ConnectedBio.org

THREE-DIMENSIONAL LEARNING

From Molecules to Populations

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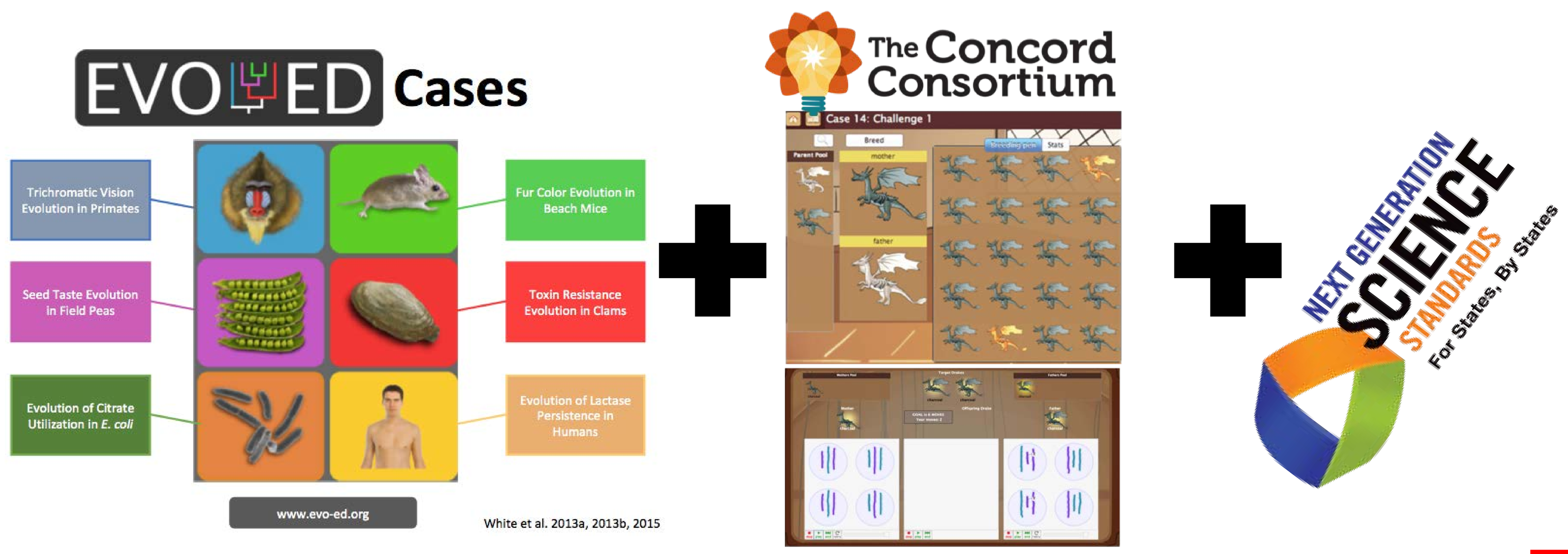
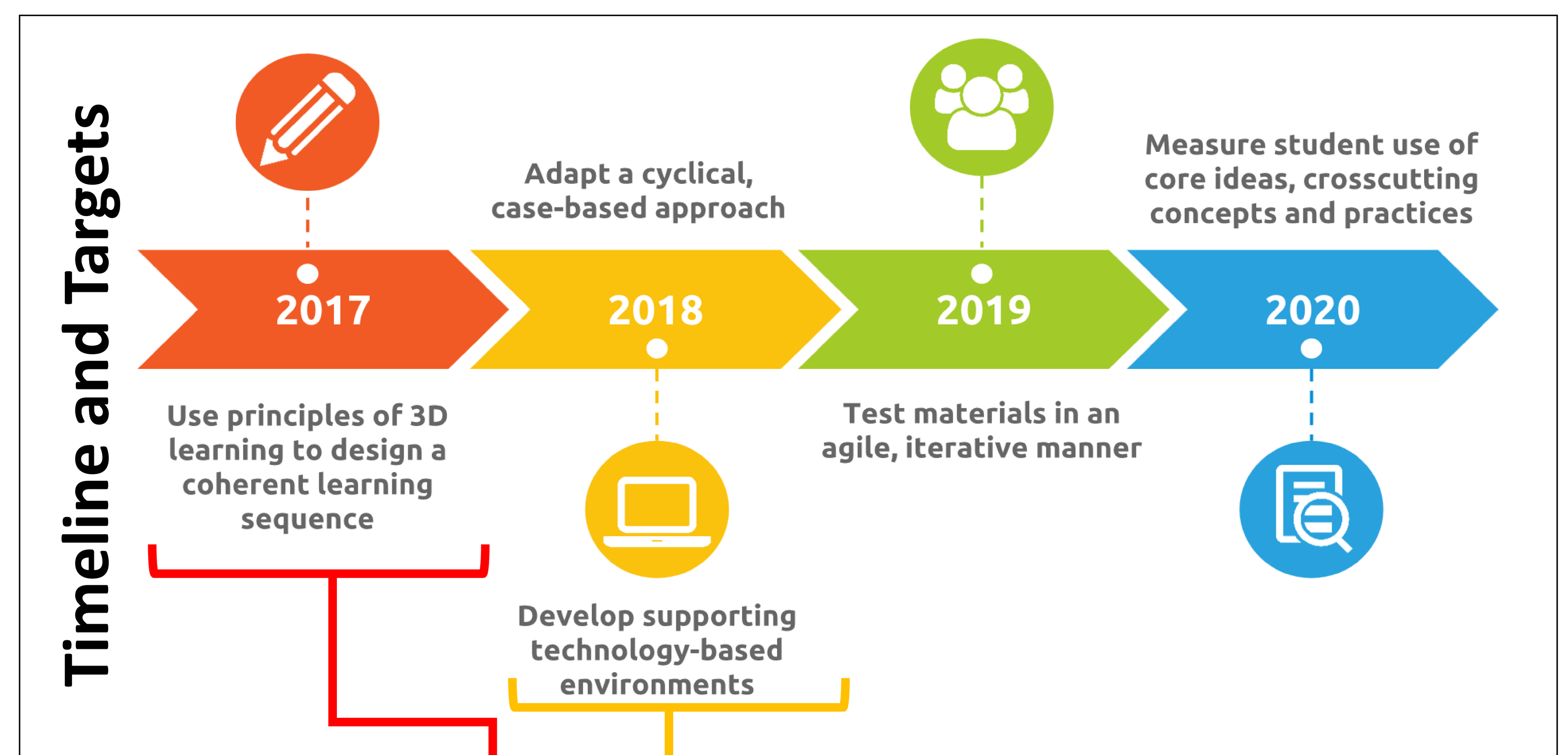
Overview: ConnectedBio is a Design and Development project that seeks to build and implement interactive lessons by combining the innovative curricular materials from the Evo-Ed.org project, with the technology-facilitated learning approach of the Concord Consortium, and the standards outlined in the NGSS.





