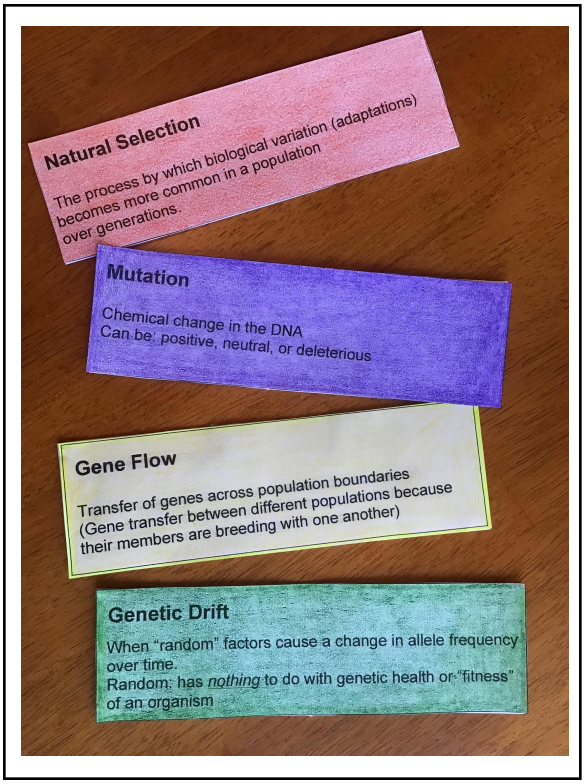
Evolutionary Detectives

Format: In-person or online



Cards of various colors help students to identify which forces of evolution are occurring - and the instructor can quickly tell where clarification is needed.

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Time needed: 60-90 minutes

Learning Objectives

- Distinguish between the different forces of evolution
- Identify which force(s) of evolution are at work in a given scenario
- Observe how multiple forces of evolution may work together to cause change in a population

Supplies Needed

- Forces of evolution cards (included). Each force should be printed on paper of a different color.
- Student worksheet with case studies (included)

Readings

- Alveshere, Andrea J. 2019. Chapter 4: Forces of Evolution. *Explorations.*

Introduction

In this activity, students will be reading short case studies and identifying what forces of evolution are at work, and how those forces work together to cause change in a population. This activity also utilizes colored “forces of evolution” cards so that groups can visually report their answers at the end of the activity.

Steps

- Students should be divided into small groups (of two to three).
- Each group should be given one set of four evolutionary forces cards (each card is a different color) and copies of the student worksheet with case studies and questions.
- Students will work through the case studies, using the evolutionary forces cards to help them differentiate between the forces. They will develop narratives that identify and explain which forces are operating in each case study, and record their answers on the student worksheet.

Conclusion

Talk through the case studies as a class, one case study at a time. Allow students time to work through the case study as a group and decide what forces are operating.

After groups work through a case study the instructor can ask, “What forces are operating? Hold up your cards!”. At that point the cards typically create a sea of purple, orange, etc. The colors help the instructor identify who is having trouble, and class-wide discussion can help identify why.

A class-wide discussion that explains why specific forces are operating in this case study, and why other forces are not operating, will help clarify for students the differences between the different “forces”. For instance, students often have difficulty distinguishing between gene flow/admixture and genetic drift. Clarifying that the founder effect (a type of genetic drift) involves a situation where organisms migrate to a new place and find no other organisms of their own species in that new place that they can mate with, helps students to understand the difference between genetic drift and gene flow. The organisms that migrate to that new place have no choice but to mate only amongst each other. This is different from gene flow, where alleles are carried by new migrants into a population of already existing organisms of that same species, and interbreeding occurs.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Students could be provided the worksheets to do this activity individually for submission, or given an electronic version of the colored forces of evolution cards and case studies (e.g. in Google Slides) and asked to complete the activity in small groups during a synchronous activity time.

Tips and Suggestions

I recommend making the gene flow and the genetic drift cards strikingly different colors as these two concepts are frequently confused by students.

Be sure to welcome all ideas and explain that this is a difficult activity, or else students will be shy about holding up the cards that correspond with their genuine thoughts about the case studies. What you do not want is for students to copy the majority decision because they are afraid to guess incorrectly! Normally, there are many “errors” in the forces that students identify. You want to encourage those “errors” and talk through why a case study involves some forces, but not other forces. Along the way you can clarify the differences between the “forces”. This should be very tricky for everyone involved - when a class does this perfectly, it signals to me that many are hiding that they are having trouble!

For Further Exploration

Andersen, Paul. Five Fingers of Evolution. TedEd Animation and Lesson. https://ed.ted.com/lessons/five-fingers-of-evolution

Andrews, Christine A. 2010. Natural Selection, Genetic Drift, and Gene Flow Do Not Act in Isolation in Natural Populations.*Nature Education Knowledge* 3(10):5 https://www.nature.com/scitable/knowledge/library/natural-selection-genetic-drift-and-gene-flow-15186648/

Sheehy, Bob. 2006-2020. Web PopGen II (Population Genetics Simulator). Radford University. https://www.radford.edu/~rsheehy/Gen_flash/popgen/

References

Alveshere, Andrea J. 2019. “Chapter 4: Forces of Evolution.” In *Explorations: An Open Invitation to Biological Anthropology,* edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Evolutionary Detectives

Introduction

Evolutionary biologists reconstruct evolutionary processes like detectives. They compare the frequency of alleles in a population over time, and use their understanding of evolutionary forces to work out what's happened to cause any shifts in allele frequencies. In this activity, you will do the same!

