Assignment 4

STUDENT LEARNING OUTCOMES

- Be able to recognize their own misconceptions, especially:
  - Misconception #1: Evolution by natural selection occurs only slowly
  - Misconception #2: Agency – Adaptation by natural selection occurs due to need (i.e., organisms *needed* to adapt in response to a selection pressure)
- Dispel their misconceptions and understand why their prior understanding is inaccurate

MODULE WALK-THROUGH

Introduction	
Topic introduced:	- Evolution includes mechanisms such as genetic drift and natural selection - This module will focus on **natural selection** as it is the only mechanism that consistently results in **adaptation** - Learning outcomes
Visual format:	- Illustration

Experiment 1	
Topic introduced:	- **Generation time**
Purpose:	- Introduce the concept of generation time in the context of natural selection - Relatively simple concept to help students familiarize with module process - Promote students to recognize whether or not they understand the concept of generation time - Promote students to understand how the length of generation time may impact rate of adaptation
Visual format:	- Animation of each scenario (short vs long generation time) - Feature: graphical representation of generation time

Structure:	- *Predict:* How does the length of generation time impact the rate of adaptation?
	- *Experiment:* (note – no order to scenarios, dependent on whichever the student picks first)
	  - *Scenario 1:* Toggle on short generation time / off long generation time – show population quickly adapting to strong selection pressure (such as a toxic dump to the species' environment)
	  - *Scenario 2:* Toggle on long generation time / off short generation time – show population slowly adapting to the same strong selection pressure

	- *Observation and analysis:* 2-3 questions to direct student's attention to… o What happened in the experiment o How their prediction may be correct/wrong (and why) o Probe for their understanding of generation time (how deeply they understand the concept)
Background:	- Adaptation may occur faster since generation time is shorter so there are more "rounds" of reproduction and selection

Experiment 2

Topic introduced:	- **Genetic variation** and (secondarily) population size
Purpose:	- Introduce the concept of genetic variation and its relationship to population size - Promote students to recognize the misconception of "agency" - Promote students to understand how genetic variation plays a role in natural selection; that genetic variation (advantageous traits) must be present in order for adaptation by natural selection to occur
Visual format:	- Animation of each scenario (large vs small population size) o Feature: visual representation of genetic variation
Structure:	- *Predict:* How may population size and diversity impact the rate of adaptation? - *Experiment:* (note – no order to scenarios, dependent on whichever the student picks first) o *Scenario 1:* Toggle on large population size / off small population size – show a highly diverse population that can quickly adapt to strong selection pressure o *Scenario 2:* Toggle on small population size / off large population size – show a population with little diversity that either slowly or does not adapt to the same strong selection pressure - *Observation and analysis:* 3-4 questions to that prompts students to…. o Explain what happened in the experiment o Explain how their prediction may be correct/wrong (and why) o Recognize their misconceptions regarding agency o Recognize that without the genetic basis (advantageous traits) present, adaptation by natural selection cannot occur o Evaluate their understanding of genetic variation (diversity) and population size
Background:	- Larger population size with higher diversity means higher genetic variation leading to more chances of beneficial/advantageous mutations (in terms of rapid evolution, this means it would take less

	time to adapt since you're working with a large pool of mutations already) - For example, tomcod fish develop resistance to toxic waste dump versus other animals who do not (due to not having genetic traits to do so)
Misconception targeted	- Adaptation occurs due to need; if advantageous traits aren't present for adaptation, the species cannot adapt no matter how strongly they "need" to

Experiment 3

Topic introduced:	- **Heritability**
Purpose:	- Introduce the concept of heritability and its connection to genetic variation - Promote students to recognize the misconception of "agency" - Promote students to understand how heritability plays a role in natural selection; that genetic variation (advantageous traits) must be present AND heritable in order for adaptation by natural selection to occur
Visual format:	- Animation of each scenario (heritable vs non-heritable trait) o Feature: visual representation of genetic variation, and heritable and non-heritable traits
Structure:	- *Predict:* How may genetic heritability impact adaptation? - *Experiment:* (note – no order to scenarios, dependent on whichever the student picks first) o *Scenario 1:* Toggle on "traits are heritable" / off "traits are not heritable" – show a population that can quickly adapt to strong selection pressure, organisms with a certain trait are consistently selected for and are able to survive and reproduce o *Scenario 2:* Toggle on "traits are not heritable" / off "traits are heritable" – show a population that does not adapt to the same strong selection pressure, random selection of organisms regardless of traits - *Observation and analysis:* 3-4 questions to that prompts students to…. o Explain what happened in the experiment o Explain how their prediction may be correct/wrong (and why) o Evaluate their understanding of heritability including genotype and phenotype o Recognize their misconceptions regarding agency o Recognize that without the heritability and genetic basis (advantageous traits) present, adaptation by natural selection cannot occur

