the Shape of Life

Activity Guide

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Activities At-A-Glance

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See www.shapeoflife.org for information about ordering the complete set of *The Shape of Life* DVDs.

The Shape of Life Activity Guide

Explorations, activities, and lessons to accompany *The Shape of Life* video series for informal science educators, teachers, students, and families

Dear Educators and Parents,

It's one of the greatest – and most perplexing – biological mysteries of all time. How did animal life emerge on Planet Earth? Now, thanks to a recent revolution in scientific understanding, it is a story that can at last be told. *The Shape of Life* television series chronicles this revolution, where breakthroughs in genetics, paleontology, and biology are enabling scientists to rewrite – with unprecedented detail – the rise of animal life on Earth. Clue by clue, scientists are piecing together how the first animals of Earth have led to the astonishing diversity of creatures we know today.

The Shape of Life is a celebratory tale that probes our most basic queries about our biological beginnings: What are animals? How did the diversity of animals that surround us come to be? Why do animals look, behave, and function as they do? How has this history been shaped by the raw genetic material available when animals first appeared? How did the opportunities and constraints of a few, simple body plans affect the process of evolution?

The activities and explorations contained in this companion to the television series make the messages of *The Shape of Life* relevant to learners of all ages. For additional activities, explorations, and information, follow the links on www.shapeoflife.org. Enjoy and learn!

Mark Shelley,
Executive Producer

Nancy Burnett
Executive Producer

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Introduction to Series

An exciting eight-part television series that reveals the dramatic rise of the animal kingdom as it is being pieced together through new scientific discovery.

Episode 1: "Origins"

Today, scientists are piecing together the dawn of animal life. And for the first time ever, they believe they have gathered substantial evidence that points to a single animal group of creatures that gave rise to all animals, including humans. Join this fast-paced detective story as we search for – and find – the origins of the animal kingdom.

Episode 2: "Life on the Move"

When we think of animals, we think of movement. Surprisingly, the diverse and graceful ballet of movement may have started with a single group of creatures whose descendants were the first to harness the power of muscles and nerves. How did their dramatic forays forever transform the world?

Episode 3: "The First Hunter"

The first animal to develop a head, eyes and a brain also pioneered a new way to survive: it would become earth's first hunter. Dramatic new evidence points to an unlikely and oddly charismatic subject…a flat worm-like creature, whose hunting and sexual exploits helped mark a defining moment in the shape of life.

This episode discusses sexual reproduction in terms that might not be appropriate for children and early teens.

Episode 4: "Explosion of Life"

According to fossil evidence, it appears as if in one dramatic moment – the Cambrian Explosion – an amazing menagerie of animals suddenly appeared on earth. What animals appeared? What caused this sudden proliferation of life? Surprisingly, one of the least suspecting and simplest of these new life forms – the annelid worms – would help shape the world we know today.

Episode 5: "The Conquerors"

For hundreds of millions of years, animal life resided only in the oceans. And then, in one extraordinary event, something happened that enabled one group of animals to emerge from the sea. Follow scientists as they track how the shape of life transformed to create the animals that led the first successful land invasion and were the first to pioneer flight.

Episode 6: "Survival Game"

To survive, all animals rely on incredible offensive and defensive strategies. Octopus, squid, cuttlefish, and snail – all molluscs – evolved from the same animal design. How did the struggle for survival lead to such different variations? What secret do they reveal about the survival game?

Episode 7: "Ultimate Animal"

At first blush, one might believe that animals like us – creatures with heads, eyes and brains – are evolution's crowning achievement. Yet there are animals with no head, eyes or centralized brains that accomplish feats impossible for us even to attempt. Enter their bizarre world as we try to determine if there's an ultimate animal on earth.

Episode 8: "Bones, Brains and Brawn"

From the beginning of human history, we have told stories to explain our place among the animals. Today's scientists are writing new tales, populated by faceless creatures, giant gelatinous blobs, killer dragons and monstrous dinosaurs. How is it possible that our big, brawny, brainy bodies owe their very existence to some of the oddest creatures of the animal kingdom?

Introduction to Phyla

Earth carries millions of animal species that come in a spectacular array of shapes and sizes. Some even challenge our conceptions about animals. Despite this wealth of species, the diversity of animal types is based on a limited number of fundamental blueprints called body plans.

Each body plan represents a phylum (*pl.* phyla) which can be defined as a group of organisms sharing a common ancestry and a unique assemblage of traits. While all phyla are distinct, the features characterizing them are not. In fact, some of the same features, as listed below, may be found in more than one phylum, or could be absent from a specific member of a phylum.

While there may be as many as 35 different phyla in the animal kingdom, 98 percent of all animals fall into only eight main ones. Each episode of *The Shape of Life* features one of these eight phyla.

Phylum Porifera
Sponges

Episode One of *The Shape of Life*, entitled "Origins," features the rather unassuming phylum Porifera – commonly known as the sponges. Sponges are considered the oldest of the animal phyla. The name Porifera means "pore bearer" in Latin. The surface of a sponge's body is covered by a skin, one cell thick. This is penetrated by numerous small pores and a few large openings. These are respectively the entrances and exits for a complex system of canals and chambers through which the sponge pumps a current of water. The body of the sponge between this system of canals is a loose assemblage of cells that secretes a supporting skeleton of collagen fibers and mineral spicules (glass or calcium carbonate) and carries out the process of growth, repair, nourishment, and reproduction.

Features:

- **Asymmetrical**
- **Organized as an assemblage of different kinds of specialized cells, e.g.,collar cells**
- **No tissues**
- **Skeleton lacking or made of spicules**

As the sponge pumps in water, it captures tiny food items – as small as a single micron in diameter. Specialized cells, called collar cells or choanocytes, allow sponges to pump water through their bodies at an amazing rate: Many sponges can filter their entire body volume in less than one minute! That's an important attribute, considering that some sponges must pump over a ton of water to secure just a single ounce of food!

Phylum Cnidaria
Jellyfish, Corals, Anemones, Hydra

Episode Two of *The Shape of Life*, entitled "Life on the Move," features the phylum Cnidaria, which includes such animals as jellyfish, corals, sea pens, sea anemones, and hydras. Many cnidarians alternate between two different body forms in their life: the free-swimming form, called the medusa, and the stationary form, called the polyp. Both body types follow the same basic plan. Each has a single opening that serves as both the mouth and the anus (where waste is excreted). That shared opening is typically surrounded by a ring of tentacles, allowing the animal to capture prey in all directions.

Cnidarians also have a defined top and bottom and two discernible tissue layers: an epidermis outer layer and an internal gastrodermis. Contained between these tissue layers is a layer called mesoglea. In medusa, the mesoglea is an elastic, clear jelly with fibers made of a protein called collagen. The mesoglea helps in locomotion by elastically recoiling in response to muscle contractions. Cnidarians' muscles and nerves are located at the base of the tissue layers. The internal space, surrounded by the layers of tissue and mesoglea, is the gut or gastrovascular cavity.

Features:

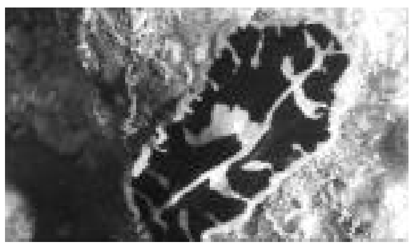
- **Two tissue layers with nerve and muscle tissues**
- **Nematocysts – structures contained in special cells called cnidocytes or cnidoblasts that can act in both offense and defense**
- **Two main life forms – free-swimming medusa (e.g.,jellyfish) or stationary polyp (e.g., anemone)**

One of the unique features of cnidarians is the stinging cells they use to capture prey. Located in their tentacles, these stinging cells, called cnidocytes, contain tiny, often toxic harpoons, called nematocysts. (The name Cnidaria comes from the Latin word meaning "nettle.") Triggered by touch or by certain chemicals, nematocysts fire out of the cnidocyte housing at lightning speed. Some hydra can fire these harpoons with an acceleration force equal to 40,000 times the acceleration of gravity. That's 10,000 times the acceleration force of a space shuttle. Often, lethal poisons are then injected into the prey once the nematocyst hits its mark.

The combination of differentiated tissues, muscles, nerves and a gut allowed ancestral cnidarians to be the first animals on the planet to show animated behavior.

Phylum Platyhelminthes
Flatworms

Episode Three of *The Shape of Life*, entitled "The First Hunter," features the phylum Platyhelminthes. This lesser-known group includes such animals as freshwater planaria, colorful marine polyclads and parasitic tapeworms and flukes. The name Platyhelminthes in Latin means *flat worm*.



Features:

- **Bilaterally symmetrical with a head and a tail**
- **Centralized nervous system**
- **Three tissue layers**
- **No coelom (body cavity),no circulatory system and no hard skeleton**

Fossilized worm tracks in the early Cambrian period (over 550 million years ago) hint at the origin of this body plan. While the actual classification of Platyhelminthes remains controversial, flatworms share distinctive features: Flatworms are bilaterally symmetrical with a defined head and tail region and a centralized nervous system containing a brain and nerve cords. Clusters of light-sensitive cells make up what are called eyespots. The head region of the flatworm also contains other sense organs, which are connected to the flatworm's simple brain. Like most animals, except sponges and cnidarians, flatworms possess three tissue layers making them triploblastic. The middle tissue layer, called the mesoderm, helps form true organs, including reproductive organs, such as ovaries, testes, and a penis.

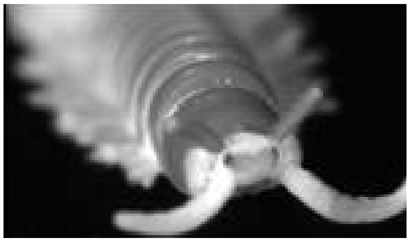
Flatworms are hermaphroditic and capable of sexual and asexual reproduction. They are, as their name implies, flat. They have no circulatory system or body cavity (coelom), but they do have an excretory and digestive system. Passive diffusion through the skin supplies oxygen to their body parts. The highly branched gastrovascular (gut) cavity distributes nutrients to their cells.

Most species of flatworms are parasitic, having evolved protective skin coverings and elaborate attachment mechanisms to allow them to live inside their hosts. One example featured in this episode is the tapeworm.

This episode discusses sexual reproduction in terms that might not be appropriate for children and early teens.

Phylum Annelida
Polychaetes, Earthworms, Leeches & Cambrian Explosion

The Cambrian period began approximately 543 million years ago. Of the eight major phyla covered in *The Shape of Life* series, two were known from fossils of this time – Porifera and Cnidaria. Shortly thereafter, a profuse radiation of fossils representing the other animal body plans occurred over a relatively brief span of about 10 million years (by some estimates, 530 million years ago.) The rest of the animal phyla all evolved during, or shortly after, this evolutionary explosion of new life forms in the Cambrian period.



Features:

- **Elongate and bilateral with segmented true body cavity (coelom)**
- **Complete circulatory system with capillaries,arteries and veins**
- **Body wall made of circular and lengthwise muscles**
- **Continuous gut running from mouth to anus with own musculature**
- **Bristle-like structures,called setae, projecting from body (except in leeches)**

Episode Four of *The Shape of Life*, entitled "Explosion of Life," features the phylum Annelida which includes animals like earthworms, polychaetes, and leeches. The Annelida body plan is equal in complexity to that of chordates. Far from being lowly worms, these creatures are impressively powerful and capable animals.

Annelids are bilaterally symmetrical. They also contain three tissue layers and a true body cavity, or coelom. The coelom surrounds a one-way muscular digestive tract that runs from the mouth to the anus and includes a pharynx, intestine, and other structures. Annelids have a closed-circulatory system with capillaries connecting to arteries and veins, as well as a segmented central nervous system that includes a simple brain located in the head region.

One of the distinctive traits of an annelid is that it has many segments, or rings, that comprise its body. In fact, Annelida means "little ring" in Latin. Each segment has a number of bristles, called setae, which help the worm move. The evolution of segmentation is an important step for the annelids because it provides an opportunity for separate regions of the body to specialize in different tasks. The fluid-filled coelom was another important innovation for annelids, as it insulated the gut from body locomotor muscles and provided a hydrostatic fluid skeleton against which the muscle system could work quite effectively.

Phylum Arthropoda

Crustaceans, Spiders, Millipedes, Centipedes, Insects

Episode Five of *The Shape of Life*, entitled "The Conquerors," features the phylum Arthropoda – a group that includes crustaceans, like lobsters and shrimp, spiders, millipedes, centipedes, and insects. Of all the phyla in the animal kingdom, Arthropoda is by far the largest and most diverse.

Features:

- **Hard exoskeleton made of chitin and protein**
- **Possess numerous jointed appendages and a segmented body**
- **Must molt to grow**

All arthropods have segmented bodies and are covered in a hard, yet flexible, protective armor called an exoskeleton. Their body muscles attach to the inside of the exoskeleton. The name Arthropoda means "jointed foot" and refers to their jointed appendages. In order to grow, arthropods must shed their exoskeleton periodically, engaging in an activity called molting. When an arthropod passes through specific developmental stages during molting, it is said to be metamorphosing. Radical changes in body design can come from metamorphosis. For example, an arthropod like a dragonfly can start life in a pond as a swimming larva and then metamorphose into a completely different-looking, winged adult.

Arthropods, like all animals, first appeared in the sea, yet became the first animal group to invade land and even take to the skies. (Our direct ancestors, the chordates, didn't invade land for another 100 million years.) Once on land, arthropods adapted superbly to the new environment.

The incredible diversity and success of the arthropods can be attributed to their extraordinarily adaptable body plan. A key feature of this plan lies in the development of myriad types of appendages (antennae, claws, wings, shields, mouthparts) that allowed arthropods to exploit nearly every niche on Earth.

Phylum Mollusca

Clams, Snails, Slugs, Nautilus, Octopus

Episode Six of *The Shape of Life*, entitled "The Survival Game," features the phylum Mollusca. Animals in this phylum, including chitons, snails, slugs, clams, squid, and octopus, show an amazing degree of diversity. All molluscs have soft bodies. In fact, the name Mollusc means "soft" in Latin. Most molluscs are generally covered by a hard shell, which is secreted by a layer of tissue called the mantle that overlays the internal organs of the mollusc.

