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Skulls and Bones: Comparing Form and Function of Vertebrate Skeletal Systems

Curriculum Unit 12.03.07
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Introduction

The primary intention of this curriculum unit is to bring more science instruction into the elementary classroom. As a teacher of English Language Learners, I have found firsthand that young students need to connect with real content material to grasp academic language fully and incorporate it into their own vocabularies. However, with curriculum heavily focused on literacy and math instruction, but lacking overarching themes, it is difficult to create an instructional environment with an emphasis on language that is purposeful and authentic.

I have also noticed, and believe it is a well–known fact, that young children love to learn about animals. They love to read about animals, play with animals, and observe them in their natural environments. Some of the best stories my students have written in our writer's workshop have been about trips to the zoo, aquarium, or pet store. Some of my students' favorite books, and the ones that engage them the most, teach them about the diverse world of animal species. For this reason, I am developing this curriculum unit around the anatomy of animals, comparing and contrasting form and function of skeletal structures. I believe students will be engaged in learning about animal skeletons (including humans') and why they are built the way they are. Through this engagement students will develop critical thinking and questioning skills that will transfer across subject areas to help them in their literacy and mathematics learning as well.

This unit is intended for lower elementary students, and places a special emphasis on developing academic vocabulary. It can easily be incorporated into literacy units on informational text and vocabulary development but also employs a hands–on and visual component to promote the scientific concepts of the skeletal system and evolution. The unit also taps into a number of higher–order thinking skills and tasks, and will evaluate students' learning through performance–based assessments.

Rationale

My second grade students, all of whom are bilingual English Language Learners in the Spanish–English transitional bilingual program at John S. Martinez School, are starved for science. Their faces light up when they see "Science" on our daily objectives board, and their enthusiasm is palpable when conducting the experiments from the district science kits. However, there is hardly enough time to fit in the 100 recommended weekly minutes of science, nor is this enough time to allow for the full development and understanding of the concepts or vocabulary. Many of the district science units fail to reach the depth of understanding that my students are ready for, or may not stress the higher–order thinking that could be taking place during scientific inquiry and instruction.

For these reasons I have developed a unit that can be integrated into daily teaching so that instructional time is maximized, and important reading and writing skills are emphasized along with scientific ones. It is a hands–on, interactive unit that encourages students to take an active role in their own learning and become fully engaged in the material. It culminates in a creative project that allows students to demonstrate what they have learned in a variety of ways.

Comparing and contrasting is an important skill for early elementary students. It is crucial for students to begin to make connections between their own lives and the academic material presented to them in class, as well as among the diverse topics they are learning about at school. In order for them to truly understand a new idea, and to demonstrate this understanding, they have to be able to explain how it relates to other ideas and how it presents a new way of thinking. As early as kindergarten, students learn to sort objects into groups with similar properties, and throughout the grades they continue this task, from the more concrete objects to the abstract. In second grade, students need to work with something in between. Comparing and contrasting animals' skeletal systems will give them the opportunity to look at something concrete and begin to notice similarities and differences, but also to begin to think more abstractly about why these similarities and differences exist and how they contribute to the magnificence of the natural world. As Steve Jenkins describes in his picture book, Bones:

> A leopard pounces with powerful legs. Its flexible spine and tail make it balanced and agile. Its skull holds forward–looking eyes to fund prey and sharp teeth to grab and eat it. This big cat is a fearsome hunter, but the rabbit's long legs, big feet, and quick reflexes might be enough to help it escape the leopard's lunge. [1]

By analyzing an animal's structure, students can begin to think about why animals move, acquire food, and defend themselves the way they do, and then make generalizations that can extend to new information they gather about animals they are not as familiar with. Ultimately, students will gain a better understanding of living things and how they evolved in the way they have.

Unit Objectives

Along with addressing the Connecticut State and Common Core standards for second grade science and literacy, the objectives of this unit include:

- Students will become familiar with the structure and function of the major bones in vertebrates.
- Students will be able to identify and name, using common as well as scientific terms, the major bones in vertebrates.
- Students will be able to explain and infer why bones are shaped the way they are, based on their evolution and current function.
- Students will be able to compare two animals' skeletons and explain similarities and differences.
- Students will create their own animal's skeleton, and explain how the bones allow for its patterns of movement and survival.

The Human Skeletal System

The skeleton is the hard part of our body that provides its structure, protects our vital organs, and allows us to move in many complex ways. In animals, the skeletal system can be found either inside the body (called an endoskeleton) or outside of the body (called an exoskeleton). Animals with external skeletons or non–bony skeletons are called invertebrates (insects being the most common example), and most animals with internal bone structures are called vertebrates. The skeleton is usually symmetrical across the body's midline. Skeletons can also provide sensory information to animals, transmitting vibrations that are used for hearing. And, in some bony fish, it can act as a flotation device that adjusts the animal's buoyancy so it can move at different depths in the ocean. [2]

The first bone appeared in fish, around 400 million years ago. While it was mostly comprised of internal cartilage in the skin, it provided protection and mineral reserves for these animals [3]. Over time, it has evolved to create the complex structures seen in animals and humans today.

Bones

We can all feel the bones in our bodies, and many of us have had the chance to see x–rays to know what our bones actually look like. Some have even seen real bones preserved from human bodies! The human skeleton contains over 300 bones at birth, but we end up with 206 as adults as the cartilage hardens and some of the bones fuse together, including the bones of the skull. [4] Some cartilage remains, which we can feel in our ears and the soft end of our nose. The skeleton first begins its formation in the embryo at about 6 weeks post–conception. [5] It develops as cartilage, and then is later ossified, the process by which cartilage is replaced by bone. The bones continue to lengthen and harden, while the epiphyses, or heads of the bones,

ossify last (looking at these epiphyses is a good way to guess someone's age!). Hormones dictate the growth and development of bone throughout later years into puberty, while hormonal imbalances can cause developmental disorders such as gigantism or dwarfism. Adequate intake of necessary vitamins and minerals, such as calcium, phosphate, and vitamins D, A, and C is crucial to bone development. [6]

Bones are strong yet lightweight, and able to grow, be strengthened, and repair themselves throughout our lives. The outer layer of bones, or the periosteum, is a thin membrane containing blood vessels and nerves. Underneath this is a denser, hard layer of compact bone (what we're used to seeing). This layer is made up of curved layers of calcium phosphate and collagen protein fibers that work to support a body's weight efficiently. Calcium is a strong mineral that provides resistance to compression, while collagen allows for flexibility and resistance to tension. [7] The inside of bones, or spongy bone, is soft and springy. On the very inside is bone marrow. The red bone marrow produces most blood cells. [8] If a bone breaks, the blood cells around it act immediately to repair the bone, forming a clot while new bone cells grow and attach to each other and the original bone. [9]

The human skeleton provides five major functions: support, storage, blood cell production, protection, and leverage. [10] Our skeletons provide our bodies' structure, without which we would be merely a pile of skin and organs. Our bones also store calcium, phosphates, and fat cells to maintain normal levels throughout our body. Furthermore, they work closely with the skeletal muscles to allow us to move in both large and more delicate ways.

