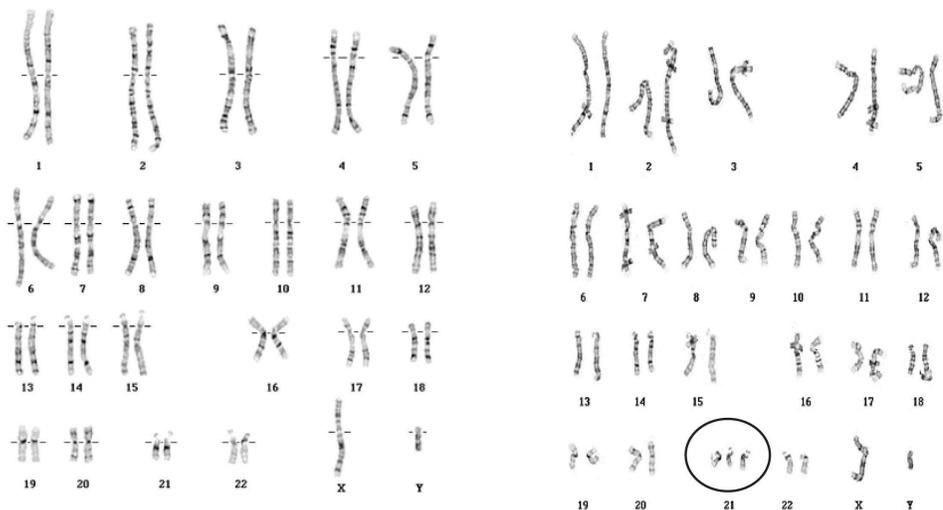


Assessment of Biological Reasoning (ABR) Instrument

1. Meiosis

Biologists use the concept of *meiosis* to explain the condition where there are extra or missing chromosomes. One such example of this condition is Down's syndrome where an extra chromosome 21 is present. Karyotypes (or images of chromosomes within cells) are used to explore this condition. Below are the karyotypes used to compare a person with and without Down's syndrome.



Male without Down's Syndrome

Male with Down's Syndrome

1.1 Select the answer that **best** represents the products of *meiosis*.

- Genetic material is copied twice and divided twice.
- One diploid parent cell divides to form two diploid daughter cells.
- The passage of genetic materials from parent to parent.
- One diploid parent cell divides to form four cells that can become gametes.*

1.2 Use your knowledge of *meiosis* to select the statement that **best explains** the presence of an extra chromosome which resulted in the male with Down's syndrome. During the process of *meiosis*, chromosomes...

- and their DNA patterns get messed up because they come from older parents who have a greater chance of creating flawed gametes.
- mutated because they experienced an error during prophase, causing extra chromosomes.
- did not properly split during gamete formation, resulting in some gametes ending up with extra chromosomes.*
- come from a parent who has an unexpressed extra chromosome, resulting in gametes receiving more chromosomes.

1.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (1.2)? Individuals with Down's Syndrome have an extra chromosome because...

- a parents' gametes ended up with extra chromosomes from abnormal separation of chromosomes into different cells.*
- the offspring's grandparents ended up with extra chromosomes which were passed down to the child.
- during meiosis, a mutation occurred which produced a fourth chromosome causing Down Syndrome.
- during the process of meiosis, the parents overproduced chromosomes which resulted in the three chromosomes.

* indicates correct response

2. Evolution

Figure 1 is a cladogram, that is a suggested evolutionary pathway, of several different species of organisms that are all classified as African Great Apes. The arrangement of this cladogram is based on genetic information taken from the mitochondria of the various apes. In contrast, Figure 2 shows an analysis of genetic information taken from the genomes of four of the species included on the cladogram: human, chimpanzee, orangutans, and gorilla. Scientists use these different tools to understand the process of speciation. Please examine both of the figures to answer the next three questions.

