1. A new drug inactivates the helicase enzyme by binding to its active site. How will this drug most likely affect the process of DNA replication?

(A) Proofreading of the replicated DNA will not occur because the helicase will be unable to bind with each newly replicated strand to determine if the DNA is in the proper sequence.

*Distractor Rationale:*
This answer suggests the student may understand that there is a proofreading step after DNA replication, but *does not understand* that proofreading is done by DNA polymerase II, not helicase, and proofreading cannot be completed until DNA unwinds and begins replicating. The student *may confuse* the role of helicase—separating base pairs in the strands of a DNA helix and creating the replication fork that allows for replication—with the role polymerase II plays in DNA replication.

(B) There will be no DNA replication because binding to the DNA at the replication fork will be prevented and separation of the DNA helix will not occur.

*Rationale:*
This answer suggests the student *understands* that helicase is involved in separating the base pairs in strands of the DNA helix and creating the replication fork that allows for replication. Without the successful separation of the strands of the DNA helix, DNA replication would not be possible, and the transmission of genetic information would not occur.

(C) The DNA will not coil correctly, which will prevent replication because DNA polymerase will be unable to attach complementary nucleotides to the DNA helix.

*Distractor Rationale:*
This answer suggests the student may understand that DNA coiling may prevent DNA replication and that there are proteins that can uncoil DNA, but *does not understand* that topoisomerases are involved in this process. The student *may confuse* the role of helicase—separating base pairs in the strands of a DNA helix and creating the replication fork that allows for replication—with the role polymerase II plays in DNA replication.

(D) The DNA strands will be replicated, but there will be multiple fragments of DNA because the helicase will be unable to covalently link the DNA fragments together.

3.11 A: DNA Replication Quiz
Distractor Rationale:
This answer suggests the student may understand that there is a ligation step after DNA replication to link stretches of replicated DNA together into a single molecule, but does not understand that DNA ligase, rather than helicase, is involved in this process. The student may confuse the role of helicase, separating base pairs in the strands of a DNA helix and creating the replication fork that allows for replication, with the role DNA ligase plays in DNA replication.

Aligned to: LO 3.11 CA 3.11: Evaluate DNA Transmission Data

2. In the DNA replication diagrams shown below, the dark strands represent the original DNA from the parent cell, and the light strands represent newly synthesized DNA.

![Diagram A and Diagram B]

Which statement identifies the diagram that best illustrates the semi-conservative model of DNA replication and explains how this method of DNA replication accurately transmits heritable material from one generation to the next?

(A) Diagram A, because the entire double helix serves as a template for the first new strand, ensuring that genetic information is accurately transmitted by keeping the original DNA molecule intact
Distractor Rationale:
This answer suggests the student may understand that the potential exists for replication errors during the process of DNA replication, but does not understand that the semi-conservative model of replication (diagram B) more accurately transmits heritable material because separation of the two original strands provides two templates from the original double helix for replication. The process of the conservative method of replication shown in diagram A would not ensure that information is correctly transferred between generations, because the new strands are not synthesized by pairing with a strand from the original helices during the first replication.

(B) Diagram A, because a hybrid double helix of old and new DNA strands is never created, ensuring that genetic information is accurately transmitted by only pairing compatible DNA strands in a double helix, new with new and old with old

Distractor Rationale:
This answer suggests the student may understand that the two strands in a double helix must have complementary base pairs, but does not understand that the pairing of old and new DNA strands should not pose any incompatibility in this pairing as long as DNA replication takes place successfully. The student may not understand that the semi-conservative model of replication depicted in diagram B more accurately transmits heritable material, because separation of the two original strands provides two templates from the original helix for replication. The process of the conservative method of replication shown in diagram A would not ensure that information is correctly transferred between generations, because the new strands are not synthesized by pairing with a strand from the original helices during the first replication.

(C) Diagram B, because one strand of the original DNA helix serves as a template for each of the new strands in the new molecule, ensuring that genetic information is accurately transmitted by pairing a new strand with an original strand, against which errors can be checked
**Rationale:**

This answer suggests the student understands that diagram B shows the semi-conservative model of DNA replication, in which the first DNA replication results in two newly synthesized DNA helices, each composed of one original strand and one newly synthesized strand, because the original DNA strand serves as a template for the new strand in each new molecule. This production of two molecules, combining a new strand and an old strand of DNA, during the first replication helps limit the number of replication errors or mutations that occur, ensuring the accurate transmission of heritable information from parent to offspring.

(D) Diagram B, because the strands in the original double helix are equally divided during the first replication, ensuring that genetic information is accurately transmitted by maintaining an equal split of old and new strands in each subsequent DNA molecule that is created.

**Distractor Rationale:**

This answer suggests the student may understand that, after the first round of DNA replication, two molecules of DNA, each with a new strand and an original strand, are produced, but does not understand that the percentage of original DNA decreases after each subsequent round of replication. The student does not understand that the reason why the semi-conservative model of replication (diagram B) more accurately transmits heritable material is that separation of the two original strands provides two templates from the original helix during the first round of replication, and this helps limit the number of replication errors or mutations that occur.

**Aligned to:** LO 3.11 CA 3.11: Evaluate DNA Transmission Data
3. A microorganism is discovered on a moon in the solar system, and a sample is brought back to Earth. Analysis shows that the microorganism is a carbon-based life form composed of cells containing DNA. Some cells of the microorganism are grown in a medium containing heavy nitrogen (\(^{15}\text{N}\)) and then transferred to a medium containing \(^{14}\text{N}\) for an additional round of replication. The cells are then placed in a centrifuge to isolate the DNA. This experiment is repeated with bacterial cells found on Earth. The results are shown below.

Which conclusion best explains the variations in nitrogen isotope levels observed in the DNA from the two organisms?

