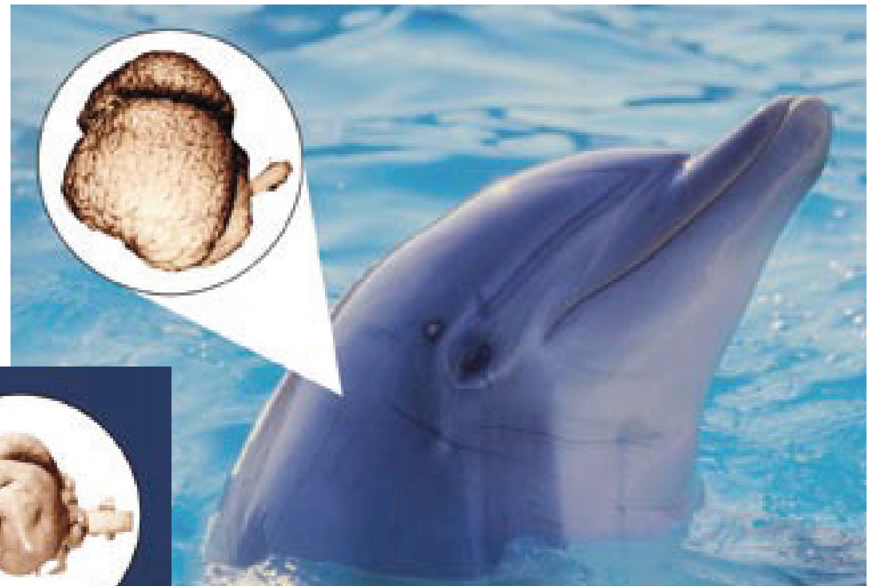
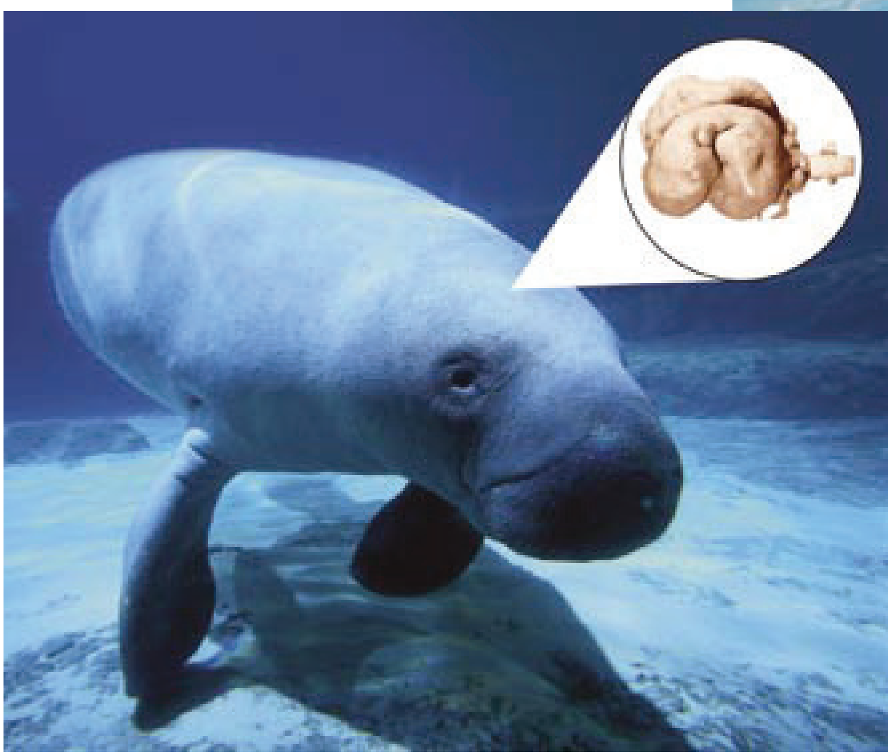
The Marine Mammal BRAIN GAME





Students compare the brains and behaviors of dolphins, sea lions, and manatees in this unique standards-based activity

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Dolphins, manatees, and sea lions are all aquatic mammals but are not closely related taxonomically. All three species are marine mammals, meaning they spend part or all of their lives in the sea and contiguous bodies of water. Dolphins belong to the taxonomic order Cetacea, which includes whales, dolphins, and porpoises. Manatees (sea cows), however, belong to the order Sirenia, which also includes the dugong. Sea lions were once placed in the order Pinnipedia, with seals, but now belong to the order Carnivora with bears, dogs, and raccoons. Even though these species at first glance may seem similar, the way they are classified shows that each has very different characteristics and abilities.

