Stardust to Storytellers

Prehistory Lab Book

Older Learners Edition

INVESTIGATION QUESTION
Does the distance between galaxies increase at the same rate, or do galaxies that start farther apart move more?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

balloon, marker, ruler, paper circles, tape

PROCEDURE

Summarize what you did in your own words.

Data Table

Galaxy Pair	Deflated	Half-Inflated	Fully Inflated
Pair 1: ___ & ___			
Pair 2: ___ & ___			
Pair 3: ___ & ___			

ANALYSIS

Total increase for each pair (Fully Inflated minus Deflated):
Pair 1: _____ Pair 2: _____ Pair 3: _____
Which pair increased the most? _____
Which pair started farthest apart? _____

CONCLUSION

Was your hypothesis correct? What pattern did you find? What does this tell you about how the real universe expands?

CONNECT IT

Edwin Hubble discovered that farther galaxies appear to move away from us faster. Does your data support this? Explain.

THINK FURTHER

Is there any dot on your balloon that is the center of the expansion? What does your answer mean for the real universe?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How do stars produce the elements that make up living things?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

play dough in multiple colors, marble or foil ball

PROCEDURE

Summarize what you did in your own words.

Element Tracking Table

Color Used	Element It Represents	Where It Forms in the Star

ANALYSIS

What happened when you pressed two colors together? Could you separate them back out? What does that tell you about nuclear fusion in a real star?

CONCLUSION

Was your hypothesis correct? What is the connection between stars dying and life existing on Earth?

CONNECT IT

Pick one element in your body -- iron, carbon, calcium, oxygen, or nitrogen. Research what type of star produced it and write two sentences about what you found.

THINK FURTHER

Some elements only form in supernova explosions. What does that mean for how common the ingredients for life are in the universe?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does Earth's size compare to the larger structures it is part of?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Scale Research Table

Layer	Approximate Size or Distance Across
Earth	
Solar System	
Milky Way Galaxy	
Observable Universe	

Scale Comparison

If Earth were the size of a period (about 0.5mm), approximately how large would the Milky Way be? Show your work.

ANALYSIS

Which comparison surprised you the most? Why?

CONCLUSION

What does your cosmic address tell you about Earth's place in the universe?

CONNECT IT

Look up the Pale Blue Dot photograph (Voyager 1, 1990). In 2-3 sentences describe what you see and what it makes you think about.

THINK FURTHER

There are an estimated two trillion galaxies in the observable universe. Write a sentence putting that number in perspective using something from your everyday life.

ADDITIONAL NOTES

INVESTIGATION QUESTION
Does the mass of an object affect how fast gravity pulls it down?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Results Table

Trial	Object 1	Object 2	Which landed first?	Why?
1 -- flat vs. crumpled paper				
2 -- full vs. half-full bottle				

PhET: Gravity and Orbits (phet.colorado.edu)

Change Made	What Happened to the Orbit?
Double the Sun's mass	
Move Earth twice as far away	
Remove the Sun entirely	

ANALYSIS

Why did the two bottles land at the same time even though one was heavier? Why did the flat and crumpled paper NOT land at the same time?

CONCLUSION

Was your hypothesis correct? Explain the difference between gravity and air resistance in your own words.

THINK FURTHER

Galileo supposedly dropped two cannonballs of different sizes from the Leaning Tower of Pisa. What did he discover, and why did people find it so hard to believe at the time?

INVESTIGATION QUESTION
How does the thickness of each Earth layer compare to the others, and what does that tell us about how Earth formed?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Layer Data Table

Layer	Thickness (km)	Main Material	Solid or Liquid?
Crust			
Mantle			
Outer Core			
Inner Core			
Total (Earth's radius)			

Calculate

What percentage of Earth's total radius does each layer take up?
Show your work. Crust: _____% Mantle: _____% Outer Core: _____% Inner Core: _____%

ANALYSIS

Which layer surprised you the most in terms of thickness? Why?

CONCLUSION

Why do you think heavier materials like iron ended up in the center of Earth rather than on the surface?

CONNECT IT

Inge Lehmann discovered the inner core in 1936 by studying earthquake waves. What property of waves allowed her to figure out that the inner core is solid? (Hint: look up P-waves and S-waves.)

THINK FURTHER

Earth's magnetic field is generated by the movement of liquid iron in the outer core. What would happen to life on Earth if the magnetic field disappeared?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How do the same materials transform into three completely different types of rock?

HYPOTHESIS
Hint: try writing it as "If _____, then _____, because _____."