Project Impact: Implementation and beta-testing of our project curriculum and interactives is set to happen in five States. Through our Evo-Ed.org and Concord Consortium networks, we expect this to grow as our interactives and associated material come online.

Our project will provide high school biology teaching and learning materials that are focused on helping students reach an integrated understanding of biology and evolution. The information gleaned from our research on how students learn with these materials will help all investigators in science education learn how students can achieve greater levels of sophistication and they build their understanding and make connections between concepts to increase the complexity of their thinking.

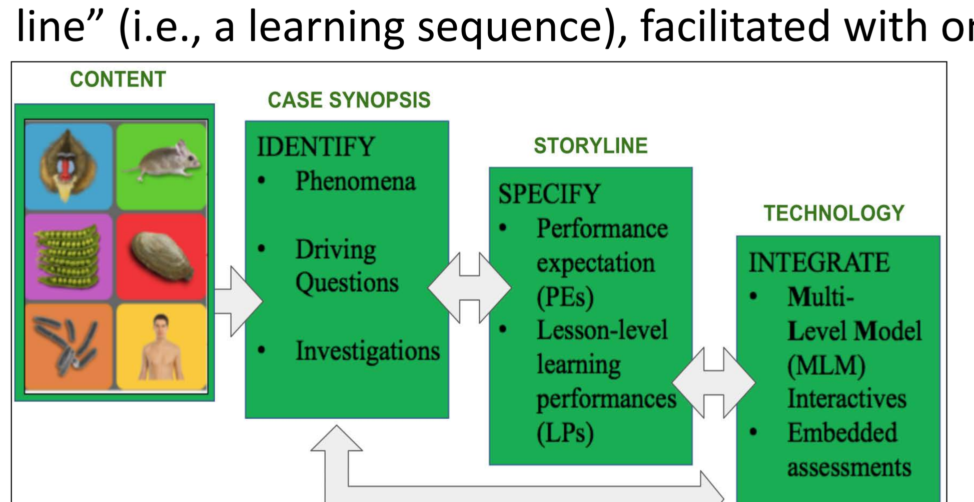
Specifically, the project that seeks to research how technology-based materials designed to foster interlinked, three-dimensional learning of high school genetics and evolution increase sophistication of student understanding of core ideas, crosscutting concepts and science practices. We are specifically interested in how materials designed to support three-dimensional learning can support growing complexity in student understanding of the linked ideas of evolution, traits, and the underlying molecular mechanisms through the practices of analyzing and interpreting data, constructing scientific explanations and the crosscutting concepts of patterns and cause and effect.

