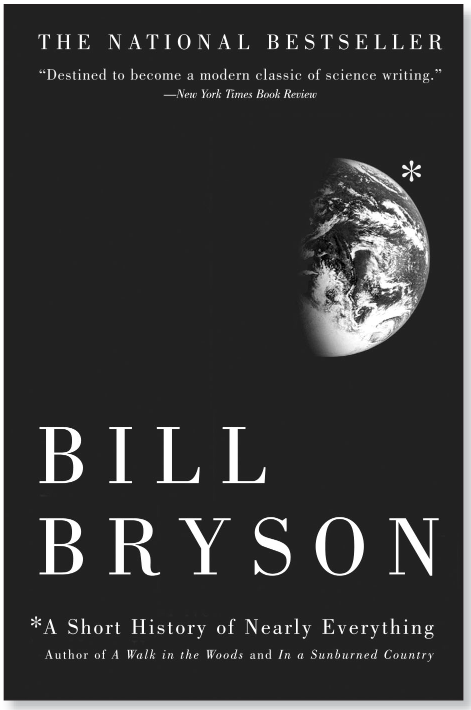
A Short History of Nearly Everything

Written by Bill Bryson



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READING LEVEL: 9TH Grade

"This wonderful book is highly recommended as an inspiration to budding scientists and those who spend moments wondering about the world around them. Essential."

—*Choice* (American Library Association)

WINNER, 2004 Outstanding Academic Title, *Choice Magazine*

WINNER, 2004 Aventis General Prize, which celebrates the very best in popular science writing for adult readers.

about this book

In his introduction, Bill Bryson states "This is a book about how we went from there being nothing at all to there being something." *A Short History of Nearly Everything* is a book about *how* science works, and *how* scientists know *what* they know. He includes many stories and examples of science (and scientists) in action. What are some of the answers to the Big Questions? How old is the universe? How big is the Earth? What is life? How did life begin? How did humans develop? As is so often the case in science, the answer is: "No one really knows." It is also a book about "What we *don't* know and *why* don't we know it."

The book is filled with such interesting statements as: "How can scientists so often seem to know nearly everything but then still can't tell us whether we should take an umbrella with us to the races next Wednesday?" It is a fascinating trip through the history of science, and would be a great supplement to your textbook.

about the author

BILL BRYSON is a bestselling author of several humorous travel books. He received the Aventis Prize for Science writing in 2004 and the Descartes Prize for science communication in 2005 for *A Short History of Nearly Everything.*

about the guide writer

CINDY MARIS has a Ph.D in Chemical Oceanography and has been teaching High School and AP Chemistry for 15 years. She has written numerous lab exercises, demonstrations and worksheets for use in her classroom.

note to teachers about the guide

This guide is an attempt to make this book a useful addition to your science curriculum in several courses. You will probably not use the entire book in any one class, but sections can be used for many different science classes. I have tried to identify the chapters that would be of interest to each subject. Obviously, many chapters overlap and are of interest to several disciplines. The book is probably most appropriate for high school and college students.

In the guide, I have tried to list some of the Big Questions Bryson asks (and sometimes answers) in the book. Be warned: If you use this book in your class, you as a teacher will have to be willing to say "I don't know" in answer to students' questions. Very often the answer to the questions listed in the guide is "*No one* knows." National Science Standards currently emphasize teaching Science as Inquiry. The book is especially good at describing the history of science and "how science as inquiry works." It emphasizes that science is about questions, not answers, and that there are no easy answers. Bryson does explain what we *do* know, and *how* we know it, but in a world where students are used to sound bites and easy answers, a book about thinking and questioning is important.

In this reading guide, most chapters contain several types of Teaching Ideas and reading prompts:

Demonstrations and Analogies: Descriptions of class demonstrations or analogies described by Bryson to illustrate abstract ideas. These can be used as pre-reading class exercises to increase interest in the chapters. As a Class Activity, enlist students to help with these demonstrations, either before or after reading.

Statements to consider: Many of these are quotes from other books, or from scientists Bryson interviewed. These can be used before reading to say, "Read the chapter to find out why he says this" or after reading to say, "What do you think?"

Thinking questions: Many of these are the big, unanswered, interesting questions of science, and the chapter often examines how we know what we *do* know.

Information based questions are included to help you find which chapters apply to your curriculum.

Organization of the book by subject:

Astronomy: 1, 2, 3, 4

Biology: 19 - 30

Chemistry: 1, 2, 7 - 12, 16 (gas laws, elements on earth), 17, 18 (properties of water), 22 (isotopes), 26

Geology: 4 - 7, 12 - 15, 27

Meteorology: 17, 27

Oceanography: 17, 18

Physics: 1, 2, 4, 11

Mathematics: 1, 4, 26

(Obviously, there is a lot of overlap between disciplines, so check out other chapters, too. The book includes an index to help you.)

A List of the big questions from the entire book. Add "How do we know?" to all of them. Many are not answered because "we just don't know."

- How old is the universe? How did the Universe begin?
- How big is the universe? What's "outside" the Universe? Is it "open" or "closed?"
- Where did the elements come from?
- Is there life on other worlds? Is life rare or "inevitable?"
- How old is the Earth? How big is the Earth?
- Where is the Earth in the universe?
- How do we know the earth's crust is moving? How does that affect the world?
- How small is an atom? What is an atom?
- What is life made up of? What is a cell? What is the most successful life form on Earth?
- How diverse is life? How many species are there?
- Why/How did life begin? Why/How did it begin just once?
- Why did the dinosaurs die out? What causes extinctions? How do extinctions affect life?
- What is DNA? Why is 97% of DNA "useless?"
- What is the "Human genome?" What is "human?"
- Why was our human evolution (or any evolution) "risky?"
- What influences the Earth's climate? Why is today's climate abnormal?
- What may be the effects of global warming?
- Why are there no "missing links" in the fossil record?
- Where did humans come from? What is our human ancestry? How did we migrate around the world?
- Why is your life amazing?
- Are we both the living universe's supreme achievement and its worst nightmare?

teaching ideas, discussions by chapter:

INTRODUCTION

Bryson lists some questions he considered when he was young, and then again the ones that made him want to write this book. What are the "Big Questions" you wish a science text book would answer?

CHAPTER 1:

Demonstration: Put TV on a blank station and watch the birth of the universe.

Statement to consider: Biologist J.B.S. Haldane once observed, "The universe is not only queerer than we suppose, it is queerer than we can suppose."

1. How small is a proton?
2. How small was the "singularity" that began the universe? What was "outside" it?
3. How did the universe begin?
4. How did long did it take to go from there being "nothing" to being "stuff?"
5. How old is the universe?
6. What does the static on a blank TV station have to do with the Big Bang?
7. Why is the universe "unlikely?"
8. What is "outside" the universe?

teaching ideas, discussion (continued)

CHAPTER 2:

Demonstration: Read the "Trip Across the Solar System."

Analogy: Solar system: If the Earth is the size of a pea, Jupiter is 1,000 feet away and Pluto is a bacteria 1 1/2 miles away. The nearest star is 10,000 miles away!!

Where is "here?" Where is the Solar system in the universe?

1. Is Pluto really a planet?
2. How big is the solar system?
3. What's wrong with the picture of the solar system in most textbooks?
4. What does a comet from the Oort cloud have to do with Manson, Iowa?
5. Is there life on other planets? What is Drake's Equation?

CHAPTER 3:

Analogy or Demonstration: Scatter salt on a tablecloth, then change the tablecloth. This is what Evans can do to find a new supernova (except on a parking lot full of tablecloths!)

1. What is a supernova and why are they important to us?
2. What would it be like if a star exploded near us?
3. How are elements created? Where do the heavier elements come from?
4. How does it feel to find out that you are made of "star stuff?"
5. How was the Solar system formed?
6. Have you ever known anyone like Zwicky who had a big idea but didn't know why it worked?
7. Compare Evans' method of finding a supernova to the new computerized methods. Which would you prefer? Do you agree with Evans?

CHAPTER 4:

Statement to consider: Newton's Laws are the first universal laws of nature ever propounded by a human mind.

1. How big is the Earth?
2. Why did a group of French Scientists go to Peru to measure the Earth?
3. What is triangulation?
4. How was trigonometry used to measure the Earth and the distance from Earth to Sun?
5. How did a bet lead to the greatest mathematical book ever written?
6. Is the Earth a perfect sphere? What does it matter?
7. What is a transit of Venus?
8. How do you measure the distance from Earth to the Sun?
9. How do you "weigh" the Earth? How do you weigh another planet?
10. How did Cavendish weigh the Earth?
11. Why do you think Newton, Cavendish, and Gibbs were secretive about their discoveries? Compare them to others like Watson (26) (who was not secretive!).
12. How did Triangulation help determine the size of the Earth? Distance of Earth to Sun? Use Triangulation to measure something around your school, like the height of a tree.

CHAPTER 5:

Statement to consider: In the 19th century, we knew the "order" of ages, but had no idea how long any of those ages were!

