

EXPLORATIONS LAB AND ACTIVITIES MANUAL



Explorations

Explorations Lab and Activities Manual

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TABLE OF CONTENTS

Licensing

1: Introduction to Biological Anthropology

- 1.1: Knowing and Believing
- 1.2: Icebreaker Science
- 1.3: Science and Belief- Just Because We Can, Doesn't Always Mean We Should

2: Evolution

- 2.1: The Scientific Method- Converting Curiosity into Study
- 2.2: Misconceptions about Evolution

3: Molecular Biology and Genetics

- 3.1: Blood Typing Lab
- 3.2: Protein Synthesis- One Act Play
- 3.3: Protein Synthesis Pizza

4: Forces of Evolution

- 4.1: Natural Selection Lab
- 4.2: Bingo Chip Evolution
- 4.3: Evolutionary Detectives

5: Meet the Living Primates

- 5.1: Primate Classification
- 5.2: Primate Tweets
- 5.3: Creating a Monster Phylogeny
- 5.4: Modern Primate Museum

6: Primate Ecology and Behavior

- 6.1: Watching Primates
- 6.2: Primate Behavior Part I
- 6.3: Primate Behavior Part II

7: Understanding the Fossil Context

- 7.1: Stratigraphic Dating and the Harris Matrix
- 7.2: Dating Exercise
- 7.3: Reconstructing Paleo-environments

8: Primate Evolution

- 8.1: Fossil Primates
- 8.2: Prehistoric Primate Museum
- 8.3: Extant and Fossil Catarrhine Morphology

9: Early Hominins

- 9.1: Australopithecine Locomotion
- 9.2: Tactile Evolution
- 9.3: Fossil Hominins

10: Early Members of the Genus Homo

- 10.1: Hominin Dinner Party
- 10.2: Early Homo Lab

11: Archaic Homo

- 11.1: Hominin Review- Evolutionary Trends
- 11.2: The Genus Homo
- 11.3: Brain, Language, Lithics

12: Modern Homo sapiens

- 12.1: Modern Human Art
- 12.2: What Does it Mean to be Human?

13: Race and Human Variation

- 13.1: Patterns of Human Variation - online
- 13.2: Patterns of Human Variation - in person

14: Human Adaptive Significance Approach

- 14.1: Thermal Stressors
- 14.2: Human Skin Color Variation - Part I
- 14.3: Human Skin Color Variation - Part II

15: Bioarchaeology and Forensic Anthropology

- 15.1: Articulating MNI in the Cranium
- 15.2: Roll-Up, Life-Sized Juvenile Age Estimation

16: Contemporary Topics- Human Biology and Health

- 16.1: Stone Age Bodies, Space Age Challenges
- 16.2: Global Distribution of BMI

17: Appendices

- 17.1: Appendix A- Osteology - Directional Terms
- 17.2: Appendix B- Primate Conservation
- 17.3: Appendix C- Human Behavioral Ecology - The Evolution of Cooperation

Index

Glossary

Detailed Licensing

Licensing

A detailed breakdown of this resource's licensing can be found in [Back Matter/Detailed Licensing](#).

CHAPTER OVERVIEW

1: Introduction to Biological Anthropology

Learning Objectives

- Recognize and differentiate scientific fact from different ways of knowing.
- Articulate the importance of differentiating between belief and knowledge without discounting alternative ways of knowing or acquiring beliefs

[1.1: Knowing and Believing](#)

[1.2: Icebreaker Science](#)

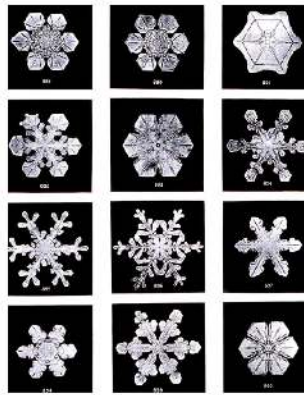
[1.3: Science and Belief- Just Because We Can, Doesn't Always Mean We Should](#)

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1.1: Knowing and Believing

Knowing and Believing

Format: In-person or online



Snowflakes by [Wilson Bentley](#) (1902)

Authors: Sydney Quinn Chizmeshya & Katherine E. Brent

Time needed: 20-40 minutes

Supplies Needed

- Activity sheet for each student (attached), or statements projected on a screen for the class to see
- Writing utensil
- Textbook

Introduction

The learning goal of this activity is for students to become comfortable recognizing and differentiating scientific fact from different ways of knowing. Additionally, students should acknowledge the importance of differentiating between belief and knowledge without discounting alternative ways of knowing or acquiring beliefs in hopes of maintaining cultural relativity.

Procedure

- Distribute one activity page to each student, or project the statements listed below onto a screen. This activity can be done individually, in groups, or as a class. There is also an opportunity to start the activity individually, and to consequently take up answers in a pair-and-share or class discussion.
- Before beginning the activity, students should write the definitions of 'knowledge' and 'belief' in their own words. Subsequently, they should compare these with the definitions put forth in the textbook. Putting class concepts into one's own words helps to solidify concepts for students.
- Next, students should be instructed to read each of the following statements and indicate on the activity sheet, adjacent to each example phrase, whether the statement reflects knowledge or belief.

Statements

1. The sun rises in the East and sets in the West.
2. All living things need water to survive.
3. God is real.
4. No two snowflakes are identical.
5. Lord of the Flies is the best novel ever written.
6. Ottawa is the capital of Canada.
7. The Mona Lisa is the most beautiful painting in the world.
8. Broccoli is delicious.
9. Carbon monoxide is dangerous to humans in large quantities.
10. Dr. G is the best professor.

- After responding to the given statements, each student should write a statement of belief and a statement of knowledge on the activity sheet.
- Once students have labelled each statement accordingly, and written their own statements, discuss in groups, or as a class.
- Ensure that you bring forth any discussions as to why students labelled statements as belief or knowledge into a classroom discussion. Students should use the textbook definitions of “knowledge” and “belief” to aid in justifying their answer.
- Instructors can further engage the class by discussing why it is important for anthropologists to be cognizant of both knowledge and beliefs-- this can introduce the idea of anthropologists as both scientists and cultural relativists.
- Additionally, the idea that knowledge and beliefs can sometimes become ‘tangled’ should be addressed. For instance, it is not uncommon to see scientific knowledge (e.g. that climate change is real) as a belief, or a belief (e.g. that race is biologically founded) as knowledge. As such, differentiation is important.

Statement Answer Key

Statement	Belief or Knowledge?
The sun rises in the East and sets in the West.	Knowledge
All living things need water to survive.	Knowledge
God is real.	Belief
No two snowflakes are identical.	Knowledge
Lord of the Flies is the best novel ever written.	Belief
Ottawa is the capital of Canada.	Knowledge
The Mona Lisa is the most beautiful painting in the world.	Belief
Broccoli is delicious.	Belief
Carbon monoxide is dangerous to humans in large quantities.	Knowledge
Dr. G is the best professor.	Belief
Write your own statement of belief.	<i>To be evaluated</i>
Write your own statement of knowledge.	<i>To be evaluated</i>

Adapting for Online Learning

1 Not adaptable 2 **Possible to adapt** 3 Easy to adapt

This activity could be using various online programs such as Quizlet, Kahoot, or as an activity completed and submitted through the school’s respective online Learning ManagementSystem. Creating an online discussion board to articulate the reasoning behind answers as well as follow up questions is highly recommended. This activity may also be used as an iClicker activity.

References

Nelson, Katie, Lara Braff, Beth Shook, and Kelsie Aguilera. 2019. “Chapter 1: Introduction to Biological Anthropology” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

Image Attributions

[SnowflakesWilsonBentley](#) by [Wilson Bentley](#) is marked as [public domain](#).

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1.2: Icebreaker Science

Icebreaker Science

Format: In-person

 Diagram Description automatically generated
Illustration of a retreating glacier.

Author: Keith Chan

Time needed: 60 minutes

Learning Objectives

- Experience the scientific process
- Interact with classmates
- Explore statistical sampling and analysis

Supplies Needed

- Writing supplies

Readings

-

Introduction

The first day of lab sets expectations for the rest of the course. A lot has to be accomplished: attendance, the syllabus, a learning activity, and becoming familiar with each other. This activity addresses the latter two goals in a way that also uses the scientific method and statistical thinking.

Students are given each question ahead of time so they can consider their own answer as well as what the class is like as a group. After this step, students move around the classroom and chat in different groups based on having something in common. When all of the questions have been explored, the instructor can review the results of each item to learn whether the students' expectations were met or not.

Steps

- Ask students to write what percent of the class fit each of the categories listed on the Categories sheet. This is the hypothesis part of the activity.
- For each category, students move to a certain part of the class. For example, students who have been on a roller coaster stand to the left and those who have not stand to the right.
- Give students a minute to meet each other in their group for each category.
- Record the percent of students on each side for each category. This is the observation part of the activity.
- After the categories have all been surveyed, have the class return to their seats.
- Go through each category and ask students for their impressions. Did they get close or not?

Conclusion or Review Questions

This activity got students moving and interacting each other while exploring the scientific process of hypothesis testing. Here are a few questions to conclude the activity:

- Are these results representative of the country? The city? The school? Why or why not? This question can segue into a discussion of bias and sampling methods.
- Which hypotheses could be considered “close enough” to the results? This can lead to an introduction to statistical inference and the standards used in science.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Students could form breakout rooms for each category, raise their hands, or respond in chat.

Tips and Suggestions

Come up with your own questions related to your school or community. Avoid questions that can be too personal (e.g., are you parents still together or not?) or involve knowledge that is too specific (e.g, did you like the last season of Game of Thrones?).

Image Attributions

Thornberry-Ehrlich, Trish L., Colorado State University. (2017). Glacier Features [Illustration]. United States Public Domain Mark 1.0. <https://flic.kr/p/Rji5E7>.

Icebreaker Science Categories

Ridden a roller coaster or not
Is a dog or cat person
Have been to Europe or not
Is a morning or night person
Like to go jogging or not
Have eaten an insect or not
Have done karaoke or not
Have their birthday in the first or second half of the year
Like to eat seafood or not
Like group work or solo work

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1.3: Science and Belief- Just Because We Can, Doesn't Always Mean We Should

Science and Belief: Just Because We Can, Doesn't Always Mean We Should.

Format: In-person or online (discussion or lab activity)

 Icon Description automatically generated

Image Caption: International Symbol for Deafness and Hearing Loss

Author: [Anne E. Pfister, PhD](#)

Time needed: 45-75 minutes

Learning Objectives

- Distinguish between science and belief
- Apply anthropological theories and methods to understanding real-world issue

Supplies Needed

- Short readings (provided)
- Worksheet (provided)
- Space for discussion (if in-person)
- Discussion board (if online)

Readings

-
- Sprigs, M. 2002. [Lesbian couple create a child who is deaf like them](#). *Journal of Medical Ethics*. 28:283.
- Ives, James. 2020. [Researchers Treat Deafness with Gene Therapy](#). *News Medical Life Sciences*.

Introduction

Chapter two author, Jonathan Marks (2017) presents anthropology as the “science of mediation”. This lesson and activity invite Marks’s style of intellectual dialogue, encouraging us to find nuanced connections between some seemingly contradictory concepts. In this lesson, we contemplate two different relational concepts fundamental to the anthropological study of human beings as a species.

Students read two articles that approach deafness from different perspectives and analyze the role of culture and biology with regard to human conditions and diversity as well as the role of science and belief in bio-medical intervention (and other scientific pursuits).

Steps

- Introduce (or review) the properties of science and the properties of belief systems. Remind students that both science and belief systems are valid ways of exploring and evaluating phenomena; they are systems we use to understand the world around us. Belief systems take many forms (ethics, morals, philosophy, religion and laws, for example) and science comes from a specific historical context which then spread on a global scale.
- Distribute the worksheet and the readings listed above. Give students approximately 20-30 minutes to read both articles/summaries (they are reading for big ideas, not doing close readings).
- Discuss students’ reactions to the articles.
- Ask students what big ideas are in tension. How can these dyadic concepts be “mediated” through anthropological approaches?
- Dyadic concepts to discuss might include: Culture and biology; science and belief; nature and nurture; ontology and epistemology.

Takeaway Ideas and Points for Review:

All humans use science AND belief systems to explore the world in our attempt to understand it. Sometimes we have the science to ameliorate problems, but our belief system (ethics, morals, laws) dictate whether (and how) we put science into action (or not!). Think about cloning, for example. We have advanced science capable of cloning our pets (see Brogan, 2008 article in the For Further Exploration below). Does that mean we should? What about cloning your little brother?

Therein lies the irony of the presentation of these two articles together. Gene therapy works only for people with genetically inherited deafness (i.e. folks that are born into deaf families). People are born deaf or deafened for many reasons (genetic causes account for about half of childhood cases, [according to the CDC](#)). More importantly, many deaf people, like the couple in one of the articles, do not view deafness as a disability and many people who approach deafness from a deaf cultural perspective do not view deafness as a loss but often as gain (see Bauman et. al., 2014 article in the For Further Exploration below). In fact, some ethnographic research suggests that deaf families (i.e. families with deaf relatives) are the least likely to seek medical intervention (like gene therapy) because they prioritize the shared cultural and linguistic experience in deaf communities and through the use of sign language (see readings in the For Further Exploration section below for examples and discussion).

