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Assessing Evolutionary Reasoning of Introductory Biology Students

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ASSESSING EVOLUTIONARY REASONING OF INTRODUCTORY BIOLOGY STUDENTS

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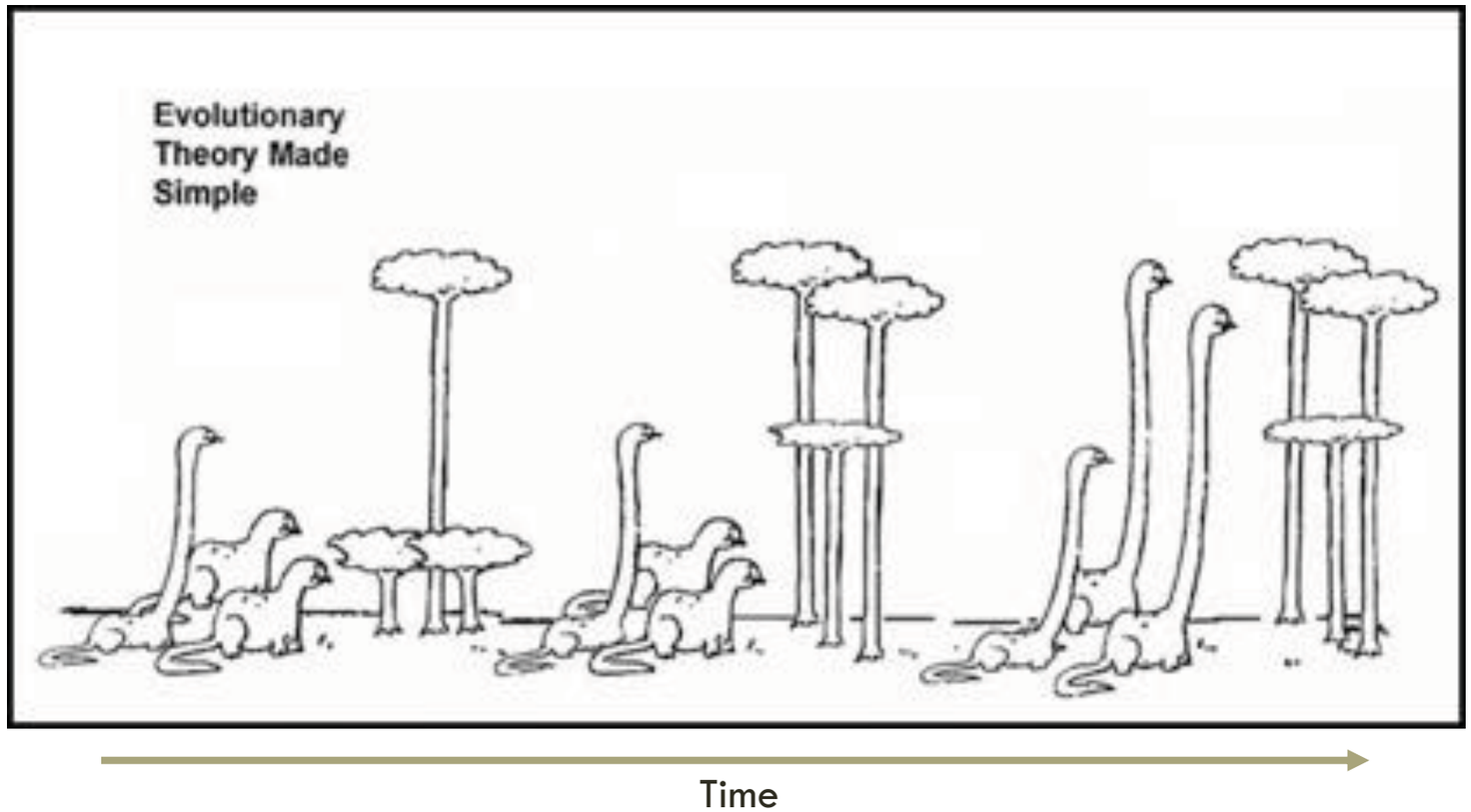
OVERVIEW

