Oklahoma Geological Survey

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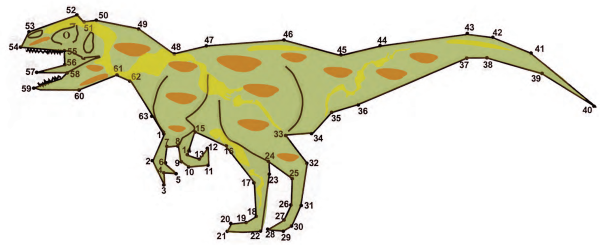
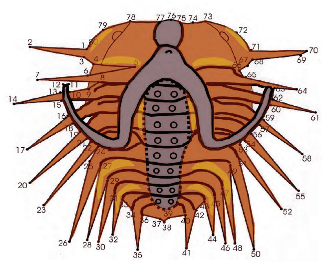
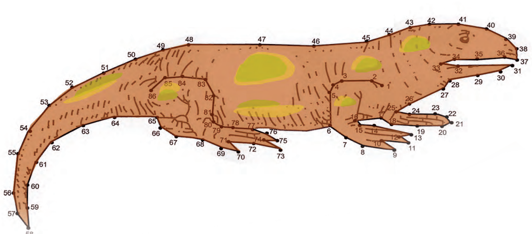


DOT-TO-DOT EARTH SCIENCE ACTIVITIES FOR GRADES 1-8

FOSSIL EDITION





Jim Chaplin
Oklahoma Geological Survey
Edited by Brittany Pritchett

Fossil Edition of Educational Publication 10

Oklahoma Geological Survey
G. Randy Keller, *Director*

DOT–TO–DOT

EARTH SCIENCE ACTIVITIES

FOR GRADES 1–6

James R. Chaplin
Oklahoma Geological Survey
Norman, Oklahoma

Mewbourne College of Earth and Energy
The University of Oklahoma
2011

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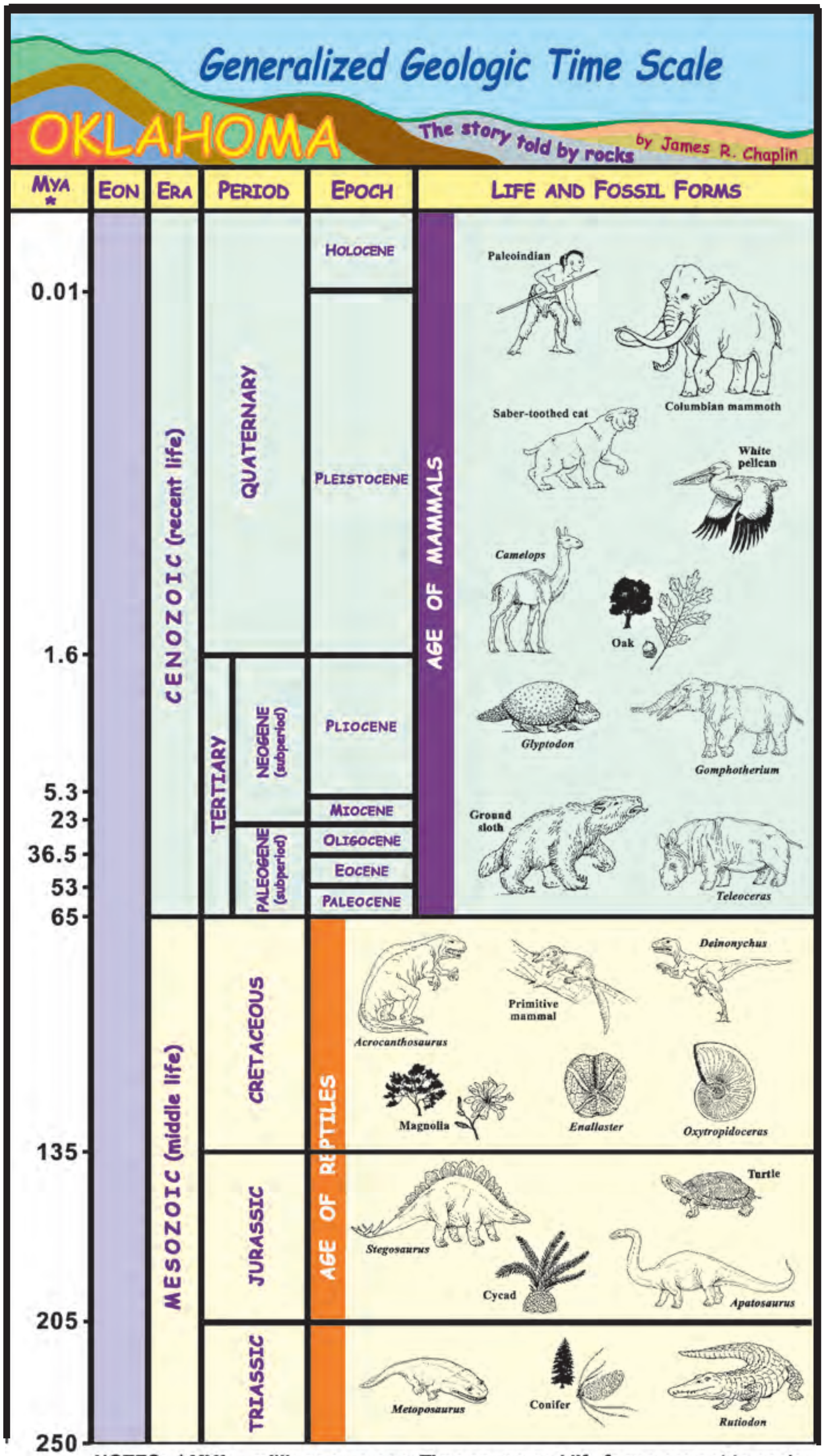
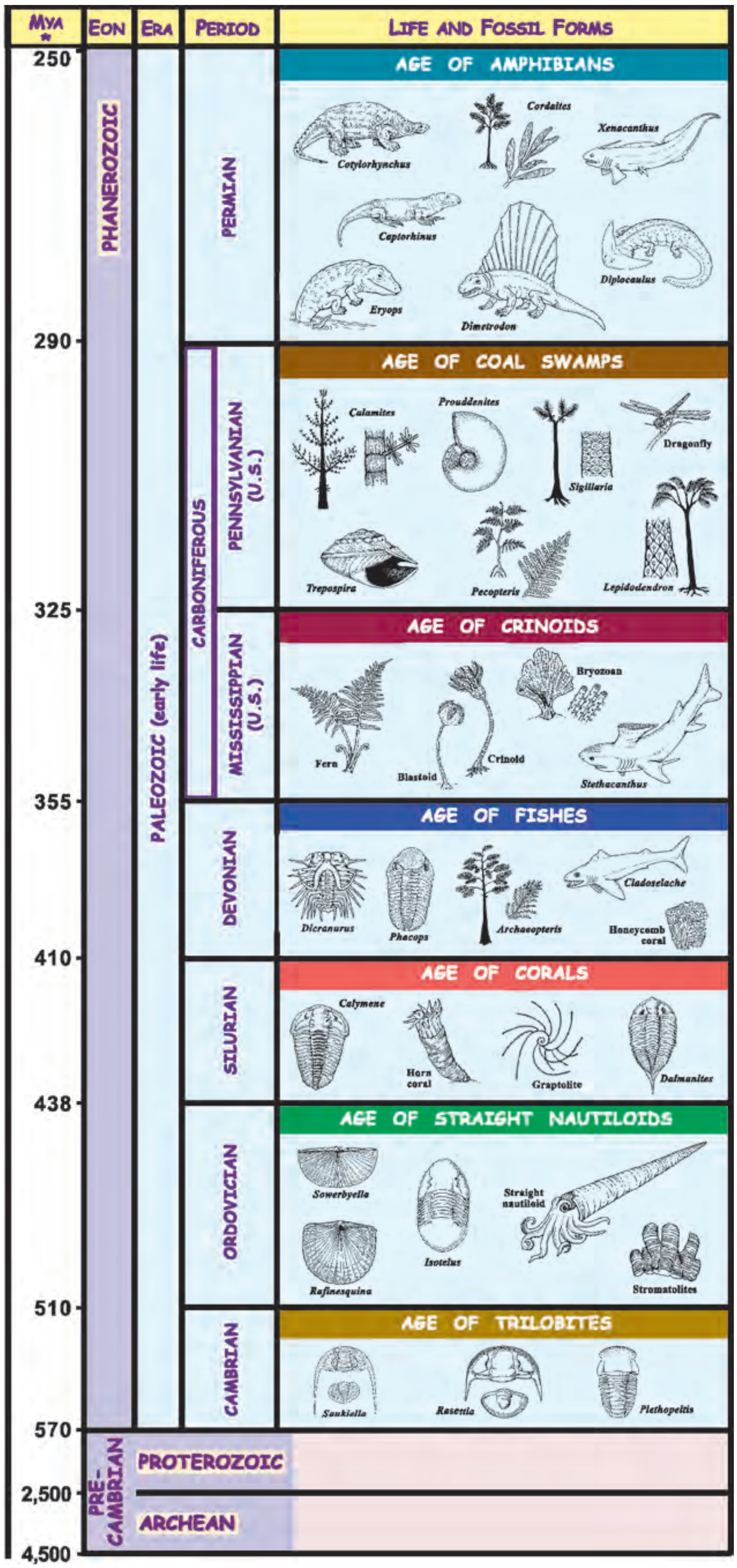


NOTES: * MYA = million years ago. Time spans and life forms are not to scale.
Source for ages: Cowie, J. W., and Bassett, M. G., 1989, Global stratigraphic chart: International Union of Geological Sciences, Episodes, v. 12, no. 2, supplement.

