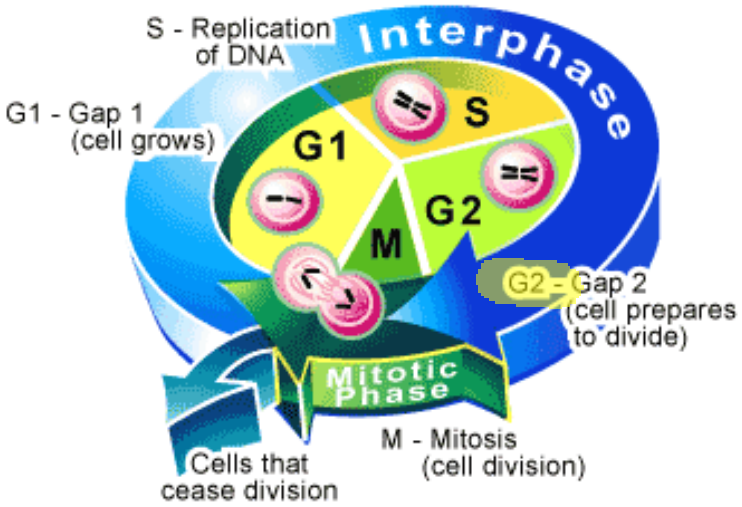




Gap 2 (G_2 phase)

The cell completes its growth in preparation for division.

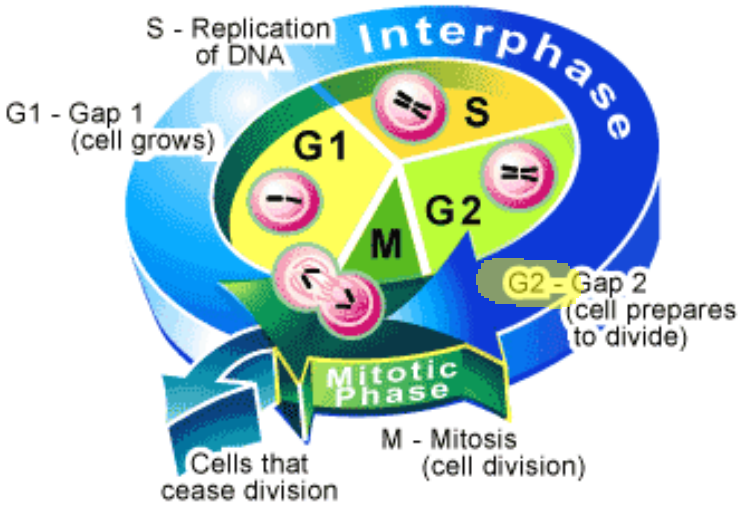
Increases its supply with even more proteins.



Mitotic Phase (M phase)

This phase is the mechanical division of the nucleus and cytoplasm of the cell which results in full cell division.

Both daughter cells will enter G1 phase after the mitotic phase is complete.



14 At which stage does DNA replication occur?

- A Gap 1
- B S phase
- C Gap 2
- D Mitotic phase

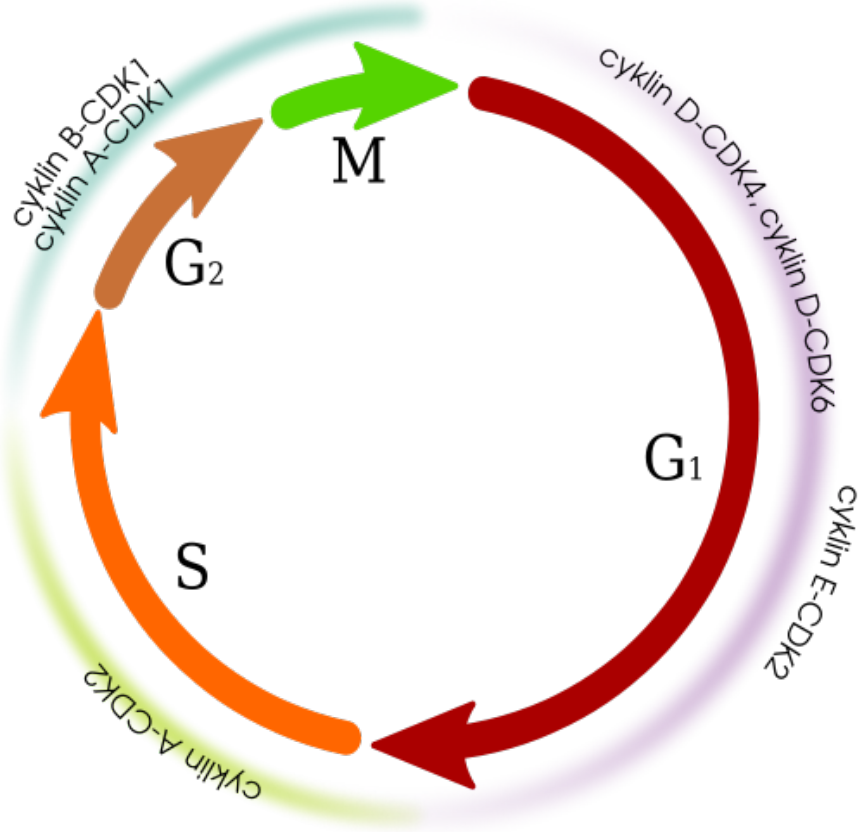
15 At which stage does duplication of organelles occur?

- A Gap 1
- B S phase
- C Gap 2
- D Mitotic phase

Cell Cycle Checkpoint Control

Cell cycle checkpoints are control mechanisms that ensure the proper division of cells. These checkpoints verify whether the processes at each phase of the cell cycle have been accurately completed before progression into the next phase.

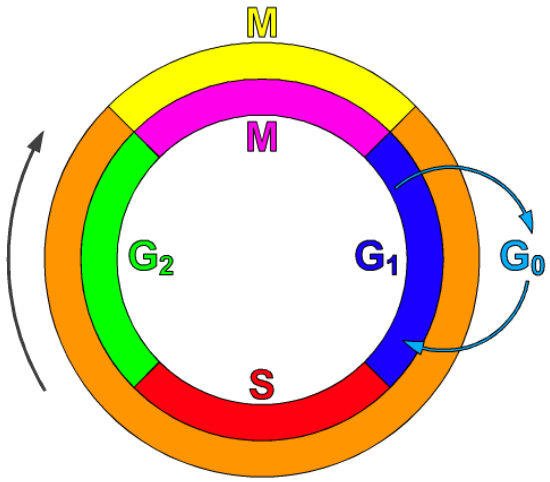
The cell cycle checkpoints are made up of **protein kinases** and adaptor proteins that all play roles in the maintenance of the cell division.



Cell Cycle Checkpoint Control

G1 Checkpoint - The first checkpoint is located at the end of the cell cycle's G1 phase, before entry into S phase. This is a key point that dictates wether the cell should divide, delay division, or enter a resting stage.

The G1 checkpoint is where eukaryotes typically arrest the cell cycle if cell division is unnecessary or impossible. Then the cell passes into **G0** for an extended period of no division or growth



Nerve and Muscle cells are non-dividing cells which get stuck at a "G_0 phase" because the G_1 checkpoint is never given the ok to proceed.

Cell Cycle Checkpoint Control

G2 Checkpoint - The second checkpoint is located at the end of G2 phase, triggering the start of the M phase. In order for this checkpoint to be passed, the cell has to check a number of factors to ensure the cell is ready for mitosis. Most importantly is that the chromosomes have duplicated properly.

If this checkpoint is passed, the cell initiates the many molecular processes that signal the beginning of mitosis.

Cell Cycle Checkpoint Control

Metaphase Checkpoint - The mitotic spindle checkpoint occurs at the point in metaphase where all the chromosomes have aligned at the mitotic plate. The tension created by **spindle fibers**, the mechanism for pulling chromosomes apart, is what is checked before division proceeds.

If this checkpoint is not passed the cell division will be halted and the cell will die. If the mechanism has failed then the resulting daughter cells may be dangerous to the rest of the organism.

Kinases Control the Checkpoints

Cyclin-dependent kinases (CDKs) are a family of protein kinases first discovered for their role in regulating the cell cycle.

Kinases are enzymes that catalyze the transfer of a phosphate group from ATP to a specified molecule. When activated these proteins have a large impact on cell processes.

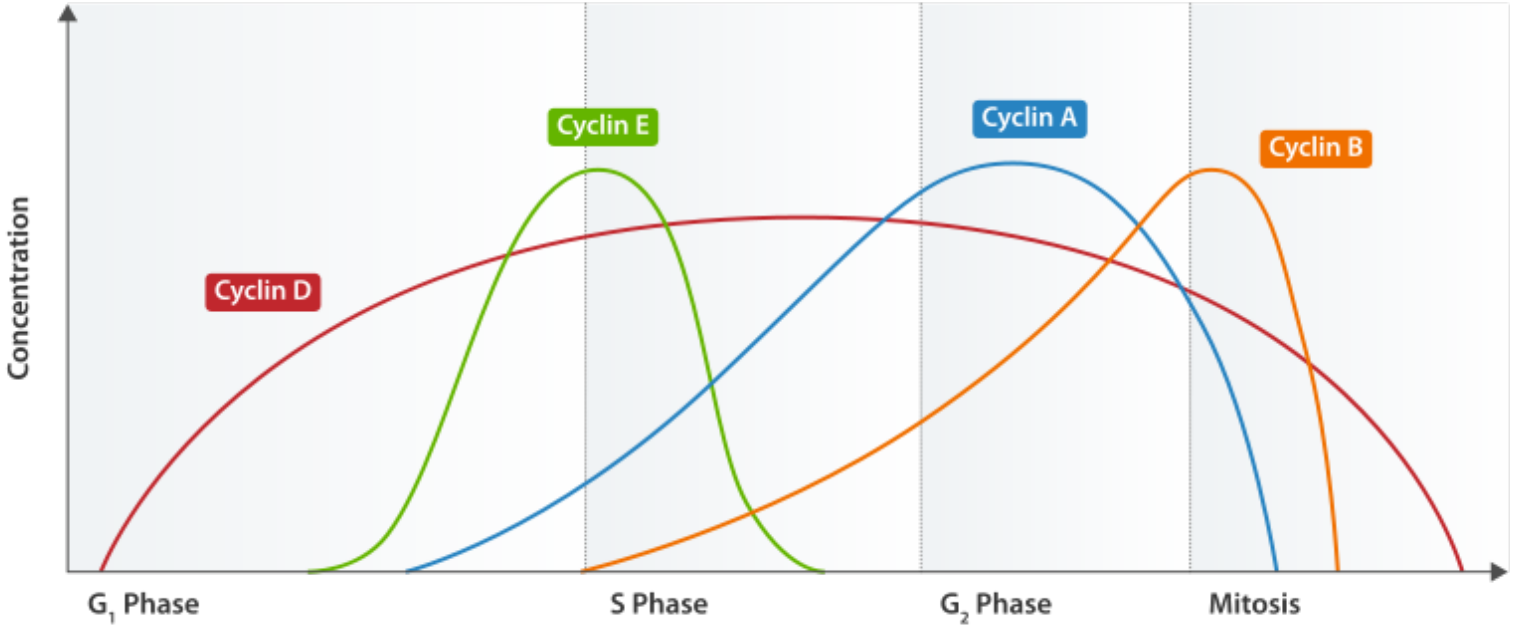
CDKs must be activated by a chemical known as a **cyclin.** The complex is known as maturation promotion factor (**MPF**).

Cyclins

Cyclins are a family of proteins that control the progression of cells through the cell cycle by activating cyclin-dependent kinase (Cdk) enzymes.

Cyclins were originally named because their concentration varies in a cyclical fashion during the cell cycle. The oscillations of the cyclins, namely fluctuations in cyclin gene expression, induce oscillations in Cdk activity to drive the cell cycle.

Cyclin Activity During the Cell Cycle



Kinases Control the Checkpoints

The CDK, Cyclin, MPF control system is highly complex. Many factors are still unknown. The important points are:

-Cyclin is produced when the cell is completing S-phase as a signal that chromosomes have been successfully copied.

-When Cyclin and CDK combine and form a high concentration of MPF in the cell, the cell will begin to enter M phase

-When chromosome pairs are successfully separated there is a release of a chemical that breaks down cyclin, reducing MPF. This low MPF induces the start of G1 phase

S-Phase
(Replication of Genes)

Return to
Table of
Contents

Replication

The functions of a cell are determined by its DNA.

Cells have to reproduce many times. In complex organisms, trillions of copies are made from one original cell.

But when cells reproduce, they must **replicate** (or copy) their DNA.

The structure of DNA reveals how trillions of copies of the DNA in one of your cells can be made, and be almost exactly the same each time.

Watson & Crick

When Watson and Crick published the structure of DNA in a short article in 1953 they stated:

"It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

The fact that there are two DNA strands that are mirror images of one another suggested how copies could be made of each DNA sequence.

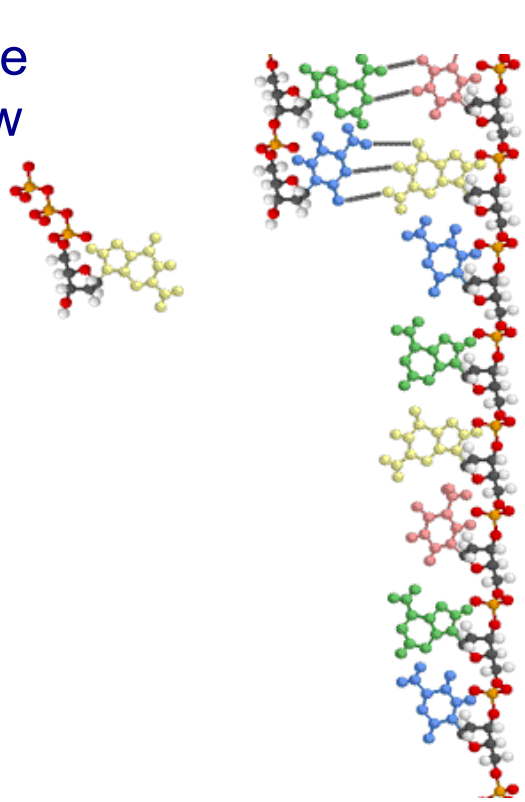
DNA Molecule as Template

Each molecule of DNA is made of a template strand and a new strand.