BRAIN PHOTOS COURTESY OF WWW.BRAINMUSEUM.ORG

Students can learn about the convergent and divergent characteristics of these animals by examining their physical, physiological, and behavioral traits, along with their ecological niches. The Marine Mammal Brain Game (MMBG) described in this article introduces students to the intricate relationships between form and function, movement and behavior, and the role of each animal in the ecosystem. Students compare and contrast dolphins, manatees, and sea lions, discover the structure and function of these animals and their various adaptations, and learn how the marine mammals' brains, behaviors, and habits differ. Students also have the chance to practice oral communication and chart-reading skills.

Although marine mammals are used as the example in this game, educators may also develop similar games and activities comparing other animals: lions and zebras can be used to compare carnivores and herbivores, or domesticated goats and white-tailed deer can demonstrate similar types of animals that differ in their human interactions. Students can also use the MMBG as a model to develop their own games, which can compare everything from moles and bats to camels, elephants, and humans.

The content of this game meets requirements set by the National Science Education Standards (see "Addressing the Standards," p. 29) and covers topics ranging from taxonomy and diversity to anatomy and physiology. The game can be used in classes studying environmental science, natural history, life science, and even psychology. The content can be modified to expand instruction in a specific area such as environmental biology or to cover a broader range of topics such as evolution, biodiversity, and oceanography.

Comparing brains

The primary focus of the MMBG is, as the title suggests, learning about the animals' brains. Just as different animals have unique external characteristics, they also have different adaptations of the brain. One of the more obvious adaptations is brain size. Larger animals have larger brains in order to control a greater number of muscles and bigger, more complex systems. However, overall brain size is less important than the relative brain size—the brain size adjusted for body weight. If two species of animals have the same brain weight, for example, it is likely that the species with the lower body weight is more intelligent.

Neurons are packed in more densely in the brains of some advanced animals (which results in an increased brain weight but not brain size) through convolutions (foldings) in the cerebral cortex. More advanced animals tend to have more complicated cerebral cortexes. An animal with a relatively smooth cerebral cortex is called *lissencephalic,* while an animal with a very convoluted cerebral cortex is called *gyrencephalic*. One clear example of this is a comparison of the brains of the lissencephalic manatee to the gyrencephalic bottlenose dolphin (see brain images on p. 24).

Additionally, the cerebral cortex comprises a greater proportion of the overall brain in more complex animals. Another obvious external feature of the brain is the relative size of the cerebellum, which is important for balance and coordination. A proportionately larger cerebellum is evident in animals that are able to perform complicated behaviors. The olfactory bulb is also easily identified and is important for the sense of smell. The brain images used in the MMBG are presented with a corresponding linear scale alongside the image from the Comparative Mammalian Brain Collection site *(www.brainmuseum.org)*—a collection of brain images from the University of Wisconsin, Michigan State, and the National Museum of Health and Medicine. Thus, several mathematical extensions of the game are easily conducted. For example, students can measure the sizes of specific structures of the brain or measure and calculate absolute and relative volume of these structures.

Gathering materials

For this activity, teachers will need the game questions (Figure 1, p. 26), random number generator dice, pictures of the three animals and their brains (see "On the web" at the end of this article for a list of internet resources), brain specimens (optional but highly desirable), and other three-dimensional representations of the animals such as stuffed animals or plastic models (also optional).

To construct the game, teachers should copy and paste the questions from Figure 1 onto 3 × 5 index cards. The opposite side of each card should then be labeled with a number ranging from 1–12 to match with the corresponding question number. Multiple questions for each number are provided so that students who pick duplicate numbers will not be asked the same question. The cards may be placed into a small card file separated by numbers to make the experience more gamelike.

A number of easily accessible images are required to play the game unless it is played in a computer center with sufficient access to online images. Images of dolphin, manatee, and sea lion brains can be downloaded from the Comparative Mammalian Brain Collection site. A labeled manatee brain image should also be downloaded from *www.manateebrain.org* because it provides information about the functional organization of the brain, which is required to answer Question 9 (Figure 1). Additionally, teachers should gather images of dolphins, manatees, and sea lions from the online resources listed at the end of this article (see "On the web," p. 29). If printed, these images can be laminated or inserted into protective sleeves for use in other classes or in subsequent years.

