Child Cognition Lab
BOSTON UNIVERSITY

How the Piloses Evolved Skinny Noses

Book Orientation and Supplementary Materials Manual

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I. Introduction: Using this Manual

This manual provides an orientation for using the book *How the Piloses Evolved Skinny Noses* and its supplementary online materials, which are accessible here. Each section of this manual overviews each supplementary activity, and offers instructions on how to run that particular activity.

Section I: Introduction | Learn about the instructional goals of the unit.

This section provides a basic introduction to the materials and to the concepts embedded in those materials. It explains how our book, *How the Piloses Evolved Skinny Noses*, and its supplementary assessment materials were designed. It also provides an inventory of all materials needed for the complete unit.

Section II: Lesson Plan | When and how to use the materials.

This section provides guidelines for how these research-based materials should be used, as well as basic information about each activity. Each activity is described in fuller detail later in the manual.

Section III: Facts and Misconceptions | Adaptation by natural selection – facts and misconceptions.

This section describes what research has identified as the building blocks of the concept of adaptation by natural selection. It also describes several early-developing and enduring misconceptions that make it difficult for children and adults to learn about the concept. Teaching these facts and addressing these misconceptions to scaffold children's accurate understanding of adaptation by natural selection is the goal of this unit.

Section IV: Activities and Assessment Materials | Detailed instructions for lesson plan activities.

This section provides detailed information about the activities briefly listed in the lesson plan. It details how to read the book, how to use the assessment worksheets, and provides an overview of the in-class simulation activity **[For reasons of length, this simulation activity has its own instruction manual here]**.

Although reading the book may seem straightforward, our lab has a specific method of calling attention to certain aspects of natural selection via pointing. A video detailing this pointing method can be found here.

Section V: Assessing Evolutionary Understanding | Assessing and responding to student (mis)understanding.

This section describes how to assess students' understanding of adaptation by natural selection. It refers back to Section III (Facts and Misconceptions) and details ways to address and correct students' lack of understanding, misconceptions or missing facts.

Section VI: Additional Resources | Contact information, FAQs, and additional resources.

This section contains contact information for the Evolving Minds Research Team and a link to our Evolving Minds Project FAQ page. We seek your feedback and ideas because we are constantly working to improve and add to these teaching resources.

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I. Introduction: What is this Unit?

What is this unit*?* *How the Piloses Evolved Skinny Noses* and its associated assessment materials were designed by the Child Cognition Lab at Boston University as part of the National Science Foundation-funded Evolving Minds Project. The Evolving Minds Project is developing research-based educational materials to support children's understanding of evolution by natural selection in elementary school. Click here to learn more about this project.

Why focus on teaching evolution? Evolution is one of the cornerstones of biology education. However, it can be a difficult topic to grasp. Many people hold persistent misconceptions about the process. Various psychological studies have suggested that these misconceptions develop from a young age and persist well into adulthood. Adaptation by natural selection is a core evolutionary concept that is particularly difficult to understand. Because of its educational importance, it is very important to catch misconceptions about it from early on and introduce young children to scientifically accurate material. This unit aims to do just that. It provides a step-by-step, misconception-free way to teach this foundational evolutionary idea to elementary school students.

Instructional goal of this unit: This unit provides a way to thoroughly explain the process of adaptation by natural selection to young children. It is easily integrated into curricula based on the Next Generation Science Standards or related STEM standards. The overall goal is to provide students with an accurate framework for understanding adaptation by natural selection–a basic and integral principle of evolution–so that they can apply it across a range of scenarios involving various species. In many state science standards, ideas about adaptation are introduced around third grade. Our classroom materials have been developed so that they can be used as early as second and third grade.

How were these materials designed?: To learn about the research underlying the development of these materials, please take a look at our research page. To get answers to some questions that you might have (e.g. why we used realistic but fictional animals), please check out the Evolving Minds Project website FAQ page.

How do you pronounce "piloses" and "pilose"??

