ConnectedBio

CURRICULAR UNITS

Three-Dimensional Learning from Molecules to Populations

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CREATE for STEM Work-in-Progress Seminar

The Concord Consortium

NSF

MICHIGAN STATE UNIVERSITY

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Outline

Introduction to the Connected Bio Project

- Project goals
- Curriculum framework & development process

Integrating across Levels

- Deer mice example
- Demo of interactives
- Student data

Next Steps

- Plan for research in Spring 2019
- Questions for discussion

Evolution is important...

Evolutionary processes explain the diversity of life on the planet, and research in this field continues to shed light on everything from the microbiome in your body to the ancestors that made you who you are

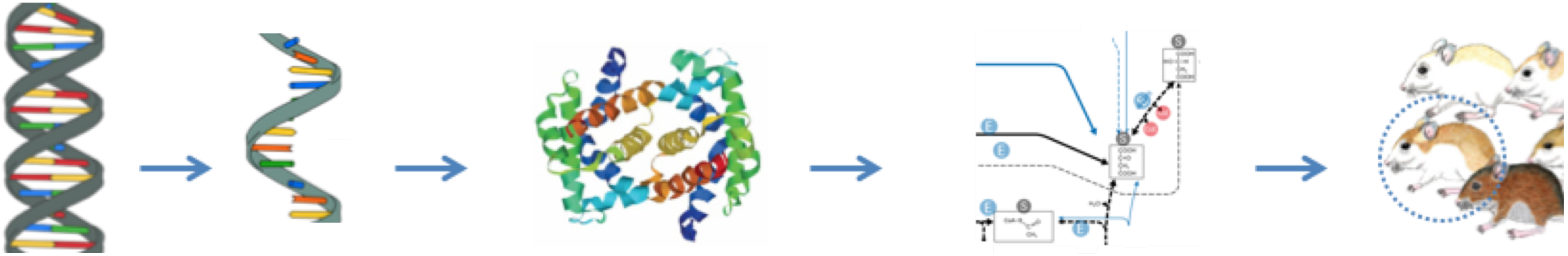
Evolution education

All the current reforms place evolution as important….however

- Evolution is often taught as an isolated topic

INSTEAD:
Evolution should connect biological concepts across the curriculum

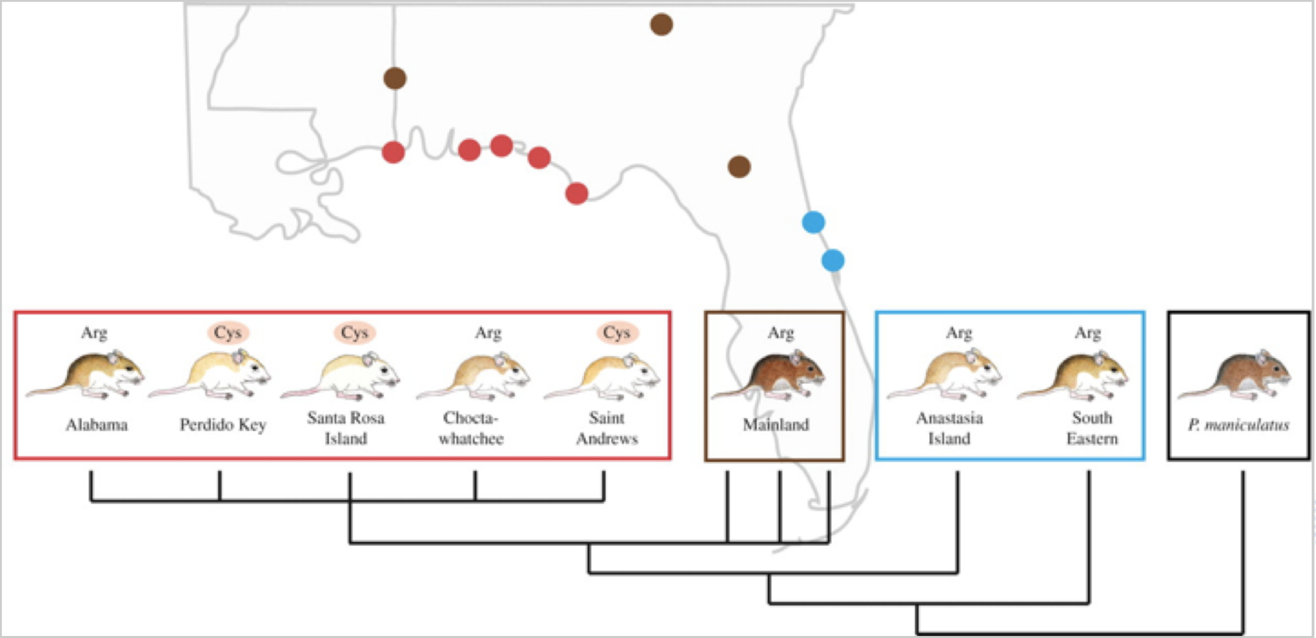
Genotype → Phenotype

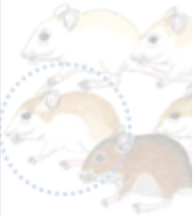


DNA | RNA | Protein | Pathway | Trait

genotype | | | | **phenotype**

Genotype → Phenotype → Evolution





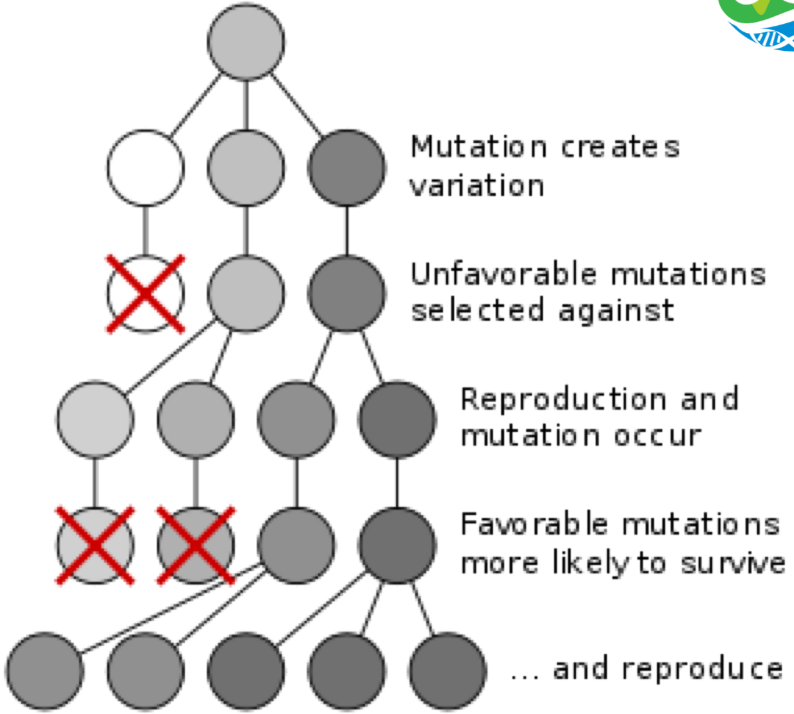
DNA RNA Protein Pathway Trait

genotype **phenotype**

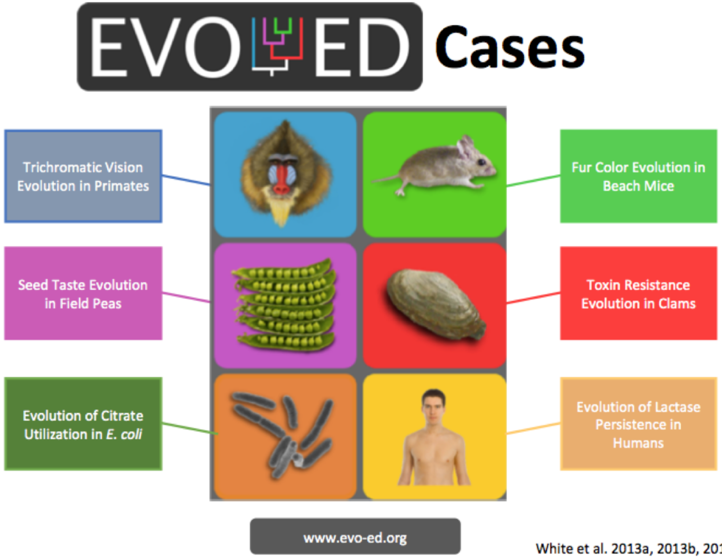
Evolution education

- Evolution key concepts: variation, heritability, selection
- Threshold concepts: randomness, probability, spatial scales, temporal scales

(Tibell and Harms 2017)