- Important: Pointing out this irony does not suggest that either approach is wrong. Again, anthropological theories and methods help us embrace that which is apparently contradictory and “mediate” common ground for more holistic understandings of complex issues like deafness.
- A nuanced approach to deafness –one that acknowledges the connections between culture/biology and science/belief – might better focus resources and programs for deaf people and their families.
- Other dyadic concepts to consider: nature & nurture; ontology & epistemology; organic & synthetic; individual & group; extraordinary & mundane

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

For Further Exploration

Bauman, Dirksen and Murray, Joseph. 2014. [An Introduction to Deaf Gain](#). *Psychology Today*.

Brogan, Jason. 2008. [The Real Reason You Shouldn't Clone Your Dog](#). *Smithsonian Magazine*.

Centers for Disease Control and Prevention. 2020. [Hearing Loss in Children](#). *National Center on Birth Defects and Developmental Disabilities*.

Cooper, Rachel. 2007. [Can it be a Good Thing to be Deaf?](#) *The Journal of Medicine and Philosophy*. 32(6):563-583.

Kusters, Annelies. 2015. *Deaf Space in Adamorobe: An Ethnographic Study in a Village in Ghana*. Gallaudet University Press.

Mullin, Emily. 2020. [The End of Deafness](#): Gene Therapy Could End Deafness. Should it? *Future Human*.

Pfister, Anne E. 2017. [Forbidden Signs: Language Socialization and Therapeutic Approaches to Language in Mexico](#). *Ethos*. 45(1):139-161.

Image Attributions

[International Symbol for Deafness and Hearing Loss](#) by the State of Rhode Island is in the public domain.

References

Marks, Jonathan. 2017. *The Alternative Introduction to Biological Anthropology*, 2nd Edition. Oxford University Press.

Nelson, Katie, Lara Braff, Beth Shook, and Kelsie Aguilera. 2019. “Chapter 1: Introduction to Biological Anthropology” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

Science and Belief Worksheet

Embracing Anthropology as a “science of mediation”

Jonathan Marks (2017) presents anthropology as the “science of mediation”. This lesson and activity pursue intellectual dialogue, encouraging us to find nuanced connections between some seemingly-contradictory concepts that inform our understanding of what it means to be human.

In this lesson, we contemplate two different relational concepts fundamental to the anthropological study of human beings as a species.

Step 1

Using the chart below, jot down some adjectives that describe the characteristics of science and belief (you may also use associated words, or those that can be used interchangeably).

SCIENCE	BELIEF
---------	--------

Step 2

Now, do the same for biology and culture. Jot down some adjectives that describe the characteristics of each.

BIOLOGY	CULTURE
---------	---------

Step 3

Now, read the two short articles. Don't get bogged down by too many details. Instead, read so you understand the general idea behind the two very different approaches to deafness. Then, review the discussion questions below and prepare your thoughts for the discussion. You may wish to jot down your thoughts ahead of the discussion.

Questions for Discussion:

1. Prior to reading these articles, did you think about deafness as being primarily biological or cultural?
2. Do either or both articles consider deafness from a predominantly biological approach?
3. Do either or both articles approach deafness from more of a cultural understanding?
4. What are the roles of science and belief in each of the articles?
5. Did reading these articles and discussing them change any of your ideas about science/belief and culture/biology? About approaches to deafness?
6. How can anthropological methods and theories help inform our understandings of deafness and other conditions/statuses/phenomena?
7. What other seemingly-contradictory concepts do these articles underscore?
8. Do you perceive any irony in the contrast between these two articles?

Note

Review the Take-away Ideas Conclusions document once instructed to do so.

Take-away Ideas and Conclusions:

- All humans use science AND belief systems to explore the world and attempt to understand it. Sometimes we have the science to ameliorate problems, but our belief system (ethics, morals, laws) dictate whether (and how) we put science into action (or not!). Think about cloning, for example. We have advanced science capable of cloning our pets (see article below). Does that mean we should? What about cloning your little brother?
- Therein lies the irony of the presentation of these two articles together. Gene therapy works only for people with genetically inherited deafness (i.e. folks that are born into deaf families). People are born deaf or deafened for many reasons (genetic causes account for about half of childhood cases, [according to the CDC](#)). More importantly, many deaf people, like the couple in one of the articles, do not view deafness as a disability and many people who approach deafness from a deaf cultural perspective do not view deafness as a *loss* but often as *gain* (see article below). In fact, some ethnographic research suggests that deaf families (i.e. families with deaf relatives) are the least likely to seek medical intervention (like gene therapy) because they seek the shared cultural and linguistic experience in deaf communities and through the use of sign language (see articles below).
 - **Important:** Pointing out this irony does not suggest that either approach is wrong. Anthropological theories and methods help us embrace that which is apparently contradictory and “mediate” common ground for more holistic understandings of complex issues like deafness.
 - A nuanced approach to deafness—one that acknowledges the connections between culture/biology and science/belief—might better focus resources and programs for deaf people and their families.

- Other dyadic concepts to consider: nature & nurture; ontology & epistemology; organic & synthetic; individual & group; extraordinary & mundane

References

Marks, Jonathan. 2017. *The Alternative Introduction to Biological Anthropology*, 2nd Edition. Oxford University Press.

Further Reading:

- Bauman, Dirksen and Murray, Joseph. 2014. [An Introduction to Deaf Gain](#). *Psychology Today*.
- Brogan, Jason. 2008. [The Real Reason You Shouldn't Clone Your Dog](#). *Smithsonian Magazine*.
- Centers for Disease Control and Prevention. 2020. [Hearing Loss in Children](#), *National Center on Birth Defects and Developmental Disabilities*.
- Cooper, Rachel. 2007. [Can it be a Good Thing to be Deaf?](#) *The Journal of Medicine and Philosophy*. 32(6):563-583.
- Kusters, Annelies. 2015. *Deaf Space in Adamorobe: An Ethnographic Study in a Village in Ghana*. Gallaudet University Press.
- Mullin, Emily. 2020. [The End of Deafness](#): Gene Therapy Could End Deafness. Should it? *Future Human*.
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- Pfister, Anne E. 2017. [Forbidden Signs: Language Socialization and Therapeutic Approaches to Language in Mexico](#). *Ethos*. 45(1):139-161.

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CHAPTER OVERVIEW

2: Evolution

Learning Objectives

- Operationalize questions using the scientific method.
- Evaluate methods for scientific study of human phenomena.
- Distinguish between science and dogma.

[2.1: The Scientific Method- Converting Curiosity into Study](#)

[2.2: Misconceptions about Evolution](#)

Thumbnail: The alchemist by Carl Spitzweg

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2.1: The Scientific Method- Converting Curiosity into Study

The Scientific Method: Converting Curiosity into Study

Format: In-person or online (discussion or lab activity)

Author: Anne E. Pfister, PhD

Time needed: 30-40 minutes

Supplies Needed

- Worksheet (provided)
- Vides (links provided)
- Space for discussion (if in-person)
- Discussion board (if online)

Readings

-
-

Introduction

During this activity, students learn to operationalize ideas and form a hypothetical research design using the scientific method. This introductory activity is designed to get students thinking about topics that interest them that fall within the realm of anthropological study. Most of all, it helps them identify what topics can be approached scientifically and which cannot.

Steps

1. Introduce the concepts of science and belief, explaining that humans use both systems to learn about the world. Explain that science is self-correcting while dogma is unwavering. Discuss examples (i.e. we have the science and technology to clone animals, should we clone humans? This illustrates how science depends on ethics, a belief system. Beliefs cannot be scientifically 'tested' while natural phenomena can be).
2. Review the steps of the scientific method and the assumptions of science introduced by Jonathan Marks in the beginning of Chapter Two: Evolution in *Explorations*.
3. View the short video Turtles and Snakes by Mark Rober to underscore how nearly any idea or curiosity can be converted into scientific study using the tenants of the scientific method: https://www.youtube.com/watch?feature=player_embedded&v=k-Ep7fIAWMA#!
4. Distribute worksheets and have students work independently (or in pairs).
5. (Optional) ask students to share the research topics they brainstormed for the class discussion.
6. Discuss take-away ideas with the class.

Takeaway Ideas and Points for Review:

- All humans use science and belief systems to explore the world and create theories about it.
- Science is a specific way of investigating the world. Scientists use the scientific method because it helps us operationalize ideas and standardize approaches to answering difficult questions and creating theories about our observations.
- Science is self-correcting – as new (and potentially contradictory) data are introduced, theories are amended or improved upon. Dogma is static and does not change.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Tips and Suggestions

This lab activity and discussion help students and professors identify the interests of individuals in the class. It also motivates students to know that virtually anything they are curious about can be operationalized into a research project using the scientific method.

For Further Exploration

The Scientific Method, Sprouts: <https://www.youtube.com/watch?v=yi0hwFDQTSQ&v=1=en>

Science vs. Dogma, Nature: <https://www.nature.com/articles/23307>

Image Attributions

The alchemist by Carl Spitzweg is in the public domain

References

Nelson, Katie, Lara Braff, Beth Shook, and Kelsie Aguilera. 2019. "Chapter 1: Introduction to Biological Anthropology" In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

Marks, Jonathan. 2019. "Evolution" In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

The Scientific Method: Converting Curiosity into Study Worksheet

1. How does the epistemology of science differ from other ways of knowing about the world?
2. Write two (or more) questions (related to humans/anthropology) – one that COULD be investigated scientifically and one that CANNOT be tested scientifically.
 - a.
 - b.
3. Design a mock study using some of the steps of the scientific method below to answer a provocative question you have about biological anthropology.
 - a. Identify the question or the potential relationship between two or more observable phenomena:
 - b. Formulate hypotheses about expected outcomes between variables, based on existing theory:
 - c. What primary methods would you use to collect observations pertaining to the question:
 - d. What aspects of the study are holistic? In other words, which other sub-fields of anthropology might be interested in the results of your study? Why?

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2.2: Misconceptions about Evolution

Misconceptions About Evolution

Format: In-person or online



A commonly used illustration for human evolution that suggests evolution is linear and modern humans are the crowning achievement of that process.

Author: Beth Shook

Source: Inspired by [Misconception Quizzes](https://teach.genetics.utah.edu/content/misconceptions/) Teach.Genetics.utah.edu. Genetic Science Learning Center. University of Utah

Time needed: 15-20 minutes

Learning Objectives

- Identify and clarify misconceptions surrounding evolution and evolutionary forces
- Review animal examples illustrating how evolution works

Supplies Needed

- Worksheet (provided)
- Access to the internet to show a video from learn.genetics.utah.edu

Readings

-

Introduction

There are many misconceptions about what evolution is and how it works via natural selection to cause changes in species. This brief activity helps students identify any misconceptions they may hold and then helps them to achieve a more accurate understanding of evolution. To do so, they will view a short video and answer a series of questions.

Steps

- Students will individually complete the provided worksheet by checking the statements that they believe to be true.
- Instructors will show the five-minute video “[Things You May Not Know About Evolution](https://learn.genetics.utah.edu/content/misconceptions/)” (<https://learn.genetics.utah.edu/content/misconceptions/>).
- Students will check their answers as they watch the video.

Conclusion

The instructor should lead a brief discussion afterwards to see what the most common misconceptions in the class were (based on the most missed questions) and clarify any questions that students may have from the worksheet or film.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This worksheet can be provided for students to complete asynchronously and they can watch the video either on their own or in a synchronous class section. The later option would allow for a brief instructor-led discussion.

For Further Exploration

References

Marks, Jonathan. 2019. "Chapter 2: Evolution." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. CC BY-NC <http://explorations.americananthro.org/>

"Misconception Quizzes." 2011. Teach.Genetics.utah.edu. Genetic Science Learning Center. University of Utah. https://teach.genetics.utah.edu/content/evolution/files/misconceptionquiz_key.pdf

"Things You May Not Know About Evolution" 2011. Learn.Genetics.utah.edu. Genetic Science Learning Center. University of Utah. <https://learn.genetics.utah.edu/content/evolution/misconceptions>

Image Attributions

[Human evolution](#) by [Tkgd2007](#) is used under a [CC BY-SA 3.0 License](#).

Misconceptions About Evolution Worksheet

For each number, check the statement that is true.

