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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Make Your Own Paper Fossils

A computer animation and paper models

By

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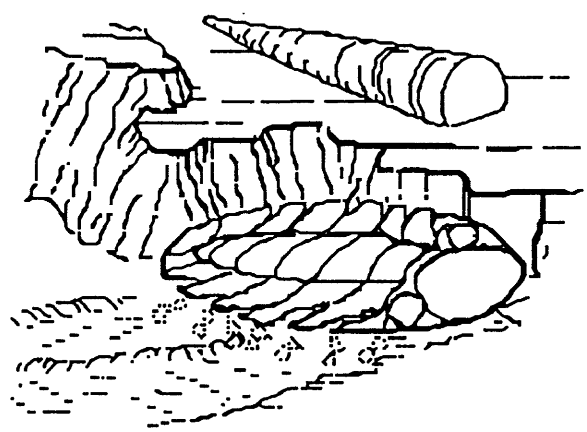
Open -file Report 94-667



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Description of Report

This report illustrates, by means of computer animations and paper models, how two organisms, a trilobite and a nautiloid, became fossils. The report is intended to help students and others visualize the size and shape of a trilobite and a nautiloid, the environment in which they lived, and the circumstances of their fossilization and subsequent discovery. By studying the animations and the paper models, students will come to understand why fossils are important in interpreting the Earth's history.

Included in the diskette version of this report are templates for making the paper models, and instructions for their assembly, a discussion of fossils, and animations of trilobite and nautiloid locomotion and habitats.

The animation is accompanied by sound. If no sound is heard, change the memory of HyperCard, to 4500K, and ensure that the control panel "Sound", which is in the "Control Panels" folder under the "Apple" menu, has the volume set to at least 2. To change the memory available to HyperCard quit this stack. Highlight the HyperCard, program icon and choose "Get Info" from the File Menu. Change the "memory requirements" to 4500K and start this stack again. The paper version of this report includes everything listed above except for the animations.

Many people provided help and encouragement in the development of this HyperCard stack, particularly Dan Jensen, Art Ford, and Lisa Baserga. This report was enhanced by the excellent reviews by Ron Le Compte, Will Elder, and Jim Pinkerton.

Description of Report

Requirements for the diskette version are: Apple Computer, Inc., HyperCard 2.2™ software and an Apple Macintosh™ computer with a high-density drive. If you are using System 7, we recommend using at least 3 MB of RAM with 4500K of memory available for HyperCard. To change the memory available to HyperCard, quit this stack. Highlight the HyperCard program icon and choose "Get Info" from the File Menu. Change the "memory requirements" to 4500K and start this stack again.

Purchasers of the diskette version of this report, which includes all of the text and graphics, can use HyperCard 2.2™ software (not supplied) to change the model (by adding geologic patterns, symbols, colors, etc.) or to transfer the model to other graphics software packages.

To see the entire page (card size: MacPaint), select "Scroll" from the"Go" menu and move the hand pointer in the scroll window. If you are experiencing trouble with user-level buttons, select "message" from the "Go" menu. Type "magic" in the message box and press return. Three more user-level buttons should appear.

The date of this Open File Report is 11/28/1994. OF 94-667-A, paper copy, 42p.; OF 94-667-B, 3.5-in. Macintosh 1.4-MB high-density diskette.

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LEARN ABOUT FOSSILS

The first evidence of human interest in fossils dates back at least 15,000 years. Scientists have found a layer of dirt in a cave in France that, along with artifacts of human occupation, contains a number of trilobite fossils with holes drilled into them. These trilobite fossils may have been worn as jewelry and were probably obtained through trade with other groups of people from far away, because no similar fossils have been found anywhere else in France. In the Western United States, the Ute Indians collected fossilized specimens of the trilobite *Elrathia* (commonly used today as refrigerator magnets) with which they made fetishes or charms. The Utes called the fossil trilobites "*timpe khanitza pachavee,*" which in their language means "little water bug like stone house in" (Boardman and others, 1987). The Aborigines of Australia used trilobite–bearing flint as tools. In Europe, Asia, and South America, trilobite fossils were often made into jewelry. Today, they are probably the most commonly sought–after fossils by amateur fossil collectors around the world.

What is a Fossil?

When you find a fossil you have found something that is interesting but also something that represents a piece of the Earth's history. Fossils are a window into the life of the past. A fossil is any evidence (bodily remains or trace) of a plant or animal that has been preserved in Earth's crust since some past geologic age. More loosely defined, a fosssil is any evidence of past life. The structure of the fossil can tell you about where it might have lived (if you found a fossil of a fish, you would probably guess that it didn't live on land) or what it ate (if you found a fossil crab, you would probably guess that it didn't eat rabbits). Sometimes you don't find an actual fossil (sometimes called a body fossil), but you find evidence of how an organism behaved (trace fossils). Trace fossils include things like worm trails and dinosaur footprints.

The rock in which a fossil is found can also tell you something about the environment in which the fossilized organism lived. Trilobite fossils are usually found in fine–grained rocks that were once mud. Because the mud did not contain sand or pebbles, we believe that it was probably deposited in a quiet place, like the bottom of the ocean. Over a long period of time, the gooey mud turned into stone.

The Making of a Fossil

Around the world, from the bottom of the ocean to high mountain lakes, you can find evidence of living organisms and their activities. But how much of this evidence of life will survive beyond today to become the fossils of tomorrow? It has been suggested that of the more than one million living animal species, somewhat fewer than 10 percent will be preserved as fossils. The preservation of a fossil is a rare event; when you look at the fossil record as a whole, it is incomplete, and individual fossil species are probably either over or under represented, even under the best conditions.

The likelihood of preservation of an organism (body fossil) or the preservation of the evidence of its activities (trace fossils) depends on several factors. These include (1) what the organism was made of, (2) how many of the organisms there were, (3) what type of environment the organisms lived in or, even more important, what type of environment they died in, and (4) what happened to them after they were buried.

The key to the preservation of a an organism as a fossil is its resistance to destruction. In general, organisms are made up of two kinds of parts, soft parts and hard parts. Soft parts decay rapidly after death, and there is little fossil evidence of organisms that were made up entirely of soft tissue (that is why trace fossils are usually the only record of earthworms or slugs). On the other hand, bones, teeth, shells, and the like are hard parts and not subject to decay after death. Once the hard parts get buried, they may eventually form a body fossil.

Another factor in fossilization is luck. Everything else being equal, the greater the number of individual plants or animals there are, the greater the likelihood that some of those organisms will be preserved as fossils.

A description of the environment in which an organism lived and (or) died includes such factors as sediment type (sand or mud), how fast the sediment was deposited, and how much energy (currents, storm waves, etc.) there was stirring up the sediments, as well as where the organism lived (in the sediment, on top of the sediment, or swimming around above the sediment). Some sedimentary environments have a better chance of being preserved than others. This, in turn, influences the chances of fossilization of the organisms that live in those environments.

The final factor in fossil preservation is what happens to the organism after it is buried. Sometimes the shell of the organism is dissolved away, leaving a mold or impression of the shell. These molds may be then filled with fine-grained sediment (usually clay) at a later time, forming what is called a cast. If the shell is not totally dissolved over a long period of time, minerals in the ground water moving through pores in the rock can replace the original shell or bone material with other minerals.

When one considers all of the things that can adversely affect the fossilization process, it is no surprise that the fossil record is so poor. Remember that such spectacular fossil finds as insects in amber, *Archeopteryx* (what most scientists consider the earliest bird), and complete dinosaurs are extremely rare and represent only a glimpse into the variety of life that existed in the Earth's past.

Trilobites

For many million years during the Paleozoic Era, trilobites were one of the most common organisms that lived on or in mud on the shallow sea floor Some of the smallest trilobites, rather than living on the sea floor like most of their larger relatives, probably swam or floated in surface waters. Today, trilobite fossils can be found (as magnets) on refrigerators around the world, holding up shopping lists or a child's work of art.

Trilobites were a part of a larger group of organisms called arthropods, a name which means "jointed foot". Living members of this group include crabs, lobsters, spiders, and, of course, insects. The importance of this group is its large number of individual animals and exceptional diversity (large number of species). The number of species of living insects is thought to be somewhere between one and two million. Although the actual diversity of easily fossilized arthropods is much lower than this number, the remains of these organisms still make up a substantial part of the fossil record.

Arthropods (usually trilobites) are important to geologists for two main reasons. First, the structure (or shape) of their bodies changed (evolved) over time. Because each trilobite shape appears only for a short period of time, rocks (say from the United States and China) containing similarly shaped trilobites are thought to be of about the same age. Second, because changes in body shape are often related to changes in the environment, fossils can be used for reconstructing ancient environments.

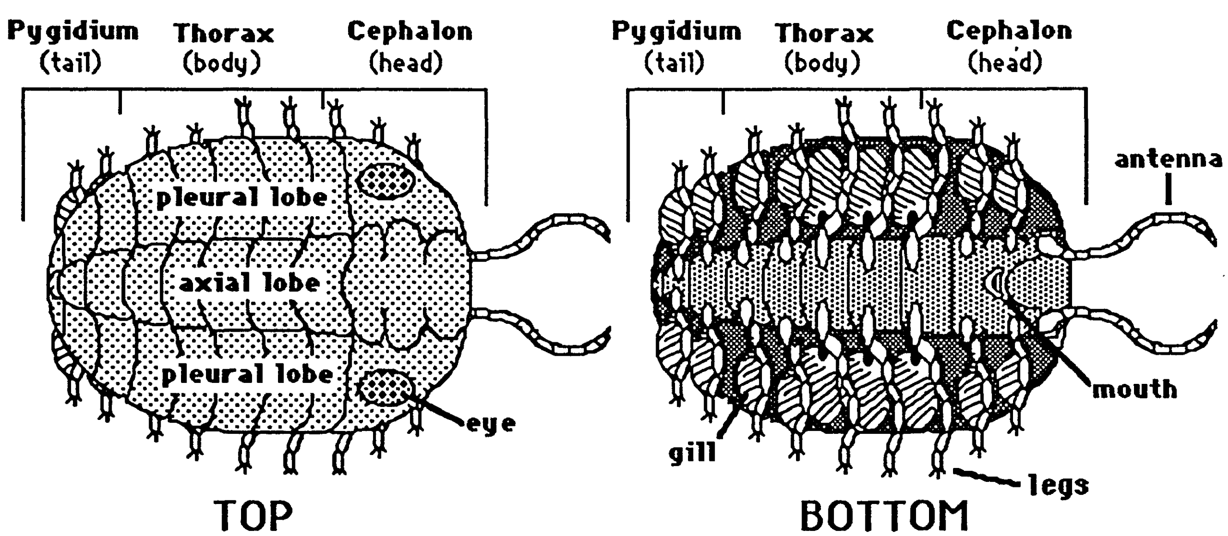
The available fossil record for the arthropods is strongly biased. This is because the external skeleton (or "shell") of the majority of arthropods (insects, spiders, most crabs, lobsters, and shrimp) is made up of a thin material that does not contain any minerals to make it hard. These "shells" do not fossilize very well. In a few groups, including trilobites, minerals are "built in" to the external skeleton, making it hard. These hard shells stand a much better chance of becoming fossils. A trilobite's chance of preservation was enhanced not only by its mineralized shell but also by the fact that trilobites shed their shells as they grew, similar to snakes shedding their skin. Therefore, there were several opportunities for every trilobite to be preserved as a fossil.