Molluscs also have a strong muscular foot, which is used for movement or grasping. They have gills, a mouth and an anus. One feature unique to molluscs is a file-like, rasping tool called a radula. This structure allows them to scrape algae and other food off rocks and even to drill into prey or catch fish.

Features:

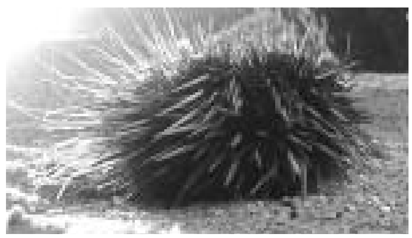
- **Rasping organ called a radula – present in all groups except bivalves and *Aplacophora***
- **Muscular foot – used for locomotion and other tasks**
- **A sheath of tissue called the mantle that covers body and can secrete the shell (if there is one)**
- **A mantle cavity that houses the gills or lungs**
- **A calcium shell present in most molluscs – some molluscs have greatly reduced their shells, e.g., squid;while others have completely lost it, e.g.,slugs, nudibranchs,and octopus**

The diversity of molluscs impressively demonstrates how a basic body plan can evolve into a variety of different forms that allow survival in specific environments. For example, the hard shell in a land-dwelling snail is relatively large and serves to protect the animal. In the fast-swimming squid, however, the shell has been reduced to a small pen-shaped structure.

Phylum Echinodermata

Sea Stars, Sea Lilies, Sea Urchins, Sea Cucumbers, Brittle Stars

Episode Seven of *The Shape of Life*, entitled "Ultimate Animal," features the phylum Echinodermata. This phylum, which is exclusively marine, includes animals such as sea stars, sea lilies, urchins, sea cucumbers, and brittle stars.



Features:

- **Internal skeleton made of little calcium plates**
- **Five-part symmetry**
- **Special fluid-filled system (called a water vascular system) that operates the tube feet**

While the majority of animal body plans are bilateral with a distinct head and tail, the phylum Echinodermata does not follow this pattern. Instead, many echinoderms begin life as a bilateral larva and later in life become radial with five-part symmetry and no central brain. Echinoderms move, feed and respire with a unique water-vascular system ending in what are called tube feet. Sea stars use their tube feet to slowly pry open clams, mussels or other prey. Some sea stars can even evert their stomach between the two shells of a bivalve and digest the soft parts inside.

The bodies of echinoderms are made of tough, calcium-based plates that are often spiny and covered by a thin skin. The name, Echinodermata, means "spiny skin" in Latin. While most echinoderms are either stationary or slow-moving, methodical animals, they are nevertheless prominent members of the marine environment.

Phylum Chordata

Tunicates, Lancelets, Vertebrates, including Amphibians, Reptiles, Mammals

Episode Eight of *The Shape of Life*, entitled "Bones, Brains and Brawn," features the phylum Chordata. The Chordata includes a wide range of animals from tunicates that look superficially more like sponges, to vertebrates, including fishes, frogs, snakes, birds, and ourselves.

Despite this diversity, virtually all chordates share certain features at some point in their lives. These include a stiffening rod, called a notochord, that in many members (e.g., the vertebrates) is later replaced by a bony, vertebral column. In most adult vertebrates, the notochord only remains as a disk between the vertebrae. Another chordate feature is a hollow nerve structure called a dorsal nerve cord that in most members becomes the spinal cord and brain. Also included in the chordate body plan are structures called pharyngeal gill slits, or clefts. These skeletal elements function as jaws and jaw supports, and in some animals take on a variety of other functions.

Features:

- **Notochord – an elongate rod-like structure located above the gut and below the nerve cord**
- **Dorsal nerve cord – a hollow tube that in most differentiates into a brain anteriorly and a spinal cord posteriorly**
- **Gill clefts – structures located behind the mouth and in front of the esophagus**
- **Segmented muscles (except for tunicates)**
- **Post-anal tail**

The most conspicuous group of chordates is the subphylum Vertebrata. Vertebrates include a wide range of animals, from the jawless fishes to the more familiar mammals and birds. Unlike arthropods that wear their skeletons on the outside, chordates have their skeletons on the inside. This design, as in the echinoderms, allows chordates to grow continuously with no need for molting. Such a robust internal skeleton helps vertebrates grow to the size of an African elephant, or support the powerful movements of swimming fish.

Another major innovation in the evolution of vertebrates is the appearance of jaws and a bony skull. A quadrupling of genetic information and the appearance of a special population of migratory, cells called neural crest, are correlated with the emergence of the all-important vertebrate jaws and skulls. These new features offered a host of new opportunities.

Vertebrates fall into two main categories: fishes, and a group of animals called tetrapods. Tetrapods developed from a distinct lineage of fishes that possessed unique internal fin bones. These structures eventually aided in supporting the weight of the animals on land and laid the foundation for arms and legs and the first amphibians. The development of a shelled, water-retaining egg, the amniotic egg, enabled tetrapods to remain on land and develop into reptiles (including birds) and mammals.

From an ancient reptilian ancestor, two groups of animals, mammals and birds, independently developed the capacity to maintain a constant body temperature. Mammals evolved earlier than birds, more than 220 million years ago, and are represented today by more than 4,500 species, including humans.

Name Game—Getting to the Root of Things

"Echinoderm" is one of many examples of animal names based on Latin or Greek roots. *Echino* means "spiny." *Derm* means "skin." So... *Echinoderm* means "spiny skin." See if you can create some animal names using the word roots below. Draw a picture of the animal to match the descriptive name.

bi = two	**tri** = three	**poly** = many	**chloro** = green
endo = inside	**ecto** = outside	**peri** = around	**noto** = back
echino = spine	**ramus** = branch	**cerv** = neck	**chele** = claw
cephal = head	**som** = body	**pod** = foot	**stom** = mouth

There are many other Latin and Greek roots used for naming animals, sciences, body parts, diseases, etc. If you learn lots of those roots, you'll find that you can figure out the meanings of words you haven't even heard or seen before.

Common Names

There's a problem with common names. They don't always describe animals accurately. That's what scientific names are all about. There is only one official scientific name for each species of living thing. A specific kind of animal might have several different common names, but only one scientific name. The scientific name makes it clear what animal it really is. See if you can find out:

- What two words make up a scientific name?
- What language(s) is (are) used to develop these two words?
- How should the two words be written?

Activity One

Questions to Explore

Episode Title: Any and all episodes

Activity Subject: Body plans and parts, animal behaviors, diversity, evolution, science careers, science process

Grade Level: Across all episodes K-12; episode-by-episode 6-12

Learning Objectives: Students examine pre-selected questions while viewing *The Shape of Life* episodes; questions cover most of the categories included in the accompanying "Video Time Code Index."

Assessment: Students participate in discussions and provide verbal or written responses to questions.

Time: One hour to view each episode, with discussion time to follow

Group Size: Entire class, groups of two to four students, or individuals

Materials and Preparation

Review suggested discussion questions before viewing each episode of *The Shape of Life*. Decide what you and your students would be interested in focusing on during the episode and in discussions to follow.

Procedure

1) Review suggested discussion questions before viewing *The Shape of Life*. Decide with your students what questions they would be interested in exploring.
2) As a class, view each or selected episodes of *The Shape of Life*. Draw attention to details that will prepare your students for post-viewing discussions.
3) Enjoy talking with your students about what you viewed together in *The Shape of Life* and the questions you have selected for further exploration.
4) Based on your discussions, assign follow-up research using the Web and/or print resources to adequately answer each selected question.

QUESTIONS TO EXPLORE Across All Episodes

Basic Questions

for pre-viewing preparation and post-viewing assessment

1) What is the name of the animal group featured in the episode?
2) How are the animals of this group alike? Different?
3) What special features or adaptations do the animals in the episode have to help them survive in their habitats?
4) How do the animals move?
5) How do the animals get food?
6) How do the animals breathe?
7) Does the episode mention any animals that lived long ago? If so, how are they different from animals that live today?
8) What kinds of scientists are featured in the episode?
9) What questions did the scientists in the episode investigate?
10) What do you like most about the animals in the episode? Why?
11) What is your favorite animal featured in the episode? Why?

Advanced Questions

for use in addition to the questions above

1) In what ways could you group the animals in the episode? In several episodes?
2) What animal behaviors did you observe in the episode?
3) What senses do the animals in the episode have? How do they use their senses?
4) Explain how the scientists use observations and experiments to learn more about animals. Describe any tools the scientists use to help them in their research.
5) Do scientists ever arrive at different conclusions? Explain.
6) How did the scientists benefit from working in a team?

QUESTIONS TO EXPLORE
Episode-by-Episode

Episode 1:"Origins"(Sponges)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) What was the first animal group? What is the evidence for this conclusion?

2) How long ago did the first animal appear on Earth?

3) How are scientists currently defining the group called "animal"?

4) Should protozoans be considered animals? Why or why not?

5) What does "multicellular" mean? What is meant by "specialized" cells?

6) What do sponges eat?

Advanced Questions
for use in addition to the questions above

1) What do you think the first animal looked like?

2) How do you think that first animal differed from today's representatives?

3) Why do you think there would even have been a first animal?

4) What do you think "evolution" means?

5) What were the little organisms that were flying along the sponge tunnels? Learn more about them by first exploring what "plankton" means.

6) How have relationships between animal groups been determined in the past? How is molecular and genetic research influencing our classification of animals into related groups?

Episode 2:"Life on the Move" (Cnidarians)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) In what way are cnidarians more complex than sponges? What characteristics did they add?

2) What do these additions allow cnidarians to do?

3) Name and describe the two different versions of the cnidarian body plan.

4) Draw a moon jelly's life cycle.

5) What are nematocysts? What do they do?

6) If the pulsing of a jellyfish isn't only for locomotion, what else does it do?

Advanced Questions
for use in addition to the questions above

1) How do animals without brains perform and control their activities?

2) What kind of a skeleton does an anemone have, and how does it work? How is it different from the human skeleton?

3) What is "symmetry"? What kind of symmetry do cnidarians have? How is it different from the symmetry of your own body?

Episode 3:" The First Hunter" (Flatworms)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) How can paleontologists find fossils of flatworms if flatworms don't have bones?

2) In what ways are flatworms more complex than cnidarians?

3) What is it about the flatworm body plan that makes it a good hunter? What are the advantages of having a bilaterally symmetrical body? What are the advantages of stereo senses?

4) What are cilia? How does a flatworm use them?

5) Name four kinds of habitats where different types of flatworms live.

6) Where is the mouth of the flatworm?

7) What is a mutation?

8) Name the special genes that control whole sets of other genes.

Advanced Questions
for use in addition to the questions above

1) What do we call an animal that produces both sperm and eggs? What are the advantages and disadvantages of such a design?

2) What were some special adaptations developed by parasitic flatworms? Use the tapeworm as an example.

3) How do genes control development and the formation of a body plan?

4) Flatworms aren't the only kind of worm. There are roundworms, ribbon worms, arrow worms, acorn worms and segmented worms. Can you name others? What do you think the term 'worm' actually means? What other living organisms or parts of living organisms are shaped like worms? What do you think the benefits of having a worm-like body might be?

This episode discusses sexual reproduction in terms that might not be appropriate for children and early teens.

Episode 4: "Explosion of Life" (Annelids)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) What complex body features were developed in annelids that their flatworm-like ancestors didn't have?
2) When did the majority of animal body plans appear?
3) In what way is the annelid digestive tract different from the digestive systems of cnidarians and flatworms?
4) How do earthworms move? How are the body segments involved in this action?
5) Name an annelid worm that sucks blood from other animals for its food.
6) What kind of annelid worm lives near hot-water vents in the deep sea?

Advanced Questions
for use in addition to the questions above

1) What reasons are offered to explain the rapid occurrence of body plan evolution known as the Cambrian Explosion?
2) How did the burrowing of worms contribute to keeping Earth from entering a major ice age?
3) What are the advantages of having a segmented body?

Episode 5: "The Conquerors" (Arthropods)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) Define these terms: exoskeleton, appendage, molting, terrestrial, detritus, and robotics.
2) What is special about arthropod appendages?
3) Where did the first arthropods live?
4) What features of the arthropod body plan allowed them to invade land?
5) What did the first arthropods on land eat?
6) See how many different uses of arthropod appendages you can list.
7) What arthropod structures are used to extract oxygen from water? What arthropod structures are used to extract oxygen from air?
8) What two major habitats of Earth were arthropods the first animals to explore?
9) What role might algal mats have played in the land invasion?

Advanced Questions
for use in addition to the questions above

1) What are the advantages and disadvantages of having an internal skeleton like ours as opposed to an external skeleton that is shed in order to grow?
2) What are the advantages and disadvantages of undergoing metamorphosis? What animals, besides arthropods, undergo metamorphosis?
3) What are the characteristics of animals that live in many different kinds of places?
4) Humans often think of insects as creepy-crawlies that are up to no good. Though some insects do sting or bite, others pollinate our crops. Make a two-column list of some of the good things and some of the bad things about insects with regard to their immediate impact on humans.
5) Insects are an enormously diverse group of organisms that often play key roles in their respective ecosystems. Write a few sentences describing three roles that insects play in the natural world to help maintain ecosystem services.

Episode 6: "Survival Game" (Molluscs)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) Name some different activities a mollusc can perform with its foot.
2) What do you call the skinlike tissue that produces the shells of molluscs?
3) What is a radula and how does a mollusc use it?
4) How do squid or octopuses move through the water?
5) Aside from the shell, what other mollusc defenses can you name?

Advanced Questions
for use in addition to the questions above

1) How does the mollusc build and repair its shell?
2) How does a chambered nautilus control its buoyancy? Compare the diversity of forms of molluscs to that of annelids. Describe which group you think covers the greatest range of body form, function, and behavior.

3) Make a list of molluscs you have known. In other words, make a list of molluscs you have encountered in your own experiences—in aquariums, at restaurants, in your garden, etc. For each one, answer the following questions:

a) Where did you see it?
b) What was it doing or what were you doing to it?
c) Where is its natural habitat?
d) What does it eat?
e) What eats it?