1. ☐ Organisms are perfectly structured for their environment.
☐ Organisms have many traits that are not perfectly structured, but function well enough to give an organism a competitive advantage.
2. ☐ Natural selection favors the development of new traits.
☐ Natural selection often modifies existing structures but must work within the limits of what is available.
3. ☐ Evolution is climbing a ladder towards perfection.
☐ Evolution may cause the loss of beneficial or complex traits.
4. ☐ Some species and some genes remain largely unchanged over millions of years.
☐ Natural selection always favors change.
5. True or False? The process of natural selection can only work on structures that are in use.
☐ True.
☐ False.
6. ☐ Evolution is a theory, which is a well substantiated explanation for observable facts.
☐ Evolution is a theory, which means it is a guess.
7. ☐ In order to accept evolution as a valid explanation, you cannot believe in God.
☐ The theory of evolution and religion can be compatible.
8. ☐ The complexity of an organism determines the size of its genome.
☐ The complexity of an organism has no correlation with the size of its genome.
9. ☐ Humans are the ultimate achievement of evolution.
☐ Humans are less complex than other organisms in many ways.
10. ☐ Evolutionary patterns look like the branches on a tree.
☐ Evolution is linear.

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CHAPTER OVERVIEW

3: Molecular Biology and Genetics

Learning Objectives

- Observe how blood agglutinates in the presence of foreign antibodies
- Explain how different genotypes can result in the same phenotype
- Explain the concepts of dominant, co-dominant, and recessive traits
- Use Mendelian inheritance patterns to draw Punnett squares and assess parentage
- Assess whether or not blood types function as a Mendelian trait

[3.1: Blood Typing Lab](#)

[3.2: Protein Synthesis- One Act Play](#)

[3.3: Protein Synthesis Pizza](#)

Thumbnail: Human blood cells photographed by an electron microscope.

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3.1: Blood Typing Lab

Blood Typing

Format: In-person or online

Authors: Katherine E. Brent and Sydney Quinn Chizmeshya

Source: Modified from [Classroom Activity on Antibodies](#), *Oxford Sparks*.

Time needed: 30-40 minutes total. 15-20 minutes for the activity; 15-20 minutes for the reflection questions

Supplies Needed

- Milk, vinegar, water
- Red gel food coloring
- Eyedroppers or pipettes (5 per group)
- Permanent marker
- Toothpicks or stirrers (6 per group)
- Small containers or sealable test tubes (5 per group)
- Blood typing test plate (attached) laminated or placed in a plastic sheet protector (1 per group)
- Student worksheet (attached)

Readings

-

Introduction

In this lab students will perform a blood type test, also called an agglutination assay, on the simulated blood of three individuals. They will observe the agglutination reaction, and determine the blood types of three individuals. Subsequently, students will answer reflection questions about the observations they made during the experiment, as well as consider the inheritance patterns for ABO blood types and what characteristics of this trait are regarded as “Mendelian”.

Steps

- Prepare three solutions: vinegar with food coloring, milk with food coloring, and water with food coloring. Slowly add food coloring little by little to ensure that the dye does not coagulate the substance.
- Each group of students should be given the following lab kit materials:
 - Labelled test tubes or small containers:
 - Individual #1: Dyed vinegar (this will simulate Type A blood)
 - Individual #2: Dyed milk (this will simulate Type B blood)
 - Individual #3: Dyed water (this will simulate Type O blood)
 - Anti-A Serum: Milk
 - Anti-B Serum: Vinegar
 - Five eyedroppers or pipettes
 - Permanent marker
 - Six toothpicks or stirrers
 - Blood Typing Test Plate (attached) laminated or placed in a plastic sheet protector (1 per group)
 - Student worksheets
- Students should use the instructions on their worksheet to complete the lab. When students perform the experiment, they must use each pipette for only the substance it is intended to be used for, as cross-contamination may provide false coagulations.
- Using the pipette for Individual #1, they will pipette several drops of Individual #1's blood sample into the circles comprising the first column of the laminated blood typing test plate. Individual #2's sample should be pipetted into to the second column, and Individual #3's sample pipetted into the third column.
- Using the pipette for Anti-A Serum, pipette several drops of Anti-A serum into each blood sample in the first row of the test plate. Using the pipette for Anti-B Serum, pipette several drops of Anti-B serum into each blood sample in the second row of the test plate.

- Students will stir each sample using a different toothpick for each of the six samples.
- Students will observe each sample to see if it has coagulated (agglutinated) or not, and determine the three individuals' blood types based on the results.
- Students will complete the reflection questions on their worksheet.

Conclusion

Students will practice observation and problem solving through this lab, as well as review key concepts about Mendelian inheritance and blood typing. Reflection questions are provided on the student worksheet and instructors are encouraged to review some or all of these questions as a class afterwards.

Adapting for Online Learning

1 Not adaptable 2 **Possible to adapt** 3 Easy to adapt

With clear directions most students could create the artificial blood and serums, as well as complete the experiment, in their home. Instructors could also record a short video showing the experiment for students to watch and reflect on at home.

For Further Exploration

ThePenguinProf. Blood Types: ABO and Rh (with donuts and sprinkles!) <https://www.youtube.com/watch?v=L06TJTMVkB0>

Wake, Carol. 2005. "ABO/Rh Blood Typing Model: A Problem-Solving Activity." *The American Biology Teacher* 67 (3): 158-162.

References

Arnold, Savittree Rochanasmita, Tussatrin Kruatong, Chanyah Dahsah, and Duongdearn Suwanjinda. 2012. "The Classroom-Friendly ABO Blood Types Kit: Blood Agglutination

Simulation." *Journal of Biological Education* 46 (1): 45-51. <https://doi.org/10.1080/00219266.2011.556750>

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. "Chapter 3: Molecular Biology and Genetics." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

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Blood typing test plate by Katherine E. Brent and Sydney Quinn Chizmeshya original to Explorations Lab and Activities Manual is under a [CC BY-NC 4.0 License](#).

Blood Typing: Worksheet

Background

This lab explores the concepts of Mendelian inheritance using the ABO Blood Group System as an example. Please review the corresponding sections: "Mendelian Genetics" and "Example of Mendelian Inheritance: The ABO Blood Group System" in *Explorations* Chapter 3: Molecular Biology and Genetics, which will provide the background information to complete the lab exercise.

In this lab, you will be performing a blood type test (agglutination assay) on the simulated blood of three individuals. Subsequently, you will answer reflection questions about the observations you made during the experiment.

As a reminder:

- Blood types in the ABO Blood Group System are A, B, O, and AB.
- A and B alleles are dominant over the O allele, and are codominant with each other. This is because possessing the A or B allele always leads to the production of the corresponding antigen.

 ABO blood group system - Wikipedia

Blood Types Table

- **Type A blood** with A antigens will coagulate (agglutinate) when they come in contact with anti-A serum (antibodies), but produce anti-B antibodies in a living person, so will not coagulate with anti-B serum.
- **Type B blood** with B antigens will coagulate (agglutinate) when they come in contact with anti-B serum (antibodies), but produce anti-A antibodies in a living person, so will not coagulate with anti-A serum.
- **Type AB blood** has both A and B antigens, and will coagulate (agglutinate) when they come in contact with either anti-A or anti-B serum (antibodies). These individuals do not produce anti-A or anti-B antibodies.
- **Type O blood** produces both anti-A and anti-B antibodies, so it will not coagulate with Anti-A or Anti-B Serum.

Lab Kit Materials

- Labelled test tubes or small containers:
 - Individual #1 Blood Sample
 - Individual #2 Blood Sample
 - Individual #3 Blood Sample
 - Anti-A Serum
 - Anti-B Serum
- Five eyedroppers or pipettes
- Permanent marker
- Six toothpicks or stirrers
- Blood Typing Test Plate laminated or placed in a plastic sheet protector

Instructions

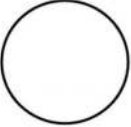
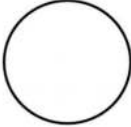
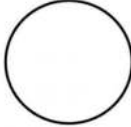
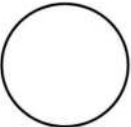
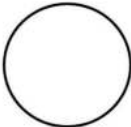
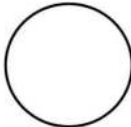
1. Using the permanent marker, label each of your five pipettes with one of the substance names (e.g. Individual #1, Anti-A serum). When you perform the experiment, you must ensure that you use each pipette for only the substance it is intended to be used for, as cross-contamination may provide false coagulations.
2. Using the pipette for Individual #1, pipette several drops of Individual #1's blood sample into the circles comprising the first column of the blood typing test plate. Individual #2's sample should be pipetted into the second column, and Individual #3's sample pipetted into the third column.
3. Using the pipette for Anti-A Serum, pipette several drops of Anti-A serum into each blood sample in the first row of the test plate. Using the pipette for Anti-B Serum, pipette several drops of Anti-B serum into each blood sample in the second row of the test plate.
4. Using a different toothpick for each of the six samples, stir each sample.
5. Observe each sample to see if it has coagulated (agglutinated) or not.

Reflection Questions

1. Observe each sample for coagulation. Based on what you see...
 - a. What blood type does Individual #1 have? What is/are the possible genotype(s) for Individual #1?
 - b. What blood type does Individual #2 have? What is/are the possible genotype(s) for Individual #2?
 - c. What blood type does Individual #3 have? What is/are the possible genotype(s) for Individual #3?
2. Suppose that the three samples are from two parents and their child.
 - a. Which individuals are the parents? Which individual is the child? How do you know?
 - b. What genotype must each individual have for this scenario to be possible?
 - c. Draw a Punnett square using the parents' genotypes. Circle the genotype that belongs to the child that you have blood typed.
 - d. What is the percent chance that these two parents would have a child with this blood type?
3. There is one blood type not represented in these samples.
 - a. What blood type is it?
 - b. What would you predict would happen if you added Anti-A serum to this type of blood?
 - c. What would you predict would happen if you added Anti-B serum to this type of blood?
 - d. Why is the genotype that codes for this blood type considered "codominant"?
4. Is ABO considered a "Mendelian Trait"?
 - a. What is "Mendelian genetics"? How would you identify a trait that follows a pattern of Mendelian genetics? Review the section "Mendelian Genetics" in Chapter 3 to help you.

- b. How does the ABO blood type system follow the rules of Mendelian Inheritance?
- c. In what ways is the ABO blood type system more complex than the pea plant traits that Mendel observed?

Blood Typing Test Plate

	Individual #1	Individual #2	Individual #3
Anti-A Serum			
Anti-B Serum			

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3.2: Protein Synthesis- One Act Play

Protein Synthesis: A One Act Play

Format: In-person



RNA polymerase carrying out transcription.

Author: Melissa Artstein-McNassar

Time needed: 45 minutes

Learning Objectives

- Demonstrate the processes of transcription and translation
- Identify the roles of the molecules involved in protein synthesis

Supplies Needed

- Printed badges identifying each actor (included):
 - DNA (A, T, C, G)
 - Ribosomes
 - mRNA
 - tRNA
 - RNA polymerase
 - Choice of amino acids (1-4)
- Chalk, masking tape, or small sports cones to map out the stage for the play
- Tape for student badges
- Amino acid chart
- Blank cards (badges) and a sharpie

Readings

-

Introduction

In this activity, students put on a play to perform what is happening inside their bodies. Students are given roles to act out the process of protein synthesis (specifically, transcription and translation). Students wear badges to distinguish their role from the roles of their peers. The goal of this play is to create a fictional protein. The instructor serves as play director and narrator.

Minimum required number of students: 11

Preferred number of students: 20 - 25

The Stage

Establish a cell that students can walk into. It is important to represent the boundaries of cell structure (nucleus and cell membrane) on the stage. Find a suitable space for the entire class to fit comfortably.

Outside: If conditions are favorable, this activity can be completed outdoors. Find a concrete or blacktop surface and use chalk to draw a rather large cell that includes two concentric circles that represent the boundaries of the nucleus and cell membrane. I recommend drawing the nucleus approximately six feet in diameter to accommodate students with an additional two or three feet around it to enclose the cell for students to fit within the cytoplasm.

Inside: Small soccer cones or tape on the floor can be used indoors to represent the boundaries of the cell (as indicated above). Furniture, such as chairs, or stools, can be used as well.

Boundaries should look like this:



Procedure: Setting Up

1. **Assign Roles.** Prior to showtime, assign student roles. List the various roles on the board and ask students to volunteer for each role. A minimum of eleven students are needed to successfully produce one amino acid for protein building, with roles assigned to students as follows:

Minimum Role to Student Ratio

Role	Minimum Students Required
DNA to make one codon	6
mRNA	1
tRNA	1
Ribosome	1
Amino acid	1
RNA polymerase	1

For larger class sizes (24 or more students), I recommend the following student assignments. Students can take turns being the “active” actor (for instance, the ribosome stringing together the two amino acids or RNA polymerase transcribing DNA).

Role to Student Ratio for Larger Classes

Role	Minimum Students Required
DNA to make two codons	12
mRNA	2
tRNA	2
Ribosome	2
Amino acid	2 (or more)
RNA polymerase	2

2. **Prepare students.** Students should be familiar with protein synthesis prior to the activity. See “For Further Exploration” (below) for a list of sources to introduce protein synthesis. You may wish to give students a bit of time to research their roles in or before class.

In addition, before showtime, students should know:

- a. Where they need to start out on stage (for example, in the cell nucleus or in the cytoplasm).
- b. Which other actors they will interact with during the play (for example, tRNA will need to find an amino acid and bring it to a ribosome).