Observation Table

Rock Type	What You Did to Create It	What It Looked/Felt Like	Real World Process
Sedimentary			
Metamorphic			
Igneous			

ANALYSIS

What happened to the original colors and layers through each stage? What does that represent in real rock?

CONCLUSION

In your own words, explain why geologists say 'rocks are always changing.'

CONNECT IT

Research the difference between granite and obsidian. Both are igneous. Why does granite have visible crystals but obsidian does not? What does that tell you about how each formed?

THINK FURTHER

Could a single rock ever complete the full rock cycle and return to its original form? Is there a beginning or end to the rock cycle?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How do different types of plate boundaries produce different geological features?

HYPOTHESIS
Hint: try writing it as "If _____, then _____, because _____."

Boundary Observation Table

Boundary Type	What You Did	What Happened	Real World Example
Divergent			
Convergent (continental)			
Convergent (oceanic)			
Transform			

ANALYSIS

Why did the wet cracker sink under the dry one during the oceanic convergent demo? What property of oceanic crust does this model?

CONCLUSION

In your own words, explain why the edges of tectonic plates are where most of Earth's volcanoes and earthquakes occur.

CONNECT IT

Look up the Ring of Fire. What type of plate boundaries dominate it? Why does it account for roughly 90% of the world's earthquakes?

THINK FURTHER

Pangea broke apart about 175 million years ago. If plates move at roughly 2-5 cm per year, what might Earth's continents look like in another 200 million years?

ADDITIONAL NOTES

INVESTIGATION QUESTION
What happens to dissolved substances in water when it evaporates, and what does this tell us about Earth's water cycle?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Observation Log

Time	Observations (describe what you see inside the bag)
Start	
30 minutes	
60 minutes	
90 minutes	

PhET: States of Matter (phet.colorado.edu)

Temperature Setting	What the Molecules Do
Very cold	
Room temperature	
Very hot	

ANALYSIS

The food coloring stayed in the water but the droplets on the bag were clear. What does this tell you about what evaporation actually does at the molecular level?

CONCLUSION

Explain in 2-3 sentences why the ocean is salty but rainwater is fresh, using what you observed.

CONNECT IT

Desalination plants turn ocean water into fresh drinking water. Based on what you learned today, explain the basic principle behind how desalination works.

THINK FURTHER

If Earth's water cycle is a closed system and the same water keeps cycling, how old is the water you drank today? Where might it have been before?

ADDITIONAL NOTES

INVESTIGATION QUESTION
Can the seven characteristics of life clearly separate all living things from nonliving things, or are there edge cases?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Station Observation Table

Object	Characteristics It Has	Characteristics It Lacks	Your Classification
Candle			
Plant			
Rock			
Toy/Fan			
Yeast			
Bread/Mushroom			

ANALYSIS

Which object was hardest to classify? What characteristic made it tricky?

CONCLUSION

Is the seven-characteristics definition of life perfect? What edge cases does it struggle with?

CONNECT IT

Research whether viruses are considered alive by scientists. Write a 2-3 sentence argument for one side of the debate, using the characteristics of life as your evidence.

THINK FURTHER

If scientists discovered something on another planet that met only 5 of the 7 characteristics, would you call it alive? Where would you draw the line, and why?

ADDITIONAL NOTES

Lesson 10: The First Life
PLATING BACTERIA

SAFETY REMINDERS Read before beginning.

Wash hands before and after. Wear gloves. Never open a plate after it has been sealed. Do not eat or drink during the activity. If any plate shows black or dark green growth, seal it immediately and dispose of it without opening.

INVESTIGATION QUESTION

What surfaces in your environment harbor the most bacterial growth, and does the result match your predictions?

HYPOTHESIS Hint: try writing it as "If _____, then _____, because _____."

SURFACES I AM TESTING

1. _____ 2. _____

3. _____ 4. _____

WHY I CHOSE THESE SURFACES

RESULTS TABLE Do not open plates. Observe through the lid only.

Surface Swabbed	Number of Colonies (estimate)	Colony Color(s)	Colony Size	Other Observations
Control (air exposed)				

ANALYSIS Which surface had the most growth? Which had the least? Did anything surprise you?

CONCLUSION Did your results support your hypothesis? Explain using specific evidence from your results table.

CONNECT IT

Each colony on your plate started as a single bacterium that divided over and over. For roughly 2 billion years, all life on Earth was single-celled. What does your petri dish tell you about how successful that kind of life is?

THINK FURTHER

Your results show what grew on nutrient agar under these conditions. Not all bacteria can grow on this type of agar. What does that mean about whether your results give you the complete picture of what was on each surface?

