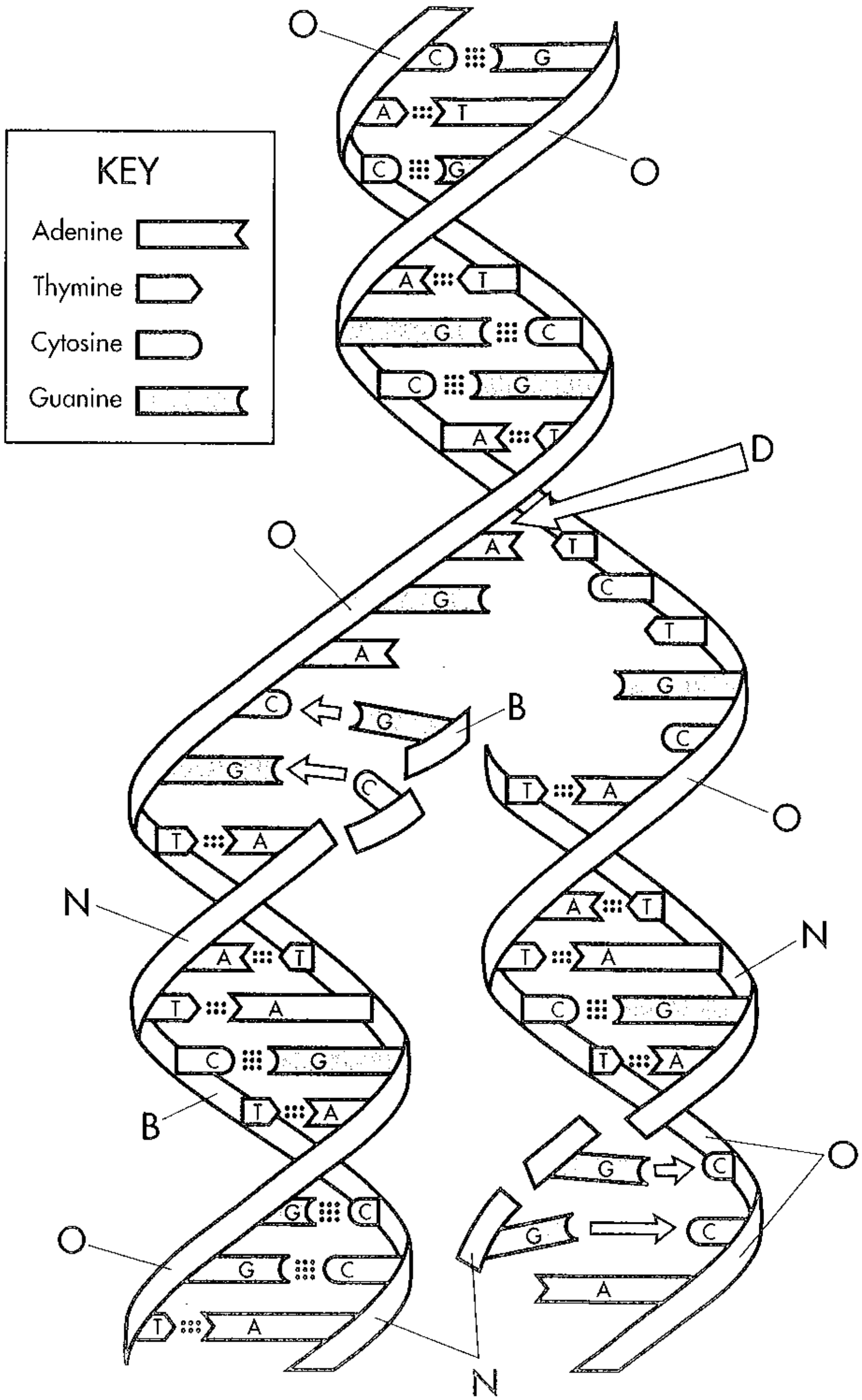
4.2 Replication of DNA



Replication of DNA

- ○ Deoxyribose-Phosphate Backbone (Old) ....O
- ○ Deoxyribose-Phosphate Backbone (New) ....N
- ○ Adenine................A
- ○ Thymine................T
- ○ Cytosine C
- ○ Guanine................G
- ○ Replication Fork ......D

