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| **Phylogenetics and Arthropod Diversity****Graduate Partnership in STEM Education****Background:** Arthropods, especially insects, are the most diverse and speciose group of animals in the world, and they display a range of morphologies, behaviors, and life styles. The higher-level phylogeny of arthropods is also well-established, with strong scientific consensus down to the order level in most cases; thus, there is a “correct” phylogeny to compare against. The purpose of the activity is to formalize knowledge of arthropod diversity, and use that knowledge to practice building a phylogeny by putting concepts about evolution into action.  |
| Learning Objective(s): **AZ DOE---Grades 6-8, Core Ideas for Knowing Science, Life Sciences:** L4: The unity and diversity of organisms, living and extinct, is the result of evolution.\* **CORE IDEA LS4—“Natural Selection and Adaptations”**LS4-2: “Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms … to infer evolutionary relationships.” \*\*1. Evolutionary history can be studied through the construction of phylogenies, i.e. representations of the branching patterns of descent of organisms through evolutionary time
2. One strategy for the construction of phylogenies is the identification, codification, and analysis of morphological and life history traits
3. Certain traits may be more useful as proxies of shared lineage than others
4. Different forms of data (morphology, genetics) can yield different results; incorporating different sources of information can lead to more robust results

 \*From: https://cms.azed.gov/home/GetDocumentFile?id=5bd338b81dcb250184c8cefc \*\*From: https://www.nextgenscience.org/topic-arrangement/msnatural-selection-and-adaptations  |
| Materials:1. (Optional) Drawer of real pinned specimens corresponding to plastic insects (for comparison / real life context)
2. Assortment of plastic arthropod toys
	1. Insects
		1. Two Diptera: mosquito (life cycle set), house fly
		2. Two Hymenoptera: ant (life cycle set), bee
		3. Two beetles: ladybug (life cycle set), other
		4. One butterfly
		5. One grasshopper
		6. One dragonfly
	2. One crab
	3. Chelicerates
		1. One scorpion
		2. One tarantula
	4. Myriapods
		1. One centipede
		2. One millipede
3. Laminate sheets with photographs corresponding to toys
4. Blank character matrices
5. Pencils/pens
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| 10 min. | **Engage**1. (Optional) Start by showing a video: <https://www.youtube.com/watch?v=rFxu7NEoKC8>, introducing concepts:
	1. Persistence of characters through descent
	2. Genetic basis of phenotypic traits
	3. Shared traits between closely related groups (e.g. between humans and other apes)
2. Ask for questions about the video, specifically if students understand the meaning of “closely related” in an evolutionary context
3. Go through accompanying PowerPoint, with two parts:
	1. Explanation of phylogenies and phylogenetic trees, introducing the idea that a phylogenetic tree represents relationships (like a genealogical tree, but on a much larger scale)
	2. Introduction to basics of arthropod diversity, specifically describing the body based on tagma, number and kinds of legs, mouthparts, and presence/number of wings

Modification: * Based on students’ familiarity with evolution and/or arthropods at this point, you may choose to simplify the activity by removing extra representatives of major groups, particularly taxonomically redundant insects
* Two major adaptations: using only insects, or using only one or two representatives of each of the four major groups (insects, non-hexapod crustaceans, myriapods, chelicerates)
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|  20 min | **Explore**1. Stations with different arthropods will be set up: plastic toy accompanied by photograph fully illustrating relevant traits (plastic representatives may be more appealing, photographs compensate for loss of anatomical detail in toys)
2. Each student given a blank character matrix after brief explanation of how character matrices are/have been used to construct a phylogeny
3. Students asked to fill out the character matrix by
	1. Identifying traits which are present across most or all of the taxa, but which vary between them (e.g. presence/absence of wings)
	2. Evaluate individuals for each trait and record character state
	3. Encourage students to think about objective/quantifiable (presence/absence, number) and more subjective (color) traits

Note: historically, character matrices have been made to be binary (i.e. “wings present” – 1 for presence, 0 for absence); it may be easier and more workable for middle schoolers to instead approach it qualitatively (i.e. “wings” – with notes for presence/absence, as well as number)  |
| 15 min | **Explain**1. Gather class back together and go through their results
2. Recreate a character matrix chart on a white board / chalk board, and ask students for input on
	1. Which traits they identified
	2. The character states of each trait for each organism
3. Using these traits, ask the class as a group to build a phylogenetic tree of the organisms they evaluated (you, the instructor, draw it on the board)
	1. Ask students to identify why they believe certain organisms are closely related to each other
	2. If they’re struggling to identify meaningful similarities, suggest clues towards established relationships (e.g. “what kind of mouthparts did you see on the scorpion and tarantula, vs. the other organisms” / “do you think number of legs is an important difference between these groups?”)
4. After a phylogeny has been established among the class, continue with the PowerPoint to the simplified consensus phylogeny among extant groups of arthropods
5. Compare the two phylogenies and identify places where they match up and diverge
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| 10 min | **Expand**1. Following on the final point of the “Explain” section, introduce another consensus phylogeny: one based on morphological evidence, from before the widespread use of genetics in phylogenetic constructions
2. Identify if there may be similarities between the class phylogeny and the older consensus phylogeny, vs. the modern consensus phylogeny
	1. E.g. one probable difference between the class and modern consensus is the placement of Crustacea (represented by a crab)
	2. Discuss how the differences between the two consensus phylogenies are attributable to new techniques, and how different data sources can impact outcomes
3. Ask students what other kinds of information they might use to construct a phylogeny (e.g. behavioral observations, embryological morphology, etc.)
	1. Relevant to educational standards: the absence of fossil or prehistoric specimens from our exercise
	2. If they mention specimens, ask if they think there are many fossilized arthropods (there aren’t), and why that might be (i.e. what kinds of tissues fossilize easiest, how might that bias our knowledge about organisms in the past)
4. Ask students what problems they think there might be in constructing phylogenies, i.e. how might historical reality be more complicated than represented in a branching diagram
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| 5 min | **Evaluate** 1. After the activity, ask students to ask questions and then write for 5 min what they learned from the activity and what they enjoyed the most/least and why, followed by a paired or group-share.
2. Go over the papers to detect any potential misconceptions that can be addressed on the spot before the lesson is over while they share their thoughts in pairs or groups.

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Lesson created by Charles Wallace