Lesson 11: Where Does Brand New Genetic Information Come From?

Overview:

Purpose:

The purpose of this activity is to recognize 1) mutations as random changes in the order and number of nucleotides in strands of DNA or in the number of chromosomes, 2) if such unintentional mistakes in replication of DNA occur during mitosis or meiosis, they can affect the entire the entire line of cells that result from this process, and 3) some forms of radiation and chemical exposure can increase the chances of a cell incurring mutations.

Connection to previous activities:

Students have explore the outcomes of genetic drift and natural selection in previous activities and found that both mechanisms tend to remove traits variations from populations and decrease the diversity of the gene pool. They have explored how sexual reproduction leads to new combinations of traits, and that new combinations are reshuffling of existing genetic information of the parents into new combinations of the genetic information. They know that sexual reproduction alone doesn't add new genes or alleles or any new genetic information into a gene pool. Based on these experiences, a question remains, "where do new trait variations comes from?"

Development of Ideas:

- **New Scientific Principles**
  - The genetic information for living creature is encoded in molecules (DNA) millions of nucleotides long using different combinations of only four types of nucleotides (abbreviated as A, C, T, G)
  - DNA is typically replicated with very few errors when a cell goes through mitosis or meiosis; When the wrong nucleotides are inserted, deleted, or substituted into replicated DNA, it results in some different genetic information (a mutation) being passed on to the new cells

Description

In this activity students will first listen to a mini-lecture on karyotypes and the structure of DNA and they will take brief notes. They then will explore a computer model attempting to compete against other students to see who can replicate DNA the fastest, and then who can replicate DNA at the fastest rate of "error free nucleotide pairing". Through both explorations, students discover the rules for correct pairing of nucleotide bases, some of the protein interactions involved in the replication process, and what a deletion, substitution, and insertion mutation is.

In the homework students read about causes of mutations. They compare how mutations in body cells only affect the daughter cells in that organism, while mutations in sex cells would affect the entire offspring and all of their offspring. They read about types of mutations that yielded deletion or duplication of one chromosome and of the entire karyotype vs. those that affect only a few nucleotide bases.

Learning Performances

- Simulate how information is duplicated in DNA molecules, through pairing four kinds of smaller molecules (abbreviated as A, C, T, and G)

- Unintentional generate two types of mutations in the replication of a DNA molecule.
- Describe why some radiation and chemicals could cause mutations.
- Compare the difference between a mutation that is the duplication and insertion of an entire chromosome, a few nucleotides in the chromosome, and the entire karyotype.
- Describe why mutations that occur in sex cells are more visible than mutations that occur in body cells.
- Describe they ways that an organism can and can not affect its own DNA and the DNA of its offspring.

Related Benchmarks:

- The information passed from parents to offspring is coded in DNA molecules, long chains linking just four kinds of smaller molecules, whose precise sequence encodes genetic information. 5B/H3*
- The genetic information encoded in DNA molecules is virtually the same for all life forms. 5C/H4b
- Genes are segments of DNA molecules. Inserting, deleting, or substituting segments of DNA molecules can alter genes. An altered gene may be passed on to every cell that develops from it. …..... …...The resulting features may help, harm, or have little or no effect on the offspring's success in its environment. 5B/H4*
- Mutations can be caused by such things as radiation and chemicals. When they occur in sex cells, they can be passed on to offspring; if they occur in other cells, they can be passed on to descendant cells only. The experiences an organism has during its lifetime can affect its offspring only if the genes in its own sex cells are changed by the experience. 5B/H5

Time: 1.5 periods

Materials

Per Student

- 1 computer per student with NetLogo installed on each along with a copy of the DNA Replication Fork.nlogo model file.

For Teacher

- Transparencies or poster paper to record conclusions and big ideas.
- 1 computer to display with NetLogo and DNA Replication Fork.nlogo model file for demo and display.
- Transparency 11

Instruction:

Launch:

Remind students that Sexual reproduction, genetic drift, and natural selection never introduce new genetic information into a population that wasn't already in the population before. And review how each of these mechanisms tends to remove alleles from gene pools over time and therefore removes trait variations from populations as well.

Point out that if these were the only mechanisms that changed the distribution of traits in populations, the individuals in a population would appear to become more and more similar over time, until eventually, all variation in traits disappeared completely from a population.

Ask students whether that is what we see happening in the populations in ecosystems. *Accept all answers (students may*

say yes that we are losing biodiversity).