Episode 7: "Ultimate Animal" (Echinoderms)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) Give the common names for the four major kinds of echinoderms.

2) How do sea stars walk and grab?

3) What term describes how an animal grows new replacements for lost body parts?

4) What is similar about echinoderms and cnidarians? In what way does echinoderm symmetry differ from that of cnidarians?

5) Describe how some sea stars feed on mussels.

6) What two kinds of structures are scattered between the spines of sea stars?

7) How could you investigate the activities of an animal that doesn't appear to move when you watch it?

Advanced Questions
for use in addition to the questions above

1) How does a water-vascular system work?

2) How can a sea star be so flexible and then suddenly become as rigid as a rock?

3) What are the advantages and disadvantages to eating with an extrusible stomach?

4) Are there benefits to being headless, brainless, and not bilaterally symmetrical? What are they?

Episode 8: "Bones, Brawn & Brains" (Chordates)

Basic Questions
for pre-viewing preparation and post-viewing assessment

1) What makes a chordate a chordate? Why are tunicates included in the same phylum as humans?

2) What is a tetrapod?

3) What are some major groups of vertebrate animals?

4) Most vertebrates have jaws. Why are jaws important?

5) What natural disaster wiped out half of the Earth's animals 65 million years ago?

Advanced Questions
for use in addition to the questions above

1) What are the advantages of having an internal skeleton as compared to an external skeleton that is shed in order to grow?

2) What is the function of the notochord?

3) Why can't an ant get as big as an elephant?

4) What happened during evolution that led to the appearance of jaws and skulls in chordates?

5) How can you investigate growth in an extinct animal? How can you investigate rate of growth in an extinct animal?

See www.shapeoflife.org for links to additional print and electronic resources to explore.

Activity Two

Phylum Fun for Young Children

Episode Title: Any and all episodes, excluding "The First Hunter" (Flatworms)

Activity Subject: Body plans and parts, animal behaviors, diversity, motion

Grade Level: K-2

National Science Education Standards: Standards are noted as (standard:benchmarks).
Grades K-2

Life Sciences	(5:1,2), (6:2), (7:2)
Physical Science	(10:3,4,5)
Nature of Science	(12:1), (13:1)

Learning Objectives: Students learn about the body plans and parts of animals and how they use them.

Assessment: Students make models and other objects; use their own bodies to imitate animal structures, behaviors, and movements; and discuss what they make and how they imitate the animals.

Time: Flexible, based on available time and number of video segments viewed; fifteen minutes to one class period; multiple class periods if desired

Group Size: Entire class

Materials and Preparation

View and pre-select age-appropriate video segments to support activities planned from the "Video Time Code Index." See additional materials and preparation for each activity selected.

Procedures

1) As a class, view pre-selected segments of *The Shape of Life* videos.
2) See additional instructions for each activity selected.

Sponge Fun!

Make sponge-paint wrapping paper

Materials:
- natural and synthetic sponges of different textures
- paint
- paper

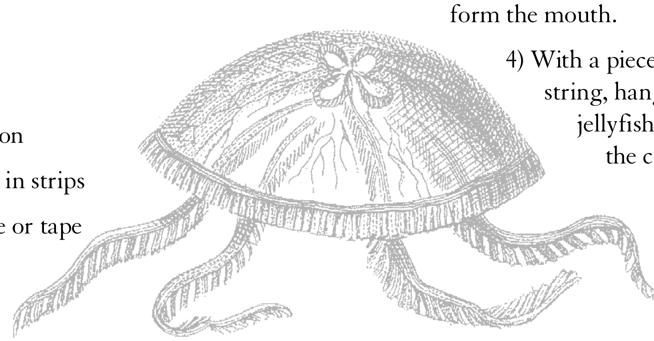
Procedure:
1) Put a small amount of paint in a shallow dish.
2) Dip sponge into paint.
3) Lightly press sponge on paper to create an underwater scene of beautiful sponges. Draw water flowing through your sponges and other animals living with your sponges.
4) Let dry.

Cnidarian Fun!

Make a jellyfish

Materials:
- paper plate
- watercolors
- curling ribbon
- paper to cut in strips
- scissors, glue or tape

Procedure:
1) Paint paper plate with watercolors to look like the body of a jellyfish. Make your designs radiate out from the center of the plate. Some jellies have tiny eyespots around the edges of the bell, and the edges are sometimes scalloped. Draw eyespots and/or scallop the edges of the plate. Let plate dry.
2) Cut and curl long pieces of ribbon for the tentacles. Attach ribbon to outside of the paper plate.
3) To form the mouth, cut out strips of paper wider and shorter than the ribbon for the tentacles. Make the edges of the strips of paper wavy and uneven. Attach several strips of paper to the center of the underside of the jellyfish to form the mouth.
4) With a piece of string, hang your jellyfish from the ceiling.



Be a jellyfish

Materials:
- long pieces of fabric, scarves, or crepe paper
- slow, flowing music

Procedure:
1) Use the fabric as your tentacles as you slowly drift through the sea to the music.

Annelid Fun!

Make an earthworm

Materials:
- clay

Procedure:
1) Roll clay between your hands to make a worm. Use a toothpick to draw the segments on your earthworm. Make a mouth at one end.

Be an earthworm

Materials:
- your body

Procedure:
1) Lie on the floor and wiggle like a worm.

Make a worm farm

Materials:
- clear jar or box
- soil
- earthworms
- moisture
- organic material for food

Procedure:
1) Put moistened soil in the jar or box.
2) Add the earthworms and organic matter for food.
3) Keep worm farm in a dark, cool place. Observe the worms' behavior.
4) After a few days, return the worms to the garden where you found them.

Arthropod Fun!

Make a crab or insect

Materials:
- pictures of arthropods
- clay, pipe cleaners

Procedure:
1) Look at pictures of arthropods. Notice the number of legs and antennae and their different shapes.
2) Make the arthropod's body out of clay. Use pipe cleaners to make the different types of arthropod appendages. Do you know how your arthropod uses its different appendages?

Walk like a crab

Materials:
- your body

Procedure:
1) Use your hands and feet to crawl sideways across the floor.

Make a butterfly

Materials:
- paper
- crayons, markers
- clothes pins
- pipe cleaners

Procedure:
1) Fold the paper in half and cut out the butterfly's wings. Open up the wings and color both sides with the same patterns and colors.
2) Use the clothespin for the butterfly's body. Attach the clothespin between the two wings.
3) Make antennae out of the pipe cleaner. Attach to the butterfly's head.
4) Take your butterfly outside and dance between flowers with it.

Be an insect

Materials:
- your body

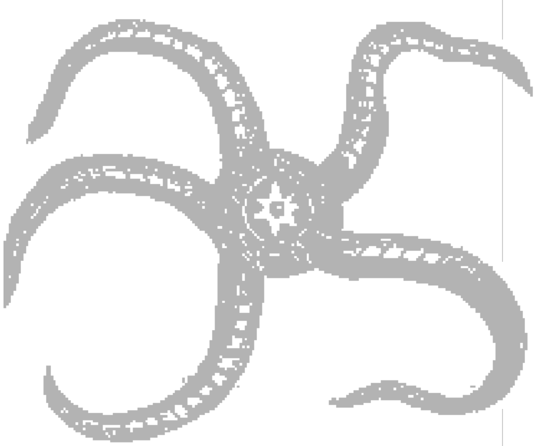
Procedure:
1) Buzz and fly like a bee.
2) Fly gracefully like a butterfly.
3) Think of ways to act like other types of insects. Show friends and family your imitations.

Mollusc Fun!

Make a squid windsock

Materials:
- tissue paper
- string
- glue
- scissors

Procedure:
1) Cut a large rectangle of tissue paper. On one of the short sides, fold over one inch of tissue paper. Cut a piece of string long enough to be glued into the fold and extend out enough to be tied. Glue the string into the fold. This becomes the reinforced end of the windsock. Let dry.
2) Cut one-inch-wide strips of tissue paper for the eight arms. Cut two longer strips of tissue paper for the tentacles. Glue the arms and tentacles on to the other short side of the rectangle. Let dry
3) Roll the rectangle into a tube and glue together. Let dry.
4) Add eyes to the head of your squid.
5) Fly your squid windsock from a long string tied to the extended piece of string on the reinforced end of the windsock.



Echinoderm Fun!

Make a brittle star

Materials:
- index card
- pipe cleaners
- glue
- crayons

Procedure:
1) Fold the index card in half. Cut out two circles for the brittlestar's body. Color the body pieces.
2) Glue the ends of five pipe cleaners to one of the circles made out of the index card.
3) Glue the other circle on top of the pipe cleaners so you can no longer see the ends and both circles line up. Let dry.
4) Shape the pipe cleaners to mimic the rays of a brittle star.

Make a sea urchin

Materials:
- half of a Styrofoam ball
- red, green, or purple paint
- toothpicks

Procedure:
1) Stick toothpicks into the Styrofoam ball.
2) Paint the toothpicks and Styrofoam ball.
3) Add a mouth to the underside of the urchin.

Chordate Fun!

Move like a chordate

Materials:
- your body

Procedure:
1) Think of a chordate. Imitate how it moves. For example: hop like a frog, slither like a snake, jump like a kangaroo, stalk like a lion, or walk like a human being. Use your imagination!

Sound like a chordate

Materials:
- your vocal cords

Procedure:
1) Think of a chordate. Imitate the sound it makes. For example: call like a bird, moo like a cow, screech like a monkey, bark like a dog, or talk like a human being. Use your imagination and see how many different animal sounds you can make.

See www.shapeoflife.org for links to additional activities.

Activity Three

Wall Displays Can Grow on You

Episode Title: Any and all episodes

Activity Subject: Body plans and parts, evolution, animal behaviors, defense, science careers, science process

Grade Level: 3-12

National Science Education Standards:
Standards are noted as (standard:benchmarks).

Grades 3-5	
Life Sciences	(5:2,3), (6:3,4), (7:2)
Nature of Science	(11:3), (12:1), (13:1,2)
Grades 6-8	
Life Sciences	(5:5,7), (6:2,3), (7:1,4,5)
Nature of Science	(11:2), (12:7,8), (13:1,2,3)
Grades 9-12	
Life Sciences	(6:1,5), (7:4,7)
Nature of Science	(11:3), (12:6), (13:5,6)

Video Segment References: Refer to the "Video Time Code Index" for segments contained in each episode on body plans and parts, animal behavior, evolution, defense, science careers, and more. Episode 6 "Survival Game" (Molluscs) and Episode 7 "Ultimate Animal" (Echinoderms) particularly highlight defense.

Learning Objectives: Students build wall displays to illustrate the main points covered in each episode of *The Shape of Life*.

Assessment: Students develop visual displays and write a paragraph or report explaining their thinking (opinion) on some aspect of the display.

Time: Flexible, based on available time and number of episodes or video segments viewed; one hour to view each episode; one to two additional class periods to complete the activity

Group Size: Entire class views videos and contributes to discussion; entire class or small teams of students construct displays.

Materials and Preparation

Have a wide variety of construction materials available, with the capability to produce and print items on a computer, if possible.

Procedure

1) Design and post the beginning template for the display yourself if time is limited, or have students design and construct the entire display. Students make and add parts as each episode or segments of each episode are viewed and discussed.

2) Before each episode or selected segments from each episode are viewed, have students look for and make note of the information required to develop the display. For example, tell students to look for and make note of new kinds of defensive structures or strategies developed by each animal group to contribute to the display on defense.

3) Displays that might be developed as the episodes or segments are viewed include: (see display ideas below)

Display Ideas

The Tree of Life

Students develop a Tree of Life and add the newly discussed phylum group to the tree as each is viewed. The phylum name and pictures or student drawings of common representatives can be included. *(See illustration on next page.)*

What's New?

Using a newspaper or newsletter format, students create headlines and short news stories telling about new body plans, parts, and systems of each animal group.

Activities

Names in the News

Using a newspaper or newsletter format, students create headlines and short news stories featuring the investigations of scientists in each episode viewed.

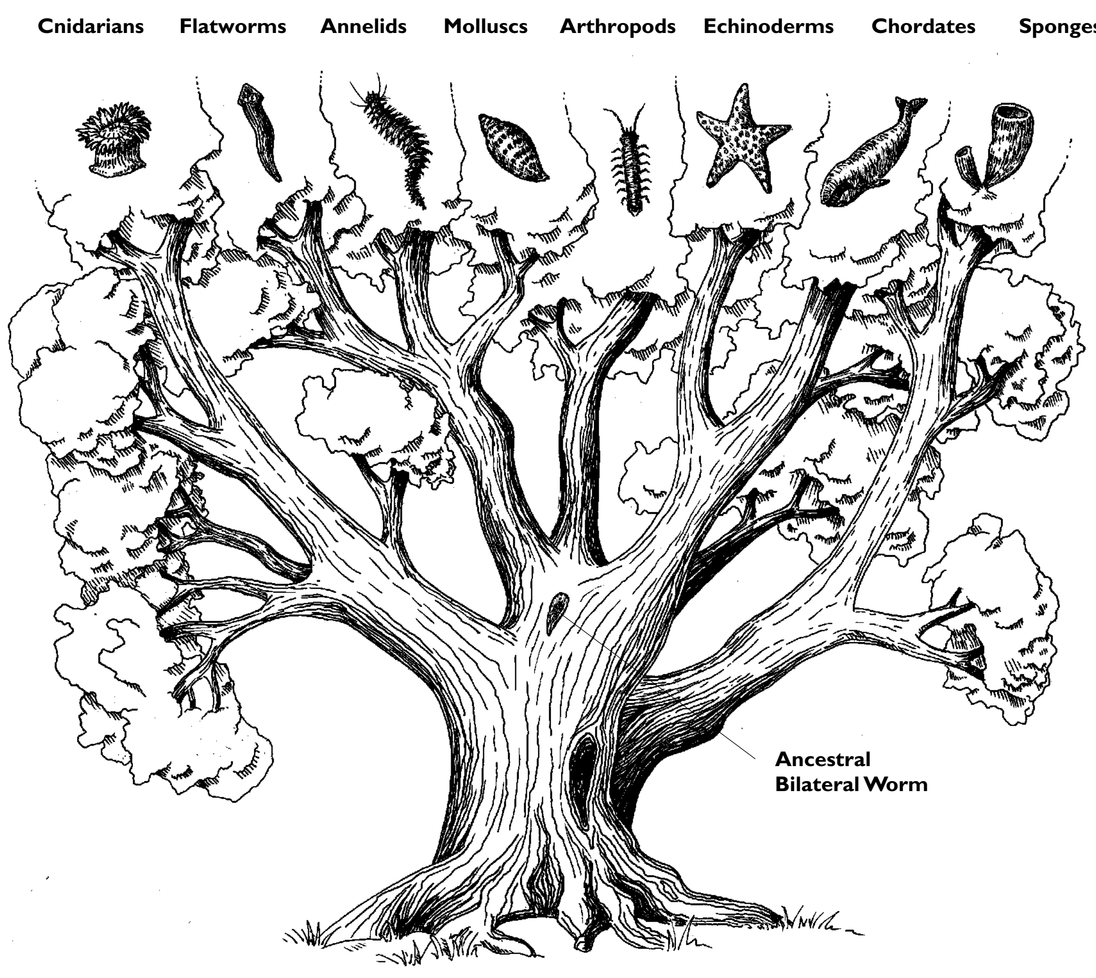
! Defense - Defense !