Piloses (pl.) = **Puh**-lo-*sez (*rhymes with "noses")
Pilose (sing.) = **Puh**-lo-*sah (*rhymes with "samosa")

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II. Lesson Plan

Certain aspects of this lesson plan are **optional**, but **highly recommended**. The lesson plan is outlined below:

1) **Optional:** Pre-Test Assessment
   a) Using one of the *food-based adaptation* assessments (**piloses**, **tardons**, **orpeds**, **rudoos**, **wilkies**) assess students' baseline understanding of adaptation by natural selection
      i) Recommended *food-based adaptation* assessment: tardons
   b) **Note**: This pre-test can be done at an earlier date than the following activities

2) Book Reading
   a) Read *How the Piloses Evolved Skinny Noses* to your class
      i) Before reading, check out the pointing guide for the book **Link**
   b) **Optional: [Strongly recommended]** After reading the book, have the students fill out the assessment post-book comprehension assessment worksheet about the piloses

3) In-Class Simulation Activity
   a) Please be sure to read the full instructions for the in-class activity [**Link**]
   b) Using the **provided materials**, set up the piloses simulation

4) Post-Test Assessment
   a) Using a **different** *food-based adaptation* assessment worksheet, assess students' understanding of adaptation (**piloses**, **tardons**, **orpeds**, **rudoos**, **wilkies**)
      i) Recommended *food-based adaptation* assessment: orpeds

5) Discussion
   a) Using students' answers on the post-test, assess how well they understand evolution
      i) Look for the presence of evolutionary facts as outlined in this manual [**Link**]
      ii) Look for the presence of evolutionary misconceptions as outlined in this manual [**Link**]
   b) After identifying any misconceptions/lack of facts, discuss them with your class

6) **Optional:** Far-Generalization Assessment
   a) Use one of the *predation-based adaptation* assessment worksheets to assess students' abilities to generalize what they have learned about adaptation to a different species and scenario (**manus**, **tomads**)
      i) Recommended *predation-based adaptation* assessment: manus

NOTE: The provided materials contain several other assessment animals that can be used for optional additional assessments. All assessment worksheets can be found **here**.

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III. Facts and Misconceptions: Facts

Understanding the process of adaptation by natural selection requires understanding five key facts that build on recognition that members of biological populations vary from each other. These facts are detailed below.

Fact	Description	Example
Differential Survival	The understanding that members of animal populations vary and individuals with advantageous traits are more likely to survive. Animals with disadvantageous traits are less likely to live and die	"The piloses with thinner trunks were able to reach the bugs and so ate and stayed healthy. The piloses with wider trunks couldn't eat and so they died."
Differential Reproduction	The understanding that animals with advantageous traits have more energy, so will have more children. Animals with disadvantageous traits have less energy, so have fewer children, or die before having any children	"Because they could eat and were healthy, the piloses with thinner trunks had lots of babies. Piloses with wider trunks were unhealthy and so didn't have any babies."
Multiple Generations	The understanding that this process happens again and again, over many hundreds of years	"…Then their babies grew up and had more babies with thinner trunks, and they grew up and had even more babies with thinner trunks…"
Inheritance	The understanding that children usually have the same traits as their parents	"...the pilose would have a thinner trunk because its parent has a thinner trunk."
Trait Constancy	The understanding that traits stay the same for the entirety of the animal's life	"This baby pilose with a thinner trunk will have a thinner trunk when it is fully-grown, too."

NOTE: The first three items on the list, **differential survival, differential reproduction,** and **multiple generations**, build on recognition that members of animal populations differ from each other. They are essential to understanding adaptation by natural selection and should be addressed if missing. The last two items, inheritance and trait constancy, are still important, but we have found that children rarely express these facts without specific prompting.

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III. Facts and Misconceptions: Misconceptions

Even after having learned about adaptation by natural selection in high school, college, and graduate school, many adults continue to have misconceptions about the process. This is why it is important to read the book *How the Piloses Evolved Skinny Noses* before teaching with it. Below is a list of the most commonly held misconceptions held by children and adults.

