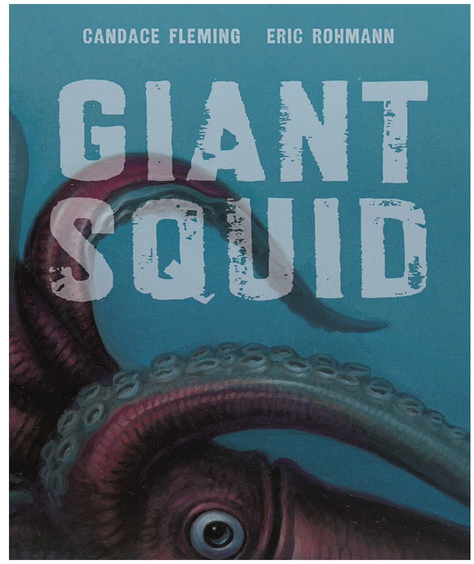
CANDACE FLEMING and ERIC ROHMANN

TEACHING GUIDE

Giant Squid

appropriate for grades 1 through 5 (and older)



Summary

The giant squid is one of the most elusive creatures in the world. They hide beyond reach deep within the sea, forcing scientists to piece together their story from those clues they leave behind.

An injured whale's ring-shaped scars indicate an encounter with a giant squid. A piece of beak broken off in the whale's belly; a flash of ink dispersed as a blinding defense to allow the squid to escape—these fragments of proof were all we had … until a giant squid was finally filmed in its natural habitat only four years ago.

In this beautiful and clever nonfiction picture book about the giant squid, Candace Fleming and Eric Rohmann explore, both visually and poetically, this hidden creature's mysterious life.

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Teaching Guide for *Giant Squid* by Candace Fleming, illus. by Eric Rohmann (Roaring Brook Press, 2016) ISBN 978-1596435995.

IV. From Mythical to Real Animal: a timeline

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For Your Lesson Planning

I. Scientific Inquiry

A. How does one find out about a creature that is rare and hard to get to due to where it lives? What steps should be taken in this research? Scientific inquiry, formerly known as the scientific process, has certain steps that should be taken.

