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Adapting to the Environment

HASPI Medical Biology Lab 24

Background/Introduction

Adapting to the Environment

Changes in the physical environment, whether naturally occurring or human-induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. When the environment changes, living organisms with **adaptations** best suited to the new environment will survive and reproduce. Adaptations can be behavioral, physiological, or anatomical.

Behavioral Adaptations

Behavioral adaptations could occur through increases in intelligence, communication, highly developed social structure, or behavioral patterns. The following are only a few examples of behavioral adaptations.

Adaptation	Description	Example
Language	Communication through sounds and gestures allows organisms to communicate things such as danger and food sources between members of the same species.	The Vervet monkey is native to Africa and is capable of communicating different sounds to warn each other of specific predators. For example, the warning call about leopards is different than the call for snakes. http://www.mpushini-fauna.com/resources/Vervet.jpg 
Learning	The process of observing and picking up new skills from others in the same species.	In Punta Norte, Argentina, a specific pod of killer whales hunts seals by beaching themselves. No other killer whales in the world hunt the same way. http://www.abc.net.au/reslib/200804/r241681_980802.jpg 
Symbiosis	A relationship that is established between individuals from different species. The relationship could be parasitic, mutualistic, or commensalistic.	The clown fish and sea anemone have a mutualistic relationship. The clown fish receives protection from the anemone's sting, while the anemone receives protection from the clown fish, which chases off fish that may try to feed on the anemone. http://www.redorbit.com/media/uploads/2013/02/science-022813-003-617x416.jpg 
Colonial Living	Individuals in the same species live closely to one another in large groups. This behavior provides many advantages, the largest of which is protection.	The meerkat is a small mammal that lives in Africa. Meerkats live in large colonies and share responsibilities for colony protection, food collection, and raising offspring. http://www.southafrica.net/uploads/blog/1.jpg 

Physiological Adaptations

Physiological adaptations can impact functions and processes within an organism. There are a large variety of physiological adaptations including the ability to regulate temperature or the ability to digest a particular food source. The following are only a few examples of physiological adaptations.

Adaptation	Description	Example
Toxic	Organisms that produce a toxin that tastes bad or is poisonous to predators. Many organisms that are toxic also display bright warning colors.	The rough-skinned newt native to North America produces a toxin that makes it poisonous to predators. One newt produces enough poison to kill an adult human. http://onh.eugraph.com/herps/rsnewt/15480405.jpg 

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Adaptation	Description	Example
Venomous	Organisms with venom are capable of injecting toxins into their victims through stinging, biting, or scratching. The venom is used to incapacitate prey, or as a defense.	There are 32 species of rattlesnakes throughout the world. Rattlesnakes are capable of injecting hemotoxic venom through hollow fangs. Rattlesnakes bite to subdue prey or when threatened.  http://www.arizona-leisure.com/gfx/venomous-rattlesnake.jpg
Herbivorous	Organisms capable of surviving completely on plant life. Some organisms require a specific plant source, while others can consume a variety of plants.	The koala is native to Australia, and its diet primarily consists of leaves from the eucalyptus tree. Eucalyptus leaves are indigestible by most mammals, but the koala has adapted to consume them.  http://www.chm.bris.ac.uk/motm/cineole/koala-eating.jpg
Temperature Tolerant	Organisms have developed physiological and anatomical adaptations to survive in extremely cold and hot environments.	Polar bears can be found in the Arctic Circle where temperatures are as low as -50° C in the winter. Polar bears have adapted to live in this extremely cold environment, and can actually overheat in temperatures above 10° C.  http://nelsonndhs.org/Per2_Fall_2010/Arctic%20Animals/Assets/724polar_bear.jpg

Anatomical Adaptations

Anatomical adaptations change the physical structure of an organism. There are a large variety of anatomical adaptations including changes in feeding structures, locomotion, or reproductive organs. The following are only a few examples of anatomical adaptations.