Chapter 4-2: Replication of DNA

The result of the cell cycle is the division of the mother cell into two daughter cells. This cell division takes place in almost all types of plant, animal, and microbial cells. Before a cell divides, the DNA in its nucleus replicates to ensure that identical copies of its genes are passed to each of the daughter cells. This replication occurs during the S phase of the cell cycle and has already been completed when mitosis begins. This plate explores the mechanism by which the DNA replicates.

As you look over the plate, note that we are presenting a single illustration of a double-stranded DNA molecule undergoing replication. Many of the colors that were used in the previous plate should be used here. As you read the paragraphs below, color the appropriate structures in the plate.

The DNA molecule is a double helix composed of two strands of DNA. Each strand is made up of alternating deoxyribose molecules and phosphate groups. Forming the rungs on the DNA ladder are the four nitrogenous bases which are connected to the deoxyribose backbone. In the plate, you should use a medium color on the **old deoxyribose-phosphate backbone (O)**; there are two of these backbones, and both should be colored.

After you color the deoxyribose-phosphate backbones of the old DNA molecule, you should select four different colors with which to color the four different nitrogenous bases of the old DNA molecule. These bases are **adenine (A)**, **thymine (T)**, **cytosine (C)**, and **guanine (G)**.

We will now begin the construction of the two new strands of DNA. As you read about the process of their construction, color the appropriate portions of the plate.

The replication process begins with an uncoiling of the original double-stranded DNA molecule. A specific enzyme untwists the double helix and separates the DNA molecule into its two complementary strands. The site of separation is referred to as the **replication fork (D)**, and an arrow points to it.

Each strand of the DNA molecule now serves as a model, or template, for the construction of a complementary DNA molecule. To construct this complementary DNA molecule, **new deoxyribose-phosphate molecules (N)** will be needed, as well as new base pairs. On the left, notice that the new backbone is being synthesized as the molecule untwists, while on the right side, it is being constructed in the opposite direction, with new molecules being added in fragments, starting at the bottom. The strand on the left is therefore called the leading strand, and the one on the right side is the lagging strand.

We will complete the construction of the two new DNA molecules by mentioning the principle of complementary base pairing. Continue using the colors for the nitrogenous bases that you used above.

Once the deoxyribose-phosphate backbones have been constructed, the nucleotides will join with one another so that base pairing takes place in a specific pattern. Thymine (T) molecules will always pair with adenine (A) molecules, and cytosine (C) will always pair with guanine (G) molecules. Thus, the order of nitrogenous bases on the original template strand determines the order of the bases on the new strands. For example, we see on the left side the base sequence: *C-G-T-T-A-G-A-G-G-T*. These code for a new strand with the base sequence: *G-C-A-A-T-C-T-C-C-A*. As you can see, this is what ensures that each new DNA molecule is identical to its parent strand.

Hydrogen bonding holds the bases of the two strands together, and a double helix forms, so that each new DNA double helix consists of an old strand and a new strand. This method of DNA replication is referred to as semiconservative replication.

4-2: Replication of DNA

a. Before a cell divides, why must DNA replicate?

b. At what point in the cell cycle does replication occur?

c. How does the replication process begin?

d. What untwists the double helix & separates the DNA molecule into its complimentary strands?