The game can be further supplemented with the inclusion of actual brain specimens. While it is difficult to gain

FIGURE 1

Questions for Marine Mammal Brain Game.

1. ◆ Match the MANATEE picture to the manatee brain.
   ◆ Match the DOLPHIN picture to the dolphin brain.
   ◆ Match the SEA LION picture to the sea lion brain.
   ◆ Which of these animals is amphibious such that it lives both in water and on land?

2. ◆ Which of these animals are often trained to perform acrobatic tricks?
   ◆ Which of these animals lack hind limbs?
   ◆ Which of these animals has a blowhole to breathe with?

3. ◆ Which of these brains is the biggest?
   ◆ Which brain has the least convolutions (wrinkles) or is the smoothest?
   ◆ Which brain has more convolutions (wrinkles)?
   ◆ Which animal has the largest brain-to-body mass ratio?

4. ◆ Which of these animals uses echolocation to find food?
   ◆ Which of these animals uses the somatic/tactile sense (touch) to find food?
   ◆ Which of these animals has the most developed olfactory sense?
   ◆ Which of these animals does not have vibrissae (whiskers)?

5. ◆ Which of these animals is not territorial and does not demonstrate any social hierarchy?
   ◆ The male of which of these animals establishes a breeding territory for their harem?
   ◆ Which of these animals travels in social groups called pods?
   ◆ Which of these animals uses a complex language?
   ◆ Which of these animals barks?

6. ◆ Which of these animals is vegetarian?
   ◆ Which of these animals is carnivorous?
   ◆ Which of these animals lacks molar teeth?
   ◆ Which of these animals eats on land as well as in the water?
   ◆ Which of these animals has only molar teeth?

7. ◆ Which of these animals is in the taxonomic order Cetacea?
   ◆ Which of these animals is in the order Sirenia?
   ◆ Which of these animals is in the order Carnivora?
   ◆ These animals are all members of which class? Phylum? Kingdom?

8. ◆ Which of these animals uses olfaction (sense of smell) to identify their babies (pups)?
   ◆ Which of these animals sleeps with only one hemisphere of their brain at a time?
   ◆ Which of these animals lacks an olfactory nerve?
   ◆ Which of these animals is endangered?

9. ◆ Using the labeled manatee brain as an example, point to the area of the dolphin brain important for hearing.
   ◆ Using the labeled manatee brain as an example, point to the area of the sea lion brain important for hearing.
   ◆ Using the labeled manatee brain as an example, point to the area of the dolphin brain important for vision.
   ◆ Using the labeled manatee brain as an example, point to the area of the sea lion brain important for vision.

10. ◆ Based on their brain structure, which of these animals would have the best balance?
    ◆ Based on their brain structure, which of these animals would be the smartest?
    ◆ Based on their brain structure, which of these animals would be the least intelligent?
    ◆ Based on their brain structure, which of these animals would have the best olfactory sense?

11. ◆ Which of these brains has the most complex cortex?
    ◆ Which of these brains has the most developed cerebellum?
    ◆ Which of these animals has the most complex auditory area of the brain?
    ◆ Why do you think dolphins have such large temporal lobes?

12. ◆ Which coronal section through the middle of the brain is from a manatee brain?
    ◆ Which coronal section through the middle of the brain is from a dolphin brain?
    ◆ Which coronal section through the middle of the brain is from a sea lion brain?

access to brains of these particular species, sheep brains are easily attainable from a number of vendors. If another animal's brain is used, the teacher should download the corresponding brain images of that species so that students can use the images for comparison.

Images of the human brain should also be downloaded because students invariably have questions about how these brains compare to our own.

Playing the game

The game's questions ask students to compare the gross brain structure of the three animals, body morphology characteristics, and behaviors such as sleeping, vocalizations, and territoriality (Figure 1). Depending on the students' background, they can play with or without the comparison chart provided as a student handout (Figure 2). The vast majority of the answers for the game can be found on the comparison chart.

Any mechanism that allows students to randomly generate a number (such as dice) can be used to play the game. When played in the classroom, to add a competitive aspect, students can be divided into two teams and the teacher can keep score. In this setting, students can be required to play independently with no help from their peers. Alternatively, students can play the game in a fashion similar to the *Who Wants to Be a Millionaire* game show and be allowed to either poll their team or ask an "expert" for their input when unsure of the answer. To ensure that all students participate equally in the game, a limit must be placed on the number of times a team can use either of these strategies.