Adaptation	Description	Example
Flight	Flight is the ability of an organism to move through the air. Flight can be used to migrate between environments, hunt prey, or evade for predation.	Bats are mammals that have adapted to flight. Unlike birds that developed feathers, the bat's forelimbs developed into webbed wings capable of holding this small mammal in sustained flight.  http://seaandsageaudubon.org/BatInformation/batsyumagrande.jpg
Egg Laying	Egg laying allows species to produce offspring that virtually have their own life support system, and require little to no additional support from the parent.	Birds, reptiles, amphibians, fish, insects, and even a few species of mammals developed the ability to lay eggs outside of their body. Some species can lay thousands of eggs at a time to increase the chance of species survival.  http://incubatorwarehouse.com/media//chick-hatching.jpg
Camouflage	Camouflage allows an organism to blend in to its surroundings. Camouflage is used most commonly by a predator to stay hidden from prey, and for prey to stay hidden from a predator.	The arctic hare is native to polar regions. It has the ability to grow a white coat during fall and winter months, and a brown coat during spring and summer months to blend in with the environment.  http://bioexpedition.com/wp-content/uploads/2012/04/Arctic-Hare.jpg
Hermaphroditic	Organisms that have both female and male sex organs are considered hermaphrodites. Some species are capable of changing their sex in response to environmental pressure.	Earthworms contain both male and female sex organs. They still need a mate to reproduce, but are capable of producing sperm and mating as a male, or producing eggs and mating as a female.  http://english-tonight.com/wp-content/uploads/2013/11/Earthworm1.jpg

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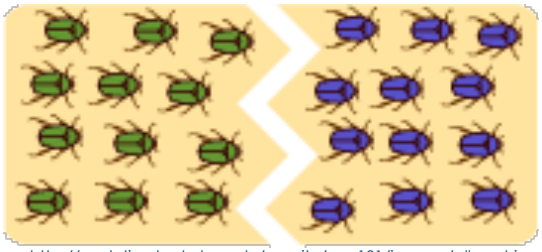
Speciation

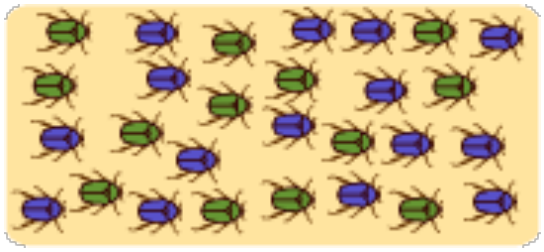
A **species** is defined as a group of organisms that are capable of interbreeding. For example, although most dog breeds look very different, they are capable of interbreeding and so belong to the same species, *Canis lupus familiaris*. When members of the same species become so different, or **diverge** from one another, that they are no longer capable of interbreeding, they are now considered a different species. This is called **speciation**. Speciation can be caused by:

- **Geographic Isolation**
  Populations of the same species are prevented from interbreeding by some type of geographic barrier. For example, a mountain range, body of water, or large chasm could separate the populations. These separate populations will continue to evolve and adapt within their own environments and may become different enough that they become different species. This is also called **allopatric speciation**.



http://evolution.berkeley.edu/evosite/evo101/images/allopatric_beetles.gif

- **Behavioral, Sexual, and Gametic Isolation**
  There may be no specific barrier to interbreeding between populations, but mating between populations of the same species may be limited or non-existent due to a difference in behavior, incompatibilities of sex organs, or an issue with gamete (sperm and egg) fertilization. The lack of random mating may create different frequencies of genes in response to environmental pressures. Over long periods of time this could lead to speciation. Speciation within populations not separated by geographical barriers would be considered **sympatric speciation**.