As you go through the included activities, keep these misconceptions in mind. If any of your students hold any of these misconceptions after learning about the piloses, use this guide to offer them a scientifically accurate way of thinking about adaptation by natural selection. When assessing natural selection understanding, check for the presence of any of these misconceptions and the facts on the previous page.

Misconception	Description	Why It's Incorrect	Misconception Examples
Need	The belief that members of a given species develop a trait *in response to a need* for that trait.	Advantageous traits do not emerge to meet a need. Members of animal populations differ from each other by chance, and individuals that have environmentally advantageous traits tend to have a higher rate of survival and reproduction	"The piloses needed to grow long noses so that they could reach the millibugs."
Developmental	The belief that an individual member of a species will develop a given, often advantageous trait, as it grows older.	While overall body size may grow/change, physical traits such as claw shape usually remain stable throughout an organism's lifetime.	"This pilose was born with a wide trunk, but it will grow longer and thinner as it gets older (potentially implied: so that it can reach millibugs)."
Transformation	The belief that one member/generation of a species is able to spontaneously acquire new beneficial traits	It takes multiple generations before traits that happen to provide some members with a survival advantage end up predominating in a population.	"The piloses with wide trunks turned into ones with thin trunks and they could eat."
Effort	The belief that an individual organism can develop a given trait through exertion	Species can develop certain physical features such as muscle mass through effort, but most traits such as claw size and trunk shape generally cannot be altered.	"The piloses just kept trying to stretch their noses until they could reach the ends of the tunnels."

NOTE: Developmental and Transformation are very similar misconceptions. The difference is that with a developmental misconception, an animal *grows into* a trait, whereas in transformation, the animal suddenly changes/acquires the trait.

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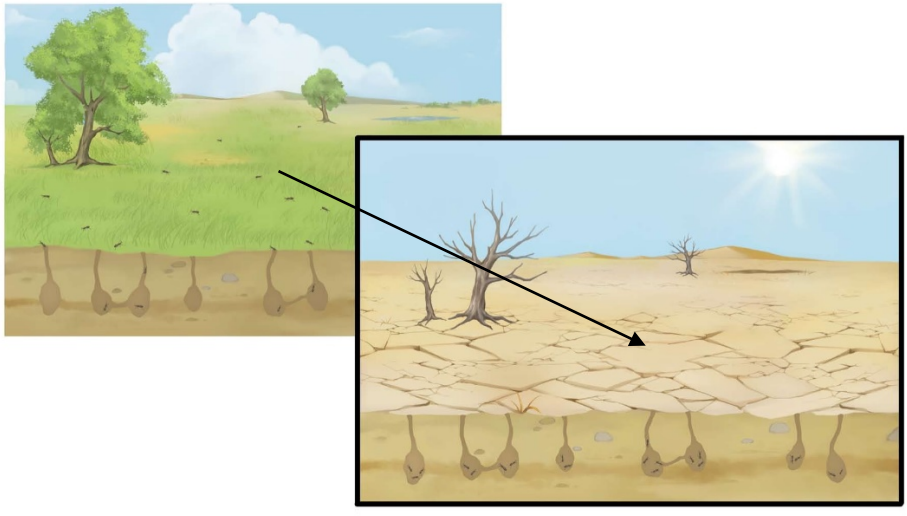
IV. Activities and Assessment Materials: Reading the Book

The storybook, *How the Piloses Evolved Skinny Noses,* was designed to introduce the idea of **adaptation by natural selection** to elementary school children. Understanding adaptation by natural selection is key to acquiring a scientifically accurate understanding of evolution. Core aspects of adaptation by natural selection are usually introduced to schoolchildren around grades three or four.