The trilobite gets its name from the fact that its body is divided into three segments, or lobes. The central lobe is called the axial lobe, and the right and left lobes are called the pleural lobes. They are called the pleural lobes because they protect the trilobite's breathing organs, the gills. The trilobite is also divided into three parts from front to back. The cephalon (head), contains sensory organs like the eyes, antenna, and the mouth. The thorax (body) contains the internal organs. Most of the legs and the gills are attached to the thorax. The third part is the pygidium (tail).

Each leg of the trilobite had two main parts. The longer part was used for walking. The shorter part, the gill, was attached to this "walking leg" near the point where the leg joins the body. In addition to being used for walking and breathing, the legs closest to the mouth may also have been used to help gather food and move it toward the mouth. Most trilobites probably fed on small fragments of plant and animal matter in the sediment. Some may have been scavengers, feeding off the carcasses of anything that settled to the sea floor. Others may have been predators, capturing small worms living in the sediment. A small number were planktonic (they floated near the surface of the ocean) and probably fed on bits of plant and animal material floating in the ocean waters.

Not much is known about the internal anatomy of trilobites. Because most of the internal parts were soft, they did not fossilize. Much of what we know about their anatomy and function is based on comparisons with modern arthropods, such as shrimp and lobsters.

As time passed in the Paleozoic sea, more predators threatened the trilobite. Available information suggests that the legs of the trilobite did not provide much speed or maneuverability to help escape from their enemies. In order to defend themselves, some trilobites rolled themselves into little balls, much like the armadillo does today.



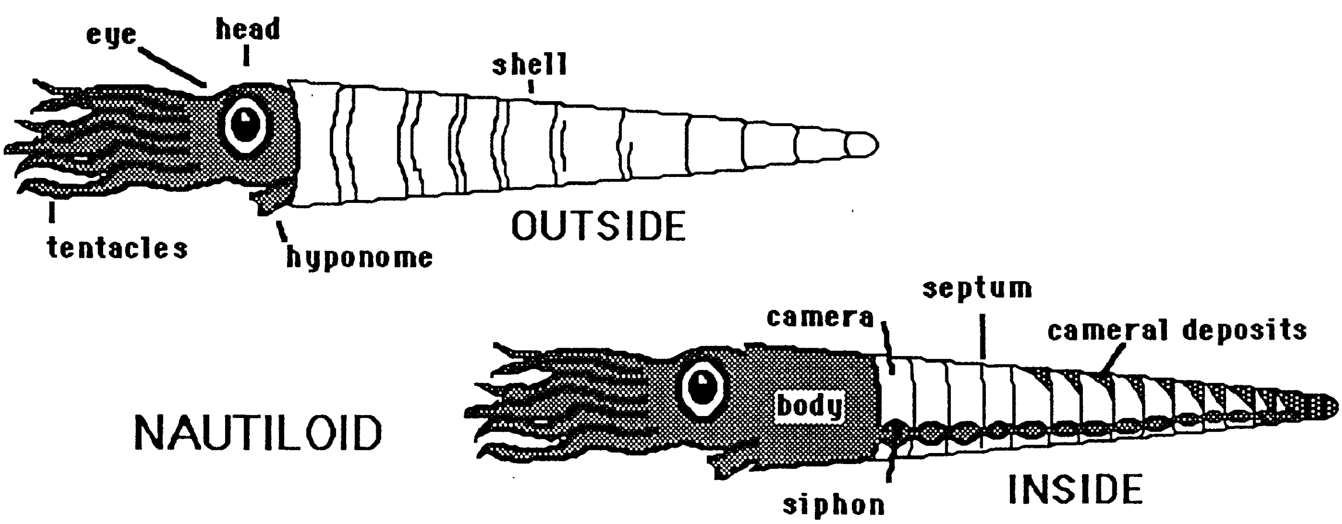
TRILOBITE

Nautiloids

Few who have read Jules Verne's "20,000 Leagues Under the Sea" will forget the giant squid that threatened to destroy Captain Nemo and the crew of the *Nautilus*. For millions of years, these giant denizens of the deep and their relatives have swum the ocean depths. The giant squid is part of a larger group, the cephalopods (a name which means "head foot"). Present-day members of this group include the octopus, cuttlefish, squid, and the beautiful chambered nautilus, which lives in the southwestern part of the Pacific Ocean. This group also included the now-extinct ammonite.

As a group, cephalopods are the largest, most intelligent, and most agile of the mollusks (a group that also includes clams, slugs, and snails). Some individuals can reach speeds of 70 kilometers per hour (42 miles per hour). The eyes of some cephalopods are similar to those found in vertebrates, such as fish, reptiles, and mammals.

Today, nautiloids are represented by five types of chambered nautilus. In nautiloids, the "foot" has been modified into a funnel or hyponome (used to produce a water jet for propulsion) and into as many as 94 tentacles. Unlike the octopus and squid, the chambered nautilus lacks an ink sac. It must rely on speed and its shell for protection from predators.



In the past, many types of cephalopods had shells covering the outsides of their bodies, but most of these shell-bearing types became extinct by the end of the Cretaceous Period. Today, only the nautiloids (unlike squids and most octopuses) have a shell covering the outsides of their bodies. (The females of one octopus type, called *Argonauta*, produce a paper-like shell in which they carry their eggs.) The shell is the most commonly fossilized part of the nautiloid. Many different shapes have been found in the fossil record, with the most common are long cones. As a nautiloid grows, the inside of the shell is divided into a series of camerae (chambers; a single chamber is called a camera) and the sizes of the camerae also increase. The chambers that over time became too small for the animal to live in are sealed off with a chamber wall or septum. The outside of the shell is usually smooth; sometimes the sutures, shallow groves which correspond to the location of a septum, are visible. The siphon runs through the interconnected chambers. The siphon allows the animal to regulate its buoyancy by controlling the amount of gas or liquid in each camera; thus, it is able to control its depth in the ocean by varying the amount of air in its shell, in much the same way that a submarine alternately dives and rises to the surface of the ocean. As its body continues to grow it is often necessary for the nautiloid to deposit shell material (cameral deposits) in some of the camerae in order to balance the weight of the increased body mass.

During the Paleozoic Era, most nautiloids and their relatives, the ammonites, were probably free-swimming marine predators or scavengers. They were probably not very choosy about what they ate, but trilobites probably were a part of their diets.

As is the case with the trilobites, nautiloids and their relatives were most common in the warm shallow oceans of the Paleozoic Era. Over the past 500 million years, most species of nautiloids became extinct (the last of the ammonites became extinct at the same time as the dinosaurs, that is, at the end of the Cretaceous Period).

One interesting characteristic of cephalopod evolution is a tendency toward gigantism. Tales of giant sea monsters date back to the epic poems of the ancient Greeks. There have been reports of giant squid (kraken) more than 22 meters (66 feet) long; giant octopi (devilfish) are known to exceed 25 meters (75 feet). The longest fossil straight cephalopod shell is about 10 meters (30 feet) (and that doesn't include the body and tentacles); the largest coiled ammonite fossil has a shell diameter of 3 meters (9 feet) [uncoiled, it would be more than 18 meters (59 feet) long].

Trace Fossils

The study of trace fossils is often jokingly called "fossil psychology," because the evidence that is studied represents the behavior of the organisms, not the organisms themselves. Trace fossils have several advantages over body fossils: (1) they are often preserved in rocks (like sandstone) where body fossils are not usually preserved, (2) the physical and chemical processes that often destroy the bodies of organisms after they die do not usually affect trace fossils, and (3) because trace fossils are formed on or within the sediment, they are found where the animals that made them actually lived. The main problem with using trace fossils is that is it difficult to make a direct connection between the body fossil and its associated trace fossil. The animation sequence in this report illustrates an extremely rare event, one where the trilobite "died in its tracks."

Trace fossils convey evidence of a number of different behaviors, including resting or hiding, locomotion (our trilobite), and dwelling and (or) feeding (within burrows and on the surface of the sea floor). Because we know that certain kinds of animals make specific traces in modern sediments, geologists can use this information in their interpretation of traces preserved in sediments formed in past environments.

Trace fossils can also tell us about the history of life. The oldest trace fossils are almost 2 billion years older than the oldest body fossils. It is interesting to note that although thousands of species of animals have come and gone over the past 570 million years, the number of kinds of trace fossils has not changed much. This indicates that animal behavior (feeding, moving, and resting) has not changed much over time even though the types of organisms have.

Sedimentary Environments

Fossilized evidence of life can be found around the world. The evidence ranges from enormous dinosaur fossils found in ancient stream channels and swamps to the tiny skeletons of single–celled plants and animals that once lived in the surface waters of the oceans. Trilobites and nautiloids fall somewhere between these two size extremes.

In the section entitled "The Making of a Fossil," the requirements for fossil formation are briefly discussed. A discussion of all the possible sedimentary environments that contain fossils is beyond the scope of this guide, so we will restrict our present discussion to the sedimentary depositional environment with which our the trilobite and nautiloid in our animation are associated.

The floor of the deep ocean is a dark and relatively quiet place. Most of the sediment (including the bodies of animals) "rains" down from the waters above. This "rain" of sediment is usually very gentle. Once the sediment reaches the sea floor, most of it remains where it lies. In some places, nonstop deep-ocean currents continually remove the finest grained sediment. This process is very slow [millimeters (a fraction of an inch) per year in some places]. This little–changing "rain" of sediment is an illustration of one of the basic principles of geology, the "Principle of Uniformitarianism."

In the accompanying animation, we have also illustrated the opposite extreme in sedimentary deposition, the rare catastrophic event. In the blink of an eye, a catastrophic "event" can deposit several meters (feet) of sediment.

"Uniformitarian" sedimentary deposition (a gentle "rain" of sediment) is a process that can take tens to hundreds of years to bury the body of an organism (in this case, a nautiloid). The trilobite was less fortunate, however, as it was buried alive by a catastrophic depositional event (called a turbidity current). The "geologically instantaneous" nature of this event covered the trilobite with so much sediment that Paleozoic scavengers (among them other trilobites and nautiloids) were unable to feed on its body. That is why the body of the trilobite was fossilized in one piece.

After the trilobite and nautiloid were buried, sediment continued to "rain" down over them for millions of years. As time passed, the increasing thickness of the sediment caused the ocean to become shallower. As the depth to the bottom of the sea floor became shallower, the composition of the sediments that was being deposited there changed. In deep water, the sediment consisted mostly of mud, whereas in shallow water it contained more sand. As the thickness of the sediment layers increased, so did their total weight. This great increase in weight helped to cause the mud and sand that once covered the sea floor to turn into solid rock.

Millions of years and thousands of meters (feet) of sediment later, dry land is formed over the site were the trilobite and nautiloid were buried.

Erosion

Once sediment and rocks are exposed at the Earth's surface, they are subject to the process of erosion. Wind and moving water (rain, streams, and rivers) are the main elements of erosion. Human activities sometimes work to speed up the erosion process.

