Exploring evolution through fox domestication

Cara A. Krieg1, Stefan Cerbin2, Damian Popovic3, Klara Scharnagl3, Suzanne Slack5

1 Department of Integrative Biology, Michigan State University, East Lansing, MI 48824, USA

2 Department of Horticulture, Plant Breeding, Genetics and Biotechnology Program, Michigan State University, East Lansing, MI 48824, USA

3 Department of Plant Biology, Ecology, Evolutionary Biology, and Behavior Program, Michigan State University, East Lansing, MI 48824, USA

5 Department of Plant, Soil, and Microbial Sciences, Michigan State University, East Lansing, MI 48824, USA

Citation:

Original article: Trut LN, Plyusnina Z, Oskina IN. 2004. An experiment on fox domestication and debatable issues of evolution of the dog. Russian Journal of Genetics 40:644-655.

Student reading material: Goldman JR. 2010. Man’s new best friend? A forgotten Russian experiment in fox domestication. Scientific American. <https://blogs.scientificamerican.com/guest-blog/mans-new-best-friend-a-forgotten-russian-experiment-in-fox-domestication/>. Accessed October 23, 2016.

**Introduction**

 In this lesson, students will learn to explore the mechanisms of evolution by artificial selection in the framework of silver fox (*Vulpes vulpes*) domestication. In advance of class, students will read an article from Scientific American, “Man's new best friend? A forgotten Russian experiment in fox domestication” by Jason Goldman. This article details an experimental effort to breed tamer foxes initiated by Russian geneticist Dmitry Belyaev. Belyaev’s foxes achieved a dramatic increase in tameness and shift in various correlated physical characteristics in the span of only 42 generations. Belyaev’s work demonstrates that artificial selection for one trait can lead to dramatic population-level changes within an abbreviated timeframe, illustrating rapid evolutionary processes that were previously thought to occur gradually. This lesson is designed to introduce a broader unit on evolution by natural selection in introductory biology courses. Students should have prior experience constructing and interpreting graphs, however prior exposure to evolution in an undergraduate classroom is not required.

 This lesson is designed to teach students the concept of evolution through a variety of active learning exercises while targeting several key misconceptions about evolution. This lesson is organized around the core idea that evolution can be defined as change in allele and/or genotype frequency in a population and is thusly manifested in changes in inherited characteristics over generations. Students can struggle with the relevance of evolution if taught solely as a process that unfolds over broadscale time (Wescott and Cunningham 2005). In this lesson, student’s misconceptions will be challenged by graphing evidence of rapid evolutionary change. Students may mistakenly believe that evolution simultaneously changes the traits of all members of the population instead of changing the proportion of individuals that have a particular trait (Alters and Nelson 2002; Bishop and Anderson 1990). This misconception is addressed in Part 1. Additionally, students often erroneously believe that evolution changes just one trait at a time and that traits change because organisms “need” them to (Wescott and Cunningham 2005; Alters and Nelson 2002; Bishop and Anderson 1990). These misconceptions are addressed in Part 2. This activity will engage students by utilizing readings, visual media (videos and graphs), and discussion modules designed to encourage an active learning environment. Using these teaching methods will leverage the diversity inherent in class participants. Throughout the lesson, student’s progressive understanding will be assessed via hand-in homework. The end-of-lesson formative assessment will gauge whether students can take what they learned about artificial selection and apply it in the context of primary literature concerning natural selection.

**Lesson Plan**

*Learning Objectives*

1. Translate a data table into a graph and interpret trait variation across generations.
2. Using evidence, explain how a population changes due to a selection event.
3. Construct a model showing how silver fox traits changed due to artificial selection on tameness.

*Lesson Timeline*

Before class: (~ 1 hour) Read article and answer homework questions

In class: Part 1\*

 (5 min) Watch video

 (10 min) Think-pair-share discussion of video/homework questions

 (15 min) Instructor led explanation of the definition and requirements for evolution

 (15 min) Part 1 graphing exercise

 Part 2

 (10 min) Instructor led explanation and introduction to Part 2

 (20 min) Part 2 modelling exercise

 (5 min) Wrap-up class discussion

\*For a 50 minute class period, instructors can teach only Part 1. Alternatively, they can shorten the time devoted to discussion in Part 1, introduce the assignment for Part 2, and assign the modelling exercise as homework.

*Part 1*

1. **Engagement**

Before class, have the students read the following article: “Man's new best friend? A forgotten Russian experiment in fox domestication” by Jason Goldman. <https://blogs.scientificamerican.com/guest-blog/mans-new-best-friend-a-forgotten-russian-experiment-in-fox-domestication/>

While reading the article, students should be instructed to define the following terms in the context of the article describing how they are illustrated in the article: evolution of silver foxes, variation of tameness, heritability of tameness, fitness of tame foxes, selection of foxes. Students are to be instructed to use examples defending your position. Students should be prepared to hand this in as homework at the start of class.