Research Questions:

(1) How does students' learning progress over time when they experience a set of coherent interactive 3D biology learning materials?

(2) How do students' understanding about the relationships between molecules, cells, organisms, and populations transfer from one biological phenomenon to another?

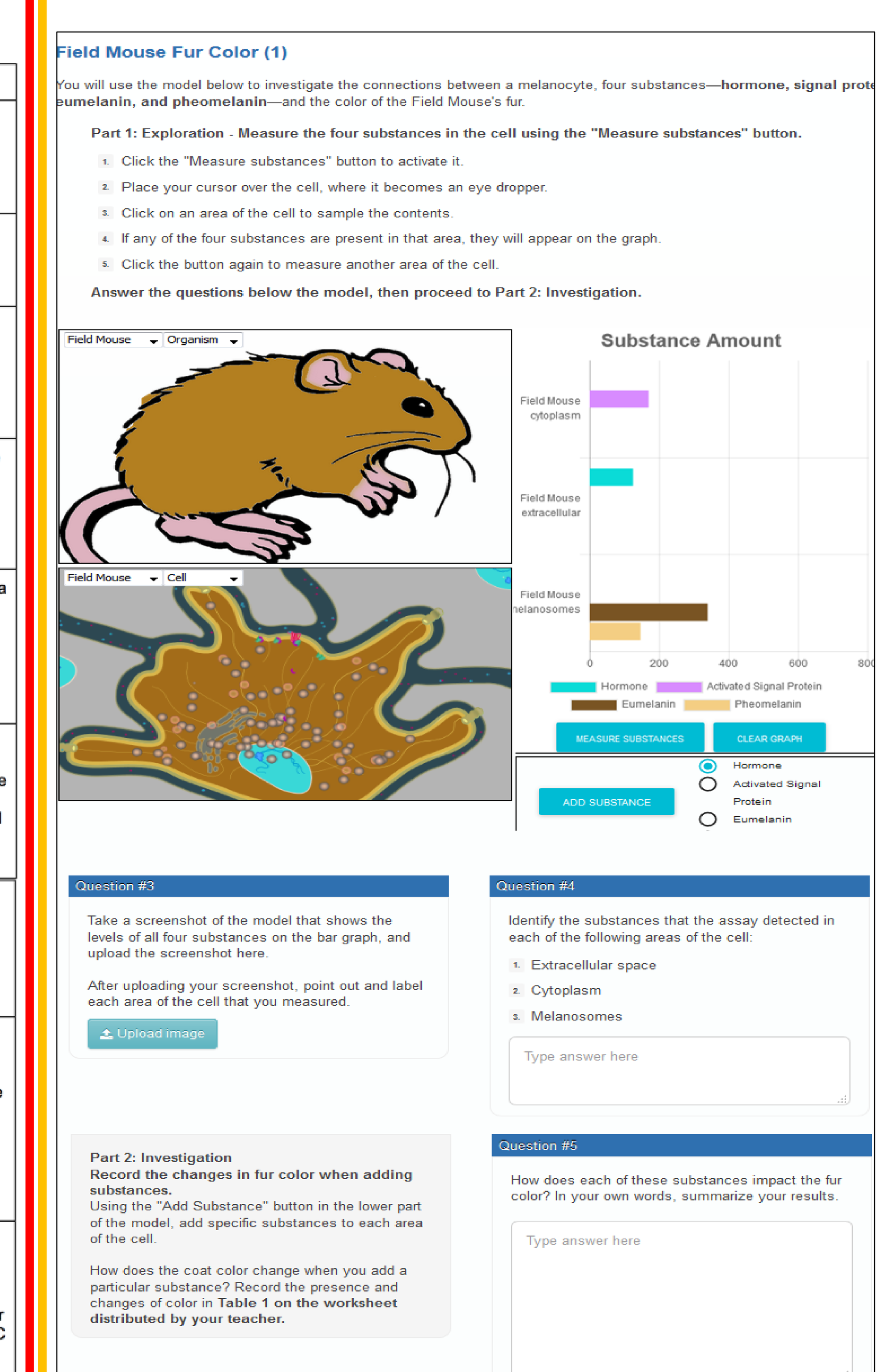
Developmental Approach: Project materials are developed using a cyclical, approach where the integrative evolution cases are deconstructed and re-assembled as a set of observable phenomena, occurring at different biological scales. These phenomena become the object of student investigations that are structured around NGSS Performance Expectations, through a coherent "story-line" (i.e., a learning sequence), facilitated with online interactive simulations.

