Once in a Million Years: Teaching Geologic Time

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articlehighlights

Helping students understand the magnitude of geologic time:

- *strengthens student understanding of biological concepts*
- *illustrates not just when things happened but also how they are interconnected*
- *identifies and addresses common misperceptions*

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Ask a group of students, or a member of the general public, to estimate the size of the container you would need to hold a million gallons of water and you're likely to get responses ranging from a backyard swimming pool to a professional football stadium. (The answer is roughly equivalent to two Olympic-sized swimming pools measuring 25 meters by 50 meters by 2 meters each). Comprehension of numbers on the order of millions or billions requires a numerical literacy that is often lacking.[1] However, that same comprehension is critical if students are to grasp

- key evolutionary concepts related to the geologic time scale
- the origin and diversification of life on Earth
- other concepts such as the national debt, human population growth, and so on[2]

Numerical literacy improves understanding of biological concepts.

Without an understanding of "billions," students cannot conceptualize the vast amount of time that has elapsed in the 4.5 billion year history of the Earth. That conceptualization is necessary to realize that even improbable events are more likely within that time span—if there is a "one in a million" chance of

some combination of characters arising or events occurring, it is likely that that combination would have occurred at some point in the history of the Earth. When such understanding is combined with information regarding how the Earth's atmosphere, climate, and geography have changed over time, students come to better appreciate how life on Earth originated and diversified.

Students need to appreciate "billions" to understand how life evolved.

An understanding of billions will also help students to appreciate that during most of the first two billion years of life on Earth, the only living organisms were unicellular prokaryotes. This could be used to emphasize our anthropocentric view of the world by reminding students that the vast majority of the history of life on Earth is the history of unicellular organisms. Understanding the relative time elapsed between various evolutionary events would help students better appreciate the evolutionary impact of innovations such as cells with nuclei, multicellularity, photosynthesis, or amniotic eggs.

Some students develop misconceptions about geologic time.

Although this type of conceptualization is critical, a common approach to teaching the geologic time scale is to present one or more lectures with a chronological history of major events, why they were important, and when they occurred, supported by diagrams illustrating the geological time scale. Such diagrams often are scaled in ways that condense the early periods of the Earth's history, reinforcing student misconceptions about elapsed time. Strong students internalize the relative order of events and the relevance of each event to the larger macroevolutionary picture. Other students may develop mnemonics to recall the various periods and eras in the appropriate order (e.g., "Prince Charles Devoured Several Old Cabbages" for the Paleozoic periods: Permian, Carboniferous, Devonian, Silurian, Ordovician, Cambrian) and perhaps also memorize the time at which each interval began. Some students simply cross their fingers and hope geologic time is only a small percentage of the exam. Regardless of the approach, the actual magnitude of time encapsulated in the discussion remains, for most students, ambiguous and abstract.

Turning abstractions

As with many challenges in teaching, there is a significant advantage in converting abstract ideas of the magnitude of time into a concrete form that the students can more easily see or feel

concrete form helps students visualize time.

or touch. For many students, viewing a pictorial representation, walking a particular distance, or drawing an analogy relevant to their own life makes learning come alive. Suggesting a relevant conversion allows the instructor to reach students with a wider array of learning styles and reduces the ambiguity of the abstract concepts. This pedagogical philosophy led us to develop a series of conversion factors related to the history of the Earth and to the diversification of life during the past 600 million years. Here, we present a variety of those conversion factors and discuss some of the strategies we have used to bring the conversions into the classroom.

The conversions

Conversions should be familiar and relevant to students.

Our goal in creating the conversions was to find comparisons that were familiar and relevant to today's students. For that reason, our student author (Andrew Lloyd) chose comparisons such as the number of M&M's® in a one-pound bag rather than, say, the number of pages in War and Peace. We created two scales for the conversions:

- **Table 1**, based on the history of the Earth (estimated at 4.5 billion years)
- **Table 2**, based on the history of most animal life on Earth (600 million years from the Ediacaran fauna)

We have found these to be the most commonly used scales in biology textbooks.[3–5] Our estimates of dates for various geological and biological events are drawn from a variety of sources and obviously should be seen as approximations rather than absolute values. Where these values differ from those published in other textbooks, instructors have an opportunity to discuss how such values are estimated and why there is an element of uncertainty.

