**Title:**Learning Taxonomy and Evolution through Opensource Databases.

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**Abstract:**The Inquiry-based learning tools presented here uses the OneZoom Tree of Life (OneZoom) platform as an easy-to-use teaching tool that allows student to access curated data sources such as the National Center for Biological Inventory (NCBI), the Global Biodiversity Information Facility (GBIF), and Open Tree of Life (OToL). Through these data-platforms students learn that multiple approaches are used in data collection when conducting studies in taxonomy. In short, students learn the science used to build the tree of life presented in OneZoom. All activities provided in this exercise are based on a family of Digenetic trematodes known as zombie snail parasites. These parasites have a complex life cycle with terrestrial snails and songbirds as obligate hosts. Videos showing how the parasites induce ‘mind control’ of snails to entice songbird predators helps to engage students in sleuthing the taxonomy of these poorly studied animals. In addition, this group is ideal for instructors interested in showing that many lineages still have major data gaps on taxonomy, distributions, ecological interactions, and evolutionary relationships. These exercises can be used in series throughout a semester in their current form or modified to meet learning objectives set by the instructor. This approach allows project-based learning of systematics in a general evolution or diversity (lower or upper level) course in synchronous or asynchronous learning environments.

**Learning objectives:**These inquiry-driven exercises are designed for students to understand the scientific process of taxonomy used to describe the diversity of life. Specifically, students will understand the concepts and definitions of taxonomic classification, distributions, species interactions, and phylogenies. Detailed exercises are provided to guide students through the collection and interpretation of data available through curated, open-source databases linked to OneZoom. Based on this approach, students will understand that the visualization of the tree of life elegantly displayed on OneZoom is built from the integration of data-driven science.

**Timeframe:**Instructor Preparation: There is minimal preparation for the instructor if worksheets are used as presented or modified to focus on other taxa.

**Notes-**

Supplementary exercise I is not intended as a resource for the semester project but can serve as an introduction to scrolling and using resources on the OneZoom Tree of Life website.

Worksheets provided are focused on understanding taxonomy, distributions, and co-evolutionary timelines among the parasitic worms and their snail/bird hosts based on curated databases of taxonomy, distributions, ecological interactions, and phylogenies. Worksheets begin with definitions before moving into instructions on database navigation. Questions are given throughout the worksheets to evaluate student comprehension. Worksheets provided are instructor copies including screenshots and answers to questions.

**List of materials:**Open-source integrative resources students will use. All links are easily accessible on OneZoom. Links to data sources embedded within primary resources below are provided in exercises, as needed.

1. [OneZoom Tree of Life Explorer](https://www.onezoom.org/)
2. [National Center for Biotechnology Information (nih.gov)](https://www.ncbi.nlm.nih.gov/)
3. [Integrated Taxonomic Information System (itis.gov)](https://www.itis.gov/)
4. [GBIF](https://www.gbif.org/)

**Procedure and general instructions (for instructor).**  
All exercises are provided to students and include screenshots as aids to complete activities. Student learning outcomes are provided for each exercise.

Supplementary exercise: Introduction to the Tree of Life.

*General notes*: This exercise is strongly recommended for an introductory course and can be modified to show relationships of lineages throughout the course. For an upper-level biodiversity or evolution course, this exercise can be used at the beginning of the semester as a refresher exercise in core concepts.

*Student learning outcome:* Students will demonstrate proficiency at using navigating tools available in OneZoom that provide an overview on basic taxonomy, cladograms, and evolutionary relationships.

*Assessment. No formal assessment- class discussions on answers is recommended.*

*Time Required* - ~30- 45 minutes; in-class, synchronous learning. ~ 30 minutes as homework.

*Acceptable Platforms*: mobile device, tablet, computer

Document 1: Zombie Snail Parasites- Taxonomy overview

*General notes*: This exercise replicates the supplementary exercise; however, this exercise begins a multi-part, inquiry-based set of worksheets that focus on taxonomy and evolution.

Resources:

1. Starting video: [Zombie Snails | World's Deadliest (youtube.com)](https://www.youtube.com/watch?v=Go_LIz7kTok&t=5s)
2. [OneZoom Tree of Life Explorer](https://www.onezoom.org/)

*Student learning outcome:* Students will demonstrate proficiency at using navigating tools available in OneZoom that provide an overview on basic taxonomy, cladograms, and evolutionary relationships through completing Part 1 – Linnaean classifications and Part 2- the need for precision in naming organisms.

*Assessment. No formal assessment- class discussions on answers is recommended.*

*Time Required* - ~ 1 hour; in-class, synchronous learning or as homework.

*Acceptable Platforms*: mobile device (phones), tablet, computer

Document 2: Zombie snail parasites. The science of Taxonomy

*General notes*: Although this exercise includes only information for the parasites; but instructions can be repeated for each host.