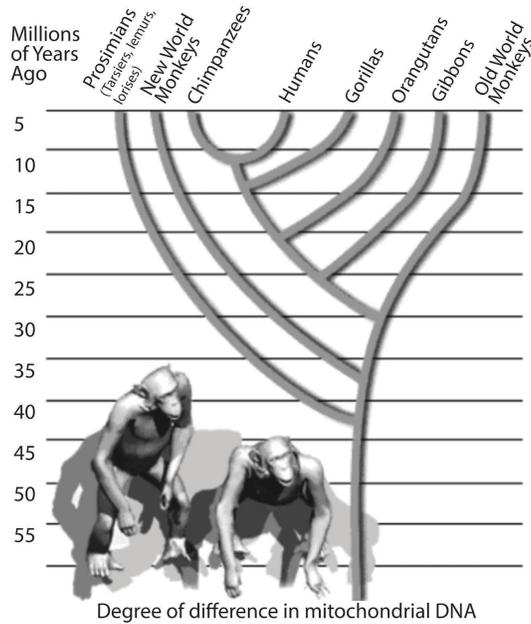


Figure 1. A hypothesized evolutionary lineage of the the African Great Apes

	AA1	AA2	AA3	AA4	AA5	AA6	AA7	AA8	AA9
Human	ARG	ARG	ARG	LYS	HIS	GLU	VAL	GLY	VAL
Chimp	ARG	ARG	LYS	LYS	HIS	GLU	VAL	GLY	VAL
Orangutan	ARG	ARG	LYS	LYS	GLU	GLU	GLY	GLY	VAL
Gorilla	PRO	ARG	LYS	LYS	GLU	GLU	VAL	VAL	VAL

Figure 2. Protein sequence analysis of genomic DNA for humans and African Great Apes. AA = amino acid

2.1 Which of the following answers **best** describes *speciation*:

- All organisms are related but descend from different ancestors to be more alike to each other.
- Related species share less of their genetic material but more physical characteristics.
- Extended periods of time are required for similar species to evolve from different ancestors.
- New species arise from older species due to genetic variation arising over long periods of time.*

2.2 Use your knowledge of *speciation* to select the **best explanation** for the relationship between the various species of Great Apes.

* indicates correct response

- Gibbons interbred with a new animal and evolved into orangutans. Orangutans interbred with a new animal and evolved into gorillas. Gorillas interbred with a new animal to evolve into humans and chimpanzees.
- Humans and chimpanzees both developed very recently (12 million years ago) and they are thought to be a more complex and successful species than the other species included in the cladogram.
- Humans share more of their DNA and genetic information with chimpanzees than they do with gorillas or orangutans, suggesting that these two species of Great Apes are more closely related than the others.*
- Scientists did not observe these speciation events because they happened millions of years ago, so they cannot know anything about the relationship between groups of organisms.

2.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (2.2)? Cladograms reflect our current understanding of evolutionary relationships between species. They are based on...

- the assumption that distantly related species will share no genetic or physical characteristics.
- the understanding that closely related species will share more genetic information and physical characteristics.*
- the assumption that all species (e.g., orangutans, apes, and chimpanzees) develop into new species over time.
- genetic information only and cladograms are not constructed based on observations or the fossil record. Because of this, they form a weak basis for conclusions.

3. Biological Species Concept

Two bears are found in North America, Grizzly bears and Polar bears. These two bears look very different: Grizzly bears (Figure 1) are a large type of brown bear, with a very prevalent hump on their back and Polar bears (Figure 2) are a large white bear. These two genetically similar bears occupy very different niches. Grizzly bears tend to live and breed on land, while Polar bears prefer to live on the water and ice.

Recently, biologists have found that Grizzly bears are moving into what was traditionally understood to be Polar bear habitat (extreme Northern Canada).

Before 1996, there was no evidence of Grizzly bears in this area. Recently, there have been three confirmed sightings of wild hybrids, a cross between Polar bears and Grizzly bears. These hybrids are creamy white in color like a Polar bear and have a humped back like a Grizzly bear. The behavior of these hybrid bears appears more like a Polar bear than a Grizzly. For example, they toss toys around as Polar bears do with their prey; they lay on the ground with their legs splayed just like Polar bears. Interestingly, there are no recorded cases of such hybrids successfully reproducing and having a next generation of hybrid bear. This leads many people to wonder – Are Polar bears and Grizzly bears actually the same species?



