

Nested Boxes and Big Numbers: The Language of Deep Time

Learning target: I can use the units of the geologic time scale, the abbreviations Ga, Ma and ka, and the evidence words of this lesson to describe new situations correctly.

Vocabulary in action

About 30 min

Individual

MS-ESS1-4 · supports

MS-LS4-1 · supports

independent practice

writing

Standards connections

MS-ESS1-4 (supports): MS-ESS1-4 is a California Grade 8 performance expectation. Knowing how the time scale's units nest, how its labels are read, and the difference between relative and absolute dating is background students need before they can explain how the scale organizes Earth's history. The PE's assessment boundary excludes recalling period and epoch names, so q1 is practice with a word bank, not assessment.

MS-LS4-1 (supports): MS-LS4-1 is a California Grade 8 performance expectation on patterns in the fossil record. The term mass extinction, and the idea that fossils disappearing from strata mark a boundary, is used here only as vocabulary.

Purpose: build · **Time:** about 30 minutes · **Format:** individual

Answers with reasoning

geologic time scale

A model that divides Earth's whole 4.54-billion-year history into named stretches of time, built from the order of rock layers and the fossils in them, with some ages in years added from datable rocks.

eon

The largest unit of the time scale. There are four; three of them cover the first 4 billion years, and the one we live in, the Phanerozoic, covers the last 539 million years.

era

A division of an eon, hundreds of millions of years long. The Phanerozoic Eon has three: Paleozoic, Mesozoic and Cenozoic.

period

A division of an era, usually tens of millions of years long.

epoch

A division of a period, the smallest unit named on most charts. We live in the Holocene Epoch, which began about 11,700 years ago.

Ga, Ma, ka

Short labels for billions, millions and thousands of years (from annum, the Latin word for year). 2.5 Ga means 2.5 billion years; on a timeline it usually means that many years ago.

relative dating

Putting rocks, fossils or events in order (older, younger) without giving an age in years. Rock layers and fossils give relative ages.

absolute dating

Measuring an age in years from the steady change of certain atoms inside a mineral. Works on meteorites, moon rocks and some volcanic rocks, including ash layers.

mass extinction

The dying out of a large share of Earth's species within a geologically short time. Rock strata show it as many kinds of fossils stopping at one level. Five big ones mark boundaries on the time scale.

principle of lateral continuity

A sediment layer spreads out sideways as a sheet until it thins out or meets a barrier. So the same layer seen in two separate cliffs can be matched, joining their records.

stromatolite

A layered mound of rock built up by mats of microbes, including the cyanobacteria that first released oxygen. Fossil stromatolites are among the oldest signs of life.

ice age

A long stretch of cooler global climate with permanent ice at the poles. Earth is in one now, and has been for about 2.6 million years.

glacial period

A colder stretch inside an ice age, when ice sheets grow outward from the poles.

interglacial period

A warmer stretch inside an ice age, when ice sheets melt back and cover less land. We live in one that began about 11,700 years ago.

nebular hypothesis

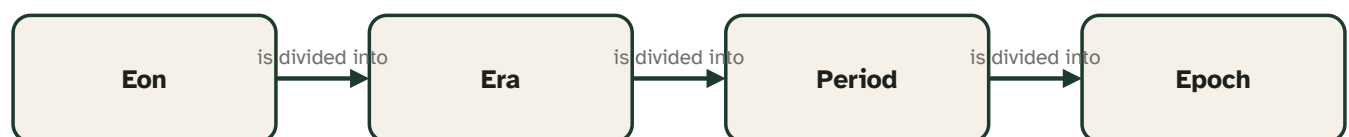
The explanation for how the solar system formed: a cloud of gas and dust shrank, spun into a disk, and clumped into the sun, the planets and leftover asteroids about 4.6 billion years ago.

giant impact hypothesis

The explanation for the moon: a body about the size of Mars struck the young Earth, and debris from both went into orbit and gathered into the moon about 4.5 billion years ago.

Part A: How the units nest

Units of the geologic time scale, longest to shortest



The units are nested like boxes inside boxes. Each arrow means 'is divided into'. Moving to the right, the boxes get shorter in time.

1. Write today's date on the geologic time scale, from the largest unit to the smallest. Word bank: Cenozoic, Holocene, Phanerozoic, Quaternary. Eon: _____ Era: _____ Period: _____ Epoch: _____

Answer: Eon: Phanerozoic. Era: Cenozoic. Period: Quaternary. Epoch: Holocene.

Why: Largest to smallest. The term box gives the eon and epoch directly; the era and period come from elimination within the word bank (Cenozoic is defined as an era, leaving Quaternary as the period).

