Developing Understanding of Evolution in Complex Contexts

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Microevolution and Disturbance

Students learn about disturbances **only** at **ecological time scales**, not evolutionary time scales.

Students learn about evolution as **separate** and focused on populations in isolation or in predator-prey scenarios with **strong selection pressure**.

Understanding evolution in the complex contexts that disturbance brings is **essential** to the to the ability to **make reasonable predictions about disturbance.**

Microevolution and Disturbance

Evolution in complex contexts:

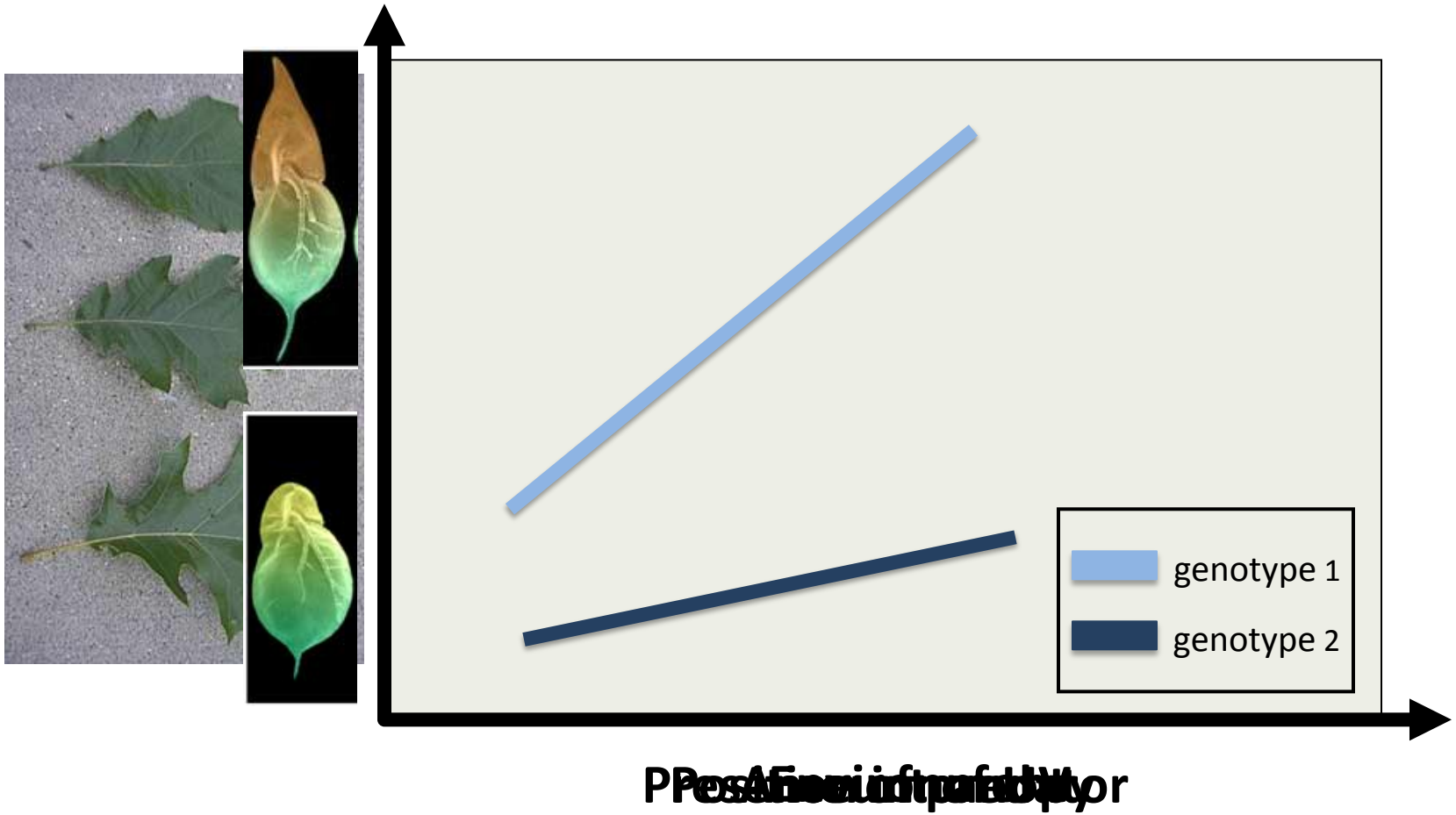
- When the traits involved are providing an advantage in a community context with ambiguous or weak selection pressures
- When the trait under selection is continuously variable or phenotypically plastic (i.e., responsive to environmental conditions)

Microevolution and Disturbance

- **Individual level**
  - organisms can respond through acclimation or phenotypic plasticity
  - if a disturbance exceeds the genetically "allowable" phenotypic plasticity of an organism → then the organism dies or fails to reproduce

- **Population level**
  - populations respond through natural selection and reproduction
  - if a disturbance requires change outside of genetic variability of the population → then the population goes extinct

What is genetically “controlled” phenotypic plasticity?