Figure 1. A Grizzly Bear



Figure 2. A Polar Bear

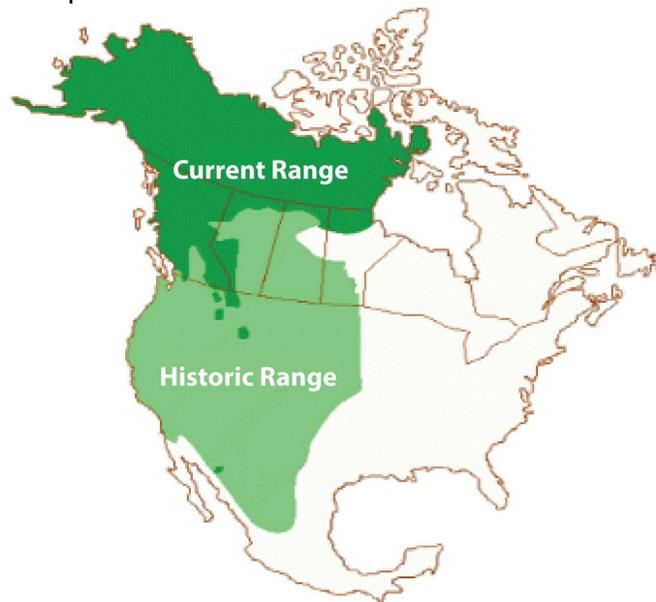


Figure 3. Current and Historic Grizzly Bear Distribution in North America

3.1 Which of the following **best describes** the *biological species concept*:

- Members of a species can interbreed to reproduce sexually viable offspring of the same species. *
- The history behind species that have evolved and change over time to become different species.
- The history behind species that have adapted to their environments over time to become one species.
- Evolution of species because of genetic anomalies and adaptations so that a new species is created.

3.2 Use your knowledge of *the biological species concept* to select the **best explanation** for why Grizzlies and Polar bears are one species or two. Grizzlies and Polar bears are...

- one species because they can successfully mate with each other and produce sexually viable hybrids.
- two species because there is no record of two hybrids mating and successfully reproducing a hybrid bear. *
- two species because they generally have different appearances and different ways of being.
- one species because the only difference is their appearance and they can live in the same habitat.

* indicates correct response

3.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (3.2)? Both Grizzlies and Polar bears are...

- the same species because of the presence of the wild hybrid mother and cub pair suggesting that they hybrid mother can viably reproduce offspring (her cub).
- two species because their appearance, behaviors, and preferred habitats, while having some similarities, are fundamentally different.
- Two species because organisms within the same species have to produce sexually viable offspring.*
- from the same ancestor but are now different species because they had to adapt to fill different niches in the now overlapping habitats.

* indicates correct response

(" F Ygd]f Ujcb

A group of scientists were interested in studying cellular respiration. To do so, four test tubes were filled with 50 ml of spring water and 3 ml of Bromothymol Blue (BTB). BTB is an indirect indicator of Carbon Dioxide (CO₂). It changes from blue to green to yellow as CO₂ lowers the pH of a solution. A change to yellow indicates a larger quantity of CO₂ than a change to green (Figure 1). Items were then added to each test tube and observed for five hours (Table 1).



Figure 1. Color scale for CO₂ levels

	Content	0 hours	5 hours
Tube 1	1 Sprig of elodea (a water plant)	 Blue-Green	 Blue
Tube 2	1 Water snail	 Blue-Green	 Yellow
Tube 3	1 Sprig of elodea 1 Water snail	 Blue-Green	 Green

Note: Tube 4, the control, is not shown.

Table 1. Data table

4.1 Which of the following statements **VYghXYgW]VYg** the] ; / & ^ • • Á ~ & ^ | ~ | æ Á ^ •] ã æ ã } ?

- A process in cells that involves the cell breathing in O₂ and breathing out CO₂.
- A process in cells that produces energy (in the form of ADP) and O₂ by changing bonds between CO₂ and H₂O and harvesting energy from those changes.
- A process in cells producing energy (in the form of ATP) and CO₂ by breaking down sugar molecules and O₂, releasing energy from their chemical bonds. †
- A process that occurs in plant cells that creates building blocks for other organelles using energy from sunlight and nutrients from the soil.

* indicates correct response

4.2 Use your knowledge of cellular respiration to select the **best explanation** for the observed changes in the color found inside the various test tubes (provided at the bottom of the picture).