Each bone contains a number of features that allow it to be easily identified, and also to give clues about its "owner", including his or her age, diet, exercise habits, and previous injuries. Bones are classified into groups such as "long bones," "short bones," "flat bones," and "irregular bones." They also have distinctive markings that show where the tendons and ligaments attach, or where blood vessels and nerves interact with them. [11]

Different bones are crucial in protecting important organs: the skull protects the brain, eyes, and ears; the vertebrae protect the delicate nerves of the spinal cord, and the rib cage, spine, and sternum protect the lungs, hearts, and major blood vessels. [12] In fact, skulls have played an important role in evolution, allowing animals to develop larger brains than animals without skulls. [13] Bones can even adapt to current stresses and needs by replacing the minerals that make up the bones and reshaping the bones themselves. Bones that are not used become thinner and more brittle over time, while bones that are stressed or attached to hard–working muscles form new ridges and become thicker. [14] This has also taken place over time through evolution.

Joints

The place where two bones meet in the body is called a joint, or an articulation. Joints allow our bones to move in many different ways. Examples of joints are shoulders, elbows, wrists, hips, ankles, and knees. Joints allow bones to pivot, twist, rotate, hinge, or slide. While some joints are immovable or only slightly movable, many are freely movable. These are called synovial joints. The bones in these joints do not make contact with one another, but rather move with the help of articular cartilage that covers the heads of the bones, the synovial membrane, and synovial fluid that lubricates the joints.

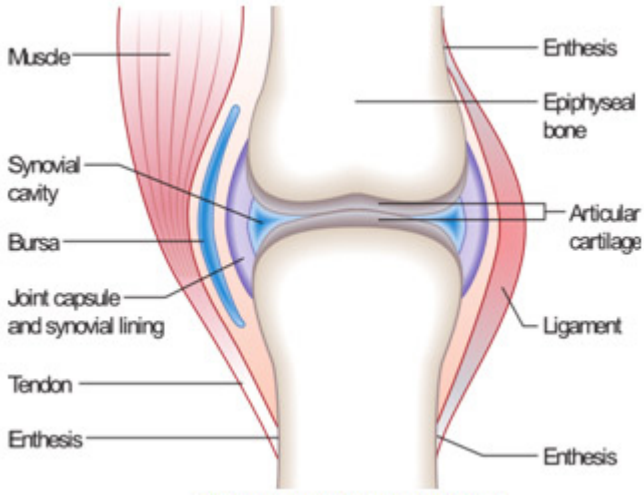


Diagram of a synovial joint http://en.wikipedia.org/wiki/File:Joint.png

Some important joints and their movements:

- The elbow and knee are **hinge joints** , meaning they can move back and forth.
- Our heads can move side to side on a **pivot joint** at the first and second cervical vertebrae.
- The thumb joint is a very mobile **saddle joint** , concave on one side and convex on the other. This kind of joint allows movement around two axes.
- Our shoulders and hips are **ball-and-socket** joints allowing for multi–axial articulation, in all directions. [15]

Ligaments

Ligaments, made up of collagen fibers, keep bones fastened together where they connect at the joints. Like rubber bands, they are able to stretch to allow for flexibility, but are also strong enough to provide stability. [16]

Muscles

Muscles work closely with our bones to facilitate voluntary movement as well as internal processes such as respiration and digestion. They connect to the bones to move them, maintain position, support soft tissues, aid digestion and elimination, and maintain body temperature [17] . They also control blood flowing through blood vessels and even keep your heart beating! Muscles are connected to bones by tendons, which are made up of collagen fibers. [18]

Evolution

The reason that our skeletons are so similar to those of so many other species is due to evolution. Over the last 2 to 3 billion years, life as we know it has evolved from a universal common ancestor. [19] Looking back at some of the first vertebrates on the earth, fish, gives us the first clues as to the development of the skeletal system. Some of the first fish did not have jaws or teeth, but they did have a bony shell that protected the head and front of their body. These fish remained small because they could not catch big prey. Millions of years later, these fish evolved and developed jaws that allowed them to catch and eat larger prey, rendering their ancestors extinct. With this new system, fish became larger. Later they developed fins made of jointed bones, which eventually adapted to carry the fish's weight out of the water and turned them into the first amphibians. These amphibians evolved into reptiles who no longer depended on the water and who developed thick protective skin to prevent evaporation of their bodies' water. The first birds also appeared, evolving thin hollow bones, decreased body weight, and feathers to enable them to fly. Mammals also evolved from reptiles, but developed the ability to regulate their own body temperature and give birth to live offspring. [20] Despite all of these changes, adaptations, and developments, each new species retained a number of features of those that came before it, including many similar bones.