If students say that biodiversity is decreasing over time, introduced a couple examples of species of plants and animals that don't appear in the ancient fossil record, but that appeared later in earth's history. One example that students may be familiar with are dinosaurs – though many of them went extinct, there was a time when they starting appearing in the fossil record but were not there before that point in history. The same is true of fish, birds, and mammals. Since the individuals in some of these species have traits that don't seem to be in any other species that came before them, it raises the question, "where do new traits come from?"

Point to the driving question board and explain that today the class will begin investigated the 3rd learning set. If time permits, encourage students to post a new question to the driving question board using post-it notes. You may want to encourage students to link each new question they pose to a previous one they heard posted. For example a student might say *"My question is about whether dogs have traits that wolves don't have and it relates to Dmitha's question about what makes something a diffferent species."*

Instruct students to take notes as part of Exploration 1 as you present new information on the Transparencies. Have them first complete the prediction section in that exploration.

Show students the karyotype at the top of the transparency. Tell them that this is a photograph of the chromosomes from a human body cell. Scientists color coded on the photograph as they started to sort out the chromosomes based on a pattern they see in every human body cell. Ask students what patterns they see? *Accept all answers.*

Ask students, based on this color enhanced photograph how chromsomes does it appear that humans typically have? *Students should say 46.*

Ask students how many pairs of chromosomes does it appear that humans typically have? *Students should say 23.*

Tell students that these chromosomes contain all the genetic information for this human. They can be found in any body cell of the human (in the nucleus). Every human typically contains 46 chromosomes. *Remind students that sex cells contain only half of these number of chromosomes (23), one from each pair that are sorted out during meiosis.*

Remind students that they have seen a Karyotype representation in one of the models before – the Fish Tank Genetic Drift Model. Show the transparency of that model and ask students how many chromsome did that species of fish appear to have? *Students should say 10.*

Ask students how many pairs of chromosomes did the fish have? *Students should say 5.*

Show students the representaiton of the sex cell karyotype from the Fish Tank activity. Ask students how many chromosomes was each parent passing on to the offspring through their sex cells. *Students should say 5 each.*

Tell students that the chromosomes are long DNA molecules that are twisted and wound up into a bundle. Show them two bundles of yarn, saying that we can use the two bundles of yarn as a physical model of two chromosomes (or a pair of chromosomes). Point out that the yarn is wound nto the bundle and needs to be unwound to more clearly see a single strand of yarn. The same is true for DNA. DNA is wound up into a chromosome bundle and it must be unwound to see the entire strand of DNA.

Next show students the twisted stair case structure of DNA on the Transparencies. Ask the students how many of them have seen this model of DNA. Ask them what they notice about the structure of the DNA.

Emphasize the feature of DNA related to its twisted shape. Tell students that some describe the structure as similar to a twisted or spiral staircase. Point out that the yarn is similar to this in that it too is made of twisted fibers. You may want to pass around a sample of yarn to show this or show it on a document camera.

Then tell students if you could picture untwisting the DNA (or the yarn) you would find it is made of two strands of nucleotides that are linked together. Each nucleotide is made of a set of similar atoms. Throughout the entire string of DNA, the same four nucleotides make up the DNA, but the order can and does change depending where in the strand you look. Tell students the names of the nucleotides if you wish (adenine, guanine, cytosine, and thymine), but tell them that for simplicity sake we often refer to them by the abbreviatons A, G, C, and T)

Point out that in transparency 10.2 on the bottom right side, the left side of the DNA shows a sequence of bases that would read A, C, T, G from top to bottom. Say that chromosomes have millions of these bases down a

length of DNA. These millions of bases encode for many thousands of genes. Cells try to copy the entire length of DNA in each chrosome before completing mitosis or meiosis. Tell them that they will try to simulate this same process for a smaller length chromosome in the computer model they will be using today.

Have students complete the notes section of exploration 1 now if they have not already. The chart below gives a general sense of what students should write:

Our Question	My Notes
What are chromosomes?	They are long stringy molecules of DNA that are wound up into a bundle; they contain all the genetic information for that individual.
Where are chromosomes found?	In plants & animals they are found in the every cell nucleus.
How many chromosomes do humans have?	23 pairs of chromosomes in body cells (46 total) 23 individual chromosomes in sex cells.
How many chromosomes were in the karyotype for the **body cells** of the fish in the genetic drift model?	10 total – 5 color matched pairs
How many chromosomes were in the karyotype for the **sex cells** of the fish in the genetic drift model?	5 in each – 1 from each color matched pairs

Next, introduce the computer model they will be using.