The template is used to make the new strand.

The template strand is also known as the **parent strand** since it came from the original DNA molecule.

The new strand is also known as the **daughter strand**.

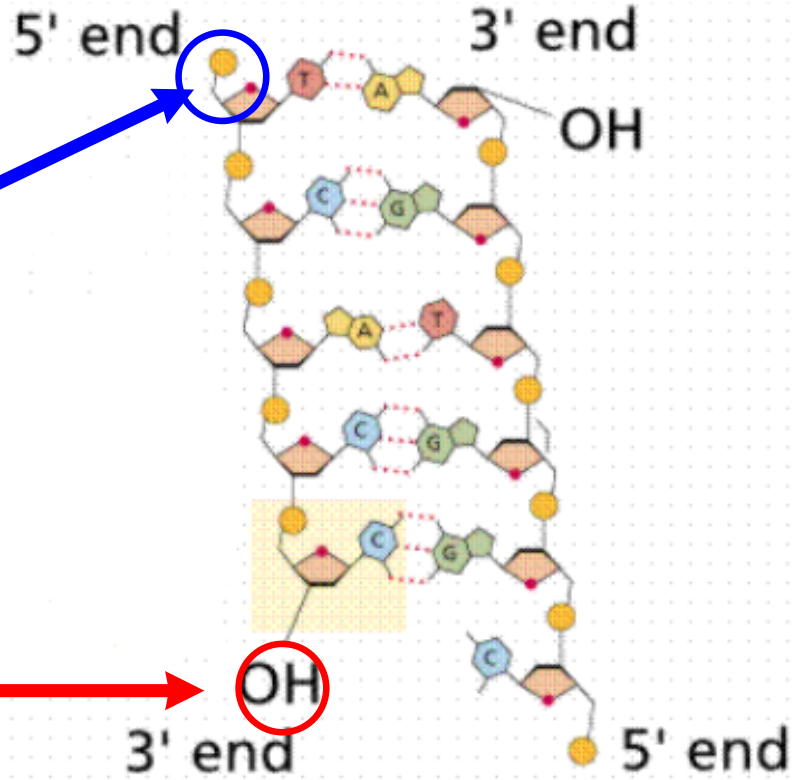


DNA is Anti-Parallel

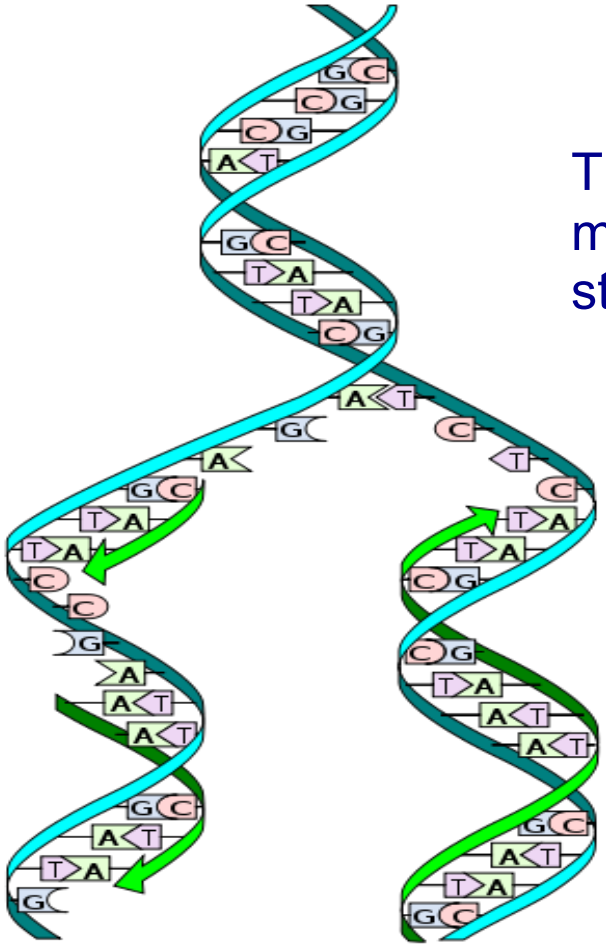
Each strand has two ends: a 5' end and a 3' end. The two strands of DNA always run in opposite directions. They are said to be anti-parallel to each other.

The 5' end has a phosphate group at the end.

The 3' end has an -OH group at the end.



Separation of Strands

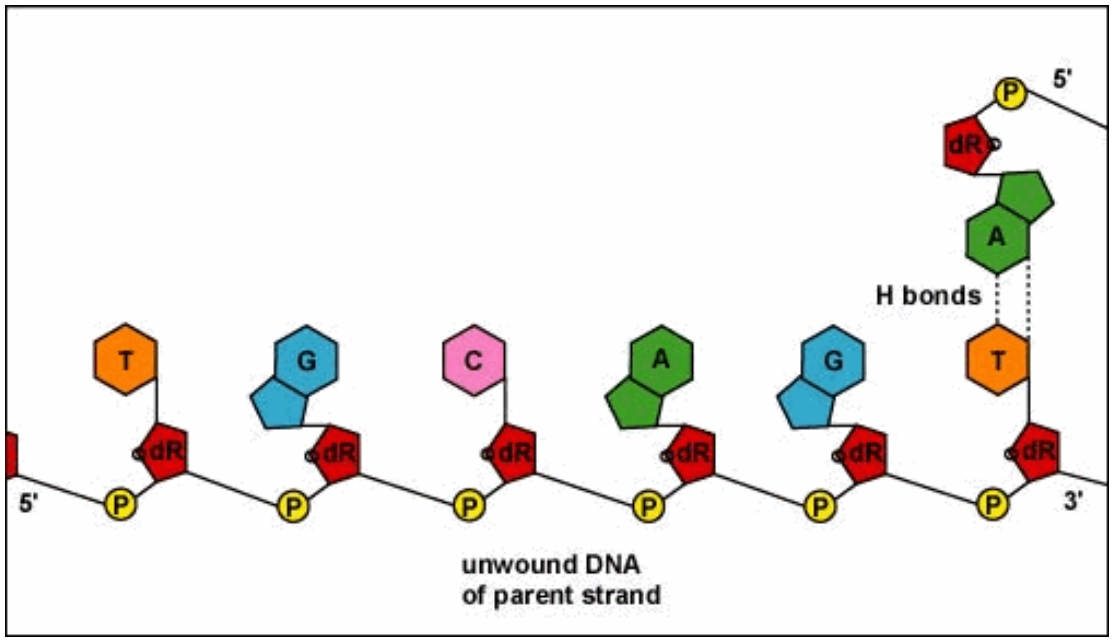


The **template strands** of the DNA molecule separate and the new strands are made on the inside.

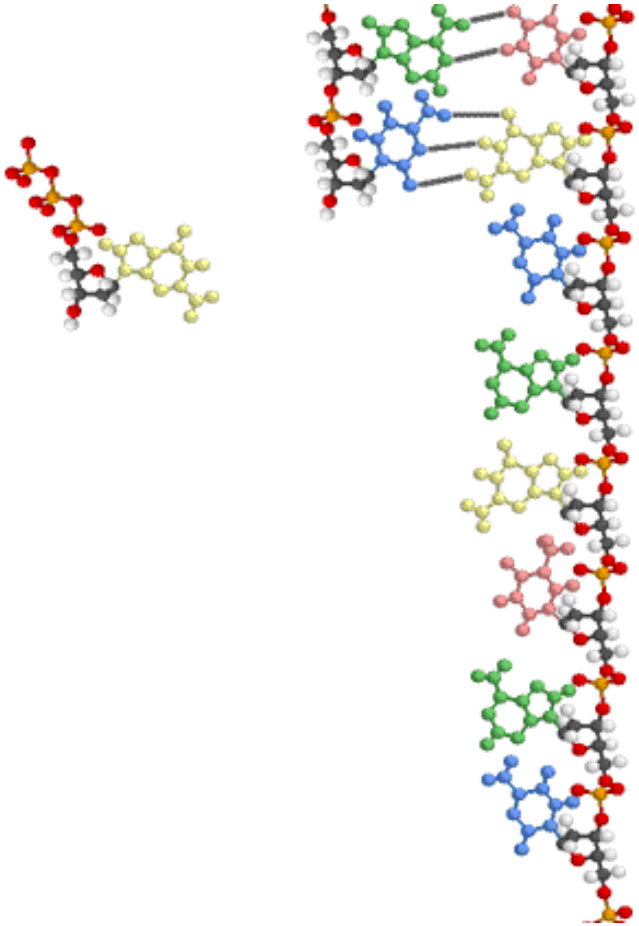
Click here to see an animation of the mechanism of replication

Adding New Nucleotides

Nucleotides can only be added to the -OH end (3`), not the 5`so all new strands are made in the 5' - 3' direction.



Enzyme Catalyzed Reaction

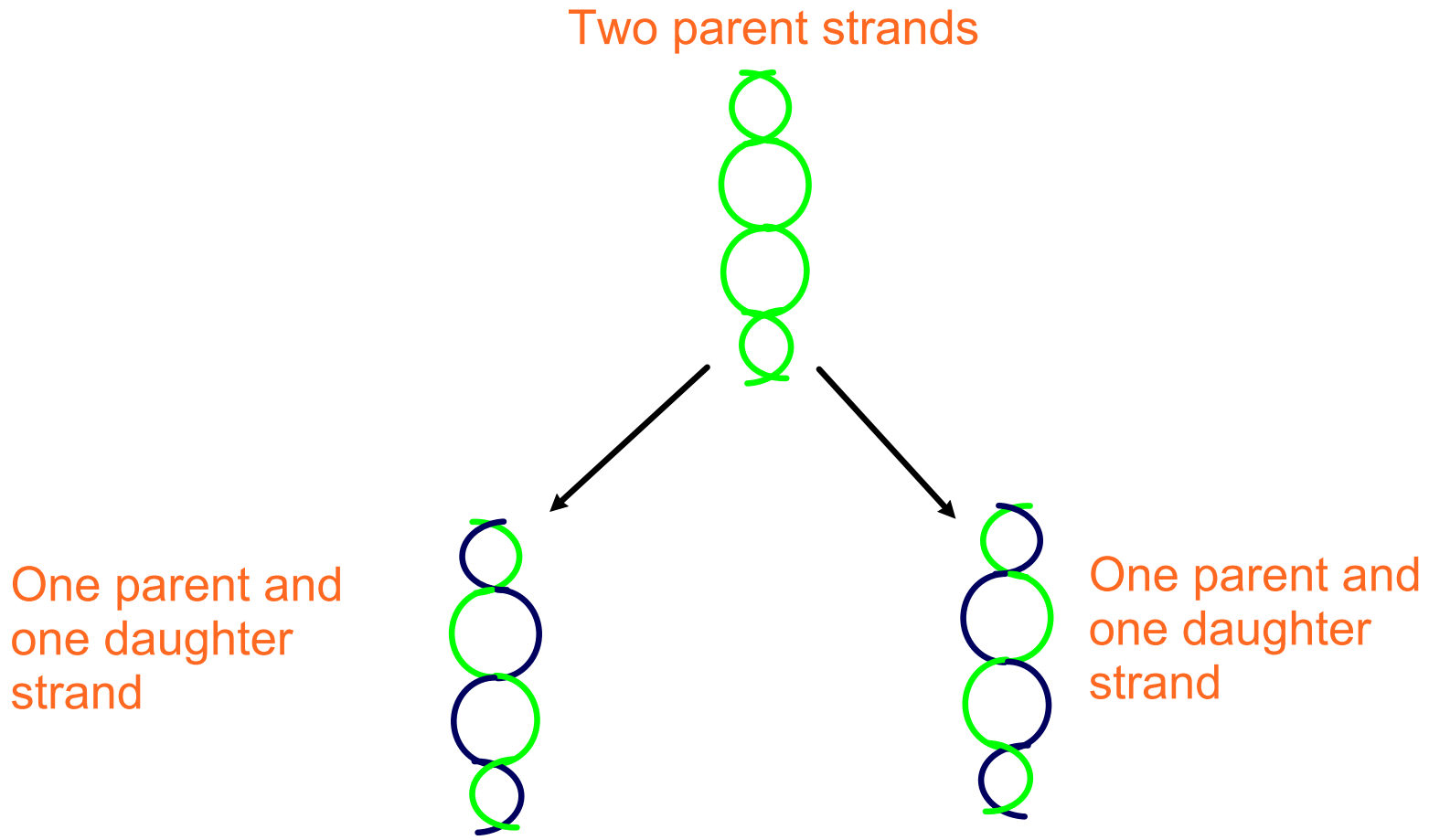


DNA nucleotide monomers are made ahead of time and stored in the cell.

DNA polymerase is the enzyme responsible for adding each new nucleotide to the growing strand.

Semi-Conservative DNA Replication

The result of this process is 2 new DNA molecules each having an old template strand and new strand. This is called semi-conservative because it "conserves" some of the old DNA in each copy.



