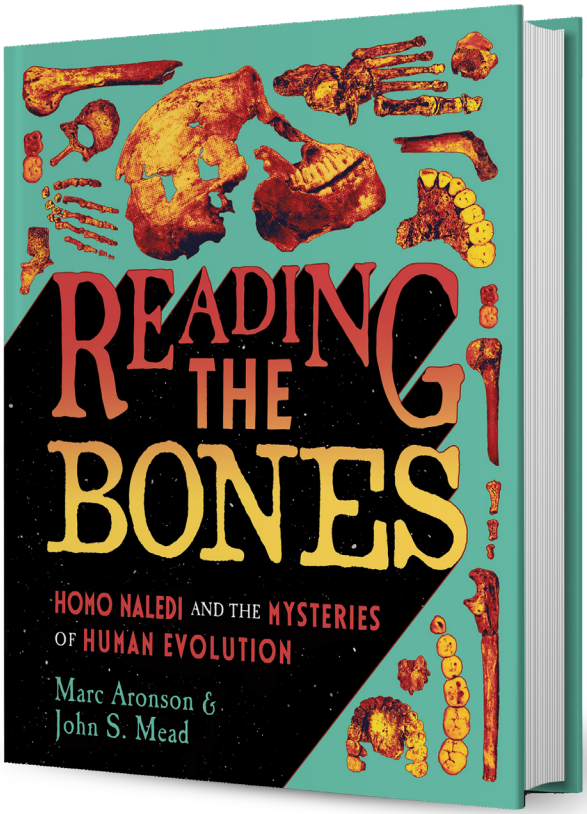
READING THE BONES

TEACHER'S GUIDE

ABOUT THE BOOK



"Are you brave enough?" That's what anthropologist Keneiloe Molopyane texted one of her graduate students, inviting her to join a dangerous underground search for a mysterious new human ancestor, *Homo naledi*. Would she dare to slide through the tight spaces and sheer drops of the Rising Star cave in South Africa's Cradle of Humankind, to help unlock the secrets of a tiny chamber filled with literally hundreds of fossilized bones?

Join us as we follow the exciting explorations of Dr. Molopyane, along with six female excavators known as the Underground Astronauts, the dynamic, controversial leader Dr. Lee Berger, and others as they puzzle over the remains of this strange new species with much smaller brains than ours who may have buried their dead, made tools, used fire, and left markings on rocks. Guided by Sibert Medal-winning author Marc Aronson and teacher John S. Mead, whose sixth-grade science class followed many stages of the exploration as it happened, *Reading the Bones: Homo naledi and the Mysteries of Human Evolution* is real science in real time. Packed with drawings, maps, and a variety of resources, this is a thrilling introduction to scientific explorers on the front lines of the hunt for connections between humans and our primate relatives and ancestors.

ABOUT THE AUTHORS

Marc Aronson has been an innovative editor and author of books for young readers for over thirty years. The winner of the American Library Association's first Robert F. Sibert Informational Book Medal, and editor of the tenth winner (Tanya Lee Stone's *Almost Astronauts*), Aronson is a passionate advocate of nonfiction. As an editor he created EDGE—the first international and multicultural YA imprint—where he published such artists as Jacqueline Woodson, Nikki Giovanni, and the first YA graphic novel memoir, Judd Winnick's *Pedro and Me*. *The Skull in the Rock*, which he wrote with Dr. Berger about the discovery of sediba, won the Subaru award for best middle grade science book. Aronson holds a PhD from NYU in American cultural history and is an Associate Professor of Public Professional Practice at Rutgers University, where he trains future youth librarians.

John S. Mead has been awarded the John H. Murrell Excellence in Teaching Award (St. Mark's School of Texas), the National Association of Biology Teachers Outstanding Biology Teacher Award for the State of Texas, the inaugural Evolution Teaching Award from the Teacher Institute of Evolutionary Studies (TIES), and the National Association of Biology Teachers (NABT) Evolution Education Award. John served as a science advisor for the Perot Museum of Nature and Science in Dallas and was the only K-12 member of the Education Board of the American Association of Biological Anthropologists. In 2019, John was selected to be a Teacher Ambassador for the National Center for Science Education (NCSE) as they sought to expand their classroom influence related to topics of evolution and climate change. He has served as President of the Texas Association of Biology Teachers.

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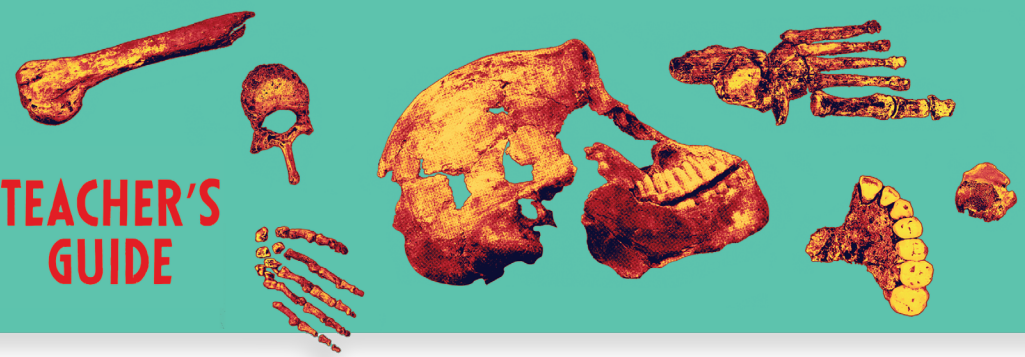


A NOTE TO FELLOW–TEACHERS

from John S. Mead

Greetings and welcome to one of the most fantastic scientific stories of the twenty-first century! My name is John S. Mead, and I am a coauthor of *Reading the Bones* as well as the author of this teacher's guide. Before you dig into the varied resources in this guide, I want you to have an idea of why this project exists in the first place, and that requires a little bit of storytelling.

For me, this story begins on August 20, 2012, at 8:54 PM Central Daylight Time. As a teacher who had taught human origins to sixth-grade science classes for more than twenty years, I was always looking for new discovery stories to share with my students. Ever since I met Jane Goodall when I was a rookie teacher and she explained the power of storytelling in science, I had made that a part of my teaching style. I had heard of a new species of hominin discovered in South Africa called *Australopithecus sediba*, but I knew little about it. In my preparation for the coming school year, I learned that *sediba* had been discovered by Dr. Lee Berger, a scientist in South Africa. Having nothing to lose, I reached out to Berger through Facebook and hoped I might get a response. That response changed my life. I asked Berger if he might share via e-mail the discovery story of *sediba*, and not only did he agree to that but when he learned that I was teaching in Dallas, he told me that he was going to be in town in November on a book tour for middle schoolers that was specifically about the discovery of Australopithecus sediba. That book, titled *The Skull in the Rock*, was coauthored by Marc Aronson, who, as luck would have it, has become a good friend and mentor, and my coauthor of *Reading the Bones*.