1999

Illustrations by Coral McCallister


MYA
EON
ERA
PERIOD
LIFE AND FOSSIL FORMS
250
290
325
355
410
438
510
570
2,500
4,500
PHANEROZOIC
PALEOZOIC (early life)
PERMIAN
CARBONIFEROUS
PENNSYLVANIAN (U.S.)
MISSISSIPPIAN (U.S.)
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRE-CAMBRIAN
PROTEROZOIC
ARCHEAN
AGE OF AMPHIBIANS
Cotylorhynchus
Cordaites
Xenacanthus
Captorhinus
Diplocaulus
Eryops
Dimetrodon
AGE OF COAL SWAMPS
Calamites
Prouddenites
Dragonfly
Sigillaria
Trepospira
Pecopteris
Lepidodendron
AGE OF CRINOIDS
Bryozoan
Fern
Blastoid
Crinoid
Stethacanthus
AGE OF FISHES
Cladoselache
Dicranurus
Phacops
Archaeopteris
Honeycomb coral
AGE OF CORALS
Calymene
Horn coral
Graptolite
Dalmanites
AGE OF STRAIGHT NAUTILOIDS
Sowerbyella
Straight nautiloid
Isotelus
Rafinesquina
Stromatolites
AGE OF TRILOBITES
Saukiella
Rasettia
Plethopeltis

CONTENTS

DOT–TO–DOT ACTIVITIES FOR EARTH SCIENCE STUDENTS GRADES 1–6

ACTIVITIES

LIST OF ILLUSTRATIONS

INTRODUCTION

The primary objective of this educational resource is to expose more teachers and students (grades 1–6) to the fossils/geology of Oklahoma through some dot–to–dot activities Hopefully, the activities will help parents and teachers stir children's curiosity about earth science.

The resource contains sufficient basic information, through fact sheets on earth science concepts, to provide a foundation for a beginner to ask, as well as answer, some questions about the fossils of Oklahoma. The fact sheets differ in complexity of information in order to provide for a variety of ability levels and thinking skills of students It is the teacher's responsibility to use his or her own discretion in deciding what and how much of the technical information on the fact sheet is important in the learning process.

The dot–to–dot activities cover fourteen different fossils of varying types: official State fossil of Oklahoma, vertebrate fossils, and invertebrate plant and animal fossils. All of the fossils used in the activities are common to Oklahoma. In addition, this resource includes some hands on activities such as how to make paper models of a nautiloid cephalopod and a trilobite.

Answer keys for all activities are provided for the teacher. The students may color the completed dot–to–dot activities.

The learning process can be fun. I hope the students enjoy the different dot–to–dot activities. While simple and fun, these activities can be used to create an early interest of earth–science concepts in their daily lives.

A good teacher/parent resource to complement this educational publication is Educational Publication no 6—"Generalized Geologic Time Scale for Oklahoma—The Story Told by Rocks" available from the Oklahoma Survey Publication Sales Office (see Appendix 1). This colorful 22 in x 34 in wall poster summarizes the history of ancient life as found preserved in rocks of Oklahoma.

ACTIVITY ρ

FACT SHEET

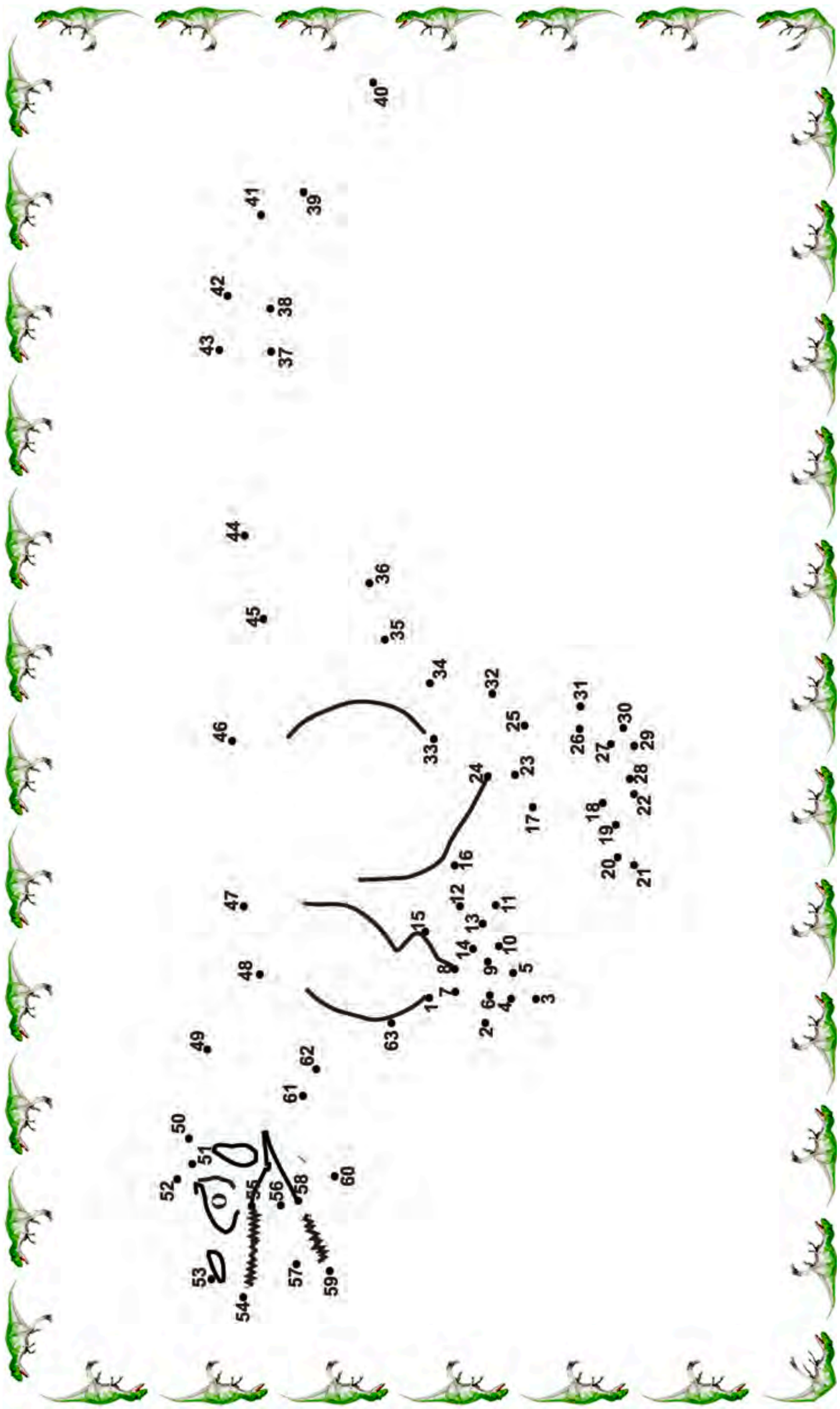
Saurophaganax maximus ("Greatest King of the Reptile Eaters")

Saurophaganax maximus, a carnivorous dinosaur of Jurassic age is the Official State Fossil of Oklahoma. The only known skeletal remains of this meat–eating dinosaur were found between 1931 and 1938, in the same pit as the dinosaur *Apatosaurus* by a team of Workers Progress Administrators (WPA) workers. The workers were led by University of Oklahoma paleontologist Dr. J. Willis Stovall, who served as director of the Stovall Museum from 1943–1953. Both skeletons, as well as the remains of other animals, were found in a single pit in Cimarron County in the Morrison Formation, of Jurassic age (~150 million years ago). The Morrison is a world–famous dinosaur–bearing strata which occurs throughout much of Colorado, Wyoming, Utah, and the Oklahoma Panhandle.

When alive, *Saurophaganax maximus* was about 40 ft in length from head to tail; weighed about 4,000 pounds, and had a skull nearly 4 ft in length. It was equipped with long arms and hands with three claws that allowed it to grasp and hold its prey. The deadly claws of *Saurophaganax* are the largest of any meat–eating dinosaur. *Saurophaganax* was likely capable of bringing down and killing prey equivalent to its own size or much larger.

Cub Scouts of Den 3, Pack 349, Edmond, are credited with suggesting that the Oklahoma State Legislature designate a State Fossil. Governor Frank Keating signed the enabling legislation on April 17, 2000.

ACTIVITY ρ

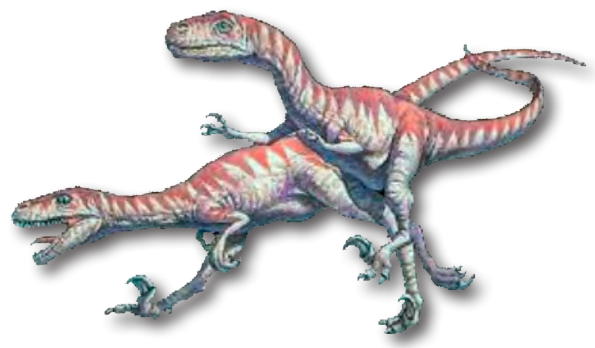


I am the official State fossil of Oklahoma

ACTIVITY ς

FACT SHEET

Deinonychus



Although the "kick–boxing" carnivorous dinosaur *Deinonychus* was only about as big as a two–passenger compact car, every inch of this dinosaur contributed to its reputation as being one of the world's deadliest dinosaurs. The name *Deinonychus* literally translates to "terrible claw."