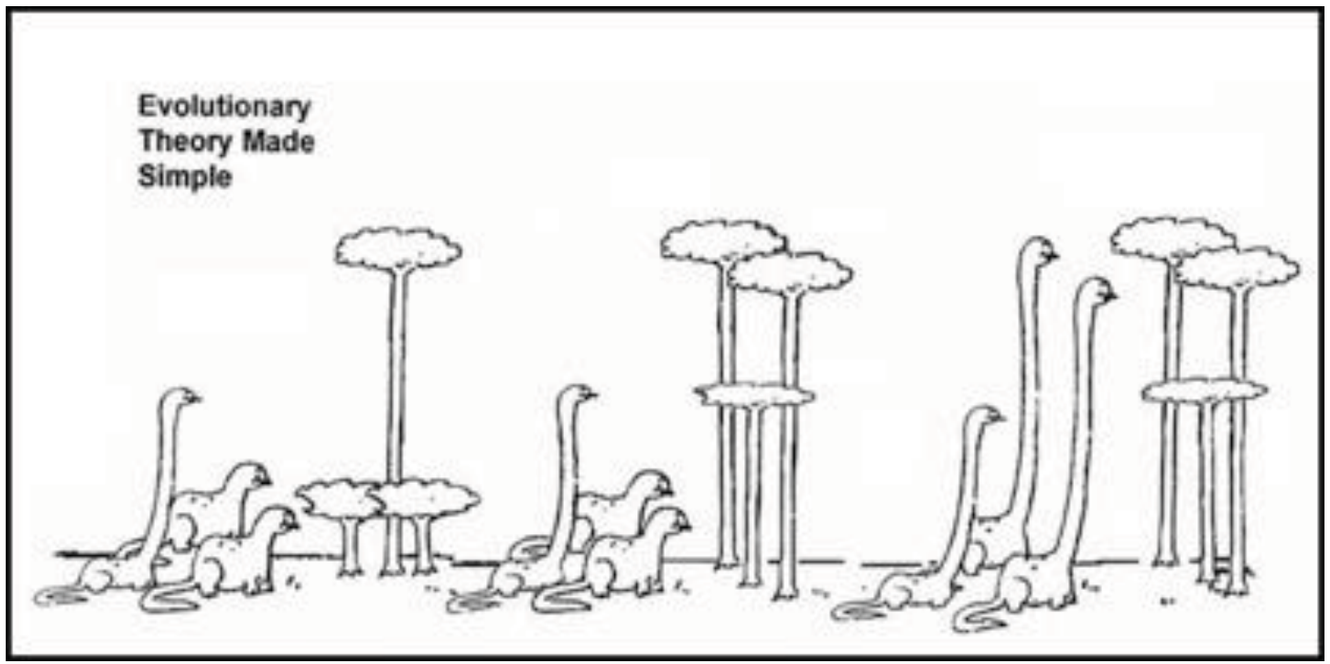
- Brief introduction of selection and evolution
- Methods and Analysis
  - Assessment
  - Interview
- Feedback

NATURAL SELECTION



The cartoon above represents change that has occurred in a population of dinosaurs and a population of plants over thousands of years (time is read from left to right). Use your current understanding of evolution by natural selection to explain how the changes came about.

NATURAL SELECTION



Time

Components of Natural Selection

1. Phenotypic variation
2. Genetic variation
3. Reproductive potential
4. Limited resources/carrying capacity
5. Competition/limited survival potential
6. Selective survival based on heritable traits
7. Change in the distribution of individuals with certain heritable traits

(Nehm & Reilly, 2007)

THE DIFFICULTY OF EVOLUTIONARY CONCEPTS

Fitness = Survival x Reproductive Potential

Misconceptions:

- Relating fitness to survival but not reproductive success
- Teleological reasoning

Evidence of evolutionary misconceptions in:

- Middle school and high school students
- Undergraduate biology students – majors and non-majors
- Medical students
- Biology teachers

(Brumby, 1984; Settlage, 1994; Tekkaya, 2001; Nehm & Reilly, 2007; Coley & Tanner, 2012)

Natural Selection Assessments

Concept Inventory of Natural Selection (CINS)

- (Anderson et al., 2002)

Open Response Instrument (ORI)

- (Nehm & Reilly, 2007)

Assessing Contextual Reasoning About Natural Selection (ACORNS) Instrument

- (Nehm et al., 2012)

- Missing analysis of sexual selection concepts specifically

ADAPTATIONS FOR REPRODUCTIVE POTENTIAL ARE NOT ALWAYS OBVIOUS

Student reasoning can vary based on context (Nehm et al., 2012).