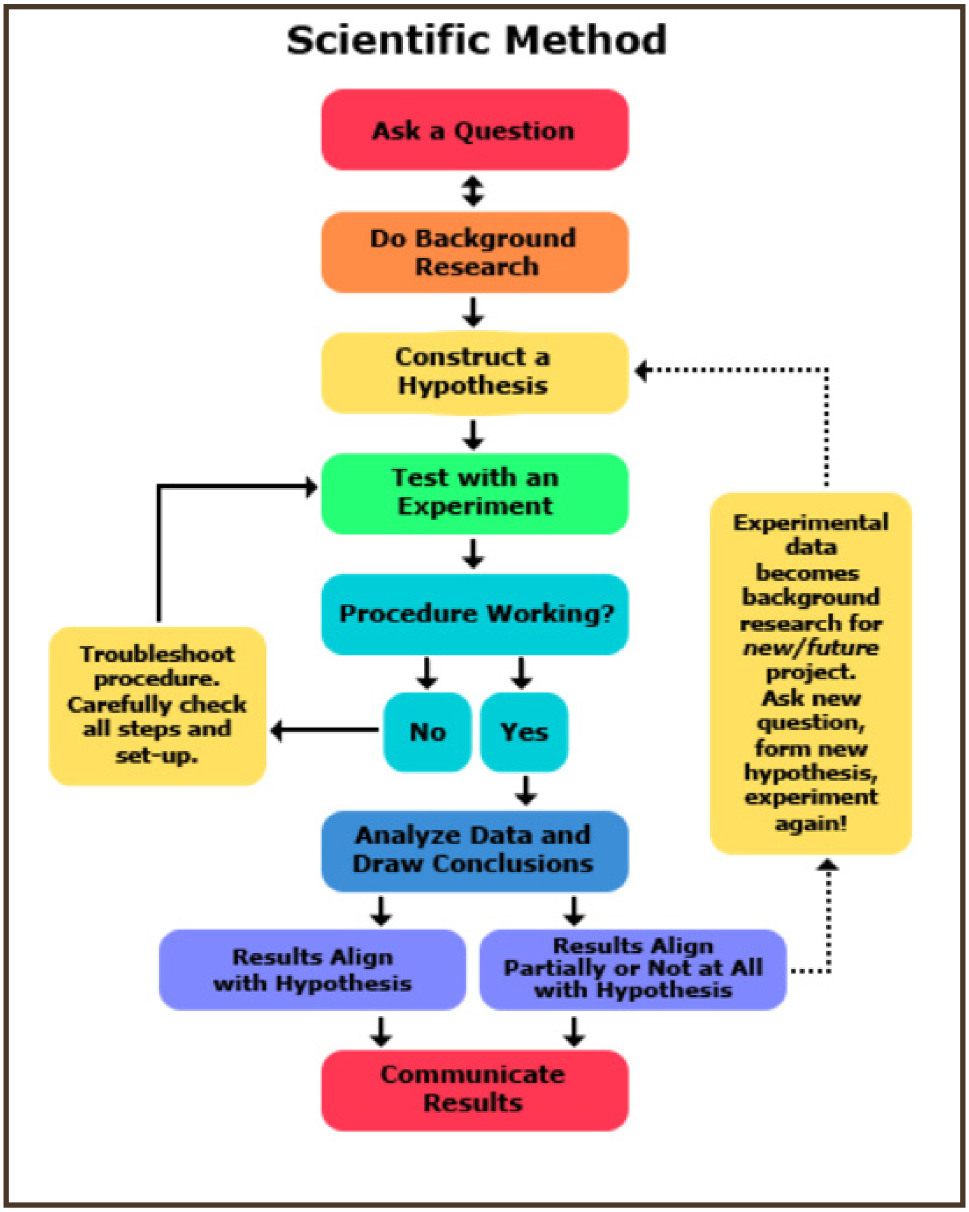
One succinct definition can be found in the Minnesota Academic Standards in Science: "Scientific inquiry is a set of interrelated processes incorporating multiple approaches that are used to pose questions about the natural world and investigate phenomena." Students should "generate questions that can be answered when scientific knowledge is combined with knowledge gained from one's own observations or investigations."

The national "**Next Generation Science Standards** (NGSS)" were developed from "***A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas***" created by the National Research Council (NRC) of the National Academy of Sciences. The NGSS can be summed up as:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

For a more detailed explanation of each step, and a comparison of science versus engineering, see p. 42 and pp. 50-53 of the ***Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*** (2012).

B. Another way to visualize the process is this Scientific Inquiry flow chart from **Sciencebuddies.org**:



Scientific Method flow chart is used here with permission from **ScienceBuddies.org**.

C. THE KWL chart

So, how to apply this process to an animal that lives deep in the dark ocean? As a classroom, you can't do direct investigations. But your students can design a plan on how they would gather and get more information. No "S.W.A.G.," no scientific wild guesses. To paraphrase Sheldon Cooper on the TV show *Big Bang Theory*, "I make conclusions based on observations and experimentation. No guessing."

Use this simple format for them to complete, as they think through the scientific inquiry process. (This "KWL" form adapted from Donna Ogle, 1986, and the **Prairie Wetlands Learning Center**, Fergus Falls, MN.)

For a downloadable version of this KWL chart, access **Scholastic**.

Since students can't do actual observations or experiments on giant squid, they will have to look up the answers to their questions: books, magazine articles, interviews, TV specials, DVDs, websites. *Giant Squid*'s bibliography has some resources to get your students started.

After they have tried to answer their question, students will write down what they learned (or haven't, in the case of giant squids; there are many unanswered questions!)

LOWER ELEMENTARY KWL

What I Know	What I Wonder & Want to Know	What I've Learned
existing knowledge	question(s) to be answered	after reading or research

UPPER ELEMENTARY KWL

What I Know	What I Wonder & Want to Know	How I Can Find Out	What I've Learned	Conclusions	New Questions
existing knowledge	question(s) to be answered	gathering knowledge: observations, tools, experiments, associated variables	after reading or research		giant squid are lesser-known animals, so many questions will arise!

