

Four and a Half Meters of Time: a String Model of Earth's History

Investigation question: If all 4.54 billion years of Earth's history were stretched along a 4.54-meter string, where would the first animals, the last non-bird dinosaurs and the first modern humans sit, and what does the spacing reveal that a textbook chart hides?

Physical model

Groups of 4

1 session

Setup 8 · Activity 35 · Cleanup 5 min

MS-ESS1-4 · practice

Scientific purpose

Students build a physical, to-scale model of Earth's entire history, converting each event's age in millions of years into a distance in centimeters, placing event cards along a string, and then measuring the stretches between them. The model turns the abstractions Ga, Ma and ka into lengths students can walk beside, exposes how little of the string belongs to animals and how much less to people, and lets students critique the not-to-scale chart in their textbook as a model with a purpose.

Why this helps students with this chapter

Students read 'billion' and 'million' as roughly the same kind of big. Dividing each age by ten million to get centimeters, then finding that the whole age of animals fits in the last half meter and all of human existence in a fraction of a millimeter, replaces vague bigness with proportion. The model also surfaces the misconception that the Phanerozoic is most of Earth's history, because the Precambrian takes up four of the four and a half meters.

Standards connections

MS-ESS1-4 (practice, the scale and organization of Earth's history, without recalling period names): A California Grade 8 performance expectation met here as practice: students organize major events on a scaled model and reason about proportion, which prepares them to explain how the time scale organizes Earth's history. Event cards are chosen for their place in the story, not as names to memorize.

Roles (rotate each session)

- **Calculator:** Converts each event's age in millions of years to centimeters from the 'today' end (divide by 10) and reads the result aloud; shows the work on the sheet.
- **Measurer:** Measures each distance from the 'today' end with the tape or meter sticks and marks the spot with a small piece of masking tape.
- **Card placer:** Clips the correct event card at each mark, checks that the cards read in order along the string, and keeps the string straight.
- **Checker and recorder:** Recomputes every third conversion independently, records the group's predictions and measurements, and reports to the class.

Materials

Item	Quantity	Per	Note
String, cord or thin ribbon, cut to 460 cm	1 length	group	Extra 6 cm gives room to tie off the ends; the 'Earth forms' card sits at exactly 454 cm.
Tape measure (3 m or 5 m) or three meter sticks	1 set	group	
Index cards cut in half, with the 20 events written on them	20	group	Write the event name only; students compute the position.
Clothespins or small binder clips	20	group	
Masking tape	1 roll	group	
Calculator	1	group	
Fine marker and a hand lens	1 each	group	The last three events are marks a few millimeters or less from the end; the lens helps students see them.
Recording sheet	1	student	

Estimated cost: 6 to 10 per class (an estimate; A 50 m spool of cotton string (about \$4) supplies ten groups; clothespins (about \$3 for 50), index cards and masking tape are standard stock. Tape measures and meter sticks are reused.)

Safety

- Strings on the floor are a tripping hazard; keep lanes clear, walk only alongside the string, and have the card placer call out before anyone crosses a lane.
- Scissors only for cutting string and cards; pass them handle first and keep them closed on the desk when not in use.
- No chemicals or heat are used. If the activity is run outdoors, keep groups away from stairs and traffic.

Teacher preparation and setup

1. Cut one 460 cm length of string per group and tie a loop at one end labeled TODAY with a tag; the other end is left plain so the group places 'Earth forms' at 454 cm themselves.
2. Prepare the 20 event cards per group (or have groups copy the list from the recording sheet onto blank cards during setup to save prep time).
3. Clear floor space: each group needs a straight lane about 5 m long; a hallway, gym or outdoor walkway works. Mark lanes with tape so strings do not cross.
4. Do one run yourself so you know how small the last marks are: the Quaternary card sits 2.6 mm from the end and the modern-humans card 0.3 mm, closer than the width of a pencil line.
5. Write the scale on the board: 1 cm = 10 million years; 1 mm = 1 million years; 1 m = 1 billion years.

Investigation design

Independent variable Age of each event in millions of years before today

Dependent variable	Distance of the event's card from the TODAY end, in centimeters, at the fixed scale of 1 cm per 10 million years
Controlled	Scale: 1 cm = 10 million years for every event; All distances measured from the TODAY loop; The same source dates for every group (the recording-sheet list); The string kept straight and taut while measuring
Trials	One string per group; the class compares the measured Precambrian length across groups (every group should be within a few centimeters of 400 cm).
Comparison	Students' guessed positions versus the computed and measured positions for the first animals and the end of the non-bird dinosaurs.