Also acceptable: None; the word bank fixes the answer.

2. Which is longer, an era or a period? Explain how the diagram tells you, using the word *divided* or *nested*.

Answer: An era is longer. The diagram shows an era is divided into periods, so a period is one piece of an era and must be shorter (the units are nested, each inside the one before it).

Why: Students must read the arrow direction, not just recall the order.

Also acceptable: Accept 'several periods fit inside one era.'

- Says era is longer
- Explains using divided-into or nested

3. A student says, 'Every period is the same length, like every hour is 60 minutes.' Use the definition of **mass extinction** to explain why periods are not all the same length.

Answer: Boundaries on the time scale are placed where the rock and fossil record shows a big change, such as a mass extinction when many kinds of fossils stop at one level. Those changes happened at irregular times, so the stretches between them, the periods, have different lengths. Hours are defined by a clock; periods are defined by events.

Why: This is the lesson's central idea about how the scale is organized: by events in strata, not by equal ticks.

Also acceptable: Accept an answer using 'the appearance of new kinds of fossils' as the boundary event.

- Says boundaries are placed at big changes or mass extinctions in the record
- Concludes that unequal spacing of events makes unequal periods

Part B: Reading and converting the big numbers

4. Complete the table. (a) 2.5 Ga to Ma. (b) 66 Ma to ka. (c) 11.7 ka to years. (d) 539 Ma to Ga. (e) 300 ka to Ma. Write the multiplication or division you used in the Answer column.

Answer: (a) $2.5 \text{ Ga} \times 1,000 = 2,500 \text{ Ma}$. (b) $66 \text{ Ma} \times 1,000 = 66,000 \text{ ka}$. (c) $11.7 \text{ ka} \times 1,000 = 11,700 \text{ years}$. (d) $539 \text{ Ma} \div 1,000 = 0.539 \text{ Ga}$. (e) $300 \text{ ka} \div 1,000 = 0.3 \text{ Ma}$.

Why: Each step between units is a factor of 1,000; down the ladder multiply, up the ladder divide.

Also acceptable: Accept 0.54 Ga for (d) if the student rounded and said so.

5. The label **66 Ma** can mean a *date* (66 million years ago) or a *length* (66 million years long). Write one sentence that uses it as a date and one that uses it as a length.

Answer: Date: 'The non-bird dinosaurs died out at 66 Ma, when an asteroid struck Earth.' Length: 'The Cenozoic Era has lasted 66 Ma so far, from the extinction to today.' (Any correct pair of sentences.)

Why: Students must show the two readings of the same label. The lesson's timelines use Ma as a date; the term box warns that it can also be a length.

Also acceptable: Accept any true or clearly hypothetical events as long as the two uses are distinct.

- One sentence uses 66 Ma as a point in the past
- One sentence uses 66 Ma as a span of time

Part C: Which term fits? Name the term and give the reason

6. A geologist finds the same pale volcanic ash layer in two cliffs 60 km apart and concludes the two cliffs once shared one continuous layer.

Answer: Principle of lateral continuity. A layer spreads sideways as a sheet, so the same ash layer in two cliffs was once one continuous layer, which lets the two records be matched.

Why: The key feature is matching one layer across a gap.

Also acceptable: A student who adds that the ash layer could also be dated absolutely is right but must still name lateral continuity for the matching.

- Names lateral continuity
- Reason mentions the layer spreading sideways or being one continuous sheet

7. A laboratory reports that the minerals in a sample of volcanic rock formed 201 million years ago.

Answer: Absolute dating. The lab measured an age in years from the minerals' steady atomic change; relative dating would only say older or younger.

Why: An age in years is the signature of absolute dating.

Also acceptable: None.

- Names absolute dating
- Reason: an age in years was measured

8. In a stack of layers, nine kinds of shell fossils appear in every layer up to one thin line of rock; above the line only two of those kinds are found.

Answer: Mass extinction. Many kinds of fossils stop at one level in the strata, which is what a large share of species dying out in a short time looks like in rock. (The order of layers is relative dating, and this kind of line is where geologists place a boundary on the time scale.)

Why: Students should connect the fossil pattern in strata to the definition.

Also acceptable: Accept 'relative dating' as a second term if mass extinction is also named.

- Names mass extinction
- Reason: many fossil kinds disappear at one level

9. Ice sheets are growing outward from both poles and covering land that was bare a few thousand years earlier. Give the most specific term.

Answer: Glacial period. Ice sheets growing outward from the poles is the defining feature; 'ice age' is correct but less specific, since an ice age also contains interglacial periods when ice shrinks.