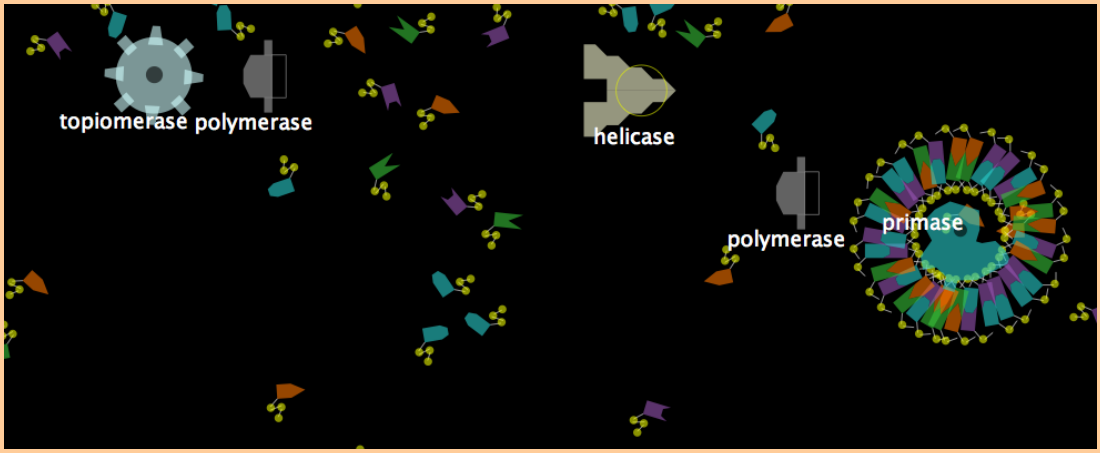
Teacher Demonstration Directions

1. Open the "DNA Replication Fork" model.
2. Set the initial values to:

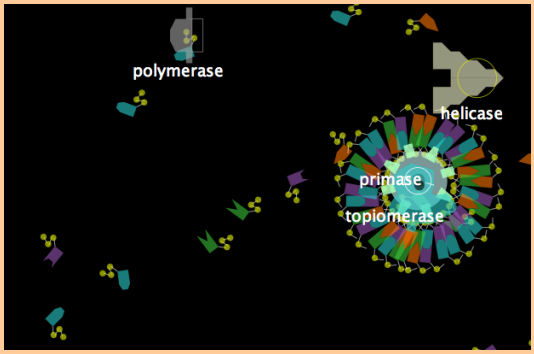
Setting	Value
SUBSITUTIONS?	Off
DNA-STRAND-LENGTH	30
#-FREE-NUCLEOSIDES	50
ENZYME-LABELS?	On
NUCLEO-LABELS?	Off
TIMER?	"None"

3. Press SETUP.

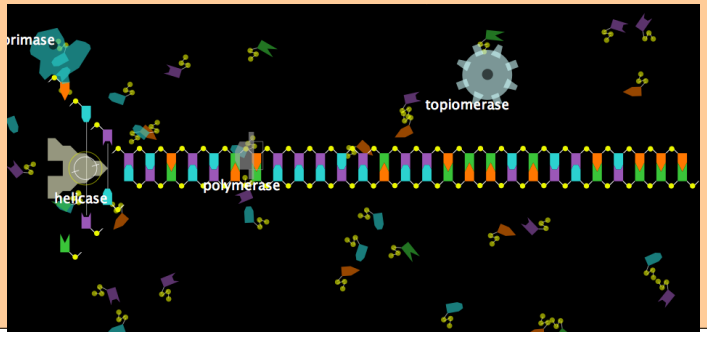
4. Point out that a twisted strand of DNA will appear on the right, many large proteins will be floating around, and many small nucleosides will be floating around too. These all represents some of the important molecules found in the nucleus of every cell that help DNA replicate during mitosis or meiosis.



5. Next, show students that they will need to unwind the DNA in this model before they replicate it. This process is similar to what has to happen in the nucleus of cells too. To do this they must drag and drop the topiomerase protein complex on top of the primase protein which is at the center of the wound up DNA strand. The picture on the right shows how to do this. The topiomerase protein will inrease its rate of spin when you are at the right location (on top of the primase). Drop the topiomerase protein here.