Wind blows loose sediment from place to place. Sometimes, when that sediment is blown against rocks, bits of the rock are chipped off and carried away by the wind (the process is similar to sandblasting old paint off of a house).

Water works in much the same way as does the wind. Rain washes sediment into streams and then into rivers. These rivers dump most of their sediment into the ocean.

In a matter of hundreds or thousands of years, erosion can remove layers of sediment that took millions of years to form. Humans can accomplish the same thing in a local area in hours or days.

Geologic Time

The length of time (or magnitude of time) in Earth history is one of the most difficult concepts to teach.

Around 600 B.C., Greek naturalists observed that shells on mountain tops a great distance inland were similar to those found living along the seashore. They also noted evidence that the sea had once covered part of the Island of Malta. They reasoned that the sea had once been present where the shells were found and that the position of the shoreline was constantly changing.

Leonardo da Vinci noted sea shells in the mountains of northern Italy. He reasoned that these rocks had once been mud at the bottom of the sea. He also suggested that the differences between the shells he found in the mountains and those he found on the beaches of Italy were due to the process of fossilization.

THE GEOLOGIC TIME SCALE

Eras	Periods	Millions of years ago
Cenozoic (Recent life)	Quaternary	1.6
	Tertiary	66.4
Mesozoic (Middle life)	Cretaceous	144
	Jurassic	208
	Triassic	245
Paleozoic (Ancient life)	Permian	286
	Pennsylvanian	320
	Mississippian	360
	Devonian	408
	Silurian	438
	Ordovician	505
	Cambrian	570
Precambrian		

(The Earth is over 4 billion years old.)

Ironically, the Roman occupation of Great Britain from the first century B.C. to the fourth century A.D. offered a clue to the age of the Earth. Near the end of the eighteenth century, members of the Royal Society of Edinburgh were thinking about the age of the Earth. They reasoned that since Hadrian's Wall (a structure that crosses northern Great Britain) was less than 1,000 years old and showed few signs of deterioration, the age of the Earth must be much greater than a few thousand years.

The early nineteenth century was a time of great cultural activity in England. The population was growing rapidly, and the Industrial Revolution was getting underway. The least expensive means for transporting goods from city to city was by horse–drawn barge. To do this, an elaborate system of canals had to be constructed. During the construction of these canals, the engineers began to notice that certain collections of fossils (called assemblages) were found in a certain order (for example, assemblage A was always found below assemblage B, no matter where the two assemblages were found).

Building on the ideas that older rocks were always overlain by younger rocks (Law of Superposition) and that less complex organisms were usually followed by more complex organisms (Faunal Succession), geologists and naturalists began to assign relative ages to the rocks. These geologists and naturalists found that it was possible to apply these fossil relationships around the world.

Throughout the nineteenth and early twentieth centuries an increasing number of naturalists and geologists, working all over the world, continued to refine this series of relative ages into a time scale. They found that as they refined the time scale, there were regional variations in the fossil successions (fossil successions in England did not always match those in North America). However, on the whole, the larger divisions of the time scale could be applied all over the world. Most of the divisions of the time scale are named for rocks that are found in Europe. Two of the divisions (Mississippian and Pennsylvanian Periods) were named for rocks that are present in the United States. In the middle of the twentieth century, analysis of radioactive elements that occur naturally in some rocks was used to give actual ages (in years) to the rocks, resulting in an absolute time scale.

What's in it for me?

Fossils have many uses other than holding grocery lists on refrigerator doors. Geologists and paleontologists (a person who studies the history of life) use fossils to guide their search for oil and minerals. Oil is the product of the remains of thousands of ancient organisms, and fossils can be used to date the rocks where oil first formed and where it accumulates. Knowing the ages of the rocks and their distribution helps scientists decide where to drill for oil. Using fossils to date rocks located on both sides of a fault (a break in the Earth's surface along which there has been movement) can help geologists tell how long ago and how much a fault has moved. The "Theory of Evolution" is based in part on fossil evidence, and fossils can tell a lot about what life was like in the past. Archeologists use fossils to determine what kinds of food ancient people ate and what kinds of animals they raised. It's interesting to study trilobites because they are one of the most numerous animals ever to populate the Earth. Last, but not least, FOSSILS ARE FUN!!!

Questions for further study

1. What organisms do you think might one day become fossils? Give reasons why.

2. Make a list of different environments (deep ocean, beach, river, and mountain top) and discuss whether or not fossils could form in each of these environments.

3. Can fossils be found on the top of a mountain, on the beach, or at the bottom of the ocean?

4. Which environments do you think have the best chance of preserving fossils. Give some reasons why?

5. Do you have a favorite fossil? Why is it your favorite?

6. What are some of the ways that fossils are formed?

7. Does your State have a State Fossil?

8. What part have fossils played in the development of the Theory of Evolution?

9. Is there a place near your home or school where fossils can be found?

10. Is there a place near your home or school where you can go to see fossils?

11. Why were trilobites so successful? Think about why their relatives, the insects, are so successful today.

12. Why do you think that trilobites and nautiloids are often found in one piece, whereas dinosaur skeletons are found scattered and with various pieces missing?

Glossary

Ammonite—A coiled cephalopod similar to a nautiloid. The name is derived from Ammon, an ancient Egyptian god. Since Ammon considered the ram (male sheep) to be divine, he is represented in ancient Egyptian mythology by the head of a ram, with twisted, spiral horns similar in shape to an ammonite shell.

Archeologist—A person who studies the physical evidence of the history of Man. This often includes studing ancient ruins in exotic places, including under the sea.

Cambrian—The earliest Period of the Paleozoic Era. It is thought to have spanned the period of time from about 570 to 505 million years ago. Derived from the word "Cambria", the Roman word for Wales, in the southwestern part of Great Britain.

Cenozoic—The youngest Era, extending from the beginning of the Tertiary Period (about 66.4 million years ago) to the present. Paleontologically, it is characterized by the rapid evolution and abundance of mammals, mollusks, and birds. The terms "Recent Life" and "Age of Mammals" are sometimes used to refer to this Era.

Cretaceous—The youngest Period of the Mesozoic Era. Thought to have spanned the time interval from about 144 to 66.4 million years ago. The last Period during which the dinosaurs existed. The term "Cretaceous" comes from "Creta", the Latin word for chalk, which is common in the sea cliffs of northeastern Great Britain ("white cliffs of Dover," if you're old enough to remember the hit song from the Second World War).

Denizen—An inhabitant of a particular place. In this case, we are referring to the giant squid, octopuses, and other "monsters" that inhabit the deep, dark parts of the World's oceans.

Glossary Cont.

Devonian—A Period in the Paleozoic Era thought to have spanned the time interval from 408 to 360 million years ago. Named for the county of Devonshire, England where rocks of this age were first studied. Often referred to as the "Age of Fishes."

Era—The largest (for our purposes) division of time. Each Era includes at least two Periods (for example, Cretaceous, Devonian), the next smallest division of geologic time.

Faunal Succession—The idea that certain groups or assemblages of organisms precede or succeed each other. The members of the younger assemblage are usually more advanced (or complicated) than members of the older assemblage (for example, fish preceded dogs in the fossil record).

Fossil—Any evidence of bodily remains or the trace of a plant or animal that has been preserved in the Earth's crust since some past geologic age. More loosely defined, a fossil is any evidence of past life.

Jurassic—Middle Period of the Mesozoic Era. Spanned the interval of time from about 208 to 144 million years ago. It is named for the Jura Mountains, which are present in France and Switzerland.

Law of Superposition—The law upon which the geologic time scale is based. It states that in any sequence (stack) of sedimentary rocks or strata (that has not been structurally modified, for example, overturned), the oldest rocks or sediments are present on the bottom.

Mesozoic—The Era of geologic time that occurs between the Paleozoic Era and the Cenozoic Era. It is also called the "Age of Reptiles."

Mississippian—A Period in the Paleozoic Era that is thought to have covered the span of time from 360 to 320 million years ago. It is named after the Mississippi River valley, where there are extensive exposures of rocks of this age.

Ordovician—The second oldest Period of the Paleozoic Era, spanning the time from 505 to 438 million years ago. It is named after the British Celtic tribe, the Ordovices. Because a large number of different kinds of organisms evolved in the shallow seas of the Ordovician, it is often called the "Age of Marine Invertebrates."

Organism—Any individual form of organic life, plant, or animal.

Paleontologist—A person who studies the history of life. This usually does not include the study of Man (see Archaeologist). Paleontologists usually study fossils in one of four major groups—invertebrates (trilobites, nautiloids), vertebrates (dinosaurs), plants, or micro-organisms (diatoms, foraminifers).

Paleozoic—The geologic Era that occurs between the Precambrian Era and the Mesozoic Era. Also referred to as the Era of "Ancient Life."

Pennsylvanian—A Period in the later part of the Paleozoic Era, spanning the interval from 320 to 286 million years ago. It is named after the State of Pennsylvania, where many of the of rocks of this age contain layers of coal. Because the coal is from the deposits of fern forests and swamps, this Period is often referred to as the "Age of Coal."

Period—The intermediate interval in the hierarchy of geologic time between an Era (longer) and an Epoch (shorter).

Permian—The oldest Period of the Paleozoic Era, spanning the time interval from 286 to 245 million years ago. It is named after the Perm region of the Commonwealth of Independent States (the former U.S.S.R.). It is also called the "Age of Amphibians" because of the large number of skeletons of amphibians that have been found in swamp deposits of this age.

Precambrian—All geologic time before the Paleozoic Era. Rocks of this age generally carry no signs of multicellular forms of life. Spans the interval from 570 million years ago to the formation of the Earth, about 4.6 billion years ago.

Preservation—The process by which the remains of an organism are saved.

Principle of Uniformitarianism—One of guiding principles of geology. Geologic processes and natural laws operate in the same way today as they have in the past (gravity has always existed, and its strength has not changed through time). The classic statement of this concept is "the present is the key to the past."

Quaternary—The last Period of the Cenozoic Era. Ranges in age from about 1.65 million years ago to the present day. Sometimes referred to as the "Age of Man."

Sediment—Materials that are commonly called "dirt" or "mud." Sediment can consist of deposits of clay, silt, sand, pebbles, cobbles, and boulders.

Silurian—A Period in the Paleozoic Era that spanned the interval between 438 and 408 million years ago. Named for the Silures, a Celtic tribe in Great Britain.

Species—A group of organisms, either plant or animal, that are the same kind.

Specimen—An individual example of a species.

Tertiary—The youngest Period of the Cenozoic Era, following the Cretaceous Period of the Mesozoic Era and occurring prior to the Quaternary Period of the Cenozoic Era.

Triassic—Oldest Period of the Mesozoic Era; it spanned the time interval from 245 to 208 million years ago. The Triassic is named for the three different kinds of rocks of this age that occur in Germany, where the name "Triassic" was first used.

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Berry, W.B.N., 1968, Growth of a prehistoric time scale: W.H. Freeman and Company, San Francisco, 158 p.