Research on Student Understanding

Students tend to view the genetic structure of natural communities as more adaptable than is biologically accurate, including:

- Teleological (internally-directed, purposeful) change
- Lamarckian (inheritance of acquired characteristics) change

Anderson et al, 2002; Bishop & Anderson, 1990, Brumby, 1984; Chan, 1998; Clough & Driver, 1986;; Clough & Wood-Robinson, 1985; Cummins et al1994 Evans, 2008; Lawson & Wesser, 1990; Nehm et al 2009, Rudolph & Stewart, 1998; Settlage, 1994; Scharmann & Harris, 1992 Tamir & Zohar, 1991

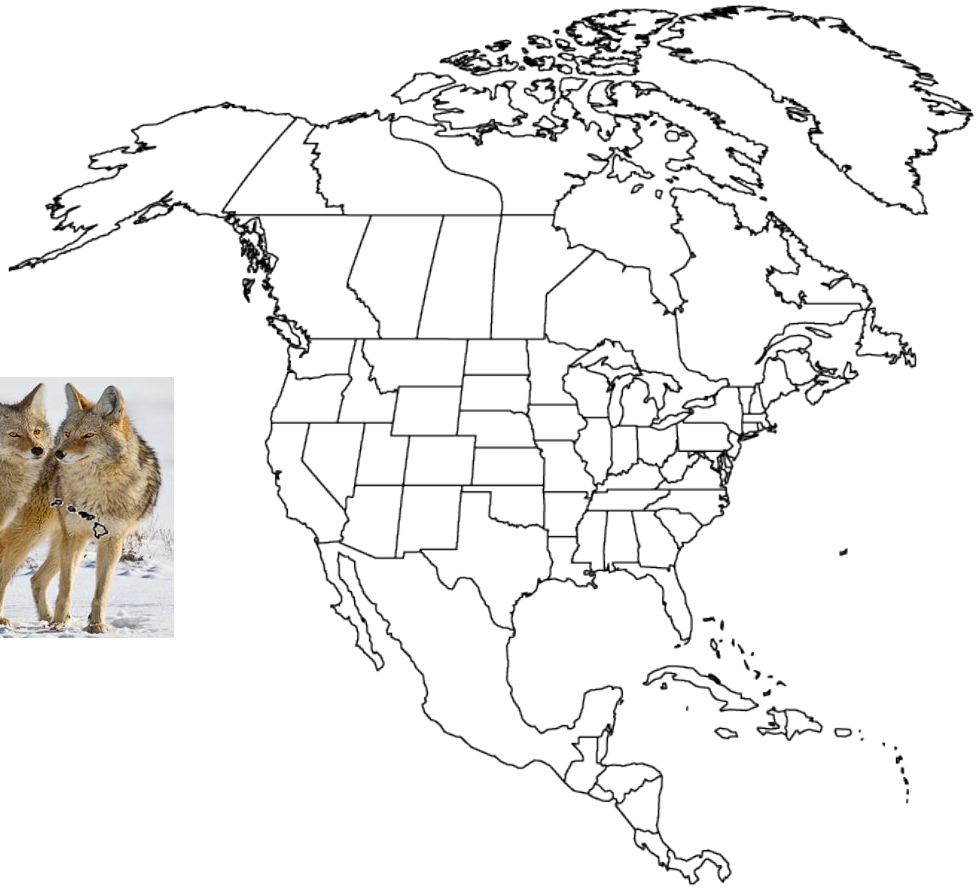
Research Goal

Develop a learning progression framework to describe how grade 6-16 students reason about evolution in the complex contexts of ecological disturbance.

Methods

- Administered semi-structured interviews about evolution in three complex situations
  - 46 grade 6-12 students, 3 undergraduates, and 4 graduate students from rural Michigan, suburban Colorado, and urban Baltimore, Maryland
- Used grounded theory coding to analyze interview transcripts and uncover emerging patterns

Disturbance where the trait of interest is phenotypically plastic



Coat thickness in North American coyotes moving from Alaska to Arizona

Disturbance due to introduction of a new species

Opossum migration into an area with raccoons.

