

## Tree of Life Assignment

### MICROBIAL DIVERSITY

**DUE AT THE START OF CLASS (12:30pm) on TUESDAY, January 27, 2009**

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The goal of this assignment is fourfold: to introduce you to phylogenetic thinking; to introduce you to the concept of the tree of life; to help you see the structure and form of the tree; and to help you explore the interconnections among all of life, from microbes to macroscopic organisms.

To start this worksheet, please go online to the Tree of Life Web Project, a scientific and educational project coordinated by Dr. David Maddison in the Department of Entomology at the University of Arizona. You can access the Tree of Life Web Project here:

<http://tolweb.org>

Please note that some of the text on this worksheet, especially that in italics, is considered 'fair game' for Exam 1. You will get this worksheet back with comments from me; use it when you study for the first test. Don't worry about the relationship of organisms in section 2 and 3; these sections are just to help you learn how to navigate around the Tree of Life.

First, let's start with a few introductory thoughts. Then, you'll head off to explore the Tree of Life.

#### **SECTION 1. What is the Tree of Life?**

*Almost 150 years ago, Charles Darwin used the term 'tree of life' in landmark work, On the Origin of Species, to describe the evolutionary patterns that link all life on earth. The Tree viewed in much the same way today: the **Tree of Life is the vast evolutionary tree that links all living organisms.***

There are several *important concepts that are implied by the Tree of Life:*

- a. All species on Earth share a common ancestor.*
- b. All species on Earth are genetically related.*
- c. Different species arise from previous forms by descent.*
- d. Some lineages die out (go extinct), while others persist and diversify.*

Darwin said this eloquently, and with a degree of poetry rare in today's terse scientific writing:

"The affinities of all the beings ... sometimes [have] been represented by a great tree. The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species . . . The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was small, budding twigs.... From the first growth of the tree, many a limb and branch has decayed and dropped off, and these lost branches of various sizes may represent those whole orders, families, and genera ... which are known to us only from having been found in a fossil state.... As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all a feebler branch, so by generation I believe it has been with the **Tree of Life**, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications." Charles Darwin, 1859

How did this differ from previous views? *Until Darwin, life was generally thought to be organized like a ladder or 'chain of being,' with 'primitive' creatures at the bottom and humans at the top. First proposed by Aristotle and codified in Europe before in the 14<sup>th</sup> century (i.e., before the Renaissance), this view has been referred to as the **scala naturae** (ladder of nature). The **scala naturae implies that all living things are unchanging units that can be ordered from the simplest to the most complex.** Although persistent in western thinking, the **scala naturae** is no longer considered an appropriate model for the organization of life. We will explore this reasoning in the lecture portion of our course.*

The Tree of Life depicts the **phylogenetic relationships** among all of life on earth. Let's use the Tree of Life Web Project to explain what this means. Please follow these steps to do so:

- I. At the ToLWeb home page (tolweb.org), you will see a conceptualization of the tree in the center of the page. Below that, you'll see some text that starts with 'The Tree of Life Web Project (ToL) is a collaborative effort...'. In that paragraph, click on 'phylogeny'.
- II. You will be taken to a page that starts with the title 'What is phylogeny?'.

Answer the following based on the text on this page:

1. What is meant by 'the phylogeny of organisms'?
  - a. In the words from the website:
  - b. Paraphrased into your own words:
2. Where on the tree (trunk, branches, leaves) are the living species that we see today?
3. Look at figure 2. What do those shaded boxes at the branching points represent?
4. What kind of organism is thought to have been the shared ancestor of beetles and humans?
5. Is that exact creature – that common ancestor of beetles and humans –
  - a. still alive today
  - b. not still living, but instead, represented by its genes in the characteristics shared by humans and beetles?

(Choose one by circling A or B.)

6. About how many leaves are there on the great Tree of Life (estimated by scientists; wide range)?

**SECTION 2.** Now, let's go to the page for a single species. This is called a 'leaf' page in the ToL Web Project. Much like leaves on a living tree, leaves on the Tree of Life are connected to one another by the branches that bear them. In the ToL Web Project, leaf pages are connected by branch pages. Let's look at a nice leaf page for a cool organism: *Habronattus americanus*. *Habronattus* is a genus of jumping spiders, and the species *Habronattus americanus* is a colorful and elegant little spider. Check it out by following these steps:

- I. First, go back to the ToL home page (back button on your browser, by clicking 'home' on the left menu bar, or by entering *tolweb.org* as the URL).
- II. In the search window at the left side, type 'Habronattus americanus' (no quotes).
- III. You should see a page of search results, with the first one listed as *Habronattus americanus*. Click on this link.
- IV. You'll end up on the leaf page for this neat jumping spider.

Leaf pages typically contain pictures of the species, as well as some additional information about life history, evolutionary history, ecological attributes, and other things. The page for *Habronattus americanus* only has pictures, but those pictures tell us a lot. For example...

7. What is an obvious difference between male and female *H. americanus*?

Now, let's explore the evolutionary history and relationships of this leaf on the Tree of Life. At the top of the *H. americanus* page, click on 'Habronattus americanus group.' This is the group of organisms that includes *H. americanus*. You'll be taken to another page: one that shows the relationship of *H. americanus* to other, closely related species (that is, other species of *Habronattus* that are closely related). This is the 'Habronattus americanus group' branch page.

Look for *Habronattus americanus* on the tree. Do you see it? If you click on it, you'll go back to the leaf page for this species. If you click on any other species name in blue on the tree, you'll go to the leaf page for that species. For example, click on *Habronattus tuberculatus*, a species with elegant zebra stripes.