1. How old is the Earth?
2. Why does Bryson call Hutton's book *Theory of the Earth* "maybe the least read important book in science (if not for so many others)?"
3. How do ancient fossil clamshells get to the mountaintops?
4. How was this explained by 18th-century geology?
5. What were the theories of plutonism and neptunism?
6. How was this explained by 19th-century geology?
7. What were the theories of Catastrophism and Uniformitarianism?
8. Who was Lyell? Why was he called "the father of geologic thought?"
9. How is geologic time divided and classified?
10. Did geologists in the 19th century believe the earth was 6,000 years old (per Bishop Usher)?
11. What were some of the attempts to determine age of Earth?
12. How did Lord Kelvin undermine geology?
13. Why do you think measuring the age of the Earth was so much more difficult than measuring its mass or size?

CHAPTER 6:

1. Who were the great fossil hunters of the 19th century and what are their stories?
2. What's the story behind an unlucky man, an unscrupulous nasty man, and an American rivalry?
3. Where was the first dinosaur fossil discovered?
4. Why did Europeans in the 18th century disdain American animals?
5. What was worrisome (at the time) about Cuvier's original theory of extinctions?
6. Why were fossils an important piece of geologic evidence?
7. Why does Bryson consider Mantell "unlucky?"
8. Why does Bryson consider Owen "unscrupulous?"
9. How did a rivalry between Cope and Marsh help the study of dinosaurs and paleontology?
10. What was the problem with the number of fossils and geologic eras and extinctions and the proposed age of the Earth?
11. Why was the age of the Earth still thought to be 20-200 million years?

teaching ideas, discussion (continued)

CHAPTER 7:

Statement to consider: "In late 18th century…Scientists everywhere searched for and sometimes believed they had actually found things that just weren't there" (like *elan vital*).

1. Why is The Periodic Table of the Elements called "the most elegant organizational chart ever devised?"
2. How old is the Earth?
3. What are the elements and how were they discovered?
4. How did a Swedish pharmacist discover eight elements and why have you never heard of him?
5. What is alchemy?
6. What was *elan vital*?
7. How did a French noble (and his wife) "found" chemistry, and then get beheaded?
8. What was the "drug of choice" in the early 19th century? How did this drug lead to the death of a famous chemist?
9. How big is Avogadro's number?
10. How did a card playing, crazed looking Russian chemist bring order to chaos?
11. Why is chemistry broken up into organic and inorganic?
12. What is radioactivity and what does it have to do with the age of the earth?
13. How did radioactivity undermine Lord Kelvin's age of the earth?
14. What is the current estimate for the age of the Earth?

CHAPTER 8:

Analogy: If galaxies were the size of peas, there are enough galaxies to fill the old Boston Garden.

1. How old is the universe?
2. How big is the universe?
3. How many galaxies are there?
4. Who is Gibbs, "the most brilliant man that most people have never heard of?" What did he do?
5. Why did scientists think there was "not much left for scientists to do" in the late 19th century?
6. What is quantum theory and why is it so strange?
7. What does $E = mc^2$ mean and why is it so important?
8. How does radioactivity work?
9. What is relativity?
10. Why do we think the universe is expanding?
11. How were women used as "computers?"

CHAPTER 9:

Analogy 1: The relative size of an atom is to a millimeter as a sheet of paper is to the Empire State building.

Analogy 2: If an atom is the size of a cathedral, the nucleus is a fly, but the fly is many thousands of times heavier than the cathedral.

Statement to consider: "You probably contain about a billion atoms from Shakespeare."

1. How small is an atom?
2. Why do you think Feynman said, "The most profound scientific statement ever made is 'All things are made of atoms.'"
3. Rutherford is often used as an example of a scientist who was looking for one thing but found something else. Why?
4. What is a quantum leap and why is it strange?
5. The very small is called "an area of the universe our brains just aren't wired to understand." Why do you think that is?
6. Why are the rules governing the very small different from the rules governing what we can see?

CHAPTER 10:

1. How old is the Earth?
2. What is radiocarbon dating? What is radioactive dating? What forms of radioactive dating are used to determine the age of the Earth?
3. Why is it a good thing that your car uses unleaded gasoline?
4. What does the determination of the age of the Earth have to do with unleaded gasoline?
5. Why does Bryson say Thomas Midgley had "an instinct for the regrettable that was almost uncanny?" What did Midgley invent?
6. What does Bryson think is the "worst invention of the 20th century?" Why?
7. Why should you be aware of "who funded this scientific study?"
8. Who is Claire Patterson and how did he help determine the age of the Earth?
9. Research and discuss any other examples, such as the story of Tetraethyl lead, in which a large corporation (or maybe government?) influences science reporting.

CHAPTER 11:

Statement to consider: "Physics is a search for ultimate simplicity."

1. How old is the universe?
2. What is the connection between tiny subatomic particles and the start of the universe?
3. What is CERN? What is a cloud chamber?
4. What are some of these subatomic particles?
5. Can you keep breaking down subatomic particles forever?
6. Why does Bryson quote: "It is almost impossible for the non-scientist to discriminate between the legitimately weird and the outright crackpot?" What do you think of this statement?
7. How can the universe be younger than its oldest stars?
8. What is "dark matter"?

Bryson summarizes this section on p. 172: "We live in a universe whose age we can't quite compute, surrounded by stars whose distances we don't altogether know, filled with matter we can't identify, operating in conformance with physical laws whose properties we don't truly understand."

Is this statement frustrating to you? Or does it make you want to learn more? Are you annoyed that Bryson doesn't "answer" the questions he poses?

CHAPTER 12:

Statement to consider: In 1944, a book reviewer complained that Arthur Holmes "…presented the arguments [for continental drift] so clearly and compellingly that students might actually come to believe them." What is the irony of that statement? Does it affect how you think science works?

Analogy: The European and North American plates are moving about as fast as your fingernails grow.

1. What are "continental drift", "sea floor spreading" and "plate tectonics?"
2. Why was there such resistance to the idea of "continental drift?"
3. What is the current evidence for plate tectonics?
4. What was Pangaea?
5. Where does all the sediment go?
6. How fast are the European and North American plates moving?
7. Is it a coincidence that Earth is the only planet with plate tectonics and the only planet with life?
8. How do plate tectonics explain earthquakes, island chains, mountains, etc?
9. What do we still not understand about plate tectonics?

CHAPTER 13:

Analogy 1: Think of the Earth's orbit as a kind of freeway on which we are the only vehicle, but which is crossed regularly by pedestrians who don't know enough to look before stepping off the curb.

Analogy 2: In 1991, an asteroid passed the Earth at a distance of 106,000 miles—the cosmic equivalent of a bullet passing through one's sleeve without touching the arm. It wasn't noticed until after it passed the Earth.

1. How did the dinosaurs become extinct?
2. What does a comet impact on Jupiter have to do with mass extinctions on Earth?
3. What does a meteor crater in Iowa tell us about the extinction of the dinosaurs?
4. How dangerous would it be if the Earth was hit by a meteor? Is there anything we could do about it?
5. How many species became extinct at the KT (Cretaceous Tertiary) boundary?
6. Why was there such resistance to the connection between impacts and extinctions?

CHAPTER 14:

Analogy 1: If the Earth were the size of an apple, we haven't broken the skin.

Analogy 2: To attempt to drill the "mohole" (the discontinuity between crust and mantle) is "like trying to drill a hole in the sidewalks of New York from atop the Empire State building using a strand of spaghetti."

Statement to consider: "We understand the interior of the Sun far better than we understand the interior of the Earth."

1. What is the inside of the Earth like? How do we know? What difference does it make?
2. How did the Earth get its crust?
3. What does volcanic ash in Nebraska have to do with Yellowstone Park?
4. How do we know the Earth's interior has "layers?"
5. Where were the largest earthquakes in history? How damaging were they?
6. Where are earthquakes common?
7. How is the Earth's magnetic field formed? Why does it reverse from time to time?
8. Why would it be bad to lose the Earth's magnetic field?
9. Why can't we predict earthquakes or volcanic eruptions?

CHAPTER 15:

Statement to consider: "Life is infinitely more clever and adaptable than anyone had ever supposed. This is a good thing, for we live in a world that doesn't altogether seem to want us here."

1. Identify a volcanic caldera 45 miles across, which has erupted about 100 times. (Its last eruption was 1,000 times greater than Mt. St. Helen's.) The blast, two million years ago, produced enough ash to cover California to a depth of 20 ft. Where is this caldera located? (Answer: Yellowstone's volcano)
2. How do volcanic eruptions influence climate?
3. How do we know that Yellowstone won't erupt again? What would happen if it did?
4. How did the Grand Teton Mountains form?
5. How does a geyser work?
6. What is the connection between Yellowstone and the human genome project?
7. What is an "extremophile"?

CHAPTER 16:

1. Why is there life on Earth (but apparently no where else in the solar system)?
2. What are the dangers of being under water in a deep water dive? Why?
3. What is "the bends"? What is dangerous about it? How can it be prevented?
4. Why did John Scott Haldane expose himself to carbon monoxide?
5. How and why did his son, J. S. B. Haldane, experience collapsed lungs, perforated eardrums and seizures? How did he get others to do the same?
6. Where did Aldous Huxley get the ideas for the genetic manipulation in *Brave New World*?
7. What is nitrogen narcosis (intoxication)?
8. Consider the statement, "In terms of adaptability, humans are pretty amazingly useless." Why does Bryson say this?
9. What about the environments on other planets makes them inhospitable to life?
10. Discuss the "necessities of life": location, tectonics, twin planet, timing. Which do you think is most important? Why? Can you think of any more?
11. What elements are needed for life? What is the abundance of the elements on Earth?
12. What is the difference between the element and the compounds it makes?
13. Did we evolve because the Earth is hospitable to life, or is Earth hospitable to us because we evolved here? What do you think?
14. Are we here because the universe is hospitable to us, or is the universe hospitable to us because we are here?