A thoroughly readable and interesting history of the development of the concept of geologic time. The revised edition (1987) is substantially revised and expanded.

Boardman, R.S., Cheetham, A.H., and Rowell, A.J., 1987, Fossil Invertebrates: Blackwell Scientific Pub., Palo Alto, California, 713 p.

This book is now considered by many to be the best textbook for college-level invertebrate paleontology courses. The information on evolution, biology, and ecology are all up-to-date. Many of the illustrations are black-and-white photographs. Compliments Moore, Lalicker, and Fischer (listed below).

Clarkson, E.N.K., 1979, Invertebrate palaeontology and evolution: George Allen & Unwin, London, 323 p.

The text is easy to understand, even if it is a little dry. The real advantage to this book is that the illustrations are excellent. A third edition is now available.

Levi–Setti, Riccardo, 1975, Trilobites: A Photographic Atlas: University of Chicago Press, Chicago, 213 p. (updated edition now available)

This book is really a photographic atlas, meant for both the professional scholar and amateur natural historian. It contains more than a hundred black-and-white photographs, illustrating the magnificent diversity within the trilobite group. There is also some information on the possible biology and ecology of trilobites.

McKerrow, W.S., ed., 1978, The ecology of fossils: an illustrated guide: The MIT Press, Cambridge, Massachusetts, 384 p. (updated edition now available)

One of the best books illustrating how fossils fit into their environments, and where those environments were located. Illustrated with numerous maps and block diagrams.

References Continued

Moore, R.C., Lalicker, C.G., and Fischer, A.G., 1952, Invertebrate fossils: McGraw–Hill Book Company, Inc., New York, 766 p. (out of print, but occasionally available in used book stores)

For many years this was the textbook used in invertebrate paleontology courses at many colleges and universities. Although the information on the biology and ecology is somewhat dated, the book contains hundreds of illustrations that are still useful. Compliments Boardman, Cheetham, and Rowell (listed above).

Murray, J.W., ed., 1985, Atlas of invertebrate macrofossils: John Wiley & Sons, New York, 241 p.

As the name implies, this book is meant to be used as a reference. It is probably the best source of photographs of fossils.

Ward, P.D., 1987, The natural history of nautilus: Allen and Unwin, Boston, 267 p.

A somewhat advanced text by an expert in the field of cephalopod biology and paleontology. It includes many useful and interesting photographs.

Ward, P.D., 1988, In search of nautilus: three centuries of scientific adventures in the deep Pacific to capture a prehistoric Living Fossil: Simon and Schuster, New York, 238 p.

More general in coverage than "The Natural History of Nautilus," this book tells more of the adventure of conducting scientific research in the waters of the southwestern Pacific Ocean.

Additional Models

Alpha, Tau Rho, 1989, How to construct two paper models showing the effects of glacial ice on a mountain valley: U. S. Geological Survey Open-File Report 89-190 A&B (Available as a 3.5-in. MACINTOSH disk or a 30-p. report)

Alpha, Tau Rho, Lahr, John C., and Wagner, Linda F., 1989, How to construct a paper model showing the motion that occurred on the San Andreas fault during the Loma Prieta, California, earthquake of October 17, 1989: U. S. Geological Survey Open-File Report 89-640A&B (Available as a 3.5-in. MACINTOSH disk or a 10-p. report)

Alpha, Tau Rho, and Lahr, John C., 1990, How to construct seven paper models that describe faulting of the Earth: U. S. Geological Survey Open-File Report 90-257 A&B (Available as a 3.5-in. MACINTOSH disk or a 40-p. report)

Alpha, Tau Rho, 1991, How to construct four paper models that describe island coral reefs: U. S. Geological Survey Open-File Report 91-131A&B (Available as a 3.5-in. MACINTOSH disk or a 19-p. report)

Alpha, Tau Rho, and Gordon, Leslie C., 1991, Make your own paper model of a volcano: U. S. Geological Survey Open-File Report 91-115A&B (Available as a 3.5-in. MACINTOSH disk or a 4-p. report)

Additional Models Cont.

Alpha, Tau Rho, Page, Robert A., and Gordon, Leslie C., 1992, Earthquake effects, a computer animation and paper model: U. S. Geological Survey Open-File Report 92-200A&B (Available as a 3.5-in. MACINTOSH disk or a 4-p. report)

Alpha, Tau Rho, Starratt, Scott W. and Chang, Cecily C., 1993, Make your own Earth and tectonic globes: U. S. Geological Survey Open-File Report 93-380A&B (Available as a 3.5-in. MACINTOSH disk or a 14-p. report)

Alpha, Tau Rho, and Stein, Ross S., 1994, Make your own paper model of the Northridge, California, earthquake, January 17, 1994: U. S. Geological Survey Open-File Report 94-143 4-p.

Alpha, Tau Rho, and Stein, Ross S., 1994, The Northridge, California, Earthquake of January 17, 1994: A computer animation and paper model: U. S. Geological Survey Open-File Report 94-214 30-p.

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Trilobite

Return to paper fossils

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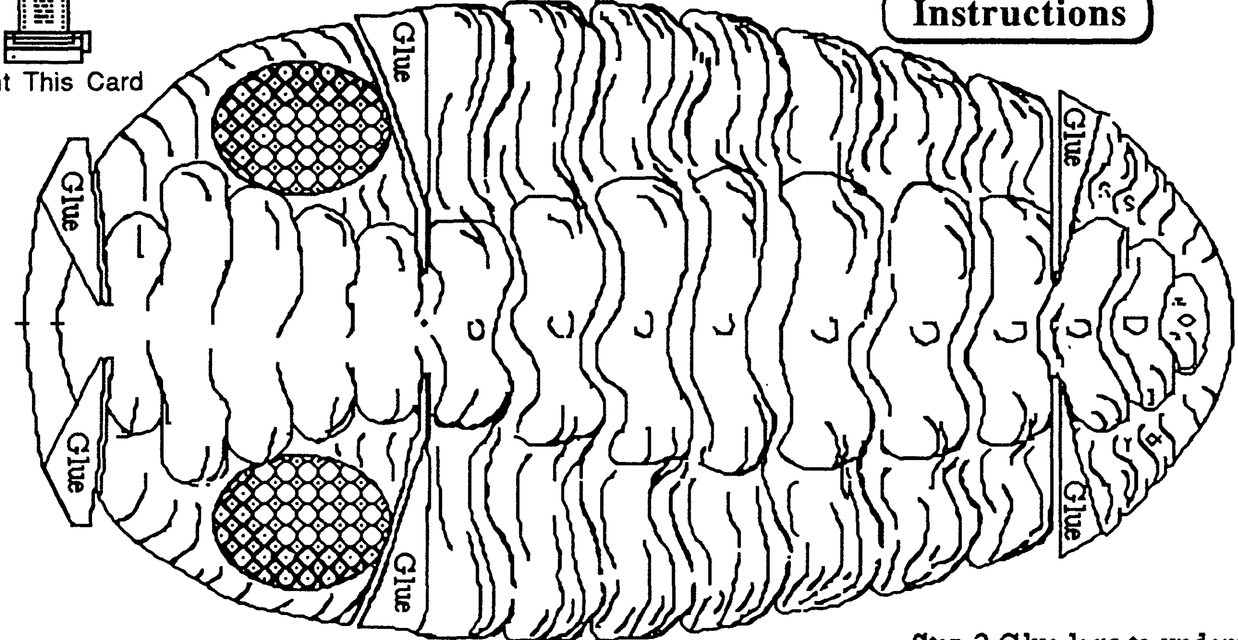
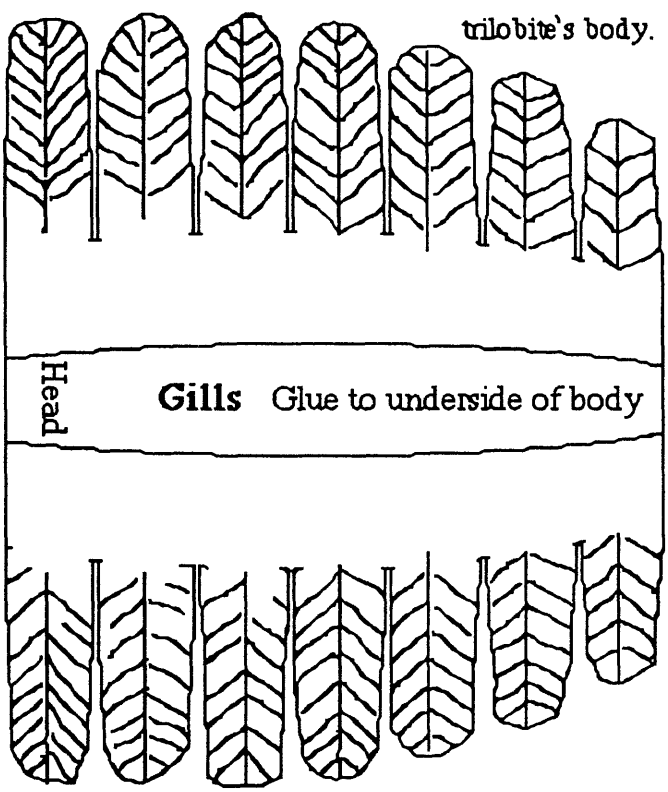
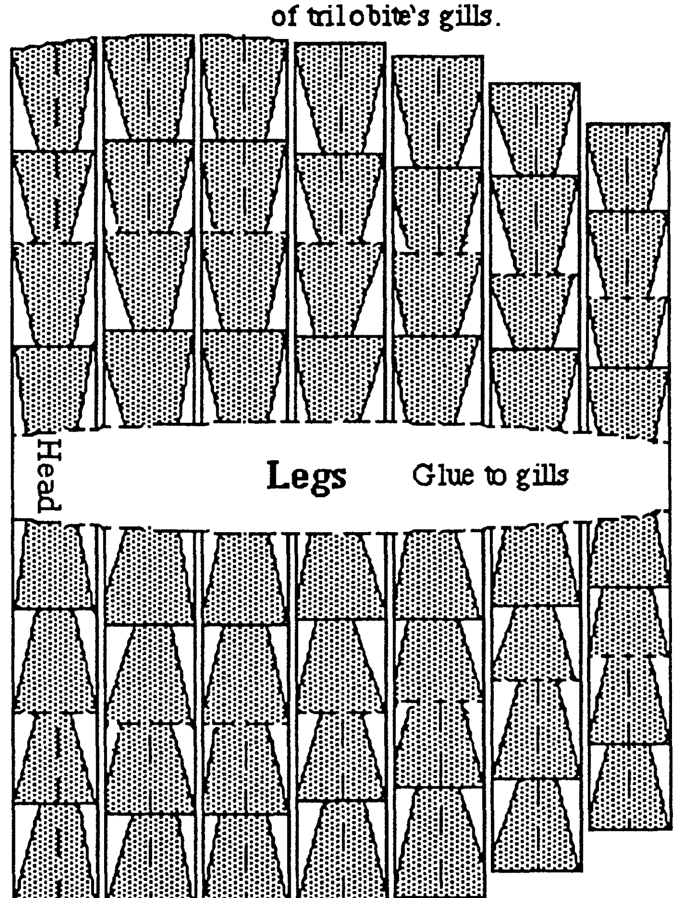


Step 1, Cut out trilobite's body, gills, and legs.