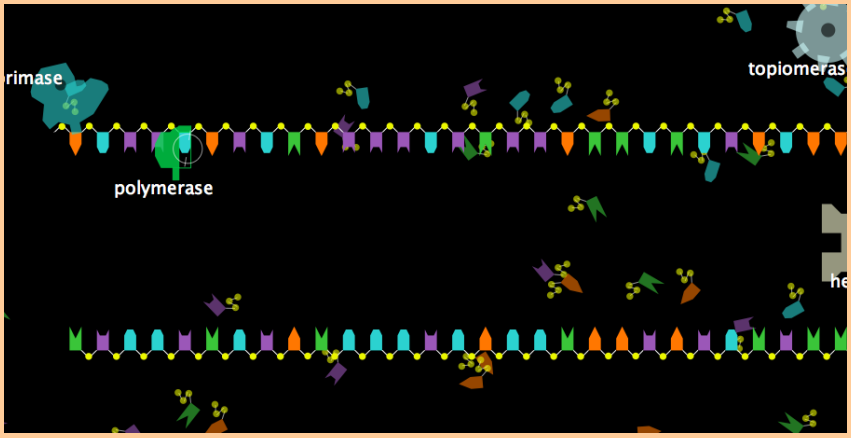


6. The DNA strand will unwind. Next drag and drop the helicase protein complex to the left end of the DNA. Use it to unzip the DNA by releasing it on the left edge of the middle of the DNA. As it moves to the right it will force open (wedge open) the DNA

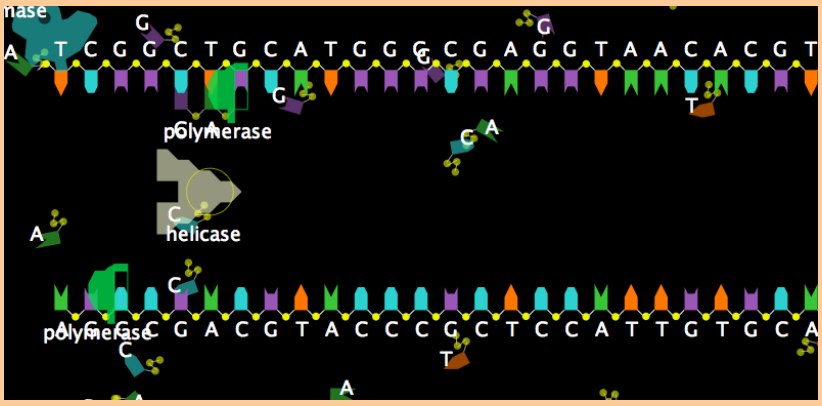


strand, breaking apart the nucleotide base pairs.	

7. Tell students to make sure they unzip the entire strand of DNA before doing the next step.

8. Now drag and drop a polymerase protein complex to any nucleotide in either the top or bottom DNA strand. Release it there. It will attach to the nearest nucleotide.	

9. Next drag and drop a floating nucleotide over to the polymerase and drop it there. If it is the correct nucleotide to pair to the existing nucleotide, it will automatically attach. Otherwise it will float away. Tell students that if a nucleotide floats randomly into that location and it is the correct one the polymerase molecules will bind it to the DNA strand automatically.

10. Tell students it may be useful to turn the NUCLEO-LABELS? Switch on at some points in order to see what type of nucleotide bases they are trying to pair together. Show them this now.	

Explore:

Instruct students to make mini-teams of 2-3 people with the person to their right or left or both and begin explorations 2 (and then 3) with their team on their activity sheets.

Summarize:

Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to the lesson question. Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the areas listed. Try to write the categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Conclusions & Big Ideas:

- **As a class: :** Where does genetic information come from and where does brand new genetic information come from?
-
- Genetic information
  - *Example student idea: DNA contains four nucleotides that are the genetic code*
  - *Example student idea: DNA contain lots of the same type of nucleotides.*
  - *Example student idea: Chromosomes are made of DNA*
  - *Example student idea: Chromosomes are in the nucleus of cells.*
  - ***Summarize with this idea: On chromosomes, the genetic information is encoded in molecules (DNA) millions of nucleotides long and using different combinations of only four nucleotides (abbreviated as A, C, T, G)***
- Replication of DNA
  - *Example student idea: Chromosomes get replicated before cells divide.*
  - *Example student idea: Cells have to pair up certain nucleotides with others in order to replicate it.*
  - ***Summarize with this idea: Old cells try to replicate exact copies of their chromosomes to pass some (meioisis) or all (mitosis) on to new cells; This is done by proteins that work together to pair A with T and C with G and vice-versa for each nucleotide in the DNA.***
-
- Mutations
  - *Example student idea: Mutations cause genetic information to change..*
  - *Example student idea: nucleotides can be lost when replicaton occurs*
  - *Example student idea: Sometiems the wrong nucleotide is paired in replication.*
  - *Example student idea: Mutations are just the wrong nucleotide that shouldn't be threre if everything was copied correctly.*
  - ***A mutation is any insertion, deletion, or substitution of a one or more type of nucleotides (A, C, T, and G) in a DNA molecule that wasn't originally there.***