Very interesting statement to consider about us (intelligent life): "If you wish to end up as a moderately advanced, thinking society, you need to be at the right end of a very long chain of outcomes involving reasonable periods of stability interspersed with the right amount of stress and challenges and marked by a total absence of real cataclysm. We are very lucky to find ourselves in this position."

teaching ideas, discussion (continued)

CHAPTER 17:

Analogy 1: "If you shrink the Earth to the size of a desktop globe, the atmosphere would be about the thickness of a couple of coats of varnish."

Analogy 2: "To move a couple of thousand feet closer to the sun (like up a mountain) is like taking a step closer to a bushfire in Australia when you are standing in Ohio, and expecting to smell smoke."

Analogy 3: "A fluffy cloud may contain about enough water to fill a bathtub."

Analogy 4: "A six-inch cube of Dover chalk contains a thousand liters of compressed CO^2."

1. Why is it a good thing that we have an atmosphere?
2. What is the danger of living at high altitudes?
3. What are the layers of the atmosphere?
4. Why does it get colder as you climb a mountain?
5. What influences air movement in the atmosphere?
6. How are clouds classified?
7. What was the "salinity crisis"?
8. How do the oceans influence climate and weather?
9. How does the Gulf Stream influence weather?
10. What is "thermohaline circulation"?
11. Does life help keep the world hospitable? Are we humans disrupting this balance?

CHAPTER 18:

Analogy 1: "If all the ice in Antarctica melted, sea level would rise 200 feet. If all the water in the atmosphere fell as rain, the oceans would deepen by an inch."

Analogy 2: "It's as if our firsthand experience of the surface world were based on the work of five guys exploring on garden tractors after dark."

Analogy 3: "For every pound of shrimp harvested, about four pounds of fish… are destroyed."

Statement to consider: "We have better maps of Mars than we have of our own oceans."

1. What are the unique properties of water? Why are we looking for water on other planets?
2. Why shouldn't you drink seawater?
3. Where is most of the water of the world located?
4. Why should our world be called "Water" instead of "Earth"?
5. Why do we know so little about the oceans?
6. What were some of the earliest deep ocean exploration vessels? The most recent?
7. Why is it so much harder to build a deep ocean exploration vessel than a space exploration vessel? What are some difficulties involved in each?
8. Are the depths and floor of the ocean "lifeless," flat and uninteresting?
9. Why do you think we seem to be more interested in space exploration than ocean exploration?
10. Why is ocean exploration so difficult?
11. Where is there a world independent of the sun?
12. What do we know about life beneath the seas?
13. How do scientists study life beneath the surface?
14. Where does most life in the sea occur? Why?
15. Why is knowledge of the ocean life important to fishermen?
16. Discussion question: "We know very little about Earth's biggest system." What do you think about this statement?

CHAPTER 19:

Analogy 1: Protein synthesis: By all the laws of probability, proteins shouldn't exist. Imagine 1,055 slot machines, with 22 symbols on each wheel. How long would you have to pull the handle before all 1,055 symbols came up in the right order? Effectively forever.

Analogy 2: "It is rather as if all the ingredients in your kitchen somehow got together and baked themselves into a cake, but a cake that could divide when necessary and produce more cakes!"

Statement to consider 1: "Life is amazing and gratifying, perhaps even miraculous, but hardly impossible—as we repeatedly attest with our own modest existences."

Statement to consider 2: "Whatever prompted life to begin, it happened just once."

Statement to consider 3: One of biology's great unanswered questions addresses this idea: "…if you make monomers wet they don't turn into polymers—except when creating life on Earth. How and why did it happen then and not otherwise?"

1. Describes Miller's experiment. What does it have to do with the origin of life?
2. What is a protein? Why is it hard to make them? What is so strange about protein synthesis?
3. Discuss the statement: "It is little wonder we call it the 'miracle of life.'"
4. What makes something "life"?
5. Discuss the statement: "Living things are collections of molecules, like everything else."
6. What makes life "miraculous"?
7. When did life begin on Earth?
8. What is the theory of "panspermia"? What are some issues with it?
9. Why does Ridley state: "All life is one."?
10. What is a stromatolite?
11. What was early life like? Is there any evidence of it still existing today?
12. How do scientists study early life?
13. What was the world like 3.5 billion years ago?
14. How long ago did life begin?
15. How long ago did complex life begin?
16. What are mitochondria? Where do they come from? What is strange about them?

CHAPTER 20:

Analogy: "A single bacterium (dividing in nine minutes) could theoretically produce more offspring in two days than there are protons in the universe."

1. What is the most abundant form of life on the world?
2. What type of organism is Bryson talking about when he states: "This is their planet. We are on it only because they allow us to be."? Why does he say this? Do you agree?
3. What do bacteria do for us?
4. Where can bacteria live?
5. How are very small organisms classified?
6. Comment on this statement: "Biology, like physics before it, has moved to a level where the objects of interest and their interactions often cannot be perceived through direct observation."
7. Why do microbes want to hurt us? *Do* they want to hurt us?
8. Discuss the statement: "Too much efficiency is not a good thing for any infectious organism."
9. How do our bodies fight bacteria?
10. What is "antibiotic resistance"?
11. What is a virus?
12. Comment on some of the epidemics Bryson describes. A concern today is the "bird flu". Does reading about these earlier epidemics add to your concern, or make you feel better? Why?

CHAPTER 21:

1. Why are fossils so rare?
2. How do we know about life long ago?
3. What were trilobites?
4. What is the Burgess shale? What does it tell us about early life? How has it been interpreted (or maybe misinterpreted)?
5. Is evolutionary success "a lottery"?
6. What happened to life in the Cambrian (500 million years ago)? What was the "Cambrian Explosion"? Was it really an "explosion"?
7. How did Gould interpret the Burgess shale? Why did other scientists disagree with his conclusions?

CHAPTER 22:

Analogy 1: Stretch your arms to their fullest extent and imagine that width as the entire history of Earth. All of complex life is in one hand, and "in a single stroke with a nail file you could eradicate human history."

Analogy 2: If the 4.5 billion year history of the Earth were compressed to a 24 hour day "…99.99 % of all species that have ever lived are extinct".

Statement to consider: "Life is an odd thing. It couldn't wait to get going, but then, having gotten going, it seemed in very little hurry to move on." Why does Bryson say this?

1. Why does Bryson say that "life is risky"?
2. When did land life begin? Why does Bryson say the move to land was "risky"?
3. How do scientists know what the atmosphere was like in the past?
4. What did the extra oxygen in the atmosphere do to plants and animals?
5. What were the first terrestrial vertebrates? Why do we know so little about them?
6. Why does Bryson call extinction "a paradoxically important motor of progress"?
7. How many mass extinctions have there been? What are the effects and characteristics of mass extinctions?
8. What are the possible causes of mass extinctions?
9. Why do some species survive the conditions responsible for mass extinctions?
10. How was mammalian evolution assisted by the Cretaceous extinction?

Bryson summarizes this section saying, "Life wants to be; life doesn't always want to be much; life from time to time goes extinct. Life goes on." Discuss this statement.

Comment on the statement: "It is hard to grasp that we are here only because of timely extraterrestrial bangs and other random flukes." Is this a difficult concept for you to accept? What do you think about human "inevitability"? Has this book changed your thinking about it?

CHAPTER 23:

Statement to consider: "We don't have the faintest idea—'not even to the nearest order of magnitude' of the number of things that live on our planet. Estimates range from three million to 200 million."

1. How are living things classified? What difference does it make?
2. How do you spend 42 years studying one species of plant?
3. Why is it so difficult to classify organisms?
4. Who was Sir Joseph Banks and what did he do?
5. What is the Linnaean system of classification?
6. Comment on the statement: "Taxonomy is described sometimes as a science and sometimes as an art, but really it's a battleground."
7. How diverse is life?
8. How many species of life are there? Why is it so difficult to determine this?
9. Why do we know as little as we know about the number of species of life?
10. Why do some plants produce medically useful compounds?
11. Bryson states, "The Linnaean system of nomenclature is so well established that we can hardly imagine an alternative." Can you devise another method of classification?

CHAPTER 24:

Analogy: A cell has been compared to "a complex chemical refinery" or to "a vast teeming metropolis." Comment on these statements.

Analogy 2: If an atom were the size of a pea, the cell would be a sphere a mile across. Within it, basketballs and cars would whiz around you.

Analogy 3: Read Bryson's description of a cell in terms of a large scale. Does this help you picture what happens in a cell?

Statement to consider: "We understand *a little* of how cells do the things they do."

1. What is a cell?
2. What do your cells do for you?
3. How does the poisonous compound Nitric oxide (NO) help your cells?
4. Who were Hooke and Leeuwenhook and how did they help us learn about cells?