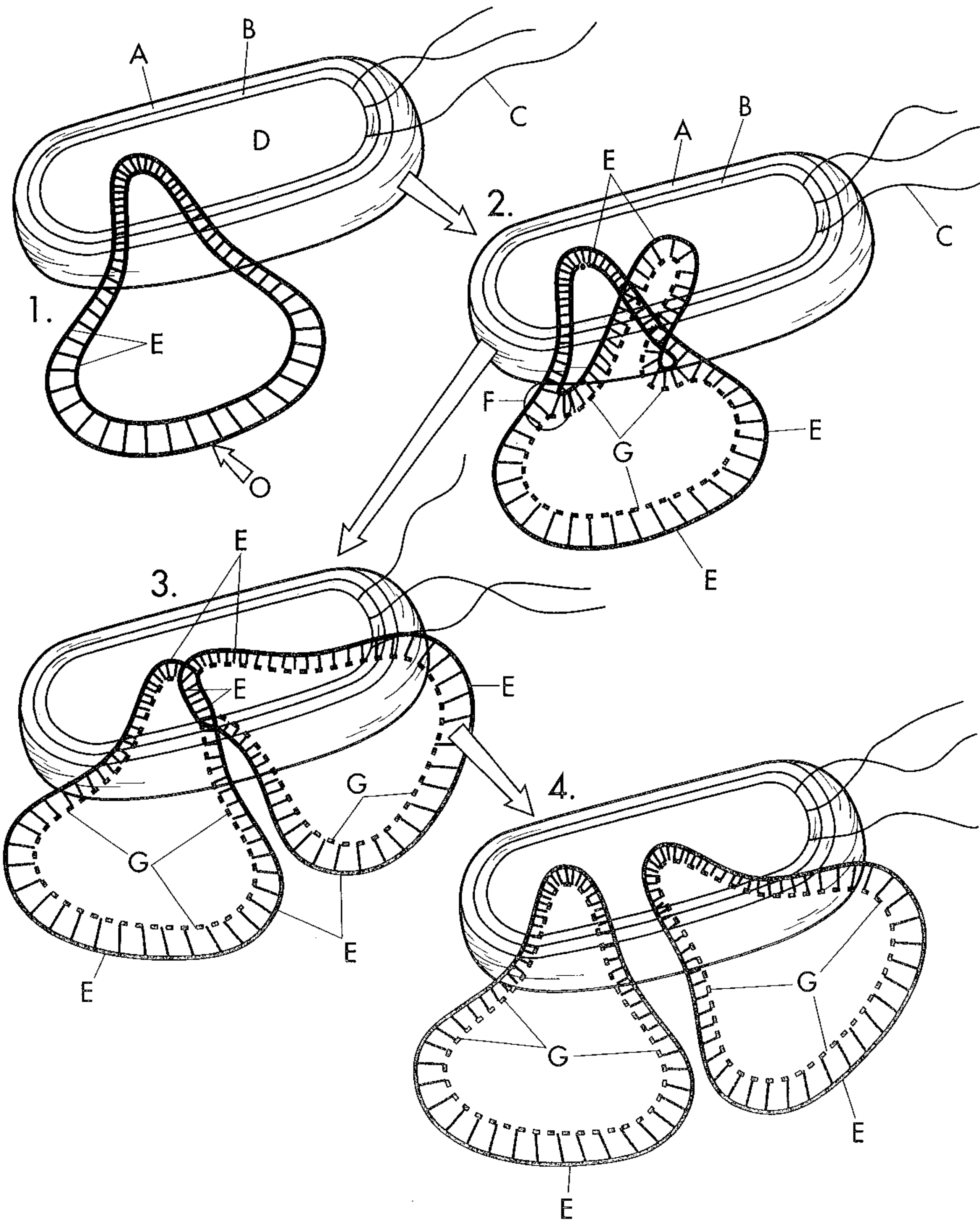
e. What is the site of separation referred to?

f. What is the strand that is synthesized as the molecule untwists called?

g. What is the strand formed in the opposite direction (in fragments) starting at the bottom called?

h. What is this method of replication called?

4.3 Prokaryotic DNA Replication



Prokaryotic DNA Replication

○ Bacterial Cell Wall ....A

○ Bacterial Cell Membrane ....B

○ Flagellum.............C

○ Cytoplasm.............D

○ Original DNA ....E

○ Enzyme ....F

○ New DNA................G

○ Origin of Replication...........O

Chapter 4-3: Prokaryotic DNA Replication

As we explained in the last plate, the replication of DNA involves the unwinding of the parent strands and complementary base pairing between the two new strands so that each new DNA molecule contains one old and one new strand. This is the semiconservative model of DNA replication.