16 The 3' end of a DNA strand has a phosphate at the end.

- ◯ True
- ◯ False

answer

17 Why does a DNA strand only "grow" in the 5' to 3' direction?

- A because DNA can only add nucleotides to the 3' end of the molecule
- B because DNA can only add nucleotides to the 5' end of the molecule
- C because mRNA can only read a DNA molecule from 5' to 3'
- D because mRNA can only read a DNA molecule from 3' to 5'

answer

Replication Practice

3' ATCGGGTTAACGCGTAAA 5' *template strand*

5' _____ *3' new strand*

What is the sequence of the new strand?

3' GGTTACTAATCGAGCCCCT 5' *template strand*

5' _____ *3' new strand*

What is the sequence of the new strand?

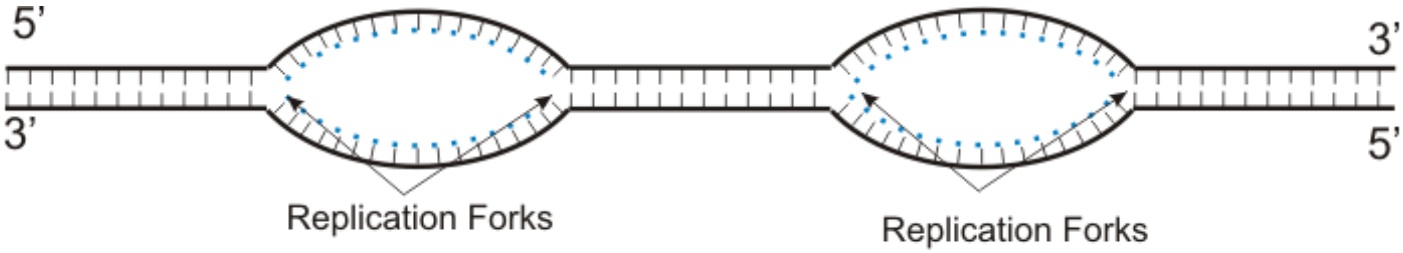
18 If the parent DNA strand is 5' ATCGATACTAC 3', what will the daughter stand be

- A 5' TAGCTATGATG 3'
- B 3' ATCGATACTAC 5'
- C 5' UAGCUAUGAUG 3'
- D 3' TAGCTATGATG 5'

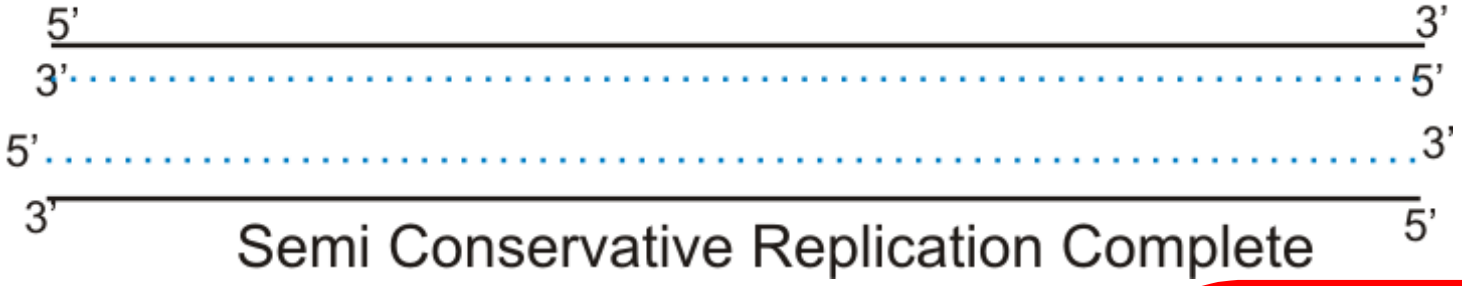
answer

The Molecular Process of Replication

A strand of DNA is replicated in segments. At intervals down the DNA molecule portions of the 2 strands separate creating **replication bubbles**. Either side of the replication bubble is know as a **replication fork**.



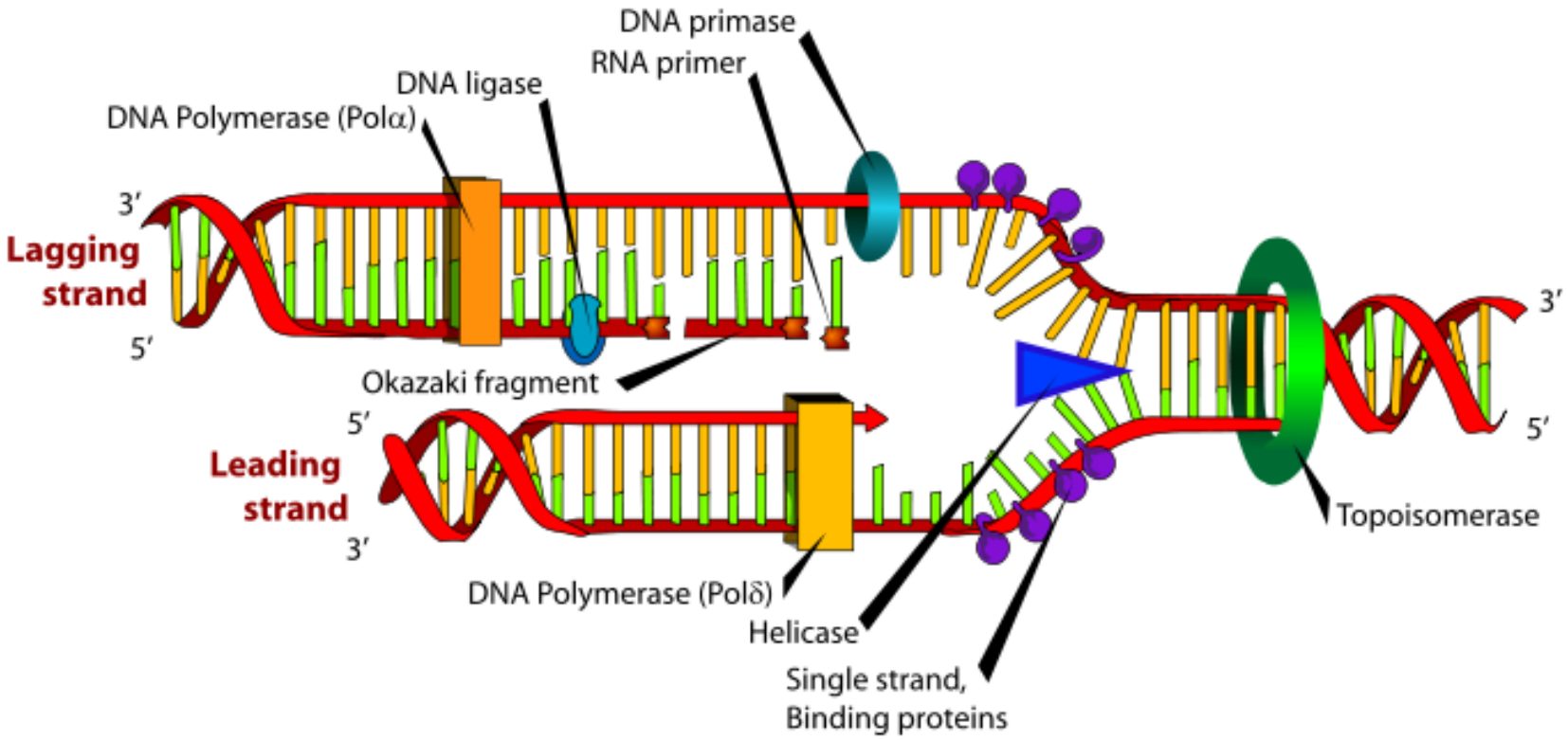
Replication bubbles form in DNA



Semi Conservative Replication Complete

Click Here for Animation

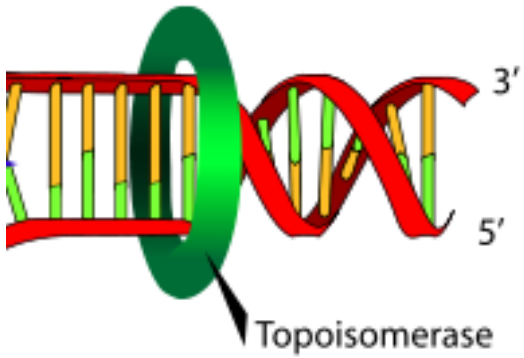
Replication Fork



DNA replication is a precise process that must minimize error. To do this cells use many enzymes in a complex process that uses template strands to create new DNA molecules

DNA Replication In-Depth

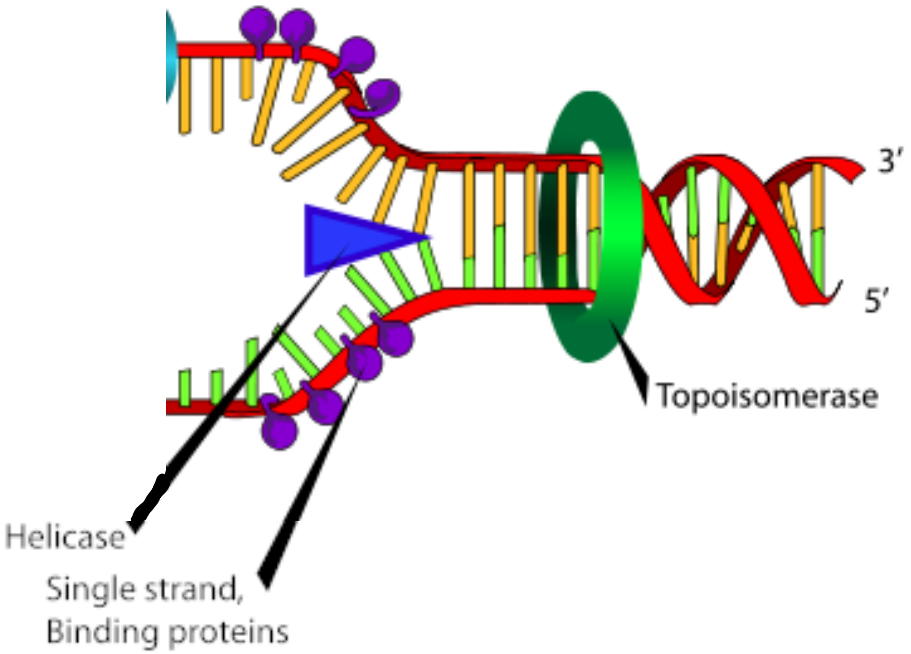
Topoisomerase binds to the DNA strand and cuts the double helix, causing the molecule to untwist and relax.



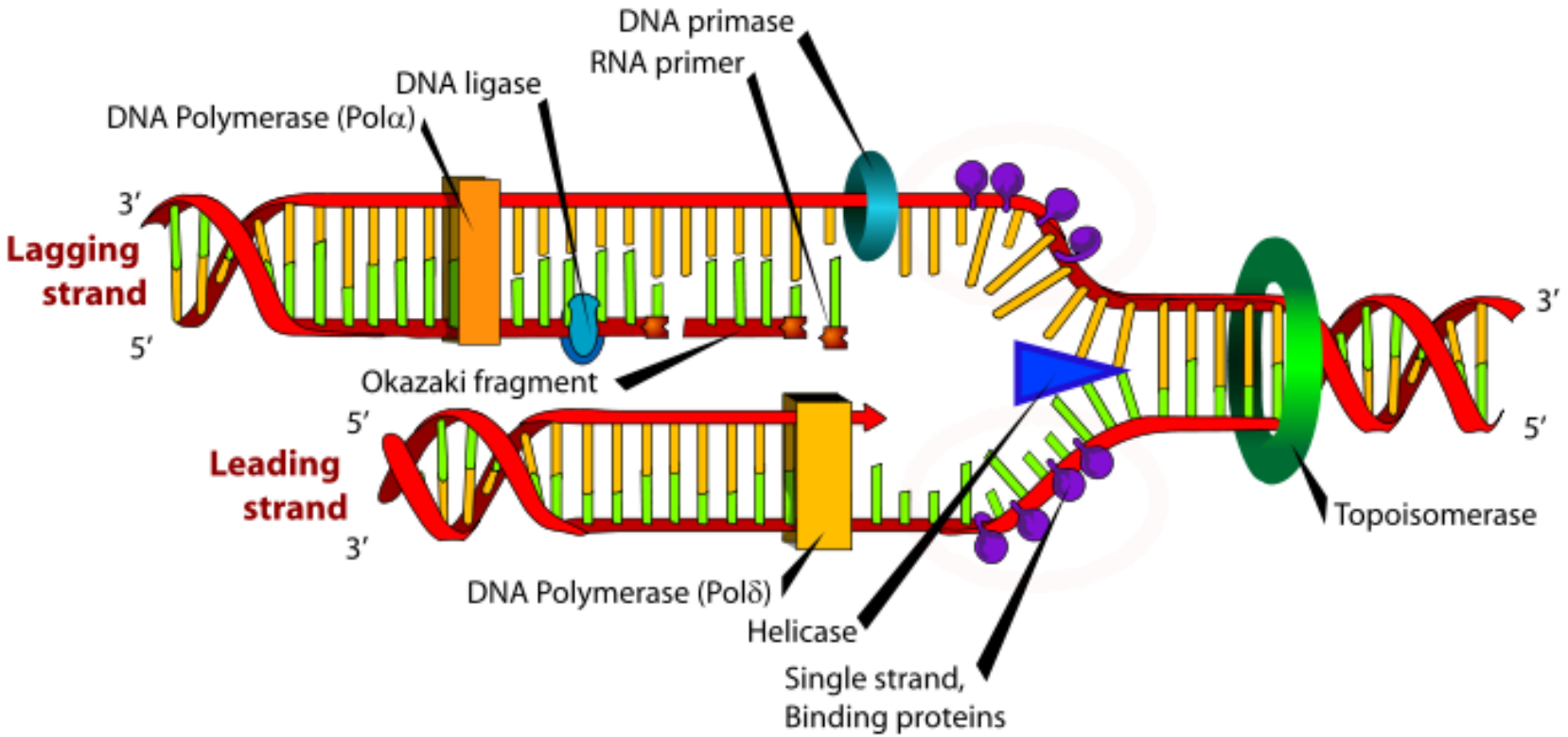
DNA Replication In-Depth

Helicase breaks hydrogen bonds between nucleotide base pairs causing the two strands to separate and form a **replication fork**.