CHAPTER 25:

Statement to consider: "At the beginning of the 20th century the best scientific minds in the world couldn't actually tell you where babies come from. And these were men who thought science was nearly at an end."

1. What was Darwin's "single best idea that anyone has ever had"? Why was it called that?
2. What are some of the results of Darwin's voyage on the Beagle?
3. Why do you think Darwin didn't publish his ideas on evolution right away?
4. Who was Alfred Russell Wallace? What did he contribute to evolutionary theory?
5. What were some of the problems with Darwin's ideas in *On the Origin of Species*?
6. Who was Mendel and what did he contribute to biology?
7. How are genetic traits passed on?
8. Why does Bryson say that Mendel and Darwin could have benefited from knowing each other's work?
9. How do the ideas of Mendel and Darwin help explain evolution?

teaching ideas, discussion (continued)

CHAPTER 26:

Statement to consider 1: "There are two yards of DNA coiled inside each nucleus of your cells."

Statement to consider 2: "We are all uncannily alike. You share 99.9 % of the same genes with any other human being."

Analogy 1: DNA is an instruction manual for the body.

Analogy 2: The human genome is a parts list of what we are made of which says nothing about how we work.

1. Why does Bryson say DNA is "a molecule that is not itself alive and for the most part doesn't do anything at all"?
2. What is "the human genome"?
3. What are the odds against you being here?
4. DNA is one of the "most non-reactive, chemically inert molecules in the living world". Why does Bryson say this?
5. Why did scientists think DNA was "too simple" to be important to life?
6. How is DNA like Morse code?
7. What is a gene?
8. How was the structure of DNA discovered?
9. How similar are your genes with other organisms?
10. How do genes work?
11. What is the "human proteome"?
12. Why does Bryson include the most profound true statement there is: "All life is one." Why do you think he feels this is so important? Do you agree?

Consider another big, unanswered question of biology: Why does so much of DNA not *do* anything?

Summary of this section: All topics discussed evolved just once and have since stayed pretty well fixed across the whole of nature. Every living thing is an elaboration on a single original plan. All life is one. Do you have any comments on this section of the book?

CHAPTER 27:

Statement to consider 1: "Cool summers make ice ages, not cold winters."

Statement to consider 2: "All human history has taken place within an atypical patch of fair weather."

Statement to consider 3: "The Extraordinary fact is we don't know which is more likely: more ice, or more heat."

1. What is an "ice age"? Did you know we are still in one?
2. What are the causes of ice ages?
3. How did the 1815 Tambora explosion lead to the "year without a summer"?
4. Why was there such resistance to the idea of worldwide glaciation?
5. Who was Louis Agassiz?
6. What did a janitor (James Croll) contribute to the study of glaciation?
7. Do ice ages begin quickly or slowly?
8. What did Milankovitch contribute to the study of glaciation? What are "Milankovitch Cycles"?
9. What and when was "Snowball Earth"? What are some problems and contradictions with studying conditions then? How did it warm up again?
10. How has the temperature of the Earth changed in the last 12,000 years? What are the causes for these changes?
11. Does this chapter change any of your ideas about "global warming?" How?

CHAPTER 28:

Statement to consider 1: "Since the dawn of time, several billion human (or humanlike) beings have lived… but our understanding is based on the remains… of perhaps 5,000 individuals." Of these fossils, which led to us and which are evolutionary dead ends?

Statement to consider 2: "There is more [genetic] difference between a zebra and a horse than between you and the furry creatures your ancestors left behind when they set out to take over the world."

1. Where did "humans" come from? What do we know about human ancestry?
2. Why does Bryson say, "Did you have a good ice age?"
3. How did the ice age influence human development?
4. Where and how were the first human fossils found?
5. Bryson states, "In their eagerness to reject the idea of earlier humans, authorities were willing to embrace the most singular possibilities." What are some examples?
6. Who were "Java man" and "Neanderthal man" and "Peking Man"?
7. Who was Dart and what was the "Taung child"?
8. Why was there such confusion of human fossils and identification in the 1950s?
9. What are the classifications of human fossils?
10. What are some of the problems with identifying human fossils?
11. How was (and is) human fossil identification another example of "fitting the evidence to our preconceptions."
12. Who was "Lucy"? Is she a human ancestor?
13. What were some of the "risks" in human development?
14. Why does Bryson say bipedalism and large brains are "risky"?
15. What is the current knowledge of human history?

CHAPTER 29:

This chapter continues the discussion from Chapter 28: What is human and where do we come from?

Statement to consider 1: "The most recent major event in human evolution—the emergence of our own species—is perhaps the most obscure of all."

Statement to consider 2: "There's more [genetic] diversity in once social group of 55 chimps than in the entire human population."

1. What were the first human made tools? What's strange about them?
2. How did humans get to Australia 60,000 years ago?
3. What do we know about human migration? How did we get around the world?
4. How did the earlier humans of "the first wave" (i.e. Neanderthal, etc.) die out? Did *homo sapiens* interbreed with them?
5. Who were the first *homo sapiens*? When and where did they live?
6. How is biochemical evidence being used to study human evolution? What does it say about who we are and where we come from?
7. What are the problems with using DNA evidence to study human history?
8. Bryson mentions a factory that existed for a million years. Where was this "factory" located? What did it make and why? What is strange about it?

teaching ideas, discussion (continued)

CHAPTER 30:

Statement to consider 1: "Over the last 50,000 years or so, wherever we have gone, animals have tended to vanish, in often astonishingly large numbers."

Statement to consider 2: "The people who were most intensely interested in the world's living things were the ones most likely to extinguish them."

1. What is the connection between humans and extinctions?
2. How did the dodos and passenger pigeons become extinct?

Bryson summarizes this section, and indeed the whole book, with these two statements:

- "It's an unnerving thought that we may be the living universe's supreme achievement and it's worst nightmare simultaneously."
- "We enjoy not only the privilege of existence but also the singular ability to appreciate it and even to make it better."

1. What do you think about these statements?
2. Does this chapter (or book) influence how you feel about being human? Our responsibility to the world? Our ability to influence the world?

suggested activities

The following topics deal with themes from the entire book. They would be good topics for class discussion, reports, presentations or even "essential questions."

1. This book presents science as a series of questions—mostly unanswered! Is this surprising to you? How has science been presented in your classes in school?
2. Bryson mentions that several times in the past scientists have often thought, "All the questions are answered." Research or comment on this in terms of physics (8), geology (12, 27), or DNA (26).
3. The practice of science: A major theme of the book is *resistance* to new scientific ideas even though there is a lot of evidence for them including: Big Bang (1, 2), plate tectonics (12), evolution (25), "old earth" (7), atoms (9), possible connection between meteor impact and extinctions (13), climate changes like glaciation (27), and human evolution (28, 29).

   Similarly, Bryson addresses the idea of *too much attachment* to widely held, but disproven ideas such as: "the Ether" (8), *elan vital* (7), creationism (25, 28, 29), young earth (7), and "land bridges" (27).

   a. Why do you think scientists are resistant to change? Are they any different from "ordinary" people in this regard?

   b. What current widely held idea do you think may become disproven in the future?

   c. Or is there an "emerging idea" that may gather enough evidence to be accepted? (Panspermia? Chaos theory?)

   d. How does Bryson describe what people do to hold onto the old ideas or reject the new ideas.

   e. In Chapter 12, Bryson discusses the resistance to the theory of plate tectonics. Consider the following examples:

   p. 177: In 1944, Arthur Holmes presented the arguments for continental drift so clearly and compellingly that students might actually come to believe them.

   p.180: In 1963(!), "Such speculations make interesting talk at cocktail parties, but it is not the sort of thing that ought to be published under serious scientific aegis."

   What is the irony of these statements? Does this discussion affect how you think science "works"? Are scientists any different from "normal people"?

   f. In Chapter 27, Bryson addresses three stages of scientific discovery:

   1. Deny it's true
   2. Deny its importance
   3. Credit the wrong person

   He mentions this in terms of glaciations, but what are some of the other instances of this in the book?

g. Bryson states that scientists often interpret results to most flatter themselves. He refers specifically to human fossils (27), but are there other instances you know of in which this occurs?

4. The Earth:

   a. Bryson often cites examples of "global" crises that may have influenced the Earth in the past such as meteor strikes, "salinity crisis," volcanoes, changes in solar output. Apply this to our current consideration of "global warming." What are some other current environmental "crises" where this may apply? Find out more about them.

   b. Bryson cites several examples of global influences of the "natural processes in the Earth" including hurricanes, thunderstorms, plate tectonics, earthquakes, volcanic eruptions, and ice ages. Has this book changed your ideas of humans being "masters of the earth?" Can we really "control" what happens on Earth? Discuss some recent events (tsunamis, earthquakes, etc.) in these terms.

   c. Chapter 30 describes the human involvement in extinctions. Today many species are "protected." Does reading Chapter 30 affect how you feel about protecting other species on earth?

5. Life Itself: A theme in the "Life" part of the book is that "life is risky" (take using oxygen, moving to land, walking on two legs, and general intelligence, for example). Discuss one of these. Do you agree it is "risky"? Can you think of any other "risky" adaptations?