Image Source: American Bird Conservancy

Image Source: Easy Science for Kids

Question: Does proficiency in natural selection knowledge predict the quality of student reasoning of reproductive potential as a component of fitness?

Hypothesis: Students with higher scores on the Concept Inventory of Natural Selection (CINS) will have more accurate descriptions of reproductive potential as a part of fitness.

Goals:

- Assess student ability to reason about fitness and selection in a variety of contexts
- Assess student reasoning of evolutionary implications of an ecological scenario

METHODS

STUDENT POPULATION

Institution: University of Nebraska – Lincoln

Course: Fundamentals of Biology II (LIFE121)

- Topics: Evolutionary processes, plant and animal ecology
- Textbook: Campbell Biology in Focus
- Second semester biology (or related) majors

Timing: 2 weeks after Evolution unit exam

- Normally first or second exam of the semester

QUANTITATIVE ANALYSIS - CINS

Concept Inventory of Natural Selection (Anderson et al., 2002)

- Questions about natural selection in the context of finches, guppies, and lizards.

Conceptual Inventory of Natural Selection

D.L. Anderson and K.M. Fisher

Your answers to these questions will assess your understanding of the Theory of Natural Selection. Please choose the answer that best reflects how a biologist would think about each question.

Galapagos finches

Scientists have long believed that the 14 species of finches on the Galapagos Islands evolved from a single species of finch that migrated to the islands one to five million years ago (Lack, 1940). Recent DNA analyses support the conclusion that all of the Galapagos finches evolved from the warbler finch (Grant, Grant & Petren, 2001; Petren, Grant & Grant,, 1999). Different species live on different islands. For example, the medium ground finch and the cactus finch live on one island. The large cactus finch occupies another island. One of the major changes in the finches is in their beak sizes and shapes, as shown in this figure.

Choose the one answer that best reflects how an evolutionary biologist would answer.

1. What would happen if a breeding pair of finches was placed on an island under ideal conditions with no predators and unlimited food so that all individuals survived?
   Given enough time
   a. the finch population would stay small because birds only have enough babies to replace themselves.
   b. the finch population would double and then stay relatively stable.
   c. the finch population would increase dramatically.
   d. the finch population would grow slowly and then level off.

Anderson et al., 2002

QUALITATIVE ANALYSIS - INTERVIEW

Semi-structured Interviews

Baseline questions followed by four scenario questions

- Questions about natural selection in general
- Similar organisms (birds) in all scenarios helps keep the focus on changes in context
- Questions will follow specific order – not randomized

OPENING QUESTION: GENERAL NATURAL SELECTION QUESTION

Open-response questions based natural selection Open Response Instrument (ORI) by Nehm and Reilly (2007)

- Questions based on ORI:
  - Please define natural selection to the best of your ability.
  - What types of phenomena impact natural selection?

Concept	Context	Goal
Trait unrelated to reproductive potential	Finch Beaks	Assess student reasoning of a scenario with no clear sexual ornamentation; males and females are the same
Trait that benefits both surivival and attractiveness	Poison Dart Frog Color	Assess student reasoning of sexual selection in a scenario where a trait benefits both attractiveness and survival
Trait with trade-off between surivival and attractiveness	Widowbird Tails	Assess student reasoning of sexual selection in a scenario with trade-off between attractiveness and survival
Evolutionary Implications of an Ecological Scenario	Chickadees and Traffic Noise	Evaluate student ability to identify evolutionary implications of an ecological change imposed on a species