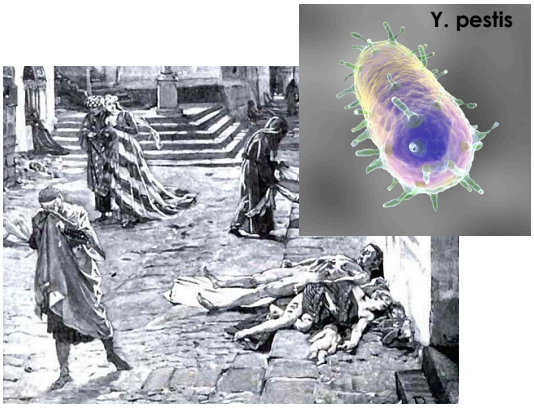


http://evolution.berkeley.edu/evosite/evo101/images/allopatric_beetles.gif

Extinction

Extinction is the disappearance of an entire species. When a species goes extinct, all of the genetic variation that the species contained no longer survives, and will not be reproduced again. A species becomes extinct when it is unable to adapt with changes to its environment. This could be through natural environmental changes, such as temperature change over time or volcanic eruption. Extinction could also be caused by human actions, for example overhunting or habitat destruction. It is estimated that 99.9% of all the species that have ever existed on Earth are now extinct.

While in general we view extinction as a negative event, in some cases it can actually benefit humans. For example, the bacterium that caused the Bubonic Plague, called *Yersinia pestis*, is now believed to be extinct. *Y. pestis* killed millions of people during the mid-14th century and was transferred by vectors, such as fleas, or in some cases was airborne.



http://i1-news.softpedia-static.com/images/news2/Bubonic-Plague-Kills-Teenager-in-Kyrgyzstan-378567-2.jpg
http://thecripplegate.com/wp-content/uploads/2012/02/the_plague.jpg

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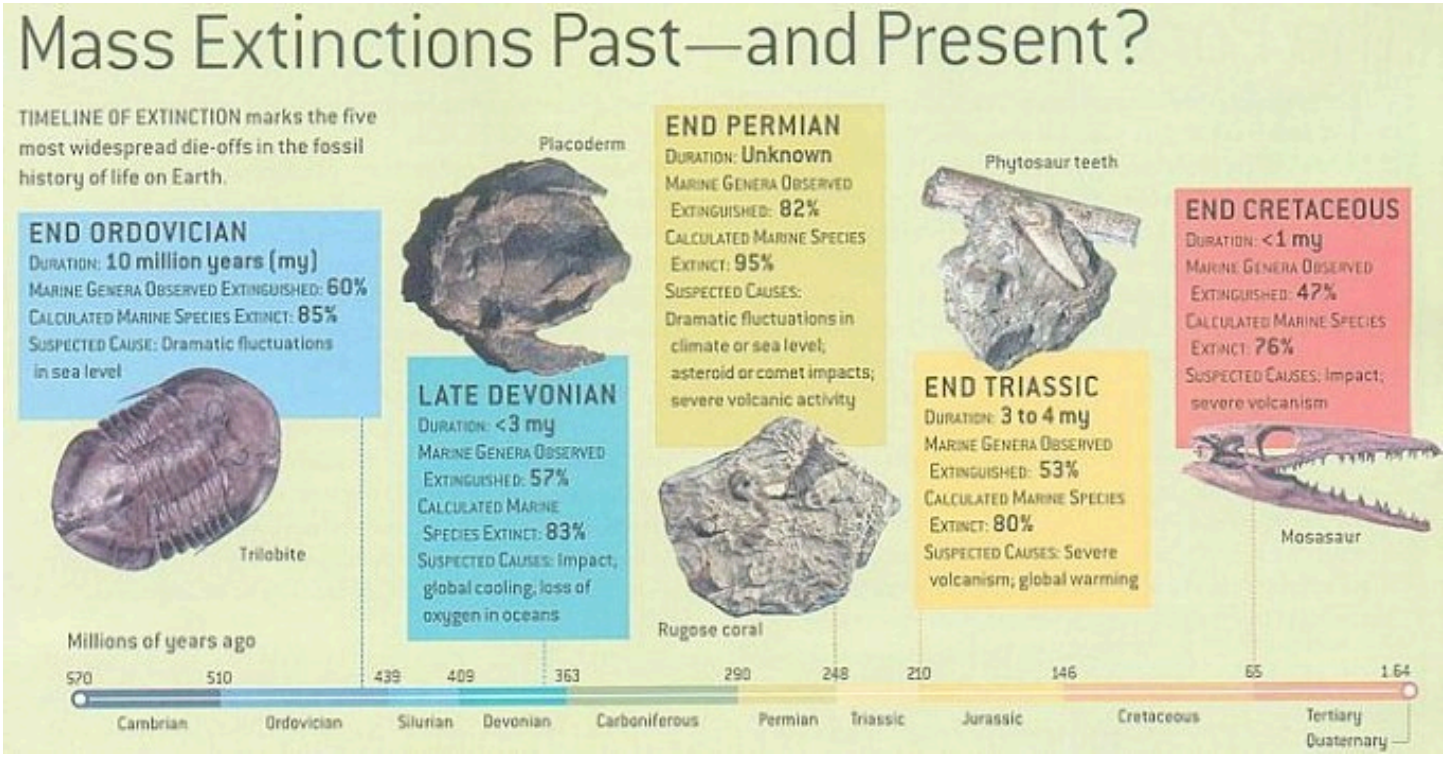
At several points in Earth's history, there have been large-scale environmental changes that have led to mass extinctions. A **mass extinction** occurs when multiple species become extinct during a short amount of time. These mass extinctions may have been caused by a drastic shift in weather, volcanic eruptions, or by a meteor strike. Some researchers believe that Earth is currently in the midst of a mass extinction, as extinction rates are higher now than they have ever been in human history. These researchers estimate that 50% of all animal and plant species that currently exist will be extinct by 2100.