INVESTIGATION QUESTION
What evidence can we observe that confirms yeast is a living organism?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

active dry yeast, warm water, sugar, clear glass, optional second cup with cool water

PROCEDURE

Summarize what you did in your own words.

Observation Table

Time	Warm Water Cup	Cool Water Cup (if used)	Notes
Start			
5 minutes			
10 minutes			
15 minutes			

ANALYSIS

Which characteristics of life did you observe in the yeast? List them and describe the evidence you saw for each.

CONCLUSION

Was your hypothesis correct? How does observing yeast help us understand what early life on Earth may have looked like?

CONNECT IT

Extremophiles are organisms that live in extreme environments like boiling hot springs or highly acidic water. Look up one example. What does it tell us about where life might exist on other planets?

THINK FURTHER

For over 2 billion years, all life on Earth was single-celled. What conditions might have prevented multicellular life from appearing sooner?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does biological gas production demonstrate the way cyanobacteria changed Earth's ancient atmosphere?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

active dry yeast, sugary cereal (crushed), warm water, sealable plastic bag

PROCEDURE

Summarize what you did in your own words.

Observation Log

Time	Bag Appearance	Estimated Size Change	Notes
Start			
10 minutes			
20 minutes			
30 minutes			

ANALYSIS

What gas inflated the bag? Write the fermentation equation in words:

_____ + _____ + _____ --> _____ + _____

CONCLUSION

How does this model what cyanobacteria did to Earth's early atmosphere? What is similar and what is different?

CONNECT IT

Look up banded iron formations. What are they, and what do they tell geologists about when oxygen first appeared in Earth's atmosphere?

THINK FURTHER

Oxygen was initially toxic to most early life on Earth. How did what could have been a mass extinction event eventually lead to more complex life?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How is the organization of a eukaryotic cell an improvement over a prokaryotic cell, and what evidence supports endosymbiotic theory?

HYPOTHESIS
Hint: try writing it as "If _____, then _____, because _____."

Organelle Function Table

Organelle	Material Used to Model It	Function in the Real Cell
Nucleus		
Mitochondria		
Cell Membrane		
Cytoplasm		
Endoplasmic Reticulum		
Ribosomes		

ANALYSIS

What would happen to the cell if the nucleus were removed? What about the mitochondria?

CONCLUSION

Why was the development of the eukaryotic cell such an important step in the history of life on Earth?

CONNECT IT

Lynn Margulis proposed endosymbiotic theory and was rejected for years. Look up two pieces of evidence that support her theory today and explain each one.

THINK FURTHER

A plant cell has chloroplasts in addition to the organelles an animal cell has. Based on what you know about endosymbiotic theory, where do you think chloroplasts originally came from?

ADDITIONAL NOTES

INVESTIGATION QUESTION
Why did bilateral symmetry become the dominant body plan for complex animals?

HYPOTHESIS
Hint: try writing it as "If _____, then _____, because _____."

Symmetry Sorting Table

Animal	Type of Symmetry	Has Head/Tail?	Typical Lifestyle (predator/filter feeder/etc.)
Jellyfish			
Sea anemone			
Starfish			
Flatworm			
Human			
Fish			

ANALYSIS

What pattern do you notice between symmetry type and how an animal finds food?

CONCLUSION

Why might bilateral symmetry have been a major advantage when predators first appeared during the Cambrian Explosion?

CONNECT IT

Look up Dickinsonia, an Ediacaran organism. Scientists have debated for decades whether it was an animal, fungus, or something else. What evidence has been used on each side?

THINK FURTHER

Humans have bilateral symmetry. What would your daily life look like if you had radial symmetry instead?

ADDITIONAL NOTES

PICK YOUR ACTIVITY

○ Option A: Impression Fossil (clay + object)
○ Option B: Mold and Cast Fossil (clay + object + plaster of Paris)

INVESTIGATION QUESTION

How does the process of making an impression or cast fossil model the way real fossils form in nature, and what does the Cambrian Explosion have to do with why we have fossils at all?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

OBJECT SELECTION

What object did you choose to press? _____

Suggested objects: a shell, a leaf, a small bone, a pinecone scale, a textured rock

Why did you choose it? Consider texture, hardness, and how clearly it might leave an impression.

_____

Would this object fossilize well in real life? Before the Cambrian Explosion, organisms had no hard parts. How does your object connect to what changed during the Cambrian?