Neil Shubin, a paleontologist, outlines this idea very clearly in his book, *Your Inner Fish* . His discovery of a fish with bony wrists (known as *Tiktaalik*), provided evidence for the existence of species that created evolutionary links between animals that appear to be quite different. Scientists have used years of research with fossil records and DNA to show that in many ways diverse animals, both alive and those that have been extinct for millions of years, are more alike than different, and that living things can be classified into subgroups based on their similarities. This allows for predictive power when scientists make new discoveries, which can then be fit into the existing record of living things over time. [21]

Other vertebrates

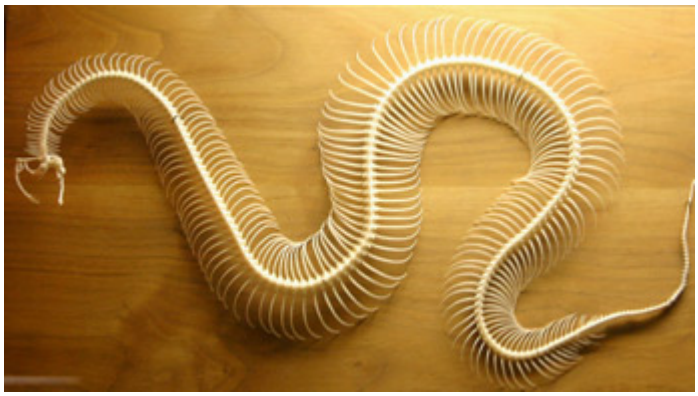
Most vertebrates have a similar skeletal structure. For example, the composition of the arm includes a number of small bones in the hand connected to another group of small bones in the wrist, connected to two longer forearm bones, connected to one large upper arm bone. [22] Depending on the animal, these bones are shaped and connected in different ways to facilitate a variety of movements, from grabbing, to digging, to swinging, to flying. Similarly, the legs of most animals share a common set of bones: the thigh bone (femur), connected to the knee bone (patella), connected to the leg bones (tibia and fibula), connected to the ankle and 26 small foot bones.

Obviously the size of an animal depends on the size of its bones, and vice versa. Large animals such as elephants have longer, thicker, stronger leg bones to support their incredible weight. Flying animals such as birds rely on porous or hollow thin bones to keep them in the air. The same bone can look very different in different animal species, such as the femur, which can vary from 80 centimeters in an elephant to 5 centimeters in a cat. While humans have 12 pairs of ribs, a two–toed sloth has 24 pairs, and a python has 400 pairs! While in many animals the ribs are separate entities, in a turtle the ribs fuse together to make their

shell. [23] And, even though a giraffe's neck is far longer than that of a man, both species contain the same seven bones in their neck. [24]

Below I have outlined information on a number of different vertebrates. However, depending on your students' interests and background knowledge, you might choose to research others to present in class. Some interesting comparisons might be made between sharks and bony fish, as well as among the pterosaur, bird, and bat. I attempted to present examples of vertebrates from the different animal kingdoms, but feel free to adapt your lessons using animals of your choice, and of course always seek out more information! The information below is mainly constrained to the skeletal characteristics that affect movement and eating habits in these animals.

Snakes



The snake skeleton is primarily made up of vertebrae and ribs.
http://en.wikipedia.org/wiki/File:Snake_skeleton.jpg

Snakes are reptiles that may live on land or in water. The snake's skeleton is different from most other vertebrates in that it does not have any appendages. It is made up primarily of the skull, vertebrae (up to 500!), and ribs, which are connected to the vertebrae. Attached muscles allow for snakes to move prey they have swallowed down their bodies and also to move in a variety of ways, slithering, swimming, hurling themselves across sand, and looping themselves to climb trees. Some snakes, such as boas and pythons, do have remnants of pelvic bones. One important bone in the snake's skeleton is the columella, a small bone in the ear, which the snake uses to "hear" vibrations through the ground. Snakes have also adapted a special type of jaw, made up of bones connected by elastic ligaments so that they may eat prey larger than themselves. The jaw is also attached in such a way that it may open very wide, and then move laterally to allow for the prey to pass through it, then "walk" its prey through its mouth as it swallows. [25]

Snakes also have specially adapted teeth depending on the way they hunt and kill their prey. Constricting snakes (such as the Burmese python) are *aglyphous* , meaning their teeth are not specialized and all have a similar shape and size. They do not have fangs through which to deliver venom, and are therefore non–poisonous. *Opisthoglyphous* snakes (such as a hognose snake) are "rear–fanged", and have fangs in the back of their mouths that inject venom into their prey. *Proteroglyphous* snakes (such as king cobras) are the most poisonous, delivering their venom through one large fang towards the front of their mouths. These snakes do not have many other teeth in the front of their mouths, but must hold onto their prey for a number of seconds to fully inject their venom. Finally, the *solenoglyphous* snakes, which are vipers (including the rattlesnake), deliver venom through two fangs that curve backward and efficiently hook into prey to inject

large amounts of venom deep inside. [26] Snakes' teeth are adapted to curve backwards and help them swallow their prey, hooking onto their prey and stopping it from escaping. Some of their teeth grow back when lost (often while feeding) while others are permanently attached to the bone. [27]

Sharks

Sharks are cartilaginous fish that live mostly in salt water. They are missing the swim bladder possessed by most other fish to create buoyancy, but make up for this deficiency through a massive liver and a skeleton made up of cartilage rather than bone. As discussed earlier, cartilage is strong but lightweight and flexible. Where the shark needs extra support, as in its backbone and jaws, the cartilage is "calcified", making it stronger and more similar to bone but still keeping it lightweight. [28] Sharks do not have rib cages, and can be crushed by their own weight when out of water [29] .

Like snakes, most modern sharks have jaws that can swing down and open to swallow large prey (which they break into smaller pieces but do not actually chew before swallowing). They also have specialized (and replaceable) teeth depending on their diet. Some sharks have dense, flat teeth perfect for crushing crustaceans and mollusks, while others have needle–shaped teeth to grip onto fish. Sharks that eat larger prey such as mammals have serrated upper teeth to cut and pointed lower teeth to grip their prey. Finally, sharks that feed on plankton and do not need to chew have small, non–functional teeth. [30] In some cases you can even predict the size of a shark based on the length of its teeth [31] !

Aside from possessing cartilaginous rather than bony skeletons, other differences between sharks and most bony fish include the fact that sharks can only swim forwards while other fish can swim both forwards and backwards, sharks do not have covers over their gill slits, sharks' eggs are fertilized inside of the female's body rather than in the water, and sharks' scales are rough and sandpaper–like rather than slippery and overlapping. [32]

Elephant

The elephant is the largest land mammal currently in existence. In order to support its extreme size and weight, its skeleton accounts for 16.5 percent of its total body weight. It has a massive, barrel shaped rib cage with 20 ribs, and a large percent of its bone mass is made up of spongy bone to provide support without adding weight. Its vertebrae are flat, which help to support its head and tusks. Unlike many other vertebrates, elephants do not have collarbones but instead have large shoulder blades. While generally similar, the Asian and African elephants do have skeletal variations, as do the male and females of each species. [33]

Pterosaurs

Pterosaurs were the first animals to evolve with the ability to fly. Though not actually dinosaurs, they existed around the same time as dinosaurs and were also prehistoric reptiles [34] . Like birds (which had not yet evolved!), they had hollow bones to allow for flight, but more similarly to reptiles they had jaws and often teeth as well, depending on what they ate [35] . Pterosaur wings were unique in that they usually attached to the hind as well as front limbs (connected to an extended fourth finger in the front). They were made up of a membrane as well as muscles, skin, blood vessels, and stiffening fibers [36] . Like other reptiles, they laid eggs, which had to incubate for a number of weeks rather than days, and evidence suggests that they were able to walk and fly almost immediately after hatching [37] ! Most pterosaurs appear to have eaten fish or other

water–based creatures. Research also suggests that pterosaurs may have been quadrupeds, staying erect when necessary using their back legs and fingertips [38].