A single individual should be designated as "dice roller" for the team while other students answer the questions in turn. Depending on the abilities and dynamics of the class, either select students or teachers can serve as judges of the correct answers. The easiest questions are numbered 1–6, so for some student groups it may be appropriate to have students roll only one die. (Editor's note: An alternative set of questions for students who may find the questions in Figure 1 too challenging is provided with the online version of this article at *www.nsta.org/highschool#journal.*)

Extensions and modifications

If a number of computers are available, playing the game in an online environment may encourage students to compare the brain images of the species used for the game with others available online at the Comparative Mammalian Brain Collection site. The website also has written descriptions of the various mammalian orders and the life histories of some species within these orders, which could

FIGURE 2

Student comparison chart for Marine Mammal Brain Game.

Brains and behavior of aquatic mammals: A comparison of dolphins, sea lions, and manatees.

	Dolphin	**Sea lion**	**Manatee**
Class	Mammalia	Mammalia	Mammalia
Order	Cetacea	Carnivora	Sirenia
Governmental status	depleted	generally protected	endangered
Appendages	flippers (forelimbs) and fluke (tail)	flippers (forelimbs) and hind-limbs (legs)	flippers (forelimbs) and fluke (tail)
Primary foraging mechanism (how to find food)	echolocation (sound)	visual	tactile (touch)
Diet	shrimp, fish	fish	sea grasses
Dentition	all conical and interlocking	pointed canines and molars	flat molars
Habitat	bays, lagoons, open ocean, can be in rivers	coastlines, can be in rivers	rivers, bays, coastlines
Vocalizations	complex language, distinctive whistles	barks	mother-pup identification
Territorial	no	yes	no
Dominance hierarchy	yes (live in pods)	yes	no
Tricks	acrobatic and balance	acrobatic and balance	none
Sleep	single hemisphere at a time	paradoxical (deep sleep)	may be single hemispheric
Olfaction	olfactory lobes and nerves absent	pup identification	used for determining location at night
Cerebral cortex	convoluted (folded)	convoluted (folded)	smooth
Brain weight	1550 g	365 g	360 g
Body weight	180–300 kg*	Male: 270–360 kg; Female: 90–180 kg	360–550 kg
Body length	2.5–3 m*	Male: 2–2.4 m; Female: 1.5–2 m	3 m

*Body size of typical Atlantic bottlenose dolphin *(Tursiops truncates)*

FIGURE 3

Higher-order thinking skills (HOTS) questions.

The following questions require some thought and are open-ended or require meta-analysis of learning. These questions can be used to play the game with smaller groups or can be used as extensions to the game.

- Why are dolphins able to learn complicated tricks? Why are manatees not?
- What aspect of the manatee's brain may contribute to its increased incident of boating accidents? What aspects of its body may contribute to these accidents?
- What are the advantages of a convoluted brain?
- Is the dolphin the smartest of these animals? Is the dolphin smarter than humans? What constitutes "intelligence"?

(A more extensive list of HOTS questions can be found on the online version of this article at *www.nsta.org/highschool#journal.)*

facilitate interspecies comparisons similar to those evoked in the game. Additionally, after students learn the basic structural areas of the brain and their functions, they can go online and determine the homologous structures in the brain images of other species. These activities can emphasize both diversity of the mammal brain (i.e., differences in convolutions and relative sizes of various structures) as well as how the brain structure overall is largely conserved across species (i.e., all mammalian brains have a cerebellum and two cerebral hemispheres).

This activity can also be adapted by giving students a blank chart and requiring them to find and fill in the appropriate information before playing the game. In addition, the activity can be modified to be inquiry-based by familiarizing students with some aspects of these animals' life histories and asking them to hypothesize about the anatomy of the brain (e.g., relative brain versus body sizes, amount of convolution, absence of olfactory nerves, and areas for species that do not experience olfaction), and vice versa. Educators interested in devoting time to these subjects (e.g., those teaching marine biology) may extend the ideas and content into a webquest format.