Deinonychus was one of the most deadly species of the Cretaceous Period, which began ~135 million years ago. In the United States, fossils of this dinosaur were recovered from Montana, Oklahoma, Wyoming, Arkansas and Maryland.

Adults were about 5 ft in height and 9 ft in length, and weighed about 176 lbs. When its powerful jaws opened, over 60 dagger–like teeth flashed, ready to dig into much larger dinosaurs. This dinosaur wielded sickle–shaped claws on the second toe of each "foot." It could retract these like a switchblade but, to preserve the sharpness of its valuable weapons, *Deinonychus* lifted its sickle–shaped claw upward and instead ran on its third and fourth toes. Thus, the "terrible claw" didn't drag on the ground, where they could catch or become blunt. Claws on its grasping hands could inflict severe damage that would have been compounded if *Deinonychus* decided to karate–kick unfortunate victims with one, or both, of its toe claws.

Despite possible heavy *Deinonychus* losses during battle, this carnivore could attack in multiple ways. The curved and flexible neck and a big head gave it a huge advantage over its competitors in hunting. The strength and agility of this dinosaur, as well as the extremely good coordination of the body parts and an ability to leap great distances, imparted a huge advantage in its hunt. Because its tail was strong, it might have balanced on one foot while it gored and disemboweled victims with a toe claw. Given its muscular legs, it could have also jumped directly on prey, digging its claws into the victim as it landed.

While an individual *Deinonychus* would have made a formidable opponent, this species probably hunted in gangs and packs similar to wolves to fell especially large, meaty dinosaurs.

The agile *Deinonychus* was lightly built and was a close relative of the velociraptors, which were featured in the movie *Jurassic Park*.

Feather–like structures linked to close relatives of *Deinonychus* suggest feathers covered the dinosaur's muscular, yet lightweight, body. This dinosaur also shared other anatomical features with today's birds, such as the shape and structure of its pelvic bones, although its inclusion in warm–blooded animals is a matter of contention among some scientists. Its moves can be compared to that of a flightless bird, running, swerving and balancing with astonishing speed.

Bones of the "kick–boxing" carnivorous dinosaur *Deinonychus* were discovered with bones of its presumed prey, the "duck–billed" relative *Tenontosaurus* in the Antlers Formation of Early Cretaceous age (~130 million years ago) in Atoka County, Oklahoma.

***Deinonychus* skeletons currently are being excavated and studied by vertebrate paleontologists at the Sam Noble Oklahoma Museum of Natural History in Norman, Oklahoma.**

ACTIVITY ς

I am the "kick–boxing" dinosaur.

ACTIVITY σ

FACT SHEET

Captorhinus sp.

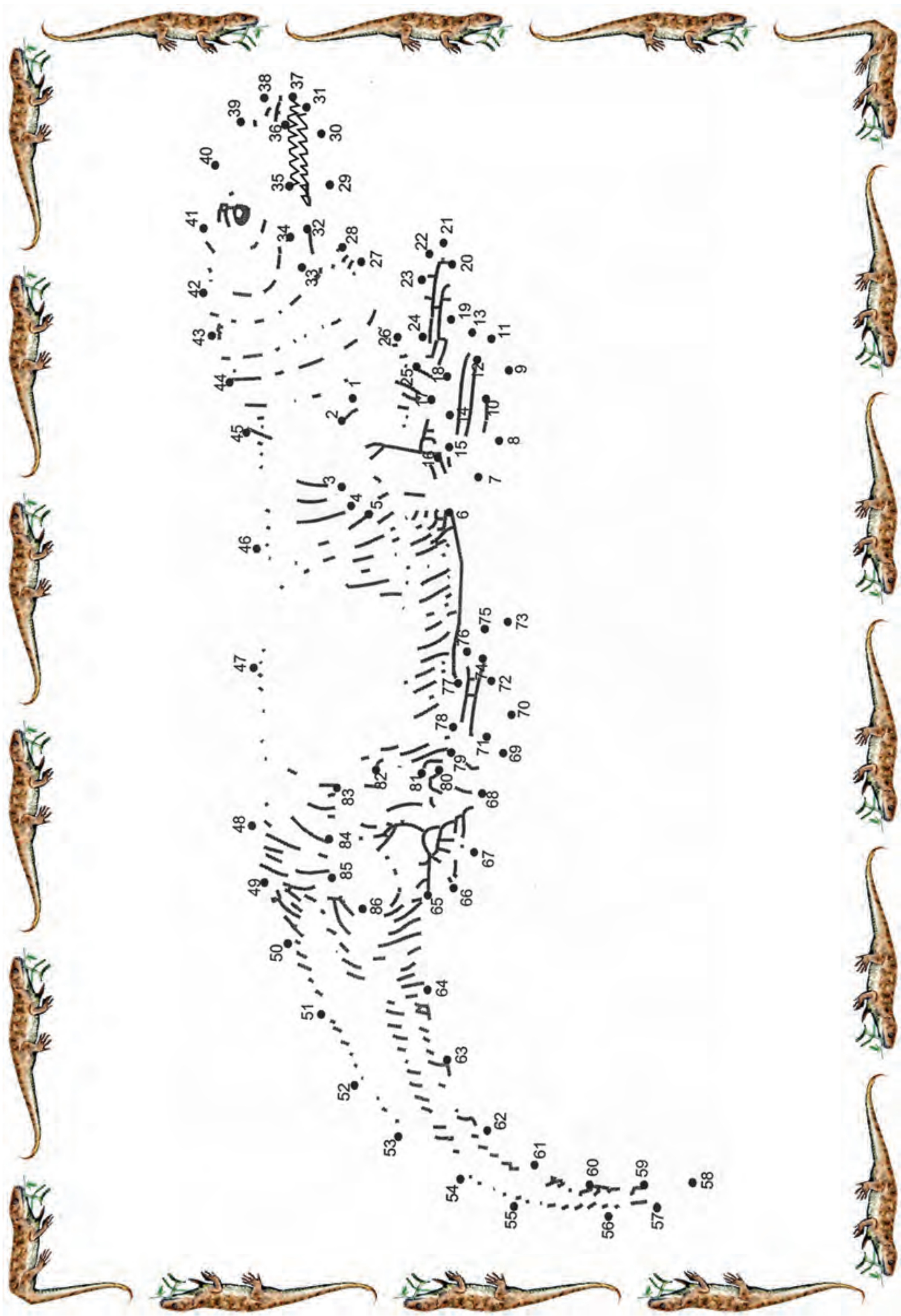
This primitive small reptile first appears in Early Permian (~270 million years ago) terrestrial redbeds of central North America. Identification of this reptile is based mainly on jaws and parts of skulls. The skull was truncated at the back and the quadrant bone for the support of the lower jaw was vertical in position. The very long jaw possessed numerous sharp, pointed teeth and a multiple row pattern of cheek teeth. Multiple–rowed marginal dentition is characteristic of the genus *Captorhinus.* Many specimens were up to 2–3 ft in length.

Dentition (teeth patterns) suggest that early captorhinids were probably carnivorous, preying on small amphibians, reptiles, and perhaps even on large insects. Like many small, present–day carnivorous tetrapods, these primitive carnivore reptiles may have preyed opportunistically upon invertebrate animals, namely arthropods.

The large quantity of broken and scattered bone that commonly occurs as a bone breccia suggests frequent reworking and redeposition of these sediments by fast–moving, probably intermittent streams in the lowland, deltaic, and pond deposits of south–central Oklahoma and north–central Texas.

The Dolese Brothers limestone quarry at Richards Spur, near Fort Sill, Comanche County, Oklahoma, contains the richest most diverse deposit of Early Permian reptile and amphibian fossils in Oklahoma. It is one of the richest known sources of Permian tetrapod (an animal that has four limbs, such as an amphibian, reptile, etc.) skeletal remains in the world. The fossils occur in fissures (pockets) and solution cavities of residual clays in the karsted Kindblade Limestone of Ordovician age (~490 million years ago). These openings were later filled with Early Permian sediments and bones. About 90 percent of the vertebrate bones found in the Richards Spur deposits are of the reptile genus *Captorhinus.*

ACTIVITY σ



I am the most common vertebrate fossil found in a quarry at Richards Spur in Comanche County, Oklahoma.

ACTIVITY τ

FACT SHEET

Dimetrodon sp.

This “sailback” carnivorous reptile has a large skull and large teeth. An aggressive dominant carnivore in the Early Permian of North America, it attained a length of 7 ft, a height of 3–4 ft and a weight of nearly 220 lbs.

