Telomerase is not active in adult somatic cells. Adult somatic cells that undergo cell division continue to have their telomeres shortened. This essentially means that telomere shortening is associated with aging. For her discovery of telomerase and its action, Elizabeth Blackburn (Figure 10.17) received the Nobel Prize for Medicine and Physiology in 2009.

Figure 10.17 Elizabeth Blackburn, 2009 Nobel Laureate, was the scientist who discovered how telomerase works. (credit: U.S. Embassy, Stockholm, Sweden / Concepts of Biology OpenStax)

DNA Replication in Prokaryotes

While both eukaryotes and prokaryotes share many similarities when it comes to the process of DNA replication, the structural differences in the chromosomes necessitate some modifications. Recall that prokaryotes typically have one circular chromosome compared to the multiple linear chromosomes found in eukaryotic cells. We will only briefly discuss prokaryotic replication in this chapter, but students that take microbiology will have the opportunity to look more closely at this process.

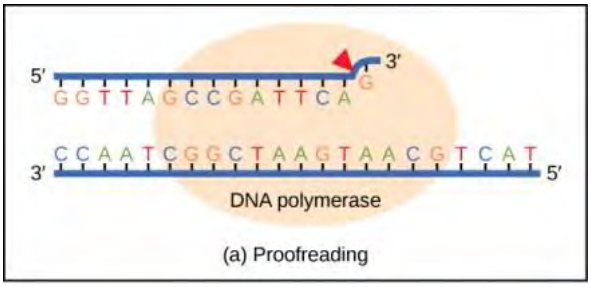
DNA replication has been extremely well-studied in prokaryotes, primarily because of the small size of the genome and large number of strains that exist and are readily available. *Escherichia coli* has 4.6 million base pairs in a single circular chromosome. The entire chromosome gets replicated in approximately 42 minutes. The process begins from a single origin of replication and proceeds around the chromosome in both directions. Many of the same enzymes used in eukaryotic DNA replication are also used by prokaryotes, including helicase, DNA polymerase, and ligase. As DNA replication proceeds, approximately 1000 nucleotides are added per second. The process of DNA replication is much more rapid in prokaryotes than in eukaryotes. This results in a higher mutation rate in prokaryotes.

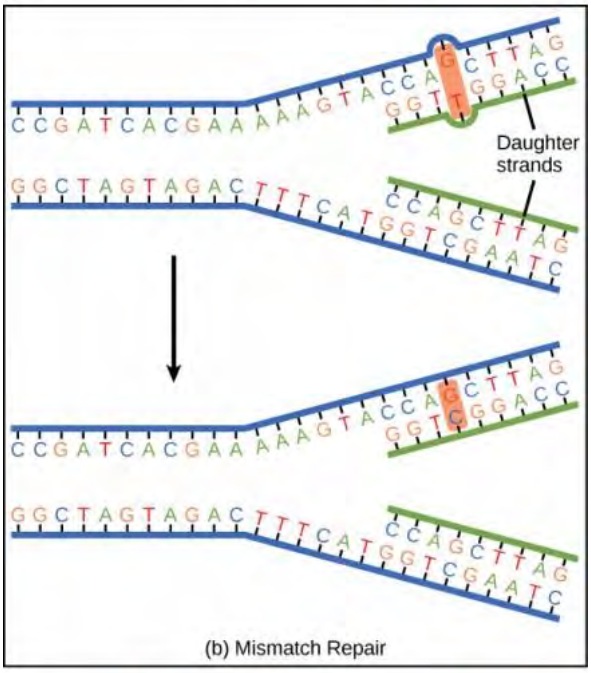
Table 10.1 Differences between Prokaryotic and Eukaryotic Replications (credit: Fowler et al. / Concepts of Biology OpenStax)

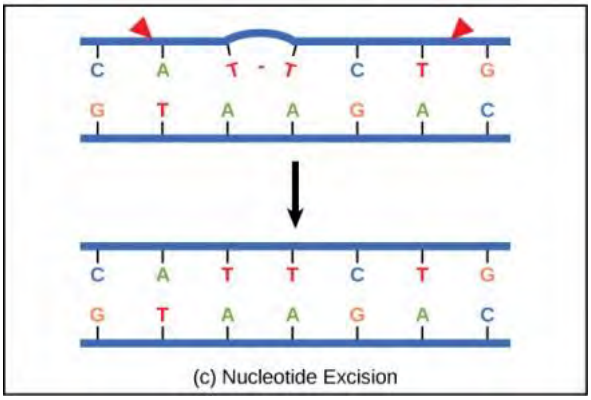
Property	**Prokaryotes**	**Eukaryotes**
Origin of replication	Single	Multiple
Rate of replication	1000 nucleotides/sec	50 to 100 nucleotides/sec
Chromosome structure	Circular	Linear
Telomerase	Not needed	Present

DNA Repair

Because DNA polymerase can make mistakes while adding nucleotides, it is important that the enzyme goes back and edits the DNA by proofreading every newly added base. Incorrect bases are removed and replaced by the correct base before the process continues (Figure 10.18 **a**).







