

Section 6.4: DNA Replication and Repair

Mini Investigation: Constructing a Model of DNA Replication, page 289

- A.** The tape in Step 11 represents hydrogen bonding between the nitrogenous bases.
- B.** DNA is said to replicate in a semiconservative manner because the template strand is used to build a complementary strand. The new DNA molecule in the model contains one strand labelled “original parent strand” that is conserved and one strand that is new and unlabelled, representing semiconservative replication.
- C.** The two strands were not replicated in the same direction because the template strands were facing different directions and DNA polymerase only reads DNA in a 5' to 3' direction.
- D.** Answers may vary. Sample answer: Of the animations watched I would recommend “DNA replication (advanced detail)” to my classmates. It was the most accurate and conceptually useful. It allows for the isolation of different components of DNA replication and allows the viewer to get a feel for the sense of the mechanistic flow that occurs during DNA replication.

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1. (a) Answers may vary. Answers should include:

Step 1. Strand separation occurs when helicase binds to a replication origin and starts to unwind the two strands, breaking the hydrogen bonds that hold the strands together. Topoisomerase relieves tension on the strand as it is unwound and single-strand binding proteins attach to the DNA preventing it from annealing. Gyrase relieves twists and knots that occur during strand separation. This forms a replication bubble around a replication origin sequence.

Step 2. Building complementary strands occurs when the enzyme RNA primase builds a small complementary RNA segment that can DNA polymerase can use to add new DNA nucleotides to the growing complementary strand in a 5' to 3' direction. The replication fork has a leading strand that is oriented in the 5' to 3' direction and a lagging strand that is oriented in the 3' to 5' direction. DNA replication occurs in segments called Okazaki fragments initiated by RNA primase and extended by DNA polymerase III. The RNA primers are replaced with DNA by DNA polymerase I and the fragments are joined by DNA ligase.

Step 3. Dealing with errors during DNA replication starts with DNA polymerase enzymes. Base-pair mismatches cannot form hydrogen bonds so they cause the strand to become unstable resulting in DNA polymerase III being unable to move past until it backs up and fixes the error. After replication, DNA polymerase II works in complexes of proteins and enzymes including DNA polymerase I to repair damage between replication events. The repair mechanism cuts out the section of the complementary strand containing the error and replaces it with the correct sequence. DNA ligase joins the fragments.

(b) Answers may vary. Answers should reflect on the learning process and contain any information from part (a) not originally presented.

2. During DNA replications the enzymes are used in the following order: helicase, topoisomerase, RNA primase, DNA polymerase III, DNA polymerase I, DNA ligase.

- 3. (a)** If topoisomerase was not available for DNA replication the strands would not be able to relieve the tension created by helicase untwisting them. This may destabilize the strand and prevent binding and proper manipulation by other replication enzymes.
- (b)** If DNA ligase was not available the lagging strand and any new segment of DNA would not be attached to the rest of the DNA in the strand. If the strands were to dissociate the DNA would be fragmented.
- (c)** If single-strand binding proteins were not available as the strands became separated they would anneal to themselves and each other forming complex secondary and tertiary structures that could affect or stop the replication process.
- 4.** DNA replication is slower on the lagging strand than on the leading strand because upon initiation the leading strand has an RNA primer added so the synthesis of the new DNA can be continuous in the direction of the replication fork and only needs to be ligated when it encounters another replication fork. This is because replication is proceeding in a 5' to 3' direction, the direction in which DNA polymerase III can synthesize a new DNA strand. On the lagging strand, many RNA primers need to be added to keep the process continuing. Since many RNA need to be attached to the parent strand, the formation of short Okazaki fragments occurs opposite to the replication fork. This is opposite to the direction of DNA polymerase III's ability to work in a 5' to 3' direction. The additional step of removing the primers has to be completed by DNA polymerase I, in addition to replacing the appropriate nucleotides. Lastly, DNA ligase must then join the Okazaki fragments, all of which takes additional time.
- 5.** DNA is an example of a polymer. It is built of subunits in a repeating pattern. It can be polymerized and depolymerized using separate process.
- 6.** Both template strands cannot be replicated continuously because the DNA polymerase has a 5' to 3' directional preference. Since the lagging strand is oriented 3' to 5', the synthesis must be done in discontinuous fragments.
- 7.** An enzyme is not required to bring the strands back together because the complementary base pairing ensures that the strands will anneal on their own.
- 8.** Answers may vary. Sample answer: In scenario one, if we assume that the DNA is double stranded and, during unwinding, replication must be starting at opposite ends and is a continuous process so that there is only one replication site per strand, replication would be a much slower process. In scenario two, we might assume that this organism uses only single-stranded DNA, in which case the replication would have to occur twice to replicate the parental strand. This would allow DNA polymerase III to proceed in the proper 5' to 3' direction but be an extremely slow process.
- 9.** Answers may vary. Sample answer: I would ask: "How many strands are in this life form's DNA?" If, for example, there were four strands, there could be two 3' ends and two 5' ends at each end of the DNA, which would allow replication in both directions using a similar mechanism to the one native life forms use. I would ask: "How many different nitrogenous bases are on the life form's DNA?" The answer to this question might indicate that the nitrogenous bases on the DNA form a pattern that could be read from either end. I would also ask: "How many types of DNA polymerase are present in the life form's cells?" If several types were present, it would open up the possibility that one or more of them could read in the 5' to 3' direction.

10. The two strands of the DNA model developed by Watson and Crick show how semiconservative replication was possible. It is clear to see that the strands could separate and serve as templates for new strands to be made.

11. Xeroderma pigmentosum is associated with sensitivity of the eyes and skin to the sun. Symptoms include dry skin, blistering, eye irritation and abnormal growths, changes to skin colour, and various neurological abnormalities. Individuals with this disease are most susceptible to DNA damage caused by UV radiation.