Student procedure

1. Lay the string straight along your lane with the TODAY loop at one end. Before measuring anything, place a sticky note where the group guesses the first animals belong and another where the non-bird dinosaurs end. Record both guesses in centimeters from TODAY on the recording sheet.
2. Measure 454 cm from TODAY and clip the 'Earth forms (4,540 Ma)' card there. Check with the tape that the distance is 454 cm, not the full string length.
3. For each event on the recording sheet, the calculator divides the age in millions of years by 10 to get centimeters from TODAY, says the result aloud, and the checker records it. Work in the order listed, oldest first.
4. The measurer measures each distance from the TODAY loop, never from the previous card, and marks it with a small piece of masking tape. The card placer clips the card at the mark.
5. When you reach the events younger than 10 million years, switch to millimeters (1 mm = 1 million years) and use the hand lens. Decide as a group whether the last three cards can be placed at separate spots or must share one clip, and record what you decided.
6. Walk the finished string from the Earth end to TODAY. Measure and record the length of the Precambrian stretch (from 'Earth forms' to 'Cambrian explosion') and the length from 'Cambrian explosion' to TODAY.
7. Compare your two guesses from step 1 with the measured positions and write one sentence about each.
8. Measure the gap between 'Chicxulub impact' and 'modern humans appear' and record it, then answer the analysis questions individually before discussing them as a group.

Expected observations

- Computed positions: 454, 450, 440, 400, 350, 240, 53.9, 50.8, 44.3, 37.2, 30, 25.2, 23, 20.1, 18, 6.6, 5, 3.4, 0.26 and 0.03 cm from TODAY.
- The Precambrian stretch measures about 400 cm and the Phanerozoic about 54 cm; the five mass-extinction cards crowd into the last half meter, and the three youngest cards cannot be separated by eye.
- Student guesses for the first animals usually fall between 150 and 300 cm from TODAY, far earlier than the real 54 cm.

Likely difficulties

- Measuring each card from the previous card instead of from TODAY accumulates error; insist on measuring from the loop every time.
- Dividing 2.58 by 10 and then converting 0.258 cm to millimeters trips many students; have the checker write the millimeter value next to it (2.6 mm).
- Students place the Earth-forms card at the cut end of the string (460 cm) instead of at 454 cm, which shifts the whole Precambrian by 6 cm; the step-2 check catches this.
- Groups may argue about whether 'Pangaea assembled' belongs at 300 or the textbook's 252; explain that geologists place its completion near the start of the Permian and that the card uses the current value.

Structured debrief

1. Pool each group's Precambrian length on the board; they should cluster near 400 cm. Ask what that length means in years (about 4 billion) and in percent (about 88).
2. Ask the group with the smallest sticky-note guess for the first animals to explain their reasoning. Most guesses land far earlier than 54 cm because students read chart space as time; name the misconception explicitly.
3. Hold up a card and ask how its date was obtained. Meteorites, moon rocks and zircons: absolute dating of the material itself. Extinctions: the level in the rock where fossils vanish, pinned in years by dated volcanic layers near that level. Make the point that most of the string's ages come from a combination of relative order and a few absolute anchors.
4. Close on q8: the string shows durations and order superbly, but it shows nothing about where events happened, how fast each one unfolded, or how much evidence survives for each stretch; the Precambrian is long but thinly recorded.

Recording sheet: what students fill in

Lab 1 recording sheet: Four and a half meters of time

Scale: **1 cm = 10 million years**, so centimeters from TODAY = age in millions of years $\div$ 10. One millimeter is one million years. Fill in the guesses before you measure anything.

Guesses before measuring

Event	Our guess (cm from TODAY)	Measured position (cm)	How far off were we? (cm)
First animals appear (Cambrian explosion)			
Non-bird dinosaurs die out (Chicxulub impact)			

Event positions (dates rounded from the current international chart and USGS, NASA and Smithsonian sources)