Birds

Birds "are feathered, winged, bipedal, endothermic (warm–blooded), egg–laying, vertebrate animals" [39]. Related to the pterosaurs described above, they evolved around 160 million years ago, during the Jurassic period. However, modern birds no longer have teeth, fur, or claws on their wings, and their hind limbs are not attached to their wings. They are known for their ability to fly, although of course there are species of flightless birds, including the penguin. Birds have hollow bones and strong chest muscles to allow for flight. Unlike other vertebrates, they have a keeled sternum, which supports the chest muscles. They also have fewer bones than other animals because many of their bones are fused together to provide a more rigid structure, but more vertebrate to help their neck flexibility for grooming and acquiring food. [40] They do not have teeth, but can use their beaks to break up their food and then swallow the pieces without chewing.

Bats

Bats are the only flying mammals. Like other mammals, they have fur, give birth to live young, and feed their babies milk. They have many of the same skeletal structures as other mammals (including humans!) but are not equipped to walk easily. Some bats, called *microchiropterans* , are carnivorous, eating mainly insects or small animals to survive, while *megachiropterans* feed on fruit and nectar [41]. The difference between these bats is seen in their skulls, which are either short and blunt (insectivores) or longer and narrower (nectar eaters) [42].

Unlike birds, bats have marrow–filled instead of air–filled bones. To allow for flight, their bones are lightweight, small, and flexible. When bats "flap their wings", they are actually moving their fingers, which are attached by a thin membrane, rather than their entire forearms as with birds [43]. The muscles in a bat's wing are extremely efficient and require little effort to maneuver. In order to sleep hanging upside down, bats have toe claws on their hind legs that lock in place with the help of a tendon [44].

Fun facts

Students might be interested to know about the following facts. You might even frame them as a question and answer game, and have students make predictions based on the knowledge they have learned throughout the unit.

- The longest bone ever found was the femur of a dinosaur, at 10 feet long!
- The longest bone in most animals is the femur. The smallest is the stapes, inside the ear.
- The largest overall skeleton is of the blue whale. The smallest vertebrate skeleton is of a fish in Sumatra.
- Only 3% of animals have bones. The rest either do not have skeletons, or have exoskeletons, which are often heavy and cannot grow but rather must be shed and re–grown. [45]

Strategies for Instruction

As mentioned earlier, this unit emphasizes strategies to reach English Language Learners who may not have the background experiences and language proficiency to immediately interact with and master the scientific skills and vocabulary. In order to support these students, this unit incorporates strategies from two educational models found to be very successful in teaching academic vocabulary to ELL students: the SIOP (Sheltered Instruction Observation Protocol) model of instruction, and Project GLAD (Guided Language Acquisition Design). Lessons may be taught during the science block, but will extend to literacy instruction throughout the day as well.

SIOP Model

The SIOP model is a research–based method that was developed for teachers working with English language learners in "sheltered instruction" classes. Its goal is to "prepare teachers to teach content effectively to English learners while developing the students' language ability" [46]. Teachers using SIOP develop lesson plans that present content knowledge while simultaneously placing an emphasis on language objectives to go along with the content objectives. They employ a number of techniques to assist student learning and make content accessible, such as the use of visual aids, connections to background knowledge and vocabulary, cooperative learning, peer tutoring, graphic organizers, and vocabulary previews [47]. For more information on integrating the SIOP model into your instruction, please consult the book *Making Content Comprehensible for English Learners: The SIOP Model.*

GLAD

In my previous experience teaching in Northern California, I was trained in a model of instruction called "Project GLAD." According to the Project GLAD website, it is a program which "develops metacognitive use of high level, academic language and literacy. [48]" Like the SIOP model, it trains teachers to use a variety of teaching techniques to develop language proficiency, make content material accessible, and create lasting learning experiences so that students retain the information and vocabulary presented through the unit. However, Project GLAD employs a number of specific activities that can be adapted to the content material being taught, including:

- *Gallery walks:* Before beginning direct instruction on the content material, the teacher creates a number of visuals (posters or photographs) of images that pertain to the material, and hangs these images around the room. Students move around the room (often in pairs), and make observations about the images, recording their thoughts on sticky notes that are placed directly on the images. Once students have had the opportunity to interact with all of the images, the teacher can present the different students' ideas and foster a conversation about what students anticipate learning about the topic.
- *Chants:* Another component of GLAD is the frequent use of chants to reinforce the vocabulary taught throughout the unit. As any adult can attest to by the fact that they remember nursery rhymes and songs from their own early educational days, the rhythm and repetition of chants are fun and easy ways to permanently remember language and make it automatic.

- *Cognitive Content Dictionary:* An ongoing part of any GLAD unit is the cognitive content dictionary, a running list of new vocabulary words that are introduced throughout the unit. Each day, the teacher presents a new word, and students discuss whether or not they have heard the word, what possible definitions could be, and finally the teacher defines the word with an image next to it. The class also decides on a gesture to go along with the word, and this word is then used as a transition tool throughout the day; for example the teacher may say, "When I say the word 'exoskeleton,' you say 'hard covering', make the gesture, and then walk quietly to the carpet." As the cognitive content dictionary grows, the teacher can revisit the previously taught words and make sure students understand and can flexibly use them and define them in their own words.
- *Pictorials:* Pictorials are a way to present and reinforce information visually. The teacher prepares a pictorial by sketching an image (for example, a skeleton) in pencil on chart paper. S/he also prepares information about the different parts of the image (more detailed than just labels). Then, in front of the class, s/he presents the different parts of the diagram, tracing over the pencil with a marker and writing in the information as it is presented. The teacher stops frequently to give students the opportunity to discuss the information they have learned thus far. As with the cognitive content dictionary, the teacher frequently revisits the information and checks for understanding throughout the course of the unit.