At the beginning of class, students will watch a video to supplement reading. <https://www.youtube.com/watch?v=0jFGNQScRNY>

**2. Exploration**

After watching the video, students will be posed with the following questions in order to gauge their current understanding of evolution: **[Q1]** Does this experiment illustrate evolution? **[Q2]** Why/why not? Allow them sufficient class time to discuss their answers, fostering think-pair-share in student groups. Instructors should visit several groups during discussion to address student misconceptions. Instructors should then call on individual groups and summarize the responses.

**3. Explanation**

Following a classwide discussion, instructors will present their students with the definition of evolution and lecture on the conditions needed for evolution to occur. Heritability, phenotypic variation, and fitness advantages will be discussed accordingly. This section is appropriate to reiterate responses from homework, drawing connections between broader evolutionary concepts and what students read the night prior. An example powerpoint is provided in the supporting information.

After giving a short lecture, instructors pivot back to the students and ask: **[Q3]** Where in the experiment are the conditions of heritability, phenotypic variation, and fitness advantages met? Ask for examples from the reading. This can be conducted as a small group or whole class discussion depending on class size.

**4. Elaboration**

The next section will involve working with data sets from Belyaev’s original domestication experiments. Students will practice illustrating graphical data and engaging in evidence based arguments. In groups, students will be challenged to translate the data table listed below into a graph. There are intentionally multiple ways students may choose to represent these data.

(Trut et al., 2004)

While groups make progress on the prompt, instructors and teaching assistants can traverse the classroom providing input where appropriate. As the assignment wraps up, instructors can choose several groups with different graphs to demonstrate diverse, yet acceptable methods to present these data.

 Students will then be asked the following: **[Q4.1]** What percentage of elites are observed in generation 42? **[Q4.2]** Why did the ratio of elites fail to reach 100% by 2002 (gen. F42)? Optional auxiliary questions include: how this graph represents the elements of evolution over time can be asked. This final elaborative exercise may be completed and handed in at the end of class for participation points. However, should resources and time permit, it would be most ideal to have student groups sketch their graph on mobile, personal whiteboards.

**5. Evaluation**

Student’s grasp of the material introduced will be gauged by their answers to in-class discussion questions. To determine if understanding has improved over the course of Part 1, instructors will compare in class answers to those provided in the homework. Progress from the homework to the in class questions provides evidence that students misconceptions are indeed being addressed. With larger classroom sizes, instructors and learning assistants may opt to subsample responses, aggregating common mistakes to be address the following class period. Ultimately, this would allow for better time use efficiency.

*Part 2*

In Part 2, students will explore the pleiotropic effects of selection on tameness. Belyaev’s silver foxes underwent other unusual changes in phenotype over the course of their domestication. These included coat color, ear structure, tail shape, and skull morphology. These parallel phenotypic shifts demonstrate a pleiotropic effect of selection on tameness. Meaning, selection on one seemingly independent trait promoted a generational change in auxiliary traits previously unknown to be correlated with one another. This suggests that some genes regulate the outcome of many phenotypes (pleiotropy), providing a possible mechanism for rapid evolution. In this section, students will work with a graph from the Trut et al. paper illustrating that hormonal regimes were found to be significantly different in tame foxes compared to the non selected foxes.

**1. Engagement/Exploration**

 Students will discuss the following question in groups: **[Q5]**: If the scientists selected foxes for tameness, why do we also see directional changes in auxiliary features (including coat color, floppy ears, etc.)? Many students erroneously believe that traits change because they “need” to. This question is posed specifically to challenge this misconception.

**2. Explanation**

Students will be given a handout featuring a graph from Trut et al’s paper with the following narrative (handout provided in supplementary information):

Belyaev’s foxes showed other changes beside their increased level of tameness. Some foxes had floppy ears and some had spotted coats. Floppy ears and reduced fear are both characteristics that baby foxes have but lose as they get older.

Belyaev’s tame foxes showed much lower levels of cortisol in their blood stream, a hormone that increases when an animal is stressed. An animal with lower cortisol will exhibit

less fear. Cortisol is part of a group of hormones known as glucocorticoids. While glucocorticoid levels may be influenced by only a couple genes, glucocorticoid levels can impact other characteristics. Glucocorticoids impact the production of pigment cells responsible for color, are thought to impact the rate of development for other tissues, and have an important impact on behavior (Trut et al. 2004; Trut et al. 2009).

