The Dawn of Diversity
LIFE IN THE BURGESS SHALE

LESSON #4: What am I?
Trying to interpret the fossil evidence of an enigmatic species

Focus questions

1. How do scientists interpret data?
2. Why do scientific theories and hypotheses often change?

What students do in this activity
Students are given a series of photographs and drawings of one of the most unusual and controversial Burgess Shale animals, Hallucigenia, to try to interpret its appearance. They will have the opportunity to draw the animal. The goal is to get the students to think about how scientists work: they gather information, form hypotheses, test them, and adapt the hypotheses to new information.

Alternative method
If you want to conserve paper, you could copy the drawings and photographs on to an overhead and work with those instead of handing out the drawings to each student.

Estimated teaching time
One class period

General supplies to complete this lesson plan:
- Paper
- Paper cutter

Each student will need the following:
- Copies of photos and drawings of Hallucigenia
- Paper
- Pencil

Learning goals

Students will:

1. Learn how enigmatic some of the Burgess Shale fossils are
2. Learn that scientists need to be open to new evidence
3. Learn that hypotheses are not conclusions
4. Learn how adding layers of information can help build better conclusions

Advanced preparation
Copy the handouts of drawings and photographs. The drawings are set up two per page, so that you can cut the pages in half.

Introducing the activity

1. Tell the students that they are going to be investigating one of the most unusual species from the Burgess Shale, a species that has confounded paleontologists for almost 100 years. It is a species that paleontologists are still debating.
2. Describe the history of studying this species, how Walcott first found it 1910 and described it in 1911. Then in 1973, Conway Morris found specimens in the drawers of the Smithsonian, looked at in new ways, and redescribed the species. In 1991, paleontologists in China found a relative of this species, which led to another redescription. A year later, closer analysis led to another redescription, and finally in 1995, another Chinese specimen, a species in the same genus, led to the latest redescription.

Teacher's tip:
Make sure that you only hand out one figure at a time. If the students receive all of the figures at once, it will weaken their learning experience.

Facilitating the activity

1. Hand out Figure 1. Do not tell them which way it faces or which is top or bottom. Don't tell them if it is a plant or animal.

2. For each of the figures that you hand out, ask the students to consider the following questions.
   a. Is it a plant or animal?
   b. Did it live on the land or in the sea?
   c. Is this the entire plant or animal or only part of it?
   d. Which way is up?
   e. If it is an animal, identify parts such as head, legs, arms?
      i. How did it move?
      ii. What did it eat?
   f. If it is a plant, how big did it get?
      i. Describe its lifestyle.

3. Ask them to draw what they think the plant/animal is.

4. Hand out Figure 2. Ask them if this drawing of the species makes sense from the photograph. Does it look like what they drew? Tell them that the paleontologist who made this interpretation named the species Hallucigenia, because of its "bizarre and dream-like appearance."

5. Tell them that this is indeed an animal. Ask them the questions above about Hallucigenia. In particular, ask them how Hallucigenia moved.

6. Tell them that, in the late 1980s, paleontologists in China found a close relative of the species, which had similar clawed tentacles and that the paleontologists figured out that the appendages with claws were legs.

7. Hand out Figure 3. Ask them how their interpretation of Hallucigenia changes when combined with the new information from China.

8. Hand out Figure 4. Tell them that this is the drawing based on the new information. Does this look like an animal? Is anything missing?

9. Hand out Figure 5. Tell them that this is the latest incarnation of Hallucigenia. Ask them how they think that paleontologists reached this interpretation.

Summarizing and reflecting

Ask students to report on what they thought the animal/plant was. Ask them "Why do you think we did this activity?" "What does it illustrate?" Ask them to consider how it illustrates how science works.

Additional ideas for consideration:

Science involves ongoing reanalysis. What is the point of revisting something that scientists already have investigated? Discuss that people don't dig up textbooks, that they dig up primary information that has to be studied and considered carefully. Ask them to think about how they react to things outside the realm of their own experience. Remind them that no one had ever seen an animal like Hallucigenia before Walcott's discovery.

Students could consider that just because scientists disagree on the details they can agree on the basics. For example, after Conway Morris reanalyzed Walcott's specimens and put it in a new phylum, scientists realized that Conway Morris was correct, even though he had the details (upside down) wrong.

TEACHER BACKGROUND: What am I?

High on a steep, treeless slope in the Canadian Rockies in August 1910, paleontologist Charles Walcott collected fossils of one of the most enigmatic species ever discovered. No one had ever seen it before and even after they did they called it puzzling, ludicrous, really weird and the weirdo of weirdoes. Walcott, however, simply gave it the name Canadia sparsa and put it in the phylum Annelida, which includes earthworms and leeches, as well as marine worms. And then the specimens sat more-or-less undisturbed in drawers at the Smithsonian for more than 60 years.