_____

_____

OBSERVATION TABLE

Step	What You Did	What You Observed
Pressing the object into clay		
Removing the object		
Option B: Pouring the plaster		
Option B: Removing the cast		

ANALYSIS

The clay in this activity represents _____. The object represents _____. The plaster (if used) represents _____. What details were captured well in your impression? What was lost? How does this connect to why trilobite fossils tell us more than jellyfish fossils?

CONCLUSION

How does this activity model the real process of fossilization? What are the limits of this model? What does it not show that real fossilization involves?

CONNECT IT

The Burgess Shale preserved soft-bodied Cambrian creatures in extraordinary detail. Based on what you now know about how fossils form, why would soft-body preservation be so unusual and so scientifically valuable? What would we not know about the Cambrian Explosion without it?

THINK FURTHER

If you pressed a jellyfish into clay instead of a shell, what do you think would happen? What does that tell you about the gaps in the fossil record? What might the Cambrian ocean have looked like that we will never be able to know?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does physical structure affect the number of organisms that can survive in an ecosystem?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Results Table

Condition	Number of Objects Placed	Number That Stayed After Tilting/Blowing	Percentage That Stayed
Flat tray (no reef)			
Tray with reef structure			

Calculate

Which condition had a higher survival percentage? By how much?

ANALYSIS

How does this model explain why coral reefs support so much biodiversity in real oceans?

CONCLUSION

The concept of surface area is key here. Explain in your own words why more physical complexity in an ecosystem allows more species to coexist.

CONNECT IT

Look up coral bleaching. What causes it, and how does it affect reef biodiversity? Find one recent data point about reef loss.

THINK FURTHER

The Ordovician ended with a mass extinction that destroyed many reef ecosystems. How long do you think it would take for a reef ecosystem to recover after a mass extinction event?

ADDITIONAL NOTES

INVESTIGATION QUESTION

How does the structure of a seed compare to a spore, and why was the evolution of seeds such a turning point for plant life in the Devonian Period?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

SPORE VS. SEED COMPARISON TABLE

Feature	Spore	Seed
Needs moisture to germinate?		
Can survive dry conditions?		
Has a protective coat?		
Carries food supply for embryo?		
Can travel long distances?		
Tied to wet environments?		

OBSERVATION TABLE

Condition	Observation (start)	Observation (end)
Spores on damp paper towel		
Spores on dry paper towel		
Seed on dry paper towel		
Seed sealed in zip-lock bag		

ANALYSIS

What did the moisture test show about the difference between spores and seeds? How does the tough coat of a seed change where a plant can live and reproduce?

CONCLUSION

Before seeds evolved, even the tall Devonian trees were tied to wet environments for reproduction. How did seeds change that? Where could plants go that they could not go before?

CONNECT IT

The tetrapod transition and the seed revolution both happened during the Devonian Period. What do these two events have in common? Why do you think both happened during this same window of time rather than millions of years apart?

THINK FURTHER

Seeds were just the beginning. Later, flowering plants evolved fruit surrounding the seed, which animals could eat and carry away. How did adding fruit to the equation change the relationship between plants and animals? What advantage did fruit-bearing plants have over plants that just dropped their seeds on the ground?

INVESTIGATION QUESTION
How does available oxygen affect combustion, and what does this tell us about why Carboniferous insects were so large?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

candle, matches, small jar, large jar, stopwatch (adult supervision required)

PROCEDURE

Summarize what you did in your own words.

Results Table

Container	Estimated Oxygen Available (relative)	Time Until Candle Went Out
Small jar		
Large jar		
No jar (open air)		

ANALYSIS

What happened to combustion time as the available oxygen increased? Why?

CONCLUSION

Carboniferous oxygen levels reached about 35%. Explain in your own words how this could allow insects to grow to enormous sizes. (Hint: research how insects breathe.)

CONNECT IT

Look up Meganeura and Arthropleura -- two giant Carboniferous invertebrates. Describe each one and explain what body feature limited how large they could grow.

THINK FURTHER

If oxygen levels dropped back to 35% today, which living animals might be most affected in terms of potential body size? Which would be least affected, and why?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does an internal skeleton affect an animal's ability to support weight and grow larger?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Results Table

Creature	Has Internal Support?	Objects Supported Before Collapse	Observations
Without pipe cleaner spine			
With pipe cleaner spine			

Calculate

How many times more weight could the vertebrate creature support? Show your work.

ANALYSIS

Why does an internal skeleton allow vertebrates to grow larger than most invertebrates?

CONCLUSION

What advantages would having an internal skeleton give a Permian land animal compared to an exoskeleton? What disadvantages might an endoskeleton have?