**3. Elaboration**

After going over the handout, students will be asked to make a model explaining the processes underlying the phenotypic effects using an evolutionary process. This will be the formative assessment to be evaluated along with the other notes taken on the carbon paper before and during class.

The two questions from the handout are:

**[Q6]**: Create a model showing how selection on tameness in Belyaev’s foxes could lead to changes in other characteristics. In your model identify which characteristic was the target of selection by humans. Include the words “humans”, “glucocorticoid levels”, “cortisol levels”, “floppy ears”, “coat color”, and “tameness”. Label your model with an appropriate figure legend.

**[Q7]**: Using your model, explain why coat color changed in tame foxes. Did humans select for coat color?

 Instructors should conclude the lesson with a brief discussion on the differences between artificial and natural selection. This lesson is designed to be a jumping off point for further lessons on evolution by natural selection.

**5. Evaluation**

 The evaluation of the entire lesson includes the reading prior to class with the students note and answers to the questions. In class answers to the question and instructor reviewing of the handed in work. The goal of the evaluation is to access the students’ ability to use the scientific practices in the framework of evolution. Mastery of this assignment will include (1) logical model that accurately reflects the details provided in the paragraph, (2) correct identification of tameness as the sole target of selection by humans, and (3) an explanation of the change in coat color that reflects their model and does **not** include selection on color directly or the “need” for color to change.

**Teaching Discussion**

 This lesson utilizes a multifaceted approach using Tanner’s 5 E’s of lesson planning to teach the concept of evolution. The lesson implements reading, video, think-pair-share, working with data and making a model. The lesson requires that students have already mastered inheritance, meiosis, mutation, and other genetic concepts. The lesson draws from an experiment with fox domestication showing how breeders selected for tameness and observed many phenotypic changes. This study illustrates evolution by artificial selection showing the phenotypic differences, heritability and differential fitness.

A major challenge to teaching this topic is the misconceptions that students have about evolution; students will be coming into the classroom with preconceived notions that are not necessarily correct. Even though they have been exposed to a multitude of genetic concepts, there is still a large possibility that not everything has clicked for them regarding evolution as a process. Using a system example that they can see and understand, like the silver foxes example, can help solidify that evolution is a concept they they can accurately grasp.

The lesson’s effectiveness is based on the 5 E’s framework on which the lesson is model (Tanner 2010). This lesson has not yet been taught in an introductory biology class at the university level.

Extension of this lesson plan is broad and applicable to a core biology class syllabus. The lesson uses an experiment demonstrating a domestication process in Silver Foxes in Russia. This topic leaves open many different aspects for students to explore and build from. Introduction in following lesson may include other artificial selection experiments highlighting evolution from current literature, student interest or other applicable domains. Some instructors may find engaging experiments from their own institution that are engaging or utilize examples that are familiar to the student audience, while also addressing the diversity present in the class. Additionally the core concept of evolution can be used by drawing from other natural selection examples for the students to work with. While more reinforcement of these concepts necessitates more than one class session on evolution this lesson may be implemented in the teaching of introductory biology.

The supporting information includes an example exam question using a natural selection example from the literature. As part of a cumulative assessment, students can be assessed on their ability to perform the scientific practices in this lesson (e.g., make a graph from a table of data, engage in argument from evidence, make a model) as well as mastery of the scientific content (e.g. explain how a population changes in response to selection, identify the target of selection, identify the agent of change).

**Supporting Information**

Teacher powerpoint: Evolgroup\_lessonSlides

Student handout for Part 2 modelling exercise: “evol-Part2handout.doc”

Example exam question for cumulative assessment: “evol-Finalexamquestion.doc”

Rubric for example exam question: “evol-Examrubric.doc”

**References**

Alter BJ, Nelson CE. 2002. Teaching evolution in higher education. Evolution 56:1891-1901.

Bishop BA, Anderson CW. 1990. Student conceptions of natural selection and its role in evolution. Journal of Research in Scientific Teaching 27:415-427.

Tanner KD. 2010. Feature Approaches to Biology Teaching and Learning Order Matters: Using the 5E Model to Align Teaching with How People Learn. CBE—Life Sciences Education 9:159–164.

Trut LN, Plyusnina Z, Oskina IN. 2004. An experiment on fox domestication and debatable issues of evolution of the dog. Russian Journal of Genetics 40:644-655.

Trut L, Oskina I, Kharlamova A. 2009. Animal evolution during domestication: the domesticated fox as a model. BioEssays 31:349-360.

Wescott DJ, Cunningham DL. 2005. Recognizing student misconceptions about science and evolution. MountainRise 2 DOI:<http://dx.doi.org/10.1234/mr.v2i2.60>