Why: The question asks for the most specific term to force the glacial-versus-ice-age distinction.

Also acceptable: Accept 'glacial period within an ice age.' 'Ice age' alone earns partial credit.

- Names glacial period
- Reason: ice sheets advancing

10. A scientist slices open a layered, cabbage-shaped mound of 3-billion-year-old rock and argues it was built by mats of microbes.

Answer: Stromatolite. It is a layered mound built up by microbial mats, and the layering plus its great age are the clues.

Why: Layered mound built by microbes is the definition.

Also acceptable: None.

- Names stromatolite
- Reason: layered mound built by microbial mats

11. Moon rocks turn out to match the chemistry of Earth's mantle far better than they match the asteroids. Which explanation does this evidence support, and why?

Answer: The giant impact hypothesis. If the moon formed from debris knocked out of the young Earth (and the impactor), its rock should resemble Earth's mantle, which is what the moon rocks show. If the moon were a captured asteroid, it would match the asteroids instead.

Why: This asks students to link evidence to the hypothesis it supports, not just define the term.

Also acceptable: Accept 'the moon was once part of Earth' as the reason.

- Names the giant impact hypothesis
- Reason: moon material came from Earth's mantle, so the chemistry matches

Part D: Sorting the evidence words

12. Sort these five clues into the two columns: the lowest undisturbed layer is oldest; a volcanic ash layer whose minerals are dated in a lab; a meteorite's mineral clock; the same fossils appearing in the same order in two places; a layer that cuts across other layers is younger than them.

Answer: Order only (relative): the lowest undisturbed layer is oldest; the same fossils appearing in the same order in two places; a layer that cuts across other layers is younger than them. Age in years (absolute): a dated volcanic ash layer; a meteorite's mineral clock.

Why: Three relative clues, two absolute clues. The dated ash layer is the bridge: it is the way an age in years gets attached to a stack of relatively dated layers.

Also acceptable: None; each clue has one correct column.

13. Explain the difference between an **ice age**, a **glacial period** and an **interglacial period**. Use the word *inside* or *within* at least once. Then state which of the three we are living in today (more than one may apply) and give the starting date of each one you name.

Answer: An ice age is a long stretch of cooler climate with permanent ice at the poles. Within an ice age, the climate swings: a glacial period is a colder stretch inside the ice age when ice sheets grow outward, and an interglacial period is a warmer stretch inside the ice age when ice sheets shrink back. Today we are living in both an ice age (the current one began about 2.6 million years ago, when large northern ice sheets began their cycles) and an interglacial period (which began about 11,700 years ago). We are not in a glacial period.

Why: The common error is treating 'ice age' and 'glacial period' as the same thing, which makes students think the ice age ended 11,700 years ago. Full credit needs the nesting and both current answers with dates.

Also acceptable: Accept 'about 11,500 years ago' for the interglacial (the textbook's figure) with a note that the international chart uses 11,700.

- Defines all three terms
- Shows glacial and interglacial periods are inside an ice age
- States we are in an ice age and an interglacial
- Gives about 2.6 million years and about 11,700 years

Teacher notes

The term box is the authority for this sheet, and it corrects the textbook in several places: the Phanerozoic began about 539 million years ago (the 2024 international chart gives 538.8 Ma; the textbook uses 541 Ma), the current interglacial began about 11,700 years ago (textbook: 11,500), and the moon's debris came from both Earth and the impactor. Eon definitions are kept to counts and lengths so that the MS-ESS1-4 assessment boundary (no recall of period and epoch names) is respected; q1 is deliberately a word-bank exercise and should not be re-used on a quiz without the bank. In q9, 'ice age' alone is a common answer and is the best moment to teach the nesting in q13. Ma is used as a date throughout the textbook's timelines; q5 exists because students regularly misread it as a length.

Scaffold offered to students: Conversion ladder

Each step on the ladder is 1,000: 1 Ga = 1,000 Ma, 1 Ma = 1,000 ka, 1 ka = 1,000 years. To go down a step (Ga to Ma, Ma to ka, ka to years) multiply by 1,000, which moves the decimal point three places right. To go up a step, divide by 1,000, which moves it three places left. Check: 2.5 Ga is a very long time, so it should become a bigger number in Ma (2,500), not a smaller one.

Extension: Write the rules of a time scale for your own life

Invent a four-level time scale for one person's life, with your own names for the levels (for example 'ages', 'chapters', 'seasons', 'weeks'). Decide what kinds of events would mark the boundaries between units, then write two sentences explaining why your units, like the geologic time scale's, would not all be the same length. Finish by naming one thing about a human life that makes it easier to divide than Earth's history, and one thing that makes it harder.