Event	Age (millions of years ago)	Centimeters from TODAY (age ÷ 10)	Placed? (check)
Earth has assembled	4,540		
Giant impact forms the moon	4,500		
Oldest surviving zircon grains	4,400		
Oldest surviving whole rocks	4,000		
Oldest stromatolites (microbial mats)	3,500		
Oxygen starts building up in the air	2,400		
Cambrian explosion: first animals with hard parts	539		
Burgess Shale animals buried	508		
End-Ordovician mass extinction	443		
Late Devonian mass extinction	372		
Pangaea fully assembled	300		
End-Permian mass extinction	252		
First dinosaurs	230		
End-Triassic mass extinction	201		
Pangaea begins to split	180		
Chicxulub impact; non-bird dinosaurs die out	66		
India collides with Eurasia	50		
Antarctic ice sheet forms	34		
Quaternary begins: northern ice sheets start their cycles	2.58		
Modern humans appear	0.3		

Measured stretches

Stretch	Measured length (cm)	Share of the whole string (length ÷ 454 × 100)
Earth forms to Cambrian explosion (the Precambrian)		
Cambrian explosion to TODAY (the Phanerozoic)		
Chicxulub impact to modern humans		

- How did your two guesses compare with the measured positions? Which one surprised you more, and why?

Answer: Group-specific. Most guesses place the first animals much too early (too far from TODAY) and the end of the dinosaurs too early as well. The usual surprise is that animals occupy only the last 54 cm of a 454 cm string.

Why: Students reason from chart space, where the Phanerozoic dominates. The gap between guess and measurement is the lesson.

- Reports both guesses and both measured positions
- Identifies which surprised them and gives a reason tied to the string

- What did your group decide to do with the last three cards (Quaternary, modern humans, and the present interglacial, which began 0.0117 million years ago)? Explain the problem they caused.

Answer: At this scale the Quaternary card sits 2.6 mm from TODAY, modern humans 0.3 mm, and the present interglacial 0.0117 mm, thinner than a pencil line, so the three cannot be clipped at separate spots. Most groups stack them on one clip or write them on one card.

Why: The point is that the scale that shows the whole story cannot resolve the recent past; q6 follows up quantitatively.

- States the computed millimeter positions
- Describes the decision and names the problem (too close to separate)

Analysis questions: answer key

- Use your measured stretches to calculate what percent of Earth's history is Precambrian and what percent is Phanerozoic. Show the division.

Answer: Precambrian: about $400 \text{ cm} \div 454 \text{ cm} \times 100 \approx 88$ percent. Phanerozoic: about $54 \text{ cm} \div 454 \text{ cm} \times 100 \approx 12$ percent. (Exact: $400.1 \div 454 = 0.881$; $53.9 \div 454 = 0.119$.)

Why: Measured lengths will vary by a centimeter or two; accept 86 to 90 percent and 10 to 14 percent with the division shown.

Also acceptable: Accept the fraction form: about seven-eighths and one-eighth.

4. The Chicxulub card sits 6.6 cm from TODAY and the modern-humans card 0.03 cm. How many times longer is the gap between the end of the non-bird dinosaurs and today than the whole existence of modern humans? Show the calculation.

Answer: $6.6 \text{ cm} \div 0.03 \text{ cm} = 220$. The time since the last non-bird dinosaurs is about 220 times longer than the whole existence of modern humans ($66 \text{ million} \div 300,000 = 220$).

Why: A direct ratio; the same answer results from dividing the ages in years. The number is what matters: there is no overlap between dinosaurs and people.

Also acceptable: Accept 'about 200 times' if the student rounded 0.03 to 0.033.

5. Your textbook's time-scale chart gives the Phanerozoic Eon far more space than the Precambrian. Using your string, explain why the chart is not to scale and why geologists draw it that way anyway.

Answer: On the string, the Phanerozoic is only about 12 percent of the length, but the textbook chart gives it most of the page. The chart is drawn by the number of named units, not by years: the Phanerozoic's rocks are full of fossils, well preserved and widely exposed, so geologists have divided it into many eras, periods and epochs, each needing a line of space. The Precambrian has few fossils and few named units, so it is squeezed. The chart's purpose is to show the named units and their order, not their durations, which is why a to-scale model like the string is a useful companion.

Why: Full credit needs both halves: that the chart is not to scale (with a number) and why it is drawn that way (named units follow the fossil record).

- Uses the 12 percent or 88 percent figure from the string
- Explains that chart space follows the number of named units
- Connects the number of units to the fossil record or preservation

6. Suppose you wanted a model on which the present interglacial (11,700 years) is a full centimeter long. How long would the whole-Earth string have to be? Show your work and comment on whether the model would be usable.