Visual learning

Good teachers know that visualization is an integral part of learning and one of the most important metacognitive strategies students must master in order to be successful readers, thinkers, and learners. While we often encourage students to create their own mental images based on what they have read or heard, it is equally important to give them images on which to base new information. Images are especially critical for English learners who have not fully grasped the language, although it might be argued that all students involved in this unit are English learners, as they will not have heard many of the new vocabulary terms presented throughout the lessons. Therefore, I suggest that all teaching be accompanied by images, whether hand–drawn, pulled from the Internet and projected onto a screen, or photocopied from books. Students should be encouraged to demonstrate their understanding through the use of their own images, and science notebooks used in this unit are a great place for students to draw to demonstrate their understanding.

Hands–on learning

As the creators of the SIOP model have proven through scientific methods:

> English learners make more rapid progress in mastering content objectives when they are provided with multiple opportunities to practice with hands–on materials and/or manipulatives. […] Manipulating learning materials is important for ELs because it helps them connect abstract concepts with concrete experiences. Furthermore, manipulatives and other hands–on materials reduce the language load for students. Students with beginning proficiency in English, for instance, can still participate and demonstrate what they are learning. [49]

Therefore, another component that should be incorporated frequently into this unit is the use of hands–on activities to promote understanding of the material. Students may make representations of bones and skeletons using modeling clay, or cut out bones from paper and reassemble them using tape, glue, or paper

fasteners. It is through these activities that the vocabulary and concepts students are learning become more meaningful and relevant. These activities also provide a way to assess less verbal students' understanding.

Unit Outline

This unit is intended to take approximately 4–6 weeks to complete, with formal lessons taught two to three times a week, and informal lessons, such as the recitation of a chant or the sharing of an interactive read aloud complementing the formal lessons daily. Currently New Haven suggests/requires 100 minutes per week of science instruction, during which time the formal lessons of this unit may be taught. However, as mentioned earlier, this unit is intended to span across the curriculum, so "read–alouds" may take place during the allotted time for reading comprehension instruction, and vocabulary work may be done during the time set aside for word work. Students must be immersed in the material to truly understand and internalize it, so it is important to find as many times throughout the day to review the information, concepts, and vocabulary with your students.

The unit might be introduced through a gallery walk, during which the teacher displays a number of images of bones and skeletons around the classroom. Students walk around in pairs with sticky notes and write and post their initial observations of these images. I would include images of a number of different animal skeletons, as well as some magnified images of individual bones and joints. Once students have finished, this activity leads into a class discussion and the generation of a KWL chart (noting what students know, want to know, and learned at the end of the unit) to collect background knowledge about what students already know about skeletons as well as what they would like to know.

As the unit progresses, some daily activities could include interactive "read–alouds" about the human skeleton and other animals, the singing of songs about skeletons or animals (see resource lists at the end of this unit), exploration with puzzles and/or modeling clay, and any other creative activities you can think of! Students should also be encouraged to journal about what they are learning in a science notebook where they can draw or write about information they have learned or engage in creative tasks such as writing poetry or short stories based on the content material. Resources handed out throughout the unit can be kept in these journals to refer to later. As described earlier, one of the first activities should be the introduction of the cognitive content dictionary, where new vocabulary words are presented and defined, to be reviewed and used frequently. Ongoing assessment may be conducted orally or through worksheets, such as the labeling of a skeleton, a vocabulary quiz, or presenting students information about an animal's skeleton and asking them to make inferences about this animal's patterns of movement, feeding, strengths, and weaknesses.

This unit opens up opportunities for many different field trips as well. Perhaps your class can visit the Peabody museum in New Haven, where students can learn about animals and see fossils, and see the discovery room where they can have hands–on experiences with some animal species (http://peabody.yale.edu/exhibits). Some of the museum's resources are even available online through podcasts and online tours. The Maritime and Mystic Aquariums are two more locations that are convenient to New Haven schools and sometimes even provide funding for school field trips. For classes with more time and financial resources, a trip could be made to New York City to visit the Natural History Museum or the Bronx Zoo.

Final Performance Assessment

One option for a final performance assessment is to have students create their own animal, focusing on its skeletal system. It can be related to one of the animals they have already learned about, but could possibly have some unique features of its skeleton. Students should focus on how the animal moves and how it hunts and eats when planning its skeletal system. They might draw a labeled diagram of the animal, highlighting its important features, and write a description of the animal's anatomy, its patterns of movement and feeding, and its strengths and weaknesses. As a teacher, you can be creative about your expectations—students might complete this assignment in groups, or after creating animals individually, the class can sort them according to features and create a class presentation. Another option is to create large murals or dioramas of animal habitats that these animals would live in. And, of course expectations must be modified for students with special needs (including language support).

It is important that students be purposeful in their design of an animal, choosing features that are common across vertebrates as well as some unique features that make the animal different from others. To complete this assignment, students should begin by planning, using books and other materials for reference. Next, they create a clear diagram of the skeleton of their animal, labeling the important parts (these skeletons should be somewhat, but need not be entirely, realistic). Finally, they will write a description of their animal, with paragraphs describing its anatomy, feeding patterns, movement, strengths, and weaknesses, and present it in whatever way you see fit to the rest of the class and/or school. A sample rubric for this performance assessment can be found in Appendix C.

Formal activities (see below for lesson plans for italicized lessons):

1. Gallery walk of vertebrates with KWL chart to assess background knowledge
2. *Sing song "Dem Bones," first with common names of bones and then with scientific names.*
3. *Have students cut out skeletons, put together using paper fasteners, and label the bones with their common and scientific names.*
4. Use modeling clay to fashion some of the bones in the human skeleton.
5. *Using cutout bones to scale, measure and compare lengths of bones in different animals. Facilitate a conversation about the differences between the bones and their forms/functions.*
6. Present x–ray images of bones over the course of development: in utero, childhood, adolescence, adulthood, old age. Have students practice classifying x–rayed bones according to age range.
7. *Comparison of pterosaurs, birds, and bats. See below for more information.*
8. Comparisons between other animals (using information from read–alouds or information you present to students through pictorials or other methods).
9. Final project (this will take a number of sessions): students create and present their own animals and discuss their feeding patterns, movement capabilities, strengths, and weaknesses as based on their skeletal features.