- | | | | |
|------------------------------------|---|---|---|
| <input type="radio"/> | Elodea uses energy and cellular respiration to produce O_2 | No cellular respiration occurring | Elodea and snail produce O_2 using cellular respiration |
| <input type="radio"/> | Less O_2 due to elodea cellular respiration that is also using CO_2 in photosynthesis | More CO_2 due to snail cellular respiration | Balance of CO_2 and O_2 due to elodea and snail presence |
| <input type="radio"/> | Elodea uses energy and cellular respiration to produce O_2 | No cellular respiration occurring | Cellular respiration that produces more CO_2 than O_2 |
| <input checked="" type="radio"/> * | Less O_2 due to elodea cellular respiration that is also using CO_2 in photosynthesis | More CO_2 due to snail cellular respiration | Some CO_2 present due to cellular respiration by both organisms but photosynthesis by elodea using CO_2 |

4.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (4.2)? The water color changes because...

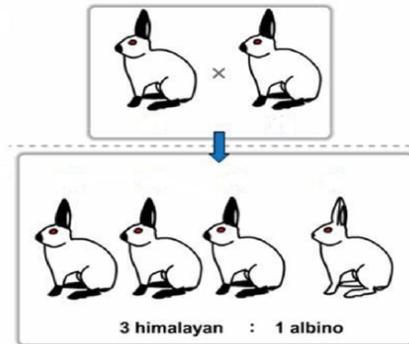
- the water stays bluer and greener because cellular respiration by the plant produces CO_2 that is used in photosynthesis.*
- the water changes color as more CO_2 is used by cellular respiration which causes the color change and allows more organisms to grow.
- as cellular respiration happens in the tubes, the changes in the amount of O_2 produced by the organisms lowers the pH to cause the color change.
- as cellular respiration is limited in some tubes, similar amounts of O_2 and CO_2 are produced.

* indicates correct response

) " A YbXY]Ub'; YbYhVg

Gregor Mendel deduced that the transmission of genetic traits are passed down in families in different patterns. He explained his results by describing the laws of inheritance that introduced the idea of dominant and recessive genes. Biologists have used these laws to explain the probabilities of traits appearing in offspring and later generations.

These laws can be used to understand results that occur when a species mates, such as the case of two Himalayan rabbits that mated and produced four offspring. Three of those offspring are Himalayan (dark fur on ears and feet) and one is albino (has solid white feet) (see below). In these rabbits, fur color is a trait that follows the laws of inheritance.



5.1 Based on the picture above, select the allele option in both parents that would result in a white-footed offspring based on the /æ • Ā -Ā @ /āā &^:

- Heterozygous †
- Homozygous dominant
- Homozygous recessive
- Sex-linked trait

5.2 Use your knowledge of the /æ • Ā -Ā @ /āā &^ to select the VYghYI d'UbUjcb for how two Himalayan rabbits produce offspring that have solid white fur.

- Genes change from parent to offspring. Genes for traits mix together in the formation of gametes and as a result, offspring's features will always look like a blend of their parents' features.
- Genes are passed unchanged from parent to offspring and the offspring gets a copy of one allele from their parents. This causes offspring to have traits that are identical to their parents.
- Genes serve as instructions for trait development. Genes are passed unchanged from parent to offspring, and the offspring receive one copy of an allele from both parents. †
- During the formation of gametes, a gene pair separates. Offspring inherit two copies of each gene and the most dominant gene is the one the offspring will receive.

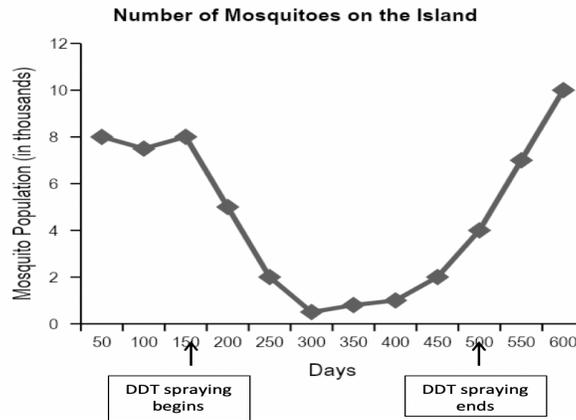
5.3 Which of the following VYghXYgW]VYg your fYUgcb]b[for the choice you made in the previous question (5.2)?