Answer: Scale needed: $1 \text{ cm} = 11,700 \text{ years}$. String length = $4,540,000,000 \div 11,700 \approx 388,000 \text{ cm} \approx 3,880 \text{ m}$, about 3.9 kilometers. The model would be unusable in a classroom; this is why no single scale can show both the whole of Earth's history and the recent past.

Why: Students divide Earth's age by the interglacial length. Accept answers from 3.8 to 3.9 km, or 388,000 cm, with the division shown.

Also acceptable: Accept an answer in meters (about 3,880 m) or 'almost 4 km'.

7. Which events on your list could be placed in order by rock layers and fossils alone, and which needed an age measured in years from materials such as meteorites or volcanic ash? Give two examples of each.

Answer: Order from rock layers and fossils alone: the mass extinctions (fossils vanish at a level), the Cambrian explosion (hard-shelled fossils first appear), the first dinosaurs (first bones), the Burgess Shale animals, Pangaea's assembly (matching rocks and fossils across continents). Years from absolute dating of a material: Earth's age and the moon's formation (meteorites and moon rocks), the oldest zircons and oldest rocks (the minerals themselves), and the year values attached to the extinctions, which come from dated volcanic layers near the fossil change. Two examples of each earn full credit.

Why: The distinction is that strata give order and absolute dating gives years; most extinction dates combine both.

- Gives two events placed by relative order with a reason
- Gives two events dated by measuring a material with a reason
- Does not claim fossils give ages in years

8. Every model shows some things well and others badly. Name one thing the string shows well and two things about Earth's history it cannot show.

Answer: Shows well: the relative lengths of spans and the order of events, especially how short the Phanerozoic is and how recent humans are. Cannot show: where on Earth events happened; how long each event itself took (the impact was a day, the Siberian eruptions went on for hundreds of thousands of years); how unevenly the record survives (the long Precambrian has few rocks and fossils); and the uncertainty in some dates.

Why: Any two real limits earn credit; vague answers such as 'it is not real' do not.

- Names a strength tied to proportion or order
- Names two specific limits of the model

Individual evidence of learning

Each student submits their own completed recording sheet (guesses, the twenty computed positions, the three measured stretches, q1 and q2) and written answers to q3 through q8. The stretch table with q3 is the primary evidence for the scale target; q5 and q8 are the evidence for reasoning about the textbook chart as a model.

Assessment criteria

Criterion	Proficient looks like
Conversions	At least 18 of 20 positions computed correctly, with millimeters used correctly for the three youngest events.
Proportional reasoning	Computes about 88 percent Precambrian and 12 percent Phanerozoic from measured lengths and uses the numbers to explain why the textbook chart is not to scale.
Dating distinction	Correctly sorts at least four events into 'order from strata and fossils' versus 'years from absolute dating of a material' with a reason for each.
Model critique	Names one strength of the string model and two real limits (for example place, rate of change, unevenness of the surviving record).

Accessibility adaptations

- Run the model as a whole-class human timeline in a hallway, with students holding cards at called-out distances, for groups that need movement or cannot kneel on the floor.
- Provide the conversion table with the first five rows worked and a laminated 'divide by 10' reminder card; allow calculator use throughout.
- Use thick cord, large-print high-contrast cards and bright tape marks for students with low vision; a partner clips while the student calls the distance and checks it on the tape.
- Accept spoken answers to q5 and q8 recorded on a device, and offer a glossary card for eon, Precambrian, Phanerozoic, scale and model in students' home languages.

Low-cost alternative

Use a 4.54 m strip of masking tape stuck to the floor and write event names directly on it with a marker; or use a roll of toilet paper at 1 sheet = 100 million years (about 45 sheets), accepting that the youngest events all land on the last sheet. Either version keeps the same calculations.

Model limitations

The string models durations and order only. It cannot show where events happened, how long each event itself lasted (an impact in a day versus eruptions over hundreds of thousands of years), or how unevenly the rock record survives: the long Precambrian stretch is thinly recorded while the short Phanerozoic is crowded with fossils. The dates are rounded and some are still debated (for example when oxygen release began and when Pangaea was complete). This activity has not been physically tested by the authors; the millimeter-scale placement of the youngest cards is expected to be the practical limit.

Teacher notes

Check conversions against the expected Observations list. The most common error is placing 'Earth forms' at the cut end of the string; a group whose Precambrian stretch measures 406 cm has done this. For q3, accept the group's own measured lengths rather than the ideal 400.1 and 53.9. Keep one finished string pinned along a hallway wall for the misconception slide and the exit ticket.