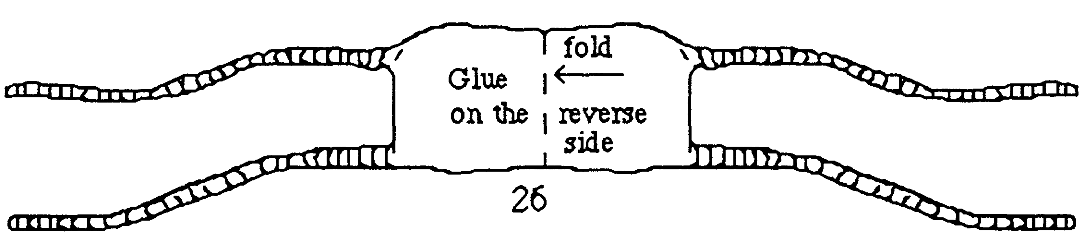
Step 3, Glue legs to underside of trilobite's gills.

Step 2, Glue gills to underside of trilobite's body.

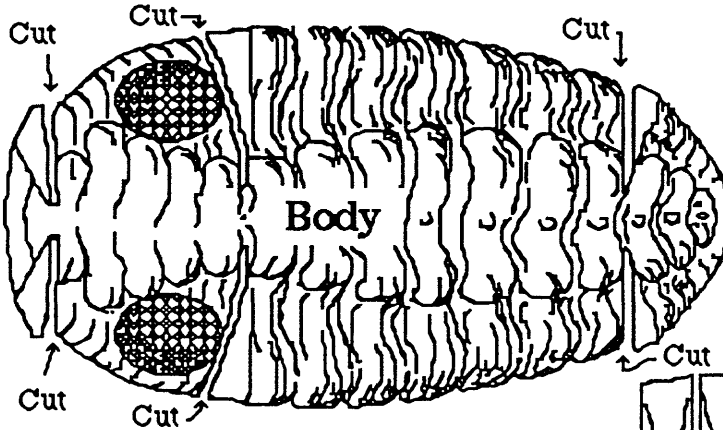


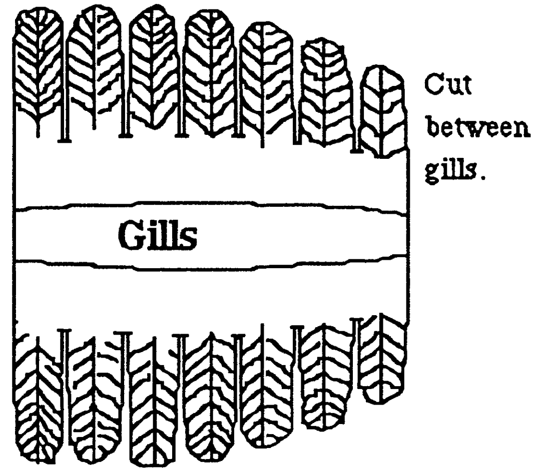


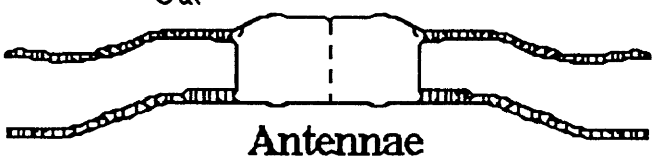
Step 4, Glue antennae to underside of head.

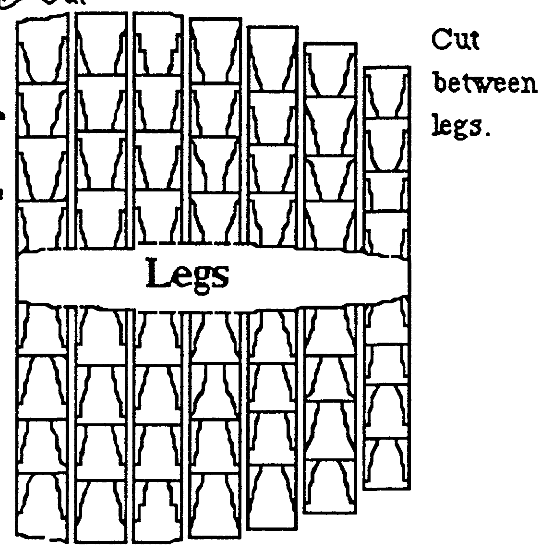


Step 1, Cut out trilobite's body, gills, legs, and antennae.

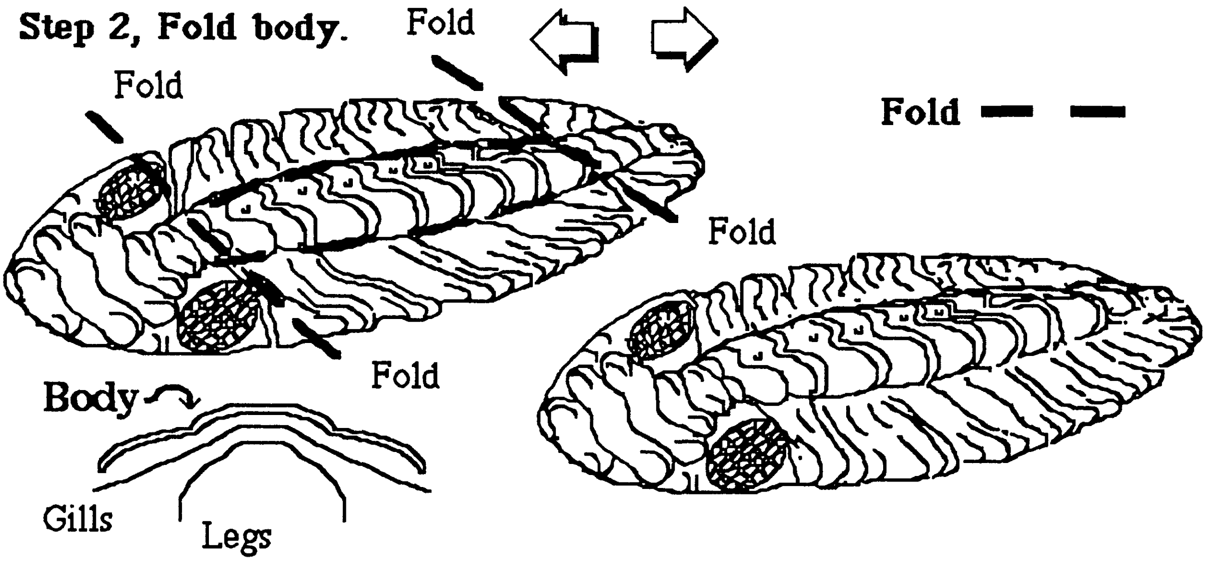






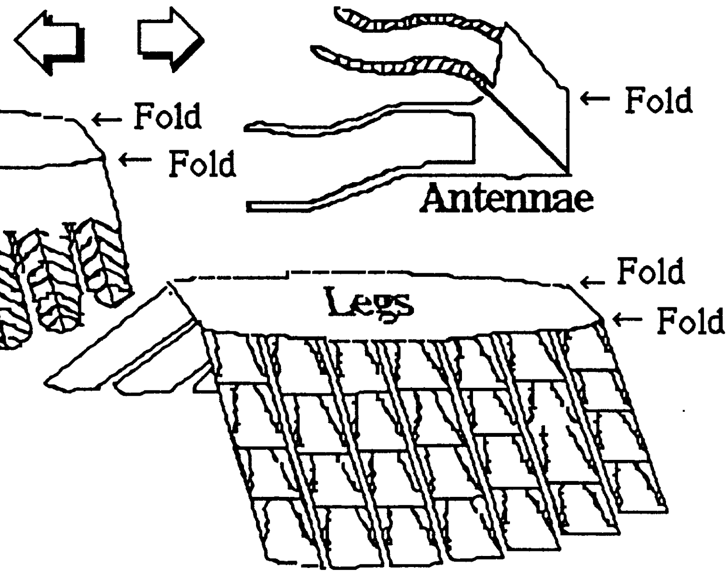


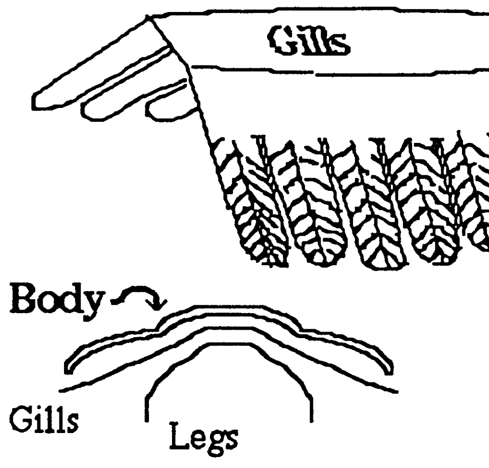
Step 2, Fold body.



Cross section of trilobite.

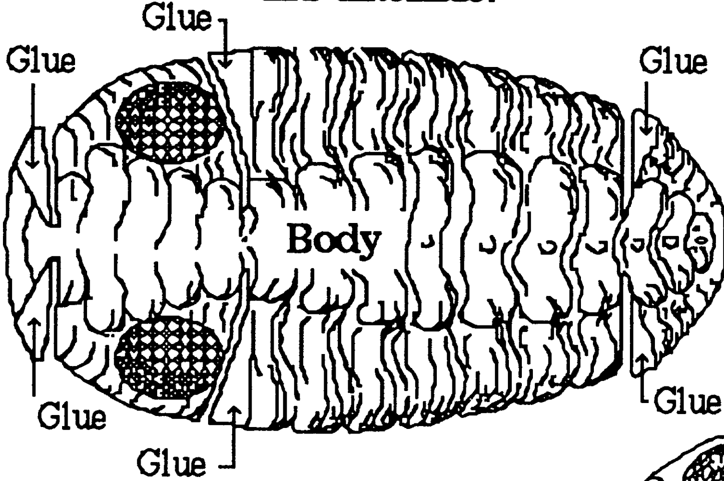
Step 3, Fold gills, legs, and antennae.

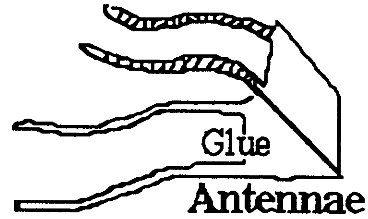


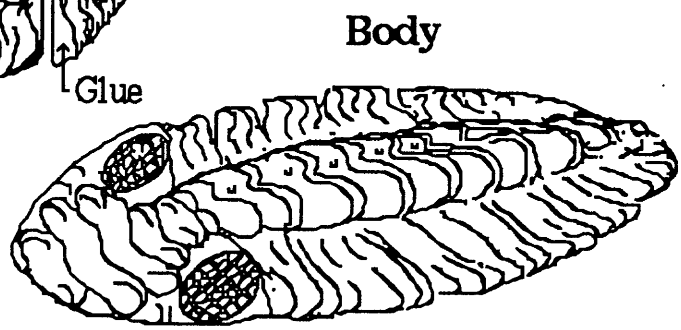


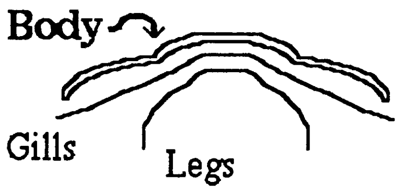
Cross section of trilobite.