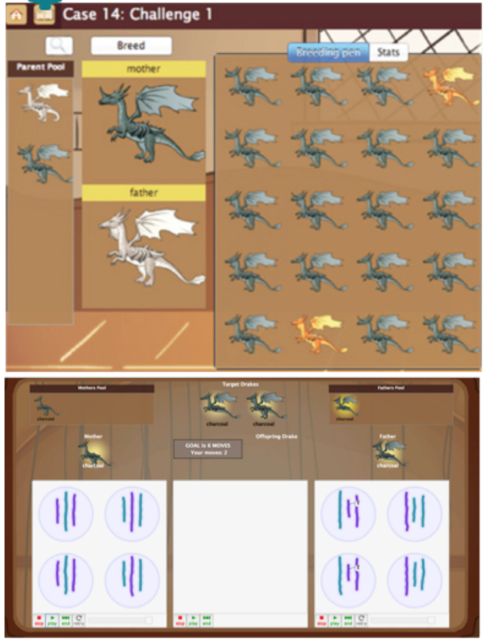


Project Background

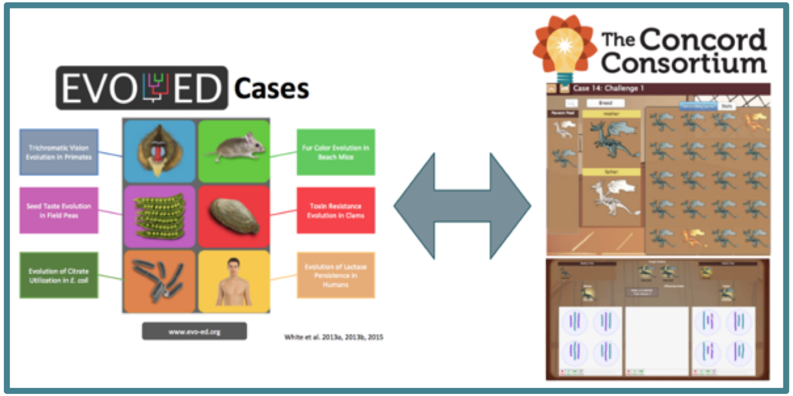


White et al. 2013a, 2013b, 2015

The Concord Consortium



ConnectedBio Project



By combining:

(a) The integrative cases of trait evolution developed by Evo-Ed/MSU

(b) The interactive online learning simulations of the Concord Consortium

(c) The intentional design of curriculum for NGSS

ConnectedBio

THREE-DIMENSIONAL LEARNING

From Molecules to Populations

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ConnectedBio

THREE-DIMENSIONAL LEARNING

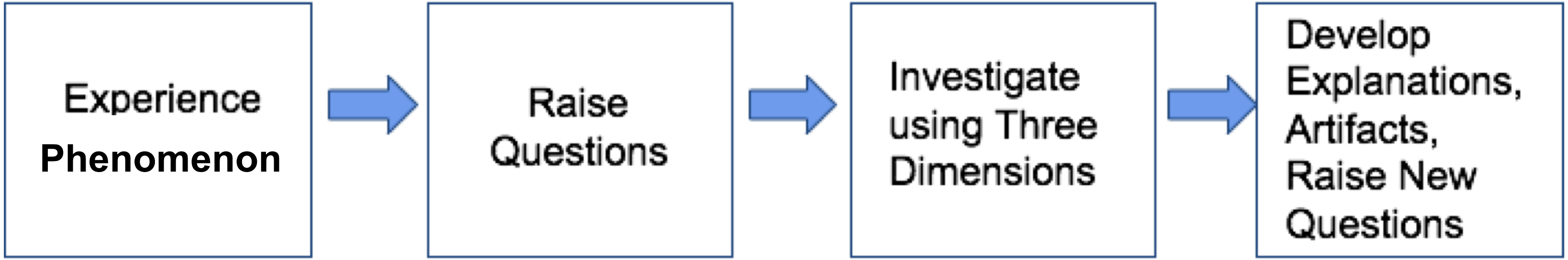
From Molecules to Populations

We can investigate how students':

1) ... learning develops over time when they experience a set of coherent interactive 3D biology learning materials.

2) … understanding about the relationships between levels of biological organization (i.e. molecules, cells, organisms, and populations) develops and transfers from one biological phenomenon to another.

Driven by Phenomena



CREATE for STEM Institute

Cases

					
Dark & light fur	Sensitive & resistant to neurotoxin	Smooth & wrinkled shape	Dichromatic & trichromatic vision	Persistence & intolerance	Cit+ & Cit-
Peromyscus polionotus	*Mya arenaria*	*Pisum sativum*	**Across primate species**	*Homo sapiens*	*E. coli*
Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic	**Prokaryotic**
Natural selection	Natural selection	**Artificial selection**	Natural selection	Natural selection	Natural selection
Point mutation	Point mutation	~800 nucleotide insertion	**Gene duplication & point mutation**	Mutation in control region	Duplication leading to novel gene regulation

