Title: “The Origin and Diversity of Armor in Girdled Lizards: A Case Study in Convergent Evolution”

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Abstract:

The girdled lizards (Cordylidae) are a family of distinctively armored lizards endemic to Sub-Saharan Africa. Students examine lizards in this family to classify the lizards based on morphological characteristics. Students graph data on the percentage of osteoderm coverage in each lizard group and discover that natural selection due to predation has resulted in lightly armored lizards living in large rocks and more heavily armored lizards living in open areas. Students then compare their morphological classification to phylogenetic trees created from DNA analysis and discover that convergent evolution is responsible for differences in ostederm coverage within the Cordylidae family and in the animal kingdom.

Subject, Grade, Level:

This activity is targeted for AP Biology.

Learning Objectives:

By the end of this activity, students will be able to:

1. Explain why molecular data provide more accurate and reliable evidence than morphological traits when constructing phylogentic trees.
2. Differentiate between convergent and divergent evolution.

Science Standards:

- **EVO-1 Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.**
    - EVO-1.D Explain how natural selection affects populations.
    - EVO-1.D.1 Evolutionary fitness is measured by reproductive success.
    - EVO-1.D.2 Biotic and abiotic environments can be more or less stable/fluctuating, and this affects the rate and direction of evolution; different genetic variations can be selected in each generation.
    - EVO-1.E Describe the importance of phenotypic variation in a population.
    - EVO-1.E.1 Natural selection acts on phenotypic variations in populations.
    - EVO-1.E.2 Environments change and apply selective pressures to populations.
    - EVO-1.E.3 Some phenotypic variations significantly increase or decrease fitness of the organism in particular environments.
    - EVO-1.GExplain the relationship between changes in the environment and evolutionary changes in the population.
    - EVO-1.G.1
    - Convergent evolution occurs when similar selective pressures result in similar phenotypic adaptations in different populations or species.

- **EVO-3 Life continues to evolve within a changing environment.**
    - EVO-3.B Describe the types of evidence that can be used to infer an evolutionary relationship.
    - EVO-3.B.1 Phylogenetic trees and cladograms show evolutionary relationships among lineages—
    - Phylogenetic trees and cladograms both show relationships between lineages, but phylogenetic trees show the amount of change over time calibrated by fossils or a molecular clock.
    - Traits that are either gained or lost during evolution can be used to construct phylogenetic trees and cladograms—
    - Shared characters are present in more than one lineage.
    - Shared, derived characters indicate common ancestry and are informative for the construction of phylogenetic trees and cladograms.
    - The out-group represents the lineage that is least closely related to the remainder of the organisms in the phylogenetic tree or cladogram.
    - Molecular data typically provide more accurate and reliable evidence than morphological traits in the construction of phylogenetic trees or cladograms.
    - EVO-3.C Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.
    - EVO-3.C.1 Phylogenetic trees and cladograms can be used to illustrate speciation that has occurred. The nodes on a tree represent the most recent common ancestor of any two groups or lineages.
    - EVO-3.C.2 Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species and from DNA and protein sequence similarities.
    - EVO-3.C.3 Phylogenetic trees and cladograms represent hypotheses and are constantly being revised, based on evidence.

Timeframe:
4 class periods (50-minute periods)

List of materials:

- Day 1
  Lizard Picture Cards
  Access to computers (SketchFab)
- Day 2
  Osteoderm % Coverage Data and graph paper
  Access to computers (to research lizard habitats)
- Day 3
  Worksheet with Ed's graph
- Day 4
  Access to computers (to research other animals with osteoderms)

Procedure and general instructions (for instructor):