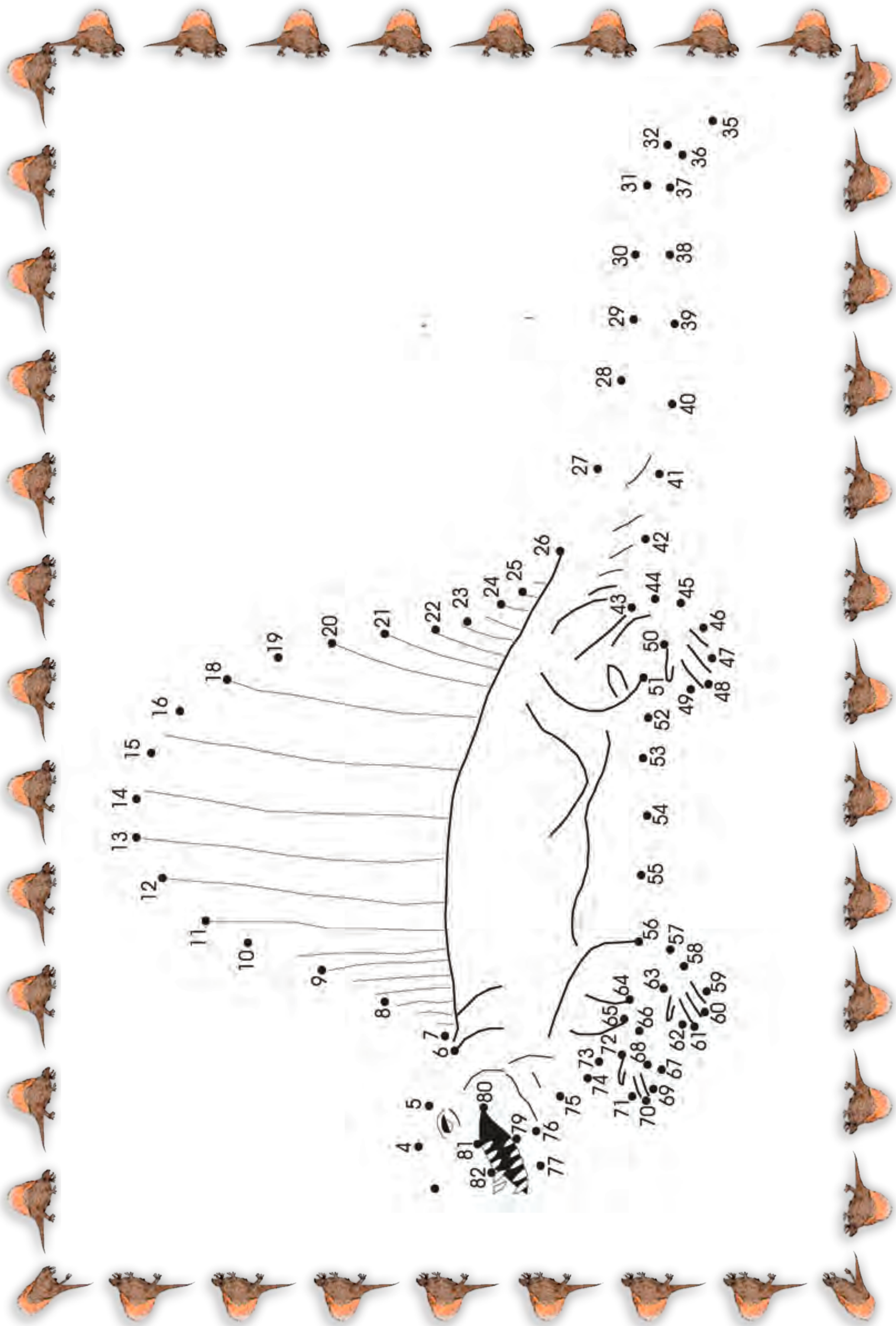
Dimetrodon possessed a rather slim body and its limbs, although primitive and sprawling in construction, were somewhat more slender than in most Early Permian reptiles, suggesting a relatively rapid gait.

Dimetrodon possessed a high and narrow skull with a rather long face; posteriorly the skull margins curved downward and forward toward the jaw articulation—a feature repeated in many therapsids (advanced mammal–like reptiles); the jaws were armed with compressed, sharp–edged, well differentiated teeth, particularly in the upper jaw—probably for its predaceous habits.

Dimetrodon was specialized in that it possessed a great “sail” that reached heights over 3 ft supported by a membranous skin. In *Dimetrodon*, the “sail” area in species of different sizes, varies proportionately to the volume of the particular species; hence, it is disproportionately higher in bigger species. This strongly suggests that the “sail” was an early attempt to develop a temperature–regulating organ, which was able to both absorb and radiate heat.

***Dimetrodon* was primarily a predator of amphibians and spent much of its time near marshes, and along streams and ponds. Fossil remains are common in continental redbeds in Oklahoma, Texas, and New Mexico.**

ACTIVITY τ



I am known as the "sailback" reptile.

ACTIVITY υ

FACT SHEET

Columbian mammoth, *Mammuthus columbi*

The Columbian mammoths' appearance is similar to the modern African and Asiatic elephants, and measured 8½–12 ft tall. Columbian mammoths probably were much less hairy than the well–known woolly mammoths because they lived farther south in a milder climate.

Mammoths were grassland grazers, closely related to modern elephants, especially the Asiatic (Indian) elephant. Although we can only speculate about how mammoths lived, their behavior was possibly similar to modern elephants—living in herds dominated by the eldest females. Older bulls, however, range alone. Modern elephants live about 50 years in the wild and it is probable that mammoths also lived at least that long.

Usually when fossils of extinct mammoths are found, they consist only of fragments of large bones and teeth. Only when complete, well–preserved skulls or skeletons are excavated, can they be identified properly.

Mammoths died out (became extinct) in North America about 11,000 years ago, near the end of the last glacial period; however, they existed much longer in others parts of the world.

During the Late Pleistocene ("Great Ice Age"), as the last great continental ice sheet was melting, the first human inhabitants of North America (Paleoindians) entered the Oklahoma area. Among the beasts they found there were huge, herd–dwelling creatures with fantastic tusks and long trunks. These were Columbian mammoths (*Mammuthus columbi*). Prior to the arrival of the Paleoindians, Columbian mammoths already had lived in Oklahoma for thousands of years.

Mammoths were hunted by the earliest Paleoindians. Evidence for the hunting of mammoths in Oklahoma is found at the Cooperton site in Kiowa County and at the Domebo site in Caddo County.

ACTIVITY υ

I am related to the modern elephant.

ACTIVITY φ

FACT SHEET

Trilobites

General Information

Phylum Arthropoda

Class Trilobita

Trilobites are extinct members of the Phylum Arthropoda that includes insects, crustaceans (crabs, lobsters, shrimp, and scorpions), spiders and extinct giant water scorpions called eurypterids. Even though they are extinct, trilobites cannot be viewed as failures because they lived on Earth for more than 300 million years—much longer than the dinosaurs or man. Trilobites first appeared in the fossil record ~570 million years ago during the Cambrian Period (Paleozoic Era) which also is called the "Age of Trilobites." They eventually died out (became extinct) worldwide ~245 million years ago at the close of the Permian Period (Paleozoic Era).

Trilobites were among the first life forms to secrete a hard shell or exoskeleton capable of easily being fossilized. The horseshoe crab, *Limulus*, is the closest living relative to the extinct trilobites, and is commonly referred to as a "living fossil."

The name trilobite (3–lobed) refers to the segmented body consisting of three lobes that run lengthwise from head to tail; one in the middle called the axial lobe and one on each side of the axial lobe called pleural lobes (Fig. 12). The trilobite body also can be divided into three parts from top to bottom: the head or cephalon consisting of fused segments; the body or thorax with a variable number of distinct articulated segments; and the tail or pygidium, which includes one or more seg-

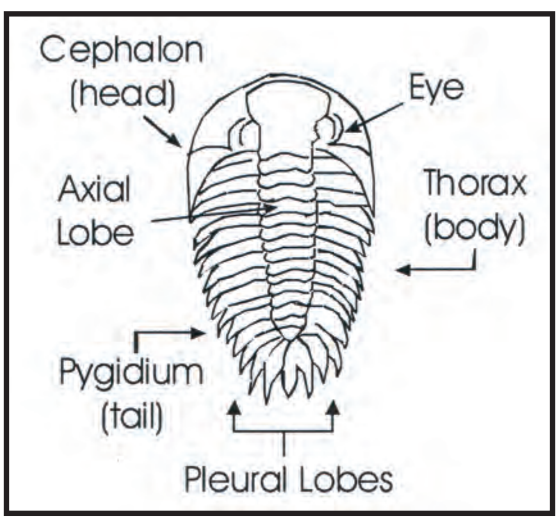


Figure 1. Trilobite body plan (From Fossil Stuff, ©2004. Reproduced with Permission from Paleontological Research Institution, Ithaca, New York).

ments fused into a rigid plate (Fig. 12). The trilobite exoskeleton was composed of a material called chitin, similar in composition to your fingernail.

Because the hard exoskeleton of the trilobite must be molted (shed) periodically to allow it to grow throughout its lifetime, trilobites rarely are found as complete body fossils, but rather their old molted skeletal parts called the cephalon, thorax and pygidium usually are separated. These isolated body parts, which laid around on the seafloor, account for the vast majority of the trilobite fossils.

The size of adult trilobites ranges from 0.25 in. to a few giant forms nearly 30 in. in length. Most trilobites, however, are 0.8–2.7 in. in length and 0.4–1.2 in. wide.

Some trilobites had compound eyes like bees and dragonflies that helped the trilobite to see in all directions at one time in order to find food and/or avoid predators. Some trilobites that lived in very deep waters in the open seas were blind because, in that lightless environment, they didn't need eyes anymore to find food or avoid predators.

Some trilobites possessed spines that functioned for floating or swimming, some served as props to prevent the animal from settling into soupy sediment, while yet others functioned as a protective mechanism to ward off potential predators.

Some trilobites could roll up (enroll) their external skeletons much like roly–poly "pillbugs" and certain insects do today. This behavior pattern probably functioned as a defense mechanism to protect the vulnerable lower or ventral part of the trilobite body to which the soft appendages were attached. The appendages or legs were used for moving around on the seafloor or swimming freely in the open sea. Trilobite legs also had gills on them that functioned for breathing underwater like fish. Most trilobites lived on the seafloor or burrowed just below it in the soft mud.

Scientists can learn about trilobite behavior from trace fossils. For example, crawling trails, feeding trails and resting structures made by trilobites, in and on the seafloor, provide evidence as to how these marine invertebrate animals once moved, ate and rested.

