Lab Handout

Lab 5. Geologic Time and the Fossil Record: Which Time Intervals in the Past 650 Million Years of Earth's History Are Associated With the Most Extinctions and Which Are Associated With the Most Diversification of Life?

Introduction

Earth scientists use the structure, sequence, and properties of rocks, sediments, and fossils, as well as the locations of current and past ocean basins, lakes, and rivers, to learn about the major events in Earth's history. Major historical events include the formation of mountain chains and ocean basins, volcanic eruptions, periods of massive glaciation (when ice glaciers increase in size because of colder than average global temperatures), the development of watersheds and rivers, and the evolution and extinction of different types of organisms. Earth scientists can determine when and where these major events happened because rock layers, such as the ones pictured in Figure L5.1, provide a lot of information about how an area has changed over time. Earth scientists can also determine when these changes happened by determining the *absolute age* or *relative age* of different layers. Earth scientists can determine the absolute age of a layer of rock by measuring the amount of different radioactive elements found in a layer, and they can determine the relative ages of different rock layers using some fundamental ideas about the ways layers of rock form over time that are based on our understanding of geologic processes.

FIGURE L5.1

Horizontal rock layers are easy to see (a) at the Grand Canyon in Arizona and (b) near Khasab in Oman (a country in the Middle East)

a b

LAB 5

There are four fundamental ideas that Earth scientists use to study and determine the relative age of rock layers. Nicholas Steno introduced the first two in 1669 (see *www.ucmp.berkeley.edu/history/steno.html*). The first fundamental idea, which is called the *principle of original horizontality,* states that sedimentary rocks are originally laid down in horizontal layers; see Figure L5.1 for an example of this principle. The second fundamental idea is called the *law of superposition*. This law states that in an undisturbed column of rock, the youngest rocks are at the top and the oldest are at the bottom. The third fundamental idea is known as the *principle of uniformitarianism*; it was introduced by James Hutton in 1785, and later expanded by Charles Lyell in the early 1800s (see *www.uniformitarianism.net*). This idea states that geologic processes are consistent throughout time. William Smith introduced the fourth fundamental idea in 1816. This idea is called the *principle of faunal succession,* which states that fossils are found in rocks in a specific order (see *https://earthobservatory.nasa.gov/Features/WilliamSmith/page2.php*). This principle led Earth scientists to use fossils as a way to define increments of time within the geologic time scale. Because many individual plant and animal species existed during known time periods, the location of certain types of fossils in a rock layer can reveal the age of the rocks and help Earth scientists decipher the history of landforms.

The geologic history of the Earth, or geologic time scale, is broken up into hierarchical chunks of time based on the major events in Earth's history. These major events can be catastrophic, occurring over hours to years, or gradual, occurring over thousands to millions of years. Records of fossils and other rocks also show past periods of massive extinctions and extensive volcanic activity. From largest to smallest, this hierarchical organization of the geological time based on the major events includes eons, eras, periods, epochs, and stages. All of these are displayed in the portion of the geologic time scale shown in Table L5.1.

The majority of macroscopic organisms (organisms that can be seen by the human eye without a microscope), have lived during the Phanerozoic eon; these organisms include algae, fungi, plants, and animals. When Earth scientists first proposed the Phanerozoic eon as a division of geologic time, they believed that the beginning of this eon (542 million years ago [mya]) marked the beginning of life on Earth. We now know that this eon only marks the appearance of macroscopic organisms and that life on Earth actually began about 3.8 billion years ago as single-celled organisms. The Phanerozoic is subdivided into three major divisions, called eras: the Cenozoic, the Mesozoic, and the Paleozoic (see the "Geologic Time Scale" web page at *www.ucmp.berkeley.edu/help/timeform.php*). The suffix *zoic* means animal. The root *Ceno* means recent, the root *Meso* means middle, and the root *Paleo* means ancient. These divisions mark major changes in the nature or composition of life found on Earth. For example, the Cenozoic (65.5 mya–present) is sometimes called the age of mammals because the largest animals on Earth during this era have been mammals, whereas the Mesozoic (251–65.5 mya) is sometimes called the age of dinosaurs because these animals were found on Earth during this time period. The Paleozoic (542–251 mya), in contrast, is divided into six different periods that mark the appearance of different kinds of invertebrate and vertebrate animals. The descriptions of these eras and periods can be somewhat misleading,

TABLE L5.1

Some of the eons, eras, periods, epochs, and stages in the geologic time scale, based on data from Gradstein, Ogg, and Hilgen (2012). Notice that different stages are nested within an epoch, different epochs are nested within a period, and different periods are nested within an era.

