**Unit Essential Question:** *Why do species change over time and should we intervene?*

**Introduction**

So far, students have begun to think about why organisms might change over time and have explored some evidence of organisms changing over time. In the last task, students looked at the fossil record to begin their reconstruction of evolutionary history. In this task, they take this a step further by looking at two more kinds of evidence that scientists use to infer lines of evolutionary descent. By looking at anatomical structures and embryos of different species students will begin to see how these pieces of evidence might be used to infer evolutionary relationships. By the end of this task, students will be able to construct an explanation for how scientists are able to reconstruct evolutionary history, using these examples as evidence to support their explanation. This adds another layer to the story students are constructing about how species change over time, thus better preparing them for their Think Tank Discussion. Note: The performance expectations for this task will not be included in the Culminating Project; rubrics are provided at the end of this document to assess students’ tasks.

**Alignment Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.] | **Constructing Explanations**   * Apply scientific ideas to construct an explanation for real world phenomenon, examples, or events. | **LS4.A: Evidence of Common Ancestry and Diversity**   * Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. | **Patterns**   * Patterns can be used to identify cause-and-effect relationships. |
| **MS-LS4-3.  Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.] | **Analyzing and Interpreting Data**   * Analyze displays of data to identify linear and nonlinear relationships. | **LS4.A: Evidence of Common Ancestry and Diversity**   * Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. | **Patterns**   * Graphs, charts, and images can be used to identify patterns in data. |
| **Equity and Groupwork**   * Discuss data in groups | | | |
| **Language**   * Orally discuss data * Interpret pictorial data and record as written data analysis * Write a CER paragraph | | | |

**Learning Goals**

This learning task explores the embryological and anatomical data that can be used as evidence for common ancestry. More specifically, the purpose is to:

* Predict which pair of species is more closely related.
* Analyze embryological and anatomical evidence for patterns in data.
* Write a CER paragraph explaining how this data can be used to reconstruct evolutionary history.
* Use patterns from the data to explain two organisms that are not related but have similar functions.
* Apply knowledge of common ancestry to add to a mock fossil record.

**Content Background for Teachers**

There are many sources of evidence for evolution, but this unit focuses on the macroscopic rather than the molecular level. At the macroscopic level, we can analyze the anatomical structures as well as the embryological development of different species in order to draw conclusions about which species are closely related and which ones are not. This will help students complete their picture of how species have changed over time by looking at species that may have come from a common ancestor but evolved differently over time.

Students examine multiple sources of evidence comparing anatomical structures and embryological development. One of the most common examples of anatomical evidence is to look at the underlying bone structures that allow humans to throw, bats to fly, whales to swim, frogs to jump, and lizards to run. Students will recognize that even though all of these species use this appendage for very different functions, they will see a pattern of similarity in bone structure, including the number of bones and their relative position. All of these appendages have a single upper bone (Humerus) attached at a joint to two different bones (Radius and Ulna), which are then attached in the wrist area to the carpal bones and fingers. This implies that all these species descend from a distant common ancestor, but each has evolved over time due to specific environmental pressures. For other examples of anatomical evidence, please see the station cards provided to students in the Explore.

Sometimes relationships not evident in the fully-formed anatomy can be seen by comparing the embryological development of different species. Each species inherits its embryological development from its ancestors, so this would imply that species that are more closely related would have more similar embryos. Over time, natural selection modifies the embryos in different ways, causing the differences seen in related, but distinct species. The exception to this rule is vestigial structures that may remain from a common ancestor. For specific examples of embryological evidence, please see the station cards provided to students in the Explore.