CONNECT IT

Dimetrodon is often mistaken for a dinosaur. Look up the synapsid lineage and explain why Dimetrodon is actually more closely related to you than to any dinosaur.

THINK FURTHER

The Permian Period ended with the Great Dying -- the worst mass extinction in Earth's history. Therapsids (mammal-like reptiles) survived it while many other groups did not. What features might have helped them survive?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does carbon dioxide gas production demonstrate the way volcanic activity during the Permian triggered a mass extinction?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

baking soda, vinegar, small plastic bottle, balloon, funnel

PROCEDURE

Summarize what you did in your own words.

Observation Table

Variable	Your Observation
Amount of CO2 produced (balloon size)	
Speed of reaction	
What happened when you increased baking soda	

PhET: Greenhouse Effect (phet.colorado.edu)

Atmosphere Setting	Temperature Result
No greenhouse gases	
Current atmosphere (today)	
High greenhouse gases (Great Dying model)	

ANALYSIS

How does the balloon in your experiment model what happened to Earth's atmosphere during the Great Dying?

CONCLUSION

The Permian extinction wiped out 96% of marine species and 70% of land species. Based on what you know about CO2 and temperature, explain the chain of events that caused this.

CONNECT IT

Look up the Siberian Traps. How long did they erupt, and what does the scale of that eruption tell you about how much CO2 was released?

THINK FURTHER

Some scientists compare the Permian extinction to potential future scenarios driven by modern climate change. What is similar? What is different?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How did upright posture give early dinosaurs a survival advantage over sprawling reptiles?

HYPOTHESIS
Hint: try writing it as "If _____, then _____, because _____."

Movement Comparison Table

Feature	Sprawling (lizard style)	Upright (dinosaur style)
How legs are positioned		
Energy required		
Speed achieved		
Distance covered		
How tiring it felt		

ANALYSIS

Based on your experiment, what specific advantages would upright posture give an animal in the Triassic environment (open landscapes, competition for food)?

CONCLUSION

Explain why upright posture may have been one of the key reasons dinosaurs eventually came to dominate the Triassic and Jurassic worlds.

CONNECT IT

Look up Eoraptor, one of the earliest known dinosaurs. Where was it found, how big was it, and what did it eat? How does it compare to your mental image of a dinosaur?

THINK FURTHER

The Triassic world was recovering from the worst extinction in Earth's history. Why might this recovery period have been a good time for a new group like dinosaurs to rise to dominance?

ADDITIONAL NOTES

INVESTIGATION QUESTION
What conditions in the Jurassic world made it possible for animals to grow to such extraordinary sizes?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

measuring tape or long string, open space, calculator

Measurement Table

Dinosaur	Length (m)	Equivalent in cars	Equivalent in your heights	Estimated weight
Brachiosaurus (~26m)				
Diplodocus (~27m)				
Stegosaurus (~9m)				
African elephant (for comparison)				

ANALYSIS

What features of the Jurassic environment (climate, plant life, oxygen levels) might have supported gigantism in dinosaurs?

CONCLUSION

Sauropods had very long necks. Research two competing hypotheses for why sauropod necks evolved to be so long. Which hypothesis do you find more convincing?

CONNECT IT

Archaeopteryx is considered one of the earliest known birds. Look up what features it shared with theropod dinosaurs and what features were more bird-like. Draw a simple diagram labeling both.

THINK FURTHER

No land animal today comes close to the size of the largest sauropods. What biological or environmental limits prevent modern animals from reaching those sizes?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does fruit structure reflect the seed dispersal strategy of the plant?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

variety of fruits, plastic knives, paper plates, magnifying glass

Dissection Data Table

Fruit	Number of Seeds	Seed Location	Fruit Characteristics (color, smell, taste)	Likely Dispersal Method
Fruit 1:				
Fruit 2:				
Fruit 3:				
Fruit 4:				

ANALYSIS

What relationship do you notice between fruit characteristics (color, sweetness, size) and how the seeds are likely dispersed?

CONCLUSION

Explain in your own words why the evolution of fruit was such an important development in plant reproduction. How did it change the relationship between plants and animals?

CONNECT IT

Darwin predicted a specific moth based on the shape of an orchid before the moth was ever discovered. Look up this story and explain what it reveals about how coevolution works.