In 1973, a graduate student from Cambridge University, Simon Conway Morris, began to rummage through the 65,000 specimens collected by Walcott from that treeless slope in the Rockies. (Walcott returned to the slope, known as the Burgess Shale, seven times in 15 years.) Conway Morris eventually found 30 specimens of Canadia sparsa at the Smithsonian, along with one at the Museum of Comparative Zoology at Harvard (collected around 1930), and three collected in 1966 by a Canadian team.

Using techniques pioneered by his advisor, such as photographing specimens at oblique angles in UV-light and prying away the matrix surrounding the fossil with a modified dental drill, Conway Morris made a startling discovery — Walcott was wrong. His minute beast was not a worm, but Conway Morris wasn't sure exactly what it was either. He placed it in a new genus called Hallucigenia, named because of the "bizarre and dream-like appearance of the animal."

Hallucigenia looked more like a sculpture than an animal. It had a tubular body with seven pairs of spines for legs and seven, single flexible tentacles, each topped with pincers, on top. The head was blobby and the tail simply ended the tube. When he showed it to a colleague, he burst out laughing. Conway Morris proposed that Hallucigenia was a mostly stationary scavenger and perhaps oddest of all, had no mouth in its head. Instead, openings in the tentacles acted as mouths and food dropped into the long body tube or central gut. He concluded that Hallucigenia couldn't readily be compared to any living or fossil animal.

Paleontologists heralded Conway Morris' interpretation. Stephen Jay Gould wrote in *Wonderful Life*, "If one creature must be selected to bear the message of the Burgess Shale… the overwhelming choice among aficionados would surely by Hallucigenia." He wrote this because Hallucigenia was one of the earliest and best of the Burgess fossils studied in the 1970s that showed the true complexity of the animals that evolved in the Cambrian, in part because it was so odd looking and no one had ever seen anything remotely like it.

Conway Morris appeared to have given a definitive explanation, although some proposed Hallucigenia might be the detached part of a larger animal.
In 1991, however, researchers discovered a new species in China. It was in a long recognized phylum, Onychophora, known commonly as the lobopods or velvet worms. What made this discovery intriguing is that the new species looked quite similar to Hallucigenia and that it had pincers on the ends of its appendages, as did Hallucigenia. Furthermore, these appendages were legs and not tentacles on top of its body.

The discovery by paleontologists Lars Ramsköld and Hou Xianguang literally turned Hallucigenia on its head, making Conway Morris' stiff legs into protective spines, and turning the top tentacles, which they proposed were paired and not singular, into flexible legs with paired pincers at the end of each leg. Furthermore, their new reconstruction turned the body around, making the old head the tail and the old tail the head.

This new interpretation now put Hallucigenia into the phylum Onychophora. Scientists, including Conway Morris, trumpeted the new discovery as the key to understanding Hallucigenia, and even life itself. In a column in *Natural History*, Stephen Jay Gould wrote "By turning Hallucigenia upside down, we have probably taken a large step toward getting the history of life right side up." It showed to Gould that scientists need to constantly rethink their interpretations and that the picture of life in the early Cambrian was more diverse and more complex than previously imagined.

Four years later, however, paleontologists stated that Ramsköld and Hou had made a mistake. Using better preserved specimens from China, they described a second species of Hallucigenia, and showed that Conway Morris had it half right, his Hallucigenia head was indeed the head and the tail was the tail. At present, paleontologists are continuing to study fossils from China and have continued to locate new areas with Burgess Shale age and type deposits. Stay tuned for the ongoing story of Hallucigenia.

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Correct orientation of drawings for "What am I?" activity

Figure 1
Photo by Chip Clark, courtesy of the Smithsonian Institution's National Museum of Natural History.

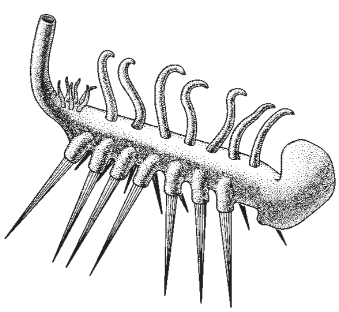


Figure 2
Drawing by Mary Parrish, courtesy of the Smithsonian Institution's National Museum of Natural History.

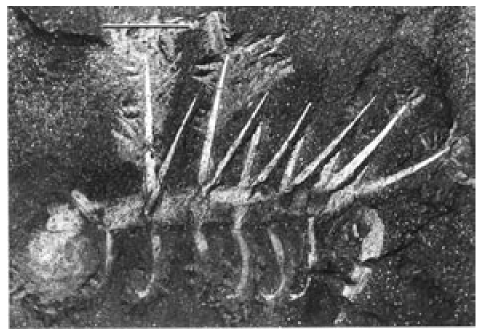


Figure 3
Used courtesy Simon Conway Morris, University of Cambridge

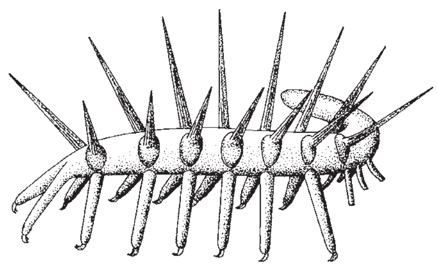


Figure 4
Courtesy of the Smithsonian Institution's National Museum of Natural History.