Small proteins called single-stranded binding proteins stabilize each strand.



Replication Fork

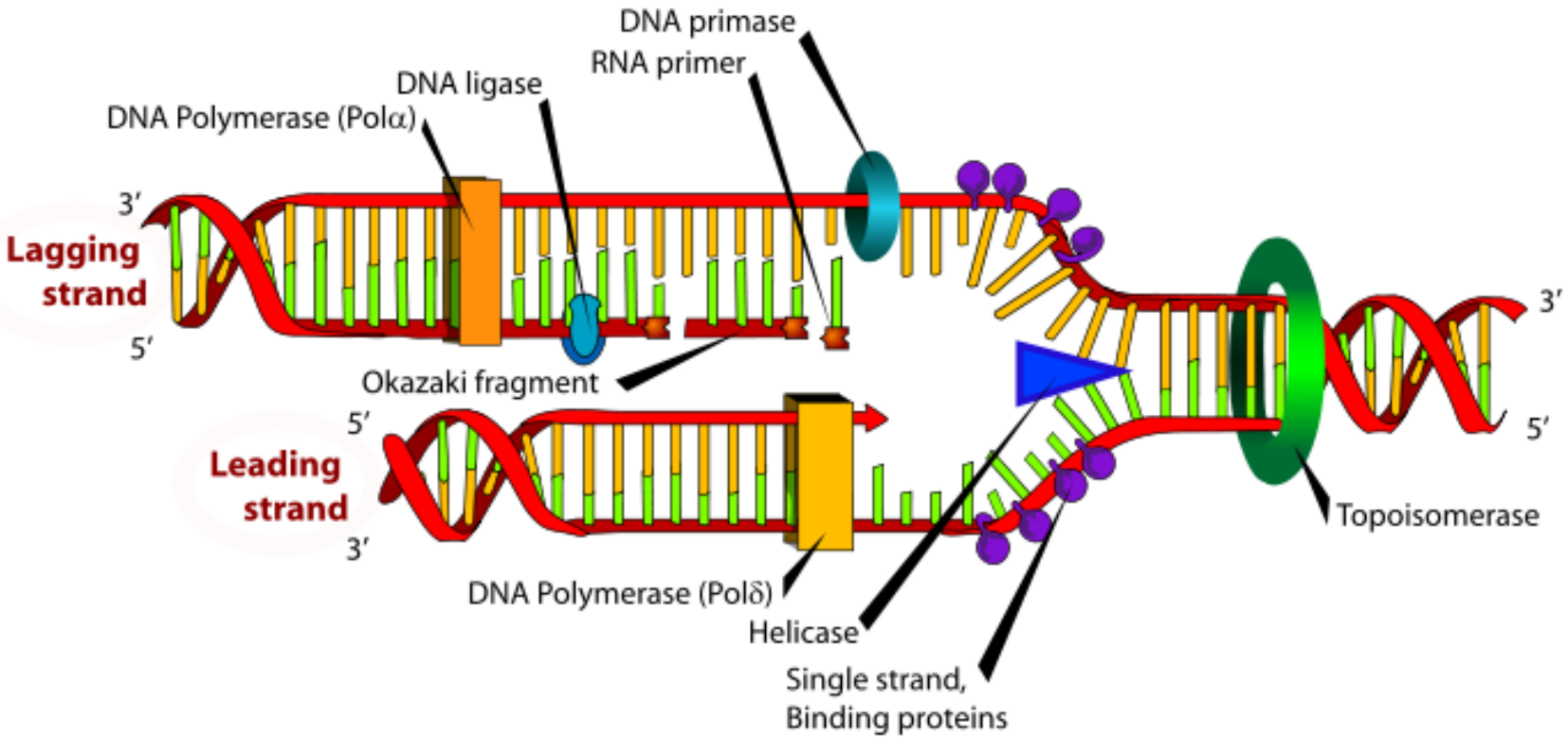


Single stranded binding proteins ensure that the nucleotide pairs do not re-bind after helicase passes.

19 Which enzyme causes the double helix to unwind by breaking hydrogen bonds?

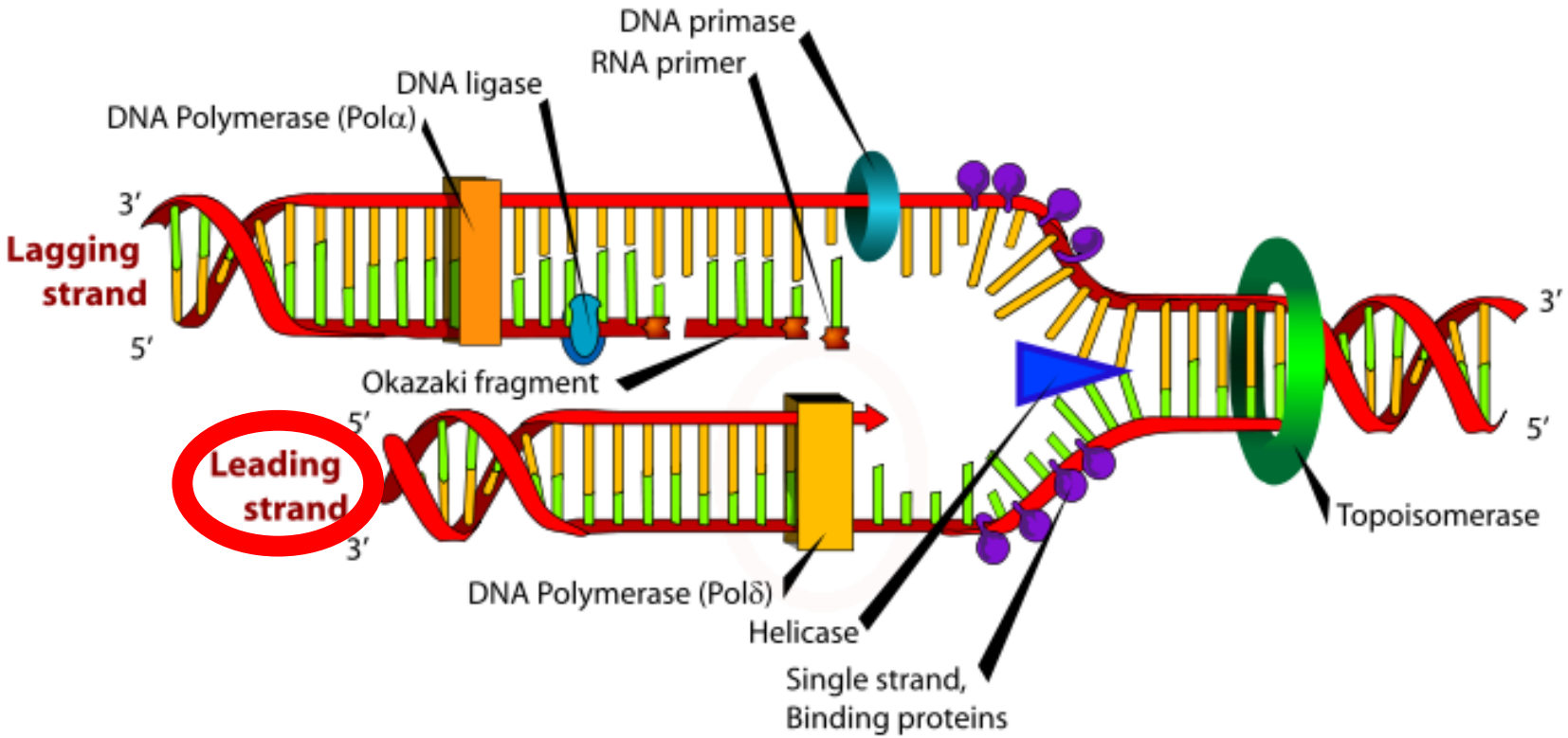
- A Topoisomerase
- B Helicase
- C Polymerase
- D RNAse

Replication Fork



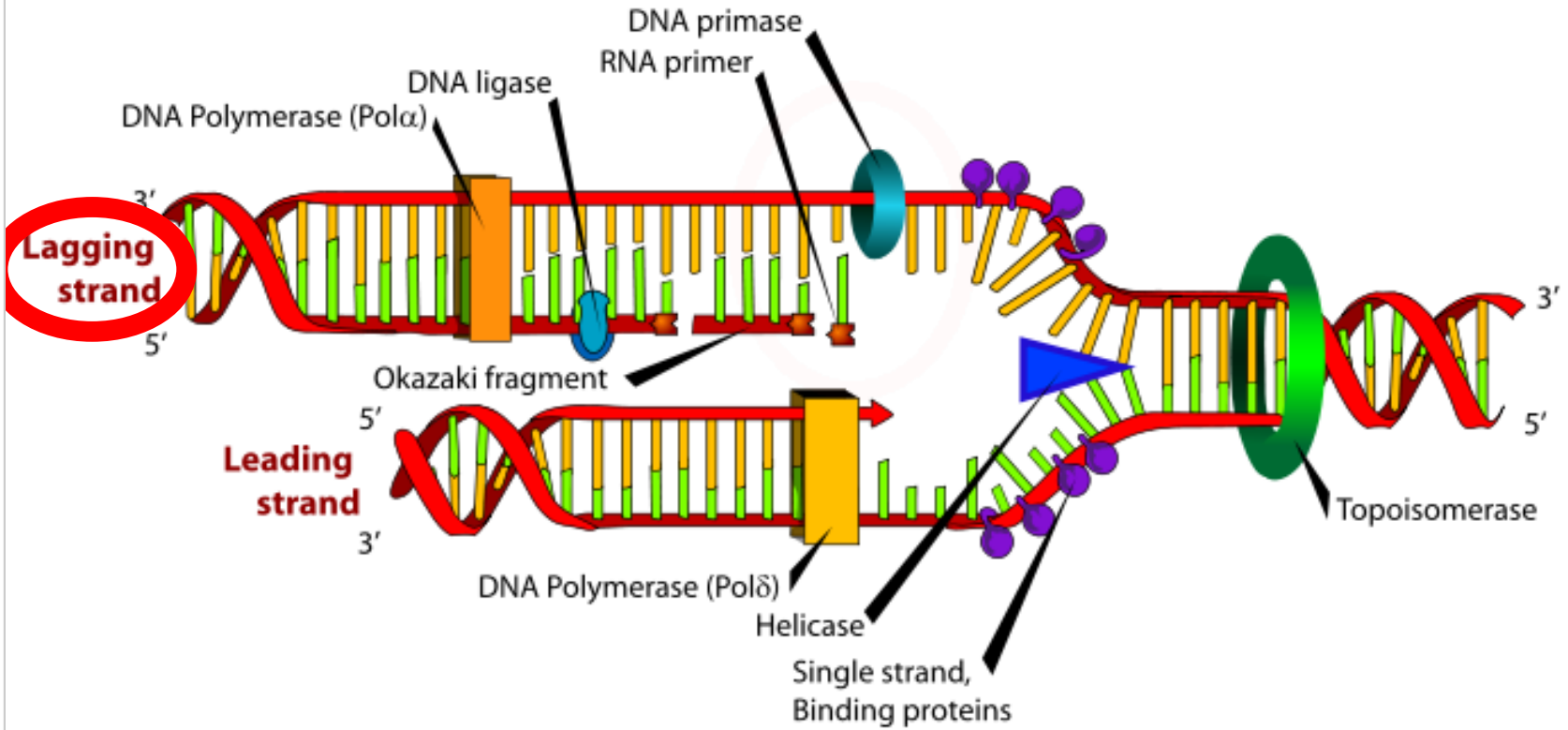
Since the strands are anti-parallel they are arranged in opposite directions. In order to replicate both strands in the same direction there are 2 different strategies, one for each template (**leading and lagging**).