6. A popular idea among non-scientists is that evolution is a grand climb up a ladder culminating in humanity. How has this book affected your thinking about this? Do you agree that evolution may be "a lottery" or that "we are not the culmination of anything" (20, 28)?

7. Research Drake's equation for life on other worlds (1). Do you think life in the universe is "inevitable" or "rare"? Why? How about complex (multi-cellular) life? How about intelligent life?

8. What do you think about human "inevitability"? Has this book changed your thinking about it? (22)

9. Bryson states, "Whatever prompted life to begin, it happened just once." Do you agree this may be "one of the most extraordinary facts in biology" or even "the most extraordinary fact we know"?

10. A major theme in the book is science as practiced by scientists. In other words: How do we know what we know? Bryson presents scientists as human beings with very human stories. Choose one and find out more about him/her and his story.

    Secretive: Newton (4), Darwin (25)

    Shy or obscure journals: Cavendish (4), Gibbs (8)

    Unintelligible: Hutton (5)

    Unlucky: Mantell (6), Scheele (7)

    World not Swedish speaking: Scheele (7)

    Unscrupulous or dishonest: Owen (6)

    Rivalries: Cope and March (6), Watson, Crick, Franklin (26)

    "The world not ready for": Wegner, Milankovitch (27), Dubois (28)

    Overlooked: Mary Anning (6)

    Beheaded!: Lavoisier (7)

    Discoverer didn't get the significance of: Wistar and dinosaur bones (6)

    Out of their field: Penzias and Wilson and Dicke (1)

    Environmentally friendly, against a mega corporation: Claire Patterson (10)

    In the "wrong" field: Luis and Walter Alvarez, and Asaro (13)

    Lack of connection: Darwin and Mendel (25)

    Just ignored: Dart (28)

    a. Many of these scientists died unhappy having received no recognition or credit for their work. How would you feel if this happened to you? Which story touches you the most? Find out more about it.

    b. Consider the common question: "Why are there no women scientists?" Does this book agree or simply tell you why we do not hear about female scientists? Research and discuss one of the following women included in the book, Mme Lavoisier (7), Curie, Franklin (27).

Planet	Actual Diameter (km)	Scaled diameter Try 1 (cm)	Scaled Diameter Try 2 (cm)	Actual Distance from sun (km)	Scaled distance from sun Try 1 (cm)	Scaled Distance from sun Try 2 (cm)
Sun	1.39×10^6			------------	------------	------------
Mercury	4.88×10^3			5.79×10^7		
Venus	1.21×10^4			1.08×10^8		
Earth	1.28×10^4			1.49×10^8		
Moon (to Earth)	3.48×10^3			3.84×10^5		
Mars	6.79×10^3			2.28×10^8		
Jupiter	1.43×10^5			7.78×10^8		
Saturn	1.21×10^5			1.43×10^9		
Uranus	5.11×10^4			2.87×10^9		
Neptune	4.95×10^4			4.50×10^9		
Pluto	2.27×10^3			5.9×10^9		

ACTIVITY: Make a Scale Model of the Solar System

An important theme in *A Short History of Nearly Everything* the difficulty of visualizing relative sizes of the very large or very small. For example, how big is the solar system? How big is the universe? How old is the universe? How small is an atom?

In this activity, we'll try to make a scale model of the solar system. If the Earth were only 2.50 cm (about the size of a quarter) what would be the size of the Sun and the other planets? What would be the size of the solar system using this scale?

1. Using the information in the Data Table, calculate the size of the Sun and other planets using the scale 2.50 cm = 12,700 km. (The Earth's diameter = the size of a quarter) Show an example calculation here. Record in the Data Table (Scaled Diameter Try 1).
2. Does this sound like a reasonable scale? Can you make Jupiter using a standard sized piece of construction paper? How about the Sun? Explain.
3. Let's see how far apart we'll have to make our planets for this scale model. Use the same scale factor from question 1 (2.50 cm = 12,700 km) and calculate the distance from each planet to the sun. Show an example calculation here. Record in the Data Table (Scaled Distance Try 1).
4. Does this sound like a reasonable scale? To help you decide, try this calculation. You calculated the Sun - Pluto distance for the scale model in centimeters. What is this "scaled distance" in miles? (1 mile is 1.61×10^5 cm) Would this model fit in your school building?
5. Let's try another scale: 50.0 cm = the distance from the Earth to the Sun. Calculate the distance from each planet to the sun using the scale 50.0 cm = 1.49×10^8 km. Show an example calculation here. Record in the Data Table (Scaled Diameter Try 2).
6. Would this model fit on a piece of paper? A roll of paper towels (about 3,000 cm for a large roll)? On the football field? (90 meters, 9,000 cm)
7. Now let's see how big to make our planets using this second scale. Calculate the size of the sun and other planets using the scale 50.0 cm = 1.49×10^8 km. Show an example calculation here. Record in the Data Table (Scaled Distance Try 2).
8. What are the limitations of the first model? (Earth = size of quarter)
9. What are the limitations of the second model? (Earth to Sun distance = 50 cm)
10. What's wrong with the pictures of the solar system in most textbooks?

Follow your teacher's instructions to make one of the scale models.

Teaching Suggestions

Numbers are generally given in scientific notation, and to three significant figures. Use what is appropriate for your students.

You can make the models using a roll of paper towels, a roll of paper calculator tape, a roll of butcher paper, fanfold computer paper, etc. Or you could put "planets" along the wall down your hallway. In any case, make sure students realize the planets are "not to scale."

It would probably be easier to make "half" the solar system. In other words, put the Sun at one end of the paper, and Pluto at the other end, rather than the sun at the center.

Have half the class make the scale models in which the Earth is size of quarter (to show the relative sizes of planets) and half make the models in which the Earth to Sun is 50 cm scale to show the relative distances. You may need to omit the sun unless you have a large roll of butcher paper available.

You could combine the two models, but be sure students understand they are not to the same scale.

For a simpler activity: Instead of having students calculate the scaled data, provide them with this data. You could start with either the "diameter" model or the "distance model". Have them determine the limitations of their scale, either before or after (or during!) construction of the scale model. You may also divide the class. After they make "their part" show them that the scales don't match, so they can't "put it together". What are the limitations of both models?

In August, 2006, Pluto was declared a "dwarf planet" rather than a full fledged "planet". The data for Pluto is included in this activity, but can be omitted, if you chose. The other unusual aspect of Pluto is its eccentric orbit. Since it does not "clear away" the neighborhood of its orbit, it does not fit the new definition of a planet. The data in this activity shows that Pluto is very small (smaller even than Earth's moon!), a reason for the debate. Is Pluto a planet?

You can do a similar activity using the age of the Earth, or age of the universe. If one billion years is 1.00 meters (100 cm), what distance represents how long humans have been on Earth? (about 1-3 millimeters) Human history? (about 0.025 mm)

Planet	Actual Diameter (km)	Scaled Diameter Try 1 (cm)	Scaled Diameter Try 2 (cm)	Actual Distance from sun (km)	Scaled Distance from sun Try 1 (cm)	Scaled Distance Try 2 (cm)
Sun	1.39×10^6	274	0.466	-------------	-------------	
Mercury	4.88×10^3	0.95	0.00164	5.79×10^7	1.14×10^4	19.4
Venus	1.21×10^4	2.38	0.00406	1.08×10^8	2.13×10^4	36.2
Earth	1.28×10^4	2.50	0.00430	1.49×10^8	2.93×10^4	50.0
Moon (to Earth)	3.48×10^3	0.685	0.00117	3.84×10^5	75.6	0.13
Mars	6.79×10^3	1.34	0.00228	2.28×10^8	4.49×10^4	76.5
Jupiter	1.43×10^5	28.1	0.0480	7.78×10^8	1.53×10^5	261
Saturn	1.21×10^5	23.8	0.0406	1.43×10^9	2.81×10^5	480
Uranus	5.11×10^4	10.1	0.0171	2.87×10^9	5.65×10^5	963
Neptune	4.95×10^4	9.74	0.0166	4.50×10^9	8.86×10^5	1510
Pluto	2.27×10^3	0.447	0.000762	5.9×10^9	1.16×10^6	1980

Teacher Answers and Data

1. Sample for Mercury

$$\frac{x \text{ cm}}{4.88 \times 10^3 \text{ km}} = \frac{2.5 \text{ cm}}{1.28 \times 10^4 \text{ km}} \quad \text{or} \quad 4.88 \times 10^3 \text{ km} \left(\frac{2.5 \text{ cm}}{1.28 \times 10^4 \text{ km}}\right) = 0.95 \text{ cm}$$

2. *Yes, Jupiter would need large construction paper (11 x 14 inch) the Sun will need something much bigger. You may have to omit the Sun, however.*

3. Sample for Mercury

$$\frac{x \text{ cm}}{5.79 \times 10^7 \text{ km}} = \frac{2.5 \text{ cm}}{1.28 \times 10^4 \text{ km}} \quad \text{or} \quad 5.79 \times 10^7 \text{ km} \left(\frac{2.5 \text{ cm}}{1.28 \times 10^4 \text{ km}}\right) = 1.14 \times 10^4 \text{ cm}$$