**Academic Vocabulary**

* Embryological Development
* Anatomical structures
* Evolve
* Common Ancestor
* Evolutionary History
* Related

**Time Needed (Based on 45-Minute Periods)**

4 Days

* Engage: 0.5 period
* Explore: 1 period
* Explain: 1 period
* Elaborate: 0.5 period
* Evaluate and Reflection: 1 period

**Materials**

* Unit 3, Task 2 Student Version

Explore

* Station Cards, laminated or in sheet protectors (2 Per Station, preferably in color)

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 2: In the last task, you looked at one source of evidence for how species change over time—the fossil record. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   * Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.
2. Transition to Task 2: Scientists can also look at species today to help them understand its evolutionary history. Today you will look at two kinds of evidence that help scientists to identify which species have a common ancestor. This helps them continue to answer the question of how organisms have changed over time.
   * Now pass out their Task 2 student guide.
3. In pairs, have students look at the pairs of pictures on their student guides: a prawn and a wood louse, a dolphin and a shark. Using whatever prior knowledge they have of these species as well as what they observe in the pictures, students make a prediction about which species are more closely related. The purpose of this question is to engage whatever background knowledge students bring to this lesson. Students may be surprised by some of the comparisons.
4. There are no right answers, as these are only predictions. After students make their predictions, share out a few. The use of equity sticks is encouraged for more equitable participation (See “How To Use This Curriculum” for more details).

* Then tell students that prawns and wood lice are actually more closely related than sharks and dolphins, despite how similar dolphins and sharks look. This will lead them into the next section.

**Explore**

1. We recommend reading this introduction aloud with students as a transition and to set the context for this segment of the task: As you saw in the Engage, things are not always what they seem when it comes to evolution—or the change of living organisms over time. Even though species may look alike or seem similar, they may not actually be related. To figure out which species are actually related, scientists need to use other sources of evidence—embryological development and anatomical structures. The more similar these are between species, the more likely they evolved over time from a recent common ancestor. This allows scientists to reconstruct evolutionary history.
2. Set up 6 stations around the room with the station cards associated with this task. We recommend putting at least two copies of the station card at each station, laminated or in sheet protectors. These station cards should also be in color as it is necessary for a few of the stations. Another option is to set up an iPad or computer at each station depicting a PDF of that station card in color.
   * Optional: To spread students out at more stations, you can set up duplicates of each station.
3. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Reporter, Harmonizer.
   * Ask Facilitator to read the directions and to make sure everyone understands the task and what the directions are asking.
   * Ask the Materials Manager to be responsible for the materials needed to complete the task, by reading information/questions from the station cards aloud.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Reporter to make sure everyone is recording their data.
4. In groups, students visit the stations around the room, analyzing different pieces of embryological and anatomical evidence. We recommend you encourage them to use the guiding questions on the station cards to help them with their analysis.
   * Optional: Model how to analyze a station card as a whole group, so students understand the process. We recommend using Station 4, since this is the most complex resource.
   * Students should take notes in the data collection table, which will help them look for patterns in the data. This emphasizes the science and engineering practice of **Analyzing and Interpreting Data** and the crosscutting concept of **Patterns** as students analyze displays of pictorial data to identify patterns in data and then use these patterns to identify cause-and-effect relationships (common ancestor resulting in similarities in embryological and/or anatomical structures).
   * Optional: You may want students to split the third column into a T chart with “similarities” and “differences” on each side. This may guide their search for patterns in the data.
5. The students’ data table should be collected and assessed using a rubric at the end of this task. A sample data collection table is shown below:

|  |  |  |  |
| --- | --- | --- | --- |
| Station # | Embryological or Anatomical Evidence? | Use the images to identify patterns in the data: What similarities and differences are there? | What does this information tell you about how organisms are related? |
| *1* | *Embryological* | * *The organisms start to develop differently after Stage C.* * *The bat and mouse look the most similar in the later stages of development.* | *The bat and mouse are likely more closely related than the turtle and the bat or the turtle and the mouse.* |
| *2* | *Anatomical* | * *As you go back in time, the horse-like organisms have more bones in the front limb, which are smaller. This is a gradual process.* * *The Pilohippus is the first horse-like organism to not have the finger-like bones.* | *It is likely that all these organisms are related. The Hycracoterium is the oldest ancestor and over time, that species evolved into species with less toes and larger toes.* |
| *3* | *Embryological* | * *At this stage of development the fish and salamander seem the most similar and the chicken, rabbit, and human seem the most similar.* * *The rabbit and human seem to have the most similar features at this stage.* | *The rabbit and human are likely the most closely related by a common ancestor. The human and the fish are likely the most distantly related.* |
| *4* | *Anatomical* | * *Most of the bivalves have the same organs present.* * *The scallop and oyster both have a large central muscle in the middle, unlike the others that have them at the ends.* * *The mussel and ark clam are the only ones with attaching threads.* | *These are all likely related, but some seem more related than others. The scallop and oyster seem closely related, but more distantly related from the mussels and ark clams.* |
| *5* | *Anatomical* | * *All of these have the same types of bones (radius, ulna, humerus, wrist bones, finger bones) connected in the same way.* * *The bones are different sizes.* | *This implies that all of these organisms are related, even though they use these appendages differently.* |
| *6* | *Embryological* | * *Major differences don’t seem to start until the third row.* * *The amphibian seems the most different in shape.* * *Monkey and human are most similar in latest stage of development.* | *The monkey and human are likely the closest related, and the amphibian is the most distant.* |