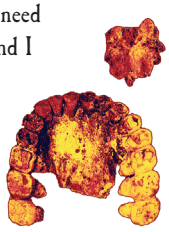
Berger's visit to my school, the St. Mark's School of Texas, in November 2012 was amazing, and a friendship began that has helped many thousands of students learn about human origins in ways that had never been possible before. That initial visit led to invitations to see Berger's work in South Africa in the summers of 2013 (to learn about *Australopithecus sediba*) and 2015 (to see and learn about the *Homo naledi* bones that had been excavated in November 2013). After years of teaching and talking about this great discovery and reading two books written by Berger, I found myself frustrated that there was nothing aimed at middle-school students, who I had learned love this great scientific adventure story. After I got tired of hearing myself whine about this, I decided to do something about it. This led to a connection with Marc Aronson, an award-winning author who had collaborated with Berger on *The Skull in the Rock*, which told the story of the discovery of *Australopithecus sediba*. We teamed up to write *Reading the Bones*, a book we both feel fills a void for young people when it comes to this inspiring discovery.

Since those early days, I have been teaching my students about *Homo naledi* as a science teacher, but in sharing this story, I have learned it has wonderful applications in other classrooms as well. While for me this started out as a science story, it has also found a home with social studies and humanities teachers, as I learned that human origins, when covered, is also frequently a starting point for ancient history lessons.

Regardless of your specific content area, another aspect of this book is the lesson it teaches about changing the culture of one's field. As you read the book with your students, you will learn that a big part of Berger's effort was to make a field of study that had been dominated by white men be more inclusive and open to people who would not have been a part of this story had it happened in the twentieth century. Indeed, the fact that Berger welcomed a middle-school science teacher to help share the story of the *Homo naledi* discovery speaks volumes about inclusivity and openness.

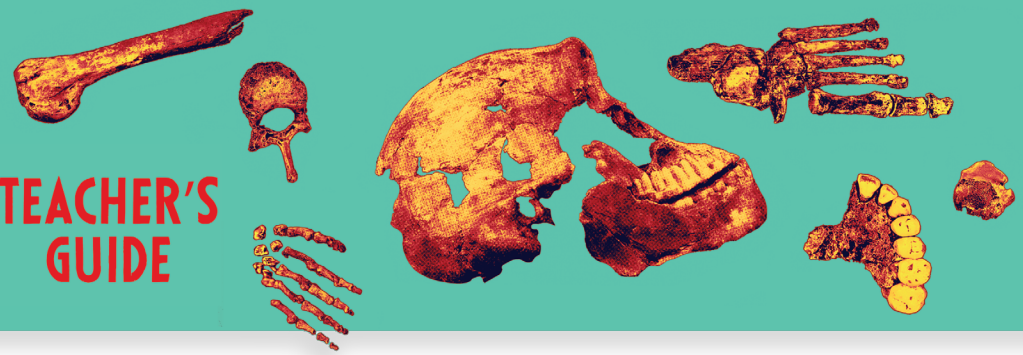
A special part of that openness is that Berger and his team have made available a significant number of fossils from both *sediba* and *naledi* to the public for 3D printing. Getting life-size fossils in the hands of students is truly a game changer for engagement. I encourage all of you who are using *Reading the Bones* in your classes to 3D print at least one naledi skull if you are capable, or by connecting with your school's makerspace or IT folks. Once students get to handle actual prints of the fossils they start asking much deeper questions about them. I have also found that my students get very excited about learning more about how they can make 3D prints—an added bonus. What started as showing off the naledi fossils in my classroom has now led to a weekly raffle of some animal skull or other that I print. Students who can identify the print to the species level are then entered in the weekly raffle.

As I have taught this story since the early days, I see it as a great adventure story first and foremost, and I would encourage you to start with that mindset. Often, students do not see science as a great adventure, and this will help shift that narrative for them, regardless of the content area of your curriculum. I am a strong believer that we need to encourage students to explore in a variety of ways, and I am hopeful this book will aid in that inspiration. I can say that I have had students who learned about *Homo naledi* in middle school come back to me from college, eager to hear the latest updates from Berger. Simply put, this story sticks with students.



READING THE BONES

TEACHER'S GUIDE



A NOTE TO SCIENCE TEACHERS

If you are a science teacher, I expect you will likely be teaching *Reading the Bones* as part of a larger evolution unit. In this teacher's guide, I am including many resources on evolution, both general and on the science of human origins, known as paleoanthropology. Please feel free to use these resources if they are new to you, and feel comfortable adapting the story of *naledi* to your existing work. As a science teacher, I see a very important part of this story in how we do science: Modern science is not the simple, linear "scientific method" that textbooks used to teach. This story offers young scientists the opportunity to appreciate the power of peer review and to experience what it means to provide adequate evidence for scientific claims. Rarely in science classes do students get to see this in action. You will also get a chance to discuss how the world of social media may impact the way we communicate about science, especially newer scientific discoveries.

Beyond issues of scientific process, it is helpful if your students have a passing familiarity with the vertebrate skeleton. Perhaps a lab where you dissect an owl pellet can be a helpful opportunity for your students to "read the bones" for themselves before digging into the details of the *Homo naledi* discovery. I have also included other interesting labs related to paleoanthropology and fossil discoveries in the resources. Some of these labs will even allow you to combine the 3D printing of *naledi* fossils with the existing skull comparison labs formulated before this discovery.

A NOTE TO SOCIAL STUDIES AND HUMANITIES TEACHERS

If you are teaching this book in a nonscience classroom, you may want to provide your students with a quick overview of evolutionary thought as background. You will also find some helpful resources if you are uncomfortable talking about evolution and concerned about religious pushback. I teach in Texas and have found minimal pushback, as most people see it as a discovery story.

If you are focused on the discovery aspect of this story, I strongly recommend connecting it to other famous hominin discoveries, such as Lucy. You will find resources for researching such discoveries in this teacher's guide. In my experience, students enjoy becoming experts on discoveries that the adults in their lives are often unaware of. Another important aspect of teaching the discovery stories is to look at the historic nature of who was involved. Paleoanthropology has a long history of being a science that was "male and pale"—dominated by Caucasian men of high academic standing—reflecting the biases of the time. The ten years covered by our book show a field of study in transition from "male and pale" to a much more inclusive model, where both women and native South African scientists are making significant contributions to a major scientific project.

One aspect of this story I am particularly excited about as a teacher is the presence of primary sources. If you are a history teacher, you appreciate the value of having students go back to primary sources as a way of reliving the history of the moment they're studying. In this case, I was lucky enough to realize in 2013 that very few people were on Twitter and thus were not seeing the tweets of the research team in real time. I was inspired after each day's tweets to create videos that I narrated about those tweets. More than a decade later, no one would know how to easily access those tweets, yet you now have a curated collection of them available for both you and your students to experience.

A follow-up to the primary sources is the set of interviews conducted with most members of the research team during my visit to the Rising Star cave in 2015. Unlike most social media posts for news clips about the story, I was lucky enough to conduct long-form interviews with all the underground astronauts, as well as members of the exploration team and senior scientists. These dozen videos run for approximately fifteen to thirty minutes and give students an in-depth sense of what was going on at the time.

PRE-READING PREPARATION AND BACKGROUND INFORMATION

If you are a biology teacher, then you likely already have your evolution instruction nailed down; however, if you are looking for a quick introduction to Charles Darwin and the theory of evolution by natural selection, the following resources should prove helpful.