http://ottawa-rasc.ca/wiki/images/c/c3/Odale_extinction.jpg

Review Questions – *answer questions on a separate sheet of paper*

1. How do changes in the environment affect the species that live there?
2. The Northern Spotted Owl makes its home in old-growth forest of the Northwest. If deforestation clears 95% of the old-growth trees, what would you hypothesize could happen to the Northern Spotted Owl?
3. What is an adaptation? Give an example.
4. "Adaptations develop in response to environmental changes. For example, if a human population was displaced into the ocean, eventually the individuals would develop gills and fins to survive in the water." Is this statement true or false? Explain your answer.
5. What are behavioral adaptations? Give an example.
6. What are physiological adaptations? Give an example.
7. What are anatomical adaptations? Give an example.
8. What is speciation?
9. What is the difference between allopatric and sympatric speciation?
10. What is extinction? What can cause extinction?
11. Explain how, in some cases, extinction could be beneficial to humans. Provide an example.
12. What is mass extinction? How many mass extinctions do scientists estimate have occurred?

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Scenario

In this activity, your class will simulate the impact of the environment on directing the increase or decrease of adaptations. The environmental condition being used is the collection of food, and the adaptation is the shape of the human hand. Each round of the simulation represents a new generation of individuals in the population. Assume that each generation is separated by approximately 20-25 years, so the entire simulation occurs over 100 -125 years. Over six rounds, the simulated population will collect the food source and live, reproduce, or die based on how well its adaptation allows it to collect food.

Materials

Masking tape
Plastic cup
Paper towels
Rice
Lima beans
Popcorn

Procedure/Directions

Your lab team will be given tasks, or directions, to perform on the left. Record your questions, observations, or required response to each task on the right.

Part A. A New Environment

	Task	Response
1	You are part of a small population whose boat has been washed to a small island in the South Pacific. The only food source is large lima beans. Individuals who are unable to collect adequate amounts of lima beans from their pods are unable to survive and reproduce. Any genes they contain will not be passed to future generations.	
2	Obtain a cup and paper towel. Place 10 lima beans in the bottom of your cup.	**All Thumbs**  **Thumb-less** 
3	Your instructor will choose 4 individuals in the class to represent the original population.	
4	There are four traits, or adaptations, for hand shape in this population. Each member has a different trait for the shape of his or her hand. With masking tape, form the following hand shapes with one hand of each of the 4 chosen individuals (see images): • **All Thumbs** – tape together all fingers EXCEPT the thumb • **Thumb-less** – tape the thumb to the hand and leave all other fingers free • **Di-finger** – tape the middle, ring, and pinky fingers together. Also tape the index finger and thumb together. • **Tri-finger** – tape the ring and pinky fingers together. Tape the middle and index fingers together. Leave the thumb free.	**Di-finger**  **Tri-finger** 