II. Biology

Bits and pieces, even decomposed bodies or multiple strandings (washing ashore, alive or dead, often without a known reason) at one time, of giant squids have floated ashore for centuries. Over 700 specimens (partial or full) have been looked at since 1639 AD. Slowly scientists pieced together what giant squids looked like as well as their size. Clyde Roper, retired researcher and squid expert from the Smithsonian Museum, spent years making expeditions to find or photograph a live adult giant squid. Why are they so difficult to locate? "They are hard to find because they occur at depths where it is challenging and expensive to work."

How big are giant squids? Do they live in schools? How fast can they swim? How do they hunt? What do they eat? Who eats them? How do they communicate? Where do they live? How deep do they dive?

How many tentacles do they have? What are their eyes, their mouths, their arms like? How do they find mates? What are their eggs and babies like? How old do they live? Do they migrate? Do they 'ink' like their fellow squid cousins? So many basic questions and so few known answers.

Some answers are found in *Giant Squid* on pages 32-35.

A. How long are they?

Activity: How long? Even this basic question is debatable. The longest properly-measured giant squid was just about 46 feet long, including the tentacles. Many are 25 to 33 feet long. Recently, scientist Charles Paxton wrote an article in the ***Journal of Zoology***, May 17, 2016. He reviewed all the known old and recent sightings and measurements about mantle and total length. He extrapolated how many giant squids there must be in the world and knowing that only 460 specimens were measured, he predicts that there could be squids even bigger than 43 feet long, even perhaps over 60 feet. Longer than a school bus! He concludes, "it is obvious that the probability that the longest individual is among those catalogued is extremely low."

Dr. Paxton's May 2016 Abstract states "Giant squid are among the largest invertebrates known, but a consensus on their maximum size is lacking. Statistical investigation of various measures of body length and beak size in Architeuthis suggests that … given the relationship of squid mantle length to standard length (from tip of mantle to end of arms) and total length (from tip of mantle to end of tentacles) length, the observed spread of individual lengths, along with a longest reliably measured ML of 2.79 m (9.15 feet), purported squid of 10 m (32.8 feet) standard length and even 20 m (65.6 feet) total length are eminently plausible."

Ask your students what other factors should be looked at or considered? For example, is there a steady growth rate? Do males and females have different maximum lengths? Do local factors affect the growth rate (Water temperature? Amount of food? Amount of local squid predators such as sperm whales?)

Dr. Paxton further states: "There are several methods that could allow elucidation of maximum lengths of giant squid: (a) anecdotal reports, (b) estimation of an asymptotic length from growth curves, (c) estimation of length from sucker scars on whales, (d) measurement of available specimens, and (e) extrapolation of total length (TL) based on recovered beaks knowing the relationship of beak size to body length". Also, "there was no evidence from these analyses that sex influenced the ratio of arms and tentacles. Males may be smaller than females but they are not differently proportioned."

Scientific process: discussing and questioning. Yet, as demonstrated by the scientific process, other scientists dispute Paxton's length estimates, his methodology, his probability calculations, or his conclusions. See **this May 2016 article** by Michael Greshko for *National Geographic*.

Greshko cites other scientists who doubt these mathematical calculations, doubt the 1879 measurements of the largest giant squid, or wonder why *more* really big giant squid beaks haven't been found in the tens of thousands of various squid beaks found in sperm whale stomachs.

Dr. Paxton counters: "O'Shea & Bolstad (2008) stated that of the 130 Architeuthis specimens they encountered, none exceeded 2.25 m (7.38 feet) Mantle Length and 13 m (42.6 feet) Total Length, but assuming a population of hundreds of thousands (from Roper & Shea, 2014), there are plenty of opportunities for animals to reach longer lengths and the conservative statistics strongly suggest this. I would argue that Architeuthis slightly larger than those proposed by O'Shea and Bolstad are probable and such a claim is not such a 'disservice to science' as they suggest."