Most mistakes are corrected during replication, but some are not. When mismatched bases are not caught, the mismatch repair mechanism is employed. Mismatch repair enzymes recognize the wrongly incorporated base and cuts it from the DNA. The enzymes then replace the mismatched base with the correct base (Figure 10.18 **b**). In yet another type of repair, nucleotide excision repair, the DNA double strand is unwound and separated. The incorrect bases are removed along with a few bases on the 5' and 3' end, and these are then replaced with the help of the DNA polymerase (Figure 10.18 **c**).

Nucleotide excision repair is particularly important in correcting thymine dimers, which are primarily caused by ultraviolet light. A thymine dimer occurs when two thymine nucleotides adjacent to one another, covalently bond to each other rather than their complementary bases. If the dimer is not removed and repaired, it will lead to a mutation. Individuals with flaws in their nucleotide excision repair genes show extreme sensitivity to sunlight and often develop skin cancers early in life.

Figure 10.18 Proofreading by DNA polymerase (a) corrects errors during replication. In mismatch repair (b), the incorrectly added base is detected after replication. Nucleotide excision (c) repairs thymine dimers. When exposed to UV, two thymines lying adjacent to each other can form thymine dimers. In normal cells, they are excised and replaced. (credit: Fowler et al. / Concepts of Biology OpenStax)

DNA Mutation

As mentioned, most mistakes are caught and corrected; however, if they are not, they may result in a **mutation.** A mutation is defined as a permanent change in the DNA sequence. Changes in the DNA sequence can have effects on the protein products, which can be either beneficial or detrimental.

Evolution, the genetic change in a population over time, is heavily dependent on mutation. Mutations in the DNA lead to variations among individuals which can lead to new or different traits within a population. These new or different traits can be beneficial to individuals within the population and can provide advantages, for example increased reproductive success, when compared to others in the population. Without genetic changes to the DNA, evolution would not occur. This topic will be discussed more in chapter 11.

Mutations can also be detrimental. Changes in the DNA sequence can lead to the inability to properly synthesize proteins. Changes in the DNA sequence can lead to changes in the amino acid sequence of a protein. If the amino acid sequence of a protein changes, the protein usually does not function properly.

There are several different types of mutations that can occur. One type, **point mutations,** occur when a single nucleotide is permanently changed in the DNA sequence. Point mutations may occur when one base is substituted for another. For example, when an adenine (A) gets replaced by a cytosine (C) (Figure 10.19). This change may cause a change in the amino acid sequence which would cause a change in the protein's structure. Sometimes the point mutation may be silent where the substitution of a base causes no change in the amino acid or amino acid sequence. These silent mutations are thought to have no detrimental impacts. All individuals are thought to have some silent mutations in their genomes.

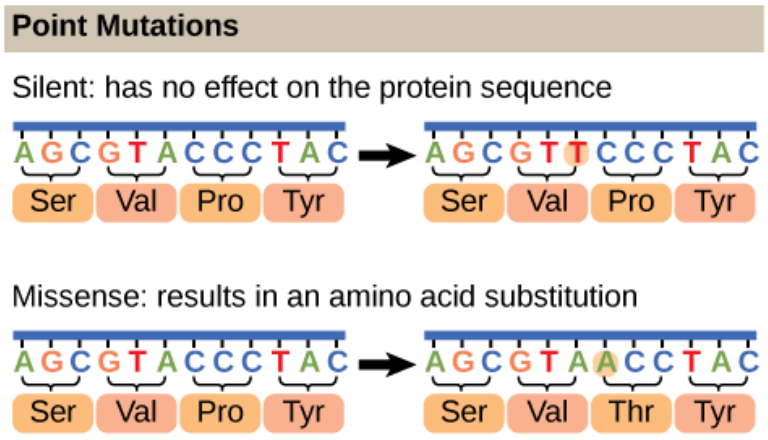


Figure 10.19 Mutations in the DNA can lead to a change in the protein sequence. (credit: Modified by Elizabeth O'Grady original work of Parker et al. / Microbiology OpenStax)