Case Similarities & Differences

TWO PHENOTYPES

SINGLE SPECIES | MULTIPLE SPECIES | SINGLE SPECIES

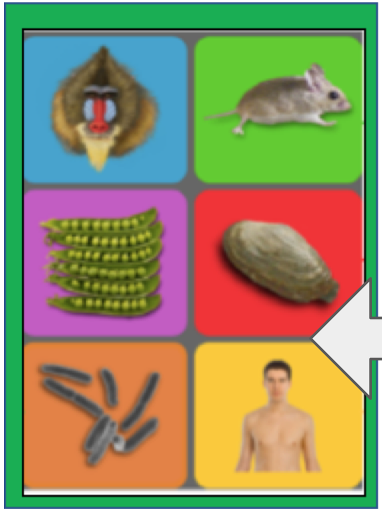
MULTICELLULAR | SINGLE CELL

NATURAL | ARTIFICIAL | NATURAL

SINGLE MUTATION | MULTIPLE MUTATIONS | SINGLE MUTATION

3D Curriculum Development Process

CONTENT



CASE SYNOPSIS/
PROCESS FIGURES

TEACHER AND
STUDENT FEEDBACK

UNIT/LESSON
GUIDES

TECHNOLOGY

IDENTIFY
- Phenomena
- Driving questions
- Investigations

SPECIFY NGSS CONNECTIONS
- DCIs
- Practices
- Cross cutting concepts

INTEGRATE
- Multi-Level Simulation (MLS)
- Embedded assessments

NEXT GENERATION SCIENCE STANDARDS

TEACHER
COLLABORATORS

Account for spatial scale

- Multiple levels of biological organization

population

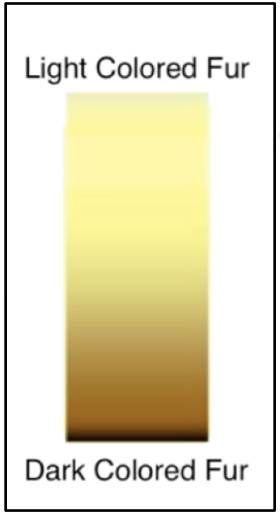
organism

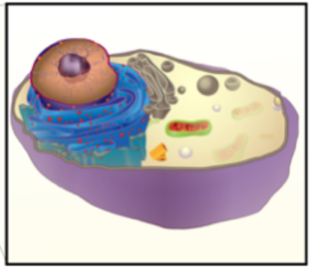
trait

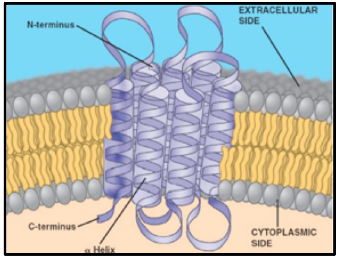
cells

proteins

DNA







Level		
Population(s)	Field/Beach	Proportion of light colored mice increases in frequency in populations living on/near beaches
Organism	Mouse	Experience differential survival and reproduction based on inherited traits
Trait	Fur color	Is genetically determined by alleles inherited from parents
Cell	Melanocyte	Can produce differing amounts of eumelanin and pheomelanin
Protein	MC1R	Binds alpha-MSH and initiates melanin synthesis
DNA	MC1R Gene	Goes through the process of replication and accumulates mutations

Integrating across levels:

Level			
Cell	Melanocyte		Can produce differing amounts of eumelanin and pheomelanin
Protein	MC1R		Binds alpha-MSH and initiates eumelanin synthesis
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Integrating across levels:

Level			
Population	Field/Beach		Comprised of individuals living in ...rticular environment
Organism	Mouse		...a particular phenotype, that ...unction of the genes and the ...ronment

Differences in heritable traits among individuals can impact survival and reproduction that changes the distribution of traits in the population

Demos

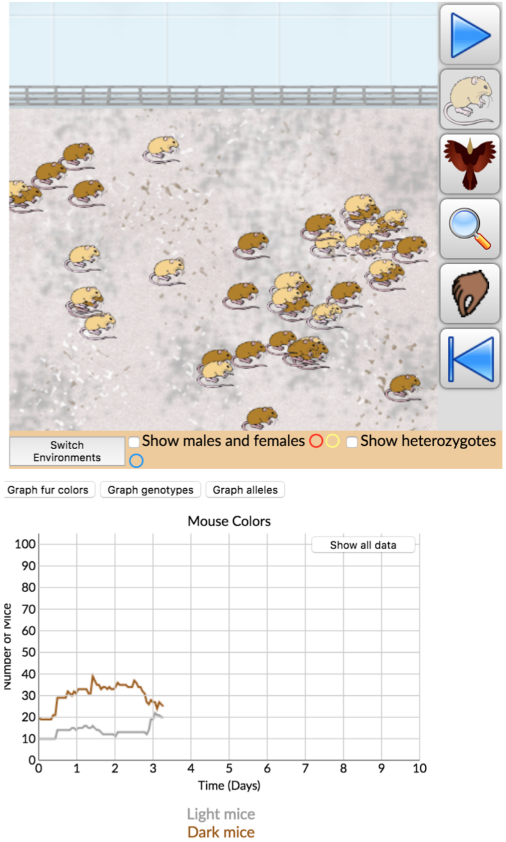
Unit 1. Lesson 1.1 Natural History of Deer Mice
https://authoring.concord.org/activities/9005