- Himalayan offspring may or may not express the white allele. Offspring get one allele from each heterozygous parent and because parents' traits pass unchanged to their offspring, the offspring are also heterozygous.
- White fur rabbits must have ancestors with white coloration in their traits. The trait for white fur (unexpressed when passed by parents), is more powerful than the Himalayan fur traits so it shows up in offspring.
- Offspring must have two copies of the white allele. Himalayan offspring may have an unexpressed white allele. Offspring get one allele from each heterozygous parent (they carry the dominant and recessive gene). †
- Offspring get alleles from each homozygous parent. When the gene was passed from parents to offspring, there was a mutation in the fur color gene that produced white fur instead. This is why the rabbit is white.

* indicates correct response

6. Natural Selection

The graph below depicts changes to a mosquito population after DDT, an insecticide, was sprayed on an island over a period of several months. Scientists have determined that some mosquitoes are DDT resistant and others are not. Measurements of the number of mosquitoes on the island every 50 days resulted in the information shown in the graph. Considering this information, explain the concept of natural selection and how it can be used to explain why the population declined and then rebounded.



6.1 For *natural selection* to occur, which of the following **must** be present?

- More offspring are produced than can survive and some have a more beneficial trait for reproduction.*
- During their lifetime variation arises within individual organisms in response to an event.
- An event must cause the need for a new genetic trait to emerge that will make some organisms stronger.
- Variation in a trait or a characteristic is often present with at least three different forms.

6.2 Use your knowledge of *natural selection* to choose the **best explanation** for the changes in the mosquito population. The mosquito population declined and then rebounded because...

- mosquitoes adapted when they needed to in response to added DDT.
- the strongest mosquitoes on the island survived in response to DDT.
- new, more successful mosquitoes were created after sudden change (DDT).
- some mosquitoes successfully reproduced while others do not in response to DDT. *

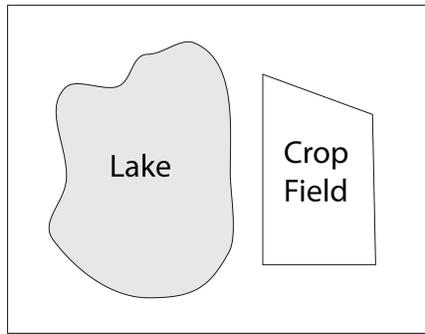
6.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (6.2)? Natural selection **explains** the change in the mosquito population when DDT was sprayed because DDT killed...

- all non-resistance mosquitos. The remaining mosquitoes needed to adapt and developed resistance resulting in a DDT resistant population after the mosquitoes reproduced.
- some non-resistant mosquitoes. Resistant mosquitoes migrated to the area and the population increased to one that was DDT resistant.
- some non-resistant mosquitoes. The remaining non-resistant mosquitoes learned to adapt allowing the population to increase.
- some non-resistant mosquitoes. The original population had variation in their resistance and over time DDT resistance mosquitoes reproduced and the population increased. *

* indicates correct response

+ "Bi If]Ybh7 nW]b[

Recently, a farmer sprayed nitrogen- and phosphorus-rich fertilizer on their field to increase crop growth. For the past few months, the fish and plants in the lake next to the field have died while algae on the surface of the lake has grown. Scientists think nutrient cycling contributed to these changes.



7.1 Which of the statements below **VYgh** describes } ~ dā} c&^ &ā * Ñ

- An ecosystem experiences little to no change when nutrients are added or taken away.
- Nutrients move through living and nonliving things in an ecosystem through different chemical processes. †
- Only nonliving things in an ecosystem change in response to the addition of nutrients.
- When an organism dies in an ecosystem, another organism gets their nutrients by consuming their body.

7.2 Use your knowledge of } ~ dā} c&^ &ā * to select the **VYghYI d'UbU]cb** for the changes that occurred in the lake.

- Changes to nutrient composition within an ecosystem alter the diversity of organisms in that system. †
- When dangerous nutrients entered the lake, they destroyed the lake and killed the fish and plants.
- When animals in an ecosystem die because of pollution other species try to get their nutrients.
- Plants and animals must adapt to nutrient composition changes within an ecosystem to survive.

