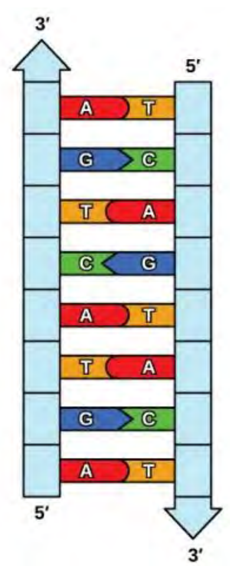
10.2 DNA Replication

Learning objectives

By the end of this section, you will be able to:

- *Explain the process of DNA replication including the role of helicase, RNA primase, DNA polymerase, and ligase*
- *Given a DNA template sequence, be able to give the complementary base pairs*
- *Understand that DNA is replicated in a 5' to 3' direction and discuss the differences between the leading and lagging strands*
- *Describe mechanisms of DNA repair*
- *Explain what DNA mutations are and how they can be harmful or beneficial*
- *Understand what the consequences are if the DNA mutation occurs in a somatic cell vs. a germline cell*
- *Be prepared to define and explain all bolded terms*

When a cell divides, it is important that each daughter cell receives an identical copy of the DNA. This is accomplished by the process of DNA replication. The replication of DNA occurs during the synthesis phase, or S phase, of interphase in the cell cycle, before the cell enters mitosis or meiosis.



The structure of the double helix provided a hint as to how DNA is copied. Recall that adenine nucleotides pair with thymine nucleotides, and cytosine with guanine. This means that the two strands are complementary to each other. For example, a strand of DNA with a nucleotide sequence of AGTCATGA will have a complementary strand with the sequence TCAGTACT (Figure 10.10).

Figure 10.10 The two strands of DNA are complementary, meaning the sequence of bases in one strand can be used to create the correct sequence of bases in the other strand. (credit: Fowler et al. / Concepts of Biology OpenStax)

Because of the complementarity of the two strands, having one strand means that it is possible to recreate the other strand. The double-helix model suggests that the two strands of the double helix separate during replication, and each strand serves as a template from which the new complementary strand is copied. What was not clear was how the replication took place. There were three models suggested (Figure 10.11): *conservative, semi-conservative, and dispersive*.

In conservative replication, the "old" parental DNA strands remains together, and the newly formed DNA strands come together to form the second helix (Figure 10.11). The **semi-conservative method** suggests that each of the two "old" parental DNA strands acts as templates. The two "new" complement strands of DNA are synthesized using the "old" template strands; after replication, each DNA helix consists of one parental or "old" strand and one "new" complement strand (Figure 10.11). In the dispersive model, both DNA helices have double-stranded segments of parental DNA and newly synthesized DNA interspersed (Figure 10.11).

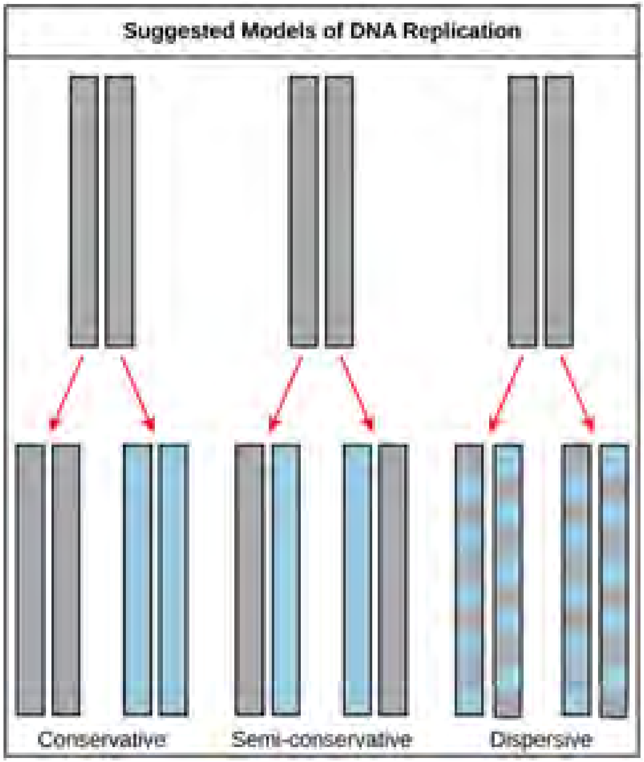


Figure 10.11 The three suggested models of DNA replication. Gray indicates the original DNA strands, and blue indicates newly synthesized DNA. (credit: Modified by Jason Cashmore original work by Clark et al. / [Biology 2E OpenStax](#))

To address these different models, scientists Matthew Meselson and Franklin Stahl carried out experiments using *E. coli* grown in different environments containing different isotopes of nitrogen. Recall that each nucleotide has a nitrogenous base, therefore nitrogen is necessary for DNA replication. Their work provided the necessary data that supported the semi-conservative replication model (Figure 10.12).