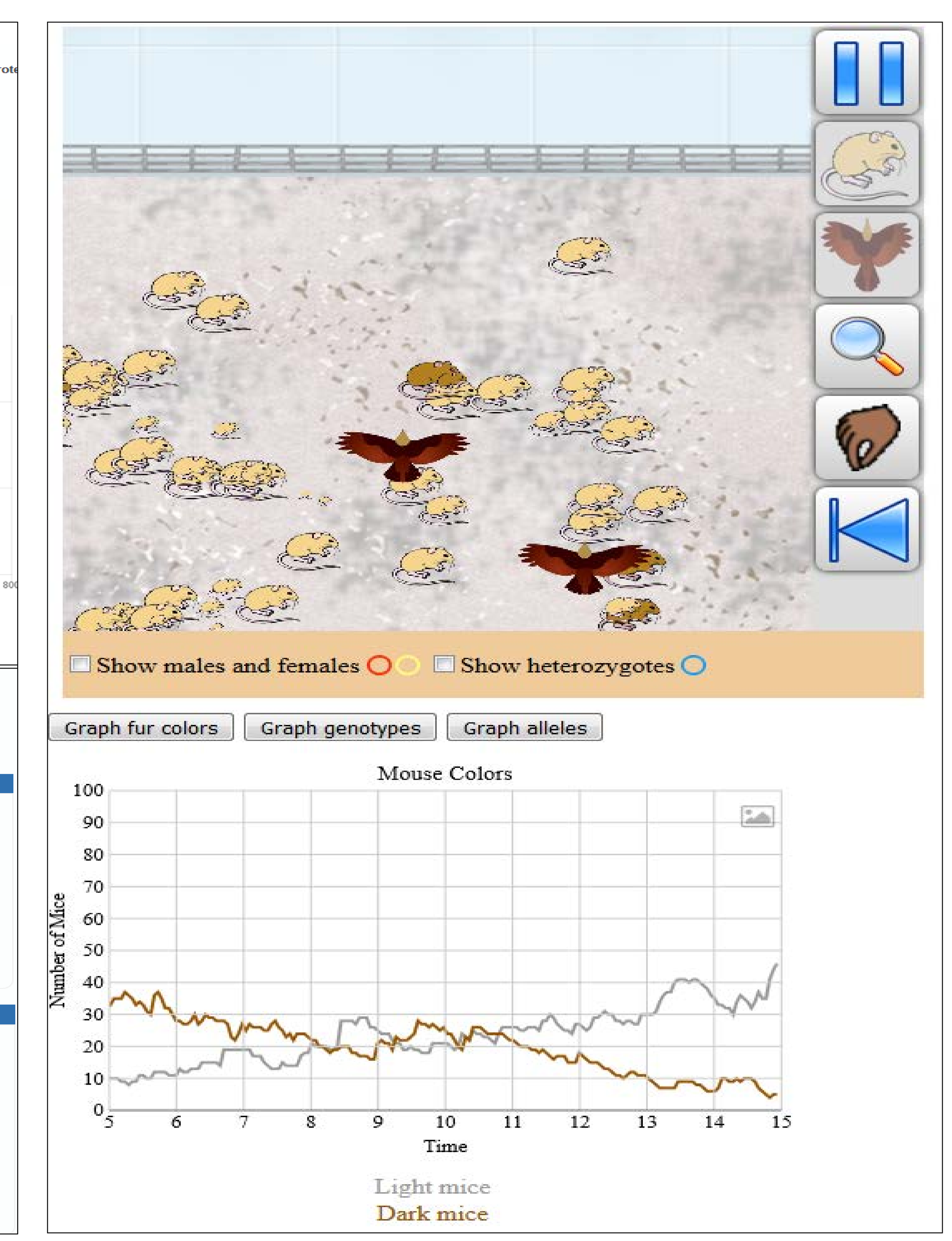


These learning materials are developed with input and feedback from Master Teachers and piloted in classrooms in grades 10-12. Phase 1-2 of the project involves technology testing and development. Phase 3-4 involves classroom trials and assessment.

DRIVING QUESTION: **How and why do mice coats on beaches end up white while those in old fields end up brown?**
Note: read the table one row at a time: move from left to right all the way across, then move to next row.