(A) The variation is due to differences in the replication process, because bacterial cells on Earth replicate DNA semi-conservatively, while the microorganisms from the moon keep the original DNA in one daughter cell and newly synthesized DNA in another.

Rationale:
This answer suggests the student understands that the Earth bacteria sample shows semi-conservative DNA replication, while the sample from the moon in the solar system shows conservative replication, as evidenced by its two separate bands, one containing only \(^{14}\text{N}\) DNA and the other containing only \(^{15}\text{N}\) DNA. These experimental results agree with the results of the Meselson and Stahl experiment in that the Earth bacteria that demonstrate the semi-conservative model of DNA replication produced only hybrid DNA after the first replication.

(B) The variation is due to differences in the reduction of chromosome number during meiosis, because the reproduction of bacteria on Earth involves crossing over and creating hybrid DNA, while the microorganisms from the moon synthesize new DNA without crossing over.
Distractor Rationale:

This answer suggests the student may understand that crossing over produces genetic recombination, but does not understand that this process does not occur in bacteria, and that the evidence does not support the crossing over of homologous chromosomes, because this would not change the isotope ratio in the DNA. The student may not recognize how this experiment is similar to the Meselson and Stahl experiment in that the Earth bacteria that demonstrate the semi-conservative model of DNA replication produced only hybrid DNA after the first round of DNA replication.

(C) The variation is due to differences in DNA replication, because bacteria on Earth replicate DNA conservatively, while the microorganisms from the moon replicate DNA semi-conservatively.

Distractor Rationale:

This answer suggests the student may understand that the process of DNA replication can theoretically be conservative or semi-conservative, but does not understand that the data indicate that the sample containing a single band of hybrid DNA is evidence of semi-conservative replication rather than conservative replication. The student may not recognize how this experiment is similar to the Meselson and Stahl experiment in that the Earth bacteria that demonstrate the semi-conservative model of DNA replication produced only hybrid DNA after the first round of DNA replication.

(D) The variation is due to differences in how the two organisms undergo cell division, because bacterial cells from Earth replicate their DNA before dividing, while the microorganisms from the moon do not undergo DNA replication before dividing.

Distractor Rationale:

This answer suggests the student may understand that DNA replication is a critical step in cell division, but does not understand that DNA replication was evident in both samples and that it was the difference in the modes of DNA replication (conservative in the microorganisms from the moon vs. semi-conservative in the Earth bacteria) that caused the variations in the nitrogen isotope levels in the DNA. The student may not recognize how this experiment is similar to the Meselson and Stahl experiment in that the Earth bacteria that demonstrate the semi-conservative model of DNA replication produced only hybrid DNA after the first round of DNA replication.

Aligned to: LO 3.11 CA 3.11: Evaluate DNA Transmission Data
4. *E. coli* is a bacterium with one circular, double-stranded DNA. To study DNA replication in *E. coli*, a culture of bacteria is grown in a medium with a heavy isotope of nitrogen, $^{15}$N, for several generations. The bacteria are then transferred to a medium with a lighter isotope of nitrogen, $^{14}$N. Every 20 minutes, the bacterial DNA is analyzed, and the amounts of $^{15}$N and $^{14}$N in the DNA are calculated. The data from the experiment are shown below.

The results from the experiment are used to model the spread of a mutation found on only one strand of the double-stranded DNA in a single bacterium. Based on the results of the experiment, which statement best predicts the percentage of bacteria descended from this original bacterium that will have the mutation after 80 minutes?

(A) 100% of the bacteria will have the mutation after 80 minutes, because after the first bacterium began replicating its DNA, 50% of the new strands had the mutation after 40 minutes, and therefore, the number of bacteria with the mutation will reach 100% after 80 minutes.

*Distractor Rationale:*

This answer suggests the student may understand that DNA replication involves transmission of the mutation in each round of cell division, but does not understand that the percentage of DNA without the mutation will not decrease to 0% after two more generations because 50% of the descendants will be based on the template without the mutation and will be without the mutation.

(B) 87.5% of the bacteria will have the mutation after 80 minutes, because DNA replicates every 20 minutes, resulting in DNA with one original strand and one new strand, and therefore, the amount of hybrid DNA decreases by half every 20 minutes.
**Distractor Rationale:**

This answer suggests the student may understand that DNA replication is semi-conservative, but **does not understand** that the percentage of DNA without the mutation will remain at 50% in all future generations after the first round of replication because 50% of the descendants will be based on the DNA strand (template) without the mutation and the DNA replicated from this template will be without the mutation.

(C) 0% of the bacteria will have the mutation after 80 minutes, because the amount of original DNA decreases by half every 20 minutes, resulting in fewer bacteria with the mutation after each round of DNA replication.

**Distractor Rationale:**

This answer suggests the student may understand that DNA replication involves the transmission of the mutation in each round of cell division, but **does not understand** that the percentage of DNA with the mutation will not decrease to 0% after two more generations because all DNA derived from the template with the mutation will also include the mutation, so 50% of all bacteria in future generations will be created based on the template with the mutation and will have the mutation present in their DNA.

(D) 50% of the bacteria will have the mutation after 80 minutes, because the first bacterium provided one template with the mutation and one template without the mutation in the first round of replication, so half of its descendants will be based on the template with the mutation.

**Rationale:**

This answer suggests the student **understands** that that each generation of bacteria contains DNA with one strand of original parent DNA and one strand of new DNA, because each strand from the double helix is used as a template in the semi-conservative model of DNA replication. All bacteria in the line of descendants from the template with the mutation will also include the mutation, so 50% of all bacteria in future generations will be created based on the template with the mutation and will have the mutation present in their DNA.

**Aligned to:** LO 3.11 CA 3.11: Evaluate DNA Transmission Data