- Darwin and Natural Selection: Crash Course History of Science #22: This Crash Course video describes the change from natural theology to the modern understanding of evolution based on the discoveries of Charles Darwin and Alfred Russel Wallace. It details Darwin's legendary voyage aboard the *HMS Beagle*, during which his observations led him to the concept of natural selection. It also highlights Wallace's work in the Malay Archipelago, which prompted the joint publication of their findings before Darwin released *On the Origin of Species*. Finally, it addresses the cultural impact of these ideas, including the later misapplication of their work to human society through social Darwinism.

- Theory of Evolution: How did Darwin come up with it? BBC News: This BBC video explains how Charles Darwin changed the field of biology by providing a scientific explanation for life's diversity. After a five-year voyage aboard the *HMS Beagle*, Darwin analyzed fossils and isolated species on islands and concluded that life evolves from common ancestors through a process of natural selection. He realized that survival is not granted to the strongest, but rather to those who best adapt to a changing environment, enabling them to pass on successful traits to their offspring.

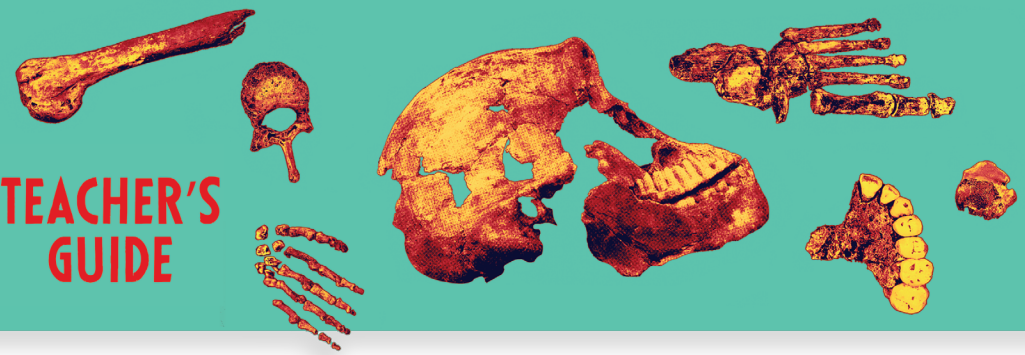
- Charles Darwin for Kids | Natural Selection & Evolution | Simple History: This biographical video is produced for younger students and follows Charles Darwin's journey, whose curiosity and voyage aboard the *HMS Beagle* led to his revolutionary idea of natural selection. By observing subtle physical variations in animals such as the Galapagos finches, Darwin proposed that organisms with beneficial traits are more likely to survive and pass those traits to their offspring. *On the Origin of Species* provided a wealth of evidence—from the fossil record to homologous structures—supporting the view that all living things are linked through a common ancestor. The video illustrates how Darwin's commitment to careful observation and questioning transformed biology, showing that nature's diverse wonders arise from a slow, continuous process of adaptation.

- The Making of a Theory: Darwin, Wallace, and Natural Selection—HHMI BioInteractive Video: This superb video from HHMI Biointeractive provides a narrative account of the parallel journeys and breakthroughs of Charles Darwin and Alfred Russel Wallace, who independently discovered the mechanism of natural selection to explain the appearance of new species. It traces Darwin's voyage on the Beagle, which led him to conceptualize a "tree of life" in which species change over time through natural laws rather than "special creation". The video then follows Wallace's arduous expeditions in the Amazon and the Malay Archipelago, where he observed biogeographical patterns—such as the Wallace Line—and vestigial structures that confirmed species arise from pre-existing, nearby species. I find this video exceptionally valuable because it humanizes the scientific process, illustrating how identical theories can emerge from vastly different backgrounds—Darwin, the wealthy, established naturalist, and Wallace, the self-made collector who survived shipwrecks and disease. It offers clear visual evidence of evolution through fossils and biogeography while emphasizing the collaborative nature of science, as both men shared credit and maintained a lifelong friendship despite their potentially competitive discovery.

- If you want to dig deeper into a biography of Darwin, you'll find a lot of options, but my favorite is David Quammen's *The Reluctant Mr. Darwin*, an easy read that details Darwin's genuine struggle with his theory.

READING THE BONES

TEACHER'S GUIDE



RESOURCES FOR TEACHING EVOLUTION

Especially for teachers who are nervous about the topic

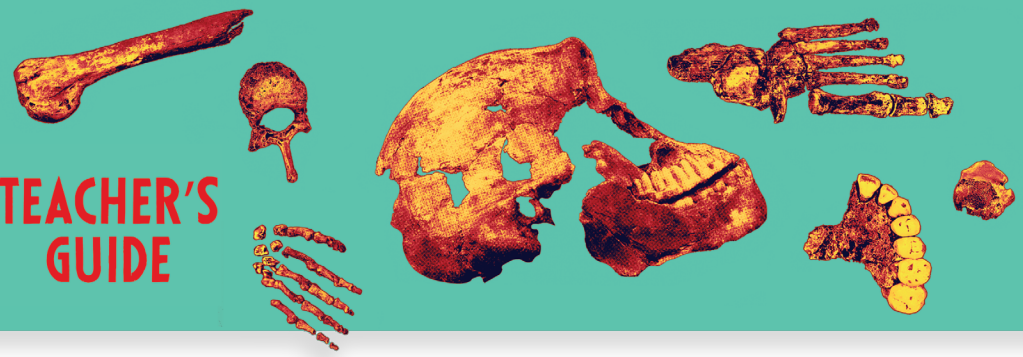
- Human Origins Education @ the Smithsonian: The Smithsonian Human Origins Program has a world-class collection of resources connected to teaching evolution, particularly human evolution.
- CRS (Cultural and Religious Sensitivity) Teaching Strategies Resource: This subset of human evolution teaching resources is especially useful for teachers concerned about pushb ack from more religious students and parents. I strongly recommend the last section of this link.
- The Clergy Letter Project: For those looking to address religious concerns about evolution, you may want to explore this site, which includes a letter signed by more than 15,500 Christian clergy who support the coexistence of evolution and Christian theology.
- "Famous Christians Who Believed Evolution is Compatible with Christian Faith": A helpful article for teachers who are nervous about the evolution/religion issue is Brad Kramer's essay, from BioLogos, an organization founded by the famed geneticist Francis Collins which aims to bridge the perceived divide between science and religion.
- TIES Evolution Lessons: The Teacher Institute of Evolutionary Studies (TIES) offers valuable resources for middle-school teachers seeking to teach evolution.
- On Teaching Evolution: TIES teachers authored this book to help teachers learn more about teaching evolution.

WHAT IS "EVOLUTION"?