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5	The individuals with unique hand shapes should stand next to their cups. When the instructor says "GO," each individual will have 10 seconds to attempt to collect lima beans from the cup.
6	These individuals can only collect lima beans ONE AT A TIME and place them on a paper towel. They can only use the "modified" hand, and not the free hand.
7	After 10 seconds, the instructor will say "STOP." Each individual will count how many lima beans were collected onto the paper towel.
8	Each individual must collect at least 5 lima beans to survive and reproduce. • If an individual DID NOT collect 5 lima beans, he or she "dies" (can assume the life of an offspring in later round). • If an individual DID collect at least 5 lima beans, he/she can "reproduce" one offspring (same hand shape).
9	Your instructor will ask those individuals who collected at least 5 lima beans to raise their hands, and will record the number of individuals who survived for each hand shape on the board for Round 1.

Table 1. A New Environment: Lima Bean Food Source

Record the number of individuals who survived and reproduced after each round, for each hand type.

Generation:	All Thumbs	Thumb-less	Di-finger	Tri-finger
Round 1				
Round 2				
Round 3				
Round 4				
Round 5				
Round 6				

10	Copy the number of individuals that survived Round 1 for each hand shape in Table 1.
11	Choose individuals to represent any offspring that were created, and use masking tape to create the same hand shape as the parent.
12	Repeat steps 5-11, collecting and recording information for Round 2.
13	Repeat steps 5-11, collecting and recording information for Round 3.
14	Repeat steps 5-11, collecting and recording information for Round 4.
15	Repeat steps 5-11, collecting and recording information for Round 5.
16	Repeat steps 5-11, collecting and recording information for Round 6.
17	Return all lima beans to the bag from which you obtained them. Keep the cup.

Part B. A Catastrophic Event

Task	Response
1	Your small island was actually a volcano that suddenly erupted! Only a few individuals were able to escape on a raft. After several days, your raft reaches a desert-like mainland. The only food source is a small white worm, called the rice worm. Individuals who are unable to collect adequate amounts of rice worm are unable to survive and reproduce. Any genes they contain will not be passed to future generations.
2	Place 20 rice worms in the bottom of your cup.
3	Your instructor will choose 4 individuals in the class to represent the original population.

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4	There are four traits, or adaptations, for hand shape in this population. Each member has a different trait for the shape of his or her hand. With masking tape, form one hand of each of the chosen individuals into the following hand shapes (similar to Part A): • **All Thumbs** – tape together all fingers EXCEPT the thumb • **Thumb-less** – tape the thumb to the hand and leave all other fingers free • **Di-finger** – tape the middle, ring, and pinky fingers together. Also tape the index finger and thumb together. • **Tri-finger** – tape the ring and pinky fingers together. Tape the middle and index fingers together. Leave the thumb free.
5	The individuals with unique hand shapes should stand next to their cups. When the instructor says "GO," each individual will have 20 seconds to attempt to collect rice worms from his or her cup.
6	These individuals can only collect rice worms ONE AT A TIME and place them on the paper towel. They can only use the "modified" hand, and not the free hand.
7	After 10 seconds, the instructor will say "STOP." Each individual counts the rice worms that were collected on the towel.
8	Each individual must collect at least 10 rice worms to survive and reproduce. • If an individual DID NOT collect 10 rice worms, he/she dies and can assume the life of offspring in a later round. • If an individual DID collect at least 10 rice worms, he/she reproduces one offspring with the same hand shape.
9	Your instructor will ask those individuals who collected at least 10 rice worms to raise their hands, and records the number of individuals who survived for each hand shape on the board for Round 1.
10	Copy the number of individuals that survived Round 1 for each hand shape in Table 2.
11	Choose individuals to represent any offspring that were created, and use masking tape to create the same hand shape as the parent.
12	Repeat steps 5-11, collecting and recording information for Round 2.
13	Repeat steps 5-11, collecting and recording information for Round 3.
14	Repeat steps 5-11, collecting and recording information for Round 4.
15	Repeat steps 5-11, collecting and recording information for Round 5.
16	Repeat steps 5-11, collecting and recording information for Round 6.
17	Return all rice grains to the bag from which you obtained them. Keep the cup.