**Explain**

1. Using the evidence they have collected in the stations, students will now individually write a paragraph to answer the following question: What do similarities and differences in anatomical structures and embryological development tell us about the relationships between organisms?
   * This asks students to use the science and engineering practice of **Constructing Explanations** as they apply scientific ideas about anatomical structures and embryology to explain the inference of evolutionary relationships**.**

* Optional scaffold: Model the process by collectively constructing a claim together as a class and identify one example of evidence that can be used to back up that claim.

Optional Sentence Stems to Provide:

|  |  |
| --- | --- |
| **Claim** | Analyzing anatomical structures and embryological development of different organisms can tell us… |
| **What is the evidence and how does it support your claim?** | In the stations showing embryological data…  In the stations showing anatomical evidence…  For example, in station….  This is because…  This means that… |

Sample Paragraph

|  |  |
| --- | --- |
| **Claim** | Analyzing the anatomical structures and embryological development of different organisms can tell us which organisms are more closely related and which are more distantly related. |
| **What is the evidence and how does it support your claim?** | In the stations showing embryological data, the embryos that looked more similar at later stages in development were from more closely related organisms. For example, in station 6, the monkey and human embryos looked much more similar than the human and amphibian embryos in the late fetal stage. This means that humans and monkeys have a more recent common ancestor. In the stations showing anatomical evidence, having structures in common implies organisms are related. For example, in station 5, all 4 organisms had the same bones joined in the same way. Even though they have different functions, these organisms are related. |

1. Optional peer review: Have table partners switch CER reports and make suggestions for revisions.

* This should be collected and assessed using a rubric at the end of this task.

**Elaborate**

1. So far, students have looked at a lot of evidence showing organisms that are related. Here students use the knowledge they have gained to confront an opposite situation. Bats and butterflies are not related by a common ancestor, and yet both are able to fly.
2. In pairs, students think about this scenario with a partner and discuss the questions that follow.

* The first question asks them to use patterns from their data to think about what the opposite might look like. How would the embryological development and anatomical structures of bats and butterflies look if they are *not* related? Most students will write that the structures will look very different anatomically and in the embryos.
* The second question asks them to propose a possible reason why they still have a similarity in function even though they are not related. Answers will vary, but students should use their prior knowledge to think about how environmental pressures may have led to both of these species evolving to have the trait of flight.

1. Optional: Share out a few responses to the questions class-wide and engage in some debate about why students made their various predictions. Again, the use of equity sticks is encouraged.
2. Return to the whole-class concept map from the Lift-Off Task.

* In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).
  + Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
  + Draw circles around each question and boxes around each concept.
  + Write connector words to describe connections between the concept boxes.
  + For this task, students may begin to connect some of their previous question circles to concept boxes about the following: evolutionary relationships between organisms, anatomical structural evidence, and embryological evidence.
* Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concepts as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
  + **Patterns**: These could be phrases such as, “has in common with” “shares,” “is also shown in,” “is the same as,” “looks the same as,” etc.
* Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content but will also help their oral and written language development.

**Evaluate: Connecting to the Culminating Project**

1. Students independently complete the Task 2 section of the Unit Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
2. Students have been tasked with arguing whether humans should intervene on the behalf of threatened or endangered species or let nature take its course. Their prompt is as follows: Look back at the fossil record you created after Task 1.
   * Draw in a pretend common ancestor at the beginning of your fossil record and a pretend modern species also related to this common ancestor.