- PBS's Evolution Series: An in-depth site created by PBS with a wealth of evolution-related material.
- How Evolution Works (And How We Figured It Out): This more advanced video from PBS EONS provides a comprehensive overview of the history and details of evolutionary theory, beginning with the independent observations of Darwin and Wallace regarding natural selection and common ancestry. It then defines evolution simply as "change over time" and explains how environmental conditions shape living organisms, thereby distinguishing between microevolution (changes within a species) and macroevolution (long-term patterns that produce new species). It further integrates the historical roles of figures such as Gregor Mendel and Thomas Hunt Morgan to illustrate how the field of genetics eventually explained the inheritance of traits, thereby filling a major gap in Darwin's original work—a very valuable video for classes that will be connecting nineteenth-century natural selection to twentieth-century genetics.
- Survival Of The Fittest—Stated Clearly: This video addresses common misconceptions surrounding the famous phrase, clarifying that "survival of the fittest" was not in Darwin's first edition and that it is often misleadingly taken to suggest that evolution is purely about physical strength or a "life or death" struggle. Instead, it explains that evolutionary success is defined by reproductive fitness—the ability of an organism to pass its heritable traits and genes onto future generations. It proposes a more accurate, foundational "bumper sticker" for natural selection: "those which happen to be better reproducers tend to reproduce better." This helps to dismantle student misunderstandings about "fitness" being synonymous with "strongest" or "fastest." Using examples such as the survival of tiny mammals over T. rex teaches that evolution is driven by inherited variation and environmental fit rather than by physical dominance alone.
- What is the Evidence for Evolution?—Stated Clearly: This video explores the basics of biological evolution—common ancestry and natural selection—by focusing on the evolutionary history of cetaceans (whales, dolphins, and porpoises). It presents four independent lines of evidence: comparative anatomy (mammalian traits and vestigial leg bones), embryology (leg buds and migrating nostrils in development), the fossil record (transitional species like Basilosaurids and the "walking whale" Maiacetus), and DNA analysis (linking whales to their closest living relative, the hippopotamus). This video models how evolutionary theory synthesizes disparate fields of study from genetics to paleontology into a single, coherent narrative that validates a scientific theory.

READING THE BONES

TEACHER'S GUIDE



TOP MISCONCEPTIONS ABOUT EVOLUTION

- The University of California at Berkley hosts a fantastic evolution education resource called "Understanding Evolution," and they have a useful list of common misconceptions to address in class.

OVERVIEW OF THE SCIENCE OF HUMAN EVOLUTION (PALEOANTHROPOLOGY)

- *From Ape to Man* is a superb documentary that details and reenacts the history of human origins discoveries and research from 1858 to 1973. A great activity to do with this long video is to assign each discovery to a group of students and then have them teach other groups about their assigned discovery.

- Human Evolution: We Didn't Evolve From Chimps: Crash Course Biology #19: This video clarifies perhaps the most common misconception in evolution. The idea that humans descended from modern apes.

This useful resource explains instead that both lineages diverged from a common ancestor approximately seven million years ago. The source describes human history not as a linear progression but as a "braided stream" where various hominin species branched out and sometimes interbred. Thus, leaving traces of Neanderthal and Denisovan DNA in modern humans. This corrects fundamental misunderstandings about evolutionary "straight lines" and provides a clear timeline of human traits, showing that bipedalism preceded the development of large brains and illustrating how we developed the diversity of skin colors in modern humans.

NAMES AND DISCOVERIES NOVICES NEED TO KNOW

- Hominin Species: A collection of concise information about most of the recognized hominin species.

- Prominent Hominin Fossils: A list of the most well-known hominin fossils, including where they were found, when they were found, and who found them.

- Timeline of Human Fossil Discoveries: A straightforward timeline that covers the major hominin discoveries since the 1850s.

- The Cradle of Humankind and discoveries made there.

BERGER'S DISCOVERIES

- Discovering *Homo naledi*: Journey to Find a Human Ancestor, Part 1: Berger describes his discovery of *Australopithecus sediba*.

- Discovering *Homo naledi*: Journey to Find a Human Ancestor, Part 2: Berger shares the initial discovery of *Homo naledi* in the Rising Star cave system.

- Discovering *Homo naledi*: Journey to Find a Human Ancestor, Part 3: Berger shares some of the challenges his team faced in the effort to recover the fossils and discusses *Homo naledi*'s significance in order to better understand human origins.

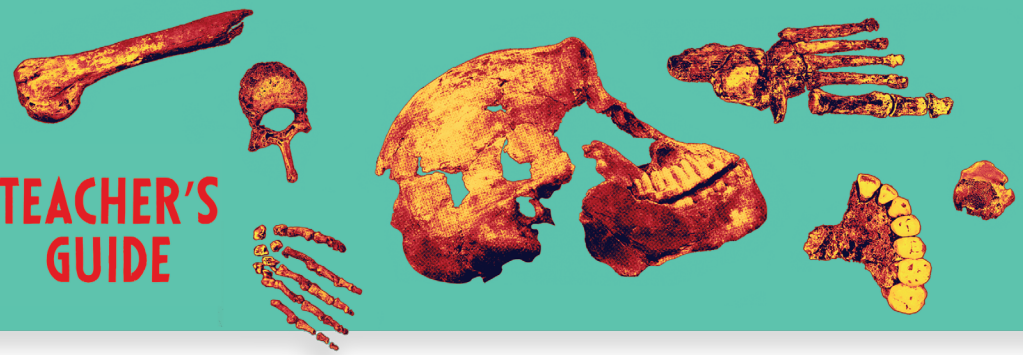
- Berger talking about the impact of *Australopithecus sediba*.

- In 2012, Aronson and Berger coauthored *The Skull in the Rock: How a Scientist, a Boy, and Google Earth Opened a New Window on Human Origins*, which tells the story of the discovery of *Australopithecus sediba*.

- The actual announcement of *Homo naledi* by Berger and Dr. John Hawks at the University of the Witwatersrand in Johannesburg, South Africa.

- A significant NOVA documentary that tells the story of both *Australopithecus sediba* and *Homo naledi* is Dawn of Humanity.

- This article on the website Understanding Science 101 explains peer review in science and how it works.



VOCABULARY

CHAPTER 1: YOU'RE GONNA WANNA SEE WHAT WE HAVE

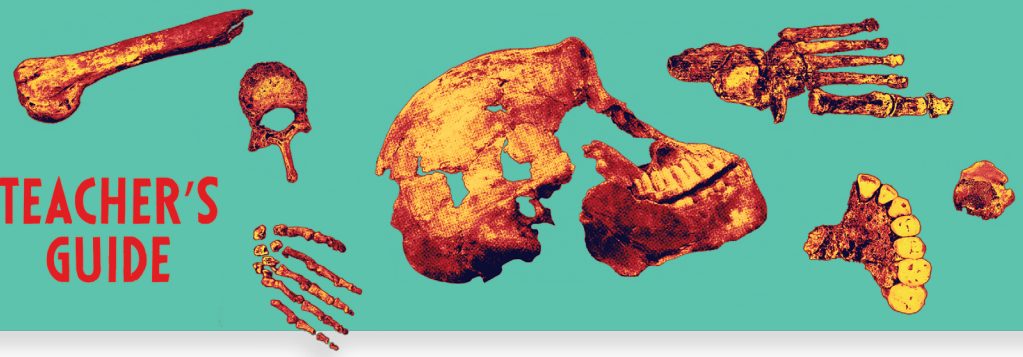
- **Geologist:** A scientist who studies the Earth's physical structure, its history, and the substances—like rocks and minerals—that it is made of.
- **Fossils:** The preserved remains or traces of ancient living things.
- **Sediments:** Layers of material, such as sand or shells, that settle at the bottom of a liquid (like an ancient seabed) and can eventually harden into rock.
- **Limestone:** A type of rock that forms over billions of years from hardened layers of sediments and shells.
- **Crevices:** Narrow openings or cracks in a rock surface.
- **Cradle of Humankind:** The official name of an area in South Africa that is a treasure trove of fossils, providing clues about human evolutionary history.
- **Labyrinthine:** Something that is like a labyrinth, full of confusing, winding, and connected cracks or passages.
- **Mandible:** The scientific name for a jawbone, specifically the lower jaw. The upper jawbone is known as the maxilla.
- **Cranium:** The scientific name for the top part of a skull, including the brain case.