EVOLUTION OF A TRAIT SHARED BY BOTH SEXES

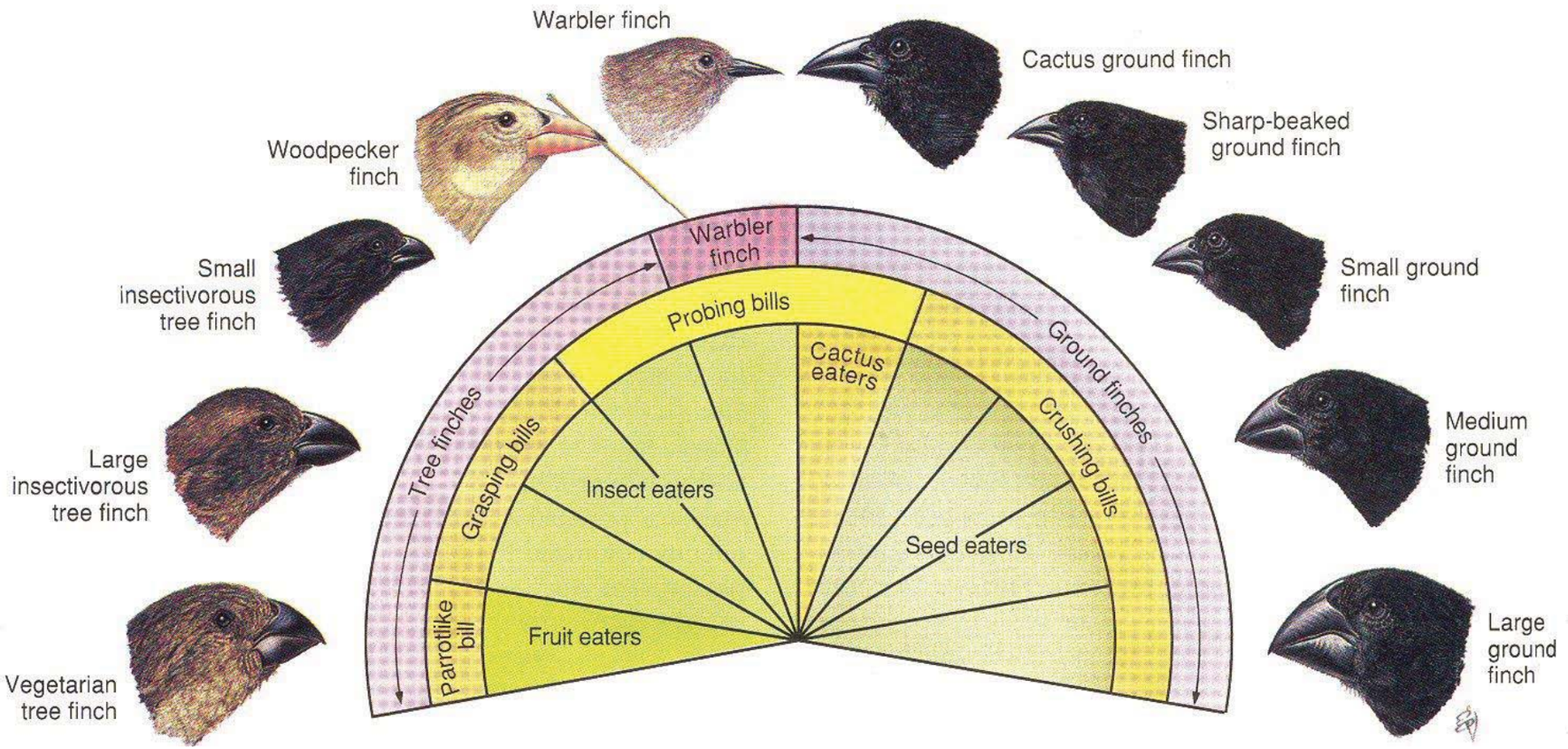


Image Source: Steven Carr

Goals:

- Evaluate student reasoning of evolution of a trait with no clear sexual selection

Potential Interview Questions:

- Do you see any morphological variation that could be selected for?
  - How can this be?
- How do you think selection is functioning in this system?
- Please explain the process of evolution with regards to beak shape.