Eon	Era	Period	Epoch	Stage	Time (mya)
Phanerozoic	Cenozoic	Neogene	Pliocene	Piacenzian	2.6-3.6
				Zanclean	3.6-5.3
			Miocene	Messinian	5.3-7.3
				Tortonian	7.3-11.6
				Serravalian	11.6-13.8
				Langhian	13.8-15.9
				Burdigalian	15.9-20.4
				Aquitanian	20.4-23.0
		Paleogene	Oligocene	Chattian	23.0-28.1
				Rupelian	28.1-33.9
			Eocene	Priabonian	33.9-37.8
				Bartonian	37.8-41.2
				Lutetian	41.2-47.8
				Ypresian	47.8-56.0

however, because many different groups of animals lived during each of them. There were also many kinds of plants living during these different eras and periods.

Earth scientists have collected a lot of data about the history of life on Earth over the last 400 years. This information not only allows scientists to determine what the conditions were like on Earth in the past, but also allows them to track when major groups of animals and plants appeared and disappeared during the past 650 million years of Earth's history. In this investigation, you will have an opportunity to learn about the extinction and diversification of life on Earth. It is important to note, however, that the fossil record only provides a partial picture how life on Earth has changed over time. Although it is substantial, the fossil record is incomplete because life forms that are common, widespread, and have hard shells or skeletons are more likely to be preserved as fossils than life forms that are rare, isolated, and have soft bodies. The fossil record, therefore, can only provide limited information about the history of life on Earth.

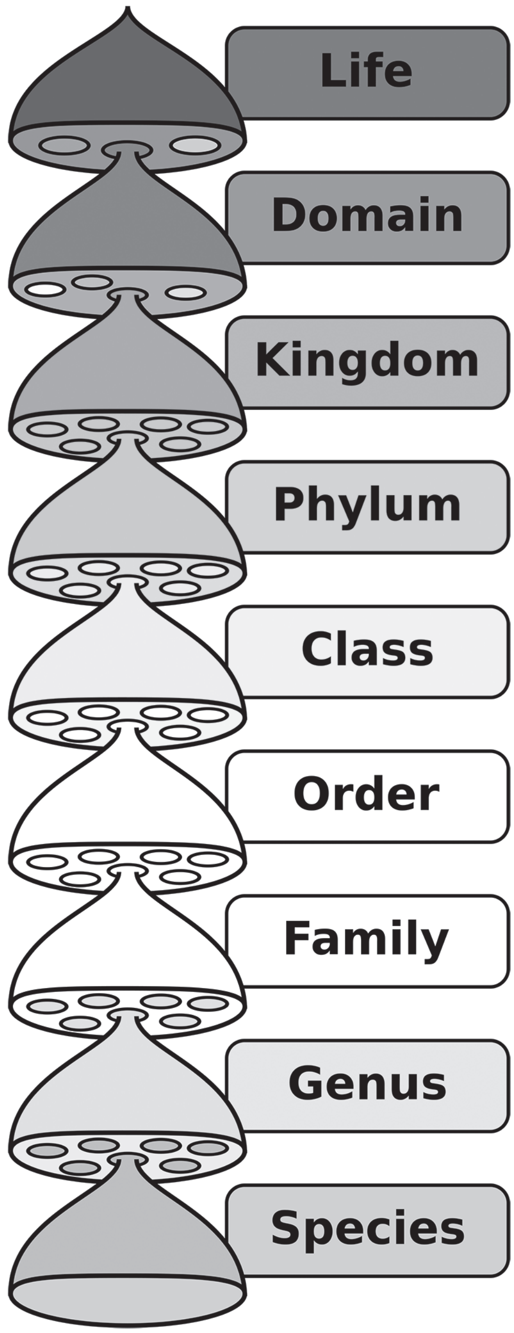
Your Task

Use a database called The Fossil Record 2 and what you know about geologic time, patterns, scales, proportions, and quantities to identify any major extinction and diversification events that happened during the last 650 million years. You goal is to determine how many of each of these important events occurred and when they happened in the geologic time scale.

