18/MHS06/042

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In order to fit within a cell’s nucleus, DNA is packed into tightly coiled structures called chromatin, which loosens prior to replication, allowing the cell replication machinery to access the DNA strands.

Before DNA replication can begin, the double helix structure of the DNA molecules has to be ‘unzipped.’ Helicase, an enzyme, is integral to this process, breaking the hydrogen bonds that hold the complementary bases of DNA together (A with T and C with G). The separation creates a ‘Y’ shape called a replication fork and the two single strands of DNA now act as templates for making new strands of DNA.

Next, the Single-Stranded DNA Binding Protein (SSB Protein) binds to the now single-stranded DNA, preventing the separating strands from joining again.

The two strands of the double-helix DNA are joined together by cross-bars, twisted around. For this to work, each DNA strand runs in opposite direction.

Step 1: Replication Fork Formation

Before DNA can be replicated, the double stranded molecule must be “unzipped” into two single strands. DNA has four bases called **adenine (A)**, **thymine (T)**, **cytosine (C)** and **guanine (G)** that form pairs between the two strands. Adenine only pairs with thymine and cytosine only binds with guanine. In order to unwind DNA, these interactions between base pairs must be broken. This is performed by an enzyme known as DNA **helicase**. DNA helicase disrupts the [hydrogen bonding](https://www.thoughtco.com/definition-of-hydrogen-bond-605872) between base pairs to separate the strands into a Y shape known as the **replication fork**. This area will be the template for replication to begin.

[DNA](https://www.thoughtco.com/dna-373454) is directional in both strands, signified by a 5' and 3' end. This notation signifies which side group is attached the DNA backbone. The **5' end**has a phosphate (P) group attached, while the **3' end** has a hydroxyl (OH) group attached. This directionality is important for replication as it only progresses in the 5' to 3' direction. However, the replication fork is bi-directional; one strand is oriented in the 3' to 5' direction **(leading strand)** while the other is oriented 5' to 3' **(lagging strand)**. The two sides are therefore replicated with two different processes to accommodate the directional difference.

Replication Begins

 Step 2: Primer Binding

The leading strand is the simplest to replicate. Once the DNA strands have been separated, a short piece of [RNA](https://www.thoughtco.com/rna-373565) called a **primer** binds to the 3' end of the strand. The primer always binds as the starting point for replication. Primers are generated by the enzyme **DNA primase**.

Step 3: Elongation

Enzymes known as **DNA polymerases** are responsible creating the new strand by a process called elongation. There are five different known types of DNA polymerases in [bacteria](https://www.thoughtco.com/surprising-things-you-didnt-know-about-bacteria-373277) and [human cells](https://www.thoughtco.com/types-of-cells-in-the-body-373388). In bacteria such as E. coli, **polymerase III** is the main replication enzyme, while polymerase I, II, IV and V are responsible for error checking and repair. DNA polymerase III binds to the strand at the site of the primer and begins adding new base pairs complementary to the strand during replication. In eukaryotic cells, polymerases alpha, delta, and epsilon are the primary polymerases involved in DNA replication. Because replication proceeds in the 5' to 3' direction on the leading strand, the newly formed strand is continuous.

The **lagging strand** begins replication by binding with multiple primers. Each primer is only several bases apart. DNA polymerase then adds pieces of DNA, called **Okazaki fragments**, to the strand between primers. This process of replication is discontinuous as the newly created fragments are disjointed.

Step 4: Termination

Once both the continuous and discontinuous strands are formed, an enzyme called **exonuclease** removes all RNA primers from the original strands. These primers are then replaced with appropriate bases. Another exonuclease “proofreads” the newly formed DNA to check, remove and replace any errors. Another enzyme called **DNA ligase** joins Okazaki fragments together forming a single unified strand. The ends of the linear DNA present a problem as DNA polymerase can only add nucleotides in the 5′ to 3′ direction. The ends of the parent strands consist of repeated DNA sequences called telomeres. Telomeres act as protective caps at the end of chromosomes to prevent nearby chromosomes from fusing. A special type of DNA polymerase enzyme called **telomerase** catalyzes the synthesis of telomere sequences at the ends of the DNA. Once completed, the parent strand and its complementary DNA strand coils into the familiar [double helix](https://www.thoughtco.com/double-helix-373302) shape. In the end, replication produces two [DNA](https://www.thoughtco.com/dna-373454) [molecules](https://www.thoughtco.com/dna-373454), each with one strand from the parent molecule and one new strand.

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DNA replication would not occur without enzymes that catalyze various steps in the process. Enzymes that participate in the eukaryotic DNA replication process include:

* **DNA helicase** - unwinds and separates double stranded DNA as it moves along the DNA. It forms the replication fork by breaking [hydrogen bonds](https://www.thoughtco.com/what-causes-hydrogen-bonding-603991) between nucleotide pairs in DNA.
* **DNA primase** - a type of RNA polymerase that generates RNA primers. Primers are short RNA molecules that act as templates for the starting point of DNA replication.
* **DNA polymerases** - synthesize new DNA molecules by adding [nucleotides](https://www.thoughtco.com/definition-of-nucleotide-605433) to leading and lagging DNA strands.
* **Topoisomerase** **or DNA Gyrase** - unwinds and rewinds DNA strands to prevent the DNA from becoming tangled or supercoiled.
* **Exonucleases** - group of enzymes that remove nucleotide bases from the end of a DNA chain.
* **DNA ligase** - joins DNA fragments together by forming phosphodiester bonds between nucleotides.