Replication Fork



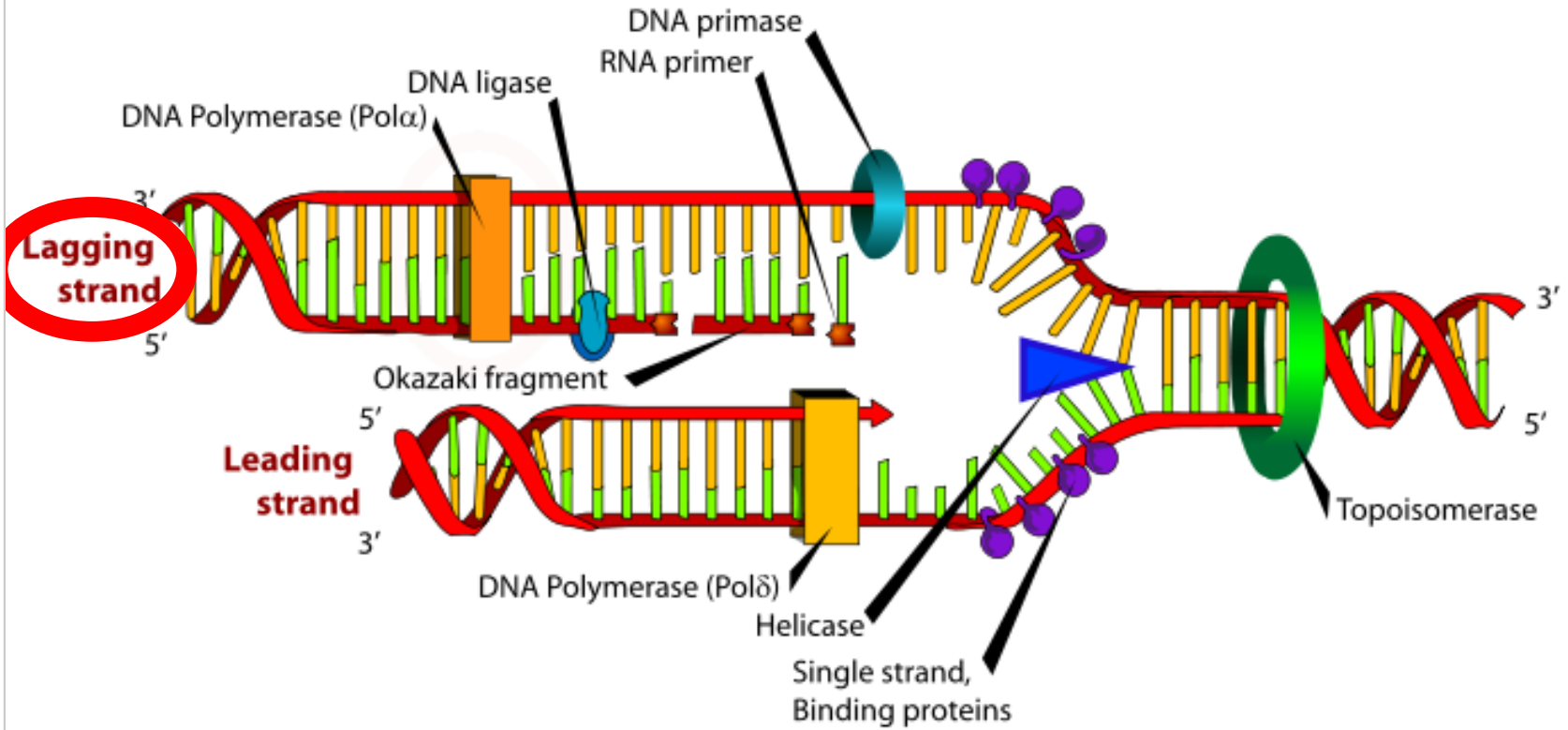
The leading strand is simple since it runs 3' to 5'. DNA polymerase can follow behind helicase and simply copy the template as it is being exposed.

Replication Fork



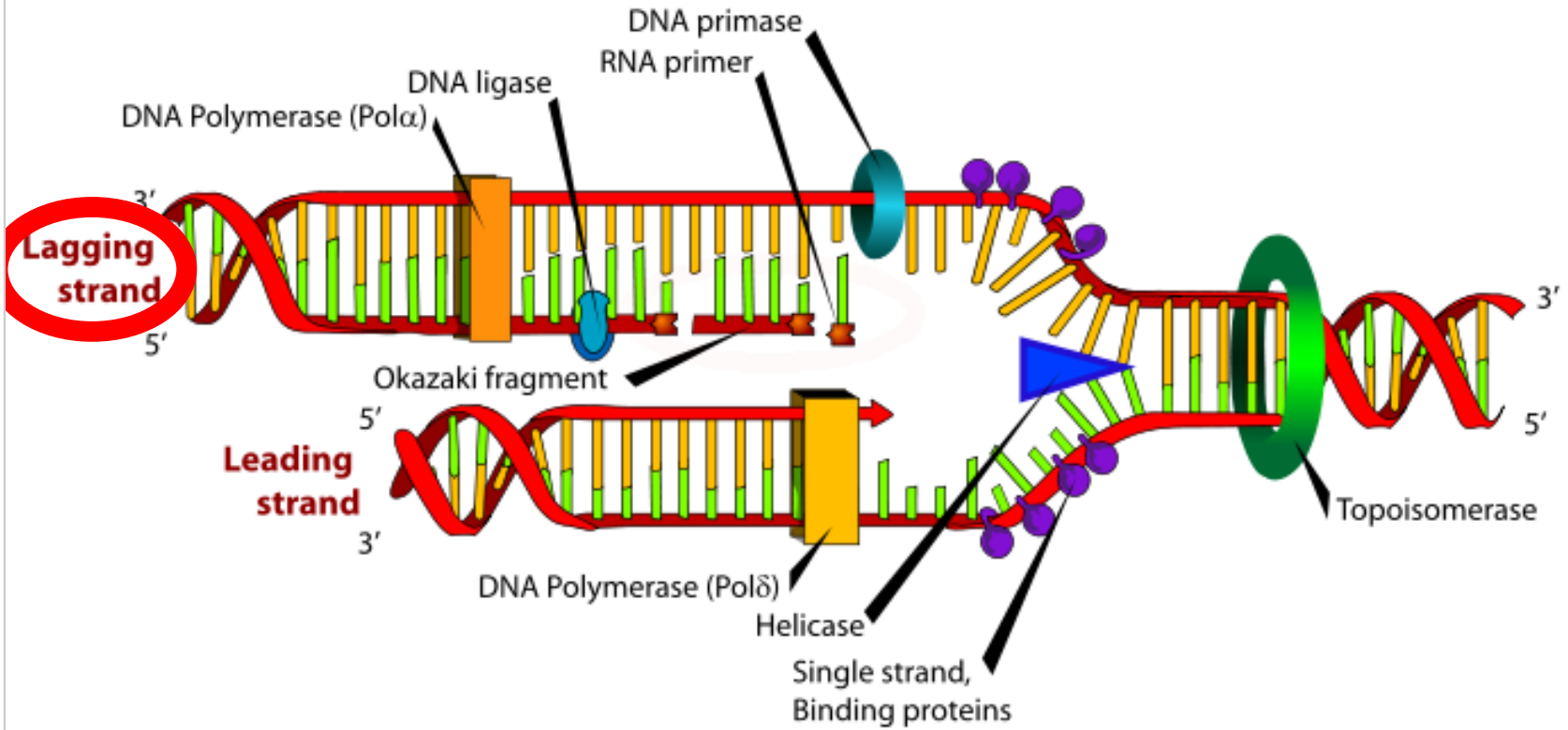
DNA polymerase can only read in the 3' to 5' direction. So on the lagging strand there has to be a way to make the new strand in reverse. It starts with an enzyme called primase that adds RNA nucleotides as a primer for DNA polymerase.

Replication Fork



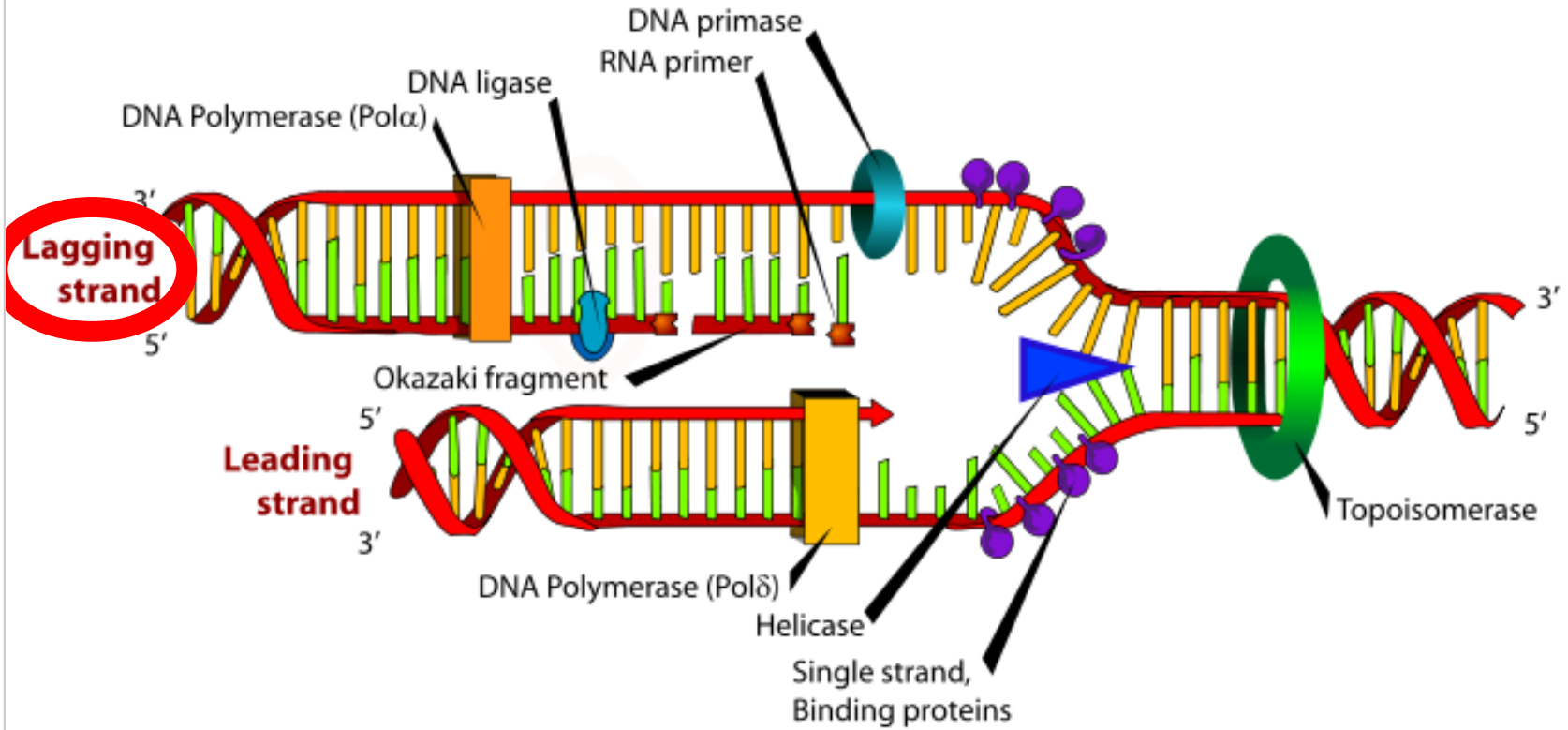
DNA polymerase can latch onto the RNA primers and begin to write fragments of the new strand. Since it is going away from the replication fork it only does a portion, then it jumps back in front of the portion it just did to start again.

Replication Fork



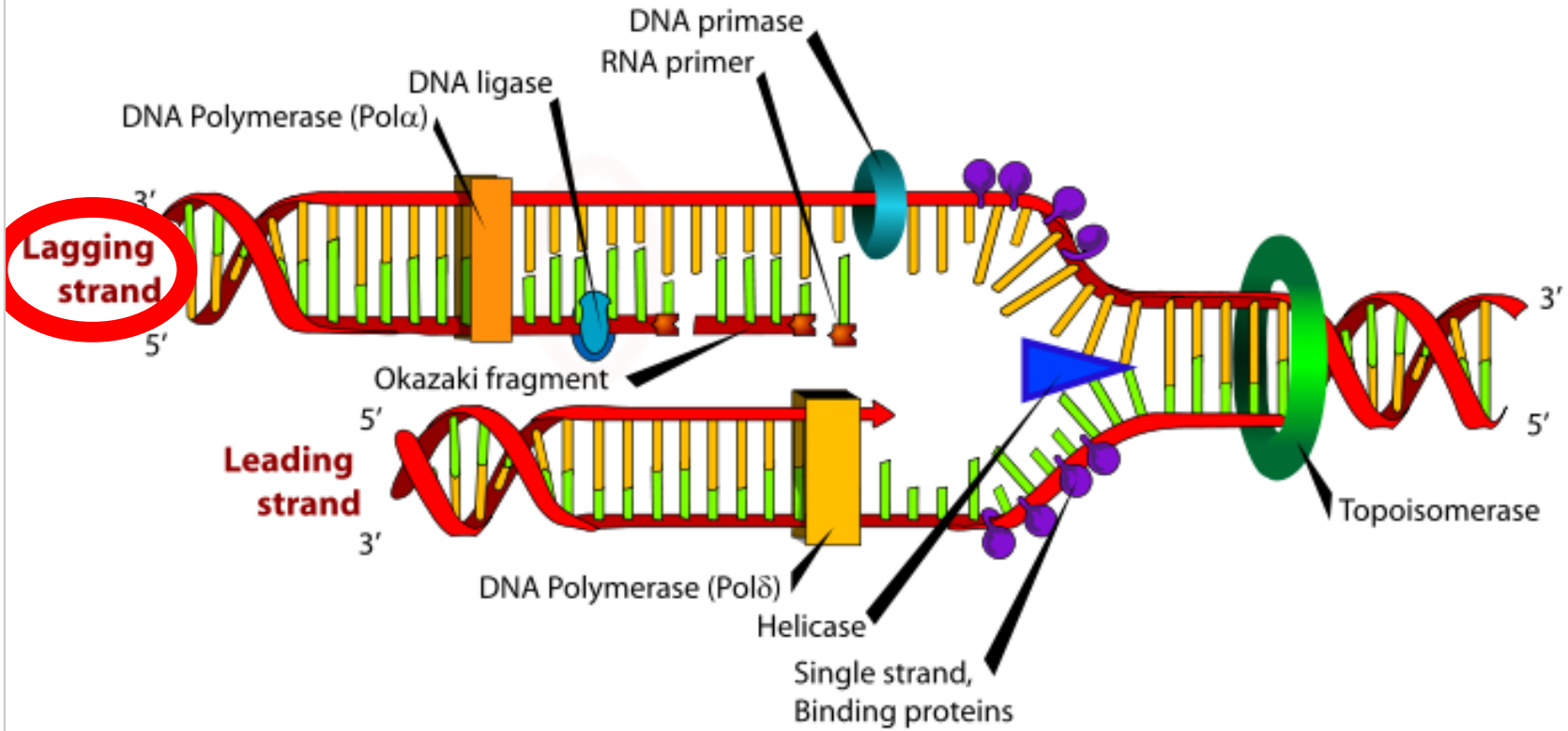
The fragments formed by this process are called Okazaki fragments. When the RNA primers fall away from the strand, gaps are left between the fragments that must be repaired.