The process of DNA replication differs in prokaryotic and eukaryotic cells. Eukaryotic DNA replication will be explained in a succeeding plate, and this plate explains prokaryote DNA replication.

This plate contains four views of a typical prokaryote, a bacterium, in which DNA is undergoing replication. The first two views are at the top of the page; the second two are at the bottom.

Unlike the DNA of eukaryotic cells, the genetic material of bacteria exists as a single circular molecule of DNA.

The bacterium displayed is a relatively simple cell. The **bacterial cell wall (A)** lies outside the **bacterial cell membrane (B)**, and it possesses several **flagella (C)**. Dark colors can be used for these structures. The **cytoplasm (D)** should be colored in a light color.

The single circular DNA molecule is within the cytoplasm of the bacterial cell. You should use a light color to highlight this molecule. The nitrogenous bases are the short lines that link the outer and inner strands. The entire circular strand of **original DNA (E)** is shown.

The replication of DNA in the prokaryotic chromosome begins at a point called the **origin of replication (O)**, which is indicated by an arrow. A bold color should be used to color the arrow. DNA replication begins when an enzyme breaks the hydrogen bonds between the two strands of DNA at the origin of replication; this break establishes the replication fork.

At the origin of replication, the paired bases are separated and the strands of the double helix begin to separate. Their unwinding is facilitated by an enzyme that is part of a replication complex. Next, an **enzyme (F)** called DNA polymerase begins the synthesis of new DNA molecules. It does so by adding nucleotides to one another.

In diagram 2, the production of a new DNA strand begins. We see the **original DNA (E)** as well as some of the **new DNA (G)**. The enzyme (F) is synthesizing new DNA at the point indicated as it proceeds around the original strand of DNA. You should use different colors for the original DNA (E) and the new DNA (G).

Continue your reading below as the replication process continues in diagram 3.

We now focus on diagram 3. Here the replication proceeds and we see the **original DNA (E)** as well as much of the **new DNA (G)**. The replication forks have been traveling in opposite directions and are close to meeting at opposite sides of the circle, and the new strands of DNA appear as ever-enlarging double loops.

In diagram 4, the loops have separated. Each new DNA molecule is double stranded, and each consists of one strand of **old DNA (E)** and one of **new DNA (G)**. Once the two DNA molecules have formed, the cell is ready to undergo binary fission and split in two. The single chromosome is attached to the plasma membrane of the bacteria, and after replication has taken place, the two copies separate from one another just before binary fission takes place. The plate entitled Bacteria discusses this multiplication process.

The process of prokaryotic DNA replication also occurs in the cytoplasm, mitochondria, and chloroplasts of eukaryotic cells. This provides evidence that bacteria were the source of mitochondria and chloroplasts in eukaryotic cells, as we mentioned in the plate entitled The First Eukaryotic Cells.

4-3: Prokaryotic DNA Replication

a. Model in which each new DNA molecule has one old strand & one new strand:

b. How does the genetic material of a prokaryote exist?

c. At what point does replication begin on a prokaryotic chromosome?

d. What facilitates the separation of the base pairs?

e. What begins the synthesis of new DNA molecules?