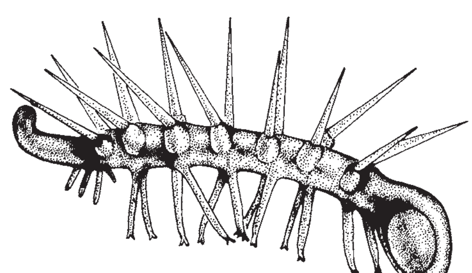
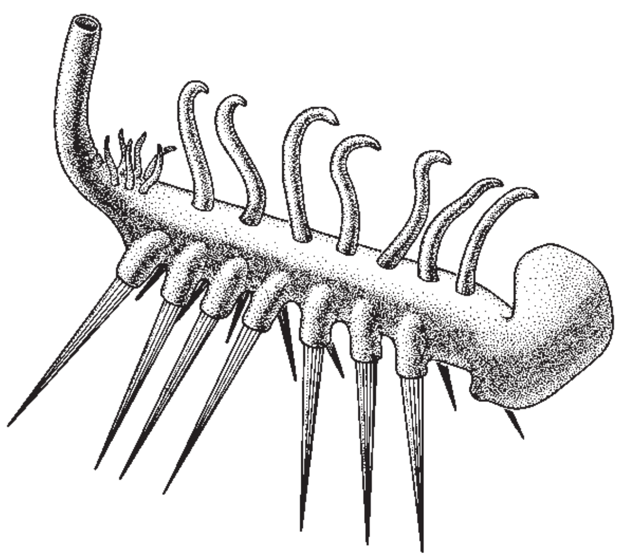


Figure 5
Drawing by Mary Parrish, courtesy of the Smithsonian Institution's National Museum of Natural History.



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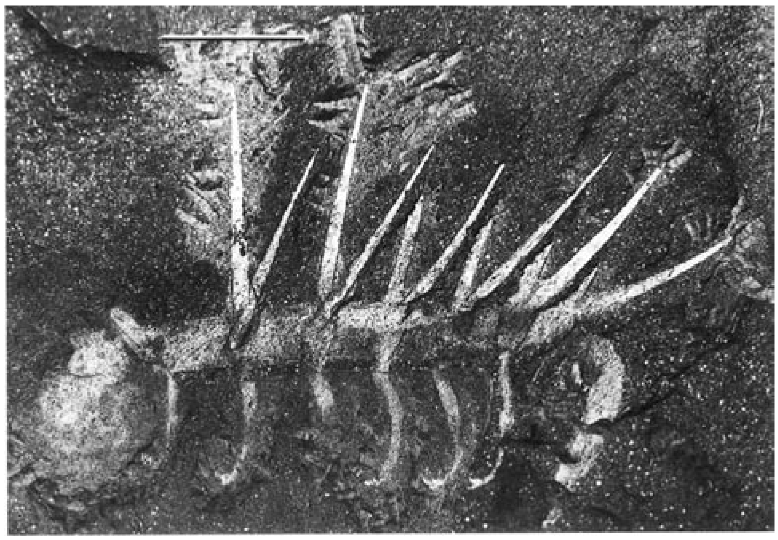

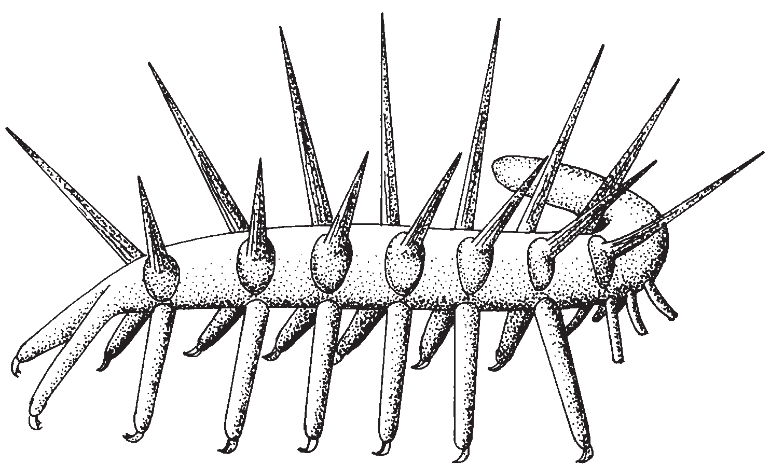

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