This game can be modified easily so that students with a variety of learning styles and interests can benefit. For example, including supplemental specimens will allow tactile and kinesthetic learners the chance to manipulate the specimens. Students should always wear gloves when handling any brain tissues. Best practices for safely handling brain tissue can be found at *http://apu.sfn.org/content/Programs/NeuroscienceLiteracy/SpecialCNLReports/cnldo.html*. Additionally, teachers can have students draw or model mammalian brains to learn about the different features. As previously mentioned, an alternative set of questions is available on the NSTA website to reach less advanced or younger students. Higher-order thinking questions can be used for advanced students or for further study (Figure 3).

Reinforcing science content

In a survey of students who participated in the game, we found that virtually all reported knowledge of new science content and most indicated that the game increased their interest in science and learning more about the brain.

For students who have previously learned this content in a didactic fashion, this game serves as a review and as a potential source of content assessment for teachers who record the number and percentage of correct answers. Furthermore, the game allows teachers to discover and clear up student misconceptions and to reinforce the important science content that students should learn. Figure

FIGURE 4

Holistic scoring rubric for students playing the Marine Mammal Brain Game

(modified from Brown and Shavelson 1996).

Outstanding rating=4. Student gives correct answer; thinking process and chart reading skills are evident; student displays good sportsman's–like conduct and team work as appropriate; student takes turn and follows directions; student has outstanding elocution such that they use a clear voice and correct, precise pronunciation of terms

Good rating=3. Student may give correct or incorrect answer; if answer is incorrect, thinking process and chart reading skills are evident; student displays good sportsman's–like conduct and team work as appropriate; student takes turn and follows directions; student has good elocution such that they use a clear voice and correct, precise pronunciation of terms

Satisfactory rating=2. Student may give correct or incorrect answer; if answer is incorrect, thinking process and chart reading skills are evident; student displays good sportsman's–like behavior and team work as appropriate; student takes turn and follows directions; student has fair elocution such that they use a clear voice, but may lack precise pronunciation of terms

Serious flaws rating=1. Student give incorrect answer and does not demonstrate thinking process or chart reading skills; or student displays poor behavior or does not follow directions or take turns; elocution is so poor that they cannot be understood (exceptions or alternative ways of responding can be made for nonnative English speakers as appropriate)

No attempt rating=0

Addressing the Standards.

Marine biology topics lend themselves to meeting national standards in biology and a number of states have even begun to institute separate marine biology standards as well. This game fits in very well with The National Science Content Standard C: Life Science Standards for grades 9–12 that includes the interdependence of organisms and behavior of organisms (NRC 1996, p. 181).

This game compares representatives from three orders of aquatic mammals that appeal to students and can serve to capture the attention of students who may not normally be interested in science. Additionally, this game can be easily adapted to meet the needs of students with various backgrounds and abilities. Thus, it addresses both Science Teaching Standard A which states that teachers should "select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experience of students" (NRC 1996, p. 30), as well as National Teaching Standard B, which calls on teachers to "recognize and respond to student diversity and encourage all students to participate fully in science learning" (NRC 1996, p. 32).

4 provides an assessment rubric designed to evaluate students' participation in this group activity.

We hope that teachers will find this game to be a useful classroom tool. We welcome any teacher feedback about the game and would encourage teachers to complete an online survey at *www.surveymonkey.com/s.asp?u=75513429419*. Survey feedback will be used to further refine this game.

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References

Brown, J.H., and R.J. Shavelson. 1996. *Assessing hands-on science: A teacher's guide to performance assessment.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

On the web

Visit the online version of this article at *www.nsta.org/highschool#teacher* for the alternative set of questions and for a more extensive list of higher-order thinking skills questions.

Images of dolphin, manatee, and sea lion brains can be downloaded from the Comparative Mammalian Brain Collection site (*www.brainmuseum.org*). A labeled manatee brain image is available online at *www.manateebrain.org*.

For information about manatee senses, visit *http://faculty.washington.edu/chudler/manat.html*. For more information about dolphin brains, visit *www.msu.edu/user/brains/turs*.

Pictures and additional information on dolphins, manatees, and sea lions can be found at numerous sites including:

- *http://dolphins.org/Learn/drc-lern.htm*
- *www.seaworld.org*
- *http://animaldiversity.ummz.umich.edu*
- *www.geocities.com/RainForest/Canopy/4708/wallpaper/Dolphin.jpg*
- *www.geocities.com/RainForest/Canopy/4708/wallpaper/Manatee.jpg*
- *www.geocities.com/RainForest/Canopy/4708/wallpaper/SeaLion-Iguana.jpg*