Adaptation and climate change

NATURE Sunday Academy 2018-2019

Project Description:

The lesson will introduce students to the evolutionary mechanisms underlying adaptation to climate (natural selection, gene-flow, drift, and mutation). Following this lesson students will be able to answer the question: how do organisms adapt to environmental change? and make linkages between genotypic and phenotypic variation. The lesson will include two group activities and one hands-on activity.

Project Objectives:

The students will be able to:

1. Identify traits plants may have evolved to adapt and persist within their native environment
2. Link genotype to phenotype by extracting DNA from different varieties of fruits or vegetables with varying phenotypes (ie: different types of onions)
3. Quantify change in allele frequencies and associated phenotypic variation across generations in response to natural selection and genetic drift
4. Relate knowledge gained to anthropogenic climate change

Session Organization:

11:00-11:30	Cultural connection/brief introduction
11:30-12:00	How do plants adapt to their environment? Activity I: Phenotype to Environment
12:00-12:45	Lunch
1:00-2:00	Genes vs. Phenotype. Activity II: Allele Frequency Game
2:00-2:45	Activity III: DNA Extraction. Climate Change.
2:45-3:00	Wrap up

ND State Science Standards:

- Performance Standard HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- Performance Standard HS-LS4-2 Construct an explanation based on evidence that the process of biological evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources,

and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

- Performance Standard HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- Performance Standard HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in increases in the number of individuals of some species, the emergence of new species over time, and the extinction of other species.

Materials and Equipment:

Index cards, computers, power point projector, onions, dish detergent, salt, water, strain, plastic cups, plastic containers, alcohol, paper towel, paper clips, knife, spoons, immersion blender, candy (m&m's), ziploc bags, paper, pencils, ice.

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Activity I: Phenotype to Environment

With this activity you will investigate traits a plant has evolved to survive and persist in its native environment and make predictions for how a changing environment might affect the plant's survival. Make a power point with your answers (maximum of three slides per group).

You are each assigned a plant – tell us a little bit about that plant:

- Find a picture!
- Does this plant have a 'common name'?
- Is this plant used by Native American communities? How?
- Is it an herb, bush, tree? How does it reproduce?
- What is its distribution and habitat preferences?

Make a hypothesis: In a rapidly changing environment what type of stresses might this plant experience?

Answers:

<u>Acer negundo</u>

- ***Common names: box elder, boxelder maple, ash-leaved maple, maple ash***
- ***Uses: sap is used as sweetener or as beverage, leaves are used to relieve dry mouth, etc.***
- ***Tree, sexual reproduction (by seed)***
- ***Native to North America but it is an invasive species in Europe, China and Australia***
- ***This species grows well in disturbed areas and is well adapted to different climates, in face of climate change, it will probably do well. Apparently it is susceptible to drought so it might suffer from drought stress in dry areas.***

<u>Amelanchier alnifolia</u>

- ***Common names: saskatoon, Pacific serviceberry, western serviceberry, alder-leaf shadbush, dwarf shadbush, chuckley pear, western juneberry***
- ***Uses: stems used for arrows, leaves boiled for tea, fruits eaten fresh or dried, etc.***
- ***Shrub, sexual reproduction (by seed)***
- ***Native to North America, from Alaska to western and north-central US, also in western Canada. Grows from sea level up to 8,500 ft in California and up to 11,200 ft in the Rocky Mountains. It is common in the understory of forests.***
- ***Since it grows in temperate regions, it might get affected if temperature raises. Since it grows in forest understory, cutting down the forests might also impact it.***

Artemisia cana

- ***Common names: silver sagebrush, sticky sagebrush, silver wormwood, hoary sagebrush, dwarf sagebrush***
- ***Uses: leaves and stems are burned as insect repellant***
- ***Shrub, sexual reproduction (produces fruits)***
- ***Native to central and western North America, distributed in the US and Canada.***
- ***It is tolerant to flooding but the seedlings are sensitive to drought so in case of severe drought, the new plants will not probably germinate.***

Betula papyrifera

- ***Common names: Paper birch, white birch, canoe birch***
- ***Uses: bark is used for making torches and also as a container for collecting sap***
- ***Tree, sexual reproduction (by seed)***
- ***Native to northern North America, distributed along north US and Canada***
- ***It is susceptible to high temperatures and humidity so it will be affected by a rise in temperature and abundant rain or floodings.***

Cucurbita foetidissima

- ***Common names: buffalo gourd, coyote gourd, fetid gourd, fetid wild pumpkin, Missouri gourd, stinking gourd***
- ***Uses: root used to treat all sorts of body ailments, fruit is used as soap, infusion made with the seeds is used to kill intestinal worms***
- ***Herb or vine, sexual (by seed) reproduction and asexual reproduction by nodal roots***
- ***Distributed in central and southern US and north of Mexico.***
- ***This species needs warm temperatures, growing in arid or semi-arid areas with little water. This plant might be susceptible to flooding and a decrease in temperature.***

Dalea purpurea:

- ***Common names: purple prairie clover***
- ***Uses: roots are chewed because of their sweetness, infusion of the leaves to treat diarrhea, poultice of crushed leaves used for curing wounds, etc***
- ***Perennial herb, sexual reproduction (by seed)***
- ***Native to central North America, distributed in central Canada and southeast and southwest US, abundant in the great plains.***
- ***It is adapted to areas with periodical fires since it likes open areas, grows in well-drained areas so it might be subject to stress if periodic flooding occur. Also, lack of pollinators might impact its propagation***

Echinaceae angustifolia:

- ***Common names: echinacea, purple coneflower, blackroot***

- ***Uses: the root is used for wounds, swelling, snake bites, seed heads chewed to relieve toothache and other ailments***
- ***Perennial herb, sexual reproduction (by seeds), also it is possible to propagate using root or stem cuttings***
- ***Native to North America, grows in central US and Canada, abundant in the Great Plains***
- ***Grows in dry prairies so it might be sensitive to floodings***

<u>Fragaria vesca:</u>

- ***Common names: wild strawberry***
- ***Uses: fruits eaten fresh or dry***
- ***Perennial herb reproduces mostly asexually by lateral shoots though it can also be propagated by seed***
- ***Distributed throughout the Northern Hemisphere***
- ***It tolerates well wet or dry conditions, but it is sensitive to extreme drought or flooding. It can also survive mild fires***

<u>Fraxinus pennsylvanica:</u>

- ***Common names: green ash, red ash***
- ***Uses: wood used for bows, tipi pins and pegs, firewood, etc***
- ***Tree, sexual reproduction (by seed)***
- ***Native to central and eastern North America but has become naturalized in Europe***
- ***This tree grows fast and is well adapted to urban areas, so it might do well in disturbed environments. It is highly sensitive to beetle infestation so if climate change favors beetle reproduction, this might significantly impact green ash populations***

<u>Galium aparine:</u>

- ***Common names: cleavers, bedstraw, goosegrass, catchweed, etc***
- ***Uses: roasted seeds are used as a coffee substitution, plant used for skin irritations***
- ***Annual herb, sexual reproduction (by seed), the fruits are hairy and attach to the hair of animals***
- ***It is considered to be native to North America by some, but it is widespread across the world.***
- ***Though this plant would probably be successfully adapted to changing environments, it generally prefers moist soils which could make it sensitive to extreme drought***

<u>Juglans nigra:</u>

- ***Common names: black walnut***
- ***Uses: walnuts are edible, bark is used for black dye, leaves are used for skin ailments, etc***
- ***Tree, sexual reproduction (by seed)***

- ***Native to eastern North America, it has been introduced in Europe and is also cultivated in Hawaii***
- ***This species prefers open habitats so if climate changes favoring herb coverage the young trees might suffer from lack of exposure to the sun. Likewise, this species is highly susceptible to beetle infestation so if beetle population increases, it can severely affect black walnuts population***

<u>Lepidum densiflorum:</u>

- ***Common names: common pepperweed, prairie peppergrass***
- ***Uses: tea made with the plant is used for the kidneys, leaves are consumed in salads, seeds are used as condiment, etc***
- ***Annual herb, sexual reproduction (by seed)***
- ***Widespread across North America, common in Canada and the US***
- ***It grows throughout a variety of environments, it can be invasive. It is probable that in a changing climate, this plant will be able to successfully adapt***

<u>Maianthemum racemosum:</u>

- ***Common names: star-flowered, false Solomon's seal***
- ***Uses: berries have a laxative effect, root is used for wounds***
- ***Perennial herb, asexual reproduction by lateral roots (rhizomes) and sexual reproduction (by seeds)***
- ***Native to North America it grows in the US, Canada and Mexico***
- ***This plant prefers shaded areas with deep, moist soils. In a climate change scenario, this plant might be stressed by drought and by deforestation***

<u>Nelumbo lutea:</u>

- ***Common names: yellow lotus, American lotus, water chinquapin, etc***
- ***Uses: seeds and tubers are eaten (cooked), leaves can also be eaten, it is considered to have some sort of mystical powers***
- ***Aquatic herb***
- ***Native to North America, it grows in the US and some countries in central America and the Caribbean***
- ***This plant is adapted to lakes and swamps and grows in flooded areas. The species would probably not survive long periods of drought***

<u>Prunus virginiana:</u>

- ***Common names: chokecherry, bitter-berry, Virginia bird berry***
- ***Uses:***
- ***Shrub or small tree, sexual reproduction (by seed)***
- ***Native to North America, distributed across most US and Canada, including northern Mexico.***

- ***It is susceptible to pests so if the weather changes in a way that is favorable for insects, it will affect the plants. Also, the wood is weak, so branches might break if snow or ice increase.***

Activity II: Allele Frequency Game

With this activity you will learn how to calculate allele frequencies in a population and observe how allele frequencies may favor in response to natural selection or genetic drift.
You have a bag of m&m's in two different colors. Let's assume these colors are 2 different types of alleles, for example: red and blue. Let's assume also that red is dominant over blue. This means that if you have a heterozygous individual (one of each color), the phenotype will be red, because red is dominant. Homozygous individuals will have two alleles of the same color.