Background:	- Natural selection requires genetic traits that are heritable and can therefore be passed down and selected for - Non-heritable traits would not be selected (in subsequent generations)
Misconception targeted	- Adaptation occurs due to need; if *genetic* (genotypic) traits aren't heritable, the species cannot adapt no matter how strongly they "need" to

Experiment 4

Topic introduced:	- **Selection pressure** and **differential survival**
Purpose:	- Introduce the concept of selection pressure and differential survival - Promote students to recognize whether or not they understand the concept of selection pressure and differential survival - Promote students to understand how the strength of selection pressure may impact differential survival and therefore, the rate of adaptation
Visual format:	- Animation of each scenario (strong vs weak selection pressure)
Structure:	- *Predict:* How does the strength of selection pressure impact the rate of adaptation? - *Experiment:* (note – no order to scenarios, dependent on whichever the student picks first) o *Scenario 1:* Toggle on strong selection pressure / off weak selection pressure – show population rapidly having a trait that becomes selected for (ie: adaptation rapidly occurring) o *Scenario 2:* Toggle on weak selection pressure / off strong selection pressure – show population stay relatively the same (ie: no/slow adaptation occurring) - *Observation and analysis:* 2-3 questions to direct student's attention to… o What happened in the experiment o How their prediction may be correct/wrong (and why) o Probe for their understanding of selection pressure and differential survival (how deeply they understand the concept)
Background:	- Natural selection requires differential survival - Larger selection pressure means more differences in survival such as climate change/environmental impacts (toxic dump, for example: tomcods quickly developed increased resistance to PCBs when a company dumped them in the Hudson River)

Experiment 5

Topic introduced:	-	Rapid evolution (by natural selection)
Purpose:	-	Application of all prior concepts in a more free-form environment (less guided) to remediate a new misconception - Promote students to recognize the misconception of slow evolution
Visual format:	-	Simulation with 4 toggles that students can do different combinations of: o Generation time o Population size o Heritability o Selection pressure
Structure:	-	*Predict:* Does evolution by natural selection occur rapidly or slowly? - *Experiment aim:* o Short generation time, large population with high genetic variation, trait is heritable, and high selection pressure leads to the population quickly adapting to a selection pressure - *Observation and analysis:* 4-5 questions to that prompts students to…. o Explain what happened in the experiment o Explain how their prediction may be correct/wrong (and why) o Evaluate their understanding of how the different variables worked together o Recognize their misconceptions regarding slow evolution
Background:	-	Rapid evolution by natural selection generally favours populations with a short generation time, large variation / large population size, advantageous trait must be heritable, and high selection pressure
Misconception targeted	-	Evolution by natural selection only occurs slowly

Summary

Structure:	-	4-5 concluding questions that summarizes the major take-aways of the module - Visual format may include illustrations or small non-static graphic

CASE STUDIES

Potential case studies

- Elephants
- Galapagos finches
- Pocket mice

Integration of case studies:

- We will aim to utilize only one or two case studies throughout in order to prevent having to introduce new information (thereby minimizing cognitive load)
- Case studies will mostly likely include only one group (genus) of animals however different features are selected for depending on the experiment type

CURRENT TIMELINE

- **December 2017**
  - Learn C#, After Effects (etc.)
  - Storyboard / Key path scenario development
  - Content development and implementation
  - Visual scaffold design
  - Wireframe
- **January 2018**
  - Ethics
  - Content development and implementation
  - Visual scaffold design
  - Wireframe
- **February 2018**
  - Needs assessment
  - Development of prototype
  - Graphic user interface design
- **March 2018**
  - Development of prototype
  - Graphic user interface design
  - Prototype testing
  - Formative assessment
- **April 2018**
  - Development of prototype
  - Graphic user interface design
  - Prototype testing
  - Formative assessment
- **May 2018**
  - Summative assessment
- **June 2018**
  - Data analysis
  - Paper writing

FINAL NOTES FROM COMMITTEE MEETING (TUESDAY, DEC 5TH 2017)

- Module should focus on promoting student recognition of their own misconceptions and acting as a tool for professors to diagnose misconceptions
  - Built in formative assessment (not summative)
- Alignment with threshold concepts

- Graphic representations (such histograms etc) should also include visual scaffolds that help students understand the graphics
- Consider using Javascript, HTML and CSS (instead of C#/Unity)