Sample Lesson Plans

These are three samples lesson plans you may use with your students. Feel free to adjust as necessary according to your students' needs!

The Human Body

Objectives:

a. Students will be able to name the major bones in the human body using both common and scientific names
b. Students will demonstrate knowledge of where each bone is located in the human body.

Materials:

a. Lyrics to "Dem Bones" written on chart paper: http://www.songsforteaching.com/folk/dembones.php (replace common names with scientific names)
b. Handouts of human skeleton, to be cut out (preferably on a thicker paper such as oak tag): http://www.enchantedlearning.com/subjects/anatomy/skeleton/Labelskeleton.shtml (must have membership to access full site, but other resources are available online as well)
c. Scissors, hole punches, paper fasteners
d. Pencils or markers

Procedure:

a. Explain to students that today they will be learning about a very important vertebrate mammal—humans! Choose one of the books included in the Student Reading List below to show students magnified images of bones and joints.
b. After spending some time with the book, introduce students to the song "Dem Bones," singing it many times and creating gestures to go along with the words.
c. Hand out the copies of the human skeleton and give students time to label the bones with their common and scientific names, and then to cut out the bones and fasten them together using hole punches and paper fasteners. Provide images for them to refer to, either in the form of a chart, books, or handouts. Encourage students to work together and discuss what they are doing as they do it, as well as to find the different bones in their own bodies as they label their skeletons.
d. Have students write or draw about what they have learned in their science journals.

Measuring and comparing bones in different animals

Objectives:

a. Students will practice measurement (with either non–standard, standard, or metric units)
b. Students will compare length
c. Students will make deductions about animals based on their bone length, and match different bones to different animals.

Materials:

a. Paper cut outs of bones prepared ahead of time by teacher on butcher paper or oak tag– you will need to look up the measurements of these bones and draw them approximately to scale. Label the bones (names of bones, not animal).
b. Rulers and yard or meter sticks (or linking cubes, paper clips, etc. if you plan to use non–standard units for measurement)
c. Suggested: Bones by Steve Jenkins

Procedure:

a. Optional: read the book Bones with students, discussing that many animal skeletons have the same bones as each other (and as humans!) but that they come in many different sizes. Ask students if they can guess which is the longest bone in most vertebrates.
b. Group students into groups of three or four, and explain that they will be working together to measure different animal bones, as well as hypothesize about which animal each bone comes from.
c. Hand out a variety of bones to each group, as well as measuring tools. Have students measure the length of each bone and record their measurements. (Students must be familiar with measuring techniques—if they are not, spend some time, possible during the math block, introducing this skill).
d. Bring students back together for a discussion of the longest bones, the shortest bones, and anything they found interesting or surprising. Ask them to guess which animal each bone belongs to, and present the correct answers.
e. Finish the activity by having students draw and write in their science journals.

Comparing three flying animals

Objectives:

a. Students will learn that animals can move in a similar way without being related.
b. Students will be able to describe the similarities between the pterosaur, the bird, and the bat.

c. Students will be able to describe the differences between the pterosaur, the bird, and the bat.
d. Students will be able to show the similarities and differences on a Venn diagram.

Materials:

a. Pictorials created ahead of time by teacher (traced using pencil) on chart paper. Some helpful websites are:

a. http://www.earthlife.net/mammals/bat–anatomy.html
b. http://www.enchantedlearning.com/subjects/birds/printouts/Skeleton.shtml
c. http://www.oceansofkansas.com/Pteranodon/NYCTOSR3.jpg

b. Markers, colored pencils

c. Tape

d. Index cards with vocabulary words printed ahead of time

e. Venn diagram template reproduced, one for each pair of students

f. *Stellaluna* by Jannell Cannon

Procedure (probably over the course of two–three days):

a. Before teaching this lesson, the teacher must prepare a pictorial on chart paper for each of the three animals: pterosaur, bird, and bat. Using diagrams found either in books or online, trace an outline of the skeleton of each animal large enough to fill most of each page of chart paper. Around each skeleton, lightly write down the information you plan to share with the students (near the part of the skeleton to which it refers), as well as labels for the important bones in the skeleton. Also, prepare index cards with important vocabulary words (i.e., names of different parts of the animal skeletons) and tape to stick them to the posters.
b. Gather students around the poster of the pterosaur. Students should be sitting near a partner with whom they are accustomed to turning and talking.
c. Explain to the class that you will be teaching them about a prehistoric reptile that could fly (pterosaurs are not actually dinosaurs, although you may explain to students that they did live during the same time period). Begin tracing the skeleton, discussing important information about each part as you trace it, and tracing over this information with marker as you talk about it.
d. Stop frequently to give students an opportunity to turn to their partners and discuss what they have learned so far. Prompt them with questions such as, "What about this animal's skeleton allowed it to fly?" Call on students to repeat to the whole class what they have discussed with their partners.
e. After completing the pictorial, hand out index cards with vocabulary words printed on them to various students, and have them take turns coming up to stick the index cards directly on the pictorial where they belong.
f. Have students draw or write about what they have learned in their science journals.

g. Repeat the previous steps with the pictorial on the bird and the bat (probably the next day). Stop frequently to ask students to make comparisons between the animals. Emphasize the skeletal features, and also that each of these animals belongs to a different animal kingdom.

h. Once all three pictorials have been completed, read the book *Stellaluna* , using information students have learned about birds and bats to discuss Stellaluna's conflicts with the birds.

i. As an assessment, have students complete a Venn diagram, choosing two of the three animals to compare and contrast. This can either be done individually or in pairs. If in pairs, I suggest students use two different colors so you can easily see that both students participated in the activity.