* What similar anatomy or embryological development might your organism have with this related species?

**Reflection**

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

* At the beginning of this task, you were asked to guess which pair of organisms is more closely related. Look back at your prediction: after collecting all the evidence today, how would you change your prediction or add to your reasoning? Use evidence from the task to justify your response and record below.
* In this task, we focused on the crosscutting concept of:
  + **Patterns:** Patterns can be used to identify cause-and-effect relationships and/or graphs, charts, and images can be used to identify patterns.

Where did you see examples of **Patterns** in this task?

* Now that you have learned more about how scientists can identify how species may be related, what questions do you still have?

1. There are no right answers but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

**Assessment**

1. You may collect students’ Project Organizer and assess using:
   * *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   * This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.
2. You may also give students time to make revisions with one of the two options:

* Students may make changes to their Project Organizer according to your comments OR
* Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

1. Collect Task 2 Student Version and assess the *Explore* and *Explain* using:

* 3-Dimensional Task 2 Rubrics, below

**Overview**: The following rubrics can be used to assess the relevant Performance Expectations for Task 2. Each rubric is aligned to the Explore or Explain sections of this task. \*If student provides no assessable evidence (e.g., “I don’t know” or leaves answer blank), then that student response cannot be evaluated using the rubric and should be scored as a zero.

Below we provide an alignment table that details the dimensions assessed for each criterion.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Part of Task to Assess** | **Disciplinary Core Idea** | **Science and Engineering Practice** | **Crosscutting Concept** |
| 1 | **Explore**: Data Table, Station 1 and Station 5   * Use the images to identify patterns in the data: What similarities and differences are there? * What does this information tell you about how species are related? | **LS4.A: Evidence of Common Ancestry and Diversity**   * Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. | **Analyzing and Interpreting Data**   * Analyze displays of data to identify linear and nonlinear relationships. | **Patterns**   * Graphs, charts, and images can be used to identify patterns in data. |
| 2 | **Explain**: Individually write a paragraph to answer the following question: What do similarities and differences in anatomical structures and embryological development tell us about the relationships between organisms? Use evidence from the stations to help support your explanation. | **LS4.A: Evidence of Common Ancestry and Diversity**   * Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. | **Constructing Explanations**   * Apply scientific ideas to construct an explanation for real world phenomenon, examples, or events. | **Patterns**  Patterns can be used to identify cause-and-effect relationships. |

**Task 2 Rubric 1**: Student writes analysis of pictorial data of embryological development and anatomical structures across multiple species and uses patterns in the data to identify relationships.

* Dimensions Assessed: DCI – LS4.A. Evidence of Common Ancestry and Diversity; CCC – Patterns, SEP – Analyzing and Interpreting Data