Day 1 – Introduction and Characterization Using Morphological Characteristics

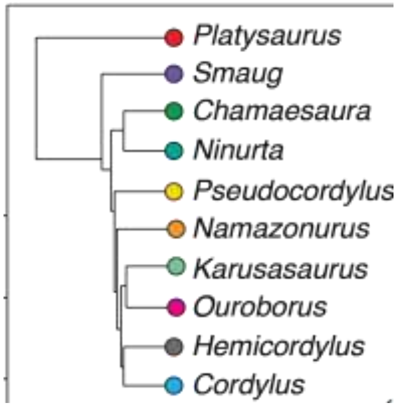
- Introduction ***10 minutes***: Lizard Defenses Warm-Up and Review of Classification System
- Part I – Lizard Picture Sorting (15 minute)
    - Students work in groups of 2-3 to divide photographs of the lizards into closely related groups (may tell them they are all part of the same family but different genera)
    - Class Discussion – Observations about differences among lizards and difficulties of grouping
- Part II – Introduction to CT scanning and the oVert project/value of museum collections (10 minute)
    - Discussion about the oVert project and its goal of creating CT scans of 20,000 vertebrates with representation from most genera.
        - Sources of information: https://www.sciencemag.org/news/2017/08/new-3d-scanning-campaign-will-reveal-20000-animals-stunning-detail
        - https://www.floridamuseum.ufl.edu/science/overt/
- Part III - Students continue to work in groups and look up the lizards on sketchfab to confirm or re-group their lizards based on internal characteristics (skeleton, amount of osteoderms) (15 minutes)
    - Class Discussion – Observations about differences among lizards and difficulties of grouping

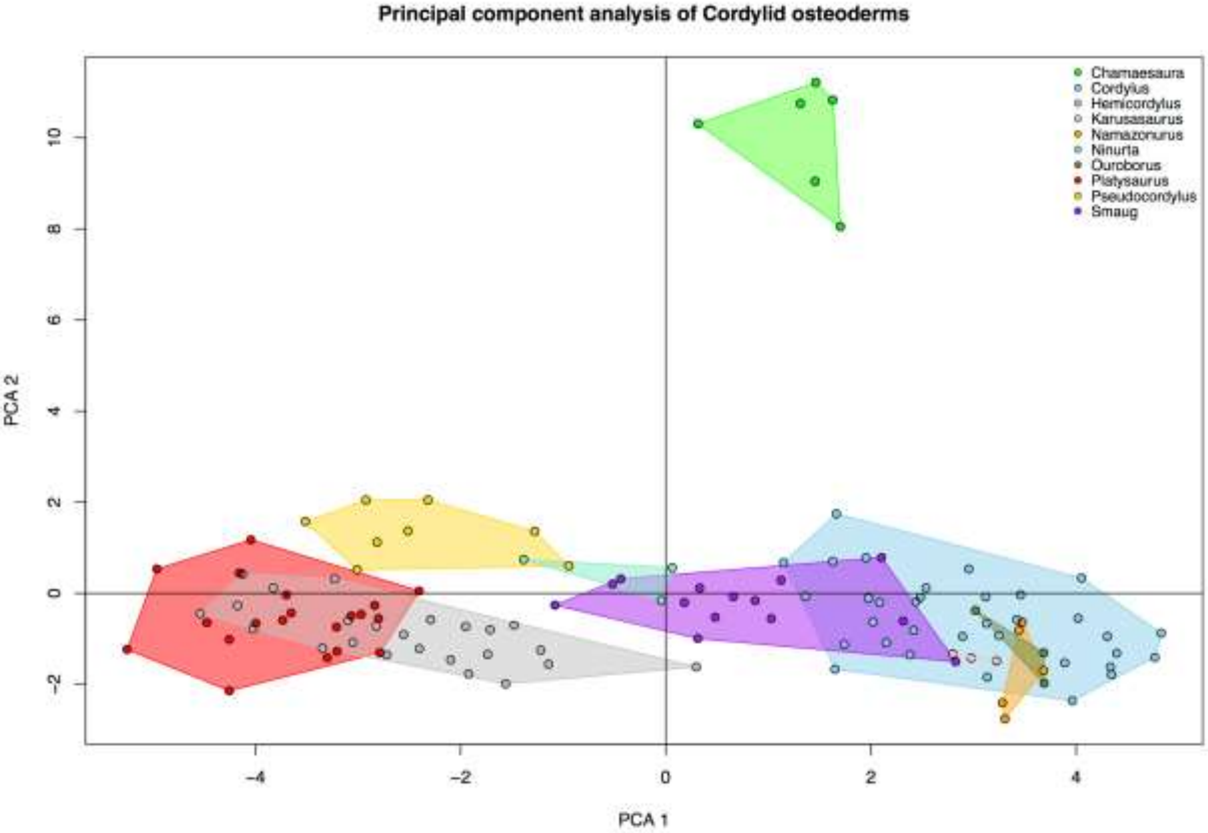
Day 2 – Correlating Osteoderms with Habitat – Natural Selection in Action