This book was designed to be used with second and third graders because research suggests that it might helpful to introduce this material in early elementary school grades. The book begins by introducing the piloses, a realistic but fictional anteater species that lives in a meadow. As the environment changes, the population of piloses changes too. The book accurately depicts this population shift, and explains how the process of adaptation works over many generations. Before reading the book to your class, there are a few things to keep in mind:

- Be sure to read the book to yourself beforehand so that you are familiar with the material.
- This book comes with a pointing guide, which you can find **here**. The book is designed to use pointing as a way to emphasize particular aspects of the process of adaptation - please be sure to look carefully at the pointing guide when reading through the book.
- The layout of *How the Piloses Evolved Skinny Noses* uses a "*double-paged spread" format* – most illustrations are spread across two pages that should be interpreted as one large picture.
- At various points in the book, the passage of time is mentioned. It is important to emphasize these sections to ensure that students are introduced to the concept of generations going by.



Pointing example: In the above picture, draw a diagonal line from left to right with your finger to call attention to **time passing** (and the climate changing with it).

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IV. Activities and Assessment Materials: Using the Assessment

Included in the supplementary materials are one-page assessments of students' understanding of adaptation by natural selection. These assessments can be used to explore how much children understand before receiving instruction and after receiving instruction.

In total, there are **five food-based adaptation** assessments including the piloses assessment: piloses, orpeds, tardons, rudoos, and wilkies. All of these worksheets involve food/foraging scenarios that have similarities to the situation described in the book. There are also **two predation-based adaptation** assessments: manus and tomads. These use camouflage scenarios that are quite different from the situation described in the book. Like the piloses, the assessment species are realistic but fictional. We use unfamiliar species to introduce children to adaptation by natural selection because using real species can make it harder for children to set aside preconceived ideas and learn accurately.

Food-Based Adaptation Assessments: When assessing children's understanding before instruction, immediately after the book, and after the classroom activity, please use different **food-based adaptation** assessments. The reason why a different species should be used for each test is so that you can explore whether or not a student can apply the concept across different scenarios. For pre-book-reading and post-simulation activity assessments, use an adaptation assessment that is not piloses. A post-book reading assessment using the piloses is **optional but we strongly recommended it to check children's comprehension-- especially if you are not conducting the classroom activity**.

Predation-Based Adaptation Assessments: Although this lesson plan was designed to teach food-based adaptation, our research shows that students can often apply or generalize much of what they have learned to other quite different cases of natural selection. **Predation-based adaptation** assessments have been provided to test whether a student can generalize the idea of adaptation to a situation that is not solely based around acquiring food. These assessments are **optional**, and, if used, should be administered at the end of all other activities.

All assessment worksheets follow the same format: (1) They begin by providing background information, such as describing the environment and making note of how the population changed over time. (2) Then, students are asked to explain how this change occurred in as much detail as possible.

On the next page, you will find a sample assessment worksheets. All worksheets can be found [HERE]. To use them:

1. Provide each student with their own worksheet.
2. Read aloud the instructions and answer questions about them.
3. Give children **5-10 minutes** to complete the assessments.
4. Once all assessments are collected, use sections III and V of this manual to check the students' answers.

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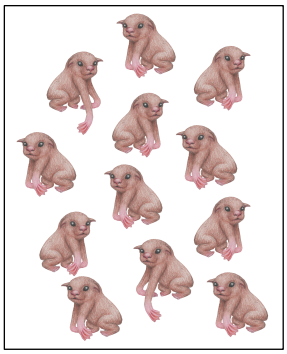
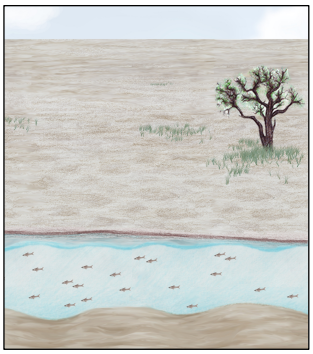
IV. Activities and Assessment Materials: Using the Assessment Continued

Let's look at animals called ***orpeds.*** I want to tell you some things about them!