CHAPTER 2: I NEED THE HELP OF THE WHOLE COMMUNITY

- **Hominid:** A broad scientific group that includes all modern and extinct humans, as well as the great apes like chimpanzees, gorillas, and orangutans.
- **Hominin:** A more specific group that only includes humans and our direct ancestors who are capable of walking on two legs.
- **Paleoanthropologist:** A specialized scientist who studies the origins of humans by examining ancient fossils and other evidence.
- **Bipedalism:** The ability to walk upright on two legs.
- **Evolution:** The gradual process of change in a species over millions of years as they adapt to their environment.
- **Binomial system:** A scientific method used to organize and name species by giving them both a genus and a species name.
- **Genus:** The first part of a scientific name that identifies a group of closely related species (for example, Homo includes humans and our large-brained relatives).
- **Species:** The most specific level of scientific classification, often describing a unique type of living thing with its own specific characteristics.
- **Scale bar:** A tool that looks like a ruler, which scientists place next to an object in a photo so the viewer knows exactly how large it is.
- **Fieldwork:** Scientific research or data collection that is done outdoors in the natural environment (like a cave) rather than in a laboratory.

CHAPTER 3: CAN'T WAIT FOR TOMORROW

- **Underground astronauts:** A nickname for the six female scientists chosen for their specialized skills and small physical size, which allowed them to navigate the narrow and dangerous passages of the cave.
- **Expedition:** A journey made by a group of people with a specific goal, such as exploring a new area or conducting scientific research.
- **3D scanner:** A high-tech portable tool used to create a precise digital record of a site's surface and the exact position of bones or other artifacts before they are moved.
- **Excavated:** The act of carefully uncovering and removing fossils or other historical remains from the ground.
- **Stalactites:** Formations that look like stone icicles hanging from the ceiling of a cave, created by minerals in dripping water.
- **Bucket brigade:** A method of moving items, where a group of people stands in a line and passes objects from person to person to reach a destination.



CHAPTER 4: "HAND LAND" TO "HIP HEAVEN"

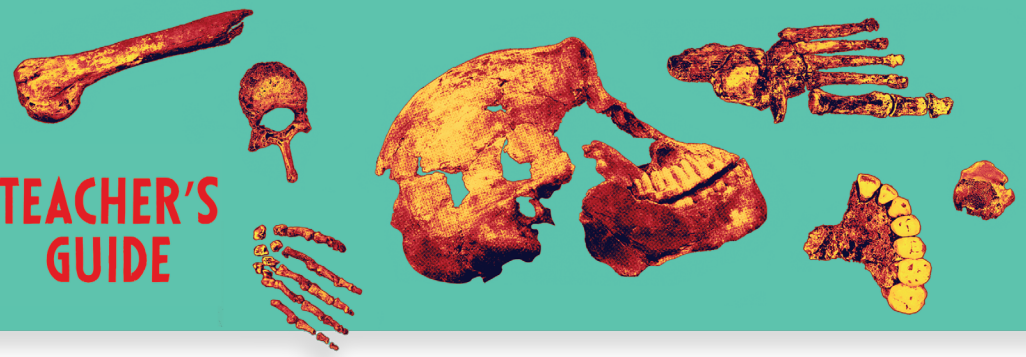
- **Phalanges:** The scientific term for finger bones.
- **Metacarpals:** The scientific term for the specific bones that make up the palm of the hand.
- **Carpals:** The scientific term for the specific bones that make up the wrist.
- **Articulation:** A rare and exciting find where a collection of fossils is discovered positioned exactly as the bones would be in real life, because they were still connected by skin and ligaments when they first arrived in the soil.
- **Anatomy:** The study of the physical structure and parts of humans and other living things.
- **CT scanner (computed axial tomography):** A high-tech tool that scientists use to see the internal details of fossils or bones without having to break them open.
- **Scavenger:** An animal that feeds on the remains of already dead animals rather than hunting for live prey.

CHAPTER 5: A NEW SPECIES OF HUMAN ANCESTORY

- **Assemblage:** A large collection or gathering of items found in one place, like the hundreds of fossil pieces found together in the Rising Star cave.
- **Paleo artist:** A specialized artist who uses scientific data and fossils to create 3D models or pictures showing what ancient ancestors might have looked like.
- **Hypothesis:** An educated guess or a possible explanation that scientists test using evidence to see if it is correct.
- **Absolute dating:** A scientific process used to find the specific age of a fossil or rock by studying something in its chemical makeup, such as radioactivity.
- **Carbon 14:** A common method of dating ancient organic materials—like wood or bone—that were alive within the last 60,000 years.
- **Flowstone:** These occur when water rich in calcium carbonate flows along the walls or floor of a cave, depositing layers of calcite. Formations can look smooth and glossy or create hanging curtains and draperies.
- **Proteomics:** A branch of science that studies proteins to learn about the past, which is helpful because proteins often last longer than DNA in warm climates.

CHAPTER 6: AS YOU RISE, YOU HAVE GOT TO RAISE OTHERS WITH YOU

- **Postdoctoral (postdoc):** A researcher who has finished their highest level of college (a PhD) and is now leading advanced scientific projects.
- **Curating:** The job of organizing, protecting, and managing a collection of items, like fossils, so they can be studied or displayed.
- **Fissure:** A narrow split or crack in a rock.
- **Incudes:** The plural form of incus, which refers to a small, anvil-shaped bone located in the middle ear of mammals. It is the central bone in a chain of three (malleus, incus, stapes) that is essential for transmitting sound vibrations from the eardrum to the inner ear; they are almost never found as fossils.
- **Virtual reality:** A computer-simulated experience that allows people to feel like they are exploring a place, such as a deep cave, without actually being there.
- **Mentor:** A trusted teacher or more experienced person who helps guide and support someone else's learning and career.
- **Apartheid:** A historical era of forced segregation and unfair treatment of people based on race in South Africa, which limited resources and opportunities for many people.
- **Principal investigator (PI):** The lead scientist who acts as the experienced main organizer of a scientific expedition.



CHAPTER 7: NEW DISCOVERIES, NEW QUESTIONS, NEW STEPS—WHAT DO WE KNOW NOW?