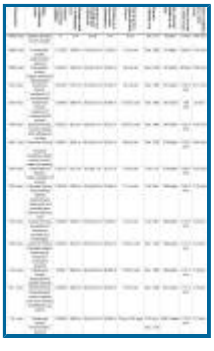

Table 1
Earth's history spans an estimated 4.5 billion years.
[view large]
download Excel file; Word doc

Using the conversions to help students visualize magnitude

The activities described below were developed for a sophomore-level ecology course. They could be modified fairly easily to a wide range of student backgrounds and abilities, as well as to a range of class sizes.

The simplest activities are those in which students are introduced to the scale of conversion to be used; for example:

A soccer field can help illustrate the magnitute of geologic time.

- Bring the class to the soccer field and explain that the 100-meter field represents the past 4.5 billion years.
- Then ask students to place themselves at particular points in time; for example, “If the field represents 4.5 billion years and the first unicellular organisms arose 3.8 billion years ago, where would you stand if you were the first unicellular organism?”
- After students have made a few similar estimations (e.g., first eukaryote, first primate, last dinosaur), it is often useful to initiate a discussion about the relative duration of a “million” as opposed to a “billion” years.

Students have a hard time believing that if the field represents 4.5 billion years, then a million years would be represented by approximately 2 centimeters (0.8 inches). This can sometimes move them from thinking a million years is impossibly long (“never in a million years”) to thinking that a million years is “a blink of an eye” in the history of the Earth.

Using the conversions to identify misconceptions

Another type of classroom activity can be particularly useful for identifying the biases or misconceptions that students might bring into the classroom. For this type of activity, students are introduced to the scale of the conversion:

A one-year calendar offers

- Bring in a one-year calendar and share with students that the class will convert the last 600 million years into the 365 days on the calendar.
- Hand students cards with various critical events (e.g., unicellular

opportunity for conversion.

life first appears, dinosaurs go extinct, and so on) and ask them to place the cards at the appropriate positions within the year.

- This can be done as a cooperative or collaborative learning activity, or students can work independently and join in a group discussion after all cards have been placed.

Students may confuse the origin of life with the origin of Earth.

As with the previous exercise, this one asks the students to wrestle with the magnitude of the time scale with which they are working. In addition, the placement of cards can give important insight into the perceptions of the students. For example, it is not uncommon for students to place “origin of life” and “origin of the Earth” cards together on the calendar. This most often reflects a belief in special creation and can provide avenues for initiating a discussion with the students about the scientific perspective of the origin of life. Similarly, students will also frequently have the evolutionary origin of humans predate the extinction of the dinosaurs—initiating a discussion of the influence of popular culture and misconceptions of “cavemen” coexisting with dinosaurs.

Reinforcing the message

After students have been exposed to and worked with the magnitude of geologic time through the exercises described above, the instructor can reinforce their understanding by sharing periodic “factoids” such as these:

- There are 2.7 million books in the Milwaukee Public Library. Only 1,000 books represent the time humans have been on the Earth.

- The distance from Carroll College to San Diego is 2,100 miles. The dinosaurs went extinct in Escondido, California, about 30 miles outside of San Diego.

- Humans blink 10,000,000 times a year. Only the last 4,000 blinks (4 hour’s worth) represent the time humans have been on the Earth.

- Every year, 227,500,000,000 pieces of mail are delivered. Only 110,000,000 pieces, which represents 0.04 percent of the total amount of mail delivered, is the time humans have been on the

Interesting factoids

Earth.[6]

the message.

- The average human will eat 60,000 pounds of food in a lifetime. Compared to the timeline of the Earth, humans have been around for the last 24 pounds.[7]

- Of all the days in a calendar year, the dinosaurs went extinct Christmas Eve, and humans started roaming the earth at 8:30 P.M. on New Year's Eve.

For additional math factoids and conversion activities, see "get involved links" that follow this article.