4. *No! It is way too big! The distance to Pluto is about 7.2 miles!*

$$1.16 \times 10^6 \text{ cm} \left(\frac{1 \text{ mile}}{1.6 \times 10^5 \text{ cm}}\right) = 7.25 \text{ miles}$$

5. Sample for Mercury

$$\frac{x \text{ cm}}{5.79 \times 10^7 \text{ km}} = \frac{50.0 \text{ cm}}{1.49 \times 10^8 \text{ km}} \quad \text{or} \quad 5.79 \times 10^7 \text{ km} \left(\frac{50.0 \text{ cm}}{1.49 \times 10^8 \text{ km}}\right) = 19.4 \text{ cm}$$

suggested activities (continued)

Teacher Answers and Data *(continued)*

6. *Pluto is about 20 meters away. This model should fit on a roll of paper towels (if you put the Sun at one end and show "half" the solar system). It would also fit on the football field.*
7. Sample for Mercury

$$\frac{x\ \text{cm}}{4.88 \times 10^3\ \text{km}} = \frac{50.0\ \text{cm}}{1.49 \times 10^8\ \text{km}} \quad \text{or} \quad 4.88 \times 10^3\ \text{km}\left(\frac{50.0\ \text{cm}}{1.49 \times 10^8\ \text{km}}\right) = 0.00164\ \text{cm}$$

8. *The planets are reasonable size, but the distances too big to use.*
9. *Now the distances between the planets are fine, but the planets are too small to see.*
10. *It is not even close to scale! Neither the sizes of planets or distances are even close to the actual relative sizes.*

ACTIVITY: Using Trigonometry to measure objects

Bryson discusses attempts to measure the size of the earth and distance from earth to sun. The method in this activity is a little different from these techniques, but uses similar principles. You're going to measure the height of an object, like a tree, a building, or your football goal post, without climbing the object!

The tangent of an angle is the opposite side divided by the adjacent side. If you know any two of these (angle, opposite side, adjacent side) and can use a calculator to give you the tangent, you can calculate the third. So if we know the Distance to our object, and the angle between us and its top, we can calculate the Height of the object.

Supplies needed for each pair of students:

- A tape measure
- A string with a large washer tied to it
- A protractor
- A straw

Procedure:

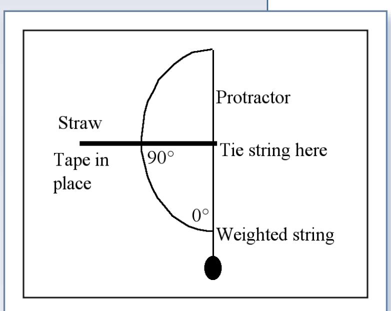


Figure 1

1. Tie the string with the washer to the center of the protractor, so the end with the washer hangs down. There should be a hole in the center of the flat end of the protractor that you can put the string through. Tape the straw to the protractor so it is lined up exactly with the 90° mark and the center of the flat side. Make sure the string can move freely. (*Figure 1*)
2. Find an object to measure. Start at the object and move away from it. Measure the distance "D" with the tape measure as you go. When you stop, you want to be far enough away so you can get an accurate angle. Record the distance, "D" in the Data Table. (*Figure 2*)

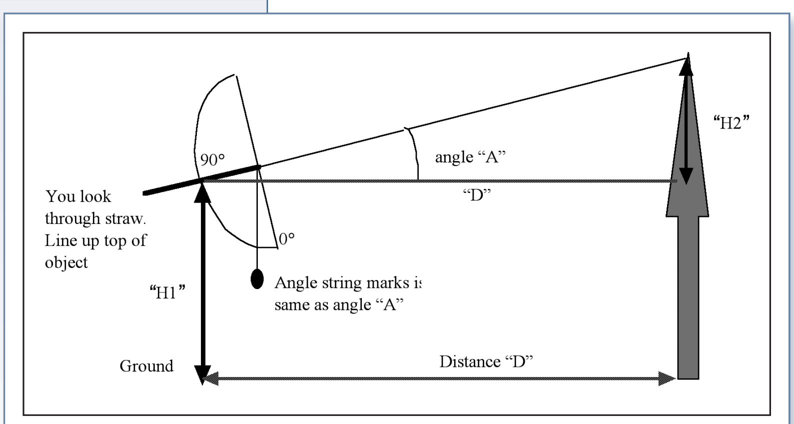


Figure 2

3. Sit at distance D. Hold the protractor so the flat end is away from you and 0° is pointed down. Look through the straw and tilt the protractor until you can see the top of the object through the straw. The angle made by the weighted string as it hangs down on the protractor is the same number of degrees as the desired angle "A." Have your partner read and record angle "A." (*Figure 2*)
4. Without moving, have your partner measure and record the height from the ground up to the protractor as you hold it. This is height "H1." (*Figure 2*)

5. If instructed to do so, repeat for a second trial. Then you're ready for the calculations. Complete the questions on the Data Table.

Data Table: Using Trigonometry to measure objects	Trial 1	Trial 2
D : Distance to object		
Angle A		
H1 : Height of protractor above ground		
Tangent of Angle A		
H2 : Calculated "opposite" side		
Total Height of object		

Questions: Please show your work and record your answers in the above Data Table.

1. Use a calculator to determine the Tangent of Angle "A".
2. The "adjacent" side is Distance D. Use this Trigonometric relationship to calculate H2, (the "opposite" side). H2 is the height of the object above the protractor.

$$\text{Tan A} = \frac{\text{opposite}}{\text{adjacent}} = \frac{\text{H2}}{\text{D}}$$

3. H2 is the height of the object above the protractor as you were "sighting" the tree through the straw. To obtain the Total Height of the object, add H1 (height of protractor above ground) and H2.

   Total Height of object = H1 + H2
4. Comment on how well your two measurements agree.
5. List some reasons why your two measurements may not be exactly the same.

Teaching Suggestions

1. If your students don't know trigonometry, you can use a calculator to give them the tangent of the angle. When they get to trig, they will know one use for it!
2. Repeat for a second trial at a different distance.
3. You can do this activity in the school gym if you do not want to go outside.
4. Have several groups measure the same object, from different distances. Compare answers. Does the measured height depend on the distance? Are your results more accurate the farther away you are? The closer you are?
5. Measure the height of the tree another way and give the answer to the students. Let them calculate their per cent error. For example, football goal posts are supposed to be ten feet high (measured to the crossbar). If you want to do this lesson in the school gym, the height of the basketball hoop should be ten feet also. Or you could measure to the height of a row of the bleachers. Get the "accepted value" by having a student climb to that level and drop a tape measure to the ground.
6. If your students are familiar with geometry, you could have them show that the angle the string makes is the same as angle "A".

suggested activities (continued)

ACTIVITY: Cell in a Bag

In *A Short History of Nearly Everything*, Bill Bryson states a cell has been compared to a "complex chemical refinery." This activity will simulate a dehydrated "cell in a bag." How does each piece fit what we know about a cell? These analogies will help you understand the function of some parts of a cell by comparing them to common objects.

Assemble the following items to make a "cell."

- Ziploc bag = *cell membrane*
- batteries = *mitochondria*
- small packet of clear gelatin = *dehydrated cytoplasm*
- small packet of dry soup mix = *dehydrated cell nutrients*
- a handful of glittery dots or paper punch dots = *ribosomes*
- small Ziploc bag = *nuclear cell membrane*
- inside small bag, yarn of various colors (two of each color) cut into varying lengths = *chromosomes*
- tie a plastic bead onto each piece of yarn = *centromere*
- empty film canisters = *vacuoles*
- to make a plant cell place the bag in a small cardboard box = *plant cell wall*

Write a sentence or two for each part explaining why the object represents that part of a cell.

Think of a few more large scale objects to represent other cell parts. Why would they represent that part of a cell?

Teacher Notes:

This activity can be performed several ways. You can give students a pile of materials and have them build their cells. You can give them a detailed list (as above). Or you can have them decide what object fits each cell part, perhaps giving them a list of parts represented to choose from. In either case they can then explain why each object fills the role of the cell material.

Or you could give students the "cell in a bag" already made, and have them take it apart, matching each piece with a check list.

You can add or subtract parts as appropriate for your class. Let students come up with more ideas or add your own.

Rationale for "Parts":

Ziploc bag = cell membrane: A flexible container for the outside of the cell. It should really be "semipermeable". Depending on how advanced your class is, or how detailed you want to be, you could (or your students could) use a pin to poke holes in the bag. If you plan to have your students open the gelatin and dry soup mix in the bag, you probably don't want to poke too many holes in the bag!

cardboard box = cell wall for a plant cell: A plant cell has a more structured outside, or cell wall, than an animal cell. The cardboard box gives the cell this structure. It is also made of cellulose, the same material as many plant cell walls. You could have some students make plant cells and others make animal cells, and let them see the difference.

batteries = mitochondria: The Mitochondria are the place in the cell where glucose molecules are converted to ATP, so can be thought of as the "batteries" of the cell, or "stored up fuel".

gelatin packet = cytoplasm: The cytoplasm in the cell is a "gel sol" mainly protein. So the gelatin represents the thick, watery contents of the cell. This analogy is a "dehydrated cell," but if students imagine watery gelatin, they get the idea of the cytoplasm.

small packet of dry soup mix = cell nutrients: The cytoplasm may contain dissolved chemicals and nutrients, ions such as potassium ions, sodium ions, sugars, proteins, etc. The soup mix represents these, again in a dehydrated form.

glittery dots = ribosomes: The ribosomes are the sites of protein synthesis. They are very small and scattered throughout the cell.

smaller Ziploc bag = nuclear membrane: Made of the same material as cell membrane, contains the nuclear material.

yarn (inside nucleus) = chromosomes: Paired chromosomes containing DNA

bead tied on yarn = centromere: thickened spot on the chromosomes, involved in cell division (mitosis).

empty film canisters = vacuoles: empty vessels that hold various cell secretions, etc.