Step 4, Glue body and antennae.



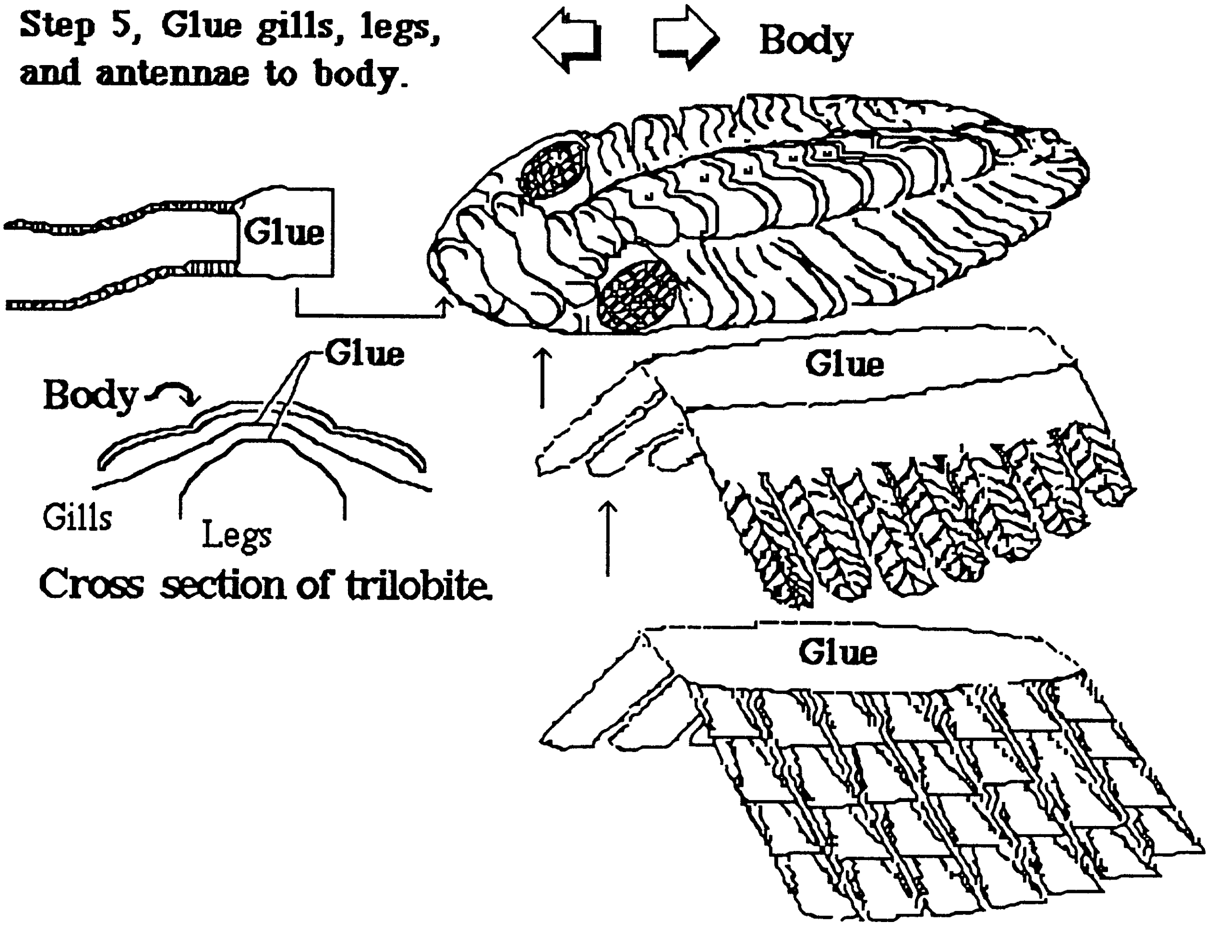






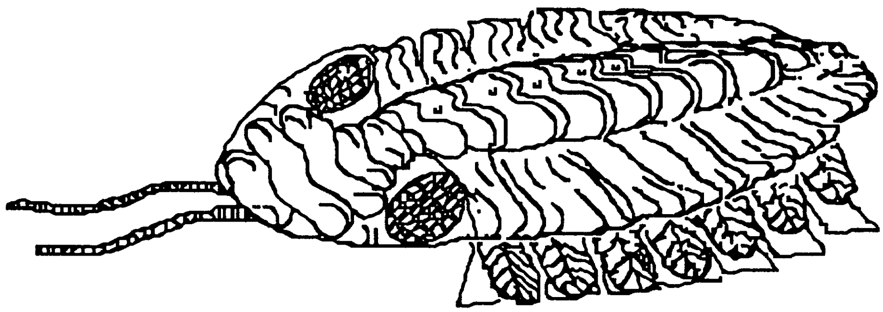
Cross section of trilobite.

Step 5, Glue gills, legs, and antennae to body.



Cross section of trilobite.

Finished trilobite



Nautiloid

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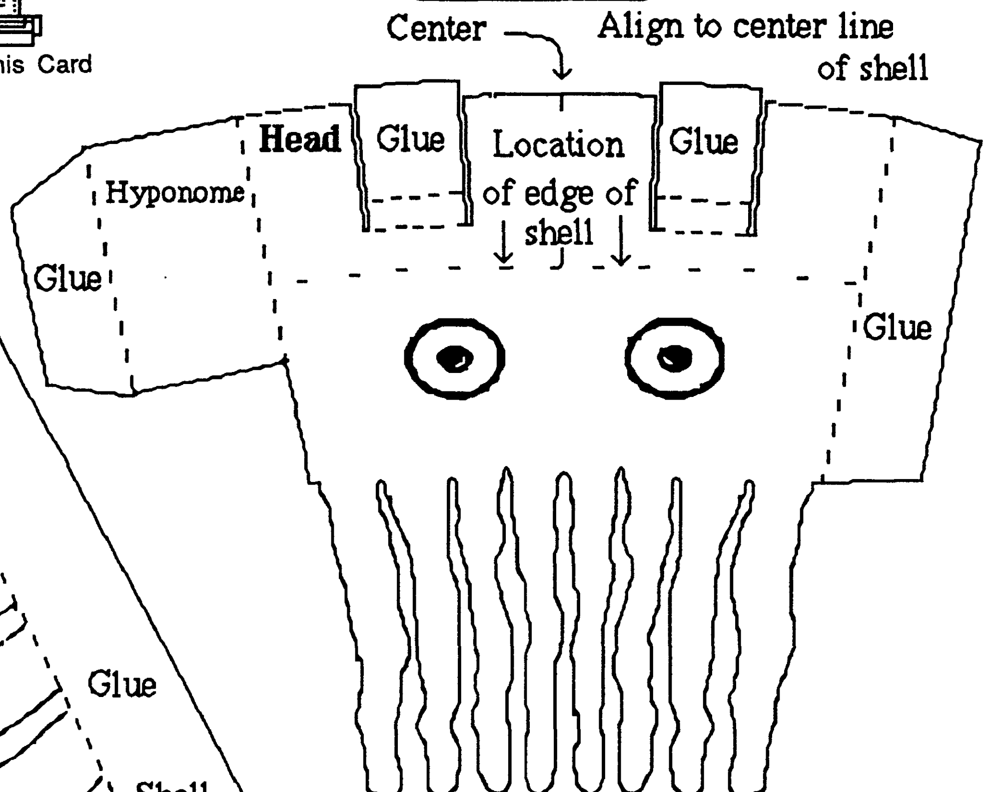
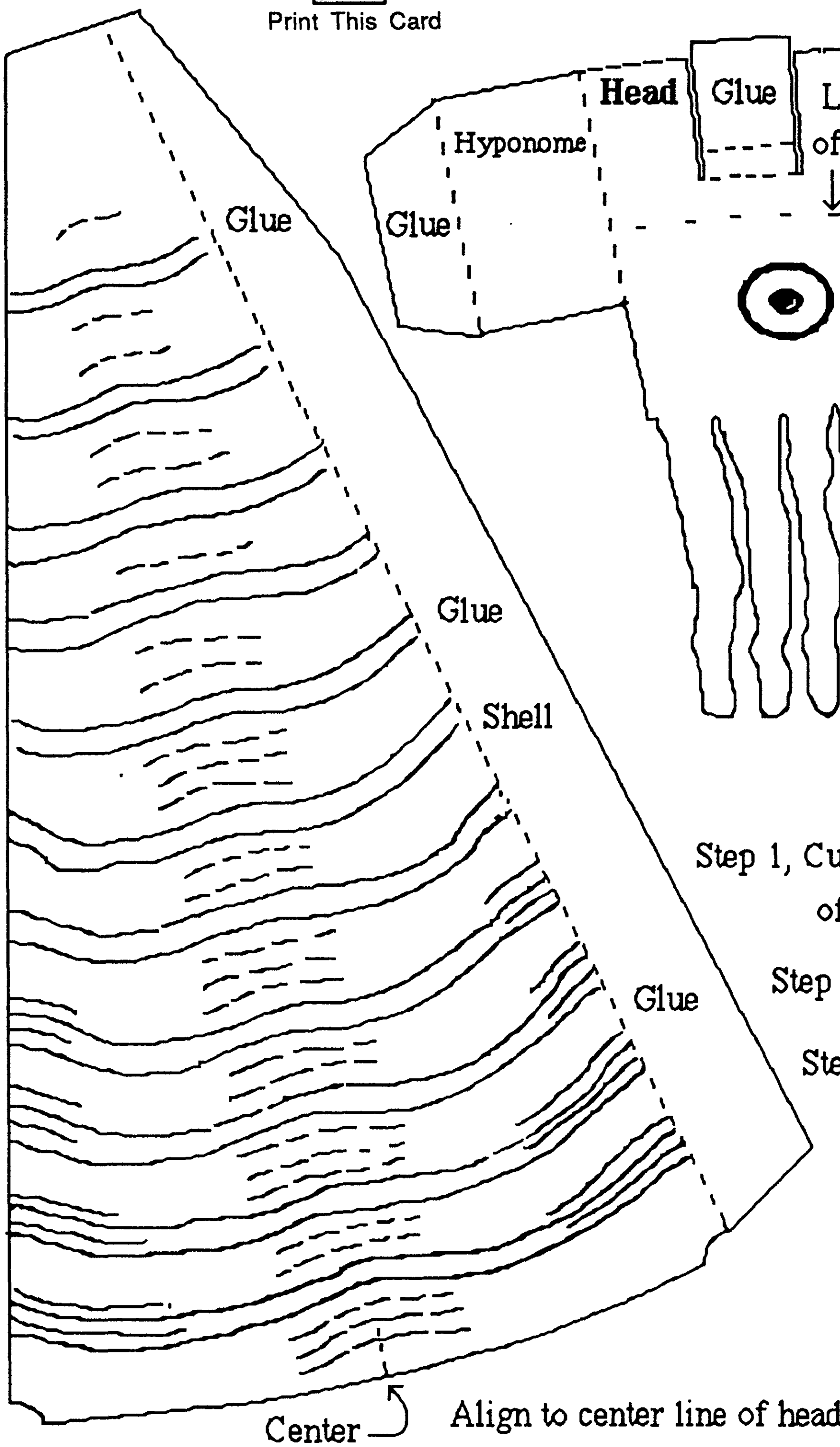