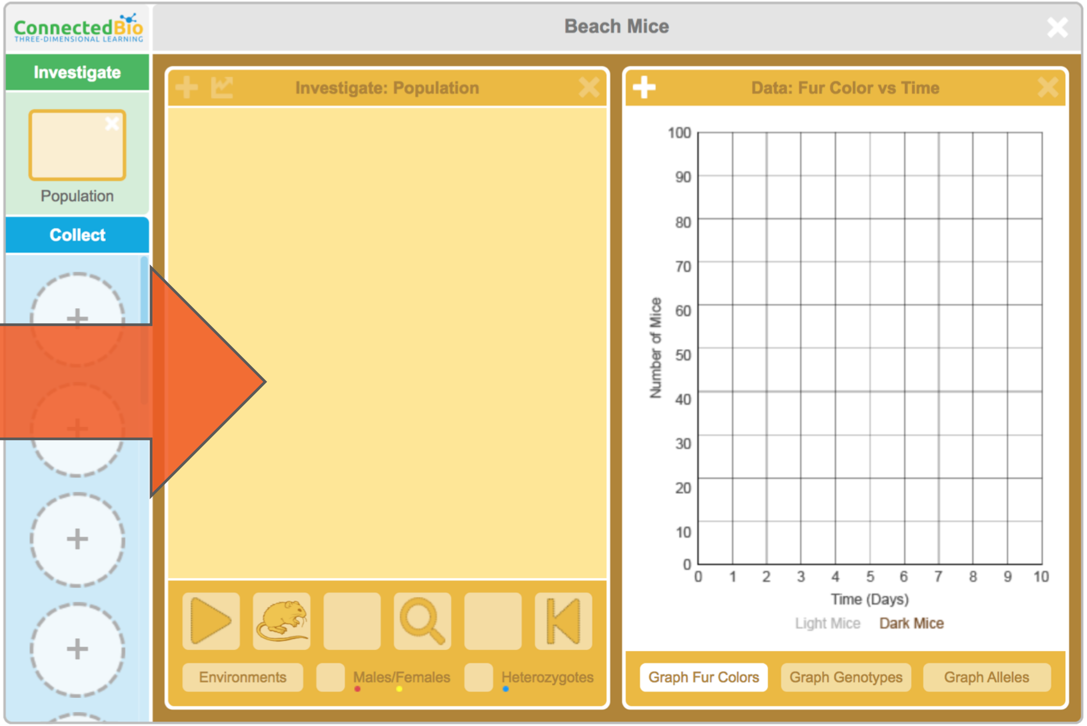
Unit 1. Lesson 1.2 Ecology Deer Mice
https://authoring.concord.org/activities/9006

Unit 2. Lesson 2.1 Cell Biology of Deer Mice
https://authoring.concord.org/activities/9083

Unit 2. Lesson 2.2 Molecular Biology of Deer Mice
https://authoring.concord.org/activities/9076/

UI/UX will allow students to move from level to level





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THREE-DIMENSIONAL LEARNING
From Molecules to Populations

We can investigate how students':

1) ... learn ... t interac

2) … unde ... organiz ... ps and transfers from one biological phenomenon to another.

What explanations do students have about the case content and evolution?
(prior to case instruction)

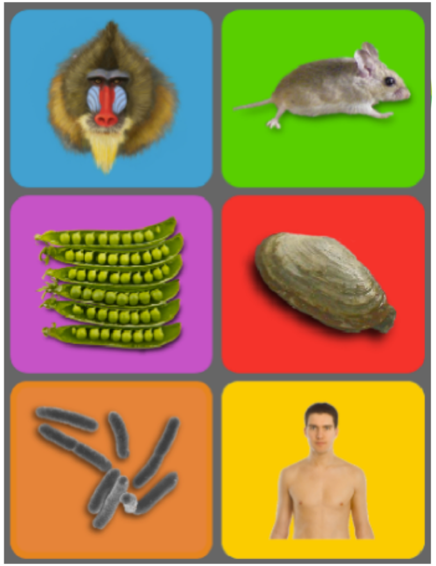
Fall 2017 - Spring 2018: Implementation and Research Goals

1. Identify which cases teachers use in their classroom. Collate materials used.
2. Design ConnectedBio curriculum (initially all cases → deer mouse case)
3. Describe what initial conceptions students have (case content & evolution).

Research Questions

1. What prior knowledge do high school biology students use when explaining evolutionary case phenomena? (specific case context and evo concepts)
2. How often do high school biology students make connections across biological levels in their explanations?
3. What kinds of connections do high school biology students make when responding to scaffolded and unscaffolded questions about evolutionary phenomena?