	Phenomenon	Question	Student Explanation	Investigation	Data & Finding
1	Mouse coat colors vary across regions that are dramatically different in soil color and brightness.	Do subspecies' fur colors vary with habitat in general, even if environmental differences are subtle?	Different kinds of mice have different colors, like cats and dogs.	Use field study data set to explore the relationship between region and fur color.	Fur and environmental characteristics are correlated with less dramatic differences in soil color/brightness.
2	Brightness of habitat varies with coat color. Lighter coat is in lighter environments and vice versa.	What happens to mice with different colors of fur in the light and dark habitats?	Predators can see contrasting colors and eat the ones that stand out.	Choose one of these: -Data set 1 (Owls) -Simulation of predation -Data set 2 (Clay mice)	Visual predators take advantage of contrasting brightness between prey and environment.
3	Predators are driving the pattern of light fur with light environment and vice versa.	How does fur become light or dark? Is it due to something in the environment?	- bleaching by the sun - Food - Dark soil dirt - temperature - seasonal change - a need to blend in (camo)	How would you test these different explanations? → investigate whether dark mice can become light when exposed to the sun/light	Fur does not become lighter when exposed to the sun. Beach mouse fur color is not influenced by immediate environmental conditions.
4	The color of fur is determined by some process within an organism's body	How does fur become light or dark?	[Have students generate hypotheses (explanations that can be tested) to explain these differences.]	Skin is made of cells. Students use MLM to zoom into the **cell level** to assay and experiment with substances and compare differences in whole cell function in the field mouse.	Pigments in the cell determine the color of the fur, and there are other substances that influence the amounts of different pigments.
5	The production of eumelanin and pheomelanin occurs as a result of different amounts of substances in and around the cell.	What makes the beach mouse different from the field mouse?	There are different substances? There are different amounts of substances? Some molecules are missing?	Students make predictions about the specific components of the pathway and how they influence fur color, develop a model for this production, and test their predictions by testing the addition of substances to the beach mouse cell.	Pigment in the fur is made by a series of interactions between the substances.
6	The MC1R transmembrane protein receptor acts differently in dark and light-colored mice.	What is the specific difference in the melanin production pathway between a dark mouse and a light mouse?	Something isn't working? Mice that don't need a particular color don't produce it?	Students zoom in to investigate the **protein level** at the cell membrane level and they can add the α-MSH and see that it binds with the membrane receptor protein in both dark and light mice and interacts with the protein but only loosens the g-protein in the dark mouse.	The difference between the light and dark fur color is due to differences in the membrane receptor protein that binds α-MSH and then activates signal protein.
7	Differences in the amino acid sequence change the structure and function of the protein.	How does the change in one amino acid influence the production of pheomelanin?	The receptor is broken?	Students explore the protein structural differences in the tertiary, secondary, and primary structure and identify the difference is this one amino acid and make predictions for how this change might influence the function.	There is a key amino acid difference, involving cysteine vs arginine at an intracellular loop of the MC1R protein.
8	Mutational changes can create differences in phenotype.	How do you get this difference in amino acid in the protein?	Genes encode proteins so there must be differences in the genes.	Find the gene for the receptor protein (MC1R) and sequence the DNA for the gene from both dark and light-colored mice. [Might want to use primers to obtain a shortened segment of the gene] Align sequence. Carry out transcription and translation to verify that a particular mutation corresponds to the amino acid difference.	A single nucleotide mutation results in an amino acid change (Arginine which we label R and Cysteine which we label C).
9	The gene (MC1R) has two forms (alleles) one having the amino acid Arginine and one Cysteine. These appear as different alleles on homologous chromosomes and determine coat color	How do these alleles interact within an individual to influence melanin synthesis?	Each allele might have a partial effect on coat color, or maybe one is dominant.	Students use the MLM and click on mice with dropdown menu corresponding to different alleles and look at how these alleles interact to create variation. Students can explore how different combinations of alleles influence coat color.	The combination of alleles an individual has determines the coat color. There is a clear pattern: beach mice with the RR genotype tend to be darker than those with the RC and CC genotype.





Each integrated case of trait evolution is re-constructed as a set of lesson-level questions, guided by phenomena observable at different scales. These phenomena are investigated by students at each scale and student findings help them piece together the integrative, cross-scale nature of trait evolution. Student investigations are designed to have explicit links to NGSS Performance Expectations and are articulated with Lesson-Level Learning Performances.

MICHIGAN STATE UNIVERSITY

The Concord Consortium

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Acknowledgement:
Support for this work was provided by the National Science Foundation's Discovery Research DRK12 program under Award Nos. DRL-1620746 and DRL-1620910 . Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.