Replication Fork



DNA ligase finishes the job by filling in the gaps between the Okazaki fragments and "proofreading" the strand to be sure there are no mismatches among nucleotide pairs.

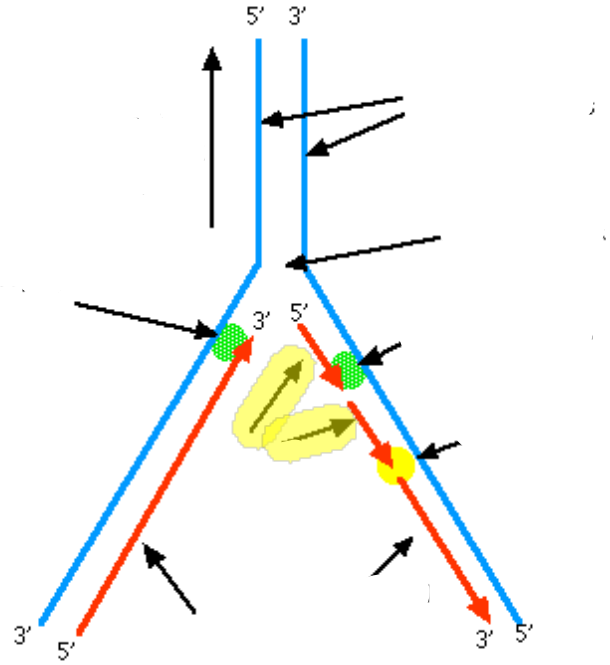
Replication Fork



DNA ligase finishes the job by filling in the gaps between the Okazaki fragments and "proofreading" the strand to be sure there are no mismatches among nucleotide pairs.

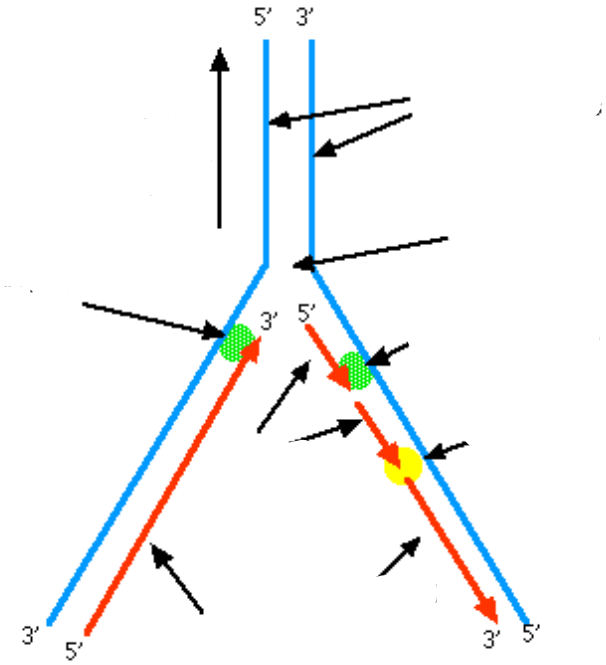
20 In this diagram, the highlighted arrows are pointing to

- A The leading strand
- B DNA Polymerase
- C Okazaki Fragments
- D DNA Ligase



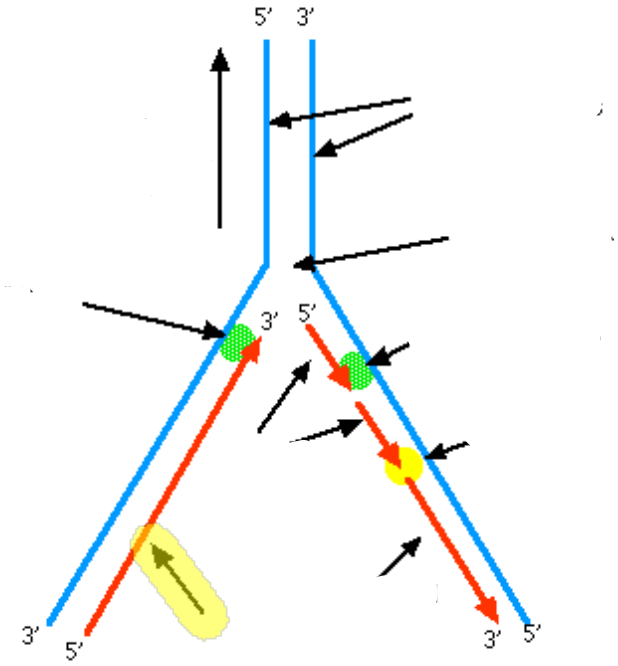
21 The green dot represents which enzyme?

- A Helicase
- B Ligase
- C DNA Primase
- D DNA Polymerase



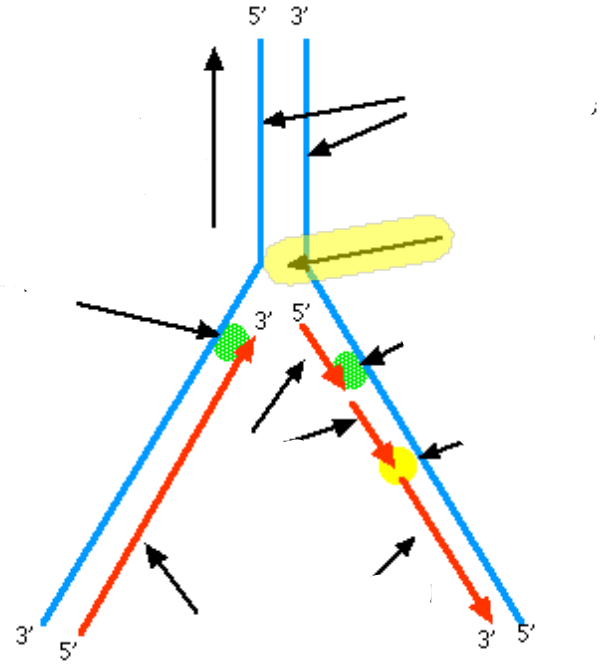
22 The highlighted arrow is pointing to the

- A Parent strand
- B Leading strand
- C Lagging strand
- D Okazaki fragment



23 The highlighted arrow is pointing to the

- A Lagging strand
- B Leading strand
- C Replication fork
- D Replication bubble



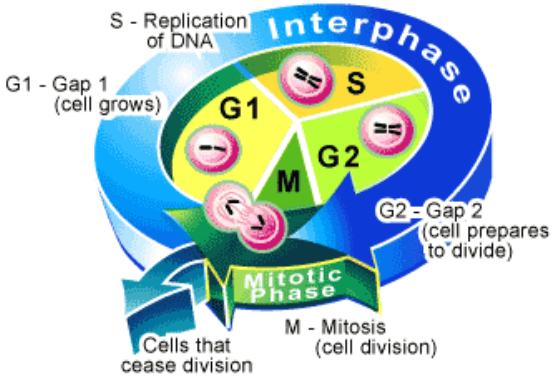
Mitosis

Return to Table of Contents

Mitotic Phase

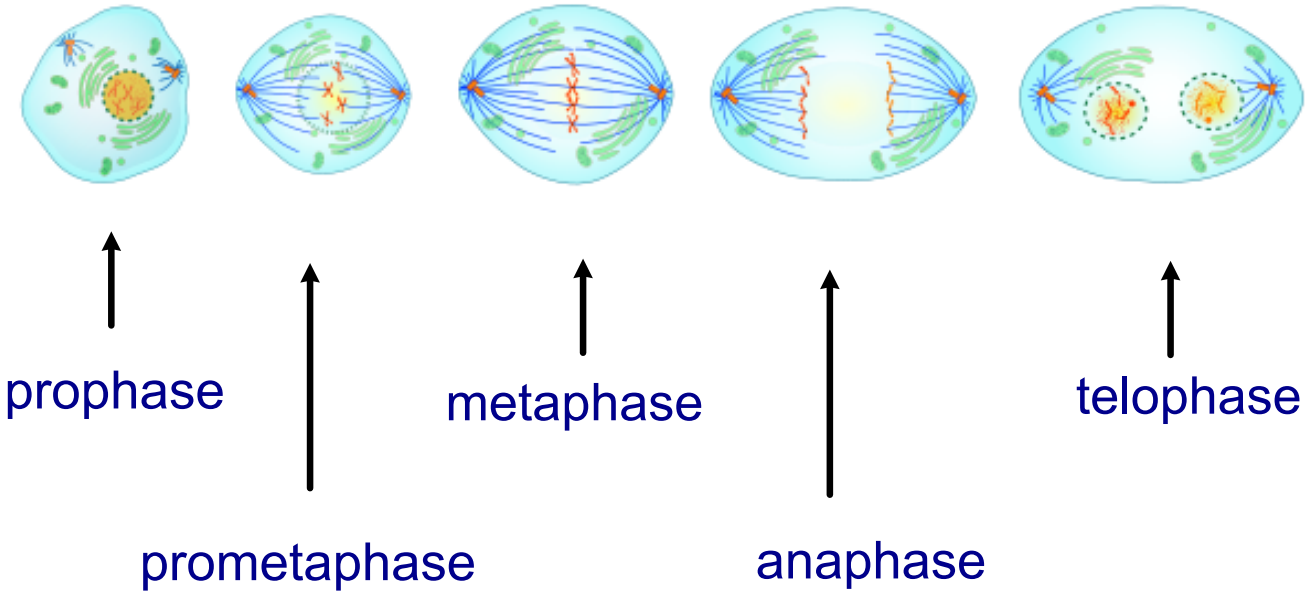
After a cell completes its preparation for division, it enters the mitotic phase.

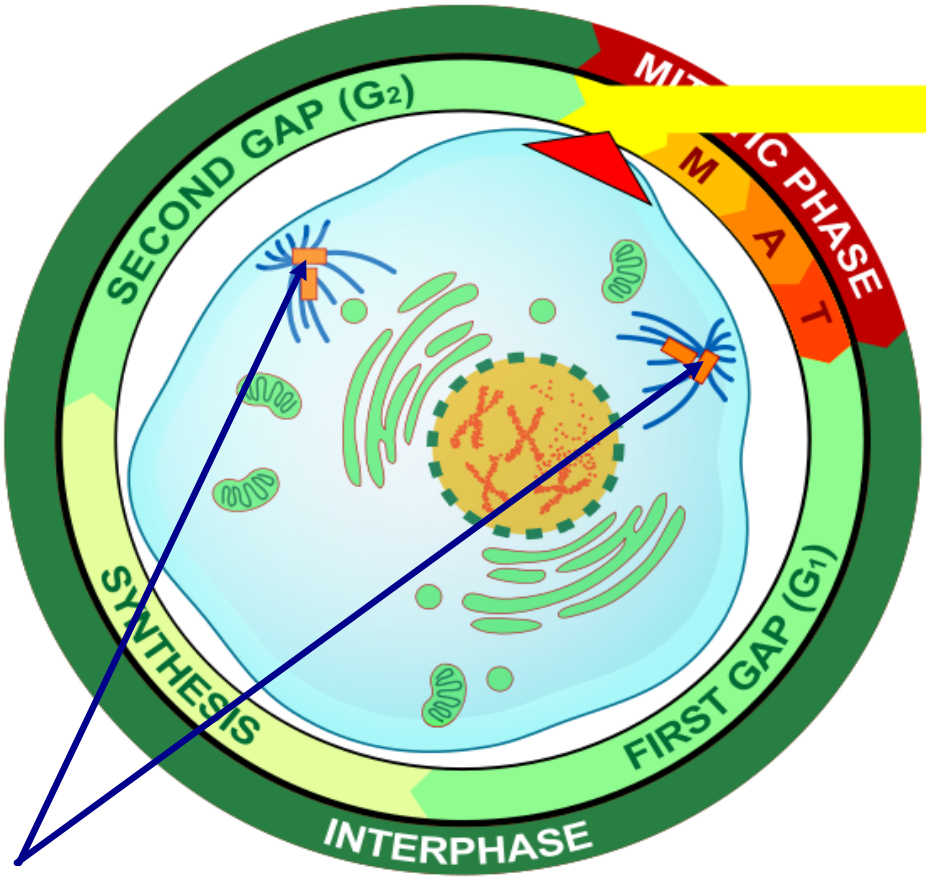
There are 2 sub-phases to this phase - **Mitosis** (the division of the nucleus) and **Cytokinesis** (the division of the cytoplasm)**.**



Sub-phases of Mitosis

Mitosis is further broken down into 5 sub-phases.