(Episodes 6, "Survival Game," about molluscs and Episode 7, "Ultimate Animal" about echinoderms particularly highlight defenses.) Students create a collage of words and phrases that headline the defensive structures and strategies of each group of animals.

Favorite Critters

Students make a three-dimensional representation of their favorite animal from each episode or from among all the episodes and mount it on the board with a list of fascinating features that the animal possesses. (Figuring out how to mount their model can be a real challenge and a learning experience itself!)

Phylogenetic Tree of Life



Activity Four

Invertebrate Critter Cards

Episode Title: "Life on the Move" (Cnidarians), "Explosion of Life" (Annelids), "The Conquerors" (Arthropods), "Survival Game" (Molluscs), "Ultimate Animal" (Echinoderms)

Activity Subject: Body plans and parts, diversity

Grade Level: 3-12

National Science Education Standards:
Standards are noted as (standard:benchmarks).

Grades 3-5
Life Sciences (7:2)

Grades 6-8
Life Sciences (4:5), (5:5), (7:1,4,5)

Grades 9-12
Life Sciences (7:7)

Learning Objectives: Students explore how animals are classified and the characteristics and common representatives of five major invertebrate phyla: cnidarians, annelids, arthropods, molluscs, and echinoderms.

Assessment: Students sort animal cards (provided) into the groups (phyla) to which they belong, and explain the critical characteristics that qualify each animal for its group. See "Procedure" # 6 and # 7 below for additional assessment options.

Time: Minimum six class periods to view the five episodes and complete the activity

Group Size: Entire class views videos and contributes to discussion; individual students or pairs or small teams of students conduct activity.

Materials and Preparation

Duplicate the accompanying "Invertebrate Critter Card" page for individual students, or for pairs or groups of students. Provide scissors for the students to cut apart the invertebrate cards.

Procedure

1) View the five episodes covered in this activity with your students.

2) At the completion of each episode, review with students how animals are classified and the characteristics that determine the phylum featured. Refer to "Introduction to Episodes and Phyla," paying particular attention to the body plan features outlined.

3) Determine the group size for the activity that will work best for your class.

4) Have students cut apart the cards and phylum headers provided, then turn the cards face down and shuffle them.

5) Have students draw one card at a time and place it below the correct phylum header. Students in pairs alternate turns, drawing and placing cards; students in groups rotate turns.

6) Have students fill in the following sentence about each card (request verbal or written responses):

This ________________________ is a(n) ______________because it has ________________________________ ________________________________.

or

This <u>(critter name)</u> is a(n) <u>(phylum)</u> name because it has <u>(these characteristics.)</u> (**Example:** This <u>earthworm</u> is an <u>annelid</u> because it has <u>segmentation and a flow-through gut.)</u>

7) When completed, collect all cards and if additional review or assessment is desired, hold up one picture card at a time from among those provided, covering the name of the animal with your fingers. Ask students to name: the animal, the group, the characteristics of that group, and other animals in the same group. Request verbal or written responses.

See following page for Invertebrate Critter Cards.

Answer Key:

Cnidarians-jellyfish,coral,sea anemone, hydra,siphonophore

Annelids-earthworm, worm,tubeworm, leech

Molluscs-slug,squid,octopus,clam, chiton,snail

Echinoderms-sea cucumber, sea urchin, sea star, sand dollar, brittle star

Arthropods-spider, butterfly, millipede, pillbug,crab

CNIDARIANS
Phylum Cnidaria

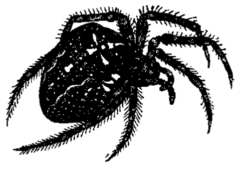
ANNELIDS
Phylum Annelida

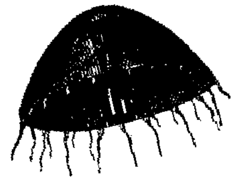
MOLLUSCS
Phylum Mollusca

ECHINODERMS
Phylum Echinodermata

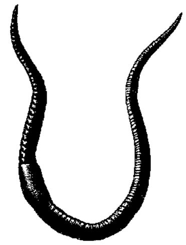
ARTHROPODS
Phylum Arthropoda


sea cucumber

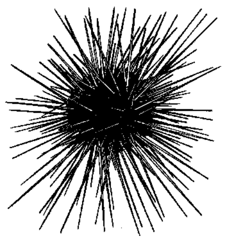

spider

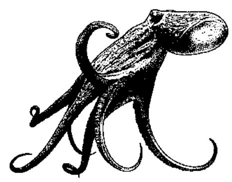

jellyfish

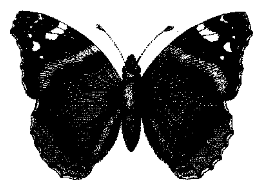

slug

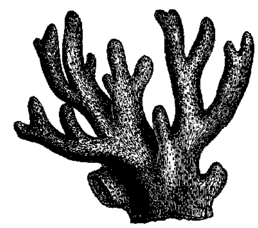

earthworm


squid

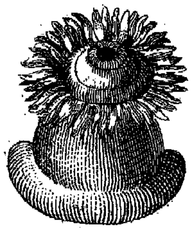

sea urchin

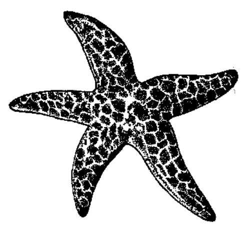

octopus

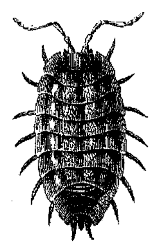

butterfly


coral


millipede

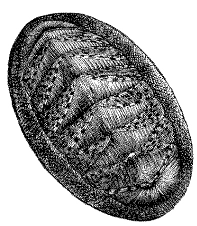

sea anemone

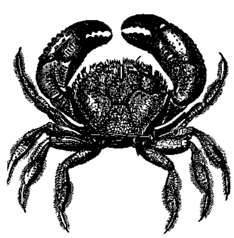

sea star


pillbug

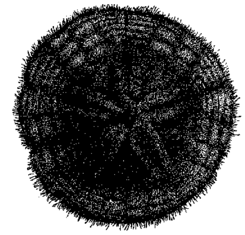

clam

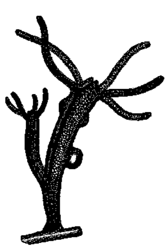

worm

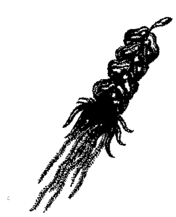

chiton


crab

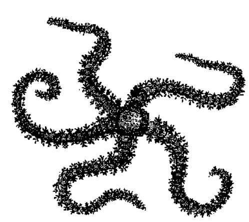

snail


sand dollar


hydra


siphonophore


tube worm


brittle star


leech

Activity Five

Phylum Comparison Challenge

Episode Title: Any or all episodes (episode review and/or series culminating activity)

Activity Subject: Body plans and parts, evolution, diversity

Grade Level: 6-12

National Science Education Standards:
Standards are noted as (standard:benchmarks).
Grades 6-8
Life Sciences (4:5), (5:4,5,6,7), (7:1,4,5)
Grades 9-12
Life Sciences (4:1), (5:5,8), (7:1,2,3,6,7)

Video Segment References: Refer to the "Video Time Code Index" for segments contained in each episode on body plans and parts, animal behavior, evolution, life cycles/ reproduction, and more.

Learning Objective: Students explore the characteristics of the eight major animal phyla.

Assessment: Students sort puzzle pieces containing animal group characteristics by phylum. For each characteristic (puzzle piece), students draw a sketch and list an example of a particular organism that has that characteristic.

Time: Flexible, based on available time and number of episodes or video segments viewed; one hour to view each episode and additional class period to complete the activity

Group Size: Entire class views videos and contributes to discussion; individual students or pairs or small teams of students conduct activity.

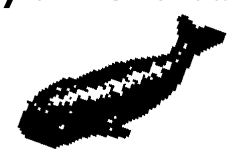
Materials and Preparation

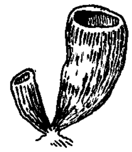
Duplicate the accompanying, reproducible "Phylum Comparison Chart Key" for each group. Provide scissors, colored pencils and/or markers, and newsprint or poster board.

Procedure

1) View the episodes or pre-selected episode segments with your students, and review the characteristics of each animal group, using the "Phylum Comparison Chart Key" provided as a guide to reinforce student learning of the characteristics of each animal group. Highlight the characteristics that are included in the chart. Note that some characteristics are found in more than one phylum.
2) Review with students the eight major animal phyla and their characteristics provided in the "Introduction to Phyla."
3) Have students design their own display on poster board or newsprint, with room for each piece of the chart and an accompanying illustration and label (provided).
4) Have students look over the "Phylum Comparison Chart" pieces. Let them ask questions about the characteristics they don't understand.
5) Ask students to cut apart and shuffle the chart pieces with printed side down, then draw and sort the pieces into the eight major phyla based on the characteristics of the animals in each phylum.
6) Have students rotate turns drawing and sorting the pieces.
7) Each group places the pieces on the display chart they have designed. For each characteristic (chart piece), have students draw a sketch and list an example of a particular organism that has that characteristic. The resulting display will have illustrations and names of organisms as well as chart pieces.
8) When all groups are finished, have students defend their placement decisions in a class discussion. This should help to reconcile any conflicting decisions.
9) Relevant sections of the chart can also be used for review of each phylum after viewing each episode or segments of each episode.

See following pages for Comparison Chart and answer key.

Phylum Cnidaria 	**Hollow body cavity for food**	**Five-part radial symmetry**	**Complete digestive tract with two ends**
Muscular “foot” used to slide, dig, or jump	**ANNELIDS**	**Tube feet used for locomotion**	**No symmetry or consistent body shape**
Some have stinging structures (nematocysts)	**Jaws and skulls important in their evolution**	**Water flows through its body, full of canals**	**Phylum Chordata** 
Increased complexity made possible by much more DNA	**Phylum Mollusca** 	**Most have inside skeleton of bones**	**Pioneered jointed legs**
Some propel, using their siphon as a water jet	**Phylum to which humans belong**	**ECHINODERMS**	**More species than any other phylum**
FLATWORMS	**Specialized cells, but not organized into organs or tissues**	**First phylum to venture into the air**	**Some spines are little pincers (pedicellaria)**
Mantle of tissue covering the body	**All have notochord; most have backbone**	**Phylum Platyhelminthes** 	**MOLLUSCS**

Spicules act as a skeleton to give it structure	Phylum Porifera 	Some of the simplest animals with bilateral symmetry	Champions of variations in appendages
CNIDARIANS	Some non-swimming polyps	Phylum Annelida 	Feeding device like a toothed, rasping tongue (radula)
Three tissue layers, but no body cavity	Exoskeleton (outside skeleton) made of chitin and protein	**ARTHROPODS**	All members live in the ocean
Most have a calcium-carbonate shell	Most members are parasitic	Tubular mouth (pharynx) at mid-body	Phylum Arthropoda 
Their active burrowing has affected global climate	Hard but flexible bodies with interlocking plates under thin skin	First muscles and nerves	**CHORDATES**
Body design basically a tube within a tube	**SPONGES**	No locomotion; stationary animal	Fluid-filled compartments used for locomotion
Phylum Echinodermata 	Bilateral phylum that added segmentation	Some free-drifting medusae	Digestive tract with the entrance being the exit

Phylum Comparison Chart Key

SPONGES

Phylum Porifera

No symmetry or consistent body shape

Water flows through its body, full of canals

Spicules act as a skeleton to give it structure

No locomotion; stationary animal

Specialized cells, but not organized into organs or tissues

CNIDARIANS

Phylum Cnidaria

First muscles and nerves

Some have stinging structures (nematocysts)

Some free-drifting medusae

Some non-swimming polyps

Hollow body cavity for food

Digestive tract with the entrance being the exit

FLATWORMS

Phylum Platyhelminthes

Some of the simplest animals with bilateral symmetry

Tubular mouth (pharynx) at mid-body

Three tissue layers, but no body cavity

Digestive tract with the entrance being the exit

Most members are parasitic

ANNELIDS

Phylum Annelida

Bilateral phylum that added segmentation

Complete digestive tract with two ends

Fluid-filled compartments used for locomotion

Their active burrowing has affected global climate

Body design basically a tube within a tube

ARTHROPODS

Phylum Arthropoda

Champions of variations in appendages

Exoskeleton (outside skeleton) made of chitin and protein

First phylum to venture into the air

Pioneered jointed legs

More species than any other phylum

Complete digestive tract with two ends

Bilateral phylum that added segmentation

MOLLUSCS

Phylum Mollusca

Feeding device like a toothed, rasping tongue (radula)

Most have a calcium-carbonate shell

Muscular “foot” used to slide, dig, or jump

Some propel, using their siphon as a water jet

Mantle of tissue covering the body

Complete digestive tract with two ends

ECHINODERMS

Phylum Echinodermata

Five-part radial symmetry

Tube feet used for locomotion

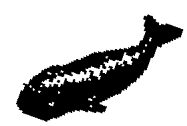
Some spines are little pincers (pedicellaria)

Hard but flexible bodies with interlocking plates under thin skin

All members live in the ocean

Complete digestive tract with two ends

CHORDATES



Phylum Chordata

All have notochord; most have backbone

Increased complexity made possible by much more DNA

Most have inside skeleton of bones

Phylum to which humans belong

Jaws and skulls important in their evolution

Complete digestive tract with two ends

Bilateral phylum that added segmentation

Activity Six

Animal Investigations

Episode Titles: "The Conquerors" (Arthropods), "Survival Game" (Molluscs)

Activity Subjects: Body plans and parts, animal behaviors, locomotion, feeding, habitats, diversity, science process

Grade Level: 3-12 (Students in elementary grades may not be able to do all of the exercises or understand all of the abstract concepts.)