|  |  |  |  |
| --- | --- | --- | --- |
| **Emerging (1)** | **Developing (2)** | **Approaching – Proficient (3)** | **Advanced (4)** |
| Student writes **inaccurate** analysis of pictorial data of embryological development and/or anatomical structures across multiple species, and **inaccurately** identifies relationships. | Student writes **relevant** analysis of pictorial data of embryological development and anatomical structures across multiple species, but **does not use** patterns in the data to **accurately** identify relationships. | Student writes **relevant** analysis of pictorial data of embryological development **OR** anatomical structures across multiple species and uses **relevant** patterns in the data to **accurately** identify relationships. | Student writes **relevant** analysis of pictorial data of embryological development and anatomical structures across multiple species and uses **relevant** patterns in the data to **accurately** identify relationships. |
| **Look Fors:**   * In column 3 of their data table, student’s analysis is inaccurate. For example, in station 5, a student may write, “All of these organisms have different bones.” * In column 4 of their data table, student identifies an inaccurate relationship between organisms, either not related to patterns or related to inaccurate patterns. For example, in station 5, “All these organisms are different and not related.” | **Look Fors:**   * In column 3 of their data table, student’s analysis notes observations of the data, but does not identify patterns. For example, in station 1, a student may write, “The turtle embryo has a curved shape.” * In column 4 of their data table, student identifies an accurate relationship between organisms, but it is not related to a pattern, which they should have noted in column 3. For example, in station 1, “The bat and mouse are likely more closely related than the turtle and the bat or the turtle and the mouse.” This may be true, but is not backed up by a pattern in the data. * This may be done with one or both of the Station rows being assessed. | **Look Fors:**   * In column 3 of their data table, student’s analysis notes relevant patterns of similarity and/or differences between organisms. For example, in station 5, a student may write, “All of these organisms have the same types of bones connected in the same way (ulna, radius, humerus, wrist bones, and finger bones.” * In column 4 of their data table, student identifies an accurate relationship between organisms that is related to a pattern they noted (see previous bullet). For example, in station 5, “This implies that all of these organisms are related, even though they might use these appendages differently.” * Unlike an Advanced response, this would only be done for either embryological (Station 1) or anatomical (Station 5) evidence, but not both. | **Look Fors:**   * In column 3 of their data table, student’s analysis notes relevant patterns of similarity and/or differences between organisms. For example, in station 1, a student may write, “All organisms start to develop differences after Stage C. The bat and mouse look most similar at later stages of development.” * In column 4 of their data table, student identifies an accurate relationship between organisms that is related to a pattern they noted (see previous bullet). For example, in station 1, “The bat and mouse are likely more closely related than the turtle and the bat or the turtle and the mouse.” |

**Task 2 Rubric 2**: Student writes a claim explaining how similarities and differences in anatomical structures and embryological development help us infer evolutionary relationships, using patterns in data to explain these relationships.

* Dimensions Assessed: DCI – LS4.A. Evidence of Common Ancestry and Diversity; CCC – Patterns, SEP – Constructing Explanations Using Evidence

|  |  |  |  |
| --- | --- | --- | --- |
| **Emerging (1)** | **Developing (2)** | **Approaching – Proficient (3)** | **Advanced (4)** |
| Student writes an **inaccurate** claim explaining how similarities and differences in anatomical structures and embryological development help us infer evolutionary relationships. | Student writes an **accurate** claim explaining how similarities and differences in anatomical structures and embryological development help us infer evolutionary relationships, using **no** patterns in data to explain these relationships. | Student writes an accurate claim explaining how similarities and differences in anatomical structures and embryological development help us infer evolutionary relationships, using **multiple patterns in data** to **generally** explain these relationships. | Student writes an accurate claim explaining how similarities and differences in anatomical structures and embryological development help us infer evolutionary relationships, using multiple patterns in data to **explicitly** explain these relationships. |
| **Look Fors:**   * Student claim is inaccurate. For example, “Similarities and differences in anatomical structures and embryological development tell us that organisms are part of the same species.” * Any evidence that is given will not match the claim. | **Look Fors:**   * Student claim is accurate, referencing how these can serve as evidence of evolutionary relationships. For an example, see first bullet in Advanced Look-Fors. * Student states general rules, but does not cite evidence. For example, “Embryos that look more similar at later stages in development are from more closely related organisms. Also, having anatomical structures in common implies organisms are related.” | **Look Fors:**   * Student claim is accurate, referencing how these can serve as evidence of evolutionary relationships. For an example, see first bullet in Advanced Look-Fors. * Student uses multiple patterns in data from the station cards. For example, “In station 5, all 4 organisms had the same bones joined in the same way.” Students would cite at least one more source of evidence, at least one for embryological. * Student then makes a general connection between the data and the claim. For example, “the more similar structures or embryos are, the more closely related they are.” | **Look Fors:**   * Student claim is accurate, referencing how these can serve as evidence of evolutionary relationships. For example, “Analyzing the anatomical structures and embryological development of different organisms can tell us which organisms are more closely related and which are more distantly related.” * Student uses multiple patterns in data from the station cards. For example, “In station 6, the monkey and human embryos looked much more similar than the human and amphibian embryos in the late fetal stage.” * Student then explicitly connects evidence to the claim. For example, “This means that humans and monkeys have a more recent common ancestor.” * Students should do this for at least one more source of evidence, and at least one should be anatomical evidence. |