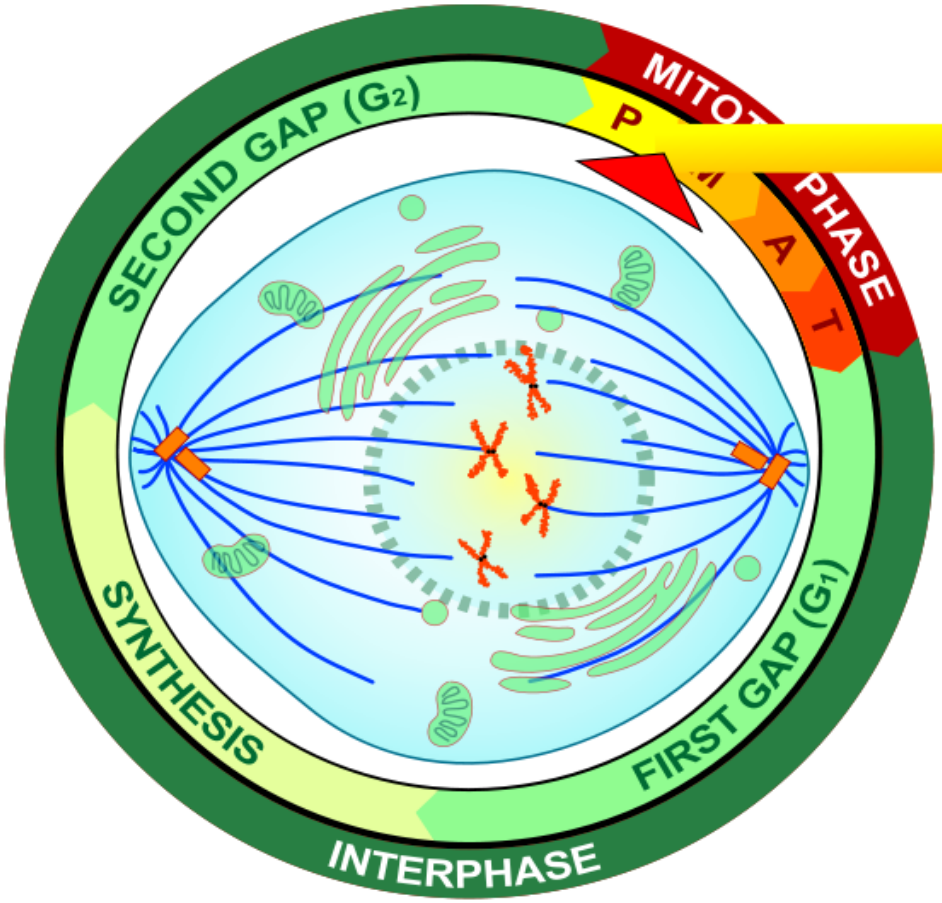
centrosomes

Prophase

· Arrays of microtubles called **spindles** start to form from 2 **centrosomes** (microtubule organizing centers in the cell)

· Centrosomes start to travel to the opposite ends (poles) of the cell

· Nuclear envelope starts to break apart



· Nucleoli and nuclear membrane disappear

· Spindle is nearly completed and ready to provide a scaffold for chromosomes to travel

· Chromosomes attach to the spindle at their **kinetochores** - a protein structure at the centromere region of the sister chromatids

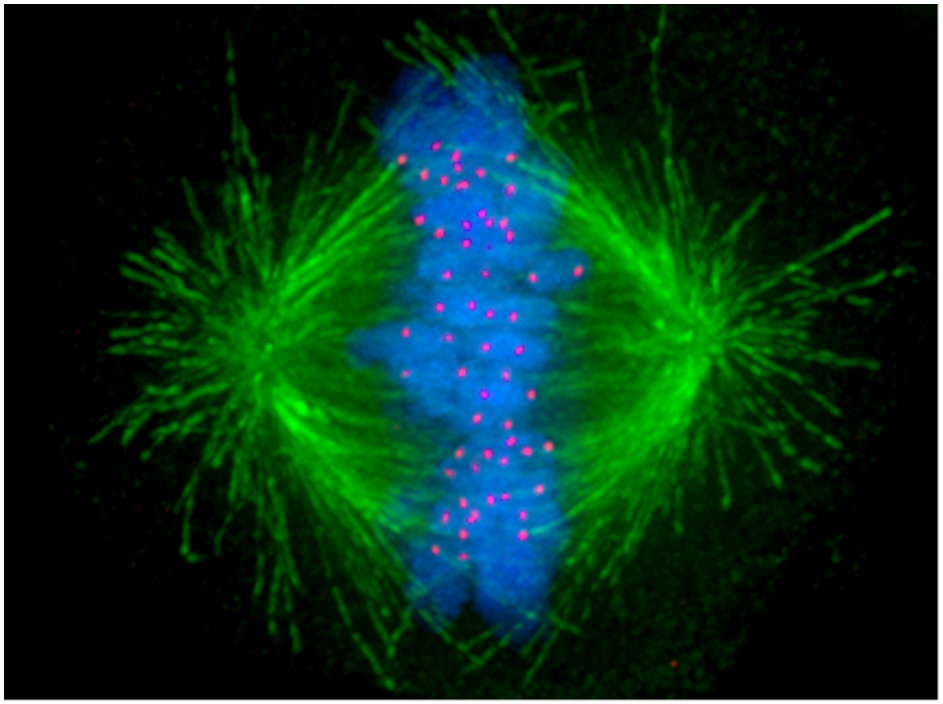
Centrosomes vs. Kinetochores

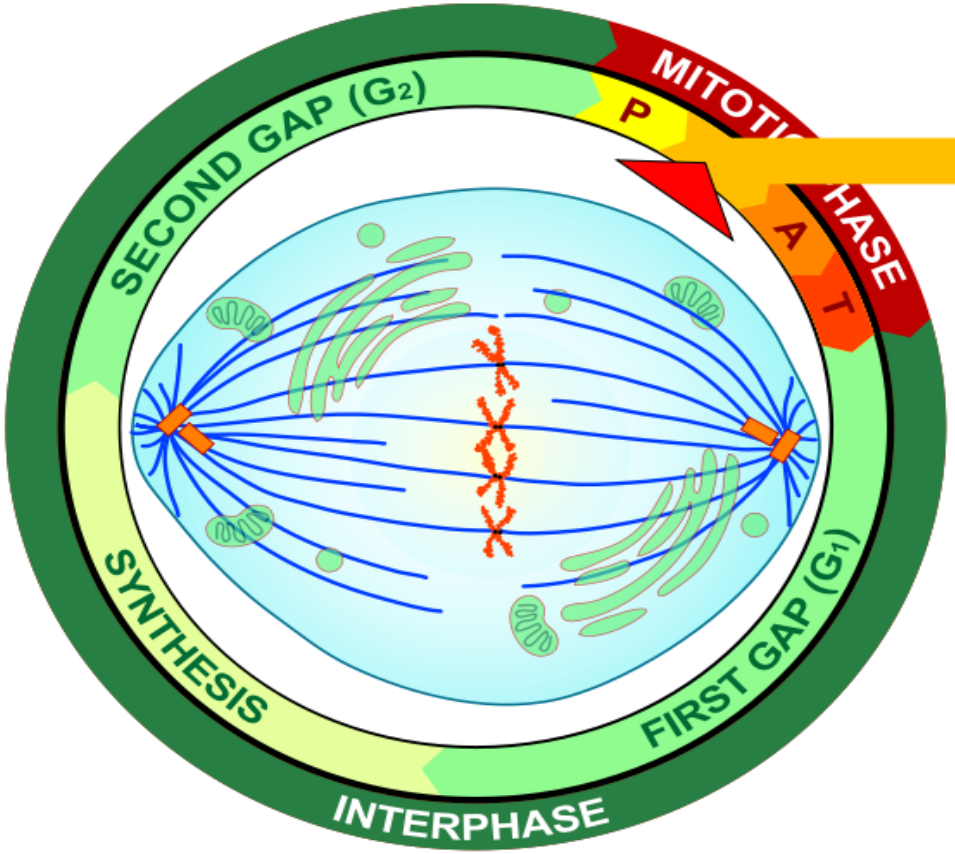
Image of a human cell during division showing:

spindles from the centrosome in **green**

chromosomes in **blue**

kinetochores in **pink**





Metaphase

- Spindle is completely formed
- Chromosomes align on the Metaphase plate (the equator of the cell)

24 The phase of mitosis during which the nuclear envelope breaks apart is called

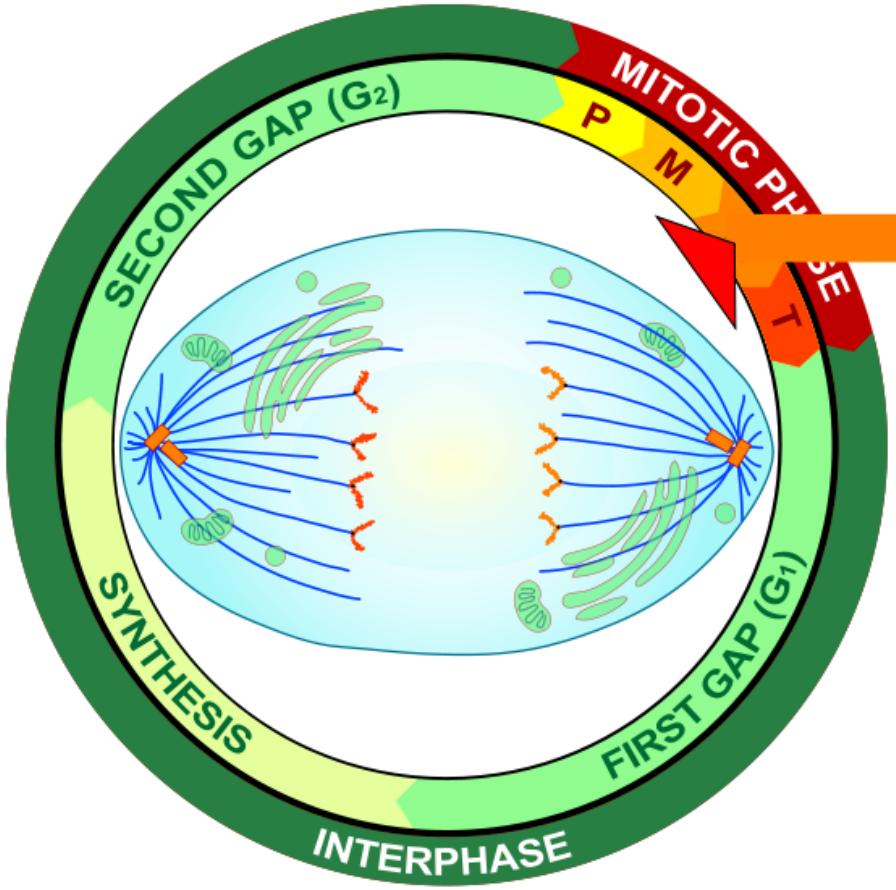
- A interphase
- B prophase
- C metaphase
- D anaphase

25 Which of the following pairs is correct?

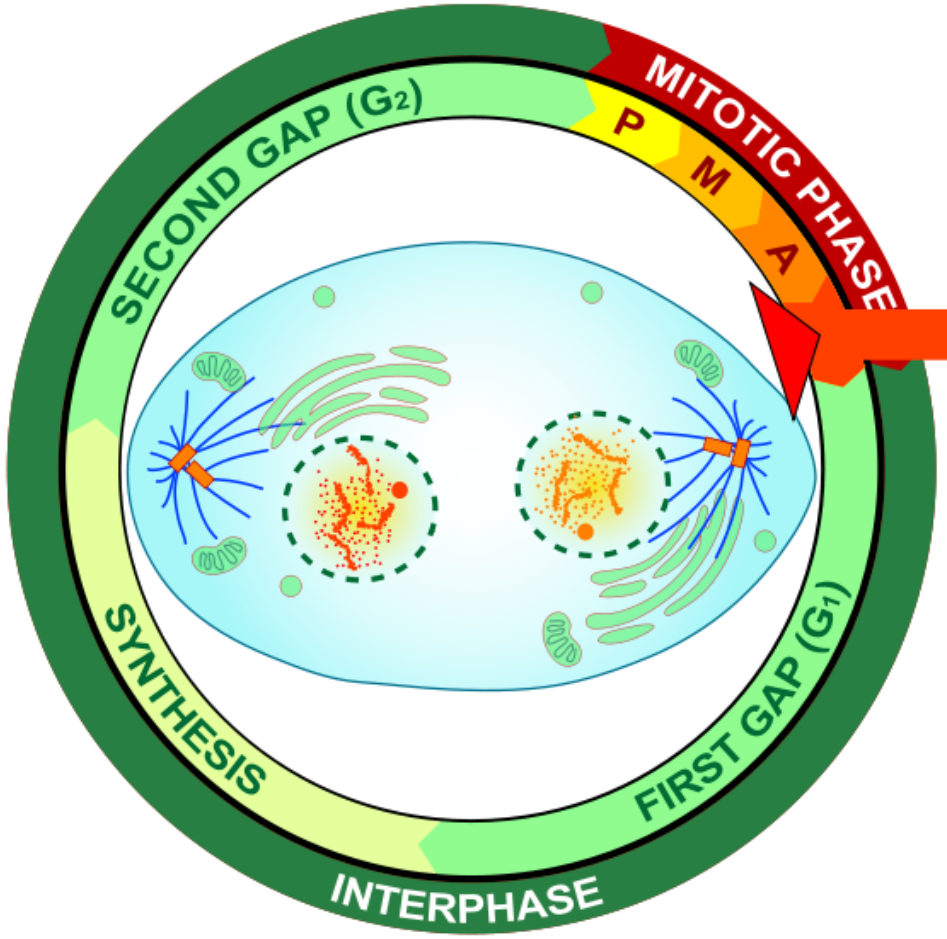
- A kinetochore:makes spindle; centromere:holds chromatids together
- B kinetochore:attaches to spindle; centrosome:holds chromatids together
- C centrosome:makes spindle; centromere:holds chromatids together
- D centrosome:holds chromatids together; kinetochore:attaches to spindle