Endnotes

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2. "Skeleton," Encyclopedia Brittanica, accessed May 14, 2012.
http://www.britannica.com/EBchecked/topic/547371/skeleton#toc41991.
3. Martini, Frederic. *Fundamentals of Anatomy and Physiology* . 238.
4. "Dem Bones," Kidzworld, last modified December 27, 2006,
http://www.kidzworld.com/article/922–dem–bones#.
5. Martini, Frederic. *Fundamentals of Anatomy and Physiology* . 214.
6. Ibid. 218–219.
7. Stewart, Bill, "The Skeletal System" (lecture, New Haven, CT, March 6, 2012).
8. Gross, Ruth Belov. *A Book About Your Skeleton* . 31–33.
9. Jenkins, Steve. Bones.
10. Martini, Frederic. *Fundamentals of Anatomy and Physiology* . 209–210.
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12. "Human Skeleton," *Wikipedia* , accessed May 12, 2012, http://en.wikipedia.org/wiki/Human_skeleton.
13. Jenkins, Steve. *Bones* . 24.
14. Martini, Frederic. *Fundamentals of Anatomy and Physiology* . 219.
15. Ibid. 228–232.
16. Solway, Andy. *The Skeletal System, The Muscular System* . 30.
17. Martini, Frederic. *Fundamentals of Anatomy and Physiology* . 298.
18. Solway, Andy. The Skeletal System, The Muscular System. 28–29.
19. "Evolution," *Wikipedia* , accessed May 24, 2012, http://en.wikipedia.org/wiki/Evolution.
20. Ruiz, Andres Llamas. *Evolution* . 6–12.
21. Shubin, Neil. *Your Inner Fish.*
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23. Ibid. 18.
24. Ibid. 20.
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http://animal.discovery.com/guides/reptiles/snakes/anatomy.html.
26. "Snake Skeleton," *Wikipedia* , accessed June 27, 2012, http://en.wikipedia.org/wiki/Snake_skeleton.
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http://animal.discovery.com/guides/reptiles/snakes/anatomy.html.
28. "Skeleton," *Canadian Shark Research Laboratory* , accessed June 27, 2012, http://www.marinebiodiversity.ca/shark/english/skull.htm.
29. "Shark," *Wikipedia* , accessed June 27, 2012, http://en.wikipedia.org/wiki/Shark.
30. Ibid.
31. "Shark Anatomy," Enchanted Learning, accessed June 27, 2012, http://www.enchantedlearning.com/subjects/sharks/anatomy/Teeth.shtml.
32. "Shark Anatomy," Enchanted Learning, accessed June 27, 2012, http://www.enchantedlearning.com/subjects/sharks/anatomy/.
33. "The Skeleton," *Elephant Information Repository* , accessed on June 27, 2012, http://elephant.elehost.com/About_Elephants/Anatomy/The_Skeleton/the_skeleton.html.
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38. "Pterosaur," *Wikipedia* , accessed July 2, 2012. http://en.wikipedia.org/wiki/Pterosaur.
39. "Bird," *Wikipedia* , accessed June 27, 2012, http://en.wikipedia.org/wiki/Bird.
40. "Bird Skeleton," *Enchanted Learning* , accessed June 11, 2012, http://www.enchantedlearning.com/subjects/birds/printouts/Skeleton.shtml.
41. "All About Bats," *Enchanted Learning* , accessed June 11, 2012, http://www.enchantedlearning.com/subjects/mammals/bat/.
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43. "Bat," *Wikipedia* , accessed July 2, 2012, http://en.wikipedia.org/wiki/Bat.
44. Ramel, Gordon, "Bat Anatomy," *Earthlife Web* , accessed June 11, 2012, http://www.earthlife.net/mammals/bat–anatomy.html
45. Jenkins, Steve. *Bones* . 20.
46. Echevarría et al. *Making Content Comprehensible for* English Learners. 5.
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49. Echevarría et al. Making *Content Comprehensible for* English Learners. 139–140.

Appendix A

Implementing District Standards

This unit will address the following Connecticut state standards for the Pre–K– second grade for scientific inquiry and literacy:

A INQ.1: Make observations and ask questions about objects, organisms and the environment.

Students will learn about animals and the environments they live in, with plenty of time for questioning and seeking answers in books and online.

A INQ.3: Make predictions based on observed patterns.

Students will notice patterns among different animal species and begin to categorize them.

A INQ.4: Read, write, listen and speak about observations of the natural world.

Students will use journals to write their observations throughout the unit, and will be given numerous opportunities to read about animals, as well as participate in class conversations to share knowledge.

A INQ.5: Seek information in books, magazines and pictures.

The teacher will provide many resources for students to engage in learning.

A INQ.6: Present information in words and drawings.

Science journals will be used to collect information and document learning through writing and drawing. The final project will incorporate drawings and written explanations to demonstrate understanding.

This unit will also address the following Common Core standards for second grade literacy (informational texts):

RI.2.3. Describe the connection between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text.

Students will connect knowledge of vertebrate skeletal systems across animal kingdoms and species.

RI.2.4. Determine the meaning of words and phrases in a text relevant to a grade 2 topic or subject area.

Students will frequently identify and define new vocabulary in informational texts related to the topic of skeletal anatomy.

RI.2.7. Explain how specific images (e.g., a diagram showing how a machine works) contribute to and clarify a text.

Students will frequently read and create their own images to learn and demonstrate knowledge.

Appendix B

Sample vocabulary words for Cognitive Content Dictionary

Carnivore	Exoskeleton	Humerus	Radius	Ulna
Cartilage	Femur	Insectivore	Ribs	
Cranium	Fibula	Pelvis	Skull	
Endoskeleton	Herbivore	Phalanges	Tibia	

Appendix C: Rubric for Performance Assessment

	1-Needs improvement	2-Developing	3-Capable	4- Excellent
1. Planning	Student does not participate in the planning process, or copies directly from another diagram.	Student drafts ideas using one resource without paying much attention to the criteria of the assignment.	Student drafts ideas using 2-3 resources and paying attention to some of the criteria of the assignment.	Student takes the time to carefully draft ideas using multiple resources and paying attention to all of the criteria of the assignment.
2. Diagram	Student's diagram is incomplete, sloppy, and without labels.	Student draws a diagram of the animal's skeletal anatomy but it is either sloppy, unlabeled, or does not make sense.	Student somewhat clearly draws and labels a diagram of the animal's skeletal anatomy. The skeleton mostly makes sense.	Student clearly draws and labels a diagram of the animal's skeletal anatomy. The skeleton makes sense.
3. Explanations	Student writes only a simple description of the animal with no attention to the categories: anatomical features, movement patterns, feeding habits, and strengths and weaknesses.	Student only uses generalities to describe the animal, and/or does not address one of the categories: anatomical features, movement patterns, feeding habits, and strengths and weaknesses.	Student writes a somewhat clear description of the animal, outlining with some detail the animal's anatomical features, movement patterns, feeding habits, and strengths and weaknesses.	Student writes a clear description of the animal, outlining with detail the animal's anatomical features, movement patterns, feeding habits, and strengths and weaknesses.
4. Presentation	Student is unable to describe animal or answer any questions posed by classmates.	Student reads directly off of description, naming some of the animal's features. May be unable to answer questions posed by classmates.	Student speaks somewhat clearly and purposefully about the animal and answers some questions posed by classmates.	Student speaks clearly and purposefully about the animal and answers all questions posed by classmates.