Table 2. A Catastrophic Event: Rice Worm Food Source

Record the number of individuals that survived and reproduced after each round, for each hand type.

Generation:	All Thumbs	Thumb-less	Di-finger	Tri-finger
Round 1				
Round 2				
Round 3				
Round 4				
Round 5				
Round 6				

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Part C. Migration to Greener Pastures

	Task	Response
1	A small group from your population is tired of living off rice worms! It is time for you to find out if there is more "out there," and you have decided to travel over the mountains looking for a better life. Your group has found a beautiful valley full of fruit trees. The only food produced by the trees is a puffy white fruit that you call poppies. Individuals who are unable to collect adequate amounts of poppies are unable to survive and reproduce. Any genes they contain will not be passed to future generations.	
2	Place 10 whole popcorn pieces in the bottom of your cup.	
3	Your instructor will choose 4 individuals in the class to represent the original population.	
4	There are four traits, or adaptations, for hand shape in this population. Each member has a different trait for the shape of his or her hand. With masking tape, form one hand of each of the chosen individuals into the following hand shapes (similar to Parts A and B): • **All Thumbs** – tape together all fingers EXCEPT the thumb • **Thumb-less** – tape the thumb to the hand and leave all other fingers free • **Di-finger** – tape the middle, ring, and pinky fingers together. Also tape the index finger and thumb together. • **Tri-finger** – tape the ring and pinky fingers together. Tape the middle and index fingers together. Leave the thumb free.	
5	The individuals with unique hand shapes should stand next to their cups. When the instructor says "GO," each individual will have 10 seconds to attempt to collect poppies from his or her cup.	
6	The individuals can only collect poppies ONE AT A TIME and place them on their paper towels. They can only use the "modified" hand, and not the free hand.	
7	After 10 seconds, the instructor will say "STOP." Each individual counts the poppies collected. The poppies must contain the kernel to count (no tiny pieces of popcorn count)!	
8	Each individual must collect at least 5 poppies to survive and reproduce. • If an individual DID NOT collect 5 poppies, he/she dies and can assume the life of offspring in a later round. • If an individual DID collect at least 5 poppies, he/she can reproduce one offspring with the same hand shape.	
9	Your instructor will ask those individuals who collected at least 5 poppies to raise their hands, and records the number of individuals who survived for each hand shape on the board for Round 1.	

Table 3. Migration to Greener Pastures: Poppies Food Source

Record the number of individuals that survived and reproduced after each round, for each hand type.

Generation:	All Thumbs	Thumb-less	Di-finger	Tri-finger
Round 1				
Round 2				
Round 3				
Round 4				
Round 5				
Round 6				

Name(s):	Period:	Date:

10	Copy the number of individuals that survived Round 1 for each hand shape in Table 3.
11	Choose individuals to represent any offspring that were created, and use masking tape to create the same hand shape as the parent.
12	Repeat steps 5-11, collecting and recording information for Round 2.
13	Repeat steps 5-11, collecting and recording information for Round 3.
14	Repeat steps 5-11, collecting and recording information for Round 4.
15	Repeat steps 5-11, collecting and recording information for Round 5.
16	Repeat steps 5-11, collecting and recording information for Round 6.
17	Return all popcorn pieces to the bag from which you obtained them. Return the cups.