Conclusions

Informal feedback from students has reinforced the value of using these conversions as an aid to understanding geologic time. Many students, especially those who learn better by doing than by hearing or reading, appreciate an opportunity to experience such abstract concepts in a more concrete way. When asked to evaluate the exercise, students' responses have been overwhelmingly positive. These are a few of their comments:

Student feedback has been overwhelmingly positive.

- I thought the exercise brought the magnitude of 4.5 billion years down to reality. Before I wasn't able to put a million years into a time frame.
- I am a visual learner, so the exercise really did help me to get a sense of how long ago the world was created, and how it compares to when life started.
- I really liked the exercise. It really helped me realize how many years this has been going on. Four and a half billion is just a number, but putting it down in a timeline and seeing that 1.8 million is less than a quarter of an inch made an impact.

Conversions are another useful tool in strengthening student learning.

A clearer understanding of geologic time allows students to hang their understanding of the biological concepts and ideas (e.g., macroevolution, continental drift, and so on) from a more understandable and manageable framework, strengthening their understanding of not just when things happened but also how they are interconnected. Another advantage of using these conversions

and the associated classroom activities is that they provide a means of quickly identifying and addressing common misperceptions that students in the class may hold. As such, they add another useful tool to the educator's toolbox.

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learnmore links

Selected geologic time web sites:

- » http://pubs.usgs.gov/gip/geotime/
- » http://www.ucmp.berkeley.edu/exhibit/geology.html
- » http://www.cotf.edu/ete/modules/msese/earthsysflr/geotime.html

US Geological Survey

Scientific agency for natural sciences, including earth science and biology. The second link takes you to their education resources.
http://www.usgs.gov/
http://education.usgs.gov/

Select geological societies in countries other than the U.S.:

» Australia: http://www.gsa.org.au/
» Canada: http://www.esd.mun.ca/~gac/ABOUT/presenti.html
» The U.K.: http://www.geolsoc.org.uk/template.cfm?name=geohome

"Not Just a Number: Critical Numeracy for Adults"

This ERIC article by Sandra Kerka examines numeracy literacy and its implications for adult education.
http://www.cete.org/acve/docgen.asp?tbl=archive&ID=A012

"Thinking Involving Very Large and Very Small Quantities"

Robert Korn's article examines mathematical thinking in everyday life, such as finance, voting, and lottery probabilities.
http://www.truthpizza.org/logic/bignum.htm

getinvolved links

Large number activities and conversions

» Charity, Mitchell. A view from the back of an envelope: Counting to ten billion on your fingers. http://www.vendian.org/envelope/dir0/counting_on_fingers.html
» Emmons, R. How many is a million? http://raymond.emmons.com/dino.htm
» Kokogiak media. The Megapenny Project. http://www.kokogiak.com/megapenny/
» Strange Facts.com. http://sbt.bhmedia.com/facts2.html
» Mudd Math Fun Facts: http://www.math.hmc.edu/funfacts/

The Geological Society of America

The society offers membership, internships, publications, education resources, and more. There are free K-12 lesson plans in the earth sciences (click on education and teacher resources on home page). The second link takes you to undergraduate resources.
http://www.geosociety.org/
http://www.geosociety.org/educate/K16_resources.htm

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2. Korn, R. 2005. Thinking involving very large and very small quantities. http://www.truthpizza.org/logic/bignum.htm (accessed Sept. 20, 2005)
3. Freeman, S. 2004. Biological Science. 2nd ed. Upper Saddle River, NJ: Prentice Hall.
4. Pough, F. H., C. M. Janis, and J. B. Heiser. 2005. Vertebrate Life. 7th ed. Upper Saddle River, NJ: Prentice Hall.
5. Purves, W. K., D. Sadava, G. H. Orians, and H. C. Heller. 2003. Life: The Science of Biology. 7th ed. Sunderland, MA: Sinauer Associates.
6. United Stated Post Office. http://www.usps.com/ (accessed Sept. 23, 2005)
7. Strange Facts: http://sbt.bhmedia.com/facts2.html (accessed Sept. 23, 2005)