Disturbance due to moving into a novel ecosystem

python invasion of the everglades

Results

We can interpret our data using two progress variables:

- Nature and origin of phenotypic traits
- Traits of successful organisms

Low: Phenotypic traits can change during an individual's lifetime and those changes are heritable

"Would you expect the puppies that grew up in Arizona to be different then the puppies that grew up in Alaska because they live in different climates?"

Lacy, 6th grader: "…The puppies from Alaska would have thick coats compared to the ones in Arizona. It was [because] the climate and the weather. …it would like make me put on warmer clothes or wear less and so it's like their fur they take off fur, they put it on."

"Would these traits be passed down?"

"Yes. ...They just kind of inherit it and then the climate would also contribute to that."

Low: Phenotypic traits can change during an individual's lifetime and those changes are heritable

"Would these traits be passed down?"

Tim, 12th grader: "the … Alaskan coyotes, they lived in Arizona for so long, [the genes] would have changed in some way. For their pups to survive, they would need to … just the adaptations."

Middle: Traits can change during an individuals lifetime but these changes are not inherited

"Would their genes change when the trait changed?"

Cynthia, 12th grader: "Their genes? I would say no."

"Do you think that if these coyotes that shed their coats had puppies, would they be born with thick or thin coats?"

Sadie, 7th grader: "Thick coats. Because their mom and dad started off to have thick coats."

High: Genetically controlled phenotypic plasticity

Aaron, graduate student: "the offspring of the second generation of coyotes in Arizona are going to look the same as their parents, which are different than the original Alaskan parents, … it's not because of specific genes and only those genes are being passed on. It's because they're in the Arizona environment and so they're accessing that same range of plasticity values as their parents did."

High: Genetically controlled phenotypic plasticity

"You said they would have a thicker coat in Alaska than they would in Arizona. … How do you think genes are involved in those differences? "

Tim, 11th grader: "I think genes develop as animals do. Like if there's a gene that you don't necessarily need in the environment that you are then maybe it becomes less evident. And if there's a gene that you need to develop then it starts to develop over time."

"But are the genes still the same?"

"I think they're the same. I think it's mostly just how they act that's different."

Low		
Middle		
High		

Discussion

Making good predictions about what will happen to an ecosystem after disturbance requires considering the limits to and constraints on the ability of both individuals and populations to change.

We have identified two aspects of disturbance scenarios that make these things difficult for students.

- Understanding of phenotypic plasticity
- Ambiguity about the nature of the selection pressure and the traits that it favors

These aspects are both common in actual ecosystems and will have significant effects on students' abilities to predict the response to disturbance.

Discussion

NGSS MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

NGSS HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Less sophisticated students: Strength or ability to fight are traits of successful organisms.

"Would that change what traits the raccoon would need to be successful?" **Martino, 7th grader: "It would need to know how to fight back. Because if they find the same food, they would have to know how to fight each other so whoever wins they could get the food." …**

"Can you describe how that would happen?" **"It would become stronger because if it was fighting for the same food they would fight each other. And once they start fighting this one might become way stronger … because he might win the fight. … Once a baby is born…, the father or the mother automatically train that raccoon to be more like them. So if this one fights a lot, then it might teach him how to fight."**

More sophisticated students: traits to reduce competition or increase getting food are traits of successful organisms.

"Would that change what traits the raccoon would need to be successful?" **Ted, 11th grader: "If they're competing for the same resources then the raccoon can potentially have to find different ways to find the same resources utilizing different strengths** that it has as opposed to characteristics of the possum which has different strengths and genetic predispositions. …They could **change their fundamental niche**. So like if the possum lives in a certain kind of tree, the raccoon could choose a different type of tree to live in."

"How could that change happen?" **"eventually … migrate to a different area or to a different niche within that area too."**

Most sophisticated students focused on traits that increase reproductive success.

"Would that change what traits the raccoon would need to be successful?" **Kathy, 12th grader: "It depends on the environment, but any sort of trait that benefits the ability to get food, like, maybe if strength is necessary in finding food, then the stronger raccoons would be more successful. And by successful, meaning pass on their traits to another generation. For them that would be the environmentally advantageous trait to have. But if it was in a situation where intelligence was a more important trait in acquiring food, then the smarter raccoons could be not strong, but smarter, and they would be more successful. Because they would meet the goal of passing on their traits and genes to the next generation."**