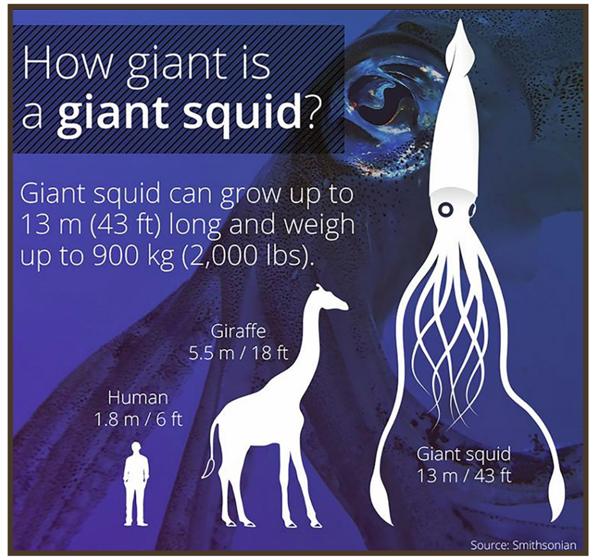
As you can see, scientists disagree!

Title page for *Giant Squid* © by Candace Fleming and Eric Rohmann

ACTIVITY: How long are giant squid and their body parts? Using the verified length of 43 feet including the two long tentacles, how long is this, *Really?* Gather 44 12-inch rulers or 15 yard sticks. Have students each hold one stick and stand side by side. 44 rulers or 15 yardsticks is the length of the longest (so far!) giant squid. You can further imagine the body part lengths using these figures:

Total length: 43 feet measured. Body = 6.5-7 feet. Arms = 10 feet. Long tentacles = 30-40 feet. Eyeball = soccer ball.

(Normal common deep sea squid are 3 feet long. Caribbean reef squid are 8 inches long. Humboldt Squid are 8 feet long. Colossal Squid are 15 to 25 feet, with wider bodies and shorter arms. The giant squid is the largest invertebrate in the world.)

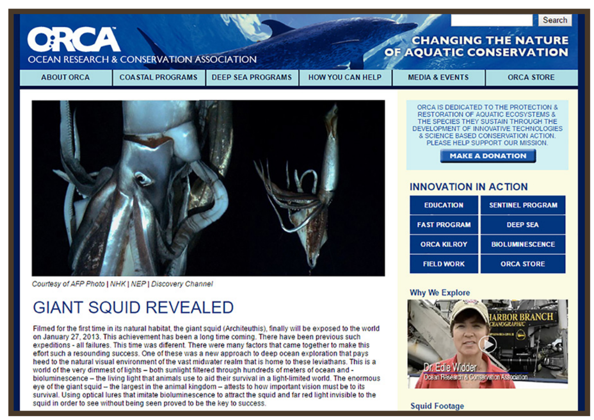


Here is **a graphic comparing a human, a giraffe, and a giant squid**. Source: Smithsonian Institution

Alternatively, you can measure and mark 44 feet on a hallway or gym floor. Demonstrate how big a giant squid is by having kids lay down, head to feet, on floor or athletic field in the shape of a giant squid.

B. How do they move?

ACTIVITY: Describe movement. Until the video of a live giant squid was taken in mid-2012, no one knew how they moved. Watch the videos below and describe the way it moves. Watch this **TED talk by Dr. Edith Widder**: footage of a a living giant squid, all six encounters, starts at minute 5:00-7:24. Another source is **this article with a video imbedded midway** or **this clip, "Squid footage"** block on the right.



ACTIVITY: Have the children describe how the squid moves. Does it use all the arms, the tentacles, jet propulsion? In what position is the body? How does it use its arms? What does it seem to be doing to the lure and camera device? What color is it?

Read more on Dr. Edith Widder's webpage about **her EITS device and expedition**.

ACTIVITY: Inking. It would be of no use as camouflage or a surprise element in the dark deep sea, but since almost all other squid do it, perhaps giant squids do it as a vestigial (i.e. left over, typically harmless) behavior. Evolution says that a behavior or body shape is continued as long as the behavior is benign and doesn't harm the squid. Albeit, it takes energy to make the ink. What do you think? How could you find out?

C. Why do they have such big eyes?

Source: **Smithsonian Institution**

ACTIVITY: There are two opposing theories on why giant squid have such big eyes. There are differences of opinion among scientists as to the reason for the giant squids' really big eyes (which are 10"–12" in diameter. The size of a dinner plate!). Some people think the large eyes help the squid see the pale bioluminescent light from their prey fish.