THINK FURTHER

Flowering plants now make up about 90% of all plant species on Earth. What advantages do flowers and fruits give angiosperms over plants that reproduce with cones or spores?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How do impact velocity and projectile size affect crater size and debris distribution?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

shallow tray, flour or sand, rocks or marbles of different sizes, ruler

Crater Data Table

Trial	Projectile Size	Drop Height	Crater Diameter	Debris Distance
1				
2				
3				
4				
5				

ANALYSIS

What relationship did you find between drop height and crater size? Between projectile size and crater size?

CONCLUSION

The Chicxulub asteroid was roughly 10 km across and struck Earth at tens of km per second. Based on your experiment, describe the scale of destruction you would expect.

CONNECT IT

Luis and Walter Alvarez proposed the asteroid theory in 1980 using iridium as their evidence. Why is iridium significant? Why did many scientists initially resist their theory?

THINK FURTHER

Some animals survived the K-Pg extinction while others did not. Based on what you know about what happened after the impact (darkness, cold, food collapse), design the profile of a survivor. What traits would help?

ADDITIONAL NOTES

INVESTIGATION QUESTION

How does the concept of ecological opportunity explain the rapid diversification of mammals after the K-Pg extinction, and what specific body changes does each new niche require?

THE ANCESTOR

THE ANCESTOR
Small, shrew-like early Paleocene mammal
Size of a mouse | Warm-blooded
Flexible diet | Can burrow and climb

For each niche below, describe the body changes needed, find a real Cenozoic mammal that filled it, and note approximately how long after the extinction that mammal appeared.

← THE BURROWER *Underground	roots, worms, soil insects*	**THE SWIMMER →** *Water	fish or aquatic plants*
← THE GLIDER *Trees	air travel	insects or fruit*	**THE LARGE GRAZER →** *Open plains	grasses and low plants*
← THE INSECT EATER *Specialized insect hunter	possibly nocturnal*	**THE FRUIT EATER →** *Forest canopy	fruit, leaves, grasping hands*

NICHE 1: THE BURROWER

THE BURROWER — *Lives underground, eats roots, worms, and soil insects*

Body changes needed: _____

Real Cenozoic mammal that filled this niche: _____

Approx. how long after extinction did it appear? _____

NICHE 2: THE SWIMMER

THE SWIMMER — *Lives in or near water, eats fish or aquatic plants*

Body changes needed: _____

Real Cenozoic mammal that filled this niche: _____

Approx. how long after extinction did it appear? _____

NICHE 3: THE GLIDER

THE GLIDER — *Lives in trees, moves through the air, eats insects or fruit*
Body changes needed: _____

Real Cenozoic mammal that filled this niche: _____

Approx. how long after extinction did it appear? _____

NICHE 4: THE LARGE GRAZER

THE LARGE GRAZER — *Lives on open plains, eats grasses and low plants*
Body changes needed: _____

Real Cenozoic mammal that filled this niche: _____

Approx. how long after extinction did it appear? _____

NICHE 5: THE INSECT EATER

THE INSECT EATER — *Highly specialized for catching insects, possibly nocturnal*
Body changes needed: _____

Real Cenozoic mammal that filled this niche: _____

Approx. how long after extinction did it appear? _____

NICHE 6: THE FRUIT EATER

THE FRUIT EATER — *Lives in forest canopy, eats fruit and leaves, needs grasping hands*
Body changes needed: _____

Real Cenozoic mammal that filled this niche: _____

Approx. how long after extinction did it appear? _____

ANALYSIS

Which niche required the most dramatic body changes from the ancestor? Which required the least? What does that tell you about how far evolution can push a body plan when the right conditions exist?

CONCLUSION

Explain in your own words what adaptive radiation is and why the K-Pg extinction created the conditions for it. Why was the ancestor's generalist nature an advantage rather than a disadvantage in the post-extinction world?

CONNECT IT

Marsupials are found mostly in Australia today because continental drift isolated that landmass before placental mammals could reach it. Research when Australia separated from other landmasses and what happened to its mammal populations after that separation. What does the Australian mammal fossil record tell us about what happens when evolution runs in isolation?

THINK FURTHER

True large mammals do not appear in the fossil record until roughly 10 million years after the K-Pg extinction. Research what scientists think explains that gap. Why did it take so long for mammals to grow big, even though the large predator and large grazer niches were immediately available?

INVESTIGATION QUESTION
How does beak shape reflect a bird's ecological niche, and what does this tell us about how natural selection works?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Beak Effectiveness Table

Beak Tool	Food Type Tested	Success Rate (1-5)	What Made It Effective or Ineffective
Eyedropper			
Chopsticks			
Nutcracker			
Tweezers			
Strainer			
Tongs			

ANALYSIS

What pattern do you notice between beak shape and the type of food it can access? What would happen to a bird with the wrong beak shape in a given environment?