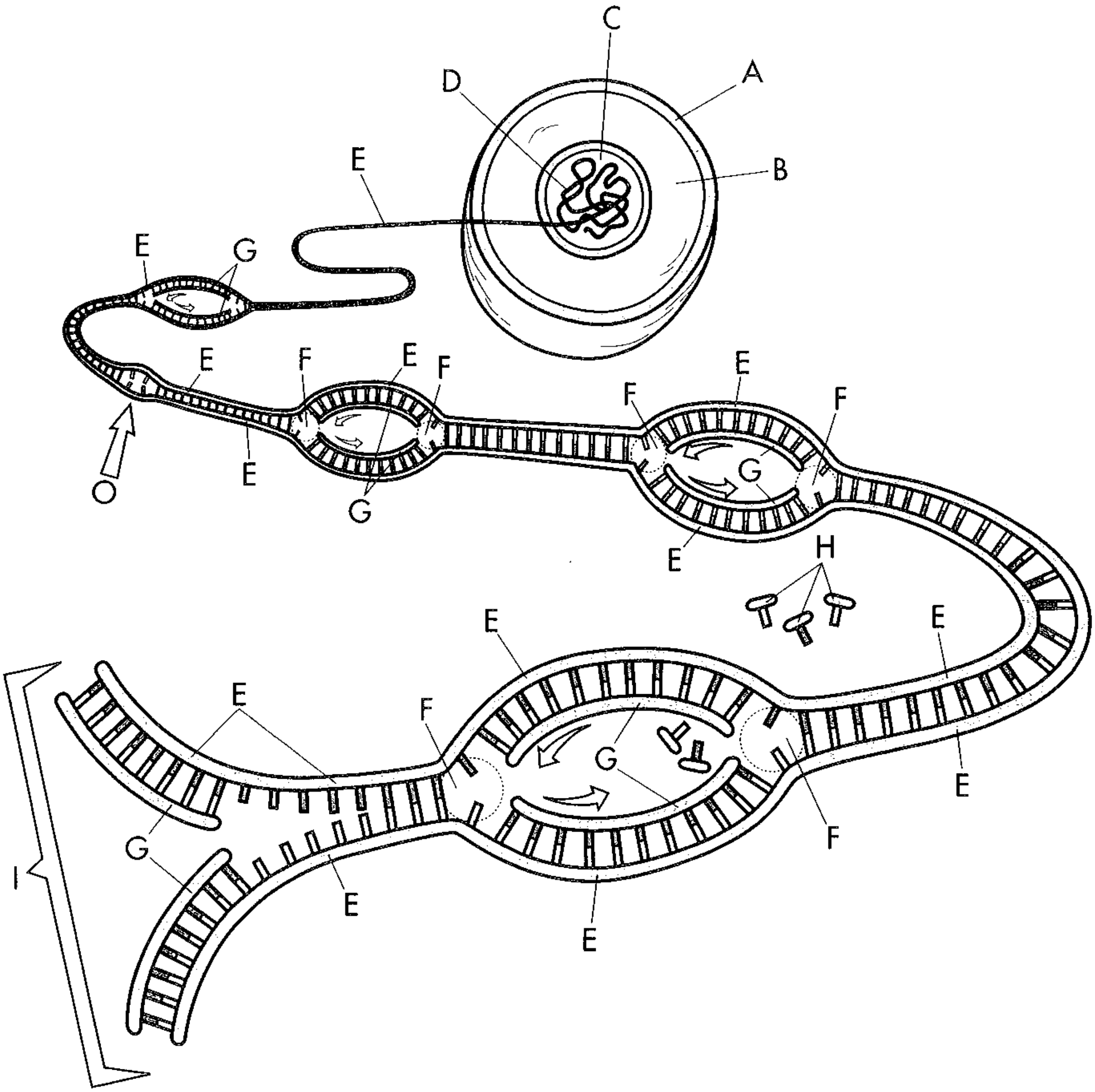
f. How does DNA polymerase synthesize a new molecule?

g. How do the replication forks travel?

h. What will the cell do after the DNA has replicated?

i. Where else does the process of prokaryote DNA replication occur?

4.4 Eukaryotic DNA Replication



Eukaryotic DNA Replication

Eukaryotic DNA Replication

- ○ Eukaryotic Cell Membrane ....A
- ○ Eukaryotic Cell Cytoplasm..............B
- ○ Nucleus................C
- ○ Chromosome ....D
- ○ Original DNA ....E
- ○ Enzyme ....F
- ○ New DNA................G
- ○ Origin of Replication............O
- ○ Nucleotides............H
- ○ DNA Double Helices I

Chapter 4-4: Eukaryotic DNA Replication

The volume of DNA in eukaryotic cells is immense. For example, a human cell has approximately one hundred thousand genes, each of which is composed of DNA. Because there is such a huge amount of DNA, replication in eukaryotic cells would take an extremely long time if it occurred in the same way as it does in prokaryotic cells. But there are processes that are unique to eukaryotic cells, and we will study them in this plate.

