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**ANATOMY**

**BCH 204**

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There are three main steps to DNA replication: **initiation, elongation, and termination.**

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.

**THE STEPS ARE AS FOLLOWS**

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.

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 molecules](https://www.thoughtco.com/dna-373454), each with one strand from the parent molecule and one new strand.

**THE FUNCTIONS OF DNA REPLICATION ENZYMES.**

**ENZYMES FUNCTIONS**

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| [DNA helicase](https://en.wikipedia.org/wiki/DNA_helicase) | Also known as helix destabilizing enzyme. Helicase separates the two strands of DNA at the [Replication Fork](https://en.wikipedia.org/wiki/Replication_Fork) behind the topoisomerase. |
| [DNA polymerase](https://en.wikipedia.org/wiki/DNA_polymerase) | The enzyme responsible for catalyzing the addition of nucleotide substrates to DNA in the 5′ to 3′ direction during DNA replication. Also performs proof-reading and error correction. There exist many different types of DNA Polymerase, each of which perform different functions in different types of cells. |
| [DNA clamp](https://en.wikipedia.org/wiki/DNA_clamp) | A protein which prevents elongating DNA polymerases from dissociating from the DNA parent strand. |
| [Single-strand DNA-binding protein](https://en.wikipedia.org/wiki/Single-strand_DNA-binding_protein) | Bind to ssDNA and prevent the DNA double helix from re-annealing after DNA helicase unwinds it, thus maintaining the strand separation, and facilitating the synthesis of the nascent strand. |
| [Topoisomerase](https://en.wikipedia.org/wiki/Topoisomerase) | Relaxes the DNA from its super-coiled nature. |
| [DNA gyrase](https://en.wikipedia.org/wiki/DNA_gyrase) | Relieves strain of unwinding by DNA helicase; this is a specific type of topoisomerase |
| [DNA ligase](https://en.wikipedia.org/wiki/DNA_ligase) | Re-anneals the semi-conservative strands and joins [Okazaki Fragments](https://en.wikipedia.org/wiki/Okazaki_Fragments) of the lagging strand. |
| [Primase](https://en.wikipedia.org/wiki/Primase) | Provides a starting point of RNA (or DNA) for DNA polymerase to begin synthesis of the new DNA strand. |
| [Telomerase](https://en.wikipedia.org/wiki/Telomerase) | Lengthens telomeric DNA by adding repetitive nucleotide sequences to the ends of [**eukaryotic chromosomes**](https://en.wikipedia.org/wiki/Eukaryotic_chromosome_fine_structure). This allows germ cells and stem cells to avoid the Hayflick limit on cell division. |