Now reduce the three ideas into two new scientific principles

- **New Scientific Principles**
  - The genetic information for living creature is encoded in molecules (DNA) millions of nucleotides long using different combinations of only four types of nucleotides (abbreviated as A, C, T, G)
  - DNA is typically replicated with very few errors when a cell goes through mitosis or meiosis; When the wrong nucleotides are inserted, deleted, or substituted into replicated DNA, it results in some different genetic information (a mutation) being passed on to the new cells.

Homework: Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.

Lesson 12: Where Do Brand New Trait Variations and Genes Originate?

Overview:

Purpose:

The purpose of this activity is to recognize 1) mutations as random changes in the order of nucleotides in strands of DNA,) that mutations change the instructions for which amino acids and in what order they are used to build new proteins 3) if such changes occur in sex cells, they can affect the entire line of cells of an offspring, 4) since such effects result in the production of new substances (or no longer producing old substances), these substances production changes affect the traits of the organism,, 4) changes in traits due to mutations may affect the survival chances depending on the environmental conditions of the organism.

Connection to previous activities:

Students have explore the outcomes of genetic drift and natural selection in previous activities and found that both mechanisms tend to remove traits variations from populations and decrease the diversity of the gene pool. They have explored how sexual reproduction leads to new combinations of traits, and that new combinations are reshuffling of existing genetic information of the parents into new combinations of the genetic information. They know that sexual reproduction alone doesn't add new genes or alleles or any new genetic information into a gene pool. Based on these experiences, a question remains, "where do new trait variations comes from?"

In previous activities students have seen that different trait variations give different competitive advantages in different environments and that a given trait variation may be advantageous in one environment and disadvantageous in another. Students have direct experience with this from the Critters HubNet and Bug Hunt Speeds models.

Development of Ideas:

- **New Scientific Principles**
  - Different proteins have different structures and different functions.
  - A single gene is a section of a DNA molecule that describes what protein to build; it starts anywhere the nucleotide sequence of ATG appears; all three nucleotide triplets after this tell the cell what amino acids (out of a possible 20) should be used to build the protein
  - Some mutations affect the number of genes, some affect the type of protein produced, and other affect DNA that doesn't code for anything.

Description

In this activity students will first listen to a mini-lecture on the structure of proteins and they will take brief notes. They then will explore a computer model to compare how genes are encoded in DNA, and how corresponding amino acids are used to build a protein for each gene. They will also conduct experiments to see how some mutations affect the number of genes, some affect the type of protein produced, and other affect DNA that doesn't code for anything. Through both explorations, students discover the start codon for genes, triplet to amino-acid pairing in tRNA, and see a simplified model of the gene → mRNA ---> protein production process.

In the homework students read about how mutations affect protein production which in turn affects trait variation when such mutations are in every cell of the organism.

Learning Performances

- Simulate the translation of genes to mRNA and mRNA to proteins.
- Discover the nucleotide code in a DNA molecule that marks the start of gene (ATG).
- Analyze how some mutations affect the number of genes, some affect the type of protein produced, and other affect DNA that doesn't code for anything.
- Record the order of amino acids used to construct particular proteins from particular genes.
- Describe why the emergence of new proteins (or lack of old protein) that cells make as a result of a mutation may help, harm, or have little or no effect on the offspring's success in its environment.

Related Benchmarks:

- The information passed from parents to offspring is coded in DNA molecules, long chains linking just four kinds of smaller molecules, whose precise sequence encodes genetic information. 5B/H3*
- The genetic information encoded in DNA molecules is virtually the same for all life forms. 5C/H4b
- Genes are segments of DNA molecules. Inserting, deleting, or substituting segments of DNA molecules can alter genes. An altered gene may be passed on to every cell that develops from it. ….....
- …...The resulting features may help, harm, or have little or no effect on the offspring's success in its environment. 5B/H4*
- The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. 5C/H4a
- Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious. 5B/H1

Time: 1-2 periods

Materials

Per Student

- 1 computer per student with NetLogo installed on each along with a copy of the DNA Protein Synthesis.nlogo model file.