This plate displays a single strand of DNA in a eukaryotic cell. We point out various areas of interest along the long DNA molecule to help situate you as you learn about eukaryotic DNA modifications.

In this plate, we show a simplified eukaryotic cell. It is enclosed by a **eukaryotic cell membrane (A)**, and the main portion of the cell is the **eukaryotic cell cytoplasm (B)**. A major organelle within the cytoplasm is the **nucleus (C)**.

Within its nucleus, the eukaryotic cell contains a number of chromosomes, which are made up of DNA. In all human cells except the sex cells and red blood cells, there are forty-six chromosomes. Approximately three billion base pairs are in all the forty-six chromosomes. In the plate, a single chromosome has been stretched out of the cell for study; this **chromosome (D)** represents any of the forty-six human chromosomes. As the chromosome extends from the nucleus, we see the **original DNA (E)**. We will study this DNA in detail in a moment.

We have begun work in the plate by pulling out a single DNA molecule for study. Our purpose is to explain unique situations that occur in the course of the replication of eukaryotic DNA. As you proceed, you should color carefully to distinguish the features of this diagram.

In the replication of DNA in bacterial cells (studied in a previous plate), a single origin of replication develops in the plasmid. But if a eukaryotic DNA molecule were to replicate with a single origin, an immense amount of time would be necessary for replication. For this reason, several origins of replication exist in the eukaryotic DNA molecule. One such origin, designated by an arrow, is shown in the plate. **Origins of replication (O)** are areas in which replication forks have not yet formed.

In numerous places along the DNA molecule, we see bubbles. In these areas, **enzymes (F)** have unzipped the strands of DNA at the origin of replication and have begun to transcribe in opposite directions on each side of the DNA molecule. The enzymes are seen at the left and right side of each of these bubbles. A pale or gray color should be used to color them.

An important part of the transcription enzyme complex is the enzyme DNA polymerase. As the two DNA polymerases proceed in opposite directions from the origin of replication, they synthesize two new strands of DNA, and a number of **nucleotides (H)** are used in this synthesis. Therefore, we see in the plate that **new DNA (G)** is forming within the confines of the bubbles. As we go from the first to the fourth largest bubble, we see more details of the new DNA. Nucleotides continue to be added to the growing DNA molecule.

The process will continue until all the replication forks meet and the replication process is complete. We can see that, at the end of the DNA molecule, for example, two **DNA double helices (I)** have emerged. The bracket that surrounds these double helices should be colored in a dark color. Eventually the two helices will continue to separate until they reach the first large bubble.

In eukaryotic DNA, hundreds of origins are formed along the length of a DNA molecule. Multiple replication sites are also essential in eukaryotes because replication complexes work more slowly than those used in prokaryotic cells. For example, bacterial replication proceeds at a rate of about one million base pairs per minute, but eukaryotic cells have a replication rate that ranges from five hundred to five thousand base pairs per minute. Since the newly synthesized DNA strands grow in bidirectional patterns, the replication of eukaryotic cells averages a few hours. Once DNA replication is complete, the eukaryotic cell is ready to begin the process of mitosis.

4-4: Eukaryotic DNA Replication

a. How many genes does a human cell have?
b. What cells do not have forty-six chromosomes?
c. How many base pairs are in all forty-six chromosomes?
d. What unzipped the strands of DNA?
e. Enzyme that synthesizes the new strand of DNA:
f. How do the DNA polymerase proceed, with regard to each other, from the point of replication?
g. What molecule is added to form the new DNA strand?
h. When is the replication process complete?
i. How many origins of replication exist in the eukaryotic DNA molecule?
j. What is the replication rate of prokaryotic cells?
k. What is the replication rate of eukaryotic cells?
l. How long, then does the replication of eukaryotic cells average?
m. What does a eukaryotic cell do after replication is complete?