CONCLUSION

Explain the connection between bird beaks today and the theropod dinosaurs they evolved from. What specific features were inherited and which were modified?

CONNECT IT

Research the Grants' study of Darwin's finches in the Galapagos. How quickly did beak shape change in response to drought? What does this tell us about the pace of evolution?

THINK FURTHER

If a new food source appeared in an environment (for example, a new plant with very hard seeds), predict what would happen to the beak shapes in a population of birds over many generations.

ADDITIONAL NOTES

INVESTIGATION QUESTION
How does blubber provide insulation, and what does this tell us about the adaptations of Ice Age megafauna?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

disposable gloves, Crisco or shortening, large bowl, ice and cold water, optional thermometer

Results Table

Condition	Time in Ice Water	Comfort Level (1-10)	Notes
Bare hand			
Blubber glove hand			

If available, record temperatures:

Temperature inside bare glove after 30 seconds: _____ C Temperature inside blubber glove: _____ C

ANALYSIS

What physical property of fat makes it a good insulator? (Hint: think about how heat moves through different materials.)

CONCLUSION

Explain why Ice Age megafauna like the woolly mammoth were so dependent on both blubber and fur for survival. What happened to them when the climate warmed?

CONNECT IT

Research the overkill hypothesis and the climate hypothesis for megafauna extinction. Find one piece of evidence for each side and write a brief argument for which you find more convincing.

THINK FURTHER

Modern whales have extremely thick blubber layers. What does this tell you about their evolutionary history and the environment their ancestors lived in?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How do glaciers reshape landscapes, and what evidence do they leave behind?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

large tray, damp sand, small rocks and pebbles, large ice block

Observation Table

Feature Observed	Description	Real World Glacial Feature This Represents
Rock movement		
Valley formation		
Sediment deposit (moraine)		
Meltwater pattern		

ANALYSIS

What is the difference between glacial erosion and glacial deposition? Find an example of each in your experiment.

CONCLUSION

The Great Lakes were carved by glaciers during the last Ice Age. Based on what you observed in this experiment, explain the process that created them.

CONNECT IT

Research the Milankovitch cycles. What are the three orbital changes that trigger ice ages? How long does each cycle take? Why are they significant?

THINK FURTHER

Sea levels drop dramatically during ice ages as water is locked in glaciers. If sea levels dropped by 120 meters (as they did during the last Ice Age), what parts of the modern world would be above water? How would this affect human migration routes?

ADDITIONAL NOTES

INVESTIGATION QUESTION
How significant is the opposable thumb to human and primate survival, and what does this tell us about primate evolution?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

small objects to pick up, timer or stopwatch, paper and pencil

Dexterity Test Results

Trial	Condition	Objects Picked Up Per Minute	Notes on Difficulty
1 Normal (with thumbs)			
2 No thumbs (folded in)			
3 Two fingers only			
4 One hand only			

ANALYSIS

Calculate the percentage decrease in effectiveness when thumbs were removed. What specific tasks became most difficult?

CONCLUSION

Beyond picking up objects, list five specific activities in your daily life that depend on opposable thumbs. What does this tell you about how important this trait was to human evolution?

CONNECT IT

Jane Goodall discovered chimps making and using tools in 1960. Look up what she observed and how it changed the scientific understanding of what makes humans unique.

THINK FURTHER

Primates share many traits including forward-facing eyes, grasping hands, and relatively large brains. These traits evolved in tree-living ancestors. How would life in trees select for each of these traits?

ADDITIONAL NOTES

INVESTIGATION QUESTION

How does bipedal locomotion compare to quadrupedal locomotion in efficiency and load-carrying ability, and how does that difference connect to the evolution of larger brains in the hominin lineage?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

Marked walking path (10 to 15 feet), small objects to carry, two bowls or cups, stopwatch, step counter or self-counted steps, paper and pencil for recording

DATA TABLE

Test	Upright Steps	Upright Time	All Fours Steps	All Fours Time
Round 1: Baseline (avg of 3)				
Round 2: Load Carry (objects/trip)				
Round 3: Multitask Sort (accuracy)				

ROUND 2: LOAD CARRY DETAIL

Upright: objects carried per trip _____, time per trip _____

All fours: objects carried per trip _____, time per trip _____

Percentage difference in objects carried: _____% more upright than on all fours

Show your calculation here:

ROUND 3: MULTITASK SORT DETAIL

Upright: objects sorted correctly per trip _____, time per trip _____

All fours: objects sorted correctly per trip _____, time per trip _____

What happened to accuracy and speed when sorting on all fours?