National Science Education Standards:
Standards are noted as (standard:benchmarks).

Grades 3-5	
Life Sciences	(5:2,3), (6:3,4), (7:2)
Physical Science	(10:4,5,6)
Nature of Science	(11:1,2,3,4), (12:1,2,5), (13:1,2,3)
Grades 6-8	
Life Sciences	(5:5,7), (6:2), (7:1,4,5)
Physical Science	(10:4)
Nature of Science	(11:1), (12:1,2,4,7,8), (13:1,2)
Grades 9-12	
Life Sciences	(5:8), (7:1,2)
Nature of Science	(11:1,2), (12:1,3,6), (13:6)

Video Segment References: *Shape of Life* video references are noted as (episode number/minute:second) in all Animal Investigation exercises. Set your VCR counter to "0" at the first frame of the video on each tape. Remember that counter accuracy will vary.

Learning Objectives:

- Students investigate the body plan and structure of a variety of animals.
- Students use the inquiry process and design investigations to study the behavior and environmental preferences of a variety of animals.
- Students work on research teams and share their findings with others.
- Students use a science notebook to record their observations, data, and conclusions.

Assessment: Students participate in discussions, write descriptions and observations, and draw illustrations.

Time: One class period per investigation (viewing only video segments recommended in each investigation)

Group Size: Entire class or pairs or small teams of students conduct investigations.

Materials and Preparation

Each student needs a science notebook before beginning investigations. Additional information is provided with each activity.

Procedure

1) Review Arthropod Investigations and Mollusc Investigations that follow, paying particular attention to the materials required and the time needed to obtain them.

2) Based on the activity or activities selected, all students should go through Exercise 1 in Arthropod Investigations and/or in Mollusc Investigations. This will give them the opportunity to get comfortable with their animal they are investigating, observe its physical structure and body plan, and get a general sense of how it will behave. After completing these general observations, proceed with one of the following steps with your students.

• Give students the opportunity to design an investigation of their own to explore some aspect of their critters. Have students prepare a simple proposal that they present to you for approval. The proposal need not be too elaborate, but should include a) the question being asked and b) the procedures the student will use. This gives you the opportunity to discuss how investigable the student's question is and the feasibility of the procedures. For older students, the proposal could also include specific data-taking techniques and a sample data table to be filled in.

• If you prefer more specific activities, offer your students the choice of one or several of the exercises described after the initial body plan observations (Exercise 1 referenced above).

3) In the spirit of inquiry, allow students the opportunity to develop questions of their own about the animals they are observing and their behavior. Talk with students about setting up investigations that test *only one variable*. For example, if they are investigating dry versus moist, they need to make sure that factors like light and temperature are kept constant. It is rather easy to overlook these other factors, setting up the experimental system with one end pointing toward a window or a radiator. Give students the freedom to repeat an investigation and determine for themselves what needs to be controlled. Remember that the students are asking questions and making observations. Since they will be reporting on those observations, they *cannot* be wrong. What they see *is* what they see. However, they may see what they *want* to see rather than what they *actually* see. That can be a great source of individual or classroom discussion.

4) The observation techniques described in all of the following activities are general in nature and will have to be modified according to the particular animals being studied. Flexibility and creativity are important attributes for all keen observers. In general, don't let the animals get too hot or too cold, too wet or too dry. Handle them gently and for short periods of time. Give them a "rest," and then handle them some more.

See www.shapeoflife.org for links to additional animal investigations.

Arthropod Investigations

Science Background

The segmentation and flow-through gut of the annelids opened the evolutionary door for an incredibly diverse group of organisms called arthropods. The term arthropod comes from the Greek *arthron* meaning "joint"(as in arthritis) and *podos* meaning "foot" (as in tripod). These organisms (crustaceans, like crabs and lobsters, spiders, insects, and a host of others) all have a hard outer covering called an *exoskeleton* made of *chitin* (5/11:50) with protein and sometimes minerals or wax. This exoskeleton provides protection from predators and the rigors of the physical environment (heat, cold, dryness, exposure to ultraviolet light, etc.) and a support structure for the attachment of the muscle system. But in order for this exoskeleton to move, it must have lots of flexible joints. And so it does. In the investigations outlined below, students will look at many examples of this *jointedness*.

During the evolution of arthropods, jointed appendages that sprouted from segments all along their bodies were modified for many new uses. There are good old legs for walking, but there are also: mouth parts for manipulating food, antennae for sensing the environment, claws for grasping, and perhaps most wonderful of all, wings for flying (5/14:00 and 5/20:30). Arthropods evolved a set of adaptations that made it possible for them to leave the marine environment and invade dry land and ultimately even get up into the air. As a result, there are more different kinds of arthropods on Earth than all other organisms put together!

Materials and Preparation

In the investigations below, students make close observations of a particular arthropod. A list of some good classroom candidates include:

Insects

- Milkweed bugs, *Oncopeltus faciatus*, can be purchased from most reputable biological supply houses. They can be purchased in various life cycle stages or as a culture kit. They are harmless, rather nice-looking, and they won't fly away.
- Mealworms (the larvae of *Tenebrio* beetles) are another possibility. Their segments are clearly seen and could be compared to the segments of annelids. Of course, they can also be used as food for other organisms. They can be purchased from pet stores and bait shops as well as biological supply houses.

Crustaceans

- Hermit crabs, fiddler crabs, crayfish, or pill bugs (sow bugs, roly-polys, 5/26:30) can be purchased or can be rather easily collected, depending upon where you live.
- Dead crabs, shrimp, and lobsters can be purchased in grocery stores.

Arachnids

- Spiders, scorpions, ticks, and mites are not so good for classroom investigations because they tend to bite or sting.
- A display tarantula is a possibility.

Millipedes and centipedes

- Millipedes are harmless vegetarians (detritus feeders), but a bit expensive. In some habitats, they occur in very large numbers at certain times of year. If you have an outbreak of millipedes, take advantage and bring some into class.

- Centipedes, like most arachnids, are not so good for classroom use. They are fast-moving carnivores (insectivores), and they may bite.

You will need various containers, tools, and other implements to house these critters and to manipulate them a bit. Exactly which containers and tools will depend on which critters you chose. Following is a general list that might be helpful. If you buy organisms from a biological supply company, the company may also suggest and sell appropriate equipment.

- aquarium/terrarium with cover to prevent escape
- water
- shoebox or shoebox lid or clear plastic box and lid
- vinegar
- hand lenses
- pencil
- straws (for gusts of "wind")
- paper towels
- otton swabs
- science notebook
- ruler

Procedures

The following exercises are designed to be read aloud to your students. Answer guidelines are provided in brackets. *The Shape of Life* video references are noted as (episode number/minute: second).

Exercise I

What is the body plan and structure of your organism?

1) Put your critter in a convenient container so that it is easy to watch but so that it cannot escape. A shoebox lid may be just the thing. Carefully look at its body plan and structure. Draw and label the organism in your science notebook. The following questions may help you decide what to put in your notebook:

a) Dogs and cats have heads and tails and legs attached to their central bodies. Does your organism have similar structures?

[Insect bodies have three major divisions, tagmata, which are groups of segments: head, thorax, and abdomen. Crustaceans are similar, though in some cases the head and thorax are fused together into a cephalothorax. Arachnids have a cephalothorax and an abdomen.]

b) What do you see at the front end? Is there a head? Are there eyes? A nose? A mouth? Ears? Are there other sensory organs? Are there other appendages on the head?

c) If you looked at earthworms, you may remember seeing lots of body segments. Does your critter have body segments? If so, do all the segments look the same?

[The segments in centipedes and millipedes look a lot like those in earthworms. The segmentation in other arthropods is not always so obvious, though the segments can often be seen on their abdomens.]

d) How about legs? Count them. Watch them. Listen to them as your critter walks about. Feel them as your critter walks on your hand (if it is safe to do this). What do the legs look like? Can you describe how the legs move with respect to one another? How many legs do mammals have? Is this true for *all* mammals?

[The word *arthropod* means "jointed foot," or more loosely translated, "jointed leg." All of these critters have appendages with lots of joints. Insects have three pairs of legs (six all together). Arachnids have four pairs (eight all together). Crustaceans are variable, and it depends on what you call a leg. For example, there are walking legs and there are claws. Centipedes do not have 100 legs, and millipedes do not have a thousand. But the former do have *one pair* of legs per body segment, while the latter have *two pairs* of legs per body segment. The overall effect is that they sure do have lots of legs! Mammals all have four legs, though we sometimes refer to the front ones as *arms*. In the case of bats, the front ones are called *wings*!]

e) Crab legs (or even whole crabs) may be available at your local grocery store. Since arthropods have hard exoskeletons, their joint movements are constrained in ways that are different from those of mammals like humans. Examine a whole leg, noting in particular the amount and angles of bending of the various joints. Now examine your own leg. Here are some questions that might guide you in writing descriptions in your science notebook:

i) How many joints are there in a crab leg?

ii) How many joints are there in a human leg?

iii) How are the joints in your leg different from the joints in your fingers?

iv) What sort of freedom of movement do you have with your leg? (Think of the agility of a soccer player.)

v) Can the crab get its legs into the same positions?

vi) Consider the "arthropod robots" you saw in "The Conquerors" about arthropods (5/43:00).

f) How about wings (5/37:15)? If your organism has them, where are they? How many?

[The only arthropods with wings are insects. They usually have *two pairs* of wings attached to their thoraxes. But the pairs are not always obvious. For example, in beetles, one pair of wings (the *elytra*) is hard and covers the second pair of wings that are used for flight. Flies have one pair of flight wings and a second pair, called *halteres*, that are used as stabilizers.]

Bats are mammals that have wings. How many legs do bats have? Given your real life experiences in seeing mammals, do you think that a winged horse (the Pegasus of Greek mythology) could have evolved?

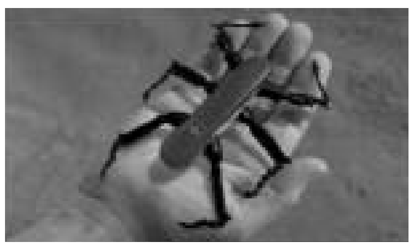
[Since all mammals have evolved from a *tetrapod* (four-footed) ancestor (8/19:20), it seems that for a horse to evolve with wings it could then only have hind legs, like a bat.]

g) Crayfish, crabs, shrimps, and lobsters live in water and have gills for breathing. If you have specimens of these critters, look for the gills as branches near the tops of their walking legs.

[Aquatic larvae of dragonflies also breathe with gills located in their rectums.]

h) How about claws, pincers, or stingers? Where are they? Are they the same size? Think about what they might be used for.

i) From your observations, you can see that arthropods have many more *appendages* than mammals. (See Swiss Army knife analogy, 5/20:30.) In fact, all those antennae, mouth parts, claws, and wings are really just modified legs! Do you think that's true for your nose, eyes, ears, jaws, and so forth?



2) In addition to your drawings, write a few sentences in your notebook describing what you have seen, heard, and felt—your general impressions. This information may be useful for answering some questions later on.

Exercise 2

Does your arthropod move toward dry or moist conditions?

1) Set up a shoebox lid with moist paper towels on one side and dry paper towels on the other side. Place several organisms in the middle of the box. At five-minute intervals, draw a map showing where each one is. Repeat these observations for one half-hour.

2) In your notebook, write a few sentences describing what you saw and what you think it means.

3) Are you sure that differences in moisture account for the organisms' behavior? Write a few sentences to show how you could repeat the investigation to validate your conclusion.

[Students may inadvertently be exposing their organisms to factors other than moisture—e.g., bright light or heat or even the students themselves, moving around and making noise. They could repeat this experiment by reversing the wet and dry paper towels and seeing if the organisms go the other way.]

What characteristics do animals share?

All animals must eat to survive. They are comprised of multiple cells differentiated in shape and function and possessing nuclei. (Hence, all single-celled organisms like ameba or paramecium are *not* animals.) All animals can reproduce sexually with sperm and egg; some can also reproduce asexually. After the egg is fertilized, it divides into cells and tissues, undergoing a process known as embryogenesis. Lastly, *most* animals are capable of movement during some stage of their lives, using muscles and nerves to accomplish this feat.

Exercise 3

How long is your arthropod?

1) Measure the length of your organism in millimeters.

2) If you worked with earthworms previously, you may remember that measuring their lengths was not easy. Why is it easier to measure the length of an arthropod?

   [Arthropods have *rigid exoskeletons* while worms are flexible bags whose body fluid forms the skeleton—a *hydroskeleton* as opposed to an *exoskeleton*.]

3) When you are done, compare your results with those of another student group. Did they use the same techniques? If not, whose techniques seem to work better?

Exercise 4

How do arthropods respond to touch?