- **Paradigm shift:** A major discovery that completely changes the way people think about or understand a specific topic.
- **Skeptic:** A person who questions a scientific finding and asks for more proof before accepting it as a fact.
- **Burial:** The deliberate and careful placement of a body in a prepared space, which archaeologists believe shows respect for the dead.
- **Speculation:** Forming a conclusion or making a guess about something when you do not yet have firm evidence to prove it.
- **Peer review:** A scientific process where a team of anonymous experts carefully reads and checks a researcher's paper before it is officially published.
- **Transparency:** Being open and honest by making the entire process of research, including the criticisms, available for everyone to see.
- **Bias:** A personal leaning or feeling that might prevent a person from giving a completely fair or neutral opinion about a discovery.

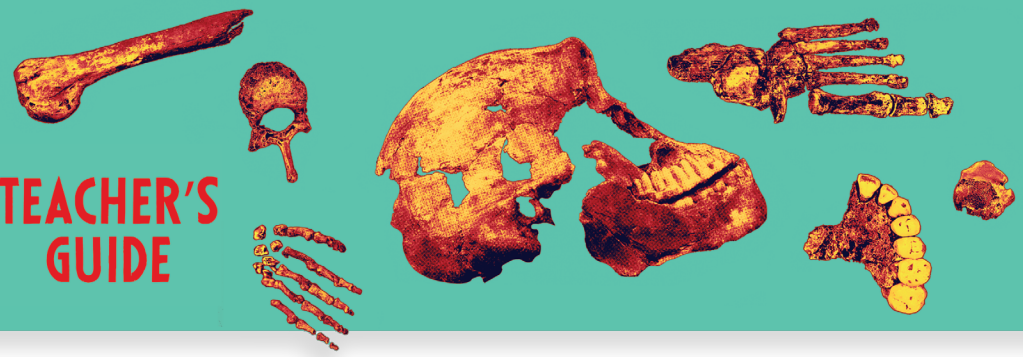
DISCUSSION QUESTIONS

CHAPTER 1: YOU'RE GONNA WANNA SEE WHAT WE HAVE

1. Why is the area north of Johannesburg called the Cradle of Humankind?
2. What makes limestone caves specifically such a treasure trove for scientists looking for fossils?
3. Pedro Boshoff initially had "no luck" and chose to return to the Rising Star cave, even though it was already "well-trod" and used to train amateurs. What does this tell you about the mindset needed for scientific discovery?
4. Why did Boshoff need to recruit Rick Hunter and Steven Tucker for the mission? What specific physical skills or qualities did they have that Boshoff lacked?
5. When Hunter and Tucker first found the teeth and the mandible, why was it important that they did not disturb the discovery before showing it to Berger?
6. When Hunter and Tucker first saw the teeth, they wondered if it was a significant ancient find or just remains from a "modern-day caver." Based on the description of where they found the bones, why was the second option a possibility?

CHAPTER 2: I NEED THE HELP OF THE WHOLE COMMUNITY

1. Berger was originally headed for a career in the navy, law, or politics before switching to TV broadcasting. What specifically inspired him to change his life path and study human origins?
2. All hominins are hominids, but not all hominids are hominins. How would you explain the difference between these two groups to your parents?
3. Donald Johanson's discovery of Lucy in 1974 was exceptional even though the skeleton was only 40 percent complete. What specific physical features of her skeleton confirmed a "key glimpse" into how our ancestors evolved?
4. Berger describes a concept called "backyard syndrome," where our expectations can "mask our vision." How can this phenomenon prevent scientists—or even you—from making new discoveries in places that have already been well-explored?



5. When Matthew Berger went into the Dinaledi Chamber, he had to use a scale bar when taking photos of the fossils. Why is this tool so important for scientists who are looking at the photos later? Where might you have seen scale bars in your schoolwork?

6. Historically, scientific funding and prestige often came from inside tracks involving high-level experts and famous universities. How did Berger's use of Facebook to find his team challenge this traditional way of doing science?

7. Berger needed a very specific "skill set and build" for his team. What were the three main requirements he listed in his Facebook advertisement, and why were they all important for this specific mission?

8. Traditionally, dangerous missions involving physical risk were associated with men, yet all six underground astronauts were women. How does this discovery and the response to Berger's ad change the assumption about who can participate in difficult field explorations?

9. Johanson, a mentor to Berger, criticized the speed of the Rising Star excavation as a "glaring example of how not to do fieldwork." Do you think science should be done slowly and traditionally, or is Berger's "new" way of using social media and open science better? What are the possible risks and benefits of each approach?

CHAPTER 3: CAN'T WAIT FOR TOMORROW

1. Marina Elliott compared the mission to the 1922 expedition that opened King Tut's tomb. How were the treasures the underground astronauts were looking for different from the golden masks found in Egypt?

2. Berger had a "stark and severe" rule: If anyone got hurt or disoriented, they had to stay in the cave until they could get out by themselves because there was no room for a stretcher. Would you be willing to take this risk for a scientific discovery? Why or why not?

3. Before removing any fossils, the team used a portable 3D scanner to record the site and took many photos. Why is it "careful science" to create a precise record of the area before anything is moved?

4. Why did the scientists have to go barefoot while working in the cave? How does the comparison to the Floor Is Lava game help you understand the challenges they faced on the cave floor?

5. During the expedition, the scientists used Skype (a predecessor of Zoom) to talk to students in Rhode Island, Taiwan, and India. How does "beaming their activities to the internet" in real time change the way people around the world experience scientific discovery?

6. Lindsay Eaves worried she might not be able to "squeeze down the slot" like her teammates. How did the team realize that having "complementary skills" was more important than everyone being exactly the same? How might this apply to your life at both home and school?

7. Historically, outside experts often took fossils away from the countries where they were found. How did the Rising Star team ensure that South Africans were part of the process and benefited from the discovery?

8. When Alia Gurtov injured her shin on the "jagged rocks," she had to spend two hours slowly climbing out of the cave. How did this accident change the way the team handled safety for the rest of the mission?

9. By the end of the first round, the team found more than a thousand fragments in a space only the size of a card table. Based on this "size and scope," what do you think they might find if they explored the rest of the cave?

CHAPTER 4: "HAND LAND" TO "HIP HEAVEN"

1. How did Berger use social media to involve middle-school students in the actual discovery process as it was happening?

2. Why do you think Berger wanted to bring "new voices" and "new faces" into his scientific research?

3. What is the difference between finding individual fossilized bones and finding them "in articulation"? Why was finding a hand in this specific condition considered such a "big reward" for the team?

4. During the Rising Star workshop, teams like "Hand Land" and "Hip Heaven" were discouraged from comparing notes. Why was Berger so strict about this "complete separation" rule?

5. According to the "How to Identify a Bone" section, what are the most critical questions scientists ask when they find a new fossil? Why is it challenging to determine if a bone belongs to a known species or a brand-new one?

6. The book compares the final assembly of the skeleton to a jigsaw puzzle where the resulting image is "really strange." Based on the description of *Homo naledi*, which parts of its body looked modern like ours, and which parts looked more primitive or apelike?

7. How can scientists "read" bones to find out if an ancient individual suffered from a disease or was the victim of violence? What specific clues on a bone might show that a community cared for an injured person?

8. During the workshop, "tensions crackled" over whose names should go first on scientific papers—the famous senior experts or the junior scholars who did much of the work. How would you solve this "fault line" if you were leading the workshop?