26 During which phase do chromosomes line up on a plane located along the equator of the cell?

- A interphase
- B prophase
- C metaphase
- D anaphase



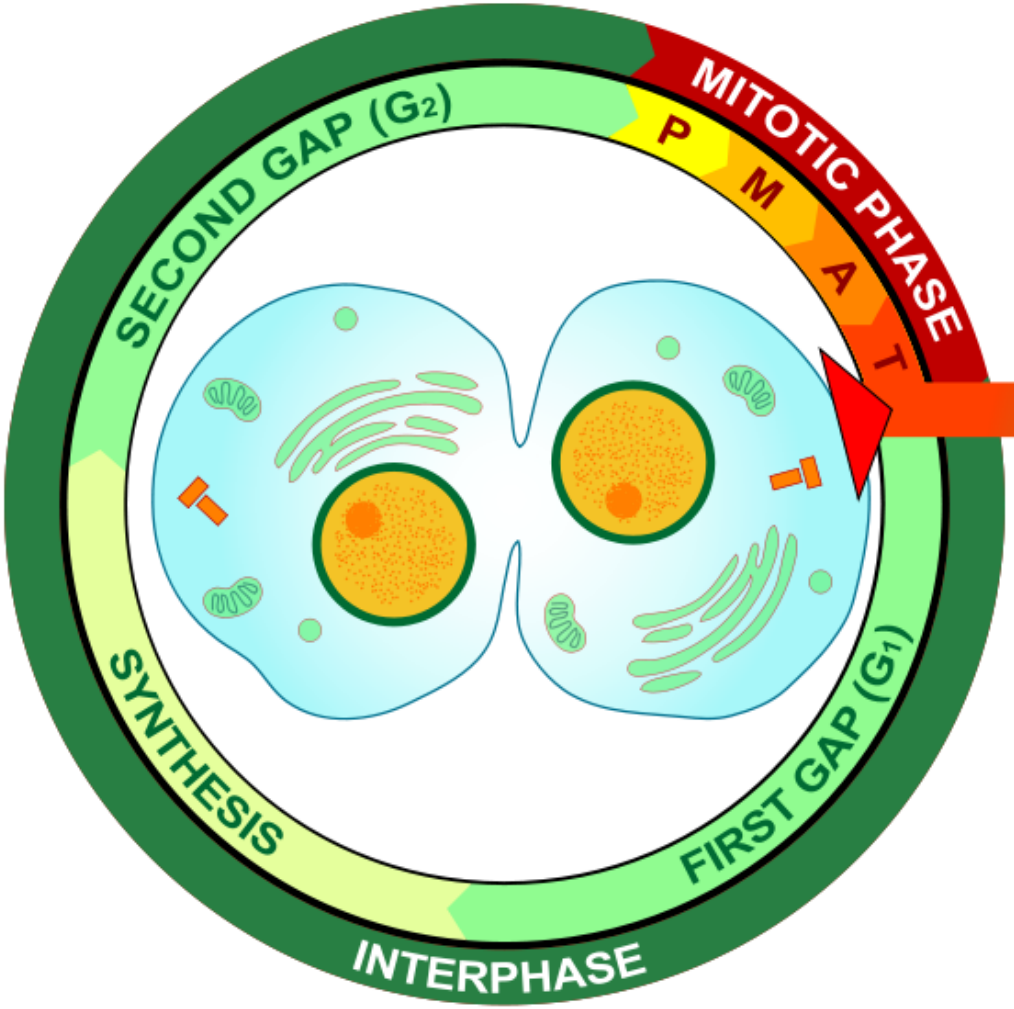
- Sister chromatids separate from each other at the centromere and are pulled to the 2 poles by the spindle fibers



- Cell elongation continues

- Nuclear envelope reappears around the chromosomes

- Nucleoli reappear



· Following telophase, the cytoplasm divides.

· Cytokinesis differs for plant and animal cells

27 During which phase does the nuclear envelope re-form?

- A interphase
- B metaphase
- C anaphase
- D telophase

28 The process by which the cytoplasm of a eukaryotic cell divides is called

- A mitosis
- B cytokinesis
- C teloplase
- D spindle formation

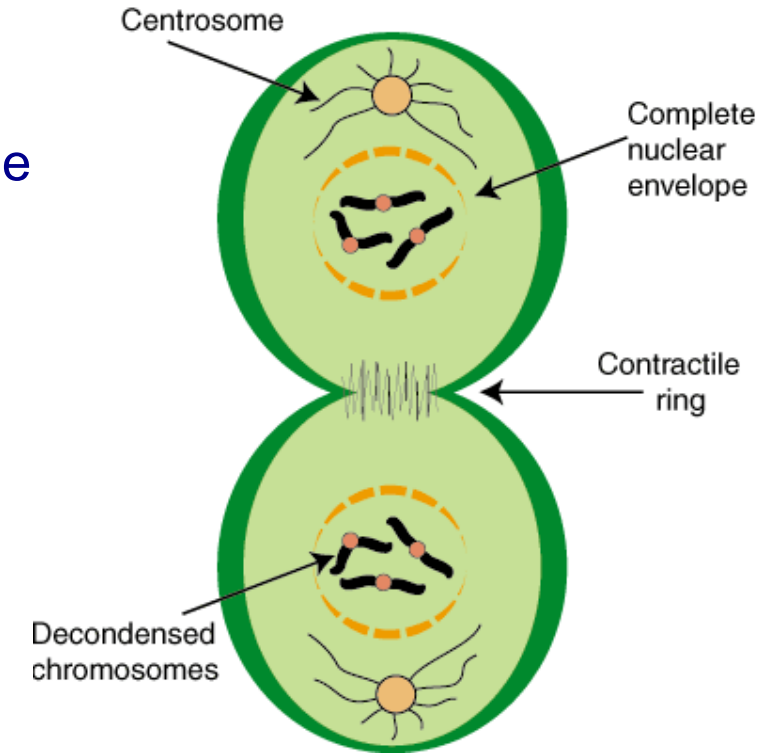
29 Which of these is not like the others?

- A Cytokinesis
- B Telophase
- C Anaphase
- D Metaphase
- E Prometaphase
- F Prophase

Cytokinesis - Animal Cells

A ring of microfilaments forms a **contractile ring** around the outside of the cell.

The ring forms a **cleavage furrow** which splits the cytoplasm in two.

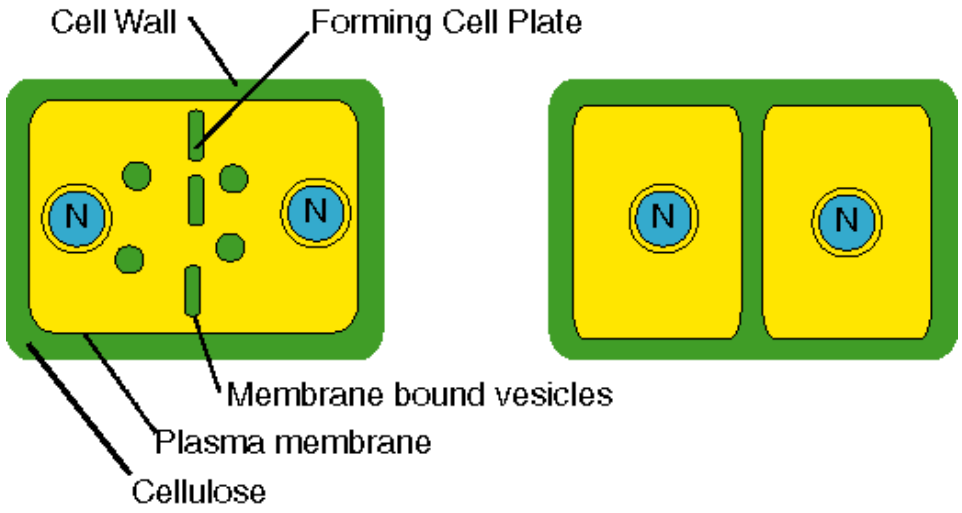


Cytokinesis - Plant Cells

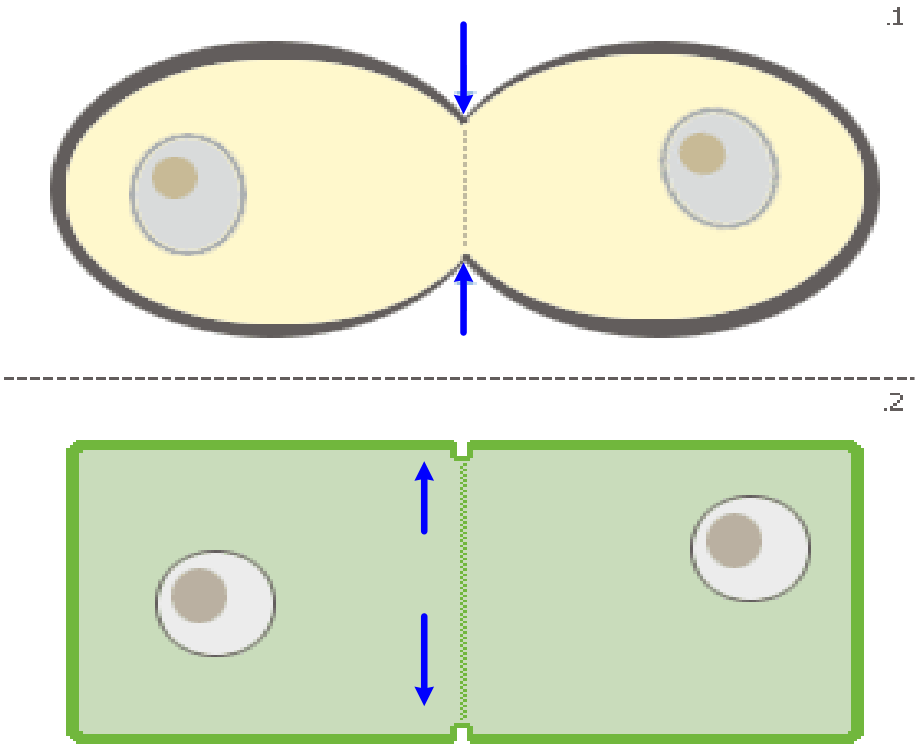
Vesicles containing cell wall material collect in the center of the cell and then fuse together.

The **cell plate** forms from the inside out and turns into a wall between the 2 new cells.

The membranes surrounding the vesicles fuse to form new parts of the plasma membrane.



Comparison of Cytokinesis



animal cell

plant cell

30 Cytokinesis in a plant cell is a result of the cell:

- A spontaneously dividing
- B forming a cleavage furrow in the middle
- C splitting from the inside out
- D a cell wall being created

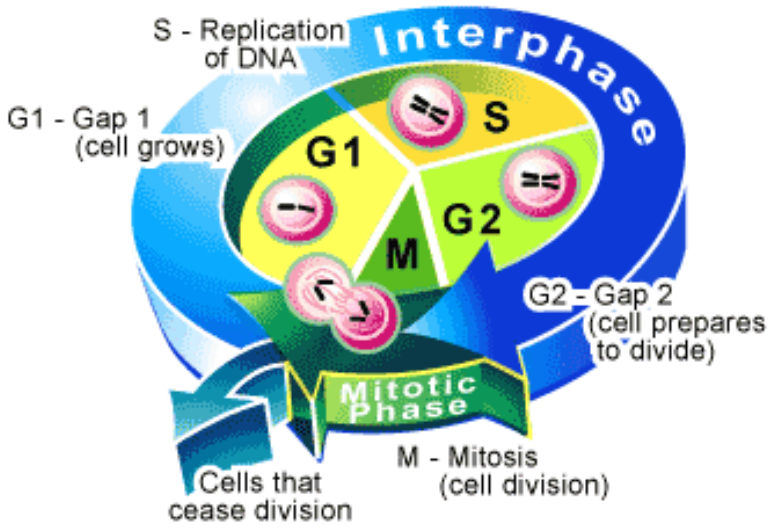
Summary of Phases of the Cell Cycle

Interphase

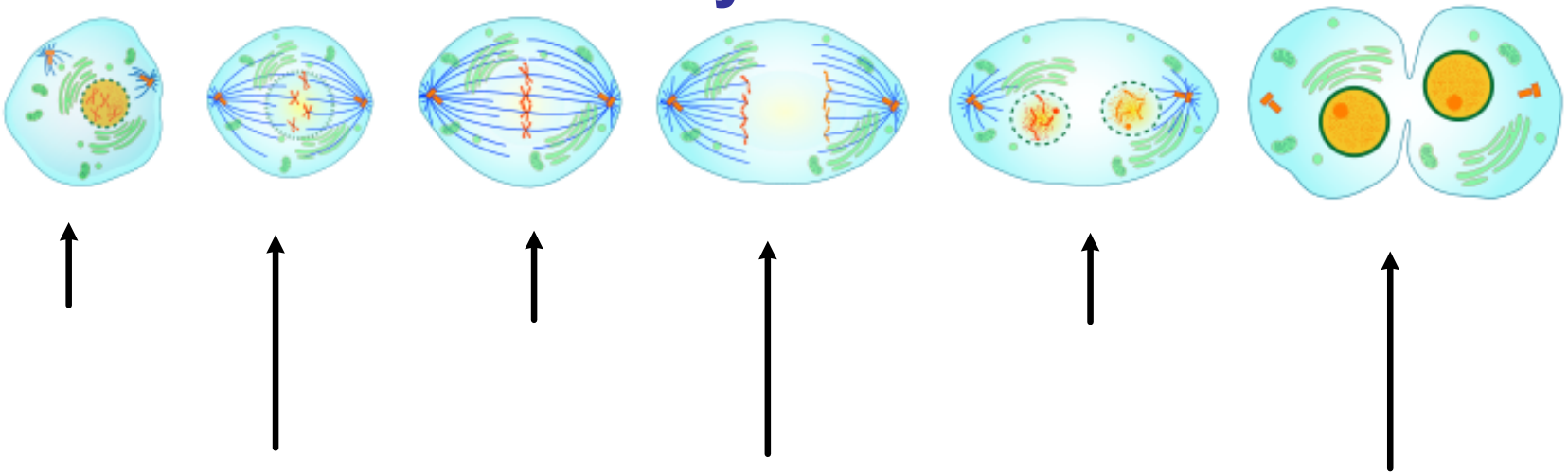
- Gap 1 (G_1)
- Synthesis (S Phase)
- Gap 2 (G_2)

Mitotic Phase (M phase)

- Mitosis
  - Prophase
  - Prometaphase
  - Metaphase
  - Anaphase
  - Telophase
- Cytokinesis



Review: Label The Sub-Phases of Mitosis and Cytokinesis



Anaphase

Metaphase

Cytokinesis

Prophase

Telophase

Prometaphase