EVOLUTION OF A TRAIT THAT IMPROVES BOTH SURVIVAL AND ATTRACTIVENESS

Poison Dart Frog

- Female select for color
- Color is also an antipredator characteristic

Image Source: Austin Penner

Goals:

- Evaluate student reasoning of evolution of a trait that benefits both survival and reproductive potential
- Assess student reasoning of behavioral evolution

Potential Interview Questions:

- Do you see any morphological variation that could be selected for?
  - How can this be?
- How do you think selection is functioning in this system?
- Please explain how you think evolution of color occurred.

TRADE-OFF BETWEEN SURVIVAL AND ATTRACTIVENESS

Female Long-tailed Widowbirds (*Euplectes progne*) prefer longer-tailed mates (Andersson, 1982).

Energetic costs and predation select against long tails (Pryke & Andersson, 2002)

Female

Image Source: Eric Landsberg

Male

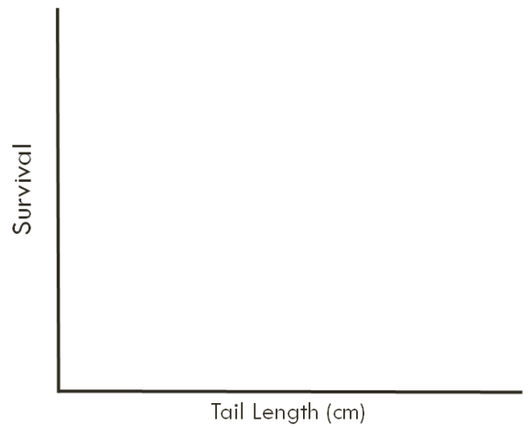
Image Source: Chris JeK

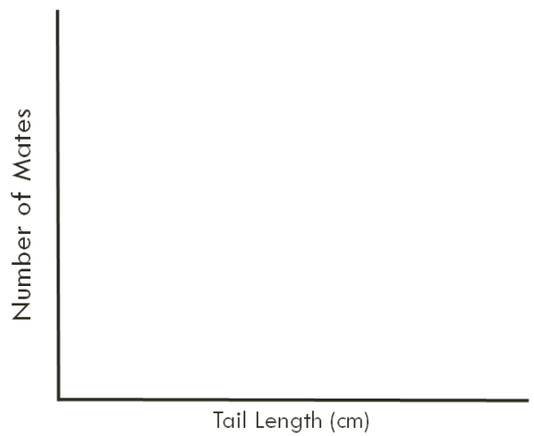
SEXUAL SELECTION FOR A MORPHOLOGICAL TRAIT

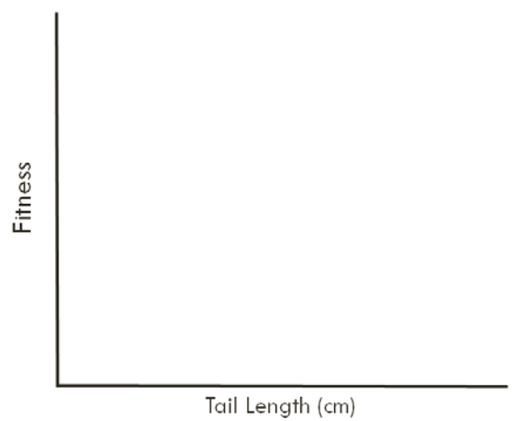
Goal: Assess student reasoning of sexual selection of a morphological trait that has survival trade-offs

Interview Questions:

- What differences do you observe between the male and female Widowbirds?
- Why do male and female Widowbirds look different?
- Would predators have an easier time catching a male or female? Why?
- How do you think selection working with regards to tail length?