9. Students were given an exam where they had to present ideas on what species the fossils belonged to, but there was no "correct" answer. Why do you think their reasoning was more important than the specific name they chose? Have you ever had such a test in your classes?

10. The team chose the name *Homo naledi*, which means "star human" in the local Sesotho language. Traditionally, how are species names chosen, and why is the choice of naledi significant given where the fossils were found?

11. Some critics worried the team was "rushing" and that having fifty scientists handle the fossils would cause damage. Contrast this with Dr. Ron Clarke, who took twenty years to release information on the Little Foot fossil. Which approach do you think is better for the scientific community?

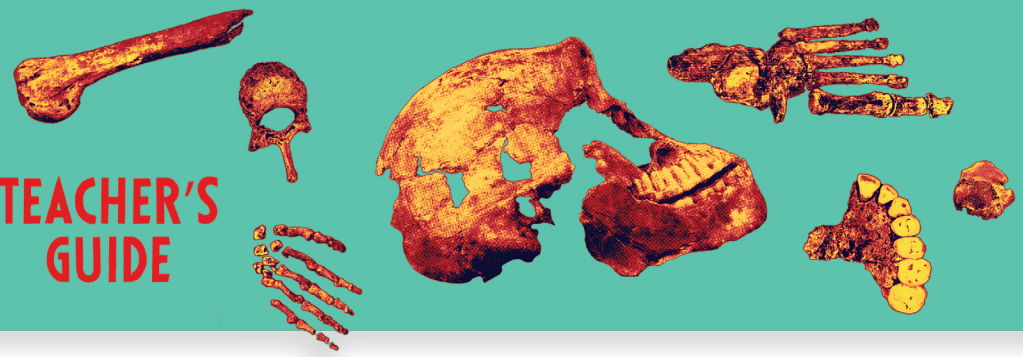
CHAPTER 5: A NEW SPECIES OF HUMAN ANCESTOR

1. The announcement of *Homo naledi* was described as "global breaking news." Why do you think a scientific discovery like this was shared through a major press conference, a TV documentary, and a *National Geographic* cover all at the same time?

2. The South African deputy president Cyril Ramaphosa said this discovery would inspire poets and writers to "retell the story of our own common ancestry." How can ancient fossils help people imagine or understand their future?

3. The team had to rule out several explanations for how the bones got into the cave, such as animal predators or flooding. What specific evidence (or lack of evidence) led them to believe the bodies were "placed in the deep cave on purpose"?

4. Until this discovery, scientists thought ritualized behaviors toward the dead were "utterly unique to *Homo sapiens*." Why is the idea of a small-brained species recognizing its own mortality and disposing of its dead deliberately considered extraordinary?



5. Carbon 14 dating only works for organic materials up to 60,000 years old. How did the team use flowstone and uranium decay to determine that *Homo naledi* lived much earlier?

6. The tests revealed that *Homo naledi* lived between 241,000 and 335,000 years ago. How does it change your perspective of history to know that this species lived in Africa at the same time as our own species, *Homo sapiens*?

7. If *Homo naledi* overlapped in time (and place) with *Homo sapiens*, should scientists reconsider who created stone tools and artifacts dated to that time of overlap?

8. Scientists often disagree on how to begin an investigation. Using the "lost sock" metaphor, explain the difference between assuming the bodies were placed there on purpose versus assuming they were dumped randomly. Which starting point do you think is more scientific?

9. Why is it difficult to get DNA from ancient hominin specimens found in tropical regions? How might the study of proteomics allow us to look even further back into the past than DNA can?

10. In the Lesedi Chamber, the team found a body on a raised ledge. What "astonishing hypothesis" did this find lead the team to consider regarding ceremonies and the way *naledi* treated their dead?

CHAPTER 6: AS YOU RISE, YOU HAVE GOT TO RAISE OTHERS WITH YOU

1. In 2013, the underground astronauts were early-career scientists who had never met, but within two years, they became a team of established professionals taking key leadership roles. What does this suggest about how a single opportunity or discovery can change a person's life and career?

2. Excavating in the Lesedi Chamber is described as being "even more cramped" than the Dinaledi Chamber, with researchers having to wriggle into narrow passages and "fumble under the seat you are sitting on." What physical and mental qualities (besides scientific knowledge) would a person need to be successful in such an environment?

3. When Dr. Keneiloe Molopyane first arrived at a wilderness dig site with purple hair and painted nails, her professor wasn't sure if she was ready for the work. However, she produced the "most beautiful" technical work the professor had ever seen. What does this story teach us about judging a person's abilities based on their appearance?

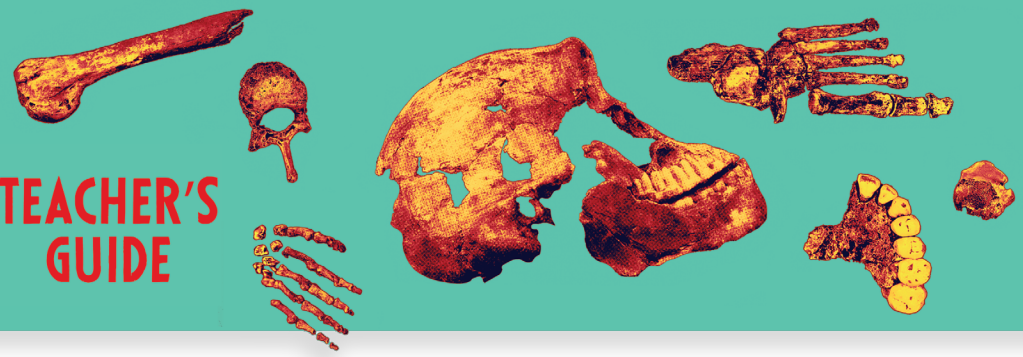
4. Molopyane was "terrified" when she first entered the Rising Star cave and had to perform a "controlled fall" through a tight chute in pitch-black darkness. Why is it important for scientists (and others) to take risks and face their fears to find hidden treasures?

5. Molopyane uses the term "parachuting in" to describe when outside researchers take all the glory and evidence from a site, leaving little for the local people. Why is it a significant change for local South African scientists to now be the "thought leaders" of these expeditions?

6. At the UW 105 cave, the team had to reconstruct blasted rocks like a "smashed Lego structure" to understand how the cave looked before it was mined. How does this process of "giving meaning to the meaningless" show the importance of patience and persistence in science?

7. At Gladysvale, Molopyane was disappointed to find that a skull her team discovered was not a hominin, but she called it the cave where she "built character." How can experiencing a hard lesson or a setback help someone become a better leader?

8. The chapter title and a key quote from Berger is: "As you rise, you have got to raise others with you." In what ways did Molopyane live out this idea by inviting younger students like Ginika Ramsawak to join her research team?



9. Ramsawak felt reassured and inspired because she found a scientist who "looks like me" in a field where she was often the only South African woman of Indian descent. Why is it important for students to see people from diverse backgrounds in high-level scientific roles?

10. Molopyane has participated in a Super Scientists project that turns real-life researchers into comic book superheroes to reach younger Africans. If you were to create a Super Scientist character, what specific "powers" or tools from this chapter would they have to help them solve the mysteries of the past?