Special note on DNA and amino acid roles: These two roles are linked. The DNA actors must arrange themselves so that they can be transcribed into a specific codon (amino acid). Students can take the lead on this and decide on one or two amino acid products.

They will then need to arrange themselves in the correct order so that when RNA polymerase transcribes one half, it will correspond to the appropriate amino acid. Students who are the amino acids need to have the appropriate signage so that they can be found in the cytoplasm when tRNA looks for them.

3. **Set the stage.** Identify the boundaries of the nucleus and cell. Refer to recommendations in the section labeled “The Stage” above.

Once students are comfortable with their roles, have them either hold their pieces of paper that indicate their roles visibly, or tape them onto their chests like a badge. RNA polymerase should have a blank badge and pen to record their transcription of DNA. RNA polymerase can record one codon on each blank badge. Ribosomes should have a codon to amino acid chart to consult to assist them in translating the mRNA message.

Lead the actors to the stage (the cell). All students initially stand outside the cell. First, point to the stage and explain the basic structure of the cell (e.g., nucleus, cytoplasm). Then, call students to take their places by introducing each role:

1. Narrator: “DNA will take their place in the nucleus and arrange themselves in a distinct way that will transcribe and translate to two (or one) amino acids”
 - a. Students who play the DNA nucleotides (A, T, C, or G) line up in pair bonds, shoulder to shoulder, in a ladder-like formation in the nucleus.
2. Narrator: “RNA polymerase and mRNA will take their place along the edge of the nucleus.”
 - a. Students who are RNA polymerase and mRNA enter the nucleus. Keep in mind, students may not be able to fit in the nucleus.
3. Narrator: “Ribosomes will take their place in the cytoplasm.”
 - a. Students who are ribosomes will enter the cytoplasm area.
4. Narrator: “tRNA will take their place in the cytoplasm.”
 - a. Students who are tRNAa will enter the cytoplasm area.

Do this until all actors are on the appropriate areas of the stage.

Showtime: The Play

Once students are staged on the cell, the play will begin. Here is the basic narration of each step:

1. RNA polymerase breaks the bonds between bases throughout the DNA molecule.
2. RNA polymerase copies the DNA message and attaches it to mRNA.
3. mRNA leaves the nucleus and a ribosome approaches and attaches to the mRNA.
4. The ribosome read the mRNA code and give instructions to tRNA.
- 5a. tRNA takes the amino acid from the cytoplasm and shuffles it to the ribosome.
- 5b. If two amino acids are being called: The ribosome reads another mRNA codon and gives instructions to tRNA.
6. Ribosomes string the amino acids together to build a protein.

As the narrator is calling out the process, the students move and act accordingly. Here is an example of both the narration and student actions (movements):

1. **Narrator:** “RNA polymerase break the bonds between bases throughout the DNA molecule.”
 - **Action:** RNA polymerase actor(s) begin to walk through the two rows of DNA base pairs, breaking the bond.
2. **Narrator:** “As the bonds break, RNA polymerase copies the DNA message to create mRNA”
 - **Action:** RNA polymerase actors begin at the beginning of the DNA message and, with pen and paper in hand, transcribe one side of the DNA. RNA polymerase then attach the message to mRNA.
 - *Note: If there are more than one RNA polymerase actors, they can check their work with one another to make sure the message is correct.*
3. **Narrator:** “mRNA leaves the nucleus and attaches to a ribosome.”

- **Action:** mRNA actor leaves the nucleus area and arrives in the cytoplasm, seeks out a ribosome, and gives the message they have just transcribed to the ribosome.

4. **Narrator:** “The ribosome reads the mRNA code and gives instructions to tRNA.”

- **Action:** ribosome actor translates the mRNA code and yells out the appropriate amino acid that is needed.

5. **Narrator:** “tRNA takes the amino acid from the cytoplasm and shuffles it to the ribosome.”

- **Action:** tRNA actor hears the ribosome’s call for an amino acid and searches the cytoplasm for the identified amino acid. tRNA actor takes the amino acid actor to the ribosome who yelled for the amino acid.

- *Note: If two amino acids are being called, the ribosome may read both amino acids at one time and two tRNA actors may assist with finding and taking them to the ribosome.*

6. **Narrator:** “Ribosomes string the amino acids together to build a protein.”

- **Action:** The ribosome actor places the two amino acid actors side by side representing a protein.

Consider repeating the play a few times. The first time is slow, and then the second and third times are faster.

A note on “mistakes”:

The first time through it will go a bit slower. The narrator may need to provide direction as to where the actors go, or to make sure each actor’s signage is visible to others.

A common mistake that occurs is the mRNA polymerase does not transcribe the DNA correctly and/or the ribosome cannot translate the amino acid correctly. These are great examples of possible hiccups in the protein synthesis process that may account for a mutation. What an excellent teaching moment!

Review Questions

1. Protein synthesis is a 2 step process that includes transcription and translation. Where does each step take place within the cell?
2. Protein synthesis relies on many molecules and organelles in the cell. Identify the molecules and organelles found in each step.
What part of this process seems the most vulnerable to mutation?

Adapting for Online Learning

1 **Not adaptable** 2 Possible to adapt 3 Easy to adapt

For Further Exploration

Stated Clearly. What is DNA and How Does it Work? <https://www.youtube.com/watch?v=zwibgNGe4aY>

Amoeba Sisters. Protein Synthesis (Updated). <https://www.youtube.com/watch?v=oefAI2x2CQM>

References

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. “Chapter 3: Molecular Biology and Genetics.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

Image Attributions

Explorations, Figure 3.22. Transcription by NIH National Human Genome Research Institute is in the public domain.

[mRNA Codon chart](#) by [Becky Boone](#) is used under a [CC BY-SA 2.0 license](#).

Badges

Print out the following roles and give them to students who will fill the roles. You may need to copy and paste several of the roles if you have multiple actors. Badges can be taped to actor’s shirts.

A

T

Key

While there are many ways you can run your play to produce any of the 20 amino acids, below are four possibilities that correspond with the provided labels.



mRNA Codon Chart

Amino Acid	DNA	mRNA
Methionine	TAC	AUG
Lysine	TTT	AAA
Proline	GGA	CCU
Leucine	GAA	CUU

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3.3: Protein Synthesis Pizza

Protein Synthesis Pizza

Format: In-person or online



A ribosome involved in translation - the last major step of protein synthesis.

Author: Jess Whalen

Source: Modified from [Taco Protein Synthesis Activity](#), [Susquehanna Township School District](#).

Time needed: 30-45 minutes

Learning Objectives

- Explain the roles of DNA, mRNA codons, ribosomes, and amino acids in protein synthesis
- Summarize protein synthesis: key steps and locations in a cell
- Practice transcription and translation

Supplies Needed

- Protein Synthesis Pizza Worksheet (included)
-
- Pizza Ingredients List (included)
- Optional Worksheets: Build Your Own Protein Pizza and Extra Practice: Go From RNA to DNA (included)
- DNA Sequences (included) printed and cut into strips

Readings

-

Introduction

In this activity, students work through the steps of transcription (DNA to RNA) and translation (RNA to amino acid chain) in protein synthesis. Instead of creating proteins, the final product is a pizza recipe with specific toppings. Just as a pizza is made up of many specific ingredients, so too is a protein made up of specific amino acids.

Steps

- Students should be divided into small groups of two or three.
- Each student begins with a copy of the Protein Synthesis Pizza Worksheet, the Amino Acids Reference Sheet or [Explorations Figure 3.25](#), and the Pizza Ingredients List. If you want to expand the activity you can also provide students copies of the Build Your Own Protein Pizza Worksheet.
- Instructors should pass out one DNA sequence to each group (provided on a paper strip).
- Students will work through the questions and record their answers on the Protein Synthesis Pizza Worksheet.

Review Questions

1. In what ways are proteins similar to pizza? How is relating proteins to pizza useful?
2. In our pizza metaphor, what are the amino acids?
3. What happened when your pizza had a few ingredients that were unexpected? What is the equivalent scenario when it comes to proteins? That is, which ingredients make up a protein, and what happens if a few ingredients are changed?

4. How do the exercises in this activity relate to natural selection?

Adapting for Online Learning

1 Not adaptable 2 **Possible to adapt** 3 Easy to adapt

Instructors could provide students their own pizza recipe and the worksheet to do this activity individually, or instructors could distribute an electronic version of the worksheet and recipe (e.g. in Google Docs) and ask students to complete the activity in small groups online.

Tips and Suggestions

It can help to explain to students that their Amino Acids Reference sheet will show them how to transcribe the nucleotide bases from DNA to mRNA, and they may rely on this sheet to find the complementary nucleotide bases. Students usually use the chart for a few questions before they realize that they can actually transcribe the nucleotide bases faster by themselves. That means they are learning how to transcribe the bases from DNA to RNA!

A table like the one below may be helpful for students as they learn to transcribe DNA triplets into mRNA codons. The row in the middle is a 'help' row where students can insert a 'T' wherever there is an A in the DNA, or (if working backwards) where there is a 'U' in the RNA codon. The other nucleotides follow DNA rules of complementarity (A-T and C-G). This table structure matches the optional worksheet Extra Practice: Go from RNA to DNA (included)

DNA	AAA	TAC	GAC	GAA	AAT	ATT	GTT	ACA	ATT
help	TTT	_T_	_T_	_TT	TT_	T__	___	T_T	T__
RNA	UUU	AUG	CUG	CUU	UUA	UAA	CAA	UGU	UAA

For Further Exploration

Leddin, Emmitt. Amino Acids and DNA and RNA Bases. <https://emleddin.github.io/comp-chem-website/AMBERguide-AAAs-DNA-RNA.html>. CC BY-SA 4.0

Serendip Studios. Introduction to the Functions of Proteins and DNA. <https://serendipstudio.org/exchange/bioactivities/proteins>. CC BY-NC 4.0

Serendip Studios. How Genes Can Cause Disease - Introduction to Transcription and Translation. <https://serendipstudio.org/exchange/waldron/gene>. CC BY-NC 4.0

References

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. "Chapter 3: Molecular Biology and Genetics." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

Image Attributions

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Protein Synthesis Pizza Worksheet

Background

Proteins are complex chemicals made up of different amino acids, of which there are a total of 20 types. Different combinations of amino acids produce different proteins. The process of making a protein is called protein synthesis, and involves two major steps: (1) transcription and (2) translation.

In transcription, a DNA strand in the nucleus forms the template for the creation of single-stranded messenger RNA (mRNA). Transcription occurs when an enzyme called polymerase strings together free-floating RNA nucleotide bases that are complementary to the exposed strand of DNA.

For translation, the mRNA strand leaves the nucleus for the cytoplasm. There, a ribosome translates the mRNA strand. Ribosomes read three nucleotides of the mRNA at a time (called a codon) and, with the help of single-stranded transfer RNA (tRNA), matches

the codon to the corresponding amino acid. This amino acid is added to the growing protein chain. When a 'stop' codon is read, the protein is complete. As the amino acid chain exits the ribosome, it folds into its unique shape, and can go to work in the body.

Part 1: From DNA to Amino Acids

This activity breaks down protein synthesis using the metaphor of PIZZA!

Warning: this activity may make you hungry!

Use your Amino Acids Reference Sheet to complete the following table. Fill in the blank spaces of each row with either the missing DNA triplet, the mRNA codon, or the Amino Acid. While there are actually multiple codons that code for any one amino acid, for this activity there only needs to be one DNA triplet and one corresponding mRNA codon recorded for each amino acid.

Remember: RNA uses uracil (U) instead of thymine (T)!

DNA	mRNA codon	Amino Acid
TTG	AAC	Asparagine
GGG		Proline
	UAU	Tyrosine
	CAC	Histidine
CGT	GCA	
AAA		
TTT	AAA	
CAA		

As you fill in the chart, you will learn how to transcribe the nucleotide bases of DNA (the As, Ts, Gs, and Cs) into mRNA using the "language" of RNA (which replaces any 'T' with a 'U'). As you continue to fill in the chart you may find that you can transcribe the triplets by yourself, using your knowledge of base pairings, without using the amino acids chart at all!

Part 2: Decoding a Protein Pizza

Your instructor will give you a DNA "pizza recipe" in DNA base triplets. Use your knowledge of transcription and translation to figure out what kind of pizza you have!

1. Write down the DNA pizza recipe in the DNA section of the chart, three letters at a time, going vertically down the chart in the far left column.
2. Transcribe each DNA triplet in the pizza recipe into a mRNA codon.
3. Once each triplet has been transcribed into mRNA, you can begin to translate the mRNA code to construct your pizza. Use the Pizza Ingredients List to decode what ingredients are in your pizza. The ingredients in the chart are in mRNA, so refer to your mRNA codons in the second column.
4. Use your Amino Acids Reference Sheet to figure out which amino acid corresponds to each mRNA codon. In this case you are doing the work of the ribosome: matching the mRNA codon to the specific amino acid that is needed for the growing protein chain. Just like all of the ingredients together make a tasty pizza, so too does each amino acid play an important role in making up a larger protein!