7.3 Which of the following **VYghXYgW]VYg** your **fYUgcb]b[** for the choice you made in the previous question (7.2)? Changes in the lake happened because...

- the fish and plants died when they were not able to adapt to the nutrient changes that occurred when the fertilizer was added. The algae in the lake adapted and grew.
- the fertilizer that washed into the lake increased algal growth on the water's surface. This reduced oxygen and light levels available to fish and plants, killing them. †
- the fertilizer from the field washed into the lake after it rained, killing the fish and plants in the lake. The algae were resistant to the fertilizer and survived.
- the addition of fertilizer resulted in more and different nutrients. The lake organisms competed for these nutrients, killing some organisms and allowing others to live.

* indicates correct response

8. Cell Theory

For many years, biologists have questioned whether or not a virus is a cell. To answer this question, scientists first refer to cell theory to understand the characteristics of a cell. Then, they consider the characteristics of viruses: Viruses share certain characteristics such as an inner core of RNA or DNA surrounded by an outer coating. Larger viruses (pictured) have an additional surrounding layer that is composed of many components that make up the cell membrane. Unlike a cell, a virus cannot replicate without first entering a “host” cell.



CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=1653285>

8.1 Select the answer that **best** describes *cell theory*.

- All new cells arise from existing cells; Cells are the basic unit for life. *
- All cells must reproduce themselves; All cells divide to create two new cells.
- All cells must reproduce themselves; All cells must contain a nucleic acid.
- All new cells arise from existing cells; Cells are complex and adaptable.

8.2 Use your knowledge of *cell theory* to select the **best explanation** for why a virus is or is not a cell. A virus...

- IS a cell because it reproduces and lives in other cells.
- IS NOT a cell because it cannot reproduce without a host cell and does not come directly from other viruses. *
- IS NOT a cell because it does not need all the requirements for life, including nutrients and water.
- IS a cell because it contains genetic information and comes from existing cells.

8.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (8.2)? A virus is or is not a cell because...

- cells are the basic structural unit of all living things and viruses have many of the same structures, like membranes and nucleic acids.
- all living things are made of cells, but no living things are made of viruses.
- all cells and viruses reproduce, just not in the same way. Cell theory does not say reproduction has to happen in a certain way.
- all new cells arise from existing cells and viruses require a different cell to act as a ‘host’, rather than reproducing on their own. *

* indicates correct response

- "D\ chcgmb\ Yg]g

Four test tubes are filled with 50 ml of spring water and 3 ml of Bromothymol Blue (BTB). BTB is an indirect indicator of Carbon Dioxide (CO₂). It changes from blue to green to yellow as CO₂ lowers the pH of a solution. A change to yellow indicates a larger quantity of CO₂ than a change to green (Figure 1). Items were then added to each test tube and observed for five hours (Table 1).



Figure 1. Color scale for CO₂ levels

	Content	0 hours	5 hours
Tube 1	1 Sprig of elodea (a water plant)	 Blue-Green	 Blue
Tube 2	1 Water snail	 Blue-Green	 Yellow
Tube 3	1 Sprig of elodea 1 Water snail	 Blue-Green	 Green

Note: Tube 4, the control, is not shown.

Table 1. Data table

9.1 Which of the following statements **VYghXYgW]VYg** the]!| &••Ā Ā @q • ^} c@•ā?

- A process that creates energy for plants using sugar, CO₂, and H₂O by breaking these molecules down in the cytoplasm of a cell.
- A process that uses sunlight and CO₂ to create sugar and O₂ and takes place in special organelles called chloroplasts. †
- A process that uses sunlight to create energy and H₂O and also causes a color change in plants.
- A process that occurs in plant cells that creates protein building blocks for other organelles using energy from sunlight and the soil.

* indicates correct response

9.2 Use your knowledge of photosynthesis to select the correct combination of the observed color changes found inside the various test tubes (provided at the bottom of the picture).