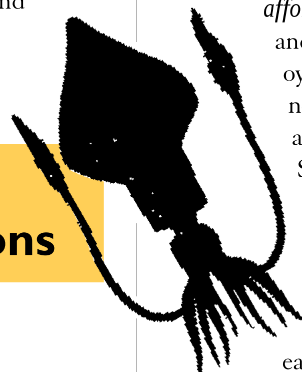
1) *Gently* touch your critter with the tip of your pencil. Use a straw to blow on your arthropod.

2) In your science notebook, record its reaction to each stimulus. Are all body parts equally sensitive? Write a few sentences describing any differences you see.

Wrap-up

The investigations above should help students explore the basic arthropod body plan and some of the behavior patterns these organisms exhibit. The possibilities for further explorations of the enormous diversity of arthropods are endless. Their segmentation, jointed appendages, and exoskeletons have allowed for an incredible evolutionary radiation. Though we, as humans, tend to think of ourselves as holding some exalted place in the hierarchy of animals, the arthropods have evolved into species that can inhabit the hottest, the coldest, the wettest, the driest, the highest and the lowest places on the surface of the Earth. Though no one species may dominate, as a whole, arthropods surely do win the numbers and diversity game.

Mollusc Investigations



Science Background

Molluscs have evolved with a remarkable diversity of different body plans. At first glance, it is difficult to see how clams and octopuses can be classified into the same phylum. However, they do share certain physical characteristics (6/6:30). All molluscs have a muscular *foot* generally used for locomotion. They all have a *radula*, a mouth-part generally used in feeding. And all molluscs have a layer of tissue called the *mantle* that usually secretes the shell. The wonderful thing about molluscs, however, is that these structures vary so widely throughout the phylum. The foot, for example, is used for gliding locomotion in snails and digging in clams, but has evolved into a jet-propulsion organ in squids and octopuses. The mantle produces the spiral shells of snails, the double shells of clams, the chambered shells of nautiloids, and the internal 'pens' of squids.

Most molluscs show characteristics similar to the other phyla explored in earlier episodes of *The Shape of Life*. For example, they have a front end with a head (except in bivalves, such as clams). They have a flow-through gut with a mouth and an anus. The exercises outlined below start with an exploration of the mollusc body plan, using snails as a convenient organism. This exploration is followed by several investigations looking at various aspects of molluscan structure and behavior.

Materials and Preparation

Probably the most interesting, *affordable* molluscs are snails and slugs. Bivalves (clams, oysters, mussels) simply will not do anything exciting in a classroom situation. Squids and octopuses are truly fascinating creatures, but are expensive and difficult to maintain. For most classrooms, snails and slugs are the easiest to get and maintain. Both snails and slugs are readily available from biological supply companies. They can also often be found in gardens and yards or under logs in most any woodland in warm weather. We suggest using terrestrial (land) snails since they are relatively active and easy to maintain in a terrarium. You can set up a simple terrarium using an empty aquarium with a lid, a water source, and lots of lettuce. Rotting sticks and leaves add a nice touch. Pond snails can be kept in an aquarium with water, and as everyone who keeps aquarium fish knows, the snails can reproduce rapidly.

You should supply several snails for each group of students. They will need one good-sized snail for close observation and several others for more general observations. This exercise is written for snails, so if you use slugs, simply make the appropriate changes. Materials for each group should include:

- snail, 1 large for close observation clear plastic cups
- snails, several (various sizes if possible)
- shoebox lid
- hand lenses
- cardboard
- cotton swabs
- straws (for gusts of "wind")
- ruler
- string
- tape
- vinegar
- paper clips
- paper towels
- markers
- science notebook

Procedures

The following exercises are designed to be read aloud to your students. Answer guidelines are provided in brackets. *The Shape of Life* video references are noted as (episode number/minute: second).

Exercise I

What is the body plan and structure of a snail?

1) Put a snail in a clear plastic cup and observe its body plan and structure. Draw and label the snail in your science notebook. The following questions may help you decide what to put in your notebook:

a) Can you tell which end is the front?

[Snails have fleshy, antenna-like structures on their front ends.]

b) The snail's shell has a spiral structure. How many turns of the spiral does your snail have? Compare several snails of different sizes.

c) Humans have a face with eyes, ears, a nose, and a mouth. Do snails have any of these structures?

2) Closely observe the foot of your snail as it moves over the surface of the plastic cup. Observe it from underneath the snail, but also try to get a side view. What do you see? Draw a sketch in your science notebook and also describe in a few sentences what you have seen.

3) Can you see the tracks of your snail? If so, describe your evidence in your notebook.

[Since snails secrete a film of mucus as they move, students should see this "slime trail" as evidence of where the snail has been.]

Exercise 2

Do snails move toward moist or dry conditions?

1) Set up a shoebox lid with moist paper towels on one side and dry paper towels on the other side. Place several snails in the middle of the box. At five-minute intervals, draw a map showing where each snail is. Repeat these observations for one-half hour.

2) In your notebook, write a few sentences describing what you saw and what you think it means.

3) Are you sure that differences in moisture account for the snails' behavior? Write a few sentences to show how you could repeat the investigation to validate your conclusion.

[Students may inadvertently be exposing their snails to factors other than moisture—e.g., bright light or heat or even the students themselves, moving around and making noise. They could repeat this experiment by reversing the wet and dry paper towels and seeing if the snails go the other way.]

Exercise 3

How do snails respond to touch?

1) *Gently* touch the snail in various places (including the shell) with the tip of your pencil.

2) How about wind? Use a straw to blow gently on your snail and record its response.

3) In your science notebook, record its reaction to each touch. Are all body parts equally sensitive? Do the different parts respond with different or similar reactions? Write a few sentences describing any differences you see.

Exercise 4

Can snails smell?

Smell and taste are defined differently. In *smell*, the chemicals that are being sensed must pass from the source to the sensor through some medium—usually air or water. In *taste*, the chemicals must come in direct contact with the sense organ. In this exercise, we suggest testing smell by holding vinegar *close to*, but *not touching* the snail. Vinegar might well damage the snail if applied directly.

1) Place a snail on a moist paper towel. Dip a cotton swab into vinegar. Hold the tip of the swab *close* to the snail's front end, but *do not touch* it. If the vinegar touches the snail, you may be testing a different sense (taste, or perhaps even pain). Record how the snail responds to the vinegar.

2) Do all parts of the snail's body have the same response? Record your data in your science notebook.

3) Do snails have a nose? What is a nose anyway? What do you use your nose for? If you were a snail, would a nose (an appendage with nostrils) help or hinder you?

4) Do snails breathe? If so, where is the air intake? If not, how do they get oxygen to their muscles? Or can they live without oxygen?

   [Snails "breathe" through their skin. This is one reason land snails maintain a moist layer of mucus covering their bodies. (Frogs also breathe through their moist skin.) This makes it possible for them to exchange oxygen and carbon dioxide with the surrounding air more readily.]

   [Slugs and snails have very functional lungs. In slugs, these lungs can be seen through their opening to the outside world called the *pneumostome*— the big gaping hole on their "saddles" on their right sides. The pneumostome is harder to see in snails. Blowing carbon dioxide (CO_2) simply by exhaling through a straw into the pneumostome will make the slug/snail need more oxygen (O_2), causing it to open the hole wider.]

Exercise 5

How much weight can a snail pull?

1) Attach a piece of tape like a sled to the backside of the snail's shell. How many paper clips can your snail pull?

2) Compare your results with your classmates' results. What can you conclude from these data? Are you sure the snail reached its limit? Or might it have stopped pulling for some other reason? What might that reason be? Write your conclusions in your science notebook.

Wrap-up

Snails are slow and relatively easy to work with, making them a useful organism for classroom work. But they are only one example of the twists and turns the molluscan body plan has taken during its evolution. For example, snails and clams use shells for protection, while squids use speed and octopuses use their remarkable intelligence. Thus, they are a wonderful group of organisms to study for exploring the "arms race" (6/4:30) between predator and prey. Molluscs are also interesting in the puzzle they provide for taxonomists. They show some of the characteristics seen in other phyla explored in *The Shape of Life* series—a front and back end, a head, muscles and nerves, and a circulatory system. On the other hand, they have their own peculiar adaptations—a foot, a radula, and a mantle. They are, in fact, a good example of why the evolutionary *tree* might better be described as an evolutionary *bush*! (See illustration on page 18).

Electron micrograph of gastropod radula

Recommended Reading for Grades 3-7

Annelid Investigations

McLaughlin, Molly. *Earthworms, Dirt and Rotten Leaves*, Atheneum, 1986.
Ross, Michael Elsohn. *Wormology*, Carolrhoda Books, 1996.

Arthropod Investigations

Ross, Michael Elsohn. *Caterpillarology*, Carolrhoda Books, 1997.
Ross, Michael Elsohn. *Ladybugology*, Carolrhoda Books, 1997.
Ross, Michael Elsohn. *Rolypolyology*, Carolrhoda Books, 1996.
Ross, Michael Elsohn. *Spiderology*, Carolrhoda Books, 2000.

Mollusc Investigations

Ross, Michael Elsohn. *Snailology*, Carolrhoda Books, 1996.

Chordate Investigations

Johnson, Jinny. *Skeleton: An Inside Look At Animals*, Reader's Digest Kids, 1994.

Activity Seven

Be a Scientist

Episode Title: Any and all episodes; "Explosion of Life" (Annelids) most exemplary

Activity Subject: Science careers and science process

Grade Level: 6-12

National Science Education Standards:
Standards are noted as (standard:benchmarks).

Grades 6-8

Earth and Space Sciences	(1:4), (2:2,7,8)
Life Sciences	(4:1,2,3,5), (5:3,4,5,6), (6:2,3,4,5), (7:1,2,3,4,5)
Nature of Science	(12:2,7,8), (13:1,2,3)

Grades 9-12

Earth and Space Sciences	(1:4), (2:5)
Life Sciences	(5:5), (6:1,2,5), (7:2,4,6,7)
Nature of Science	(11:1,2,3), (12:1,6,7), (13:2,5,6)

Learning Objectives:
- Students assume the role of a Functional Morphologist, Paleontologist, Taxonomist, or Ecologist and become contributing members of a scientific team.
- Students view *The Shape of Life* from the perspective of their scientific role.
- Students take notes according to their scientific discipline.
- Students share what they learn with their research team.
- Each scientific team shares with the class their observations on the phylum and discusses how the different fields of inquiry provide different pieces of information.

Assessment: Students complete individual worksheets, report to their scientific team, and contribute to class discussion.

Time: One hour to view a single episode ("Explosion of Life") or to view chosen sequences from several episodes; one to two additional class periods for team meetings and discussion

Group Size: Groups of four students working in teams

Materials and Preparation

Preview *The Shape of Life* series and select sequences highlighting the scientists and their study subjects in each hour for use in this exercise (see "Science Careers" and "Science Process" in "Video Time Code Index"). Alternatively, the teacher may prefer to have the students perform this exercise using a single episode. For this approach, we recommend Episode 4, "Explosion of Life," due to its rich assemblage of scientists pursuing their various interests. Copy student worksheets for each team member. The questions listed represent the types of questions a scientist or team of scientists of that specialization would explore.

Procedure

1) Divide class into research teams of four scientists, including a Functional Morphologist, Paleontologist, Taxonomist, and Ecologist and distribute the student worksheets (one for each scientific discipline per team).

2) Describe the primary focus of each specified scientific discipline, using descriptions provided in "Cool Science Careers." (Copy and distribute this page to students, if desired.) Have students obtain additional information from library and Internet research, if desired. All listed careers are subsets of Biology. An excellent web resource is found at: http://www.sicb.org/careers/index.php3 (the SICB web site).

3) Let students within the group decide who will be the Functional Morphologist, Paleontologist, Taxonomist, and Ecologist.

4) Have students view either one episode (Episode 4: "Explosion of Life") or several sequences chosen from one or more of *The Shape of Life* episodes (see "Materials and Preparations"). Have students take notes on the worksheet for their scientific profession.

5) Have each research team of the four different scientists meet and share their observations of each phylum. Additionally, you can form teams of all of the functional morphologists, all of the paleontologists, all of the taxonomists, and all of the ecologists to compare their notes and develop a class report on both the phylum observations they documented and their scientific professions.

Cool Science Careers

Functional Morphologists

John (Jack) Costello, Ph.D., Providence College (Appears in Episode Two)

A functional morphologist studies the relationship between form and function in the natural world. For example, a functional morphologist might ask questions like: How do fish use their muscles to swim? How do lizards use their lungs to breathe? How do snails use their radula to graze for food? Functional morphologists investigate how organisms use their anatomy to perform life functions and interact with their environment. Biomechanics is a sub-division within functional morphology that employs principles from engineering to investigate everything from the physiology and mechanics of whole organisms to the basic materials from which they are constructed.

Paleontologists

Geerat Vermeij, Ph.D., University of California, Davis (Appears in Episode Six)

Paleontologists study the history of life on Earth. Much of a paleontologist's work involves searching for and identifying fossils. Fossils are the remains or traces of organisms (plants, animals, fungi, bacteria, and other single-celled living things) that lived in the geological past and are preserved in Earth's crust. Using fossils, paleontologists piece together evolutionary patterns and structures and decipher how life has changed over time in relation to the environment. There are many subdivisions of paleontology, including vertebrate and invertebrate paleontology, micropaleontology (studying fossils of single-celled organisms), paleobotany (studying plant fossils), and taphonomy (studying how fossils are made).

Taxonomists

Cristina Diaz, Ph.D., University of California, Santa Cruz (Appears in Episode One)

Taxonomists are biologists concerned with the naming and classifying of the diverse forms of life on Earth. Through collections, dissections, and detailed observations, these scientists decipher relationships between and within species. Recently, new tools, like genetic sequencing, are helping taxonomists decipher some of life's most hidden secrets and interrelationships. Taxonomy has become increasingly important as scientists attempt to create a unified catalogue of Earth's many species. To date, over a million-and-a-half species have been described, and estimated tens of millions are still to be named. Compiling an accurate and complete catalog of life is fundamental to many tasks, such as understanding the impact of invasive species and developing worldwide conservation strategies.