DNA Pizza Recipe Code Write the recipe in this column, 3 nucleotides at a time.	mRNA Codon Transcribe the DNA code into the corresponding mRNA codon	Pizza ingredient Record the corresponding pizza ingredient, according to the ingredients chart (Use the mRNA codon to look it up.)	Amino Acid Record the corresponding amino acid (for a protein) using your amino acid chart!
Example: AAA	Example: UUU	Example: Stuffed crust	Example: Phenylalanine

Part 3: Reflection

Did your pizza have any ingredients that you would not usually find on a pizza? Just like one ingredient can make a pizza unique, so too can one new or different amino acid create a protein that is different from the protein that was supposed to be synthesized. DNA mutations that change, move, or delete a letter in the original DNA triplet can, through protein synthesis, result in the creation of different and new proteins in the body.

A protein that differs from the original protein that was supposed to be produced can sometimes be a good thing for an organism. If the protein results in a new functioning that gives the

organism an advantage in its environment then the “incorrect” protein would be beneficial, helping the organism achieve reproductive success. That protein could be selected for through the process of natural selection. In that case, the “incorrect” protein would increase in frequency in the population, and become the more common protein over time (and no longer be considered “incorrect”).

Amino Acids Reference Sheet

The 20 Amino Acids in Human Proteins and How They Are Coded For

Cells in the human body use information in the genetic code to directly encode 20 amino acids. The table below displays how this is done. First, a DNA base triplet is copied to create mRNA in the language of RNA. The mRNA then travels to the cytoplasm, where the ribosome reads each mRNA codon to assemble the corresponding amino acids into a growing protein chain. The “stop” codon is the last triplet in the process. It tells the ribosome that the process of making that specific protein is complete.

This table lists DNA base triplets and their corresponding mRNA codons that the ribosome reads to attach each specific amino acid. Some amino acids can be made more than one way.

Amino acids that can be made one way:

Amino Acid	DNA base triplet	mRNA codon
Methionine	TAC	AUG
Tryptophan	ACC	UGG

Amino acids that can be made two ways:

Amino Acid	DNA base triplet	mRNA codon
Asparagine	TTA or TTG	AAU; AAC
Aspartate	CTA or CTG	GAU; GAC
Cysteine	ACA or ACG	UGU; UGC
Glutamate	CTT or CTC	GAA; GAG

Glutamine	GTT or GTC	CAA; CAG
Histidine	GTA or GTG	CAU; CAC
Lysine	TTT or TTC	AAA; AAG
Phenylalanine	AAA or AAG	UUU; UUC
Tyrosine	ATA or ATG	UAU; UAC

Amino acids that can be made three ways:

Amino Acid	DNA base triplet	mRNA codon
STOP codon	AAT or ATC or ACT	UAA; UAG; UGA
Isoleucine	TAA or TAG or TAT	AUU; AUC; AUA

Amino acids that can be made four ways:

Amino Acid	DNA base triplet	mRNA codon
Alanine	CGA or CGG or CGT or CGC	GCU; GCC; GCA; GCG
Glycine	CCA or CCG or CCT or CCC	GGU; GGC; GGA; GGG
Proline	GGA or GGG or GGT or GGC	CCU; CCC; CCA; CCG
Threonine	TGA or TGG or TGT or TGC	ACU; ACC; ACA; ACG
Valine	CAA or CAG or CAT or CAC	GUU; GUC; GUA; GUG

Amino acids that can be made six ways:

Amino Acid	DNA base triplet	mRNA codon
Arginine	GCA or GCG or GCT or GCC or TCT or TCC	CGU; CGC; CGA; CGG; AGA; AGG
Leucine	AAT or AAC or GAA or GAG or GAT or GAC	UUA; UUG; CUU; CUC; CUA; CUG
Serine	AGA or AGG or AGT or AGC or TCA or TCG	UCU; UCC; UCA; UCG; AGU; AGC

Pizza Ingredients

Important: All ingredients are based on the mRNA code!

Basics: GCA - Thick crust GUA - Thin crust UUU - Stuffed crust	Acidics: CUA - Marinara sauce CUG - Barbecue sauce CUU - White sauce UUA - Garlic sauce
Aromatics: AAA - Pepperoni AAG - Sausage ACC - Chicken AUA - Bacon AUG - Pineapple	Hydroxylics: AGA - Mozzarella cheese UGU - Extra cheese (mozzarella)

Aliphatics:

AAU - Red onion
 CAA - Black olives
 CCA - Animal crackers
 CGA - Spinach
 GAU - Mushrooms
 GGA - Lettuce
 GUU - Artichoke hearts

Stop codons:

UAA - Stop codon
 UAG - Stop codon
 UGA - Stop codon

*Remember: All ingredients are based on the mRNA code!

Build Your Own Protein Pizza

Choose from the ingredients list to make your own pizza! Remember: because the ingredients are in mRNA, you have to fill in the chart working right to left from the Pizza Ingredient. Amino acids can be looked up at the end.

DNA Pizza Recipe Codons (write the recipe in this column, 3 letters at a time)	mRNA Codon (Once the DNA triplet is transcribed into mRNA, you can find the pizza ingredient)	Pizza Ingredient What pizza ingredient is this, according to the ingredients chart? (Remember: the ingredients in the chart are in mRNA!)	Amino Acid Once you have completed the activity, look up what amino acid this ingredient corresponds to in real life!
<i>Example:</i> TCT	<i>Example:</i> AGA	<i>Example:</i> Mozzarella cheese	<i>Example:</i> Arginine

Extra Practice: Go From RNA to DNA

Work backwards from the RNA strand to find the original DNA base triplet! Remember: RNA uses U (not T). So every time you see 'U' in the RNA strand, treat it just like 'T' to find the complementary nucleotide base!

DNA	---	---	---	---	---	---	---	---	---
RNA	UUU	AUG	CUG	CUU	UUA	GAU	CAA	UGU	UAA

DNA	---	---	---	---	---	---	---	---	---
RNA	AAA	GUA	AUG	CUA	UUA	GUU	CGA	AAU	UAG

DNA	---	---	---	---	---	---	---	---	---
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

RNA	GCA	AAG	UUA	GUU	UGU	CGA	CCA	AGA	UGA
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	---	---	---	---	---	---	---	---	---
RNA	GCA	AUG	CGA	AGA	GAU	CUU	UUA	CUA	UAA

DNA	---	---	---	---	---	---	---	---	---
RNA	ACC	CCA	AAU	GUA	GGA	CUU	UUA	GUU	UAG

DNA	---	---	---	---	---	---	---	---	---
RNA	AUA	AGA	UGU	ACC	AAU	GAU	CUU	UUU	UGA

DNA Sequences to Provide Students

DNA	AAA	TAC	GAC	GAA	AAT	CTA	GTT	ACA	ATT
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	TTT	CAT	TAC	GAT	AAT	CAA	GCT	TTA	ATC
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	CGT	TTC	AAT	CAA	ACA	GCT	GGT	TCT	ACT
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	CGT	TAC	GCT	TCT	CTA	GAA	AAT	GAT	ATT
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	TGG	GGT	TTA	CAT	CCT	GAA	AAT	CAA	ATC
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	TAT	TCT	ACA	TGG	TTA	CTA	GAA	AAA	ACT
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	TTT	AAA	TTA	GTT	ACA	TCT	CAA	GAT	ATT
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	TAC	CAT	TCT	ACA	AAT	CAA	GCT	CTA	ATC
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

DNA	CGT	GAC	TTC	AAT	CTA	CCT	TTA	TCT	ACT
------------	-----	-----	-----	-----	-----	-----	-----	-----	-----

Answer Key (RNA & Protein)

UUU AUG CUG CUU UUA GAU CAA UGU UAA

Stuffed crust, pineapple, barbecue sauce, white sauce, garlic sauce, mushrooms, black olives, extra cheese, stop

AAA GUA AUG CUA UUA GUU CGA AAU UAG

Pepperoni, thin crust, pineapple, marinara sauce, garlic sauce, artichoke hearts, spinach, red onion, stop

GCA AAG UUA GUU UGU CGA CCA AGA UGA

Thick crust, sausage, garlic sauce, artichoke hearts, extra cheese, spinach, animal crackers, mozzarella cheese, stop

GCA AUG CGA AGA GAU CUU UUA CUA UAA

Thick crust, pineapple, spinach, mozzarella cheese, mushrooms, white sauce, garlic sauce, marinara sauce, stop

ACC CCA AAU GUA GGA CUU UUA GUU UAG

Thin crust, animal crackers, red onion, mushrooms, lettuce, white sauce, garlic sauce, artichoke hearts, stop

AUA AGA UGU ACC AAU GAU CUU UUU UGA

Bacon, mozzarella cheese, extra cheese, chicken, red onion, mushrooms, white sauce, stuffed crust, stop

AAA UUU AAU CAA UGU AGA GUU CUA UAA

Pepperoni, stuffed crust, red onion, black olives, extra cheese, mozzarella cheese, artichoke hearts, marinara sauce, stop

AUG GUA AGA UGU UUA GUU CGA GAU UAG

Pineapple, thin crust, mozzarella cheese, extra cheese, garlic sauce, artichoke hearts, spinach, mushrooms, stop

GCA CUG AAG UUA GAU GGA AAU AGA UGA

Thick crust, barbecue sauce, sausage, garlic sauce, mushrooms, lettuce, red onion, mozzarella cheese, stop

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CHAPTER OVERVIEW

4: Forces of Evolution

Learning Objectives

- Perform calculations to determine change in allele frequencies within a population
- Document how a selective pressure can change allele frequencies and can cause evolution to occur in the ant population.
- Write and test a hypothesis

[4.1: Natural Selection Lab](#)

[4.2: Bingo Chip Evolution](#)

[4.3: Evolutionary Detectives](#)

Thumbnail: An insectivorous primate (marmoset) eating a grasshopper.

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4.1: Natural Selection Lab

Natural Selection

Format: In-person or online

Authors: Julie Wieczkowski, Susan Maguire, Melanie M. Mayberry, and Lisa Marie Anselmi

Time needed: 30-40 minutes

Supplies Needed

- Calculator

Readings

- Alveshere, Andrea J. 2019. Chapter 4: Forces of Evolution. *Explorations*.
-
- Coty-Barker, Valencia. [How to Form a Hypothesis](#).

Introduction

This lab allows students to see the impact of a selective agent, an insectivorous primate, on a population of ants. There are green and brown ants present in the population. In the rainy season, the primate eats the ants from green leaves. In the dry season, the primate eats the ants from brown branches. Calculating allele frequencies for several generations of ants in both seasons, the students will see how allele frequencies change in response to the selective pressure.

Steps

- Review dependent and independent variables, as well as key content from chapter four including natural selection, selective pressures, allele frequencies, and microevolution.
- Distribute student handouts. Students can work through the handout independently or in small groups.

Conclusion

There are things in the environment (selective pressures or agents) that select for or against certain phenotypes. These selective agents can cause allele frequencies to change, thereby causing evolution (microevolution in this population) to occur.

If the environment changes, the phenotype that is selected for may now be selected against. This illustrates that evolution does not proceed in only a one-way direction. This example also illustrates an important point about natural selection: there must be individual-level variation present in the population in order for natural selection to work.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Students can work through this activity individually as an assignment or in small groups (synchronously online). Students will need a clear introduction to the concepts ahead of time, and time to ask questions if students have them.

References

Alveshere, Andrea J. 2019. "Chapter 4: Forces of Evolution." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

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Coty-Barker, Valencia. July 10, 2013. "How to Form a Hypothesis." YouTube video. <https://www.youtube.com/watch?v=bp2f...ature=youtu.be>

Image Attributions

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Natural Selection: Worksheet

Imagine your anthropology professor studies a primate that eats insects. The primate's favorite food is a type of ant. She asks if you are interested in helping her analyze the data. You, of course, say yes!

Your professor tells you more about the ants, the primates, and the habitat. Ant color is determined by one gene. There are two alleles for this color gene: the brown allele and the green allele. The primates eat the ants year-round, but your professor knows that the way they eat the ants differs between the rainy season and the dry season. During the rainy season, when there are green leaves on the trees, the primates eat the ants off the green leaves. During the dry season, when the trees lose their leaves, the primates eat the ants off the brown tree branches.

Your professor has collected data to investigate if the primate acts as a selective pressure on the ant population, possibly changing the allele frequencies over time.

Step One: Hypothesis

You need to start with a hypothesis. The following questions will help you to frame your hypothesis.

1. How do the ants vary?
2. What is the selective pressure?
3. What is the dependent variable?
4. What is the independent variable?
5. Now, write a hypothesis for the following question: During the rainy season, which allele frequency (brown or green) will increase over time?

Step Two: The Rainy Season Data

Your professor is happy with the hypothesis that you have written. She gives you the data that she collected on the ant population. Because of the fast rate of reproduction among ants, she was able to collect a number of ants of each color over four generations. The data are in the table below.