- | | | | |
|----------------------------------|--|---|---|
| <input type="radio"/> | Less O ₂ present due to no photosynthesis by elodea | No photosynthesis happening | Photosynthesis happening that produces more O ₂ than CO ₂ |
| <input type="radio"/> | Less CO ₂ due to plant photosynthesis | Less O ₂ due to lack of photosynthesis | Balance CO ₂ and O ₂ due to presence of elodea and snail |
| <input checked="" type="radio"/> | Less CO ₂ due to plant photosynthesis | More CO ₂ due to no snail photosynthesis | Some CO ₂ but photosynthesis using CO ₂ |
| <input type="radio"/> | Elodea uses light energy and photosynthesis to produce CO ₂ | More CO ₂ due to no snail photosynthesis | Some CO ₂ but photosynthesis using CO ₂ |

9.3 Which of the following best explains your choice for the choice you made in the previous question (5.2)? The water color changes because...

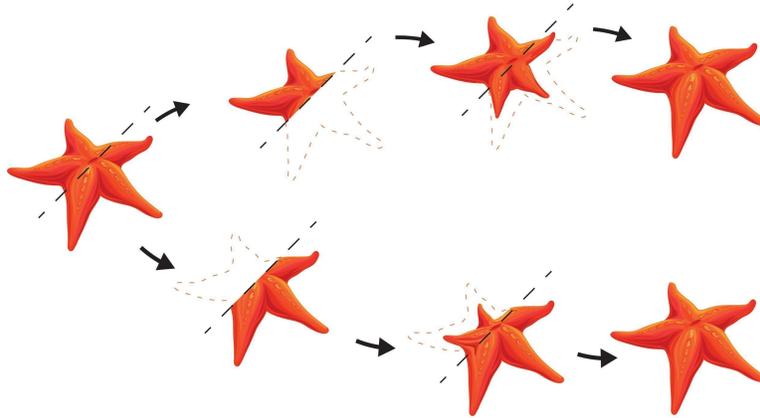
- the water changes color as more CO₂ is produced by photosynthesis, which lowers the pH and causes the color change.
- the water stays bluer and greener when photosynthesis is present because the process uses CO₂, which means less is present to lower the pH. *
- as photosynthesis happens in the tubes, the amount of light absorbed by the organisms lowers the pH to cause the color change.
- the more plants present, the more photosynthesis would occur, which would lead to more color changes in the test tube.

* indicates correct response

10. Mitosis

Sea stars prey on abalone, a type of mollusk. Humans who harvest abalone must compete with sea stars for the shellfish delicacies. At one time it was common practice for abalone fisherman to try to reduce the number of sea stars by catching them, cutting them up, and dumping them back into the sea.

In this process, the fishermen inadvertently increased the number of sea stars because they can reproduce asexually. For instance, if the arm breaks off or is cut off and has a portion of the central ring, the sea star not only regenerates the arm, but the arm can grow into an entirely new animal. This asexual reproduction is accomplished through mitosis. Scientists have labeled these sea stars as clones of one another (clones are considered to be genetically identical copies of each other)..



10.1 Which of the following **best describes** the process of *mitosis*? *Mitosis* is...

- the process of genetic regeneration that produces two identical daughter cells.
- a regulated process in which cells die and more are made to replace the old ones.
- the process when cells with some of the same DNA and chromosomes copy themselves.
- a regulated process of cell division that produces two identical daughter cells. *

10.2 Use your understanding of *mitosis* to choose the **best explanation** for why these starfish are considered to be clones. Starfish are considered clones because they reproduce which requires...

- production of four identical organisms and clones look the same and have the same function. Therefore, starfish are clones because they are exact copies.
- duplication of cells coming from one thing and then growing into another of the same thing that have exact copies of the former cells with the same DNA.
- duplication of genetic material which is identical to the original cells. When cells divide, each new cell gets copies of the genetic material from the original cell. *
- replacement of missing body parts that grow back, which scientists call clones because these new body parts are copies of the old ones.

10.3 Which of the following **best describes** your **reasoning** for the choice you made in the previous question (10.2)? Starfish use cellular division to...

- signal cells to divide into two parts to fill empty spaces in the body and create new body parts.
- as the mechanism for growth, tissue regeneration, dead cell replacement, and wound healing. *
- repair and regenerate pieces of cells which break off and divide the cells around it.
- support replication in organisms by producing a mass of diploid cells after fertilization.

* indicates correct response