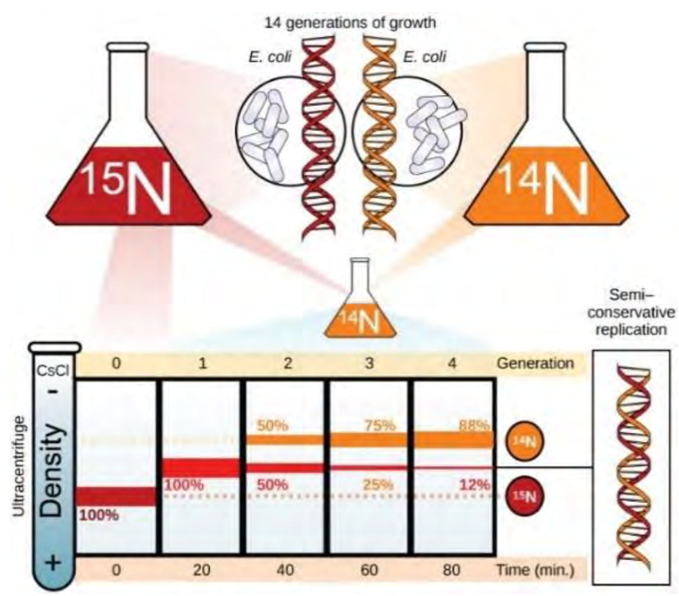
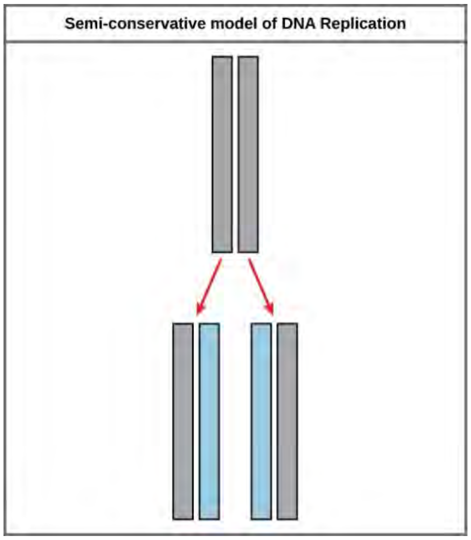


Figure 10.12 Meselson and Stahl experimented with *E. coli* grown first in heavy nitrogen (^{15}N) then in ^{14}N. DNA grown in ^{15}N (red band) is heavier than DNA grown in ^{14}N (orange band), and sediments to a lower level in cesium chloride solution in an ultracentrifuge. (credit: modification of work by Mariana Ruiz Villareal/ [Biology 2E OpenStax](#))



Based on the research of Meselson and Stahl and several others, it is understood that during DNA replication, each of the two "old" parental DNA strands serve as templates from which two "new" complement DNA strands are made. The two "new" strands will be complementary to the parental or "old" strands. Once DNA replication is complete, each new helix will consist of one "old" template strand and one "new" complement strand (Figure 10.13).

Figure 10.13 The semiconservative model of DNA replication is shown. Gray indicates the original DNA strands, and blue indicates newly synthesized DNA. (credit: Fowler et al. / Concepts of Biology OpenStax)

CONCEPTS IN ACTION – Paul Anderson explains DNA replication in this video.

DNA Replication in Eukaryotes

Because eukaryotic genomes are very complex, DNA replication is a very complicated process that involves several enzymes and additional proteins. It occurs in three main stages: initiation, elongation, and termination.

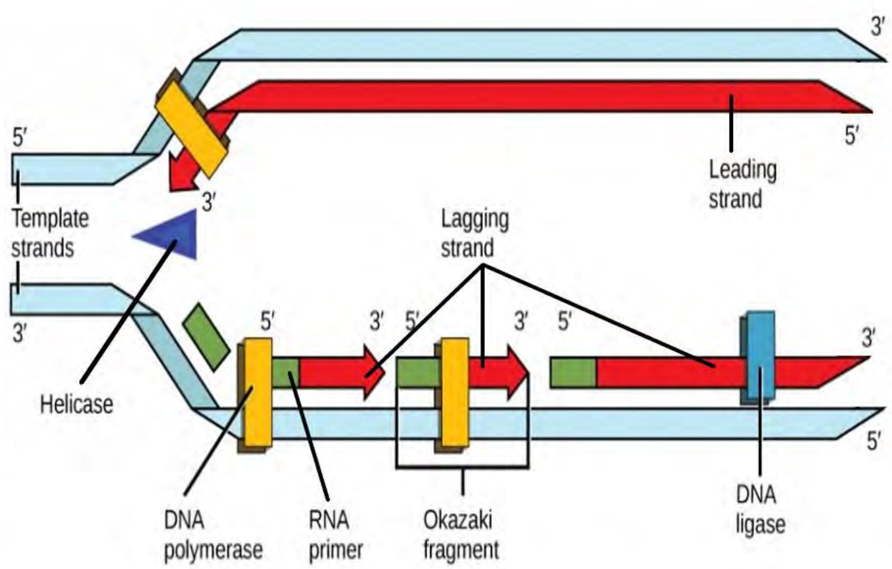


Figure 10.14 Helicase opens the DNA double helix and exposes replication forks. RNA primers are added by RNA polymerase. DNA polymerase then starts attaching DNA nucleotides to the 3' end of the primers. For the leading strand, DNA polymerase will continue adding nucleotides to make a single, uninterrupted strand. The lagging strand is constructed in short segments called Okazaki fragments as helicase exposes more of the template strand. DNA ligase then connects the fragments. (credit: Modified by Jason Cashmore original work by Fowler et al. / Concepts of Biology OpenStax)