Table 1: Number of ants collected during the rainy season

Generation of ants	Brown ants	Green ants	Total ants
Generation 1	100	100	200
Generation 2	90	120	210
Generation 3	75	150	225
Generation 4	65	170	235

Calculate the frequency of the brown allele and of the green allele in each of the generations. We assume that each ant is a homozygote. Round to the nearest thousandths.

To calculate allele frequencies within each generation:

1. Calculate the number of brown alleles by multiplying the number of brown ants (from Table 1) by 2. Calculate the number of green alleles by multiplying the number of green ants (from Table 1) by 2. Write in Table 2.
2. Calculate the total number of alleles by adding the number of brown alleles and the number of green alleles. Write in Table 2.
3. Calculate the brown allele frequency by dividing the number of brown alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 2.
4. Calculate the green allele frequency by dividing the number of green alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 2.
5. Check your math by calculating the total allele frequency. Write in Table 2.

Table 2: Allele frequencies in the rainy season

	Generation 1		Generation 2		Generation 3		Generation 4	
	brown	green	brown	green	brown	green	brown	green

Number of alleles							
Total # alleles in generation (brown + green)							
Allele frequency							
Total allele frequency in generation (brown + green)							

Answer the following questions based on the above (rainy season) data.

1. What was the general trend (comparing Generation 1 to Generation 4) of the brown allele frequency over the four generations? Did the brown allele frequency increase or decrease? Write the actual numbers for each generation here in support of your answer.
2. What was the general trend (comparing Generation 1 to Generation 4) in the green allele frequency over the four generations? Did the green allele frequency increase or decrease? Write the actual numbers for each generation here in support of your answer.
3. Was your hypothesis in Question 1 supported? Explain why or why not.

Step Three: The Dry Season Data

During the dry season, the trees lose their leaves. The primates now eat the ants off of the brown tree branches.

1. In this environment, which allele frequency (brown or green) do you hypothesize will increase over time?

Table 3: Number of ants collected during the dry season

Generation of ants	Brown ants	Green ants	Total ants
Generation 1	65	170	235
Generation 2	90	150	240
Generation 3	125	120	245
Generation 4	150	100	250

Calculate the frequency of the brown allele and of the green allele in each of the generations. We assume that each ant is a homozygote. Round to the nearest thousandths.

To calculate allele frequencies: Within each generation,

1. Calculate the number of brown alleles by multiplying the number of brown ants (from Table 3) by 2. Calculate the number of green alleles by multiplying the number of green ants (from Table 3) by 2. Write in Table 4.
2. Calculate the total number of alleles by adding the number of brown alleles and the number of green alleles. Write in Table 4.
3. Calculate the brown allele frequency by dividing the number of brown alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 4.
4. Calculate the green allele frequency by dividing the number of green alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 4.
5. Check your math by calculating the total allele frequency. Write in Table 4.

Table 4: Allele frequencies in the dry season

	Generation 1		Generation 2		Generation 3		Generation 4	
	brown	green	brown	green	brown	green	brown	green
Number of alleles								

Total # alleles in generation (brown + green)									
Allele frequency									
Total allele frequency in generation (brown + green)									

Answer the following questions based on the above (dry season) data.

1. What was the general trend (comparing Generation 1 to Generation 4) in allele frequency that you observed for the brown allele over the four generations? Did the brown allele increase or decrease in allele frequency? Write the actual numbers for each generation here in support of your answer.
2. What was the general trend (comparing Generation 1 to Generation 4) in allele frequency you observed for the green allele over the four generations? Did the green allele increase or decrease in allele frequency? Write the actual numbers for each generation here in support of your answer.
3. Was your hypothesis at the beginning of Step Three supported? Explain why or why not.

Step Four: Wrap Up

The following questions refer to the whole lab.

1. How did the ants in this population vary? In other words, what is the main difference between them?
2. Why is variation necessary for natural selection to work?
3. Explain selective pressure. What was the selective pressure in this simulation?
4. What is the definition of allele frequency? How are allele frequencies related to the idea of evolution?
5. Because some individuals in a population are more fit than others, the ultimate result of natural selection is a population that is better adapted to its environment.
 - a. What trait was adaptive in the rainy season?
 - b. What trait was adaptive in the dry season?
 - c. Are your answers for a) and b) the same or different? If different, what changed between the two seasons to cause this difference?
6. Define microevolution. Define macroevolution. Which did you observe in this ant population? Explain why?

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4.2: Bingo Chip Evolution

Bingo Chip Evolution

Format: In-person or online



Bingo chips can be used to simulate a population of simple organisms reproducing and spreading in this evolution activity.

Author: Cara Ocobock

Source: Modified from Lee et al. 2017. [Making evolution stick: using sticky notes to teach the mechanisms of evolutionary change](#). *Evolution: Education and Outreach* which is under a [CC BY 4.0 License](#).

Time needed: 60 - 90 minutes

Learning Objectives

- Calculate allele frequencies to document evolutionary change in a population
- Identify the evolutionary forces
- Model and describe the founder effect, gene flow, genetic drift, natural selection, and population bottleneck

Supplies Needed

- Bingo chips (or beads). Each set of chips for each group of students should include approximately 200 chips (50 chips of each color).
- Student worksheet (provide)

Readings

-

Introduction

This activity utilizes bingo chips to represent a population of organisms reproducing over several generations. Over time, the population of Bingo Chips expands to occupy both the mainland and island coastlines, as both regions experience various evolutionary forces. With each generation, student researchers follow the directions on their worksheet to modify their population as a result of these forces, and then record the new allele frequencies.

Steps

- Instructors will provide an overview of the Bingo Chip population, including how an organism can be haploid and reproduce via the budding process. Instructors should demonstrate how to calculate allele frequencies for the population of bingo chips.
- Students divide into small groups and are given a set of bingo chips and the student worksheet(s). At their table, students should map out the location of the island and mainland, where the bingo chips live. Students then place the first eight Bingo Chips (two bingo chips of each of the four colors) at the mainland location to begin the activity.
- Students will follow the instructions on the student worksheet, changing the Bingo Chip populations as directed.
- For each generation, students will record the number of alleles present on the tables in their worksheet. If there is sufficient time, students should be encouraged to convert these into allele frequencies. For example if 2 of 8 of the allele on the mainland are pink, the frequency of the pink allele is $2/8 = 0.25$.
- For each generation students will also discuss answers to the questions on the worksheet.

Conclusion

After each group has worked through the six generations of activities, each group should identify and share with the rest of the class:

- The final allele frequencies for both their mainland and island populations.
- The force(s) they think had the largest effect towards changing the allele frequencies, and what those changes were. Students should refer back to their tables to support their statements.
- Which event(s)/evolutionary force(s) led to the loss of any alleles in either the mainland or island population. If genetic bottleneck or the founder effect are noted, instructors can help students identify that both are types of genetic drift.

Students should compare the populations of the various small groups to identify the differences between the groups, despite that all groups experienced similar types of events/evolutionary forces. This can be tied to the random nature of many evolutionary forces.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This activity can be completed online. While students could do it individually on their own, it would be best completed in small groups synchronously (e.g. via Zoom) utilizing breakout rooms. The provided [Bingo Chips Evolution Slides](#) can be copied and modified for online classes. Individuals or small groups of students can be given edit access to complete the activities in the slides themselves. Each individual or small group of students should be provided a copy of the first couple of slides. They can then copy and paste the slide of the generation they are working on and proceed to the next generation (the next step of the activity). Each generation should have its own slide. This version of the lab is nice, as a record of each generation is preserved on a slide and can be reviewed at the end of the activity. Also, instead of recording allele frequencies in the worksheet, students can record allele frequencies on the slides.

Tips and Suggestions

Other materials can be used for this activity such as beads or post-it notes, as long as there are sets with at least 4 different colors. At its peak there are a lot of “bingo chip” organisms, so it will be important that each student set has at least 50 objects of each color.

References

Alvesshere, Andrea. 2019. “Forces of Evolution.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington,

VA: American Anthropological Association. <http://explorations.americananthro.org/>

Ocobock, Cara. [Bingo Chip or Sticky Note Evolution](#). University of Notre Dame.

Teresa W. Lee, Kathleen E. Grogan and Justine S. Liepkalns. 2017. [Making evolution stick: using sticky notes to teach the mechanisms of evolutionary change](#). *Evolution: Education and Outreach* 10:11. Open Access; [CC BY 4.0 License](#)

Lee et al. 2017. [Making evolution stick: using sticky notes to teach the mechanisms of evolutionary change](#). *Evolution: Education and Outreach* which is under a [CC BY 4.0 License](#). This *Explorations* lab is modified from this source.

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[Bingo Chips #3](#) by Scott Ableman at flickr is used under a [CC BY-NC-ND 2.0 License](#).

Bingo Chip Evolution Worksheet

Introduction

Your team has discovered a new population of Bingo Chips that lives along the coast. This organism is haploid, meaning it only has one copy of each chromosome. It has one visible phenotype (color), which is determined by the Color Gene. Like budding yeast, Bingo Chips reproduce clonally via a budding process, resulting in two individuals who have the same genome and phenotype.

They are exceptionally long-lived, meaning that each Chip can reproduce for many generations. Everything these Chips need to survive is on the coast. They can see an island off in the distance, but cannot reach it.

Generation 1: Establish Your Own Population of Bingo Chips

There will be two Bingo Chips of each color. Bingo Chips are haploid, so each chip represents only one allele. The initial phenotypic ratios are recorded for you already in the table below but you will need to record them yourself in future generations.

Generation 1	Green	Blue	Pink	Yellow
Mainland	$2 / 8 = 0.25$	$2 / 8 = 0.25$	$2 / 8 = 0.25$	$2 / 8 = 0.25$
Island	0	0	0	0

Discuss:

- Bingo Chips are haploid, so how many alleles does a single Bingo Chip have for the Color Gene?
- How many total alleles for the color gene exist in the population during generation 1?

Generation 2: The Founder Effect

A rare low tide has exposed a temporary sandbar. Some curious Bingo Chips take this opportunity to explore the nearby island, but they’re stuck there once the sandbar is covered.

Task:

- Move a few Bingo Chips of any color to the island (no more than three).
- After this tragic separation, each Chip will clonally reproduce one time. For each Bingo Chip on the island and the mainland, add another Bingo Chip of the same color to that same population.
- Record your new allele frequencies in the table below, considering the two populations separately.

Generation 2	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- After reproduction, how do the **mainland** phenotypic frequencies of Generation 2 compare to those on the **mainland** in Generation 1?
- After reproduction, how do the **island** phenotypic frequencies of Generation 2 compare to those on the **mainland** in Generation 1?

Generation 3: Gene Flow

Every so often the currents are favorable and allow some Bingo Chips to move from the island to the mainland or vice versa.

Task:

- One member of your group will choose up to five intrepid Bingo Chips to move from one population to the other. Some can move from the island to the mainland, while others can move from the mainland to the island.
- After the migration, each Bingo Chip reproduces clonally one time. For each Bingo Chip on the island and the mainland, add another Bingo Chip of the same color to that same population.
- Record your new allele frequencies in the table below.

Generation 3	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- Does evolution occur if a Bingo Chip migrates from the island to the mainland, but then dies without reproducing? Why or why not?

Generation 4: Genetic Drift

You and your team have gone to get more supplies to continue your work at the field site, so several generations go by before you can make an observation of these populations.

Task:

- Choose another group member to act out the effects of genetic drift. They will close their eyes and point to the screen, open their eyes and remove the closest two Chips from the mainland population, and do it again to remove two Chips from the island population. These unfortunate Bingo Chips have perished before they are able to reproduce.
- All the remaining Bingo Chips will reproduce clonally one time.
- The same group member will close their eyes and now remove eight Chips from the mainland population and eight from the island population.
- All the remaining Bingo Chips will reproduce clonally once again.
- Record your new allele frequencies in the table below.

Generation 4	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- Which color, if any, has become more prevalent in the **mainland** population? Which color has become more rare?
- Which color, if any, has become more prevalent in the **island** population? Which has become more rare?
- Which population looks most different from your original population at Generation 1?

Generation 5: Natural Selection

A dreaded flying predator has entered the area and is eating many of the bingo chips!

Task:

- Choose a group member to act as a predator of the Bingo Chips. This group member will choose their two favorite colors of Chips to eat. This group member will “fly” between the island and the mainland, removing ten Bingo Chips of these two colors in total (decide how many to eat from each population).
- All the remaining (and relieved) Bingo Chips will reproduce clonally one time.
- Record your new allele frequencies in the table below.

Generation 5	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- What characteristics of Bingo Chips or their environment might help one color of Bingo Chip survive better than another?
- Does evolution happen if a Bingo Chip is better at surviving, but would not reproduce?

Generation 6: Population Bottleneck

An event of mass destruction (hurricane? earthquake? zombies?) causes Bingo Chips to die in alarming numbers! Which ones die depends on the event but not on their phenotype (color). Will it be proximity to the ocean? Disease susceptibility? Completely at random?