Edith Widder thinks that a common deep-sea jellyfish emits light when attacked. And that this flashing can lure in a larger predator on the jelly attacker, which would be scared away or attacked itself (perhaps by the giant squid), thereby perhaps saving the jellyfish. Other scientists, including Japanese expert Tsunemi Kubodera think the big eyes can see the faint silhouette of prey fish when looking up towards the faint light from the ocean surface. **See halfway down this linked article**. Can you think of an experiment that scientists could do to determine the best explanation?

D. How many giant squids are there?

ACTIVITY: Count the squid population. Since giant squids are so elusive and live so deep in the vast vast ocean, it is impossible to count their population. But we have some indirect evidence of them: the hard beaks of various squid species that accumulate in the stomachs of their main predator: sperm whales. Scientists have counted the number of squid beaks in a certain number of whales and determined an average (typical) number of beaks in the stomachs. For example, there have been 5,000 to 7,000 squid beaks per whale. (That's a lot of dead squid! But only a few are giant squid beaks. The Colossal Squid seems to be the most eaten species.) Based on whale surveys and population counts, the scientists then calculate by multiplying the number of sperm whales times the number of squid eaten to get the overall populations of squid. Indications are that there are *millions* of two-foot long bioluminescent squids in the ocean.

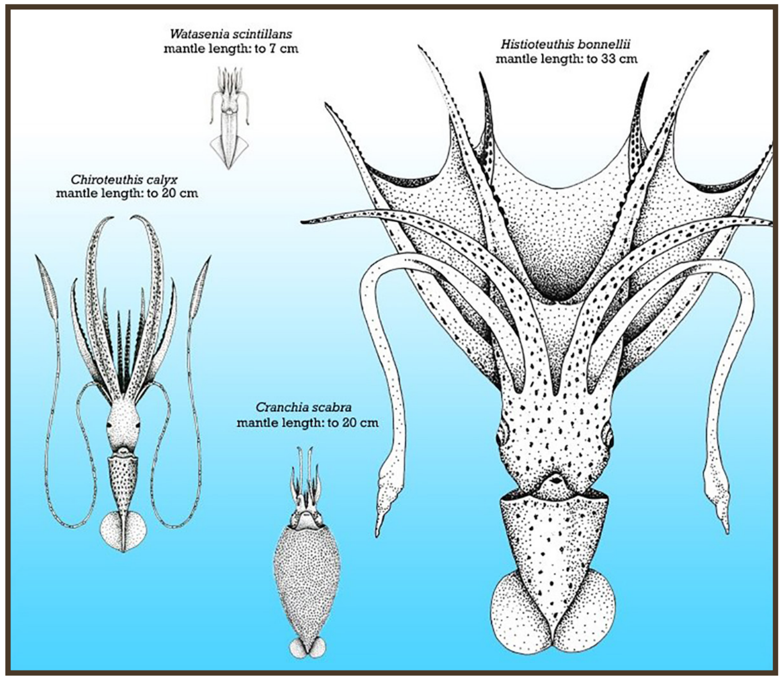
But what about giant squid beaks? There must be millions of them, too. So it is even more amazing that a live giant squid wasn't seen or filmed until recently!

ACTIVITY: How many squids? Do some math with your students. In 1973, it was estimated there were 1.25 million sperm whales, (who totally weighed 10 million tons). Each whale eats 100 tons of squid per year. What's the weight of squids that are taken as sperm whale food?

Answer: 1.25 million whales x 100 squid tons = 100 million tons of squid needed and eaten by sperm whales each year. This is larger than the total amount of fish caught worldwide for human consumption.

Note: Malcolm Clark (1980) surveyed 461 sperm whale stomachs and found giant squid beaks in only 0.26%. Thus, sperm whales do NOT eat a lot of giant squids, despite sperm whales being caught that have scars from giant squid tentacles, as the squid have fought with their attacking whales.