ACTIVITY: Atom Builder

In *A Short History of Nearly Everything*, Bill Bryson discusses the Big Bang, atoms, quarks, and how to make an atom. Using this PBS website activity, you'll learn how to make a Carbon-12 atom out of quarks.

Go to this web site: http://www.pbs.org/wgbh/aso/tryit/atom/

On the first page, you'll find the answer to this question:

1. How many protons, _____ neutrons _____, and electrons _____ are in an atom of Carbon 12? Next, find out what a "Quark" is by scrolling to the bottom and clicking on: "Atom Builder Guide to Elementary Particles".
2. What are the two types of elementary particles in an atom?
3. What's the charge of an "up" quark? _____ a "down" quark? _____
4. What elementary particles make up a proton? a neutron?

Click on the "Back" button on the tool bar to get to the first page of Atom Builder. If you want help making your atom, scroll down to "Atom Builder Guide to Building a Stable Atom." If you just want to dive right in and try it, click on "Atom Builder Activity." It will open in a separate window. Enlarge the window if you like. Here are some questions for you to answer as you try to make a Carbon atom.

5. What happens if your atom has too many neutrons (compared to the number of *protons*)?
6. What happens if your atom has too many protons (compared to the number of *electrons*)?

If you get stuck, click on the Atom Builder Guide to Building a Stable Atom page for help.

7. Briefly describe how you made your atom. (Did you add all the protons first, then the neutrons, or did you add them alternately?) Why did you do it that way?
8. When you have finished your Carbon-12 atom, call the teacher over to initial.

Congratulations! You are now a successful nuclear chemistry student!

Teaching Hints:

You can download this activity to your computer. This is nice if your school internet connection is unreliable. It works on both Macs and PCs. It requires Shockwave, which is a free download. Directions for the download are on the PBS web site.

suggested activities (continued)

ACTIVITY: Numbers, numbers, numbers

In *A Short History of Nearly Everything*, Bill Bryson makes a point of "writing out" his numbers ("one billion"), and avoiding writing them in "scientific notation" ($1x\ 10^9$). When using very large or very small numbers, scientists find it much easier to interpret numbers as "a number between 1 and 10 times a power of 10." For example, one million is the same as 1,000,000 is the same as 1×10^6. To a scientist, it is much easier to check the power of ten than to count zeros. What do you think? In this activity, you will see some important very large, or very small, numbers from Bryson's book. Can you match the words with the numbers with the scientific notation?

Part 1: Large numbers – cosmic scale

Words	Numbers	Scientific Notation
1. Average distance between stars is about 20 million miles	____________	____________
2. Distance to "trans Neptunian objects" about 4 billion miles away	____________	____________
3. The visible universe is a million million million million light years across	____________	____________
4. Mean distance from earth to sun is 150 million kilometers	____________	____________
5. The core of a neutron star is so dense a spoonful would weigh 200 billion pounds	____________	____________
6. Number of possible planets in the universe 10 billion trillion planets	____________	____________
7. Mass of the Earth is 6 billion trillion metric tons	____________	____________
8. Current estimate for age of the universe is about 13 billion years	____________	____________
9. Age of the earth is about 4.5 billion years	____________	____________
10. A typical galaxy has 100 billion stars	____________	____________

- Which of the numbers is the largest?
- Which is the smallest?
- What is bigger: a million billion billion or a million million trillion?
- Which is bigger: 1×10^{24} or 1×10^{25}?

Part 2: The very small – time after the Big Bang, size of atoms

Words	Numbers	Scientific Notation
1. Scientists can look back to one 10 million trillion trillion trillionths of a second after the big bang	____________	____________
2. The length of time for the "inflationary universe" was 1 million million million million millionths of a seconds	____________	____________
3. The size of an atom is about one ten millionth of a millimeter	____________	____________
4. The Size of a paremecium is about 2 thousandths of a millimeter	____________	____________
5. The nucleus of an atom is one millionth of a billionth of the volume of the atom	____________	____________
6. Subatomic particle come and go into being in as little as one trillion trillionth of a second	____________	____________

- Which of the numbers is the largest?
- Which is the smallest?
- What is bigger: a millionth of a billionth or a thousandth of a trillionth?
- Which is bigger: 1×10^{-14} or 1×10^{-15}?

1. So do you agree with Bryson? Which makes the most sense to you: words, numbers written out, or scientific notation? Why?

2. Does it make a difference if you have numbers that are really big or small? Explain.

"Number Bank" Part 1: Very large numbers	
Numbers *(units are left off)*	Scientific notation
a. 1,000,000,000,000,000,000,000,000	**A.** 1×10^{11}
b. 6,000,000,000,000,000,000,000	**B.** 1×10^{22}
c. 20,000,000,000,000	**C.** 1.3×10^{10}
d. 200,000,000,000	**D.** 4×10^{9}
e. 100,000,000,000	**E.** 1.5×10^{8}
f. 4,000,000,000	**F.** 4.5×10^{9}
g. 150,000,000	**G.** 2×10^{13}
h. 4,500,000,000	**H.** 1×10^{24}
i. 10,000,000,000,000,000,000,000	**I.** 2×10^{11}
j. 13,000,000,000	**J.** 6×10^{21}

Teacher Answer Sheet

Part 1: Large numbers – cosmic scale

1. *Average distance between stars is about 20 million million miles:* c, G
2. *Distance to "trans Neptunian objects" about 4 billion miles away:* f, D
3. *The visible universe is a million million million million light years across:* a, H
4. *Mean distance from earth to sun is 150 million kilometers:* g, E
5. *The core of a neutron star is so dense a spoonful would weigh 200 billion pounds:* d, I
6. *Number of possible planets in the universe 10 billion trillion planets:* i, B
7. *Mass of the Earth is 6 billion trillion metric tons:* b, J
8. *Current estimate for age of the universe is about 13 billion years:* j, C
9. *Age of the earth is about 4.5 billion years:* h, F
10. *A typical galaxy has 100 billion stars:* e, A

- *Which of the numbers is the largest?* 1×10^{24}
- *Which is the smallest?* 1.5×10^{8}
- *What is bigger, a million billion billion or a million million trillion?* (they are the same, 1×10^{24})
- *Which is bigger: 1×10^{24} vs. 1×10^{25}:* 1×10^{25}

suggested activities (continued)

"Number Bank" Part 2: Very small numbers	
Numbers *(units are left off)*	Scientific notation
a. 0.000000000000000000000000000001	**A.** 1×10^{-7}
b. 0.002	**B.** 1×10^{-24}
c. 0.0000000000000000000000000000000000000000001	**C.** 1×10^{-15}
d. 0.000000000000000000000001	**D.** 1×10^{-43}
e. 0.0000001	**E.** 1×10^{-30}
f. 0.000000000000001	**F.** 2×10^{-3}

Part 2: The very small – time after the Big Bang, size of atoms

1. *Scientists can look back to one 10 million trillion trillion trillionths of a second after the Big Bang* c, D
2. *The length of time for the "inflationary universe" was 1 million million million million millionths of a seconds* a, E
3. *The size of an atom is about one ten millionth of a millimeter* e, A
4. *The Size of a paramecium is about 2 thousandths of a millimeter* b, F
5. *The nucleus of an atom is one millionth of a billionth of the volume of the atom* f, C
6. *Subatomic particle come and go into being in as little as one trillion trillionth of a second* d, B

- *Which of the numbers is the largest?* 2×10^{-3}
- *Which is the smallest?* 1×10^{-43}
- *What is bigger, a millionth of a billionth or a thousandth of a trillionth?* (they are the same, 1×10^{-15})
- *Which is bigger:* 1×10^{-14} *or* 1×10^{-15} 1×10^{-14}

Teaching suggestions

1. If you'd like, have your students choose between parts one and two.
2. To make the activity easier, you could include the units with the numbers and scientific notation.
3. To make the activity even more challenging, you could have students match the number with what it's measuring, instead of giving it to them. (Have four lists instead of three!)
4. Or instead of comparing forms of numbers, you could just give the measurement in whatever form you choose and have students match it to what it's measuring, such as:

   150 million kilometers
   Mean distance from Earth to Sun

5. Have students convert numbers into metric system units, or vice versa, or to another metric unit.

   2×10^{-3} mm = how many meters?
   How many micrometers?

web based class activities

Chapter 1, 2, 3, 8
Here is a NASA/JPL site that includes a Flash movie of a "Grand Tour" of the Solar system.
http://voyager.jpl.nasa.gov/window/voyager_ad.htm