11. Based on your science studies about other topics, who might you deem to be a Super Scientist? What superpowers do (or did) they possess? Go to the website https://www.superscientists.org/ to see examples of the more than sixty Super Scientists who have already been identified.

CHAPTER 7: NEW DISCOVERIES, NEW QUESTIONS, NEW STEPS—WHAT DO WE KNOW NOW?

1. The book mentions that "skeptics have questioned some of the team's findings." In science, why is it important for researchers to challenge each other's ideas and ask for more proof instead of just accepting every new claim?

2. There is a major debate over whether *Homo naledi* bodies were dumped into the cave to keep predators away or buried to honor the dead. Why would a deliberate burial be considered a sign of a much more behaviorally complex species?

3. To protect fragile fossils, the team jacketed them in plaster and used CT scans to look inside. How does using technology like 3D printing and CT scans change the way scientists can share and study their discoveries without damaging the original fossils?

4. Berger believes a rock found near juvenile remains is a stone tool, while other scientists call this "speculation and guesswork." If you were a scientist, would a CT scan and a 3D print be enough to convince you, or would you need to touch the actual rock to be sure?

5. For many years, scientists believed a large brain was a requirement for high intelligence. How do species like *Homo floresiensis* and *Homo naledi* prove that brain size is not a perfect way to predict a species' abilities?

6. Berger found soot and signs of fire in the cave, but some critics wonder if he only saw what he wanted to see for a Netflix documentary. What are some other clues that scientists have to rule out before they can prove *naledi* used fire?

7. Berger has been called a pitchman for sending fossils into space and using social media to announce finds. Do you think making science exciting and accessible to the public is worth the risk of being criticized by other scientists?

8. Most scientists have their work checked privately by anonymous experts before it is published. Why did Berger's team choose a transparent path where the criticism and revisions were available for everyone to see?

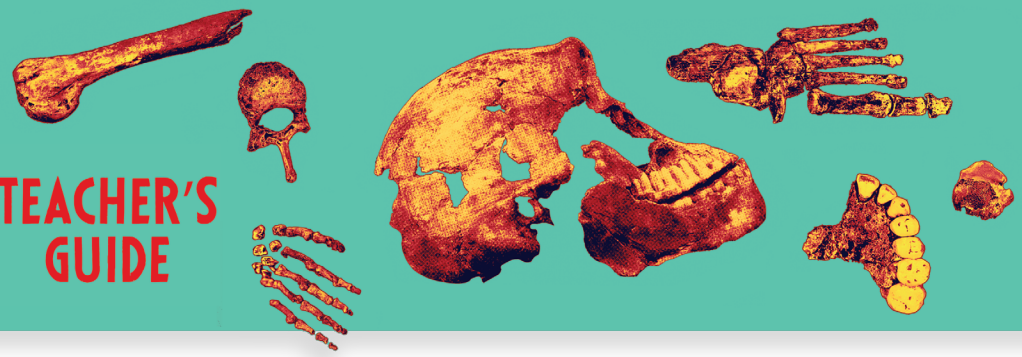
9. Molopyane and other South African scientists are now leading these missions. Why is it important for the narrow field of science to open up to people from all parts of the world and different backgrounds?

PRIMARY SOURCES

- Follow along each day of excavation with my Twitter "Play by Play" videos. Have students watch the video for a particular day and then report to the class not only what happened that day but also how it differs from what is included in the book.
- Voices of the Team 2015: Have students present each of my twelve interviews with team members to the class.
- Encourage students to watch Berger talking about *Homo naledi* (pre-2023).
- Have your students research the coverage of the official announcement from 2015. How did the world receive the 2015 announcement? Who was critical of the discovery and why?
- Now, encourage students to watch this video, as Berger explains *Homo naledi* to the Explorers Club in 2023. What was different about the reception of the 2023 announcement of behavioral discoveries?
- Have students research the critical coverage of the "Cave of Bones" controversy. What needs to be done by the team to better convince critics of the veracity of the burial/fire/art claims?
- The manuscript for *Reading the Bones* was completed in 2025. What new discoveries have been made since then that impact how people understand this story?
- Have there been any new *Homo naledi* announcements since the book was published in August 2026?
- If you had the chance to have a conversation with Berger or Molopyane, what would you ask them? What future paths do you think their research should take?

LAB ACTIVITIES

- The Great Fossil Find: Students are taken on an imaginary fossil hunt. Following a script read by the teacher, students "find" (remove from an envelope) paper "fossils" of some unknown creature, only a few at a time. Each time they try to reconstruct the creature, their interpretation may change as new pieces are "found."
- Understanding the Vertebrate Skeleton: Complete an owl pellet dissection. Reconstruct and identify the prey skeleton. This allows your students to do their own "reading of the bones."
- Cornell Owl Pellet Teaching Tips
- Barn Owl Pellet Analysis
- Carolina Biological Owl Pellet Dissection Mini Kit
- Create a narrow passageway in your classroom that is only as wide as the length of a dollar bill. Have students get a sense of how narrow the chute is by trying to get through.
- TIES (Teacher Institute for Evolutionary Studies) Skull Lab: This resource includes two options: a website for printing 3D skulls and documents for a less expensive alternative using paper copies of the skulls, with ways to measure the different traits.
- ENSI (Evolution and the Nature of Science Institutes) Cranium Lab: Students describe, measure, and compare cranial casts from contemporary apes, modern humans, and fossil hominids to discover similarities and differences among these forms and to see the pattern leading to modern humans.
- NCSE (National Center for Science Education) Human Story Shorts: A series of activities designed to help students better understand the process of evolution as well as its connection to human evolution. There are four Evolution Story Shorts.
- The Origin (and Conservation) of a Species: What is a species and why is it so difficult to define?
- Evolution of Horses: What caused changes in horse species over the past fifty million years?
- The Human Story: What can different types of scientific evidence tell us about human evolution?
- Pathogens and Vaccines: Why is a flu vaccine recommended every year, but we don't need a measles vaccine every year?



3D PRINTING RESOURCES

- Morphosource: A virtual digital "museum" with scanned data of a wide range of fossils and skeletal samples collected by researchers worldwide. Many can be downloaded and/or 3D printed for educational uses.
- *Australopithecus sediba* files on Morphosource.
- *Homo naledi* files on Morphosource.
- Human Evolution Teaching Materials Project: A fantastic site that has more than forty 3D printable files of various fossils (mostly skulls) related to human evolution. Most of these fossils also have 3D PDF files for viewing if you do not have access to a 3D printer.
- The Smithsonian also has a great collection of 3D viewable (not printable) hominin skulls for student use.
- AfricanFossils.org: A fantastic collection of hominin and animal fossils from the work of the Leakey family at Lake Turkana, Kenya. Many of these are available to download as 3D printable files, and all are available for 3D viewing online.

As a final resource, there is a curated collection of my previous writings and recorded talks about this discovery, as well as some press coverage, at *Homo Naledi Videos & Writings* by John Mead. For those of you who have questions about teaching *Reading the Bones*, please feel free to reach out to me at readingthebonesbook@gmail.com.