Resources

Bibliography for Teachers

"Dem Bones." *Kidzworld* . http://www.kidzworld.com/article/922-dem-bones#. Last modified December 27, 2006. Kid-friendly

website with information about the human skeleton and its bones.

Echevarría, Jane, MaryEllen Vogt and Deborah J. Short. *Making Content Comprehensible* for English Learners: *The SIOP Model* . 3rd Edition. (Boston: Pearson, 2008). A comprehensive guide to the SIOP model, with templates and information about all the components that go into a SIOP–based lesson.

Frisby, Holly. "Reptile Guide." *Animal Planet* . Accessed June 27, 2012. http://animal.discovery.com/guides/reptiles/snakes/anatomy.html. Information about snakes' anatomy, written by a doctor of veterinary science.

Martini, Frederic. *Fundamentals of Anatomy and Physiology* . 2 nd edition. (Englewood Cliffs, New Jersey: Prentice Hall, 1992). A textbook that outlines and diagrams all aspects of the human body.

Ramel, Gordon. "Bat Anatomy." *Earthlife Web* . Accessed June 11, 2012. http://www.earthlife.net/mammals/bat–anatomy.html. Information and diagrams of bat anatomy.

Ruiz, Andres Llamas. *Evolution* . (New York: Sterling Publishing, 1996). A look at the major developments across the animal kingdoms through evolution. Written for older children but a great teacher resource as well.

"Shark Anatomy." *Enchanted Learning* . Accessed June 27, 2012. http://www.enchantedlearning.com/subjects/sharks/anatomy/Teeth.shtml. Kid–friendly information about sharks' anatomy, with emphasis on their teeth.

Shubin, Neil. *Your Inner Fish* . (New York: Vintage Books, 2008). A paleontologist's suprisingly approachable account of how evolution accounts for so many of the similarities across animals, including his own discovery of the first fish with wrists.

Simon, Seymour. *The Human Body* . Smithsonian. 2008. Written for older students, an in–depth look at the human body. Good teacher resource, as it may be too detailed for young students.

"Skeleton." *Encyclopedia Brittanica* . Accessed May 14, 2012. http://www.britannica.com/EBchecked/topic/547371/skeleton#toc41991. In–depth information about the human skeleton.

"The Skeleton." *Elephant Information Repository* . Accessed on June 27, 2012. http://elephant.elehost.com/About_Elephants/Anatomy/The_Skeleton/the_skeleton.html.

Reading List for Students

Cannon, Jannell. *Stellaluna* . (New York: Scholastic, 1993). A children's picture book about a baby bat who gets separated from her mother and is raised by a family of birds. This book provides a sweet look at the practical differences between what seem to be similar animals (birds and bats). Also available in Spanish!

Gibbons, Gail. *Bats* . (New York: Scholastic, 1999). A student–friendly book presenting information about bats.

Gilpin, Daniel. *Scary Creatures: Bats.* (New York: Franklin Watts, 2004). Another children's book about bats, with lots of illustrations and photographs.

Gross, Ruth Belov. *A Book About Your Skeleton.* (New York: Scholastic, 1978). A very kid–friendly look into the human skeleton.

Jenkins, Steve. *Bones* . (New York: Scholastic, 2010). This book discusses the differences between different animal skeletons, and is a

very useful companion to this curriculum unit. Delightful visuals and fun facts as well.

Jenkins, Steve and Robin Page. *What Do You Do with a Tail Like This?* (Boston: Houghton Mifflin Company, 2003). Another comparison among animal species, with an emphasis on the function of different body parts.

Johnson, Jinny. *Under the Microscope: Skeleton* . (Danbury, CT: Grolier Educational, 1998). A beautifully illustrated (through microphotography) look at the human skeleton, with general information as well as specific facts and comparisons to other species. Geared toward older children.

Solway, Andy. *World Book's Human Body Works: The Skeletal System* , The Muscular System. Ed. Alex Woolf. (Chicago: World Book, 2007). Another book geared towards children with in depth descriptions of the components of the skeletal and muscular systems.

Wright, Rachel. *My Amazing Body.* (Charlotte, N.C.: CD Stampley, 1999). Another children's book (second grade and up) that teaches about the human body, and features activities students can do to get to know their bodies.

Ziefert, Harriet. *You Can't See Your Bones with Binoculars: A Guide to Your 206 Bones.* (Maplewood, N.J.: Blue Apple Books, 2003). A very child–friendly guide to the bones in the human body. Cartoon illustrations and basic vocabulary help young children understand their skeletal systems. A must–have for your classroom library.

Songs (just a selection of what can be found on the internet):

"Bones" by Jennifer Fixman

http://www.songsforteaching.com/jennyfixmanedutunes/bones.htm

"Dem Bones"

http://www.songsforteaching.com/folk/dembones.php

"The Bone Bounce" by Lucy Jensen

http://www.carlscorner.us.com/Poems/The%20Bone%20Bounce.pdf

"Them Not–so–dry Bones" Schoolhouse Rock

http://www.youtube.com/watch?v=Ns2dkT2sIug&feature=related

Websites

E– skeletons. http://www.eskeletons.org/index.html. Shows skeletons and gives descriptions of different primates. Students can scroll over different animals to see their skeletons and learn about them.

Enchanted Learning. http://www.enchantedlearning.com. This site, which does require a membership for full access, provides a number of materials for classroom use (many are available without membership). Some highlights include diagrams of the human, bat, and bird skeletons.

Kids Health . http://kidshealth.org/kid/htbw/htbw_main_page.html. Geared toward young children, a website that presents information on a number of scientific topics.

Kidzworld. http://www.kidzworld.com/. Another website that presents information on a number of scientific topics.

University of California Museum of Paleontology. http://www.ucmp.berkeley.edu/education/teachers.php. Provides a number of scientific lessons and resources for K–12 teachers.