***Isotelus* sp.**

General information about trilobites is found on page 30.

Isotelus, such as shown in this dot–to–dot activity, was among the giants of the trilobites reaching a length of nearly 2.5 ft. Distinguishing characteristics of this particular trilobite include:

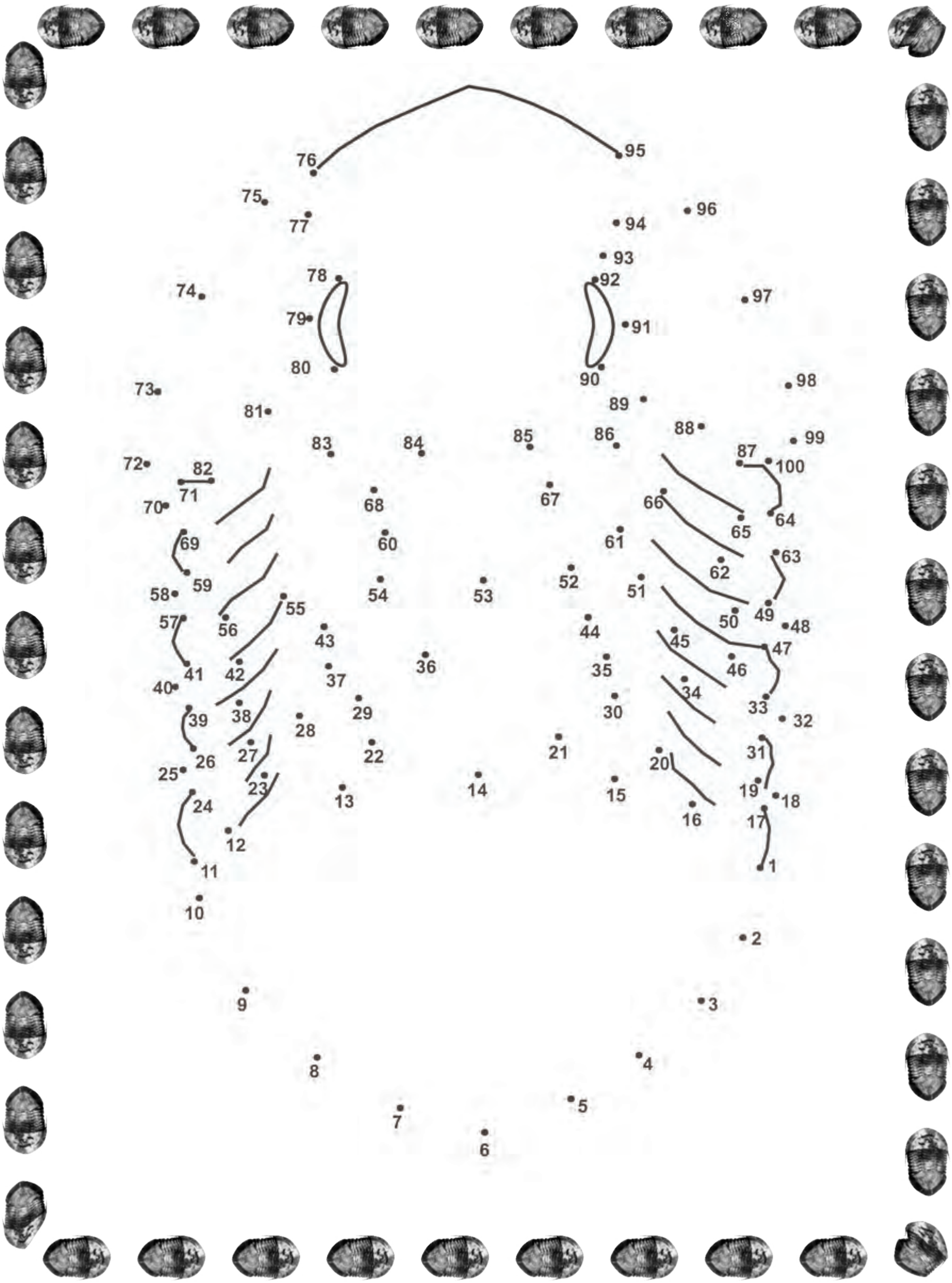
1. Absence of glabellar furrows.
2. Absence of pygidial segmentation.
3. Perfectly smooth cephalon and pygidium.
4. Absence of spines.

Isotelus represents a peculiar form of trilobite that lost every trace of sculpture on the cephalon and pygidium and also, in some specimens, lost their eyes. A burrowing lifestyle is thought to be indicated by blind trilobites that, like *Isotelus*, have smooth dorsal surfaces with decreased lobation. *Isotelus* is restricted to Ordovician–age (~510–438 million years ago) rocks worldwide.

Ranging up to 2.5 ft in length, the largest trilobites found west of the Mississippi River are found in rocks of the Bromide Formation (Ordovician–age, 465 million years ago) in the Criner Hills of Carter County, and in the eastern Arbuckle Mountains near Bromide in Johnston County.

Trilobites are found preserved in rocks throughout the Paleozoic Era (570–290 million years ago) in Oklahoma, but are most common in rocks of the Cambrian, Ordovician, and Devonian Periods. Three dot–to–dot activities will illustrate some of these trilobites found in Oklahoma.

ACTIVITY φ



I am among the giants of the trilobites.

ACTIVITY χ

FACT SHEET

***Phacops* sp.**

General information about trilobites is found on page 30.

Phacops is one of the best known trilobites of the Devonian Period and is well represented in the fossil record on several continents. Its life span (geological range) is from the Silurian Period to the end of the Devonian Period (~438–355 million years ago).

Distinguishing characteristics of this peculiar trilobite include:

1. A thorax (body) usually with 11 segments.
2. A pygidium (tail) with 10 axial segments and 6 pleural segments.
3. A cephalon (head) with an inflated or expanded bulbous, inverted pear–shaped glabella that widens or protrudes markedly toward its anterior (front) margin.
4. Possession of rounded genal angles, but no genal spines.
5. Possession of large, kidney– or bean–shaped, multifaceted compound eyes like those among many modern arthropods.

The compound eye surfaces of *Phacops* sp. were convex outward; hence, the trilobite had a wide range of vision to aid in finding food and warding off potential predators.

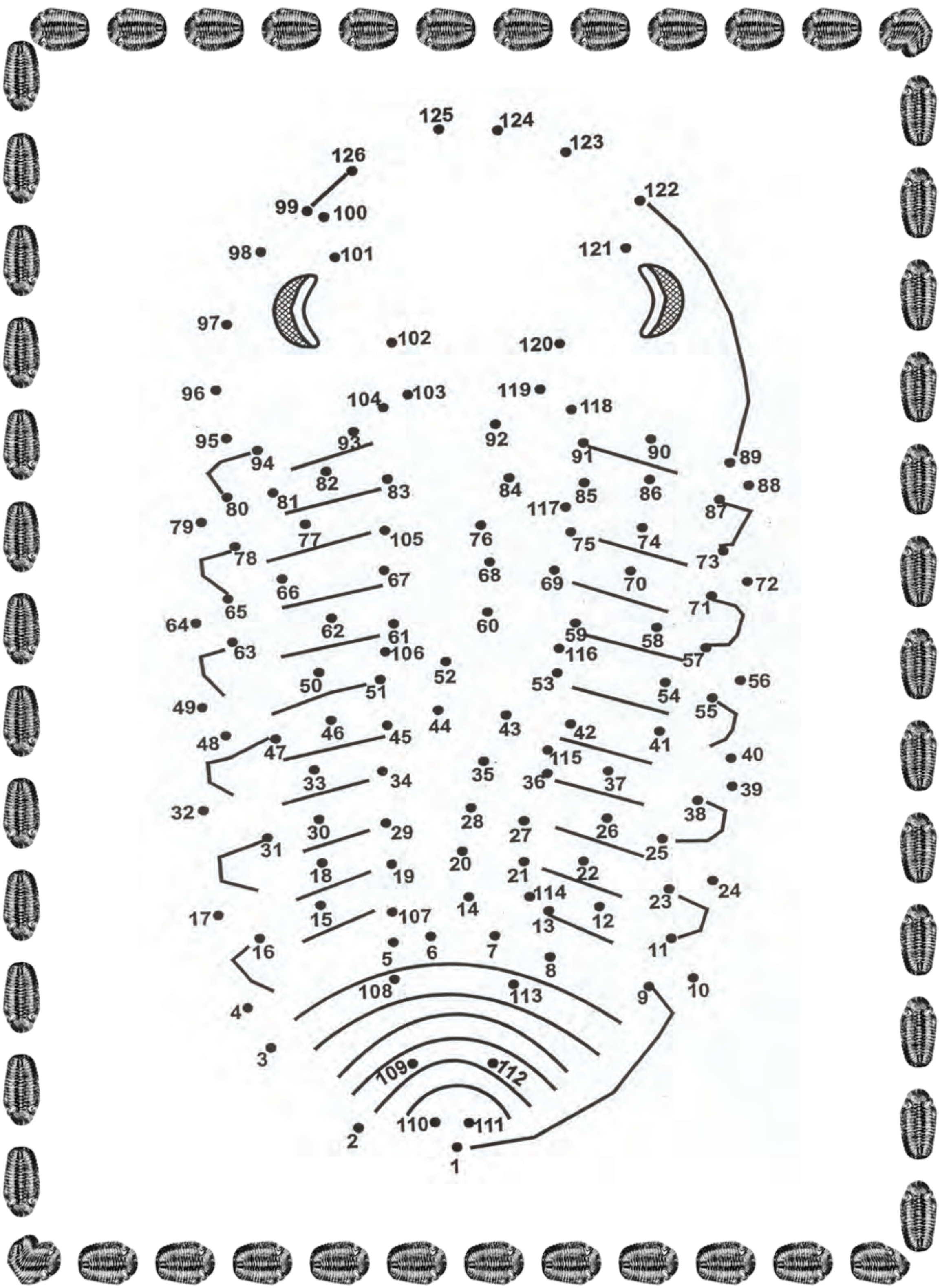
Phacops commonly is found in a rolled up position as a defensive mechanism for survival.