Analysis & Interpretation

Analysis Questions – *answer questions on a separate sheet of paper*

1. What four hand shape variations existed in the populations?
2. Did these hand variations develop in response to environmental changes, or did they already exist and simply make the individuals better or more ill-suited to survive and reproduce? Explain your answer.
3. Which hand shape was better suited to collect lima beans? Why do you think this hand shape was best suited?
4. Which hand shape was better suited to collect rice worms? Why do you think this hand shape was best suited?
5. Which hand shape was better suited to collect poppies? Why do you think this hand shape was best suited?
6. Did the hand shapes that were least effective at collecting food disappear from the population completely? Explain your answer.
7. Explain how speciation could occur in these populations after many generations.

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Connections & Applications

Your instructor may assign or allow you to choose any of the following activities. As per NGSS/CCSS, these extensions allow students to explore outside activities recommended by the standards.

1. **EVALUATE THE EVIDENCE:** In science, it is important to evaluate experiment results and evidence supporting claims before accepting information as fact. One of these claims is that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

   Using the Internet, research the following evidences to determine whether the claim is supported. Provide a 1-2 paragraph summary of the evidence followed by your analysis of whether the evidence supports or refutes the claim. Provide reference information for all of your research.
   a. 1) Environmental changes caused by urbanization and globalization have resulted in an increase of infectious disease species such as tuberculosis.
   b. 2) New strains of *E. coli* bacteria living in the human gastrointestinal tract have emerged due to changes in diet over the past 100 years.
   c. 3) The polio virus is now extinct due to the widespread use of the polio vaccine.

2. **SUPPORTING OR REFUTING AN ARGUMENT WITH EVIDENCE:** Evaluating the evidence behind currently accepted explanations or solutions to determine the merits of arguments is an important skill in science, and in life. Use research to evaluate the following statement. Formulate a 4-5 minute speech to support or refute the statement. Use a minimum of 3 researched evidences in your argument (make a notation of all references used in case they are needed again). Your speech may be presented in front of the class or only for your instructor.

"Within the next twenty years, humans will have the means to completely eradicate organisms that cause infectious disease through the use of vaccinations and antibiotics."

3. **CALCULATING EXTINCTION RATES:** How quickly are organisms on Earth going extinct? Researchers have estimated the natural, or background, extinction rate to be 0.01 - 0.1% of species every year. Unfortunately, this prediction does not take into account human influence. Current, actual extinction rates consider how humans have impacted extinction rates, and vary depending on the environment and extent of human influence. Use the information provided to answer the following questions:

   a. The background extinction rate is 0.01-0.1% of species every year. Current predictions estimate there are 8.7 million species that exist on Earth. How many species should go extinct each year according to the background extinction rate? (Show your work.)

   b. It is estimated that 20,000 species will become extinct within the next year. What percentage of species will possibly be extinct in the next year? How does this number compare to the background extinction rate? (Show your work.)

c. At certain points in the Earth's history, evidence of several mass extinctions have occurred. The Devonian period was approximately 360 million years ago (mya). Researchers estimate that 30% of all animal species went extinct during this time, and 1.2 million animal species existed in that period. How many animal species actually went extinct during the Devonian period? (Show your work.)

d. The Cretaceous period was approximately 65 mya. If 2.3 million animal species existed, and 1.38 million went extinct, what percent of animal species went extinct? (Show your work.)

e. Some researchers estimate that 40-50% of all current species on Earth will be extinct by 2050. Using the current estimate of 8.7 million species, how many species could be extinct by 2050? (Show your work.)

f. In a 2012 U.S. endangerment poll, it was determined that out of 1,880 endangered species, 85% are endangered by habitat degradation, 49% are endangered by invasive species, 24% are endangered by pollution, and 17% are endangered by overexploitation. Using these percentages, determine the actual quantity of species impacted. (Show your work.)

Resources & References

- Holsinger, K.E. 2013. Patterns of Biological Extinction. Creative Commons.
- BBC. 2013. Animal and Plant Adaptations and Behaviours. www.bbc.co.uk.

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