For Teacher

- Transparencies or poster paper to record conclusions and big ideas.
- Transparencies 12.1-12.3

Instruction:

Launch:

Show the transparency of the two dogs and the two fruit flies. Ask students what visible trait variation do they notice between the two dogs, *They should say the one on the right looks more muscular.*

Ask students what visible trait variation they notice between the two flies. *They should say the one on the right has a different color eye than the one on the left.*

Tell students that the organism on the left is the typical phenotype found in the wild, but the organism on the right shows a different phenotype due to a mutation it incurred.

Ask students how is it possible that a change in the DNA causes eye color to appear different. Its not as if you are actually seeing the DNA (which is too small to be seen). And how is it possible that a change in the DNA causes muscle mass to change? *Accept all answers*

Then put this diagram on the board:

Changes in DNA ----> ?? something different going on in the cells ??----------> A new trait variation for that individual

Tell students that a key piece to understanding what proteins do for cells and how cells make them.

Tell students to record their ideas about what they already know about proteins and how they are made on their activity sheet in the first exploration. Then have the students take notes on some transparencies and model you will be showing them.

First show them the diagram of the 20 amino acids that make up all proteins. Tell students that all proteins are made of combinations of these 20 amino acids. Ask students what atoms are common amongst these molecules. Students should say H, C, O.

Now place a different colored paper clip on the first 6 amino acids. Tell students that proteins are made of long chains of these amino acids. Show an example by chaining together 10 different paper clips. Tell students that this is a model for one type of protein made of 10 amino acids. Tell student any change in the order and arrangement of the amino acids would make a different type this would make one type of protein. Ask them whether adding or subtracting a paper clip (an amino acid) would make the same protein. *Students should say yes*.

Show them that you could make a protein out of all the same amino acids repeated over and over again and the number of amino acids used would also affect the type of protein made.

Remind students that the paper clip model is showing one way of thinking about the chemical reaction that joins amino acids together to form proteins. But its limitation is that it makes the protein molecule appear as a straight chain. In reality the chain folds up into different geometric shapes. Show this by twisting the chain of paper clips around.

If time permits have some student volunteers come up and play the part of amino acids. Have them hold hands to make a protein and show the folding up by moving around each other.

Now tell students that some proteins are much larger than just ten or so amino acids long. Some are thousands of amino acids long. This makes many proteins very large molecules.

Next show diagrams of the shape of the 3 dimensional molecule of 4 different proteins on the Transparencies. Remind students that these are all built of one long chain of amino acids that is folded up into this shape and that each protein is made of a different sequence of amino acids.

Point out that each protein has a different function. Ask students what about them allows them to function differently. *Students should say they have different structures or that they have different numbers and arrangements of amino acids or that they have different numbers and arrangements of atoms, so they are different substances and different substances have different properties.*.

Summarize for students what proteins do for cells by writing this on the boar:

Different proteins have different functions Together they perform almost all of the thousands of chemical reactions that take place in cells for:

- responding to messages from other cells.
- providing structure and support for the cell.
- allowing cells to move and change shape.
- help carry materials in and out of cells.

Tell students that all proteins get made in cells by assembling together amino acids in different orders.

Have students complete the Notes and Observations section if they have not yet done so. The notes should look something similar to these:

Our Question	**My Notes**
What are proteins made of?	They are chains of 20 different possible kinds of amino acids. Some are short (a few amino acids long), others are very long (thousands of amino acids long).
What do proteins look like?	The long chains of amino acids is folded up into complex 3 dimensional shapes. Different proteins have different shapes.
What do proteins do?	• They carry out almost all of the thousands of chemical reactions that take place in cells for: • responding to messages from other cells. • providing structure and support for the cells. • allowing cells to move and change shape. • help carry materials in and out of cells.
Where are proteins made?	In all the cells of an organism. *(more specifically in the ribosome of the cell).*

Tell students that since proteins affect all the functions of the cells we can now rephrase our diagram to read:

Changes in DNA ---- ? ---> Changes in the Proteins that Cells make ----------> A new trait variation for that individual

We can see that different proteins might yield different traits, but what we still don't know is how changes in DNA result in changes in the proteins that cells make. Figuring that out is one of the goals in the explorations with the computer model today. Have them complete the brainstorm question in exploration 1 of their activity.