If you compare *Phacops* with *Isotelus* (p. 32), it is not difficult to support the conclusion that in the shape of the glabella and the nature of the eyes, *Phacops* is the more specialized (advanced); whereas, in the type of facial suture, segmentation of the glabella and characters of the thorax and pygidium, *Isotelus* is the more specialized (advanced).

A world famous collecting locality for Early Devonian (~410 million years ago) marine invertebrate fossils is located about 3.0 miles southeast of Dougherty, Oklahoma at White Mound in Murray County, Oklahoma. At this locality, trilobites such as *Phacops* are found in rocks of the Haragan Formation of Early Devonian age (~410–390 million years ago). This locality has been closed to the general public for collecting since the 1950s. However, access can be granted with permission from the landowner and fossils collected for a fee.

WHITE MOUND
Pat and Merylyn Howe
Rt. 1, Box 323, Sulphur, OK 73086
(580) 622–5366

ACTIVITY χ



I have large bean–shaped compound eyes.

ACTIVITY ψ

FACT SHEET

Dicranurus sp.

General information about trilobites is found on page 30.

The major diagnostic features to identify this particular trilobite are:

1. The remarkable, forked, recurved spine on the cephalon that resembles the horns of bighorn sheep.

2. A thorax with 9 segments.

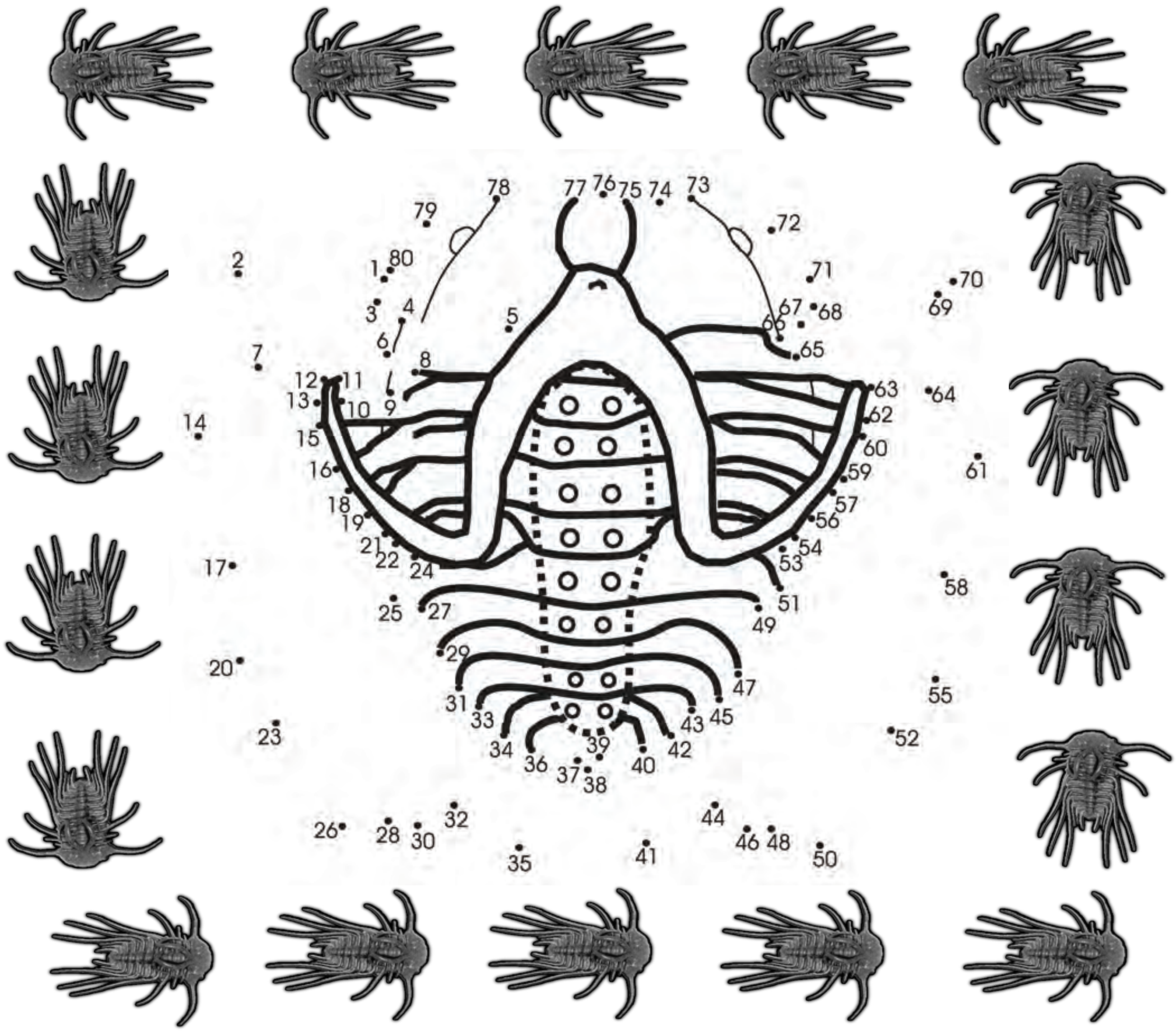
3. A pygidium with a single pair of border spines.

Note the large and abundant spines of this particular trilobite genus. The most highly adapted trilobites probably spent most of their time in the pelagic zone of the open ocean as swimmers or floaters. The best adapted forms for this lifestyle would be those, such as *Dicranurus*, whose surface area was increased by the large spines relative to its weight. These trilobites would tend to settle through the water column very slowly similar to a falling snowflake. Spines also may have been an adaptive strategy whereby they served as props to prevent the animal from settling into oozy sediments. Spinosity was also a protective mechanism to ward off potential predators (the "Porcupine" effect).

It has been suggested that in some trilobites, such as *Dicranurus*, large spines provided attachment places for other small marine life called epibionts that acted to conceal or camouflage the animal. This type of behavior is well known in some modern crabs. Spines may also have provided sensory input to the animal through bristles or setae.

***Dicranurus* is another trilobite found in the Devonian–age Haragan Formation at the world famous fossil collecting locality at White Mound in southeastern Murray County, Oklahoma.**

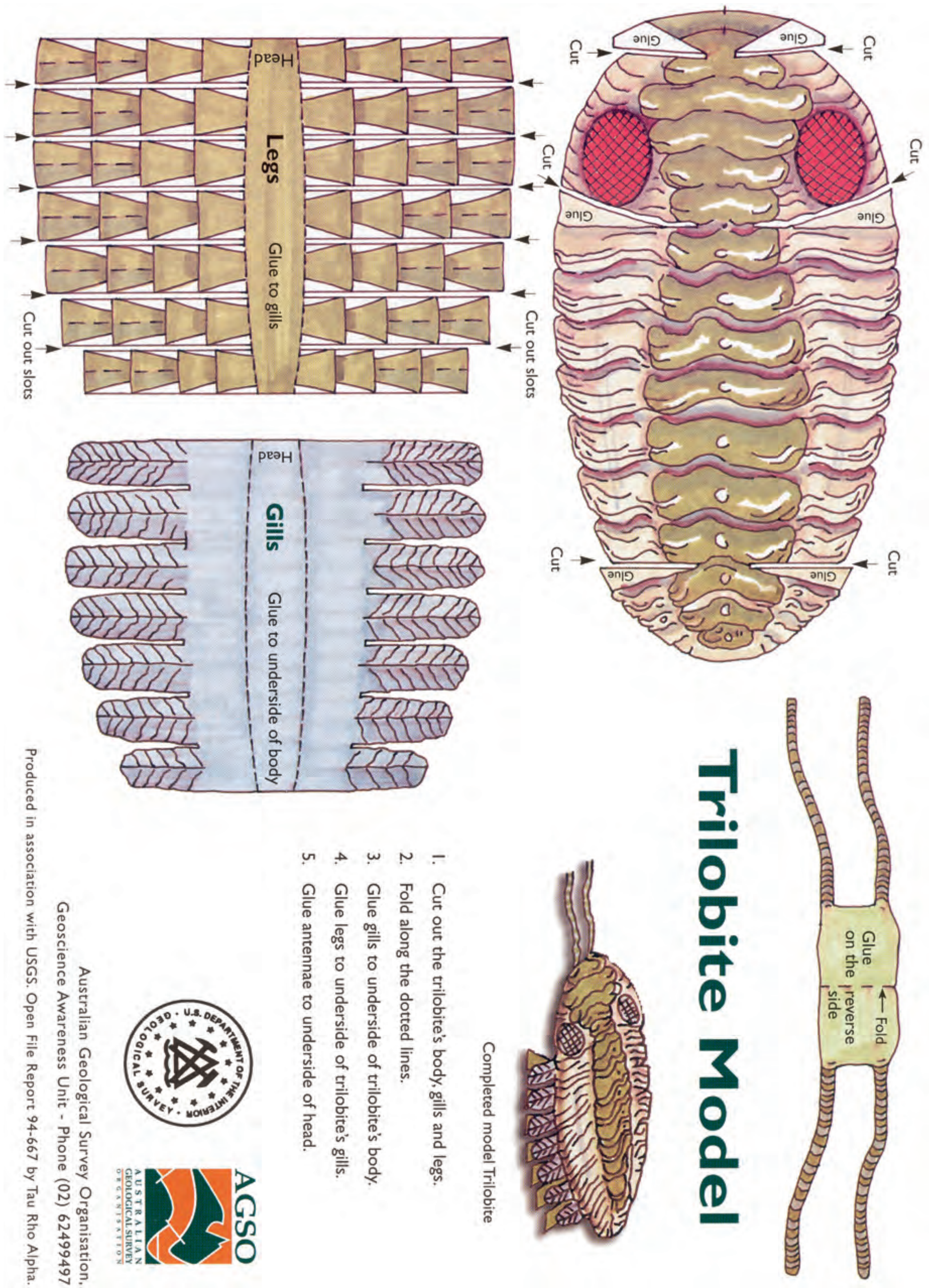
ACTIVITY ψ



As an adaptive strategy for survival, I have numerous large spines.