- Decide as a group what the event of mass destruction will be.
- Choose a group member to become a force of nature. This person will remove all but ten Bingo Chips (split the survivors between the two populations).
- These (extremely shaken) Bingo Chips are grateful to have survived and begin to rebuild their lives. They reproduce clonally one more time.
- Record your final allele frequencies in the table below.

Generation 6	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- Have any colors disappeared in either population? Will there be any Bingo Chips of this color in future generations?
- Now that you have completed your field season, describe what happened to each color of Bingo Chip over the generations you’ve observed. You will report this back to the entire class.

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4.3: Evolutionary Detectives

Evolutionary Detectives

Format: In-person or online



Cards of various colors help students to identify which forces of evolution are occurring - and the instructor can quickly tell where clarification is needed.

Author: Jess Whalen

Time needed: 60-90 minutes

Learning Objectives

- Distinguish between the different forces of evolution
- Identify which force(s) of evolution are at work in a given scenario
- Observe how multiple forces of evolution may work together to cause change in a population

Supplies Needed

- Forces of evolution cards (included). Each force should be printed on paper of a different color.
- Student worksheet with case studies (included)

Readings

- Alveshere, Andrea J. 2019. Chapter 4: Forces of Evolution. *Explorations*.

Introduction

In this activity, students will be reading short case studies and identifying what forces of evolution are at work, and how those forces work together to cause change in a population. This activity also utilizes colored “forces of evolution” cards so that groups can visually report their answers at the end of the activity.

Steps

- Students should be divided into small groups (of two to three).
- Each group should be given one set of four evolutionary forces cards (each card is a different color) and copies of the student worksheet with case studies and questions.
- Students will work through the case studies, using the evolutionary forces cards to help them differentiate between the forces. They will develop narratives that identify and explain which forces are operating in each case study, and record their answers on the student worksheet.

Conclusion

Talk through the case studies as a class, one case study at a time. Allow students time to work through the case study as a group and decide what forces are operating.

After groups work through a case study the instructor can ask, “What forces are operating? Hold up your cards!”. At that point the

cards typically create a sea of purple, orange, etc. The colors help the instructor identify who is having trouble, and class-wide discussion can help identify why.

A class-wide discussion that explains why specific forces are operating in this case study, and why other forces are not operating, will help clarify for students the differences between the different “forces”. For instance, students often have difficulty distinguishing between gene flow/admixture and genetic drift. Clarifying that the founder effect (a type of genetic drift) involves a situation where organisms migrate to a new place and find no other organisms of their own species in that new place that they can mate with, helps students to understand the difference between genetic drift and gene flow. The organisms that migrate to that new place have no choice but to mate only amongst each other. This is different from gene flow, where alleles are carried by new migrants into a population of already existing organisms of that same species, and interbreeding occurs.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Students could be provided the worksheets to do this activity individually for submission, or given an electronic version of the colored forces of evolution cards and case studies (e.g. in Google Slides) and asked to complete the activity in small groups during a synchronous activity time.

Tips and Suggestions

I recommend making the gene flow and the genetic drift cards strikingly different colors as these two concepts are frequently confused by students.

Be sure to welcome all ideas and explain that this is a difficult activity, or else students will be shy about holding up the cards that correspond with their genuine thoughts about the case studies. What you do not want is for students to copy the majority decision because they are afraid to guess incorrectly! Normally, there are many “errors” in the forces that students identify. You want to encourage those “errors” and talk through why a case study involves some forces, but not other forces. Along the way you can clarify the differences between the “forces”. This should be very tricky for everyone involved - when a class does this perfectly, it signals to me that many are hiding that they are having trouble!

For Further Exploration

Andersen, Paul. Five Fingers of Evolution. TedEd Animation and Lesson. <https://ed.ted.com/lessons/five-fingers-of-evolution>

Andrews, Christine A. 2010. Natural Selection, Genetic Drift, and Gene Flow Do Not Act in Isolation in Natural Populations. *Nature Education Knowledge* 3(10):5 <https://www.nature.com/scitable/knowledge/library/natural-selection-genetic-drift-and-gene-flow-15186648/>

References

Alveshere, Andrea J. 2019. “Chapter 4: Forces of Evolution.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

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Evolutionary Detectives

Introduction

Evolutionary biologists reconstruct evolutionary processes like detectives. They compare the frequency of alleles in a population over time, and use their understanding of evolutionary forces to work out what’s happened to cause any shifts in allele frequencies. In this activity, you will do the same!

Change in a population over time is the result of any combination of the four “forces” of evolution. But which forces are occurring? We can figure this out by considering the order in which the “forces” typically occur, and work out a narrative - a story - by which

this happens.

You can remember the forces of evolution as a sequence of stages:

Genes Mutate,
Individuals are Selected,
Populations Evolve.



Mutations are the only “force” of evolution that adds completely new variation to a population, so it comes first. The other “forces” - Natural Selection, Genetic Drift, and Gene Flow/Admixture - move this variation around in a population.

Instructions

For each of the following cases:

- Identify which forces of evolution are occurring,
- Identify if natural selection is present, and if so, how it is operating, and,
- Put this information into a coherent narrative (story) that explains how, exactly, evolution is taking place. For this step, you will need to identify the sequence by which the forces that you identified are actually occurring.

Quick Recap: Distinguishing Between the Forces

First, consider if the case study involves the introduction of new alleles - either through mutation, or through gene flow/admixture (the transfer of alleles between populations). New alleles means new traits, which can provide natural selection more variation to act upon.

If natural selection is occurring, then individuals with traits that are a better “fit” with the environment will be selected for, or favored. That means individuals with advantageous traits will have an easier time finding food, avoiding predators, surviving to reproductive age, and/or reproducing successfully and sending their traits (and the alleles that control those traits) into the next generation.

If genetic drift is occurring, we will see traits (and the alleles that control them) either increasing or decreasing in frequency, perhaps even being eliminated from a population, due to chance. This may correlate with events like natural disasters (floods, earthquakes, etc.), but also with events like overhunting by humans, or migration into a new area. With genetic drift there is no interaction between traits and the environment: it does not matter if the organism has traits that are a good “fit” with the environment. Those who survive and pass on their genes are the “lucky” ones, not the ones with the best traits.

Case #1: The Story of the Peppered Moth

In Great Britain, prior to the 1800s, most peppered moths had wings that were white with black specks. In 1848, a new ‘species’ was spotted: a completely black moth! By the 1950s, one hundred years later, more than 90% of moths were black.

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how individuals are selected, and how alleles shift over time.

Case #2: Sickle-Cell Anemia

As many as 20-30% of people living in equatorial Africa have at least one allele on Chromosome 11 that codes for sickle-cell anemia (they have an, “S” rather than an, “A” allele). This is odd because usually, 80% of people who have two S alleles die before they can reproduce - so why is the allele still around?

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #3: Lactase Persistence

Being able to digest lactose after the age of four is **common** / **uncommon** (circle one) around the world. 77% of European Americans and 14% of African Americans have the LCT gene on Chromosome 2, which codes to produce the enzyme lactase, which allows people to digest lactose in adulthood.

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #4: Founding the Colony of Zygozia

Let’s pretend that there is a community called Zygozia. They say that they founded their small island colony in the South Pacific in 1959. When they arrived, there were no people living on the island, and so they became the only inhabitants. They came ‘from the west’, most likely Southeast Asia. The Zygozians of 2018 are unusual in that 80% of them have a rare genetic condition. Populations from Southeast Asia, whom the Zygozians descended from, only show this condition in 3% of their population. What happened?

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #5: Native Americans and Type O Blood

Modern Native Americans have very high frequencies of Type O blood. In some places in North and South America, the frequency is as high as 100%. Anthropologists believe that early Native Americans arrived in North America by crossing over the Bering Land Bridge around 15,000 years ago, from East Asia. Modern East Asian populations, with whom modern Native Americans share ancestry, do not have high frequencies of Type O blood. Instead, they have some of the lowest frequencies of Type O blood in the world.

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Specifically, how is natural selection involved?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #6: Malaria in the Tropical Americas

Today, malaria appears throughout the tropical Americas. However, Native American populations only have "normal" hemoglobin (they are 100% homozygous for normal alleles and do not have any hemoglobin variations that protect them from malaria, as is seen in human populations in Africa, Asia and Europe). Why do Native Americans not exhibit any genetic diseases that make them better able to survive malaria?

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Specifically, how is natural selection involved?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #7: Skin Color Around the World

Around the world, populations near to the equator and in areas of high altitude have darker skin (their skin produces more melanin). Populations at northern latitudes have lighter skin- their skin produces less melanin.

1. What forces of evolution are at work? Tick all that apply.

- ☐ Mutation
- ☐ Natural Selection
- ☐ Genetic Drift
- ☐ Gene Flow

2. Specifically, how is natural selection involved?

3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

The Forces of Evolution Cards

Please print enough cards so that each student group has one of each type: Natural Selection, Mutation, Genetic Drift, and Gene Flow. Print each type on a different colored paper (e.g. Natural Selection cards are all yellow, Gene Flow cards are all Blue).

Natural Selection The process by which biological variation (adaptations) becomes more common in a population over generations.	Natural Selection The process by which biological variation (adaptations) becomes more common in a population over generations.
Natural Selection The process by which biological variation (adaptations) becomes more common in a population over generations.	Natural Selection The process by which biological variation (adaptations) becomes more common in a population over generations.
Mutation Chemical change in the DNA. It can be positive, neutral, or deleterious.	Mutation Chemical change in the DNA. It can be positive, neutral, or deleterious.
Mutation Chemical change in the DNA. It can be positive, neutral, or deleterious.	Mutation Chemical change in the DNA. It can be positive, neutral, or deleterious.
Gene Flow Transfer of genes across population boundaries because their members are breeding with one another.	Gene Flow Transfer of genes across population boundaries because their members are breeding with one another.
Gene Flow Transfer of genes across population boundaries because their members are breeding with one another.	Gene Flow Transfer of genes across population boundaries because their members are breeding with one another.
Genetic Drift When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.	Genetic Drift When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.
Genetic Drift When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.	Genetic Drift When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.

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CHAPTER OVERVIEW

5: Meet the Living Primates

Learning Objectives

- Explain the form and function of primate features
- Discuss and depict the primate order and suborders

[5.1: Primate Classification](#)

[5.2: Primate Tweets](#)

[5.3: Creating a Monster Phylogeny](#)

[5.4: Modern Primate Museum](#)

Thumbnail: Side and top views of postorbital closures and bars.

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5.1: Primate Classification

Primate Classification

Format: In person or online



Side and top views of postorbital closures and bars.

Author: Beth Shook

Modified from labs by Henry M. McHenry, University of California, Davis

Time needed: 50-60 minutes

Supplies Needed

- Primate and non-primate skeletons and skulls. These can be real, casts, or images. A list is provided below.
- Labels for the skeletons and skulls (e.g., Primate or Strepsirrhine)
- Resources for students to look up specific examples of Platyrrhines (e.g., Rowe. 1996. *The Pictorial Guide to Living Primates*)
- Student worksheet (attached)

Readings

- Etting, Stephanie. 2019. Chapter 5: Meet the Living Primates. *Explorations*.

Introduction

People belong to the zoological order *Primates*, which is one of the many orders within the class *Mammalia*. This lab gives students the opportunity to observe characteristics of the skeleton that differentiates primates from other mammals and compare primates to one another.

Before beginning, students should consider the following conceptual questions: What can bones tell us about the animal to which they belonged? Specifically, what might the skeleton tell us about:

- what the animal ate?
- its mode of locomotion?
- the environment it lived in?
- its behavior?

Bones can reflect the lifestyle of primates, and the characteristics they share are likely reflective of early primate ancestors. For example, most primates move about in trees by grasping with their feet and hands. Primatologists believe the common ancestor of all living primates was an *arboreal* climber with *prehensile* extremities who relied on vision more than olfaction (smell). This ancestor may have had some depth perception, made possible by the overlapping visual fields of forward-facing eyes, and hands with the ability to manipulate objects. Thus, physical traits that help us distinguish primates from other mammals include:

- a generalized skeletal structure for arboreal life;
- convergent eyes (forward facing);
- eye orbits with a postorbital bar or plate;

- reduced snout length (related to less reliance on smell);
- opposable thumbs and big toes;
- flattened nails instead of, or in addition to, claws;
- a larger brain size;
- differences in tooth morphology (reflects variable diets);
- and prehensile (grasping) hands and feet.