- Warm-up – Basic Natural Selection Questions Review (5 minute)
- Part 1 - Give students data set of osteoderm % coverage by species – students graph data and determine trends/statistical significance.
- Part II Students then research where each type of lizard lives and color code their graph according to habitat (large rocks vs. small rocks). Students also watch two you tube videos of each type of lizard in action. Students hypothesize as to why the armored lizards live in the open/small rocks habitat and the lightly armored lizards live in large rock habitats. Students then see if their graph/new information supports their conclusions on groupings from day 1

Day 3 – Interpreting Lizard Phylogenetic Trees/Convergent Evolution - Osteoderms in Other Species

- Warm- Up – Review of homologous vs. analogous structures (maybe using sketchfab images)
- Part 1 - Students are given Ed's graph and challenged to interpret what it means and examine any trends. Then through a series of guided questions students that challenge students to relate the phylogenetic tree to the graph students will realize that lizards that have a similar % body coverage of osteoderms (and live in the same habitat) are not necessarily each other's closest relatives according to DNA analysis. Students will then answer a series of guided questions on convergent evolution.
- Part II- Students are given data on additional lizards (not in the data set – including a newly discovered species of lizard!) and challenged to place it on Ed's graph.

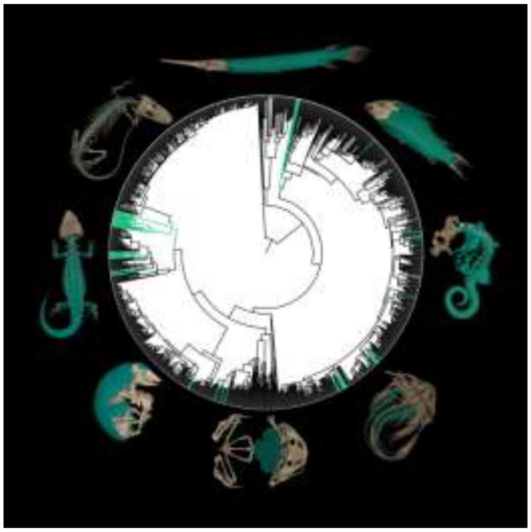




Day 4 – Other Species with Osteoderms and Lizard Conservation

- Warm-Up – Phylognetic Tree Practice with Lizards (from Ed's paper ***Here be dragons: a phylogenetic and biogeographical study of the Smaug warreni species complex (Squamata: Cordylidae) in southern Africa)***
- Part I- Other Species with osteoderms (30 minutes)

    - Students work in groups of 2-3 and do a quick research on another organism with osteoderms and share out basic info about the organism and why osteoderms are an adaption for that species. Students answer questions about a phylogenetic tree that includes all of the other species with osteoderms.



- Part II – Lizard Conservation (20 minutes)
    - Students will watch a video of lizards and the pet trade Saving Our Dragons
    - NPR For Lizards, Climate Change Is A Deadly — And Complex — Threat https://www.npr.org/sections/thetwo-way/2016/09/05/492713407/for-lizards-climate-change-is-a-deadly-and-complex-threat
    - Scientific American - Warming Threatens Reptiles More Than Birds and Mammals https://www.scientificamerican.com/article/warming-threatens-reptiles-more-than-birds-and-mammals/

    Homework: Article with questions relating climate change to natural selection.

Procedure and general instructions (for students):

- [Provide a student version of the instructions if applicable. Include any student handouts here.]

Suggestions and materials for assessing student learning

- Firefly FRQ from 2015

Reference list

Student assignments related to the activity

Any other appendices appropriate for your particular activity