This site is NASA's Solar system simulator. You can see what the solar system objects look like at different times and fields of view. http://space.jpl.nasa.gov/

"Power of 10" is a great book and movie by Charles and Ray Eames about the size and scale of the universe. This website has a number of activities and links to other sites. It also includes ways to purchase the video, so hopefully your school will not block the site.
http://www.powersof10.com/

Chapter 8
This link takes you to an interactive applet. *(Shockwave required)* Students use light from stars to identify elements in stars. It includes a brief discussion of Red Shift.
http://www.pbs.org/wgbh/nova/origins/spectra.html

Chapter 1, 9, 11
In this interactive activity, students construct a carbon atom from quarks. This activity can be downloaded from the PBS web site for use when you are not connected to the internet.
http://www.pbs.org/wgbh/aso/tryit/atom/

Chapter 13, 14, 15, 22
This website contains a great interactive activity about the search for the meteor crater that may be at the KT boundary. Scroll to Lesson 3.
http://arizona.usgs.gov/Flagstaff/Outreach/CenterEPO/craterintro_page.htm

Chapter 12, 14, 15
The USGS has a page with earthquake activities for kids.
http://earthquake.usgs.gov/learning/kids.php

This USGS site includes volcano activities
http://interactive2.usgs.gov/learningweb/teachers/volcanoes.htm

Chapter 5, 6, 13, 21, 22
This site has activities such as a fossil gallery. Or you can explore your state through geologic time. http://www.paleoportal.org/

Chapter 19, 20, 24, 26
This site includes slides of cells and interactive activities about cells. Some are available for purchase, but you can preview them on the site. http://www.cellsalive.com/

This site is an interactive "virtual cell" http://www.life.uiuc.edu/plantbio/cell/

This site also includes a virtual cell. Click "The Virtual Cell Tour." You can also download the cell tour if your internet connection at school is slow or unreliable.
http://www.ibiblio.org/virtualcell/index.htm

Chapter 23
This site is by the National Biological Information Infrastructure and includes botany projects for kids. http://159.189.176.5/portal/server.pt

This is a simple classification activity http://www.hhmi.org/coolscience/critters/critters.html

Chapter 18, 22
This site is from NOAA has on line activities from NOAA's 1998 Year of the Ocean.
It includes some "endangered species" activities. http://www.yoto98.noaa.gov/kids.htm

Chapter 17, 18, 27, 30
This interactive site shows how the Earth's climate has changed in the past.
http://www.ngdc.noaa.gov/paleo/ctl/

web-based class activities (continued)

The following sites have many links to general lessons, etc. Some activities are better than others on each site, but you can decide for yourself what fits your students.

The PBS series *Origins* has a web site that includes many activities related to the event in Bryson's book. It includes an interactive timeline of the history of the universe and using the Drake equation. http://www.pbs.org/wgbh/nova/origins/

A NASA website with activities for teachers:
http://spaceplace.nasa.gov/en/educators/teachers_page2.shtml

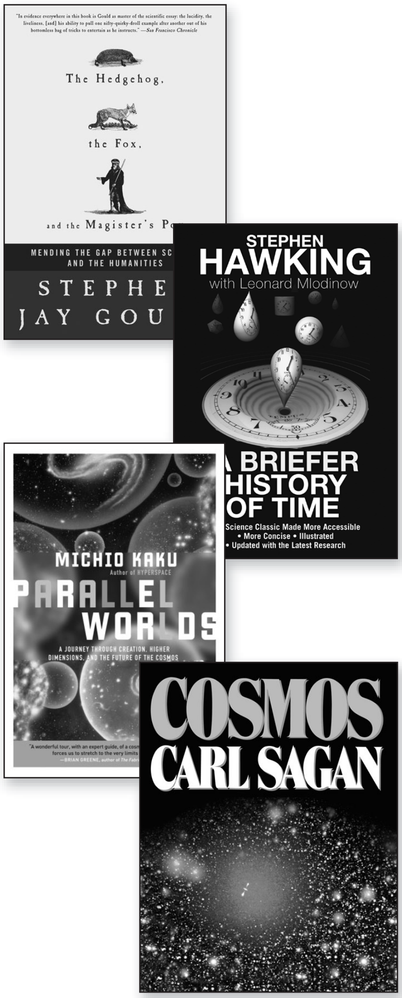
Here is NOAA's Teacher links site (Oceans and Atmospheres):
http://www.education.noaa.gov/teachers1.html

Here is the USGS (US Geologic Survey) site with Educational materials related to Geology:
http://interactive2.usgs.gov/learningweb/teachers/index.htm

This one includes links to Biology activities available in your state:
http://159.189.176.5/portal/server.pt

Educational resources about the oceans and the Earth's magnetic field.
http://www.ngdc.noaa.gov/education/education.html

other titles of interest



Also Available by Bill Bryson

Bill Bryson's African Diary

Bryson's Dictionary for Writers and Editors

Bryson's Dictionary of Troublesome Words

I'm a Stranger Here Myself

In a Sunburned Country

The Life and Times of the Thunderbolt Kid: A Memoir

Notes on Returning to America After 20 Years Away

Rediscovering America on the Appalachian Trail

A Walk in the Woods

A Writer's Guide to Getting It Right

Books by Stephen Jay Gould

Dinosaur in a Haystack

Full House: The Spread of Excellence from Plato to Darwin

The Hedgehog, the Fox, and the Magister's Pox

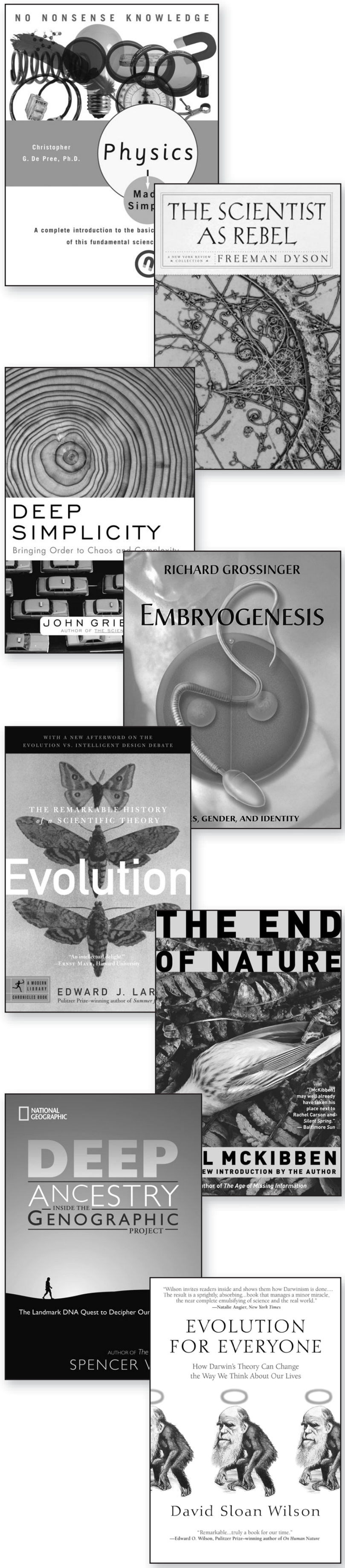
I Have Landed: The End of a Beginning in Natural History

Leonardo's Mountain of Clams and the Diet of Worms

The Lying Stones of Marrakech

Questioning the Millennium

Rocks of Ages: Science and Religion in the Fullness of Life



Books by Stephen Hawking

Black Holes and Baby Universes and Other Essays

A Brief History of Time

A Briefer History of Time

The Illustrated A Brief History of Time

The Universe in a Nutshell

Books by Michio Kaku

Beyond Einstein: The Cosmic Quest for the Theory of the Universe

Hyperspace: A Scientific Odyssey Through Parallel Universes, Time Warps, and the 10th Dimension

Parallel Worlds: A Journey Through Creation, Higher Dimensions, and the Future of the Cosmos

Physics of the Impossible: A Scientific Exploration into the World of Phasers, Force Fields, Teleportation, and Time Travel

Visions: How Science Will Revolutionize the 21st Century

Books by Carl Sagan

Billions & Billions

Broca's Brain

Cosmos

Demon-Haunted World

Dragons of Eden

Pale Blue Dot

Shadows of Forgotten Ancestors

For Further Reading

God's Equation, by Amir D. Aczel

Einstein's Universe, by Nigel Calder

The Silent Gene, by Warrick Collins

The Universe in a Single Atom, by Dalai Lama

Origin of Species, by Charles Darwin

Voyage of the Beagle, by Charles Darwin

Physics Made Simple, by Christopher G De Pree, Ph.D

The Scientist as Rebel, by Freeman Dyson

Why Things Break, by Mark Eberhart

Deep Simplicity, by John Gribbin

The Scientists, by John Gribbin

Embryogenesis, by Richard Grossinger

Darwin's Ghost, by Steve Jones

Evolution, by Edward J. Larson

The End of Nature, by Bill McKibben

The Science Book, by National Geographic

Instant Physics, by Tony Rothman

Deep Ancestry, by Spencer Wells

Evolution for Everyone, by David Sloan Wilson