Steps

- Before beginning this lab, the instructor should select skeletal materials, casts, or images of skeletal materials for students, and arrange them at various stations. All skeletal materials should be labeled with cards/small labels with terms that match the student worksheets (e.g., Primate, Strepsirrhine). Alternatively, virtual images can be
- linked to the student worksheet to create a virtual lab. Materials include non-primate, nonhuman primate, and primate skulls and articulated skeletons. Specifically:
 - Station 1: (a) primate (e.g., monkey) articulated skeleton, and (b) non-primate (e.g., cat or dog) articulated skeleton. Preservation should be good enough to see nails/claws.
 - Station 2: (a) non-primate (cow or pig) skull with teeth, (b) dog skull with teeth, (c) monkey skull with teeth, and (d) human skull with teeth. Be sure that the surfaces of the teeth are visible in addition to the eye orbits (e.g., the mandible can be separated from the skull or there are multiple images to depict various views).
 - Station 3: (a) strepsirrhine (e.g., lemur) and (b) haplorrhine (e.g., monkey).
 - Station 4: (a) tarsier. Because this station asks students whether the tarsier is more like a strepsirrhine or haplorrhine for given traits, they should have either completed Station 3 or have access to comparative materials at this station too. Additionally, because tarsiers are small, it can be difficult for students to clearly identify some of the traits, and it can be useful to also provide a diagram with a closer view.
 - Station 5: (a) New World monkey skull and (b) catarrhine skull (preferably an Old World monkey). Be sure to use adult primate skulls so that students can accurately compare their dental formulas. Additionally, this station requires photographs of these primates so that students can compare nose shapes and look up examples of different types of New World monkeys.
 - Station 6: (a) Old World monkey articulated skeleton, (b) ape articulated skeleton, and (c) human articulated skeleton. This station also asks students to compare molar cusp patterns, so it can be useful to also have separate skulls or photos of dentition.
 - Station 7: No skeletal materials are required. However, students should have completed Stations 3 through 6.
- The instructor should choose to assign this lab as an individual or small group activity.
- An introduction to encourage students to think about “form and function” of the skeleton would be helpful. Additionally, students should be encouraged to think broadly (incorporating what they already know about animals, what they eat, and how they move), especially when answering questions at Stations 1 and 2. Instructors should be sure students are familiar with the traits in the lab (e.g., foramen magnum, tooth comb, Y5 or bilophodont molar cusp patterns) or are given resources to identify these traits at the various stations.
- The lab consists of seven “stations.” Stations 1 and 2 focus on “form” and “function” of the skeleton, while stations 3 through 6 focus on the organization of the primate taxonomy. Students will rotate through stations filling out tables and answering questions on their worksheets. Instructors may assign some or all stations. Stations can be
- completed in any order, however Station 7 requires the completion of stations 3 through 6 first.
 - Station 1: Students compare **primate and non-primate postcrania** and relate the form of the skeletons to their function.
 - Station 2: Students compare **primate and non-primate teeth and crania** and relate the form of the skeletons to their function.
 - Station 3: Students compare **strepsirrhines and haplorrhines**.
 - Station 4: Students identify **tarsier** traits and evaluate their classification.
 - Station 5: Students compare **New World monkeys to catarrhines**.
 - Station 6: Students compare a **cercopithecoid to two hominoids (an ape and human)**.
 - Station 7: Students construct a **primate order phylogeny** based on the information from Stations 3 through 6.
- Instructors should have students report to the class on their answers for some/all of the stations. For example, each group could complete a small table for one station on the board. While some parts of the tables are more open-ended, there are some traits that instructors will want to be sure students identified correctly.

Conclusion

By completing this lab, students learn to distinguish primate and non-primate body forms and functions, with a focus on postcrania, teeth, and eye orbits. Students learn how to differentiate the primate suborders (*Haplorrhini* and *Strepsirrhini*) and to describe the unique characteristics of tarsiers, New World primates, and Old World primates. By the end of this lab, students will have acquired a robust understanding of primate classification.

Adapting for Online Learning

This activity could be easily adapted to online classes by linking to 3-D images of primates at educational sites (e.g., [eSkeletons](#)) and students could share their results in an assignment, virtual meeting (e.g., Zoom), or on an LMS discussion board.

For Further Exploration

David Attenborough. 2003. "Episode 9: The Social Climbers." *The Life of Mammals* (Film) [eSkeletons](#). Department of Anthropology, University of Texas at Austin. <http://www.eskeletons.org/>

2011. Primates—What is a Primate? *Odyssey Earth*. https://www.youtube.com/watch?v=BpnIS_ach-0&t=67s

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Rowe, Noel. 1996. *The Pictorial Guide to Living Primates*. Charlestown: Pogonias Press.

References

Etting, Stephanie. 2019. "Chapter 5: Meet the Living Primates." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

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Primate Classification Worksheet

Introduction

People belong to the zoological order *Primates*, which is one of the many orders within the class *Mammalia*. This lab provides the opportunity to observe characteristics of the skeleton that differentiate primates from other mammals, and compare primates to each other.

Before beginning, consider the following: What can bones tell us about the animal to which they belonged? Specifically, what might the skeleton tell us about:

- what the animal ate?
- its mode of locomotion?
- the kind of environment it lived in?
- its behavior?

Bones can reflect the lifestyle of primates, and the characteristics they share are likely reflective of early primate ancestors. For example, most primates move about in trees by grasping with their feet and hands. Primatologists believe the common ancestor of all living primates was an *arboreal* climber with *prehensile* extremities, who relied on vision more than olfaction (smell). This ancestor may have had some depth perception made possible by the overlapping visual fields of forward-facing eyes, and hands with the ability to manipulate objects. Thus, physical traits that help us distinguish primates from other mammals include:

- a generalized skeletal structure for arboreal life;
- convergent eyes (forward-facing);
- eye orbits with a postorbital bar or plate;
- reduced snout length (related to less reliance on smell);
- opposable thumbs and big toes;

- flattened nails instead of, or in addition to, claws;
- larger brain size
- differences in tooth morphology (reflects variable diets);
- and prehensile (grasping) hands and feet.

Station 1: Primate Versus Non-Primate Postcrania

Look at the skeletons or skeletal images provided. Note how the postcrania (body) of primates and non-primates differ. Carefully examine the vertebral column (backbone), the structure of the shoulder and pelvis, the shape of the rib cage, and the hands and feet. Think about what you already know about their locomotion and behavior for clues about how they move and the differences you may see on their skeleton. Record general observations in the table below.

	Non-Primates (Ex. dog, cow, pig)	Primates (Ex. monkey)
Hands and feet		
Claws or nails		
Vertebral column and rib cage		
Clavicle		
Pelvis		

How do the above characteristics suggest the locomotion and posture of primates differ from non-primates?

Station 2: Non-Primate and Primate Teeth and Skulls

Mammals typically have four different kinds of teeth: *incisors*, *canines*, *premolars*, and *molars*. Examine the teeth of the primates (monkey and human) and non-primates (cow or pig and dog). While they all have a mixture of incisors, canines, premolars, and molars, what differences do you see between the species? (Number of teeth? Shape? Cusp pattern?) What might these features tell us about their function?

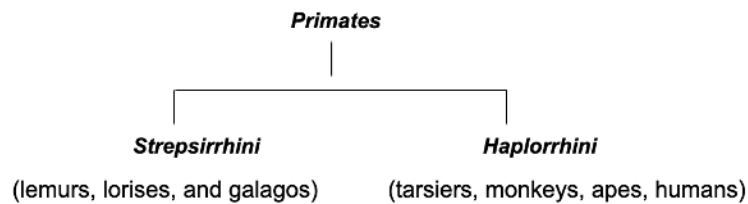
	Non-Primates		Primates	
	Cow/Pig	Dog	Monkey	Human
Distinguishing features of the teeth				
Draw the tooth row shape				
Probable diet				

The *orbit* is the bony structure that protects the eye. All living primates have a complete bony ring around the eye, but the orbit can be either open (postorbital bar) or closed (postorbital plate) in the back. Examine the orbits and their orientation. What differences do you see? Look at the *foramen magnum*: What does this tell you about the typical posture of the animal? Finally, look at the *nasal region*. Does this tell you about what senses they use most?

	Non-Primates		Primates	
	Cow/Pig	Dog	Monkey	Human
Eye orbit structure and orientation				
Foramen magnum position				
Size and complexity of nasal region				

Rely more on vision or smell?

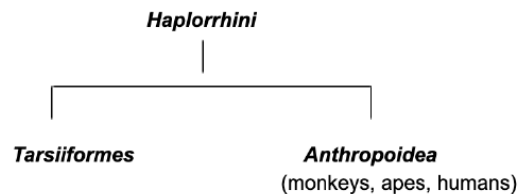
Station 3: Primate Suborders: *Strepsirrhini* and *Haplorrhini*



Most modern strepsirrhines live on the island of Madagascar (lemurs), but a few stalk the night forests of Africa (galagos) and Asia (lorises). Our own suborder (haplorrhines) live in Asia, Africa, and the Americas. It is easy to talk about ourselves as if we are higher, grander, further up the scale, etc., but evolution results from adaptation to the immediate environment without a predetermined direction. So don't be specio-centric! After all, *Loris tardigradus* (a strepsirrhine) is much cuter than *Cacajao rubicundus* (a haplorrhine)!

	Strepsirrhine	Haplorrhine
Nails or claws? Which digits?	Claw on second digit, nails on others	Nails only
Postorbital bar or plate?		
Orientation of eye orbits (forward or toward the side)		
Snout length relative to brain size		
Presence or absence of tooth comb		
Geographic location (read intro above)		

Station 4: Tarsiers

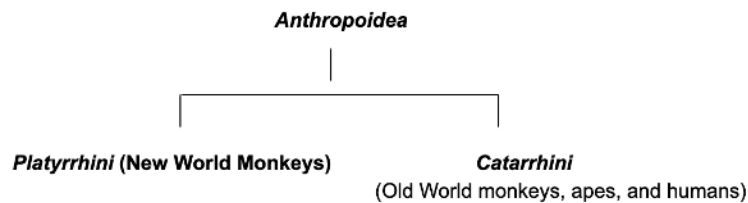


For some time, tarsiers challenged primatologists with regard to their classification: Were they closer to monkeys, apes, and humans or closer to lemurs and lorises? Genetic evidence has now provided strong support for the classification of tarsiers as haplorrhines, but their ancestors likely split off early, before the division of different types of monkeys and apes. Examine the tarsiers—what traits may have been confusing to primatologists because they are similar to lemurs and lorises or are unique to the tarsier?

	Tarsier	Is this trait more like strepsirrhines or haplorrhines, or is it unique?
Nails or claws? Which digits?	Grooming claw, and nails on other digits	
Postorbital bar or plate?		

Orientation of eye orbits (forward or toward the side)		
Snout length relative to brain size		
Presence or absence of tooth comb		
Geographic location	Asia	N/A

Station 5: New World Monkeys



Anthropoids are divided into two infraorders: *Catarrhini* (Old World monkeys, apes, and humans, all who live in Africa and Asia) and *Platyrrhini* (New World monkeys who live in Mexico, Central, and South America). The word "monkey" is confusing because monkeys in the Americas are not closely related to Old World monkeys (Old World monkeys are, in fact, more closely related to people!)

	New World Monkey	Catarrhine
Meaning of scientific name	"Broad-nosed" (separated by wide nasal septum)	"Hook-nosed" (nostrils are close together)
Direction nostrils face	<i>Look at photographs</i>	<i>Look at photographs</i>
Dental formula		
Geographic location (read intro above)		

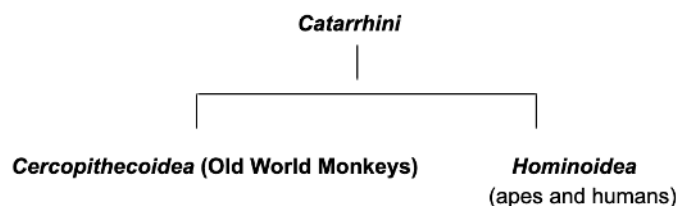
Questions:

Some New World monkeys (*Atelinae*) have prehensile tails. Look up the name of one monkey that has a prehensile tail:

One group of New World monkeys, *Callitrichidae* (marmosets and tamarins), have re-evolved claws on all but one digit. Which digit? (Do some research to find out!) _____

There is one group of New World monkeys who have a reduced or absent thumb. What type of monkey is this?

Station 6: Old World Monkeys and Hominoids



	Cercopithecoid	Hominoids
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	Old World Monkey	Ape (e.g., chimpanzee)	Human
Shape of rib cage			
Length of forelimb (arm) relative to trunk			
Length of clavicle and location of scapula			
Presence or absence of tail			
Lower molar cusp pattern (Y5 or bilophodont)			

The differences between the monkey skeletons and the hominoids may be because the common ancestor of apes and people was adapted for suspending the body by the arms and *brachiating*. The forelimbs are long, the shoulders are flexible, the elbows and wrists allow greater rotation, the chest is wide for the attachment of expanded forelimb retractor muscles, and the lower back is short. Cercopithecoids, on the other hand, are adapted to quadrupedalism, like most mammals. The bilophodont molar is their specialization for eating a wide variety of foods.

Station 7: Putting It All Together

Using what you have learned at Stations 3 through 6, construct the complete tree for the *Primates* order. Put primates at the top, divide them into strepsirrhines and haplorrhines, and then work your way down, dividing them into subgroups as you go. Use the tree in your textbook if you need help. **Then, for each group on the tree identify at least one trait that helps distinguish that group.**

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