Hundreds of thousands of years ago

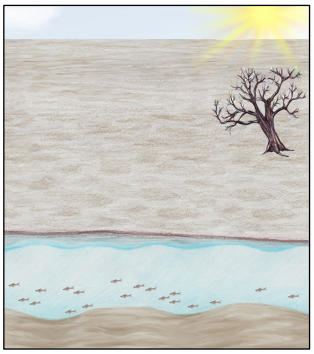


This is what the group of orpeds looked like many hundreds of years ago. Many had shorter arms, and a small number had longer arms.

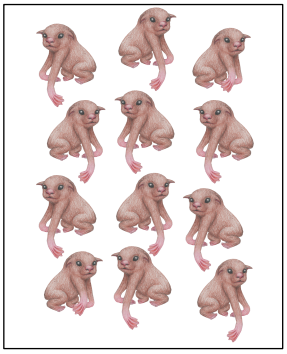


This is where the orpeds lived and what they ate, the minnows, many hundreds of years ago.

Nowadays



But then the weather became very hot and sunny all of the time, and now the minnows mostly swim at the bottom of the water. So this is where orpeds live and what they eat, the minnows, now.



And this is what the group of orpeds looks like now. See, they mostly all have longer arms.

Imagine it is your job to teach someone about what happened to the orpeds. They need to know how the orpeds went from having mostly shorter arms long ago, to having mostly longer arms now. It is your job to tell them everything about the process and all of the events from long ago up until now. On the back of this page, write down what you would tell someone so they would completely understand how this happened over time.

Example Assessment: This is a **food-based adaptation** assessment depicting the fictional orpeds.

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IV. Activities and Assessment Materials: In-Class Simulation Activity

The instructions below are a short summary of detailed instructions found here. If you have not yet read the detailed instructions for "Natural Selection in Action!", please do so now. You can find the rest of the materials here. This simulation should be run immediately after reading the book or following children's completion of the piloses assessment.

The "Natural Selection In Action!" simulation activity allows students to act out the events of the book and is intended to help students understand how gradual change takes place in a population over *multiple generations*. In the activity, students are assigned a member of piloses population and then track the progress of their member and the whole population over a number of generations. To understand this activity, read *How the Piloses Evolved Skinny Noses* first [link]. We strongly recommend watching the video guide here.

1. Prepare the materials [link to materials].

   Materials: (1) 32 1st Generation *Pilose Cards*, (2) 32 2nd Generation *Pilose Cards*, (3) 32 3rd Generation *Pilose Cards* (all cards should be cut out and folded along the dotted lines); (4) printouts of 2 *Environment Tiles* (meadow and desert), (5) 3 *Timeline Tracker Sheets*, (6) 3 *Millibug Tunnel Pages*; (7) 3 bins or baskets.

2. Set up the classroom – this simulation requires the students to move about.

   Set Up: (1) Label the bins/baskets "Piloses with Wider Trunks," "Piloses with Thinner Trunks," and "Dead Piloses" and place the three baskets/bins in different classroom locations; (2) Place the Meadow Environment Tile on a table and surround it with the 32 1st Generation Pilose cards. Display the three Timeline Trackers in an easy-to-see spot. Place the three Millibug Tunnel Pages in an easy-to-see spot.

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IV. Activities and Assessment Materials: In-Class Simulation Activity Continued

3. Pair up students if necessary. The simulation game is designed for 32 students. However, it can be run with 16 – if you have between 16 and 32 students or over 32 students, you can pair up as many students as necessary to reach either 16 or 32 – not all students necessarily need to be paired.