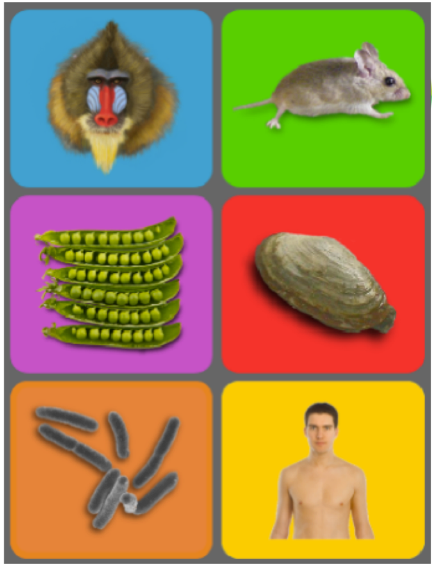
Student Prior Knowledge



- Four sets of open-ended survey questions
  1. Mouse fur color case (multiple questions)
  2. Clam toxin resistance case (multiple questions)
  3. Monkey vision case (multiple questions – phylogenies)
  4. Multi-case (one question from each case)

- Each teacher gave out 1, 2, or 3 surveys to their students in 2017-2018
- Evaluating/coding written responses

Student Prior Knowledge



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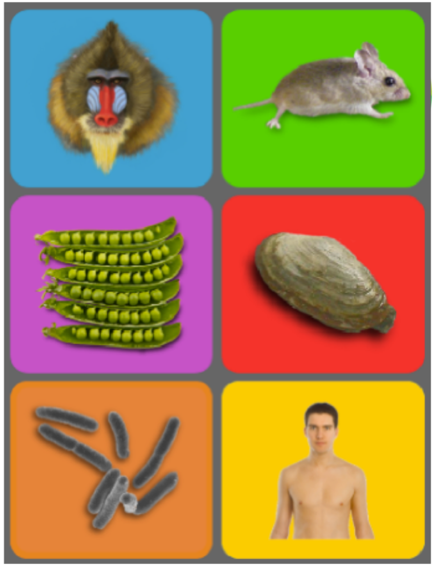
- Each teacher gave out 1, 2, or 3 surveys to their students in 2017-2018
- Evaluating/coding written responses
  1. **Common alternative conceptions** to the case context – what explanations do students have?
  2. **Evolution key concepts** – scientific (i.e. variation, heritability, etc.) vs. naïve (i.e. need, use, etc.) (used in Nehm et al. 2012)
  3. **Threshold concepts** (randomness, probability, spatial and temporal scales) (Tibell & Harms 2017)

Student Prior Knowledge



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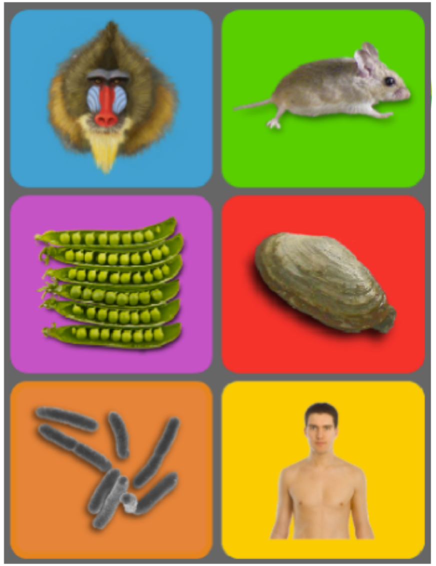

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- Evaluating/coding written responses
- Followed up with some students via interview
- **Today – preliminary results for two teachers and the deer mouse case**

Student Survey: Mouse Fur Color

1. Most mice in dark soil fields have dark fur and most mice on light sandy beaches have light fur. **Why might these fur colors be associated with these habitats?**

Student Survey: Mouse Fur Color

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2. How would you explain the differences in fur color at the **molecular** level (in terms of DNA and/or proteins)?

3. How would you explain the differences in fur color at the **cellular** level?

Jen (14 years experience): 54 9th grade general biology students
Mark (26 years experience): 42 11th/12th grade AP biology students

Explanation	% Students (9th / AP)	Example Student Quote

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Camouflage	81% / 86%	“To blend in with their surroundings so predators can't see them and the mice won't die”
Bleaching (sun bleaches the fur lighter)	11% / 0%	“because the mice in the beaches are in the sun all the time so their fur becomes lighter and the dark fur mice are always shaded because they are in a field”

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Dirty (substrate rubs off on mice)	5% / 0%	“The dark soil may rub off on the mice giving them darker fur. But also it may be genetic…”

Evolution Key Concept	% Students (9th / AP)	Example Student Quote

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Variation (mutation)	4% / 10%	"...The change in coloring may have been due to a certain mutation, or certain genes that have been turned on or off."
Inheritance	0% / 10%	"These colors of fur are associated with their respective habitats because mice with these fur colors would have a better chance of survival, and are able to have more offspring to pass down the trait."