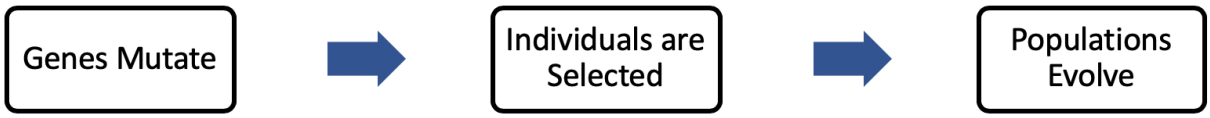
Change in a population over time is the result of any combination of the four "forces" of evolution. But which forces are occurring? We can figure this out by considering the order in which the "forces" typically occur, and work out a narrative - a story - by which this happens.

You can remember the forces of evolution as a sequence of stages:

Genes Mutate,

Individuals are Selected,

Populations Evolve.



Mutations are the only "force" of evolution that adds completely new variation to a population, so it comes first. The other "forces"- Natural Selection, Genetic Drift, and Gene Flow/Admixture - move this variation around in a population.

Instructions

For each of the following cases:

- Identify which forces of evolution are occurring,
- Identify if natural selection is present, and if so, how it is operating, and,
- Put this information into a coherent narrative (story) that explains how, exactly, evolution is taking place. For this step, you will need to identify the sequence by which the forces that you identified are actually occurring.

Quick Recap: Distinguishing Between the Forces

First, consider if the case study involves the introduction of new alleles - either through mutation, or through gene flow/admixture (the transfer of alleles between populations). New alleles means new traits, which can provide natural selection more variation to act upon.

If natural selection is occuring, then individuals with traits that are a better “fit” with the environment will be selected for, or favored. That means individuals with advantageous traits will have an easier time finding food, avoiding predators, surviving to reproductive age, and/or reproducing successfully and sending their traits (and the alleles that control those traits) into the next generation.

If genetic drift is occurring, we will see traits (and the alleles that control them) either increasing or decreasing in frequency, perhaps even being eliminated from a population, due to chance. This may correlate with events like natural disasters (floods, earthquakes, etc.), but also with events like overhunting by humans, or migration into a new area. With genetic drift there is no interaction between traits and the environment: it does not matter if the organism has traits that are a good “fit” with the environment. Those who survive and pass on their genes are the “lucky” ones, not the ones with the best traits.

Case #1: The Story of the Peppered Moth

In Great Britain, prior to the 1800s, most peppered moths had wings that were white with black specks. In 1848, a new 'species' was spotted: a completely black moth! By the 1950s, one hundred years later, more than 90% of moths were black.

1. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how individuals are selected, and how alleles shift over time.

Case #2: Sickle-Cell Anemia

As many as 20-30% of people living in equatorial Africa have at least one allele on Chromosome 11 that codes for sickle-cell anemia (they have an, “S” rather than an, “A” allele). This is odd because usually, 80% of people who have two S alleles die before they can reproduce - so why is the allele still around?

1. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #3: Lactase Persistence

Being able to digest lactose after the age of four is **common / uncommon** (circle one) around the world. 77% of European Americans and 14% of African Americans have the LCT gene on Chromosome 2, which codes to produce the enzyme lactase, which allows people to digest lactose in adulthood.

1. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #4: Founding the Colony of Zygozia

Let's pretend that there is a community called Zygozia. They say that they founded their small island colony in the South Pacific in 1959. When they arrived, there were no people living on the island, and so they became the only inhabitants. They came 'from the west', most likely Southeast Asia. The Zygozians of 2018 are unusual in that 80% of them have a rare genetic condition. Populations from Southeast Asia, whom the Zygozians descended from, only show this condition in 3% of their population. What happened?

1. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #5: Native Americans and Type O Blood

Modern Native Americans have very high frequencies of Type O blood. In some places in North and South America, the frequency is as high as 100%. Anthropologists believe that early Native Americans arrived in North America by crossing over the Bering Land Bridge around 15,000 years ago, from East Asia. Modern East Asian populations, with whom modern Native Americans share ancestry, do not have high frequencies of Type O blood. Instead, they have some of the lowest frequencies of Type O blood in the world.

1. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

2. Specifically, how is natural selection involved?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #6: Malaria in the Tropical Americas

Today, malaria appears throughout the tropical Americas. However, Native American populations only have “normal” hemoglobin (they are 100% homozygous for normal alleles and do not have any hemoglobin variations that protect them from malaria, as is seen in human populations in Africa, Asia and Europe). Why do Native Americans not exhibit any genetic diseases that make them better able to survive malaria?

4. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

5. Specifically, how is natural selection involved?

6. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #7: Skin Color Around the World

Around the world, populations near to the equator and in areas of high altitude have darker skin (their skin produces more melanin). Populations at northern latitudes have lighter skin- their skin produces less melanin.

1. What forces of evolution are at work? Tick all that apply.

   ___ Mutation

   ___ Natural Selection

   ___ Genetic Drift

   ___ Gene Flow

2. Specifically, how is natural selection involved?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

The Forces of Evolution Cards

Please print enough cards so that each student group has one of each type: Natural Selection, Mutation, Genetic Drift, and Gene Flow. Print each type on a different colored paper (e.g. Natural Selection cards are all yellow, Gene Flow cards are all Blue).

Natural Selection

The process by which biological variation (adaptations) becomes more common in a population over generations.

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Mutation

Chemical change in the DNA. It can be positive, neutral, or deleterious.

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Gene Flow

Transfer of genes across population boundaries because their members are breeding with one another.

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Genetic Drift

When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.

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