Resources:

1. [OneZoom Tree of Life Explorer](https://www.onezoom.org/)
2. Links accessed through OneZoom/Genetics will lead to these sites- but specific sites are provided below.
   1. [National Center for Biotechnology Information (nih.gov)](https://www.ncbi.nlm.nih.gov/)
      1. [Taxonomy browser (root) (nih.gov)](https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi)
         1. [Integrated Taxonomic Information System (itis.gov)](https://www.itis.gov/)
            1. [COL | The Catalogue of Life](https://www.catalogueoflife.org/)

*Student learning outcome:* Students will understand the significance of taxonomy in communicating information about an organism. Specifically, students will understand the importance of selecting relevant data sources (Part 1), the importance of taxonomists (Part 2) are ones accepted by the scientific community (Part 3).

*Time Required* – variable. Recommended as a homework assignment. Assignment should be graded to understand patterns in knowledge gaps, if any, before proceeding to a class discussion or additional activities that require using multiple web-based data sources.

*Assessment- None- but a discussion on the difficulty of identifying organisms with complex life cycles, such as flatworms, lead to discrepancies in taxonomy across databases due to unclassified species. These class discussions often yield the ‘aha’ moments in learning that the understanding of taxonomy in the tree of life is constantly evolving as more data is assembled by researchers.*

*Acceptable Platforms*: Mobile Device (phones), Tablet or computer.

Document 3: Zombie snail parasites. Parasite Host interactions

*General notes*: This exercise requires students to research all species involved in the lifecycle of the parasite. The exercise is divided into two parts. In part I, students will describe the lifecycle of the parasite. In part 2, students will compare distributions of these species and in part 3, students will describe the ecological interactions among these species. Again, reasons for data discrepancies for poorly studied organisms like parasitic worms and well-studied vertebrates will be observed.

1. [OneZoom Tree of Life Explorer](https://www.onezoom.org/)
2. [GBIF](https://www.gbif.org/)
3. Links accessed through OneZoom /Genetics will lead to these sites- but specific sites are provided below.
   1. [National Center for Biotechnology Information (nih.gov)](https://www.ncbi.nlm.nih.gov/)
      1. [Taxonomy browser (root) (nih.gov)](https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi)
         1. [Integrated Taxonomic Information System (itis.gov)](https://www.itis.gov/)
            1. [globalbioticinteractions.org](https://www.globalbioticinteractions.org/)

*Student learning outcome:* Students will understand how researchers report the localities of species. For co-evolving species, students can observe the overlap in species distributions and data gaps that often occur in poorly studied groups.

*Time Required* –Recommended as a homework assignment as some students may finish in 30 minutes and others 1 hour depending on familiarity with using databases. Assignment should be graded to understand patterns in knowledge gaps, if any, before proceeding to a class discussion or additional activities that require using multiple web-based data sources.

*Assessment- None- but a discussion on the difficulty of identifying organisms with complex life cycles; such as flatworms can lead to discrepancies in distributions. In addition, distributions of organisms included in curated (verified for accuracy based on scientific expertise) are limited by numbers of researchers that study the organisms. For species with few researchers, distribution data is far lower than for common, recognizable species.*

*Acceptable Platforms*: Mobile Devices (phones), Tablets, Computers

Document 4- Zombie snail parasites. Phylogenies

*General notes*: This exercise shows how genetic sequences from NCBI:GenBank are used to generate phylogenies displayed as cladograms. Also the link between GenBank and cladograms presented n OneZoom is shown. Here, students will continue to focus on the zombie snail parasite. However, the phylogenetic tree is generated by the instructor in MEGA or other software. A supplementary document for document 4 includes the sequences used in constructing a phylogenetic tree.

1. [OneZoom Tree of Life Explorer](https://www.onezoom.org/)
2. [National Center for Biotechnology Information (nih.gov)](https://www.ncbi.nlm.nih.gov/)
3. [GenBank Overview (nih.gov)](https://www.ncbi.nlm.nih.gov/genbank/)

*Student learning outcome:* Students will understand how genetic data can be accessed and analyzed by researchers to generate phylogenetic relationships.

*Time Required* – variable. Recommended as a homework assignment. Most students should complete the assignment in less than 1 hour. Assignment should be graded to understand patterns in knowledge gaps, if any, before proceeding to a class discussion or additional activities that require using multiple web-based data sources.

*Assessment- None- But a discussion on the importance on selecting meaningful data to include in analyses is helpful. Discussions of how the links between* OneZoom*, taxonomy browser, and GenBank sequences are used to understand the tree of life.*

*Acceptable Platforms*: Mobile Devices (phones), tablets, or computers.