Ecologists

Jennifer A. Clack, Ph.D., Cambridge University (Appears in Episode Eight)

Ecologists study how organisms live and interact with other organisms and with their environment. For example, an ecologist might study how the burrowing of worms affects nutrient cycling in a mudflat or how weather patterns and climate changes influence the structure and composition of whole ecosystems. There are numerous subdivisions in ecology, including behavioral ecology and paleoecology. A behavioral ecologist might study what role jellyfish play in the open ocean food web. A paleoecologist like Dr. Clack, above, might study ancient ecosystems by looking at fossils, tree rings, ice cores, or coral cross-sections to decipher Earth's climate and the assemblage of organisms present at a specific time in the past. The study of ecology is becoming increasingly important as scientists continue to reveal the impact of human-induced changes on specific ecosystems and the global environment.

To Be a Scientist

Scientists are often thought of as men in laboratories, wearing white coats and glasses. What were the scientists like in *The Shape of Life*? What kind of work did they do and where did they do it? Would you want to be a scientist? If so, what field of science would you choose? What education does it take to become that type of scientist?

The Shape of Life
Functional Morphologist Viewing Guide

Name ___________________________

Period ___________________________

Phylum	
What is the defining body plan of animals in this phylum?	
How do animals in this phylum move? What type of support system do they have?	
How do animals in this phylum eat? What type of digestive system do they have?	
How do animals in this phylum sense their surroundings? What type of nervous system do they have?	
How do animals in this phylum reproduce?	

Name ____________________________

The Shape of Life
Paleontologist Viewing Guide

Period ____________________________

Phylum	
What types of fossils were found representing this phylum?	
Where/when were the fossils found?	
What events/processes might have preserved the fossils?	
How do the fossils compare to animals of this phylum on Earth today?	
What do these fossils tell us about the evolution of this phylum of animals?	

The Shape of Life
Taxonomist Viewing Guide

Name ___________________________

Period ___________________________

Phylum	
How many species are in this phylum?	
What is the body plan of animals in this phylum?	
What species from this phylum are discussed in the episode?	
What specialized adaptations make the species unique?	
What characteristics distinguish this phylum from other phyla?	

The Shape of Life
Ecologist Viewing Guide

Name ___________________________

Period ___________________________

Phylum	
In which habitats are species from this phylum found?	
What are the conditions of the habitats?	
What adaptations do species of animals within the phylum have for survival in their habitats?	
What are some possible food chains/food webs for animals in this phylum?	
How are materials cycled in these habitats?	

Video Time Code Index

Time Code Key: episode:minute:second:frame number
Set VCR counter to "0" at the first frame of video.
Remember that VCR counter accuracy will vary, and not all VCRs indicate frame numbers.

Episode One: "Origins" (Phylum Porifera)

Body Plans:

Canals and chambers (fly-through)	01:30:00:25 – 01:33:04:01
Sponge variety	01:18:22:28 – 01:19:42:21
Finger sponge	01:19:53:01 – 01:20:11:23

Body Parts:

Spicules	01:25:51:16 – 01:27:44:20
Canals and chambers (fly-through)	01:30:00:25 – 01:33:04:01

Feeding:

Predation	01:36:55:16 – 01:37:41:26
Feeding and dye	01:27:43:01 – 01:31:05:01
Feeding animation	01:31:06:00 – 01:33:04:03

Habitats/Communities:

Dropoff (vase) sponge	01:16:51:25 – 01:18:23:03
Animation and variety on reef	01:18:23:02 – 01:20:11:23
Symbionts on sponge	01:34:20:04 – 01:36:55:16

Paleontology/Evolution:

Fossil record	01:38:02:04 – 01:38:42:27
Flagellates	01:13:31:11 – 01:14:02:22
Run time backwards	01:49:20:13 – 01:52:30:01

Life Cycle/Reproduction:

Spawning and fertilization	01:33:04:23 – 01:34:20:06

Anatomy/Zoology:

Tube sponge and globe sponge collecting	01:22:30:15 – 01:23:35:04
Canals and chambers (fly-through)	01:30:00:25 – 01:33:04:01

Science Process:

Cristina Diaz, Ph.D.	
Collecting sponge samples with Mark Erdmann, Ph.D.	01:20:51:02 – 01:24:54:13
Watching sponges feed	01:27:43:15 – 01:30:57:11
Mitchell L. Sogin	
Extracting DNA from sponges	01:39:49:08 – 01:49:20:12

Science Careers:

Cristina Diaz, Ph.D.	
Taxonomist free-diving in Indonesia	01:07:12:12 – 01:12:03:14
Search for first animal	01:13:02:25 – 01:15:12:25
Diving for first animal	01:15:12:25 – 01:18:22:29
Sponge structure, collagen, spicules	01:24:54:13 – 01:27:43:16
Mitchell L. Sogin	
In search of the basal animal	01:38:45:14 – 01:39:51:09

Episode Two: "Life on the Move" (Phylum Cnidaria)

Body Plans:

Nerve, muscle, movement	02:08:04:15 – 02:12:52:18
Colonialism/coral reef	02:20:50:00 – 02:22:34:28
Polyp becomes medusa	02:30:20:00 – 02:32:30:01

Body Parts:

Cilia in anemone mouth	02:10:46:02 – 02:11:24:10

Feeding:

Nematocysts	02:16:42:29 – 02:17:20:10
Nematocyst discharge	02:19:23:24 – 02:19:35:20
Hydra feeding	02:05:52:06 – 02:08:03:11
Food capture	02:13:48:25 – 02:16:42:00

Locomotion:

Origin of animal locomotion	02:04:33:00 – 02:05:49:23
Sea star flight response	02:24:03:12 – 02:26:25:24
Jelly movements	02:32:01:03 – 02:37:28:00
Jelly movements and water flow	02:39:16:17 – 02:41:18:23
Other jelly movement	02:41:22:21 – 02:42:32:26
Deep water jellies	02:47:20:20 – 02:50:51:04

Defense:

Colobonema decoy tactic	02:45:33:13 – 02:45:57:21
Anemone war for space	02:17:19:23 – 02:20:07:25

Habitats/Communities:

Deep sea jellies/MBARI	02:42:34:13 – 02:50:51:06
Coral reef	02:20:50:00 – 02:22:34:28
New deepwater species	02:48:43:28 – 02:50:05:25

Paleontology/Evolution:

History, Trembley, Hydra	02:05:17:17 – 02:08:03:08
Sponge to cnidaria	02:08:30:00 – 02:10:39:00
Two body forms of cnidaria	02:30:20:00 – 02:32:30:01

Life Cycle/Reproduction:

Spawning corals	02:22:35:10 – 02:23:26:21
Moon jelly reproduction	02:33:42:00 – 02:37:28:10

Anatomy/Zoology:

New deepwater species	02:48:43:28 – 02:50:05:25

Science Process:

John (Jack) Costello, Ph.D.	
Motion of moon jelly	02:37:29:04 – 02:42:14:00
Ian Lawn, Ph.D.	
Motivation for research	02:23:42:25 – 02:24:02:28
Investigating anemone nerves	02:26:02:06 – 02:28:41:08

Science Careers:

John (Jack) Costello, Ph.D.

Movement	02:02:00:04 – 02:02:46:02
Roots of animal movement	02:03:37:13 – 02:05:39:11
Animal motion revolution	02:08:04:14 – 02:08:28:19
Beautiful system	02:12:33:07 – 02:12:52:16
Diving for moon jellies	02:32:31:14 – 02:33:40:04

Ian Lawn,Ph.D.

Movement on rocky coast	02:12:52:18 – 02:14:00:21
What nerves did for animals	02:28:44:05 – 02:30:22:13

Bruce Robison,Ph.D.

Finding new species	02:42:34:29 – 02:50:51:12

Episode Three:"The First Hunter" (Phylum Platyhelminthes)

Body Plans:

Flatworm animation	03:08:57:15 – 03:10:05:16
Bilateral symmetry	03:10:22:02 – 03:11:16:00

Body Parts:

Nervous system and muscles	03:22:55:03 – 03:24:30:17

Feeding:

First hunter	03:11:42:24 – 03:12:17:03
Hunting	03:25:12:04 – 03:29:46:10

Habitats/Communities:

Scotland terrestrial flatworm	03:20:08:16 – 03:21:36:10
Parasites	03:29:33:18 – 03:32:17:12

Paleontology/Evolution:

Flatworm-like animal fossil tracks	03:04:35:18 – 03:09:13:00
Bilateral symmetry	03:10:22:02 – 03:11:16:00
20,000 species	03:12:17:28 – 03:13:38:18
Planarians	03:22:19:29 – 03:22:58:07
Humans and flatworms	03:42:45:27 – 03:43:23:09
Genetic blueprint and Hox genes	03:42:45:00 – 03:49:13:28

Life Cycle/Reproduction:

Reproduction	03:32:54:08 – 03:42:04:11

Anatomy/Zoology:

Tapeworms	03:29:33:18 – 03:32:17:12

Genetics:

Genetic blueprint and Hox genes	03:42:45:00 – 03:49:13:28
Similar genes in different organisms	03:49:13:06 – 03:49:49:11

Science Process:

Hugh Jones,Ph.D.

Worm detective	03:16:05:09 – 03:18:37:21
Hunting the hunter	03:18:37:21 – 03:22:10:05

Matthew Scott,Ph.D.

Genetic similarities	03:43:08:26 – 03:52:29:23

Science Careers:

Whitey Hagadorn,Ph.D.

On the trail of the first hunter	03:01:59:27 – 03:05:20:11
Intriguing fossil traces	03:06:45:07 – 03:09:12:20

Leslie Newman,Ph.D.

Finding new flatworms	03:33:40:25 – 03:37:29:01

Matthew Scott,Ph.D.

Genetic similarities	03:43:08:26 – 03:52:29:23

Episode Four:"Explosion of Life" (Phylum Annelida)

Body Plans:

Cambrian Explosion	04:09:31:17 – 04:12:18:07
Pikaia and body plans	04:19:32:12 – 04:21:34:17
Annelid diversity	04:25:43:29 – 04:32:20:07
Annelid body plan/burrowing	04:40:58:06 – 04:43:53:12

Body Parts:

Hydrothermal vent *Vestiminiferans*	04:28:38:28 – 04:29:58:14
Sabellid in sand	04:29:58:13 – 04:30:31:23
Eudistylia	04:30:33:01 – 04:31:00:10
Terebellid feeding and gills	04:31:01:19 – 04:32:20:07

Behavior:

Evolution of behavior	04:21:29:05 – 04:22:08:03

Feeding:

Hydrothermal vent *Vestiminiferans*	04:28:38:28 – 04:29:58:14
Sabellid in sand	04:29:58:13 – 04:30:31:23
Eudistylia	04:30:33:01 – 04:31:00:10
Terebellid feeding and gills	04:31:01:19 – 04:32:20:07
Diopatra	04:36:43:28 – 04:38:31:14
Leeches	04:32:20:06 – 04:35:03:22

Locomotion:

Cambrian Explosion animation	04:09:31:17 – 04:12:18:07

Defense:

Eudistylia eyes	04:30:33:01 – 04:31:00:10

Habitats/Communities:

Annelid diversity	04:25:43:29 – 04:32:20:07
Commensalism (sea star)	04:27:35:26 – 04:28:38:28
Hydrothermal vent *Vestiminiferans*	04:28:38:28 – 04:29:58:14
Sabellid in sand	04:29:58:13 – 04:30:31:23
Eudistylia	04:30:33:01 – 04:31:00:10
Terebellid feeding and gills	04:31:01:19 – 04:32:20:07
Diopatra	04:36:43:28 – 04:38:31:14

Paleontology/Evolution:

Burgess Shale	04:03:57:25 – 04:05:34:19
Anomalocaris	04:06:20:23 – 04:09:33:23
Annelids and climate	04:43:54:16 – 04:50:07:20
Cause of Cambrian Explosion	04:13:38:22 – 04:17:43:13
Aysheaia	04:17:43:12 – 04:18:32:21
Ctenophores	04:18:32:22 – 04:19:32:11

Pikaia and body plans	04:19:32:12 – 04:21:34:17
Evolution of behavior	04:21:29:05 – 04:22:08:03
Cambrian Explosion (wrap-up)	04:50:07:18 – 04:52:30:03

Life Cycle/Reproduction:

Leeches	04:32:20:06 – 04:35:03:22

Science Process:

Desmond Collins,Ph.D.	
Fossil puzzle pieces	04:05:34:18 – 04:09:22:22
Damhnait McHugh.Ph.D.	
Digging up marine worms	04:35:39:01 – 04:40:15:00
Common earthworms	04:45:47:07 – 04:47:17:10

Science Careers:

Terry Chase	
Creating animals for museums	04:12:21:03 – 04:14:33:29
Desmond Collins,Ph.D.	
The Burgess Shale	04:02:00:07 – 04:05:34:19
Damhnait McHugh.Ph.D.	
Worm watching	04:22:56:01 – 04:27:35:28
Rudy Raff,Ph.D.	
Exploring animal evolution	04:12:21:03 – 04:14:33:29

Episode Five:"The Conquerors" (Phylum Arthropoda)

Body Plans:

Joints, appendages,exoskeleton	05:09:01:24 – 05:10:23:09
Body plan and diversity	05:10:23:04 – 05:11:33:22
Appendage skeleton	05:11:33:22 – 05:12:14:10
Molting	05:12:14:05 – 05:13:34:23
Damselfly metamorphosis	05:34:02:16 – 05:35:02:00
Flight	05:35:01:29 – 05:36:09:16
Insect diversity	05:39:17:23 – 05:40:21:25
Arthropod montage (variety)	05:50:13:11 – 05:50:44:17

Body Parts:

Joints, appendages,exoskeleton	05:09:01:24 – 05:10:23:09
Appendage skeleton	05:11:33:22 – 05:12:14:10
Appendages animation	05:20:36:16 – 05:21:17:02
Gills and respiration	05:27:24:06 – 05:28:32:05
Spiracles and trachea	05:28:32:04 – 05:29:29:16

Feeding:

Feeding	05:13:34:26 – 05:15:15:21
Detritivores and carnivores	05:29:30:22 – 05:31:26:17
Dragonfly larva	05:31:46:06 – 05:34:02:18
Adult damselfly	05:34:02:16 – 05:35:02:00
Spider webs	05:38:21:13 – 05:39:17:22
Pollination	05:40:26:25 – 05:41:11:18

Locomotion:

Appendage skeleton	05:11:33:22 – 05:12:14:10
Appendages animation	05:20:36:16 – 05:21:17:02
Invention of flight	05:37:04:14 – 05:38:20:06
Locomotion,control,skeleton	05:43:19:26 – 05:45:47:22
Arthropod robot	05:46:56:09 – 05:50:13:01

Paleontology/Evolution:

Fossil evidence and invasion of land	05:04:26:19 – 05:05:52:27
Eurypterids	05:15:46:28 – 05:17:02:16
Transition to land	05:19:19:28 – 05:20:37:01
Algal scum,sea/land bridge	05:21:51:06 – 05:26:02:16
Isopod land invader	05:26:01:11 – 05:26:59:04
Horseshoe crab	05:17:02:16 – 05:19:22:11
Arthropod tracks	05:08:33:24 – 05:09:01:29
Gills and respiration	05:27:24:06 – 05:28:32:05
Detritivores and carnivores	05:29:30:22 – 05:31:26:17
Freshwater invasion	05:31:27:12 – 05:32:04:00
Emergence of flight	05:37:04:15 – 05:38:20:06
Insect diversity	05:39:17:23 – 05:40:21:25
Pollination	05:40:26:25 – 05:41:11:18

Science Process:

Simon James Braddy, Ph.D.	
Finding fossil trackways	05:03:14:22 – 05:07:44:07
Robert Full,Ph.D.	
Brainless walkers	05:43:19:20 – 05:45:47:22

Science Careers:

Simon James Braddy, Ph.D.	
Finding fossil trackways	05:03:14:22 – 05:07:44:07
Robert Full,Ph.D.	
Brainless walkers	05:43:19:20 – 05:45:47:22
William Shear, Ph.D.	
The first land animals	05:19:22:08 – 05:23:44:28
Micro-fossils	05:23:44:28 – 05:26:01:16
Mark W.Tilden,Ph.D.	
Arthropod robots	05:45:48:24 – 05:46:35:28
Ed Williams	
Robotic "crab"	05:46:37:26 – 05:50:13:03

Episode Six:"Survival Game" (Phylum Mollusca)

Body Plans:

Molluscan arms race	06:04:39:08 – 06:05:52:03
Loligo (squid) and market squid	06:36:09:04 – 06:38:25:16
Octopus	06:40:22:11 – 06:50:21:10

Body Parts:

Abalone body parts	06:06:28:00 – 06:07:58:17
Abalone foot	06:17:47:18 – 06:20:44:26
Cockle and moon snail foot fight	06:21:01:23 – 06:23:35:15
Abalone radula and electron micrographs	06:23:35:15 – 06:24:45:19
Loligo (squid) and market squid	06:36:09:04 – 06:38:25:16

Behavior:

Abalone outrunning enemies	06:17:47:18 – 06:20:44:26

Feeding:

Moon snail and cockle	06:21:01:23 – 06:23:35:15
Abalone radula and electron micrographs	06:23:35:15 – 06:24:45:19
Octopus intelligence	06:40:22:11 – 06:50:21:10

Locomotion:

Abalone foot	06:17:47:18 – 06:20:44:26
Moon snail and cockle	06:21:01:23 – 06:23:35:15
Cephalopod swimming	06:24:45:20 – 06:32:34:03
Nautilus in nature	06:34:28:23 – 06:35:39:05
Loligo (squid) and market squid	06:36:09:04 – 06:38:25:16
Octopus	06:40:22:11 – 06:50:21:10

Defense:

Shell breaking (*Calliostoma*)	06:10:53:14 – 06:11:59:09
Shells and defense;growth	06:11:59:10 – 06:17:16:13
Abalone outrunning enemies	06:17:47:18 – 06:20:44:26
Moon snail and cockle	06:21:01:23 – 06:23:35:15
Squid ink	06:38:03:05 – 06:38:25:16
Octopus intelligence	06:40:22:11 – 06:50:21:10

Habitats/Communities:

Abalone foot	06:17:47:18 – 06:20:44:26
Market squid	06:36:09:04 – 06:38:25:16
Deepsea squids	06:38:03:14 – 06:39:34:19
Octopus	06:40:22:11 – 06:50:21:10
Moon snail and cockle	06:21:01:23 – 06:23:35:15

Anatomy/Zoology:

Loligo (squid) and market squid	06:36:09:04 – 06:38:25:16
Octopus chromatophore animation	06:47:12:20 – 06:47:58:27

Science Process:

Geerat Vermeij,Ph.D.	
Mollusc armor	06:09:04:27 – 06:17:16:13
Peter D.Ward,Ph.D.	
Capturing Nautilus	06:25:11:26 – 06:28:32:14
Diving to Nautilus	06:32:32:25 – 06:35:38:14
Crissy Huffard,M.S.	
Wily octopus	06:39:50:09 – 06:49:10:24

Science Careers:

Geerat Vermeij,Ph.D.	
Getting a feel for molluscs	06:03:40:26 – 06:05:51:23
Discovering molluscs as a child	06:07:26:23 – 06:09:04:27
Peter D.Ward,Ph.D.	
Capturing Nautilus	06:25:11:26 – 06:28:32:14
Crissy Huffard,M.S.	
Importance of fieldwork	06:39:50:09 – 06:49:10:24

Episode Seven:"Ultimate Animal" (Phylum Echinodermata)

Body Plans:

Echinoderm montage	07:12:14:29 – 07:12:54:03
Sea cucumber and pencil urchin	07:08:37:28 – 07:08:52:25
Urchin,sea cucumber, reef urchin	07:09:25:00 – 07:09:44:24
Symmetry, star to urchin to cucumber	07:09:45:10 – 07:11:01:19
Ophiuroids (brittle stars)	07:19:38:02 – 07:21:46:00
Crinoids	07:48:18:11 – 07:49:24:09

Body Parts:

Internal anatomy, skeleton,nerves	07:11:06:21 – 07:12:16:02
Urchin feeding,tube feet,jaws,spines	07:13:20:21 – 07:16:41:10
Asteroid spines,gills,pedicellariae (pincers)	07:31:49:05 – 07:32:13:24
Sensory tube feet and eyespots	07:33:33:29 – 07:34:30:08
Asteroid predation on mussels	07:34:37:00 – 07:39:20:23
Pedicellariae (pincers)	07:43:58:21 – 07:44:54:26

Behavior:

Bat star time-lapse	07:27:41:26 – 07:29:57:26
Sea star locomotion,asteroid tube feet and water vascular system	07:31:38:03 – 07:33:45:26

Feeding:

Urchin grazing and creating barrens,tube feet and jaws	07:13:20:21 – 07:16:41:10
Sea cucumber feeding and locomotion	07:16:43:23 – 07:18:08:23
Ophiuroids (brittle stars) feeding	07:19:38:02 – 07:21:46:00
Asteroid predation on mussels	07:34:37:00 – 07:44:01:01
Pedicellariae (pincers)	07:43:58:21 – 07:44:54:26

Locomotion:

Urchin grazing and creating barrens,tube feet and jaws	07:13:20:21 – 07:16:41:10
Ophiuroid (brittle star) locomotion	07:19:38:02 – 07:21:46:00
Sea star locomotion,asteroid tube feet and water vascular system	07:31:38:03 – 07:33:45:26
Asteroids seeking prey	07:39:04:15 – 07:44:01:01
Crinoid swimming	07:51:13:05 – 07:51:16:15

Defense:

Sea cucumber defense	07:18:11:01 – 07:19:36:05
Pedicellariae (pincers)	07:43:58:21 – 07:44:54:26
Urchin grazing and spines	07:13:20:21 – 07:16:41:10

Habitats/Communities:

Sea cucumber and pencil urchin	07:08:37:28 – 07:08:52:25
Urchin,cucumber, urchin on reef	07:09:25:00 – 07:09:44:24
Urchin grazing and creating barrens	07:13:20:21 – 07:16:41:10
Ophiuroid (brittle star) locomotion	07:19:38:02 – 07:21:46:00
Asteroid predation on pilings	07:34:37:00 – 07:39:20:23

Paleontology/Evolution:

Symmetry, star to urchin to cucumber	07:09:45:10 – 07:11:01:19
Early evolution, fossils,radial symmetry	07:44:56:15 – 07:50:10:10
Echinoderm radiation	07:49:25:22 – 07:50:39:18
Evolution statement,collage, survival	07:50:39:29 – 07:52:30:02

Anatomy/Zoology:

Symmetry, star to urchin to cucumber	07:09:45:10 – 07:11:01:19
Internal anatomy, skeleton,nerves	07:11:06:21 – 07:12:16:02

Science Process:

Charles H.Baxter	
Echinoderm research	07:29:59:10 – 07:31:37:26
John Pearse, Ph.D.	
"Stars" of the silver screen	07:27:32:18 – 07:29:57:09
Andrew Smith,Ph.D.	
Following a different path	07:45:10:21 – 07:50:38:27
Don Wobber, M.S.	
Time-lapse filming of starfish	07:25:52:04 – 07:27:35:17
"Stars" of the silver screen	07:27:32:18 – 07:29:57:09

Science Careers:

Charles H.Baxter	
Echinoderm research	07:29:59:10 – 07:31:37:26
Gail Kaaialii,Ph.D.	
Diving for echinoderms	07:06:01:24 – 07:09:44:24
John Pearse, Ph.D.	
Echinoderm research	07:22:51:29 – 07:24:41:03
"Stars" of the silver screen	07:27:32:18 – 07:29:57:09
Andrew Smith,Ph.D.	
Following a different path	07:45:10:21 – 07:50:38:27
Don Wobber, M.S.	
Love of the ocean	07:24:41:25 – 07:25:52:06
"Stars" of the silver screen	07:27:32:18 – 07:29:57:09

Episode Eight:"Bones,Brains and Brawn" (Phylum Chordata)

Body Plans:

Amphioxus and vertebral column	08:08:47:00 – 08:09:51:12
Jaws and fish diversity	08:14:12:03 – 08:15:56:10
Tunicate diversity, feeding, evolution	08:15:57:13 – 08:18:23:14
Salps	08:16:32:00 – 08:17:08:00
Larvacean	08:17:08:02 – 08:17:43:20
Fish invasion of land	08:18:24:13 – 08:22:34:14
Snakes	08:28:58:18 – 08:31:04:22
Pikaia	08:08:01:19 – 08:08:46:19

Body Parts:

Amphioxus	08:05:19:22 – 08:06:31:21
Fish invasion of land	08:18:24:13 – 08:22:34:14

Feeding:

Jaws and fish diversity	08:14:12:03 – 08:15:56:10
Tunicate diversity, feeding, evolution	08:15:57:13 – 08:18:23:14
First land vertebrates	08:27:05:08 – 08:28:50:29
Snakes	08:28:58:18 – 08:31:04:22
Anaconda	08:31:15:25 – 08:32:53:08

Locomotion:

First land vertebrates	08:27:05:08 – 08:28:50:29

Habitats/Communities:

Amphioxus	08:05:19:22 – 08:06:31:21
First land vertebrates	08:27:05:08 – 08:28:50:29
Snakes	08:28:58:18 – 08:31:04:22
Anaconda	08:31:15:25 – 08:32:53:08
Animal diversity	08:50:26:03 – 08:52:59:25

Paleontology/Evolution:

Pikaia	08:08:01:19 – 08:08:46:19
Amphioxus and vertebral column	08:08:47:00 – 08:09:51:12
Amphioxus development	08:11:10:21 – 08:12:29:29
Jaws and fish diversity	08:14:12:03 – 08:15:56:10
Tunicate diversity, feeding, evolution	08:15:57:13 – 08:18:23:14
Fish invasion of land	08:18:24:13 – 08:22:34:14
Invasion animation	08:25:50:15 – 08:26:34:22
First land vertebrates	08:27:05:08 – 08:28:50:29
Snakes	08:28:58:18 – 08:31:04:22
Dinosaur evolution	08:35:39:27 – 08:43:01:12
First mammals	08:43:01:11 – 08:46:16:06
Play	08:45:50:05 – 08:47:21:19
Human evolution	08:47:20:25 – 08:52:59:26
Animal diversity	08:50:26:03 – 08:52:59:25

Life Cycle/Reproduction:

First land vertebrates	08:27:05:08 – 08:28:50:29

Anatomy/Zoology:

Amphioxus	08:05:19:22 – 08:06:31:21
Pikaia	08:08:01:19 – 08:08:46:19
Amphioxus and vertebral column	08:08:47:00 – 08:09:51:12
Amphioxus development	08:11:10:21 – 08:12:29:29
Fish invasion of land	08:18:24:13 – 08:22:34:14
First land vertebrates	08:27:05:08 – 08:28:50:29
Snakes	08:28:58:18 – 08:31:04:22

Genetics:

Amphioxus development	08:11:10:21 – 08:12:29:29
Large vertebrates	08:12:37:28 – 08:14:11:04

Science Process:

Jennifer A.Clack,Ph.D.	
"Boris" the tetrapod	08:18:51.04 – 08:23:01.05
Early chordate footprints	08:23:01.00 – 08:26:34.21
Linda Z.Holland,M.A.	
Amphioxus ancestors	08:04:39.17 – 08:08:35.03
Amphioxus ancestors' genetics	08:09:51.09 – 08:12:30.05
Kristi Curry Rogers,Ph.D.	
Dinosaur bones	08:38:53.12 – 08:42:19.16

Science Careers:

Ray Bandar	
Skulls and bones,teacher	08:33:10.06 – 08:35:38.22
Jennifer A.Clack,Ph.D.	
Joy of paleontology	08:18:51.04 – 08:23:01.05
Linda Z.Holland,M.A.	
Amphioxus ancestors	08:04:39.17 – 08:08:35.03
Kristi Curry Rogers,Ph.D.	
Dinosaur hunter	08:36:21.25 – 08:38:53.23

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