ACTIVITY SHEET

See page 30 for general information about trilobites.



ACTIVITY ω

FACT SHEET

Ammonoid cephalopods

Before the Mid–18th century, fossils were not understood as the remains of once–living creatures resulting in many myths and legends about their origin across many different cultures. Frequently, fossils were ascribed to have magical or medicinal properties. For example, the Navajo and Indians of the North American Plains carried ammonites in their medicine bags for health and good hunting. The name "Ammonite" came from the Greek ram–horn God called Ammon who had been adopted from the earlier Egyptian Oracle–god Amun. Ammon frequently took the form of a ram with a coiled horn, which looked very much like the beautiful coiled shape of the mysterious fossils. Some legends referred to ammonites as "thunder stones" that fell from the sky, and people who wore these "stones" as amulets around their necks would be safe from lightening bolts. In England, ammonites were frequently interpreted as being coiled petrified snakes that had somehow lost their heads and were often known as "snakestones." Some were fitted with carved heads and sold to pilgrims.

The original discus used by the ancient Greeks in their Olympics was a fossilized ammonite.

Ammonoids belong to the Class Cephalopoda, Phylum Mollusca that also includes gastropods (snails) and bivalves (clams). Mollusks are one of the most diverse groups of invertebrate (have no backbone) animals living today. During most of the Mesozoic Era (Triassic, Jurassic and Cretaceous Periods, ~260–65 million years ago), the seas were filled with swimming ammonoids—extinct relatives of the modern chambered *Nautilus*. Like the modern *Nautilus* (and the related shell–less squids, octopods and cuttlefishes), they were predators. Schools of ammonoids may have behaved like schools of fish do today, preying heavily on other animals in the seas.

Unlike other modern cephalopods, except the Pearly *Nautilus*, ammonoids were equipped with protective tightly coiled chambered shells composed of mineralized calcium carbonate. Because of the hard nature of their shells compared to soft tissues, ammonoids were more readily preserved as fossils than their shell–less soft–bodied cousins, the squids, octopods and cuttlefishes. Their shells range from a few inches to more than 3 ft in diameter—the largest ever found, from Münster, Germany, is 8.5 ft in diameter, weighs 3.5 tons, and is 78 million years old.

The ammonoids lived from the Devonian Period to the end of the Cretaceous Period, between ~410–65 million years ago. More than 2,000 genera of ammonoids are known from the fossil record. These genera evolved and became extinct very quickly, because individual types often appear only briefly in the fossil record.

Ammonoids had long tentacles for arms, a sharp beak for a mouth, an eye for excellent vision, a shell, often ornamented with external ribbing and nodes, and made up of many chambers called phragmocones (Fig. 13). All of the chambers are connected to each other and to the soft body by a fleshy tube called the siphuncle. The siphuncle is the organ for regulating (by gas and water exchange) the buoyancy of the animal in the water. Its marginal position is characteristic of most ammonoids whereas it is centrally located in nautiloids, including the modern *Nautilus*. Transverse calcareous partitions called septa separate the body chambers from the living chamber (Fig. 13). The places where the septa touch the outside walls of the chambers are called sutures. Different types of ammonoids have very distinct suture patterns on their shells. The oldest ammonoids from the Devonian Period have very simple, wavy sutures; later ammonoids have complex wavy sutures much more complicated than their older relatives; the youngest ammonoids from the Cretaceous Period have extremely complex suture patterns that resemble the branches of trees. The variety of shell forms and suture patterns in ammonoid cephalopods were probably adaptations for swimming speeds and feeding strategies at various habitat depths.

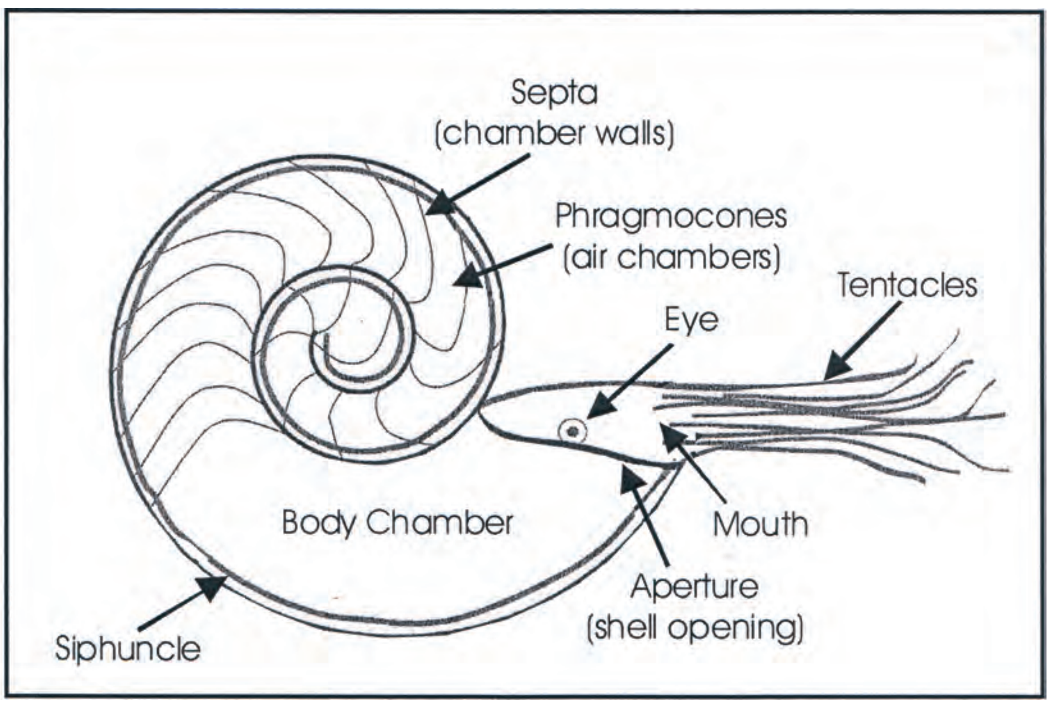


Figure 2. Inside an ammonoid. Fossil Stuff, ©2004. (Reproduced with permission from Paleontological Research Institution, Ithaca, New York).

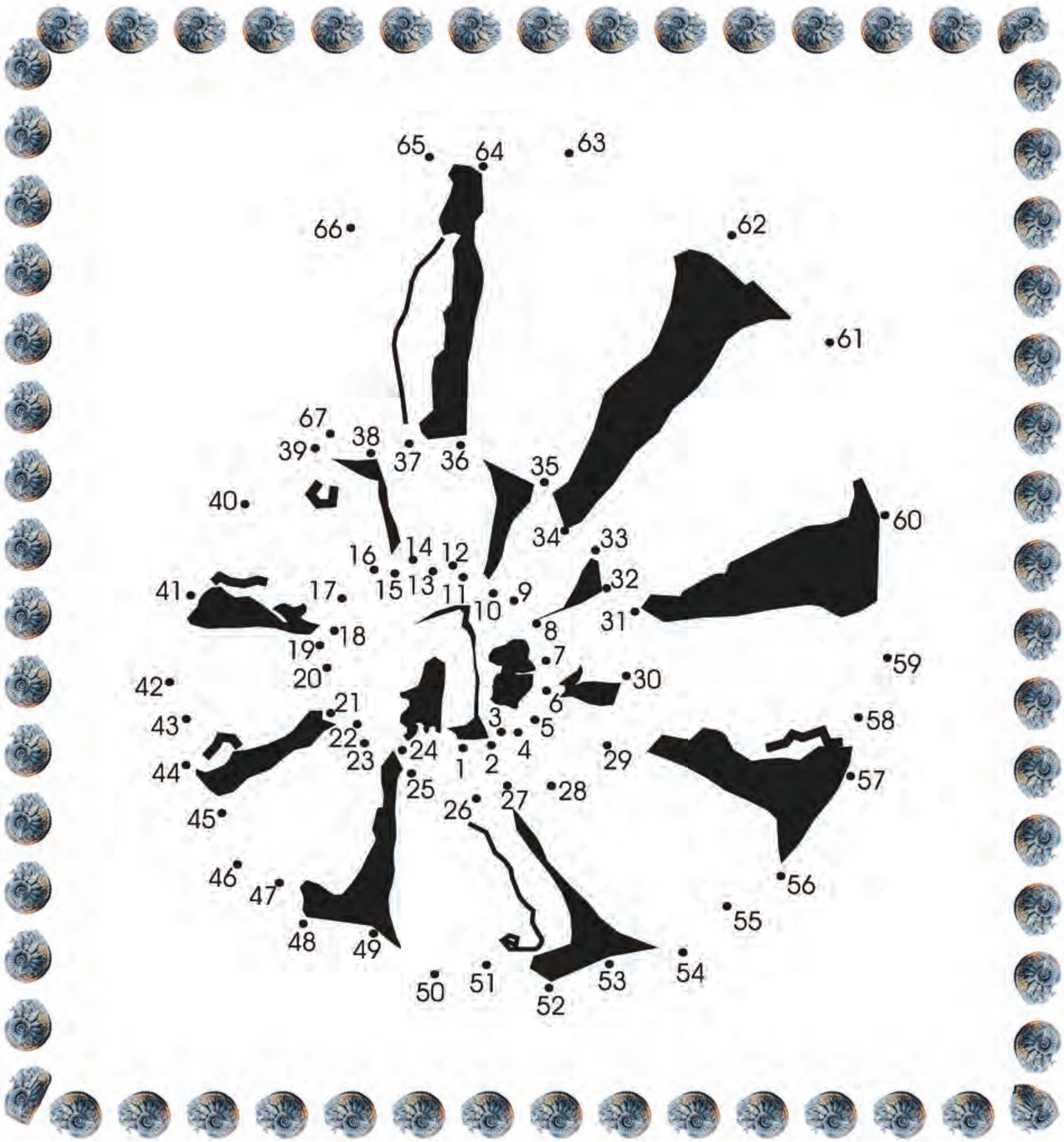
Ammonoids are extinct today, so we have to study their closest living relative, the chambered *Nautilus*, which lives in the Indian Ocean and the tropical western Pacific Ocean, to determine how they ate, moved, reproduced and stayed alive. *Nautilus* is a fast swimmer (reaching speeds over 2 mi/hr), so ammonoids probably were too. *Nautilus* moves using jet propulsion by pushing water out of its shell very forcefully. This is similar to the way a rocket fires, except rockets shoot air out to push them up. Jet propulsion of water out of their body chamber allows *Nautilus* and probably the extinct ammonoids to swim backwards.