Explore:

Instruct students to work through the remaining explorations using the computer model..

Summarize:

Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to the lesson question. Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the areas listed. Try to write the categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Conclusions & Big Ideas:

- **As a class: :** How do mutations in DNA affect the proteins that cells make?
-
- Protein Structure & Function
  - *Example student idea: Different proteins are made of different combinations of amino acids*
  - *Example student idea: Proteins are chains of amino acids*

- *Example student idea: Different proteins do different things.*
- *Example student idea: Proteins fold up into different shapes*
- ***Summarize with this idea: Different proteins have different structures and different functions.***

- Genes to Proteins
  - *Example student idea: Not all the DNA is a gene*
  - *Example student idea: Genes start with ATG*
  - *Example students ide: Sometimes there can be more than one gene overlapping*
  - *Example student idea: The part of the DNA that is a gene gets copied into a molecule that moves away from the DNA strand*
  - *Example student idea: Amino acids are matched to every 3 nucleotide bases in the gene.*
  - ***Summarize with this idea: A single gene is a section of a DNA molecule that describes what protein to build; it starts anywhere the nucleotide sequence of ATG appears; all three nucleotide triplets after this tell the cell what amino acids (out of a possible 20) should be used to build the protein***
-
- Mutations
  - *Example student idea: Sometimes mutations changed the number of genes and sometimes they didn't.*
  - *Example student idea: Some mutations only changed one of the amino acids in the protein that was produced.*
  - *Example student idea: Some mutations affected DNA that didn't contain any genes.*
  - ***Summarize with this idea: Some mutations affect the number of genes, some affect the type of protein produced, and other affect DNA that doesn't code for anything.***

Now reduce / restate the three ideas into three new scientific principles

- **New Scientific Principles**
  - Different proteins have different structures and different functions.
  - A single gene is a section of a DNA molecule that describes what protein to build; it starts anywhere the nucleotide sequence of ATG appears; all three nucleotide triplets after this tell the cell what amino acids (out of a possible 20) should be used to build the protein
  - Some mutations affect the number of genes, some affect the type of protein produced, and other affect DNA that doesn't code for anything.

Homework: Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.

Lesson 11: How Do the Mechanisms of Evolution Change Populations?

Overview:

Purpose:

The purpose of this activity is to review the mechanisms of evolution and will propose a model of interconnected mechanisms that can be used to explain an evolutionary outcome. Alternate models are compared to show that multiple models can be proposed for evolution, but all must use evolutionary mechanisms, and all must account for the outcome of evolution (changes in trait distribution in a population over time).

Prerequisite Knowledge:

- See all learning goals in learning sets 2-3.

Connection to previous activities:

Students have explored competitive advantage, environmental change, genetic drift, natural selection, mutation, and sexual reproduction. They use their previous experiences to contrast the differences and similarities in outcomes and attributes of the mechanisms.

Description

In this activity students will identify the outcomes and attributes of the mechanisms of evolution and discuss these as a class. In a small group they will propose a model of interconnected mechanisms of evolution to account for 1 of 2 case studies. Alternate models will be presented and defended and debated. Class discussion will highlight the reasonableness of presenting alternate models that account for the same outcome, and the need for such models to 1) account for the outcome, 2) integrate the mechanisms of evolution, 3) be able to make additional predictions of future changes in different environments.

In the homework students read about how evolution is both a fact (an outcome) and a set of interconnected mechanisms. And that the exact combination of mechanisms at work in a given situation can be different. Students explain why an understanding of evolution would aid in more effective treatments for infections and for pest control. They read about directed evolution as an approach to developing a new type of bacteria that can create fuels from cellulose and they propose a similar experimental design for developing a new type of bacteria to clean up oil spills.

Learning Goals

- Present a brief scientific explanation orally or in writing that includes a claim and the evidence and reasoning that supports the claim. 12D/M6**
- Seek to gain a better understanding of a scientific idea by asking for an explanation, restating an explanation in a different way, and asking questions when some aspect of an explanation is not clear. 12D/M7**

Learning Performances

- Identify and compare attributes and characteristics of different mechanisms of evolution.
- Construct and defend a scientific explanation for the evolution of a population of birds or bugs, using the mechanisms of evolution.
- Describe how understanding evolution can lead to more effective ways to develop and administer vaccines and pest controls.
- Propose an technological design plan for a "directed non-evolution" process to that could result in a new population of bacteria that is very effective at eating oil as food.