Alternatively, in Mary Cerulla's book *Giant Squid: Searching for a Sea Monster* (2012) she estimates that one sperm whale may eat 20,000 squids per week, but only 3/week are giant squids. How many giant squids are eaten per year? (3/week x 52 weeks = 150 giant squid per sperm whale per year). Current estimates are 400,000 sperm whales (could be much higher), so how many giant squids are eaten? 400,000 whales x 150 per whale = 60 *million* giant squids! And there could be many, many, many more that are *not* eaten!



Squid diversity from Smithsonian's Ocean Portal.

III. Bioluminescence

As an animal, how do you find your food, find a mate, and escape from predators if you live in an almost-lightless environment? Most land and air animals use visual behavior, noise, or color to signal their needs: locate prey food, avoid predators, and attract mates.

But in the deep, deep ocean, where there is little or no light, these usual clues don't work. Regular vision is no good. So more than 80% of deep sea animals have evolved to create their own light on demand! This is called bioluminescence. This is a controlled chemical reaction that generates no heat—but it does require a lot of body energy. The "living light" must be very useful.

Scientists think that bioluminescence is used for:

1. Defense, i.e., to startle or to confuse or to misdirect a predator
2. Offensive function such as luring, stunning, confusing prey, or lighting up prey
3. To attract predators to an attacker, a 'burglar alarm' for last-chance defense
4. To camouflage by counter illuminating the body or masking body size or full shape
5. To attract a mate and recognize the same species

A. Red vs. Blue Light

ACTIVITY: Red light vs blue light. Use a small candle in a larger room, or punch a couple of very small holes in a solid pail/can and put a flashlight inside. Sit children in a dark room and let their eyes adapt to the dark for 5 minutes. Very faint light should be emitted. Hold up various colors of construction paper in this very dim light. What colors can be seen best? What colors vanish first as the papers are moved further from the light?

Bioluminescent jellyfish in deep sea | Source: Photo-duneJackF, Photodune

Red color cannot be seen by most terrestrial animals; that is why hunters wear blaze orange and nocturnal wildlife viewing stations use red light bulbs. And red is the first wavelength that disappears in water. Deep sea animals cannot see red; their eyes are adapted to green and blue wavelengths that travel further in water.

Dr. Widder uses red lights on her ***Eye In The Sea* (EITS) machine**. Special ultra-sensitive cameras can capture images in this red light but the creatures will think it is the usual darkness around them.

Counter-illumination: Is it an invisibility cloak? Some people think that bioluminescent lights' patterns or shapes can be used to camouflage a fish in the deep sea. Or the full shape or size of the predator. Or the lights could resemble little bits of light coming from above. By flashing lights on, and then off, a predator would be confused as to where the prey animal suddenly went. What do you think? How could you prove these ideas? Brainstorm with your students. Follow up by researching whether your suggested methods have been tried.

B. Hot vs. Cool Light

ACTIVITY: Hot light vs cool light: incandescent bulb vs glow stick. To demonstrate how much energy it can take to emit light, plug in a desk lamp with an ordinary incandescent light bulb. After a few minutes, students can put their hand *above* the bulb and feel the heat, which is a by-product of the electrical reaction that creates the light. Kids already know to *not touch* a lit hot bulb! At the same time, break and activate a glow stick. Kids can touch that stick, see the light, and sense that there is no heat generated by this chemical light reaction. Relate hot and cool light to bioluminescence and the effort a giant squid would expend creating light.

C. Flash Patterns

ACTIVITY: Flashing flashlights matching patterns. To demonstrate how deep sea animals can use their bioluminescence to communicate, choose 10 children and give them flashlights in a semi-dark room. (The other children can watch the process from the sides). Give the following flashing patterns to two children: a) steady quick flashes, b) steady long flashes, c) a quick then a long flash. Repeat. d) two quick flashes and a pause. e) two long flashes, pause, repeat. Have the children scattered around the room. On your mark, they start their flashing patterns. They look for their matching pattern and go next to their 'match.' This demonstrates how creatures can find or understand each other using lights and flashing.

In real-life fish and other organisms, bioluminescence comes in many colors: shades of blue, green, red, orange, yellow, violet, and ultraviolet. To see some weird and amazing light patterns, **watch the first video here**.

D. **Bioluminescence Process**

ACTIVITY: The bioluminescent process. Purchase several packages of glow sticks. They now come in a variety of colors: green, blue, pink, yellow, orange, purple and red. (Note: During Halloween time is when many varieties are available at stores. Or shop online).