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Differential survival and/or reproduction (Selection)	9% / 31%	"Mice with dark fur can better blend in with the dark soil and mice with light fur can blend in with the light sand. This way it is more difficult for predators to hunt them. Natural selection causes the mice with the better fur for their environment to be able to survive and produce offspring."

Student Survey: Mouse Fur Color

1. Most mice in dark soil fields have dark fur and most mice on light sandy beaches have light fur. **Why might these fur colors be associated with these habitats?**

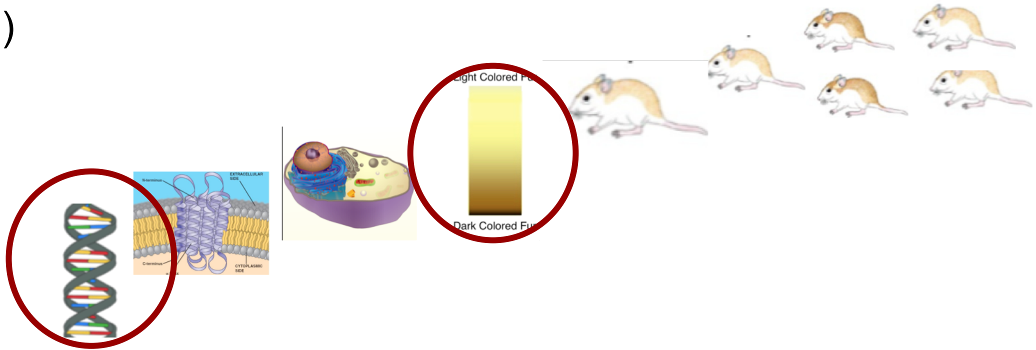
2. How would you explain the differences in fur color at the **molecular** level (in terms of DNA and/or proteins)?

3. How would you explain the differences in fur color at the **cellular** level?

Student Prior Knowledge: Connecting Levels

- Attempted connections:
  - Referenced at least two levels in their response.
  - 37% of Jen’s 9th grade students, 67% of Marks’ 11th/12th grade students
  - Example from Mark’s class: “one letter of the DNA sequence is replaced by another letter accidentally, and thus creates a different fur color.”

- Students referenced DNA/genetics, proteins, or cells, but Mark’s students had more detailed explanations, used scientific terms (nucleotide sequences, chromosomes, dominance)



Student Prior Knowledge Summary

- 9th and AP students both had the same most common explanation for the mouse fur color case (camouflage)
- None of the AP students proposed alternative explanations, but used more evolution key concepts
- Both groups of students made limited connections across levels in question 1
- Both groups of students do better at making connections with scaffolded questions (2 and 3)
- Difficult to code some alternative explanations using molecular and cellular levels (i.e. dirty - not an evolutionary explanation)

Next Steps for Initial Student Surveys

- Continuing to evaluate/code written responses for mice and clams
- Evaluating student thinking revealed by follow-up interviews (terminology)
- Using these results to develop the ConnectedBio curriculum

Project Next Steps

ConnectedBio

THREE-DIMENSIONAL LEARNING

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We can investigate how students':

1) ... learning develops over time when they experience a set of coherent interactive 3D biology learning materials.
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Project Timeline

- **2017** — Use principles of 3D learning to design a coherent learning sequence
- **2018** — Adapt a cyclical, case-based approach; Develop supporting technology-based environments
- **2019** — Test materials in an agile, iterative manner
- **2020** — Measure student use of core ideas, crosscutting concepts and practices; Analyze the findings and disseminate

Spring 2019: Implementation and Research Goals

1. Identify areas of difficulty for students and teachers
2. Iteratively update the Deer Mouse case lessons and teacher guides
3. Describe how students work through the case materials

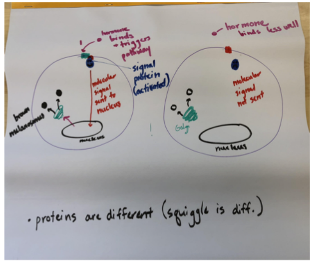
Research Questions

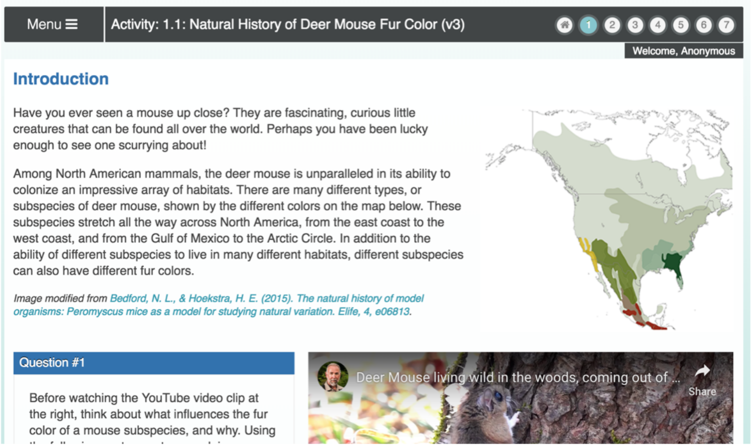
1. How do students engage with our three-dimensional materials?
    a. What does their discourse look like?
2. How do students make connections across levels throughout the case?
    a. What do their models look like?