Time: 1 periods

Materials

Per Student
- Activity sheet 11.1
- All activity sheets and Big Ideas & Conclusions sheets (activities 1 – 10) completed in class so far

Per Group of Four
- Poster paper and markers

For Teacher
- 1 computer and projector or large display screen for the teacher to demonstrate the model.
- Transparency projector
- Transparency 11.1

Instruction:

Launch:

Tell students that they are going to work in groups today to develop a model to explain an evolutionary outcome. They will need to refer to their Big Ideas & Conclusions sheets from learning set 2 and learning set 3.

Tell students to use these to help fill out the chart on the first page of their activity sheet.

Instruct students to read the procedure and instructions on the first page of their activity sheet and work in groups to complete the chart.

After students work for about 5 minutes, bring all groups back together and lead a discussion around how and why students classified their choices as they did for the last page. If students disagree with categories, this is an opportune time to have students present and defend their arguments to their peers and ask questions of each other.

Eventually there should be a class consensus on these classifications:

	mechanism of evolution					
Outcomes of this mechanism	**competition for limited resources**	**new combinations of trait variations in offspring from sexual reproduction**	**genetic drift**	**natural selection**	**changes in environmental conditions**	**mutations**
are the result of random events or interactions	yes *(some are)*	yes *(meiosis randomly separates pairs of chromosomes)*	yes	no *(these may be unintentional, but are not random)*	yes, *in that geologic and solar changes may still be poorly understood and therefore hard to predict*	yes
can add brand new variations of traits into a population	no	no	no	no	no	yes
can remove existing variations of a trait from a population	yes	yes *(meiosis may not pass on every allele, but this could be considered genetic drift)*	yes	yes	yes	yes
can contribute to a population becoming better adapted to survive a particular environment	yes, but only along with natural selection	only through random chance, a very unlikely outcome.	only through random chance, a very unlikely outcome.	yes	yes, but only along with natural selection	yes, but random mutation alone would introduce a new trait variation.
will generate the exact same outcome every time.	no, *which individuals survive may change.*	no, *every offspring can end up with different combinations of alleles from parents.*	no, *though diversity is removed, the alleles which disappear aren't predetermined nor predictable.*	no, *though there is a general direction to generate more individuals with a competitive advantage, the exact outcome can't be predetermined.*	no	no

Tell students that these mechanisms of evolution often work together to change populations over time. Tell students that they are going to work in groups of 4 to evaluate a case study of evolution. It is up to the group to determine which mechanisms of evolution were most likely at work to generate the outcome in the case study. It is very likely that different groups will propose different combinations of the mechanisms in from the chart. Any model proposed should meet the requirements of being a scientific explanation. It should:

1. Make a claim about what evolutionary mechanisms were interacting together to generate the outcome
2. Account for the evidence from the case study
3. Explain how the mechanisms of evolution could account of the evidence.
4. Predict additional phenomena.

Assign each group one of the two case studies (mosquitoes or sparrows). Have groups work 15-20 min. to write up an outline, diagram, or model to show what led to the outcome reported in the case study.

Have groups present their models very briefly (about 2-4 minutes each) and ask other students to evaluate the models based only on 1-3. Ask a follow-up question of each group to evaluate what the model would predict for future evolution of the population.

For example for the sparrows:

If the climate became warmer everywhere, what does their model predict would happen? What mechanisms would lead to this prediction?

If the sparrows from the Canadian border were introduced (as an invasive species) to an island in the Caribbean, how would the population of sparrows evolve over time? What mechanisms would lead to this prediction?

If the sparrows from the Canadian border migrated to Alaska, how would the population of sparrows evolve over time? What mechanisms would lead to this prediction?

For example for the mosquitos:

If the climate became warmer everywhere, what does their model predict would happen? What mechanisms would lead to this prediction?

If mosquitos from Iowa were compared to mosquitos from Alaska, would they both overwinter to the same time of the year? What mechanisms would lead to this prediction?

After all groups have presented their model, point out that there can be more than one possibility of combinations of mechanisms of evolution that lead to an evolutionary outcome. And tell students this is an important distinction, that the population has evolved is a fact, but different combinations evolutionary mechanisms led to that outcome could be used in an explanation of how evolution led to that outcome.

*Homework: Assign the homework for this lesson. *