There are 7 colors, depending on the chemicals used or the color of the plastic container. The glow stick contains two chemicals and a suitable dye (sensitizer, or fluorophor). This creates an endothermic reaction. The chemicals inside the plastic tube are a mixture of the dye and diphenyl oxalate. The chemical in the glass vial is hydrogen peroxide. By breaking the storage tubes and mixing the peroxide with the phenyl oxalate ester, a non-heat-producing chemical reaction takes place. And the cool light emits. **See details here**.

Bioluminescence is a similar chemical reaction controlled by the creature. The light-emitting pigment luciferin and the enzyme luciferase mix with released oxygen resulting in CO2, phosphates, and light. Other co-factors are amounts of calcium or magnesium ions or the energy source ATP. Most marine organism light emission is in the blue and green light spectrum. For a long explanation of the chemical reaction and the wide variety of organisms that utilize bioluminescence, **see the article in Wikipedia**.

To read how Edith Widder mimicked bioluminescence to attract the giant squid, read her article on her **ORCA organization** site. Her lure gave off the color and flashing pattern of a common jellyfish being attacked.

IV. From Mythical to Real Animals

There are a number of 'mythical' animals that we don't really know if they exist, such as the Loch Ness Monster, Big Foot, or the Kraken of Scandinavian sea lore. Have—and how have—researchers tried to determine the existence of these animals in the past? Direct observation, talking to people, taking photographs, setting up motion cameras, looking for evidence or signs left behind, etc.

What steps would you need to take to prove the existence of one of these creatures to the world? Which books or journals would you reference for research? Which experts would you want to contact or read about?

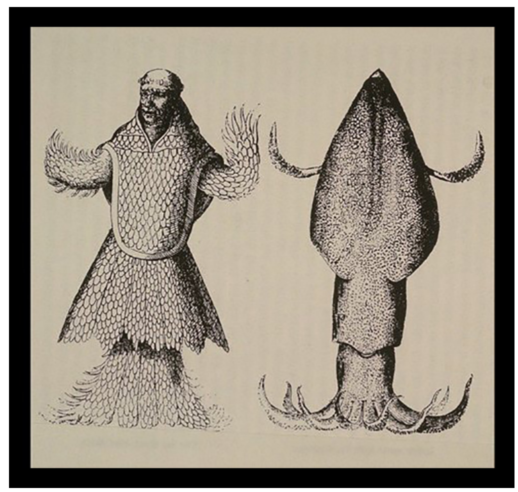
ACTIVITY: Prepare a "research timeline" for the steps you'd need to take, **something like this timeline** that author Melissa Stewart wrote when researching and writing her book *No Monkeys, No Chocolate*. Title it "Research Steps for Proving the Existence of a Mythical Creature." Or invite students to develop their scientific method, research question, research steps, with their bibliography and references, for possible inclusion. The KWL chart could be useful.

ACTIVITY: How would they proceed? Ask the students: If you spotted an animal in your schoolyard that no one had ever seen before, how would you go about verifying its existence, determining what it looks like, how it lives (eats, mates, cares for young, etc.) and documenting it for others?

Timeline Example

“Mythical Creature: from Kraken Monster to Sea Monk to Giant Squid: a timeline from myth to reality”

“For hundreds of years, the mysterious giant squid has inspired many legends, books, and movies. Over 500 years ago, sailors in Norway told tales of an enormous sea monster, which they called Kraken. According to the legend, the huge creature with many long arms would wrap its arms around a passing ship and pull it underwater. Homer’s *Odyssey* and the novels *Moby Dick* and *20,000 Leagues Under the Sea* described similar monsters. Giant squid have also appeared in lots of movies, like *Reap the Wild Wind* (1942), *A Voyage to the Bottom of the Sea* (1961), *The Beast* (1996) and three film versions of *20,000 Leagues Under the Sea* (1916, 1954, 1997).” (from Scholastic).