_____

ANALYSIS

Which round showed the biggest difference between upright and all fours? Why do you think that round was most affected? What does the multitasking round tell you that the baseline round alone cannot?

CONCLUSION

Research has shown that humans use about 75% less energy per unit of distance walking bipedally compared to chimpanzee knuckle-walking. Based on your data and that finding, explain in your own words why bipedalism may have been a key factor in the evolution of larger brains in the hominin lineage. Connect energy savings, calorie availability, and brain metabolism in your answer.

CONNECT IT

The Laetoli footprints in Tanzania are about 3.7 million years old and show clear evidence of bipedal walking. Look them up. Who made them, and what do they tell us about when upright walking evolved? How much time separates the Laetoli footprints from the first evidence of significantly enlarged brains in the hominin fossil record? What does that gap suggest about the relationship between bipedalism and brain size?

THINK FURTHER

Bipedalism came with real costs: it made early hominins slower than most four-legged predators and exposed vital organs. Look up the obstetric dilemma and explain how the same wide pelvis that makes efficient bipedal walking possible also creates problems for human birth. How does the human body try to balance these two competing demands? What does that tradeoff tell you about how evolution works?

INVESTIGATION QUESTION
What does the process of making a stone tool reveal about the cognitive abilities of early Homo?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

bars of soap, plastic knives, toothpicks, paper towels or tray

PROCEDURE

Summarize what you did in your own words.

Tool Making Reflection Table

Question	Your Response
What was most difficult about shaping the tool?	
How many steps ahead did you have to plan?	
What would happen if you made a mistake? Could you fix it?	
How long did it take to make something functional?	

ANALYSIS

What specific cognitive skills does tool making require? List at least four and explain each.

CONCLUSION

Researchers have found that making an Acheulean handaxe requires planning multiple steps ahead. What does this tell us about the intelligence of Homo erectus compared to earlier hominins who only made Oldowan tools?

CONNECT IT

Look up the Oldowan and Acheulean tool traditions. How much time separates them? What was the key innovation of the Acheulean handaxe?

THINK FURTHER

Fire changed human life in multiple ways beyond just warmth. List at least three ways that controlled use of fire would have changed early human society, diet, and survival.

ADDITIONAL NOTES

INVESTIGATION QUESTION
What environmental conditions and human adaptations made the global spread of Homo sapiens possible?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

Migration Route Table

Destination	Approximate Date of Arrival	Route Taken	Key Environmental Factor That Made It Possible
Europe			
East/Southeast Asia			
Australia			
North America			
South America			

ANALYSIS

What role did Ice Age sea level drops play in human migration? Name at least two specific land bridges that were exposed.

CONCLUSION

What combination of physical, cognitive, and cultural traits allowed Homo sapiens to survive in such a wide range of environments, from tropical rainforests to Arctic tundra?

CONNECT IT

The Monte Verde site in Chile suggests humans may have arrived in South America earlier than the traditional Bering land bridge theory allows. Look up the debate and explain the competing pieces of evidence.

THINK FURTHER

Humans are the only species to have colonized every continent on Earth (excluding Antarctica permanently). What does this tell you about human adaptability compared to other animals?

ADDITIONAL NOTES

INVESTIGATION QUESTION
What does cave art tell us about the cognitive and social lives of early Homo sapiens?

HYPOTHESIS

Hint: try writing it as "If _____, then _____, because _____."

MATERIALS

brown paper, charcoal or earthy-tone crayons, natural pigments if available

PROCEDURE

Summarize what you did in your own words.

Cave Art Analysis Table

Cave Site	Location	Age (years)	What Is Depicted	Why It Is Significant
Chauvet				
Lascaux				
Altamira				
El Castillo (Spain)				

ANALYSIS

What themes appear most often in cave art across different sites and cultures? What might this suggest about early human concerns and experiences?

CONCLUSION

Some researchers argue cave art is evidence of symbolic thinking -- the ability to represent ideas with images. Why is symbolic thinking considered a major cognitive milestone? What other behaviors also show symbolic thinking?

CONNECT IT

Recent research suggests some cave art in Spain may be 65,000 years old, predating the arrival of modern humans in Europe. Look up this debate. What evidence exists, and why are some scientists skeptical?

THINK FURTHER

Cave paintings survived for tens of thousands of years. What does the act of making art that might outlast you tell us about how early humans thought about time, memory, and community?

ADDITIONAL NOTES