1. We will create a population of 24 individuals. 6 individuals are homozygous red, 12 are heterozygous red and 6 are blue.
2. Lay out pairs of alleles on the table to create this population as specified above.
3. How many alleles does an individual have? ***Answer: 2***
4. How many alleles in total do we have within this population? ***Answer: 48***
5. How many total red alleles are in the population? ***Answer: 24***
6. What is the proportion of red alleles? (divide the number of red alleles by the total number of alleles in the population) ***Answer: 24/48=0.5***
7. How many total blue alleles are in the population? ***Answer: 24***
8. What is the proportion of blue alleles? (divide the number of blue alleles by the total number of alleles in the population) ***Answer: 24/48=0.5***
9. Both proportions (red and blue) should equal 1. Does the sum of the proportions you calculated add to 1? ***Answer: 0.5+0.5=1***

10. Let's put all the alleles in a bag. This bag represents a population!
11. Let's see what happens in a new generation. For this, draw 2 alleles from the bag at random. This represents an individual in the next generation! What is the phenotype (color) of this individual? (Remember that red is dominant over blue) _____

12. Repeat the last step two more times. Now you have three individuals which constitute the new generation. Which is the phenotype (color) of each individual?

    Individual 1:_____ Individual 2:_____ Individual 3:_____

13. Do you remember what the concept of genetic drift is?

    Answer: Genetic drift is a change in the gene pool by chance

14. Let's simulate what the effect of genetic drift would be in your population. Let's imagine that a tornado kills half of your population. For this, take half of the individuals from the bag, one at a time (remember that each individual has two alleles). Record those individuals in the Table below. Do not eat them! We will need them for later.

Individual	1	2	3	4	5	6	7	8	9	10	11	12
Phenotype (color)												
Genotype (heterozygous or homozygous)												

15. Now calculate how many red and blue alleles are left in your population. For this, look at the numbers you counted in 5 and 7):

    Red:_____ Blue:_____

16. Now recalculate the proportions of red and blue alleles:

    Red:_____ Blue:_____ (Remember the sum of both proportions has to be 1)

17. Are they different from the proportions on your original population? How? What was the effect of genetic drift in your population?

Answer: Yes, the proportions are probably different. The conclusion is that genetic drift changed the proportions of red and blue alleles and thus the morphology of the individuals also change (there are more red or blue individuals now).

18. Do you remember what the concept of natural selection is?

Answer: Natural selection is when a phenotype gives an advantage of survival to an organism, then that organism survives and reproduces, passing along the genes behind that phenotype to the next generation. This makes the offspring better adapted to that particular environment.

19. Let's simulate the effect of natural selection in your population. Put all the m&m's on the table to recreate your original population of 24 individuals: 6 homozygous red, 12 heterozygous red and 6 blue. Let's imagine that a bird eats m&m's individuals and it prefers the red ones. Randomly take half of the red individuals out (remember that the red individuals can be homozygous red or heterozygous red), those are the ones that were eaten by the bird. How many red individuals did you have in your original population? _____ How many red individuals are left?

_____

20. Now calculate the proportions of red and blue alleles in your new population: Red:_____ Blue:_____ (Remember the sum of both proportions has to be 1)

21. Are they different from the proportions on your original population? How? What was the effect of natural selection in your population?

Answer: Yes, the proportions are different. The conclusion is that because the bird prefers red individuals, the blue individuals will have a better chance to survive and thus the next generation will have more blue individuals because the proportions of blue alleles in this population increased.

Activity III: DNA Extraction

In this activity, you will be able to extract DNA out of a plant using household ingredients and will be able to see it with your naked eye.

Materials:

- ½ onion
- 2 tbsp. dish detergent
- 1 tsp. salt
- ½ cup of water
- 1 coffee filter
- ¼ cup Ice-cold alcohol

Procedure:

- Peel the onion half and put it in a container. With the help of an immersion blender, smash the onion as best as you can.
- In a plastic cup, mix together 2 tbsp. detergent, 1 tsp. salt and ½ cup of water. This will be your DNA extraction liquid.
- Add your extraction liquid to the smashed onion and mix gently with a spoon to avoid making bubbles. This will help breaking the cells to release the DNA.
- Using a coffee filter, pour the mixture into a clean plastic cup. Gently squeeze the filter.
- Slowly, pour the ¼ cup of cold alcohol down the side of the cup. Do not mix! Let sit for a couple of minutes. The alcohol will help separate the DNA from the rest of the onion mixture.
- You will see something white forming in between the alcohol and the onion mixture. That's the onion's DNA! With the use of a paperclip, gently pick up the strands of DNA.

Question:

Compare your DNA extraction with groups that have extracted a different variety of onion. Do you see any differences? Why or why not?

Answer:
The students will not see any differences between the DNAs. They must conclude that the DNA molecule is the same for the different onions and thus common to all living organisms.

Wrap-Up & Discussion:

1. How were the concepts of STEM used in today's activity?

2. What was the most successful idea you used in the activity?

3. What did you try in the activity that did not work?

4. Why do think it did not work?

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