[If you have a fast computer, a good connection, and the ability to open Quicktime movies, scroll down and click on the picture under 'Courtship Behavior' for a treat. If you can't see the movie, let me know and I'll show it to you in class. The movie shows a male in a mating display for a female. Not bad for a spider that's less than one centimeter long!]

Click back and forth to check out the different spider species in the *Habronattus americanus* group.

8. Do you think it's easier to distinguish the different species of spiders in the *Habronattus americanus* group based on the appearance of (A) the males, or (B) the females?

9. Why?

**SECTION 3.** Now, let's explore the interrelatedness of all organisms. We'll start with a different leaf page – one for a species you know well (*Homo sapiens*).

- I. First, go back to the ToL home page (back button on your browser, by clicking 'home' on the left menu bar, or by entering *tolweb.org* as the URL).
- II. In the search window at the left side, type 'Homo sapiens' (no quotes).
- III. You should see a page of search results, with the first one listed as *Homo sapiens*. Click on this link.
- IV. You'll end up on the leaf page for this interesting species.

Let's work our way from the leaf page of our species. Click on the containing group (*Homo*, which is our genus). You'll be taken to a page that shows our species in blue, and four additional species of *Homo*.

10. What are the other species of *Homo*, besides *H. sapiens*?

11. What do the little crosses mean?

Now, click on the containing group (Hominidae, which is the family within which our genus is placed).

12. List one other genus that is also a member of the Hominidae, our family. What is the common name for that genus?

Now, click on the containing group (Catarrhini), and then on the containing group (Primates). You'll see lemurs, a squirrel monkey, and a vervet monkey, all representing the primates. Now, you can click on the containing group – or, to achieve the same goal (a step back in time to the next oldest ancestor we share with other organisms), click on the arrow at the lefthand side of the tree.

13. Where does this take you (what group of organisms is described on this page)?

Let's think about what's happening here. **With each click, we are going farther back in time, finding the ever-larger groups of organisms that shared a common ancestor.**

Keep clicking those containing groups or the arrow at the lefthand side of the tree on each page. You'll go through ever-larger groups of organisms (you can start over at *Homo sapiens* if you need to.).

Mammalia (mammals), which are a lineage of Therapsida (mammals and their extinct relatives).

Therapsida are a lineage of Synapsida (a larger group of mammals and extinct relatives).

Synapsida are a lineage of Amniota (mammals and reptiles, plus extinct relatives).

Amniota are a lineage of terrestrial vertebrates (things with backbones and digits, the Tetrapods), which are part of the Sarcopterygii (lobe-finned fishes and terrestrial vertebrates), which are part of the Gnathostomata (things with backbones and jaws), which are part of the Vertebrata (things with backbones), which are part of the Craniata (animals with skulls), which are part of the Chordata (the phylum of vertebrates), which are part of the Deuterostomia, which are part of the Bilateria, which are part of the Animals, which are a lineage of Eukaryotes...you get the idea. **Keep on clicking on those arrows at the base of the trees, or on the 'containing lineage' for each page, until you reach the Eukaryotes.**

**Now, we've navigated all the way from our own leaf page – the page for our species – to the tree that summarizes the relationships of one of the major domains of life (the Eukaryotes). Here, we've reached the point of the Tree of Life in which our lineage – the branch leading to humans, plants, fungi, protists, and all other eukaryotes – first split from the common ancestor of all life.**

If we click on the containing group, we find ourselves looking at the four domains of life: bacteria (here listed as Eubacteria, Archaea, Eukaryotes, and viruses). Wow.

14. Starting at this root page of the tree of life, click on taxa on the tree to follow the evolutionary history of a lineage as far as you can. Tell me the path that you follow here, listing the title of each page as you navigate from the base of the tree toward the tips. For example, I did the following:

Page: Life on Earth	Action: Clicked 'Archaea'
Page: Archaea	Action: Clicked 'Crenarchaeota'
Page: Crenarchaeota	Action: That was as far as I could go.

Tell me your pages and actions – how far can you get? Important note: Not every branch leads to a leaf page. Of course, all branches on the real Tree of Life will have leaves at the tips, but in the Tree of Life Web Project, we sometimes don't have the data in place yet to show a leaf page. Just go as far as you can from the root, and tell me where you end up, step by step. Along the way, look at the pictures, and read some of the text – learn about where you are on the Tree of Life.

**SECTION 4.** Now that you've explored the Tree of Life Web Project a little bit, surf around the tree. The neatest way to do this is to click on the 'Random Page' link on the lefthand menu (under browse); it's also usually visible on the righthand menu. Do this a few times.

15. Pick a page and navigate around using the taxa (in blue) or the containing groups/lefthand arrows. Stop on a page that you find interesting, and that includes some text about the organisms (scroll down). Tell me about the most interesting page you find.
  - A. Organisms represented on page (e.g., Terrestrial Vertebrates):
  - B. Containing group:
  - C. Interesting fact from the text at the bottom of the page:

You may note that there aren't very many leaf pages – or very detailed branch pages – for Archaea and Eubacteria. This reflects several factors:

- a. Many of the Archaea and Bacteria have only recently been discovered. Most scientists working on biodiversity have traditionally focused on larger organisms.
- b. Many of the Archaea and Bacteria are known only by their gene sequences, having never been cultured; thus, we may have never actually seen these organisms.
- c. We are still learning where many cultured organisms should be classified in the tree of life.

That's it! Add any further thoughts below, and turn in this entire worksheet on the due date.