4. Begin running the simulation.

- Generation 1
    1. Ask the students to look at the population of piloses who live in the meadow. Ask them to count the number of piloses with thinner trunks and the number with wider trunks.
        - Record these on the Meadow Timeline Tracker
    2. Ask the children if all of the piloses can get food in the environment.
        - Answer: Yes, because the millibugs are all over the meadow
    3. Show the environment changing from meadow to desert.
        - (switch the Environment Tiles, explain that the weather became hot and sunny all the time)
    4. Place the 1st Generation Pilose cards into a box or bag, shuffle them, and ask each student/pair to pick out one of the piloses.
    5. Ask each child to unfold their piloses card. At the bottom it lists the number of millibugs their animal can eat. Ask them to proceed to the Tunnel Page that matches the amount of millibugs their member of the population can eat.
    6. Direct children to discuss with a partner about the trait their member of the piloses species has and the amount it can eat and why.
    7. Have the class reconvene and discuss together (1) what would happen to piloses that have each of the different trunks, (2) whether their member of the piloses would have children and how many they would have if they do; (3) the traits that those children would have (if there are any children) (Answer: likely the same as their parents).
    8. Direct students to go to the bin that goes with their piloses card and pick out the children the animal on their piloses card had.

- Generations 2 & 3: Explain how much time has passed and that all of the 1st Generation piloses have grown old and died. Direct students to discard the 1st Generation piloses into the dead piloses bin, and instruct them to place their new, 2nd Generation Piloses (marked with a black dot like this: ●) or 3rd Generation (marked with a dot like this: ○) around the environment tile. Repeat Generation 1 steps excluding the environmental change step.
- By the end of the simulation, adaptation by natural selection should have led the piloses species to shift from having mostly wider trunks (1st Generation) to mostly thinner trunks (3rd Generation).

V. Assessing Evolutionary Understanding

Once the simulation activity is over, assess how well your students understand adaptation by natural selection. Recall the misconceptions and facts mentioned earlier [in section III of the manual]. You can use these facts and misconceptions to gauge how well your students understand the process. When assessing students' understanding of adaptation by natural selection, we recommend taking a two-pronged approach: written worksheet assessments and oral responses. These two forms of assessments should be analyzed for the presence of both the evolutionary facts *and* evolutionary misconceptions already described.

If misconceptions are present and facts are lacking…

If you find any misconceptions or find any facts lacking, the recommended next step is **discussion**. We recommend discussion as it allows for the entire class to get involved in an active dialogue about adaptation and why animals have the specialized body parts that they do. This can help fix misconceptions and instill missing facts. For example:

Teacher: "Can anyone tell me why they think there are more orpeds with longer arms now than there were many hundreds of years ago?"

Student 1: "I think it's because the orpeds with shorter arms stretched and stretched until their arms were longer, and then their babies got longer arms, too."

Teacher: "Hmm, that's an interesting idea! Does anyone have any other ideas?"

Student 2: "I think it's because the orpeds who already had longer arms were better at getting food, and so were healthy and had lots of babies who also had longer arms!"

Teacher: "That's correct!"

We recommend discussion of any misconceptions present in any of the post-test assessments. Such discussion should explain why these misconceptions are scientifically inaccurate and should introduce scientifically accurate explanations. We recommend addressing any missing facts unrelated to misconceptions. The book and associated materials (assessments and activities) can be used multiple times.

If students are misconception-free and facts are present…

Congratulations! It looks like your students truly grasp the basics of adaptation. At this point, if you have not already, you may want to try using the predation-based adaptation assessment worksheets to check for their ability to generalize what they have learned to scenarios that are very different than the one in *How the Piloses Evolved Skinny Noses*.

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VI. Background and Contact Information

If you have any questions regarding the assessment material or the Evolving Minds project in general, please feel free to send us question at the Boston University Child Cognition Lab at childlab@bu.edu. You can also visit our Evolving Minds contact page for more ways to reach out and to sign up for our mailing list.

Check out EvolvingMindsProject.org for our FAQ page, as well as additional information about our research and ways to get involved. Based on feedback to our forum, we hope to update and post additional lesson plans and resources over time.

We will also post information about additional picture books in the Evolving Minds Project series. *How the Dormits Evolved Long Backs* is a companion book to *How the Piloses Evolved Skinny Noses*. It offers children another description of adaptation by natural selection and will be available in 2018!

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