People once thought giant squid (right) were Sea Monks or mermen (left)—mythical creatures that were part fish-like and part human male. Credit: Roeleveld Knudsen, 1980

- “The first known record of Architeuthis comes from Denmark in the 1500s, when several “curious fish” were found afloat by the sea. Historians of the time did not associate these “fish” with cephalopods; instead, they conflated their looks with those of humans, describing these creatures as having “a head like a man... and a dress of scarlet like a monk’s cloak,” and calling them Sea Monks. Not until the mid-1800s did the leading cephalopod specialist of the day, Professor Japetus Steenstrup of Denmark, conclude that the mythical beasts were, in fact, very large squid. With the two long feeding tentacles arranged just right, they could be mistaken for arms sticking out of the mantle. The rest of the Sea Monk descriptions, however, he ascribed to a combination of astonishment and imagination. “Squids on the whole make a grim impression on all those who are not accustomed to seeing them more frequently,” Steenstrup said. “Those animals aroused still greater astonishment in earlier times.” (Mermen to Architeuthis from **Smithsonian Ocean Portal**)
- **1639 to 2015:** Reality arrives: Eventually, science and observation, recording, and measuring took over. Reports were made and collected of over 700 dead giant squids (bits and pieces, too) that floated ashore, were caught in nets, or found in sperm whale stomachs. There were over 700 specimens. Hot spots for beach strandings are Newfoundland, New Zealand, and Norway.
- **1996-1999:** Dr. Clyde Roper undertakes multiple expeditions near New Zealand to catch or photograph live giant squid. Since mid-1970s he has studied them whenever possible, examining almost 100 dead specimens himself. **Watch this video** on Dr. Ropers’s efforts and him showing dead specimens.

- **2002-2004 (three falls):** Japanese giant squid expert and long-time researcher Dr. Tsunemi Kubodera makes **23 deployments of camera and bait systems off of Japan**.
- **Sept 30, 2004:** The first still photos are taken by Dr. Kubodera and his crew. A giant female squid got hooked on the lure and his team took 556 pics taken before its tentacle broke off and it got away after 4 hours and 13 minutes of struggling. He estimated the squid was 26 ft long, with an 18 foot tentacle brought up to the surface on the hook. This is **his official paper** on Dec 22, 2005.
- **2004: Part 1 Giant Squid:** Caught on Camera (pt.1) This introduces Dr. Kubodera and sperm whales, with sucker scars seen on sperm whales.
- **2004: Part 2 Giant Squid:** Caught on Camera (pt.2) This has a composite of the 556 still photos taken by the underwater camera by Dr. Kubodera in 2004
- **Dec 4, 2006: First video of a live giant squid** hauled to surface by Dr. Kubodera.
- **Summer 2012:** Five encounters over six weeks. Great footage in **Dr. Widder's TED talk** of February 2013. from Drs. Widder and Kubodera's expedition with the EITS, Medusa, and e-jelly. This expedition gave the first live footage of giant squids, who's no longer a mythical animal! Giant squid came at the e-jelly four times (at 5:00 – 5:30), one full flare (at 5:34-5:48), and live footage (from the Triton submersible) of a giant squid attacking a lit squid lure (at 6:40-7:20).
- **Jan 27, 2013: Spliced video** taken from the submersible. The giant squid is eating the smaller (red) squid bait.

All these spectacular footages brought the giant squid to life for the world. But many more questions about its lifestyle remain. Who will be the next scientist to unravel these mysteries? Could it be you??

Activity: Explore some of these or other stories about giant squid. Then try writing your own tale about the giant squid. Use your imagination, but take what you've learned about this mysterious creature to make your tale believable.

V. Other Resources:

A good overall webpage, with multiple photographs and illustrations and history is the **Smithsonian's Ocean Portal giant squid page**

Other suggestions for giant squid activities can be found at Scholastic **here** or **here**.

Try the Smithsonian's extensive **teacher guide** including basic facts and a quiz sheet pp. 16 and 17. Range maps pp. 12, 15 and 18. Life factors pp. 26 and 27. World-wide ocean temperatures. How to plan an ocean expedition.

Project Oceanography has three activities on squid: Cooking recipes on p.11. Squid Races using balloons on a line pp. 112-113. Squid ink "gyotaku" printing pp. 114-116. And two recipes p. 111.