Data Collection

5 Teachers
-Daily log
-Interviews

3 Student Groups of 3-4 Each
-Artifacts (models)
-Written responses within lessons
-Simulation use log data
-Audio (or video?) recordings
-Interviews





Data Collection

Teacher 1 | Teacher 2 | Teacher 3 | Teacher 4 | Teacher 5

Teachers 1–3:

- Iteratively update materials based on prior implementations (inform goals 1, 2)
- Piloting of interview protocols using these teachers and their students

Teachers 4–5:

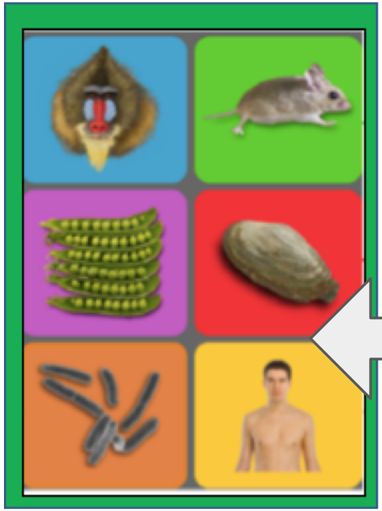
- Finalize curriculum to serve as a case study (goal 3)
- Focus on one (or two) student groups per teacher

3D Curriculum Development Process

TEACHER AND STUDENT FEEDBACK

CASE SYNOPSIS/ PROCESS FIGURES

CONTENT



UNIT/LESSON GUIDES

TECHNOLOGY

IDENTIFY
- Phenomena
- Driving questions
- Investigations

SPECIFY NGSS CONNECTIONS
- DCIs
- Practices
- Cross cutting concepts

INTEGRATE
- Multi-Level Simulation (MLS)
- Embedded assessments

NEXT GENERATION SCIENCE STANDARDS

TEACHER COLLABORATORS

Discussion Questions

- **Integrating across levels:** What other ways could we evaluate whether students are making connections between levels? How can we scaffold a question that assesses students ability to make connections across levels?

- **Research plan:** Is our plan for research in Spring 2019 sufficient to address our questions? What should 3D assessment of 3D curriculum look like?

- **Next case:** We plan to develop at least one more case. Would it be better to develop a case with a phenomenon similar to deer mice for evaluating knowledge transfer or one that is more complementary (phenomenon is less similar to deer mice)?

Case Similarities & Differences






TWO PHENOTYPES

SINGLE SPECIES | MULTIPLE SPECIES | SINGLE SPECIES

MULTICELLULAR | SINGLE CELL

NATURAL | ARTIFICIAL | NATURAL

SINGLE MUTATION | MULTIPLE MUTATIONS | SINGLE MUTATION

Clam toxin resistance

- A toxin is present in the ocean where a population of Sand Gaper clams live. All individuals in the population are exposed to the toxin. Some of these individuals, however, are negatively affected and die or become paralyzed. Other individuals in the population are unaffected. **Explain why some individuals are affected by the toxin while others are not.**

Clam toxin resistance

- **Mutation**
- **Distance** from the area changes level of exposure
- **Cells** = ? couldn’t get into the cells completely
- **Concentration** difference as it spread
- **Immune** system protects from the toxin
- **General strength/health** of the clam prior to exposure, including age and size

E. coli citrate case

- PROMPT: Scientists are growing populations of the same bacteria in 12 different containers in the lab, with one population per container. All of the populations are provided with a food source they can use (glucose) and a food source they generally cannot use (citrate). After many generations (years) the scientists noticed the bacteria in one population (Container 9) were growing more than the others. **Explain why might the bacteria in Container 9 grow more than the bacteria in the other containers (1-8 and 10-12)?**

- 9th Grade Biology

E. coli citrate case

- Out of 42 students, 38 had responses and 36 of these were coded (2 were too vague to code)

“One population of bacteria (Container 9) grows more because the bacteria was genetically lined up to match and grow more and had different modifications.”[#9]

- 14 had some mention of genetics

“One population of bacteria (Container 9) grows more because they can eat the other bacteria.” [#34]

- 30 mentioned the food source
  - 7 wrote that bacteria were eating other bacteria in order to grow more
  - 17 referenced using citrate (only 5 said using both citrate and glycose)

“One population of bacteria (Container 9) grows more because they adapted to eat the citrate, which made the bacteria less limited in how much they could grow compared to the other containers, as they had two food sourced instead of only one.” [#1]

- 8 had other explanations