Total Score: ___/50

Name _____
Section Number _____

Homework 2
Due April 17th at the beginning of lecture

Instructions:

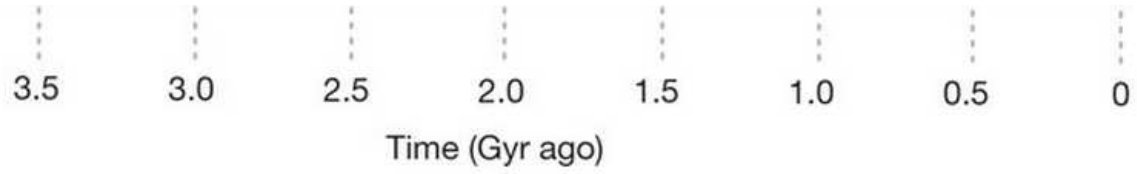
You are welcome to discuss concepts with your classmates but must compose your own answers. If you are unsure of the honor code for this course, please ask or look at the course website. http://www.its.caltech.edu/~bi1/Bi1__Micro-_to_Macro-Biology/Policies.html
The goal of this assignment is to help you understand a dense research paper. Many of the questions do not have a single correct answer. You will be given full credit as long as your answer is reasonable.
The answers must be legible and should not extend past the allotted space. Keep in mind that a few well-written sentences can give a higher score than a whole page of text.
Remember to write your full name on each page.

Part A:
The establishment of life on earth occurred roughly around 3.8 Gyr ago. Life has been constantly evolving since its emergence. A variety of biogeochemical factors have influenced the course of its diversification. Piecing together the history of life may provide details explaining how and why life is shaped the way we find it today.
In the paper, *Rapid evolutionary innovation during an Archaean genetic expansion*, the authors develop a phylogenomic method known as AnGST (analyzer of gene and species trees) to reconstruct the evolutionary history of 3,983 major gene families across the three domains of life onto a geological timeline.

Read the paper carefully and answer the following questions.
Read David and Alm (2011) Rapid evolutionary innovation during an Archaean genetic expansion. *Nature*. 469:93-96 carefully and answer the following questions.

1) In no more than 2 sentences and using your own words, what was the main finding of the paper? What's the broader perspective for this result? (4 points)

2) Draw a timeline like the one below and label the following periods or events: Archaean, Precambrian, Phanerozoic, Cambrian, Proterozoic, Archaean Expansion, and Great Oxidation Event. If any period is a subset of another, mention it in your answer. (6 points)



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3) The authors developed a program AnGST which compares gene and species trees to determine the phylogenetic history. (6 points)
a. What are the differences between a gene tree and a species tree? (2 sentences maximum)

b. Under what circumstances would the pattern on the gene tree match the species tree? (2 sentences maximum)

c. Define 2 evolutionary events that may result in observed differences between a gene tree and a species tree, and provide an example for how each evolutionary event can occur or where it occurs in nature. (4 sentences maximum)

4) What do the authors hypothesize were the evolutionary factors for the sudden increase in gene birth during the Archaean Expansion? What evidence do the authors provide to support their hypothesis? What evidence do they provide against it? (5 points) (4 sentences maximum)

5) Where do you think life existed during the time of the Archaean Expansion and for some time afterward? What evidence does the paper provide to support your guess? (3 points) (3 sentences maximum)

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6) Refer to Figure 2 to answer the following questions. (5 points)
a. Give two possibilities that can account for the decrease in Mn-binding genes over time.

b. Many microbes use iron-binding proteins that serve important roles in metabolism. Given that iron must be obtained from the environment of the organism, the authors find the rise in Fe-binding genes contradictory because Fe became less soluble in the oceans over time. How can you explain this occurrence? (4 sentences maximum)

DO NOT WRITE BELOW THIS LINE

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Part B:
In 1977, Carl Woese and George Fox published a brief paper in PNAS that established, for the first time, that the overall phylogenetic structure of the living world is tripartite. In *Phylogeny and beyond: Scientific, historical, and conceptual significance of the first tree of life*, Pace et al. describe the way in which this monumental discovery was made, its context within the historical development of evolutionary thought, and how it has impacted their understanding of the emergence of life and the characterization of the evolutionary process in its most general form.

Pace, NR *et al.* (2012) Phylogeny and beyond: Scientific, historical, and conceptual significance of the first tree of life *Proc Natl Acad Sci USA* 109:1011.

Additional suggested reading: *Phylogenetic structure of the prokaryotic domain: The primary kingdoms.* Woese and Fox. 1977. (http://www.pnas.org/content/74/11/5088.full.pdf)
Read the paper(s) carefully and answer the following questions.

1) The theory of evolution as we know it today was neither spontaneously reasoned nor obvious. Rather, the theory has gone through numerous revisions by generations of evolution pioneers. (8 points)
a. Order the following pioneers mentioned in the paper, briefly describe their theories of evolution and biological classification.
Charles Darwin, Ernst Haeckel, Carl Linnaeus, Jean Baptiste de Lamarck,
b. Describe the discoveries that led the next person to modify the theory.

2) Some questions remained after Woese and Fox (1977), but can now be answered (at least in part) today: (5 points)
a. Where was the root of the tree?

b. Is there a hypothetical last universal common ancestor

c. Were two of the urkingdoms more closely related to one another than to the third urkingdom? Or did the three spring independently from some universal ancestor?

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3) Often, results of a controversial experiment are not widely accepted until they can be used to help predict or independently verify known relationships that previously lacked rhyme or reason, or answer classic questions by providing corroborating evidence on top of existing, widely accepted fundamental knowledge. The Fox and Woese paper published in 1977 experienced significant backlash. Name some key points of contention, and list some ways in which the findings of the paper were able to stand their own. (5 points) (6 sentences maximum)

4) Describe, in your own words, the “fundamental breakthrough in biological science” that occurred in 1977. Discuss the ways that this paradigm shift influenced the fields of (a) microbiology and (b) evolutionary biology, giving specific examples. (5 points) (6 sentences maximum)