EVOLUTIONARY IMPLICATIONS OF ECOLOGICAL CHANGE

Provide students with background of my project

- There is evidence of Black-capped Chickadees (*Poecile atricapillus*) altering their vocalizations in response to loud traffic noise.
- The birds change the frequency of their call in order to not be masked by traffic noise.
- Female Chickadees select mates based on song

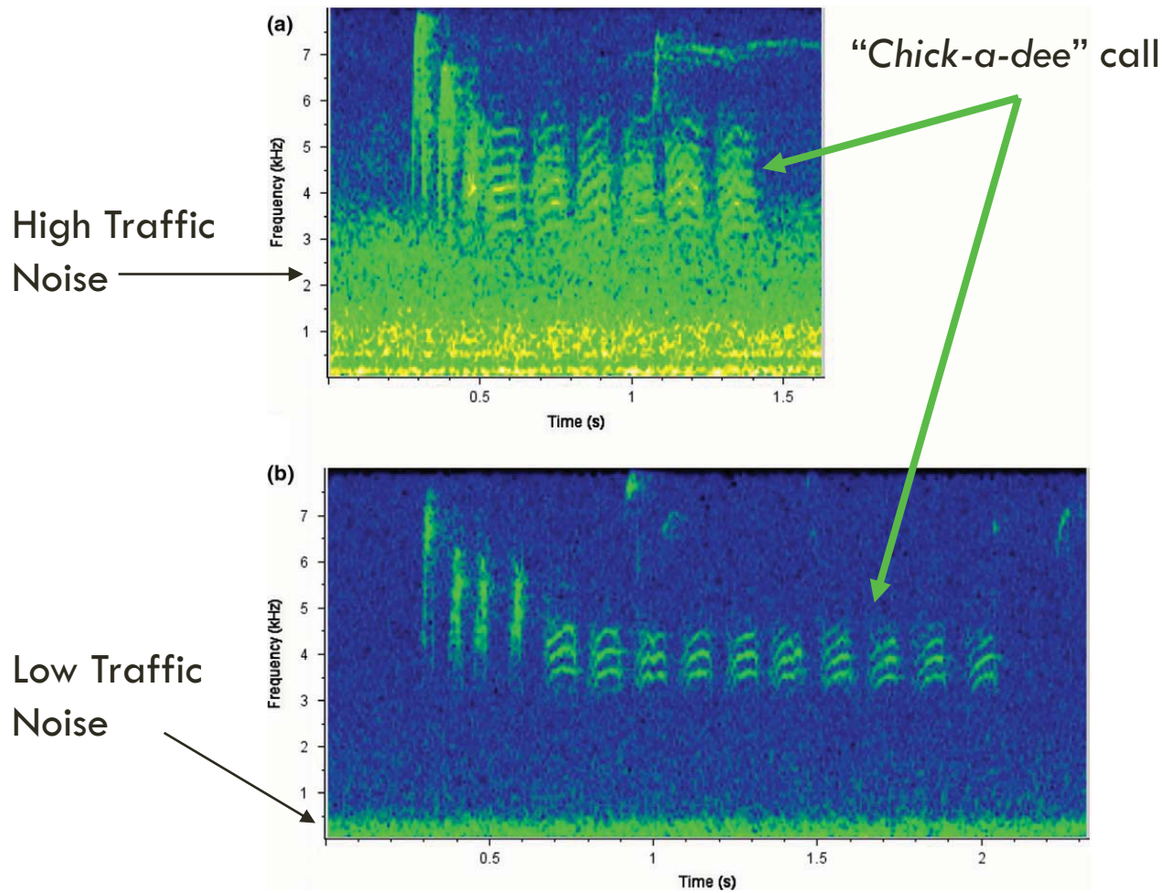



Photo: Missy Mandel

EVOLUTIONARY IMPLICATIONS OF ECOLOGICAL CHANGE

Goals:

- Evaluate student ability to identify evolutionary implications of an ecological change imposed on a species

Interview Questions:

- How could road noise impact the evolution of this species?
- What do we need to know to determine the evolutionary implications?

ANALYSIS

- Quantitative – CINS score
- Coding
  - Rubric: 7 components of Natural Selection
  - Do students address more components in certain scenarios?

Components of Natural Selection

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(Nehm & Reilly, 2007)

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