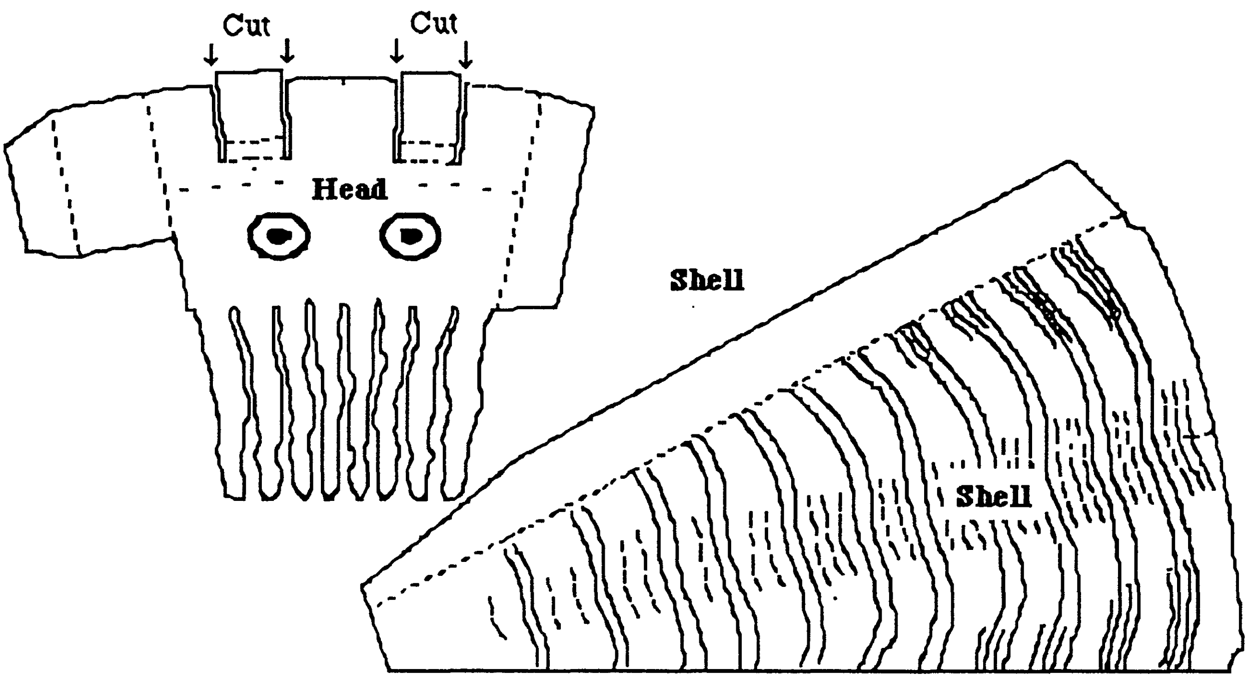
Step 1, Cut out head and shell of nautiloid.

Step 2, Roll up and glue shell.

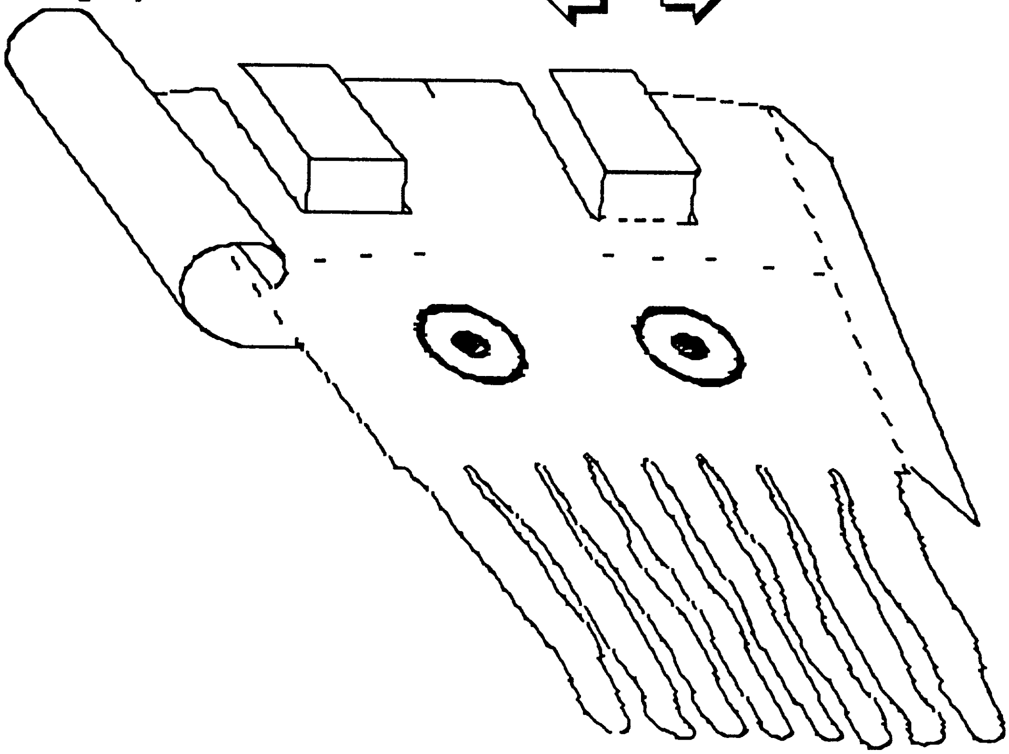
Step 3, Roll up and glue head and hyponome.

Step 4, Use the two tabs to glue head to inside of coiled shell.

Step 1, Cut out shell and head.



Step 2, Roll and fold head.



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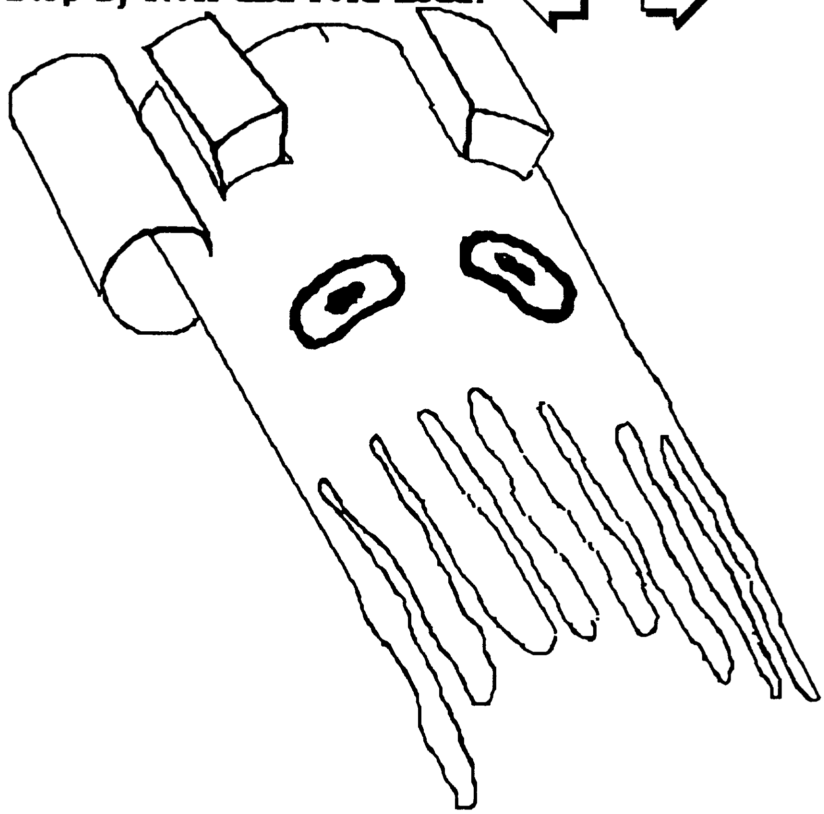
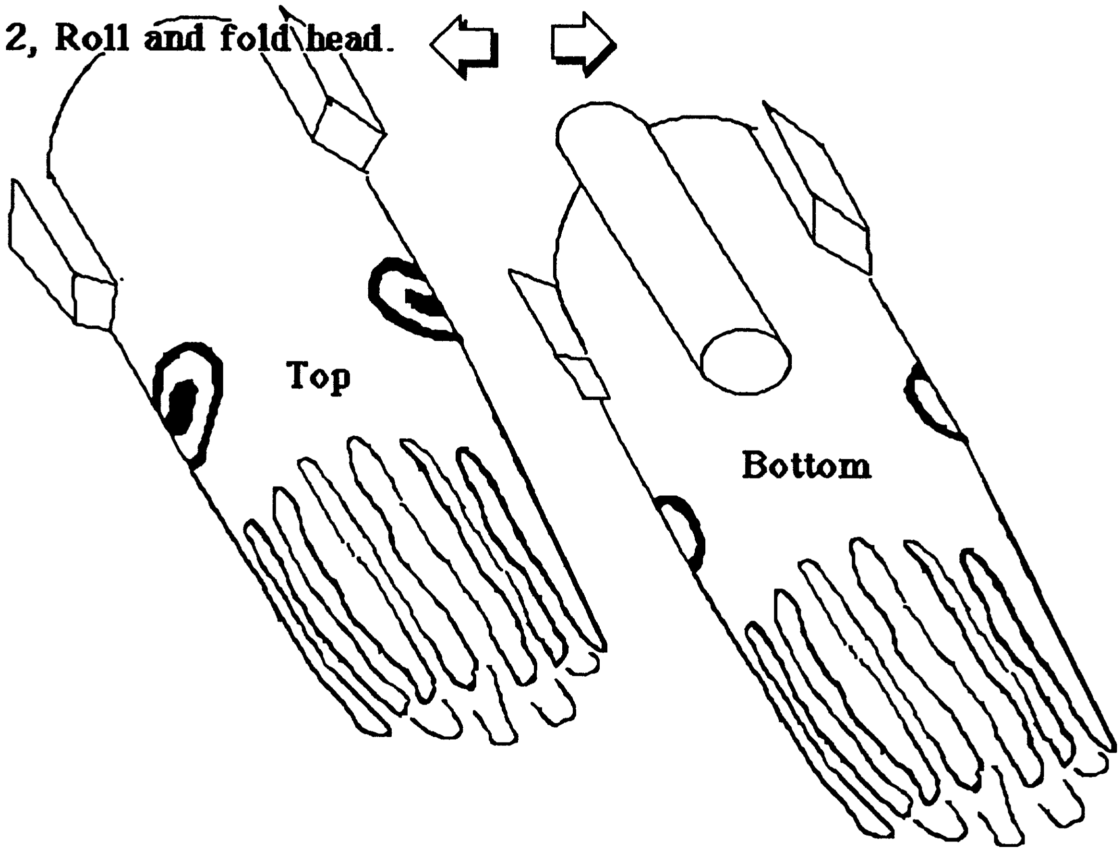
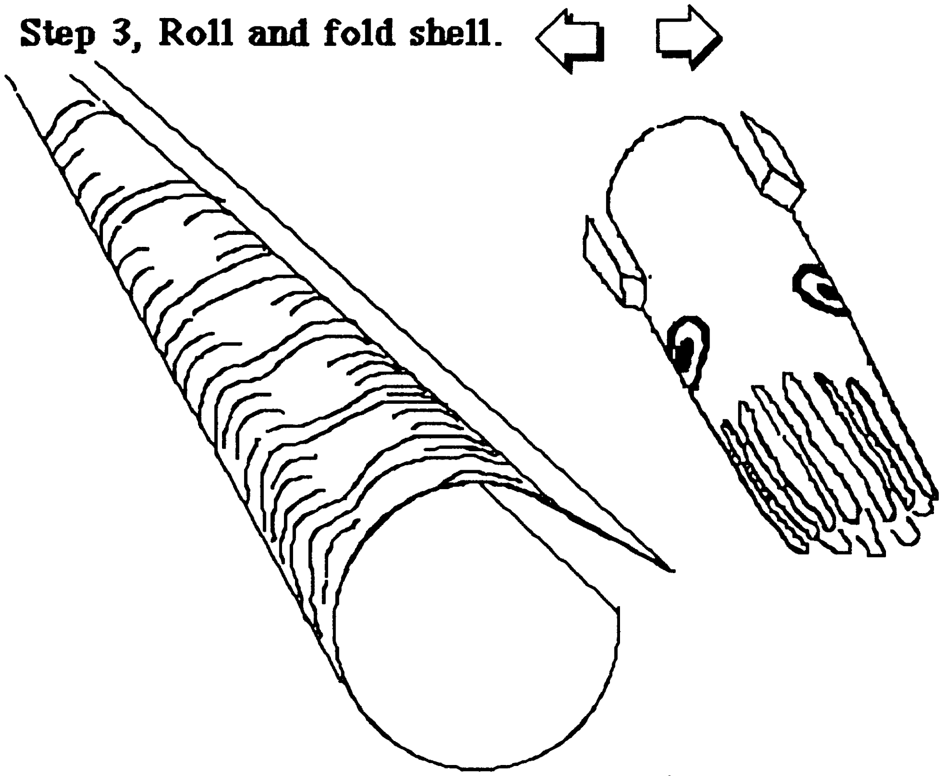