The guiding question of this investigation is, ***Which time intervals in the past 650 million years of Earth's history are associated with the most extinctions and which are associated with the most diversification of life?***

FIGURE L5.2

Levels of biological classification



Materials

You will use a computer with Excel or other spreadsheet application during your investigation. You will also use the following resources:

- Fossil Record 2 Database Summary Counts Excel file
- Geologic Time Scale information sheet

Your teacher will tell you how to access the Excel file.

Safety Precautions

Follow all normal lab safety rules.

Investigation Proposal Required?

☐ Yes ☐ No

Getting Started

The Fossil Record 2 database is a near-complete listing of the diversity of life through geologic time, compiled at the level of the family (Benton 1993, 1995). In biology, levels of classification include species, genus, family, order, class, phylum, and kingdom (see Figure L5.2), so *family* refers to a level of classification that falls between order and genus. For example, *Pan paniscus,* a species of ape commonly called a bonobo, is a part of the genus *Pan,* the family Hominidae, the order Primates, the class Mammalia, the phylum Chordata, and the kingdom Animalia.

The Fossil Record 2 database (Benton 1993) is an Excel file. Each row in this file represents a different biological family, and each column represents a different time interval. The geologic time range of each family is entered on the worksheet, with the first appearance of the family labeled as F1, presence in the fossil record labeled as 1, and last recorded appearance labeled as L1. You can download the entire database for free from this website: *http://palaeo.gly.bris.ac.uk/fossilrecord2/fossilrecord/index.html*.

You will not be using the entire database for this investigation; instead, you will be using an Excel file called Fossil Record 2 Database Summary Counts. This Excel file is a simplified version of The Fossil Record 2 database. It includes counts of the number of different families, orders, classes, or phyla found at specific time intervals in the geologic time scale. It also contains information about the number of families, orders, classes, or phyla that first appeared and were last observed in each time interval.

To answer the guiding question, you will need to analyze the data in the Fossil Record 2 Database Summary Counts. Be sure to think about the following questions before you begin analyzing your data:

- Are any of the data irrelevant based on the guiding question?
- How could you use mathematics to describe a change over time?
- What types of patterns might you look for as you analyze your data?
- How does the ratio of new families, orders, classes, or phyla and the total number of families, orders, classes, or phyla at each time interval compare with the other time intervals?
- How does the ratio of extinct families, orders, classes, or phyla and the total number of families, orders, classes, or phyla at each time interval compare with the other time intervals?
- Are there any other proportional relationships that you can look for that will help you answer the guiding question?
- What type of graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge or Scientific Inquiry

As you work through your investigation, be sure to think about

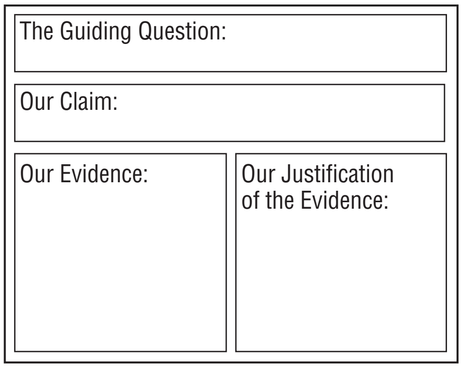
- how scientific knowledge changes over time, and
- how scientists use different methods to answer different types of questions.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L5.3.

FIGURE L5.3

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.

References

Benton, M. J. 1993. *The fossil record 2.* London: Chapman & Hall.

Benton, M. J. 1995. Diversification and extinction in the history of life. Science 268 (5207): 52–58.

Gradstein, F. M., J. G. Ogg, and F. J. Hilgen. 2012. On the geologic time scale. *Newsletters on Stratigraphy* 45 (2): 171–188.