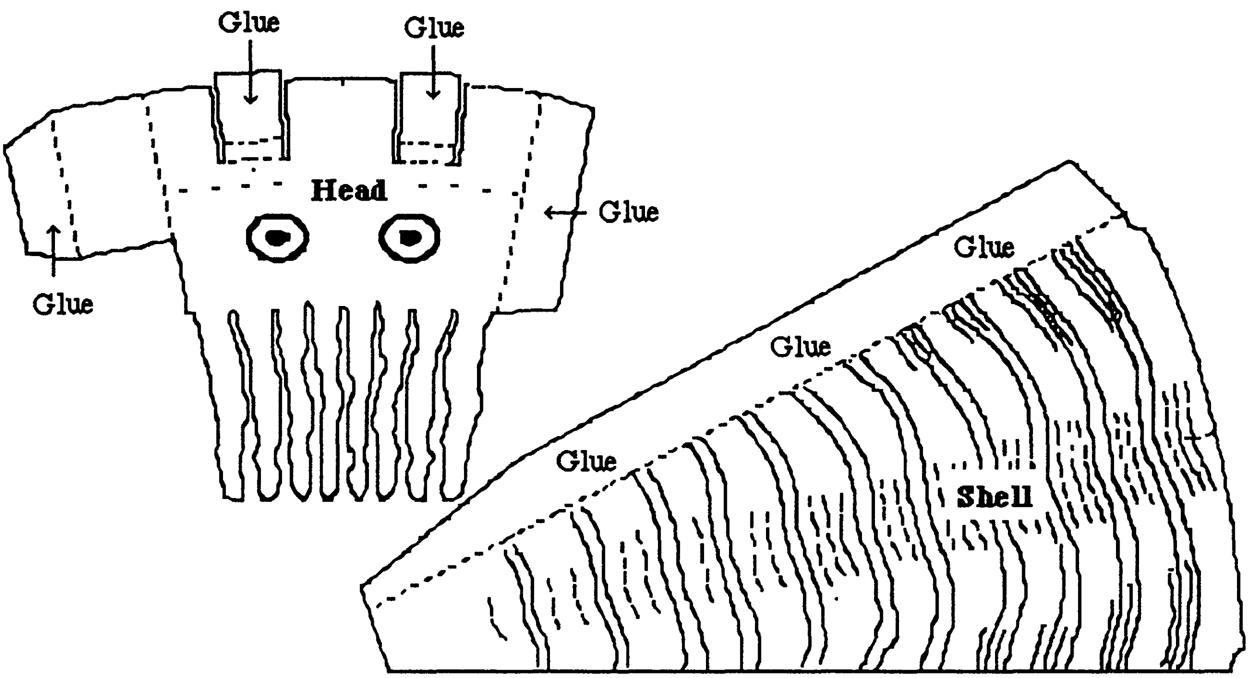
Step 2, Roll and fold head.



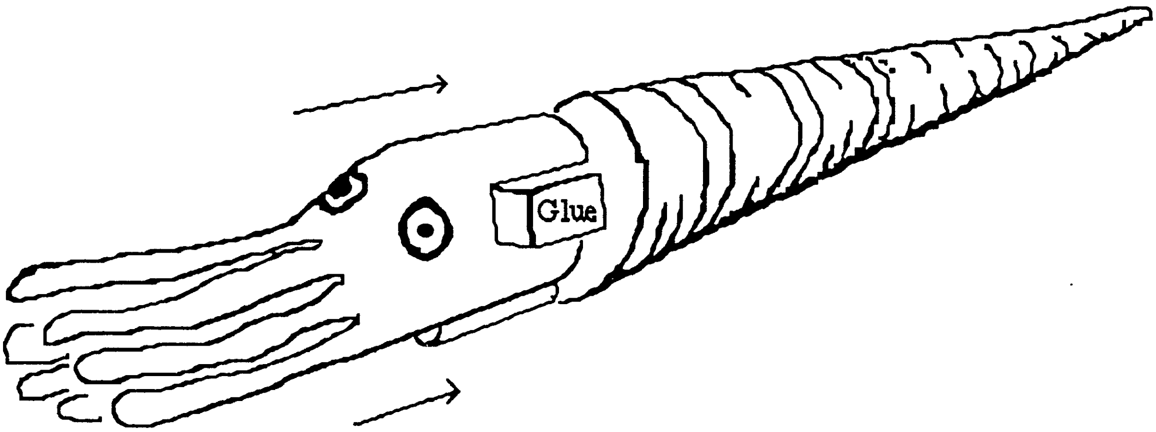
Step 3, Roll and fold shell.



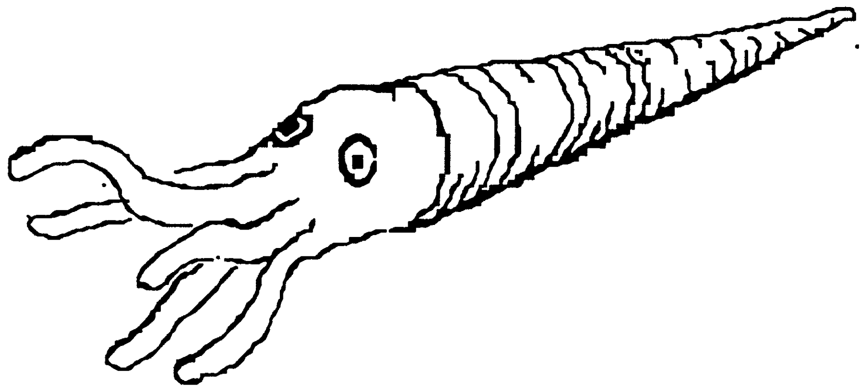
Step 4, Glue head and shell.

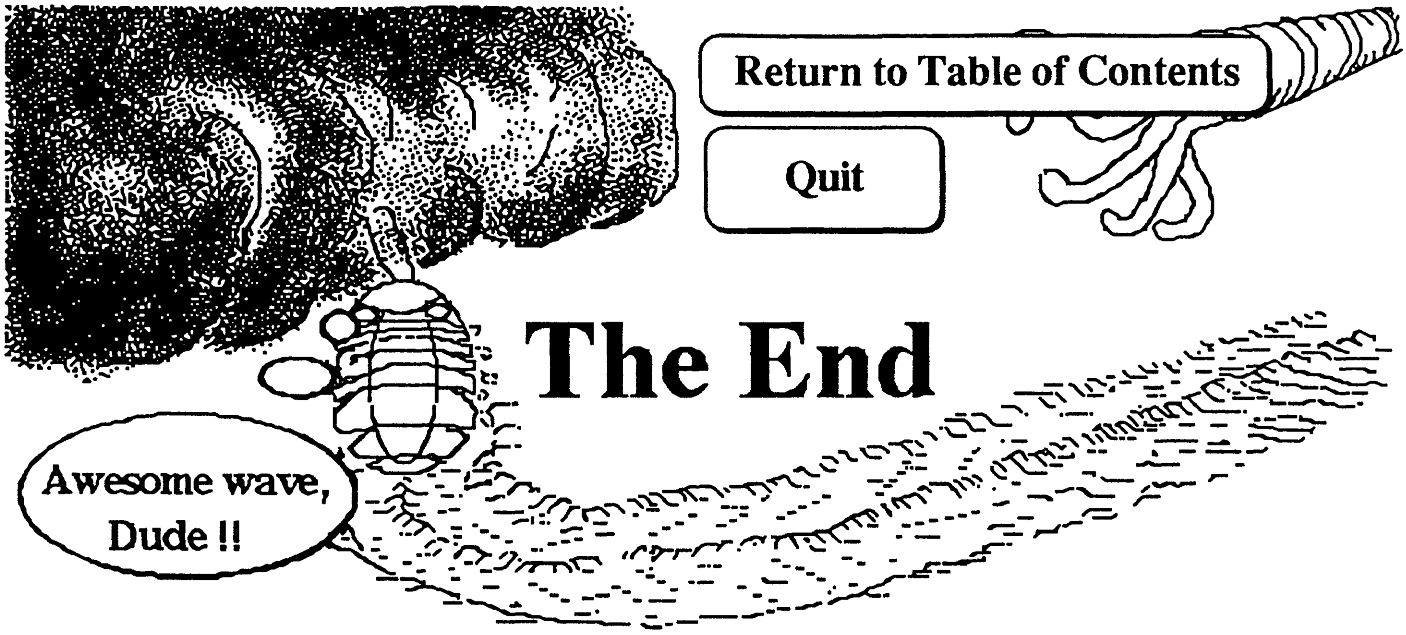


Step 5, Glue head to shell.



Finished nautiloid.



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