All ammonoids were equipped with jaws, some of which resemble those of the modern *Nautilus*, suggesting that these ammonoids, like *Nautilus*, were scavengers, feeding off the seafloor. In some ammonoids, the jaws were not particularly well designed for biting, and paleontologists have speculated that these ammonoids may have fed on plankton (floating microscopic plants and animals). Some ammonoid fossils were found with bite marks on their shells. This suggests that while ammonoids were predators, they were also eaten by bigger predators such as larger fish, sharks, and even large marine reptiles called mosasaurs.

A meteorite impact at the end of the Cretaceous Period was undoubtedly responsible for their extinction. The exact nature of the killing mechanism, however, is unclear because other cephalopods, namely the nautiloids, squids and octopods, survived. Ammonoid cephalopods are among the largest, most abundant and well–known fossils in the Mesozoic Era (~250–65 million years ago).

Ammonoids are popular with Oklahoma collectors, and are found in the lower part of the Duck Creek Member of the Caddo Formation of Cretaceous age (~135–65 million years ago) along the shores of Lake Texoma in southern Oklahoma. Some of the Lake Texoma ammonoids reached diameters of nearly 2 ft. They are commonly found in rock layers associated with irregular echinoids ("heart urchins") and oyster–like bivalves.

ACTIVITY ω



I am related to the modern Pearly *Nautilus*.

ACTIVITY ρπ

FACT SHEET

Brachiopoda ("lamp shells")

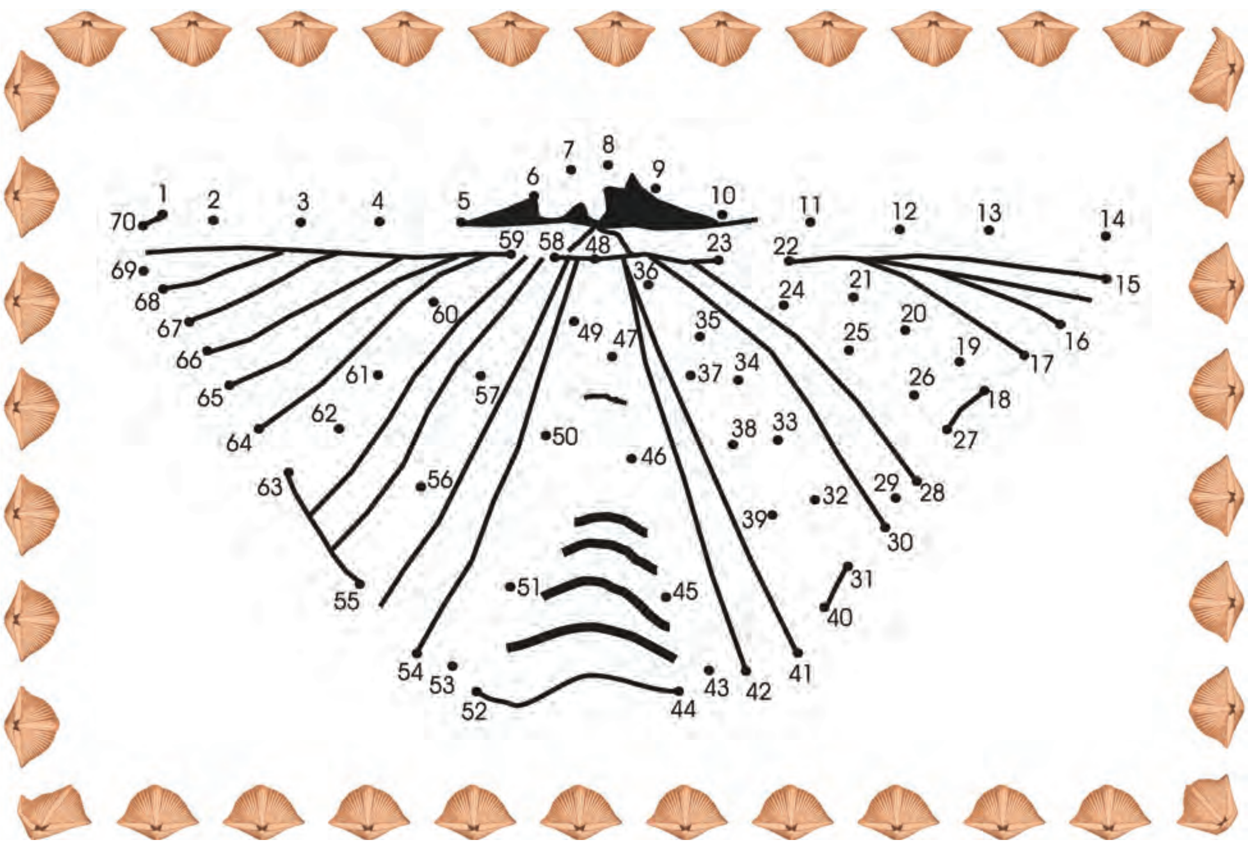
Brachiopods are similar in appearance to ancient Roman (Etruscan) oil lamps, hence the origin of the name "lamp shells." Brachiopods are exclusively marine, bottom–dwelling invertebrate animals whose soft parts are enclosed within a mineralized, two–valved shell. Although they resemble clams, brachiopods possess two unequal valves whereas most clams have two valves of equal size and shape. The two shells or valves are composed primarily of the mineral calcite. The large wing–shaped shells/valves identify the brachiopod in this activity as a spiriferid–type of Silurian age.

Today there are about 70 genera of brachiopods with ~200 species living mainly in the southwestern Pacific, off the coast of Japan, and off the New Zealand coast. Most brachiopods are filter feeders that feed on *phytoplankton* (floating microscopic plants) suspended in the ocean. Brachiopods catch *phytoplankton* with beating cilia (tiny hairs) created by currents. The cilia are located on the tentacles of a food–gathering structure called a *lophophore.*

The earliest brachiopods are preserved as fossils in Cambrian–age rocks (~570–510 million years ago). An unusual brachiopod found living today is called *Lingula. Lingula* is distributed worldwide, has two similar sized valves that are tongue–shaped, and lives in a burrow attached to the ocean floor by a long fleshy stalk called the *pedicle*. The earliest fossils of *Lingula* occur in rocks of Ordovician age (~570–438 million years ago). Because of the long geologic range (life span) of *Lingula*, Ordovician to Recent, it is often referred to as a "living fossil."

Brachiopods are probably the most common fossils found in Paleozoic rocks in Oklahoma. Brachiopods are found in marine rocks from all of the geologic periods in the Paleozoic Era. They are particularly abundant in Ordovician–age (~510–438 million years ago) and Devonian–age (~410–355 million years ago) rocks in the Arbuckle Mountains of south–central Oklahoma.

ACTIVITY 1π



I am the most common fossil found preserved in Paleozoic rocks in Oklahoma.

ACTIVITY 1ρ

FACT SHEET

Nautiloid–type Cephalopod

This fossil is an example of the oldest, most primitive nautiloid–type cephalopod (assigned to the Phylum Mollusca, Class Cephalopoda). They were most abundant during the Paleozoic Era (~570–250 million years ago); today only a single genus, the Pearly *Nautilus*, survives, and is represented by six living species in the Indian Ocean and the tropical western Pacific Ocean.

The shell has the shape of a tapered cylindrical cone, and is divided into a body chamber with many smaller closely spaced chambers separated by simple septa or partitions. Over geologic time, many of the nautiloids developed coiled shells. Nautiloids typically were 6 in. in length, but some attained lengths up to several feet.

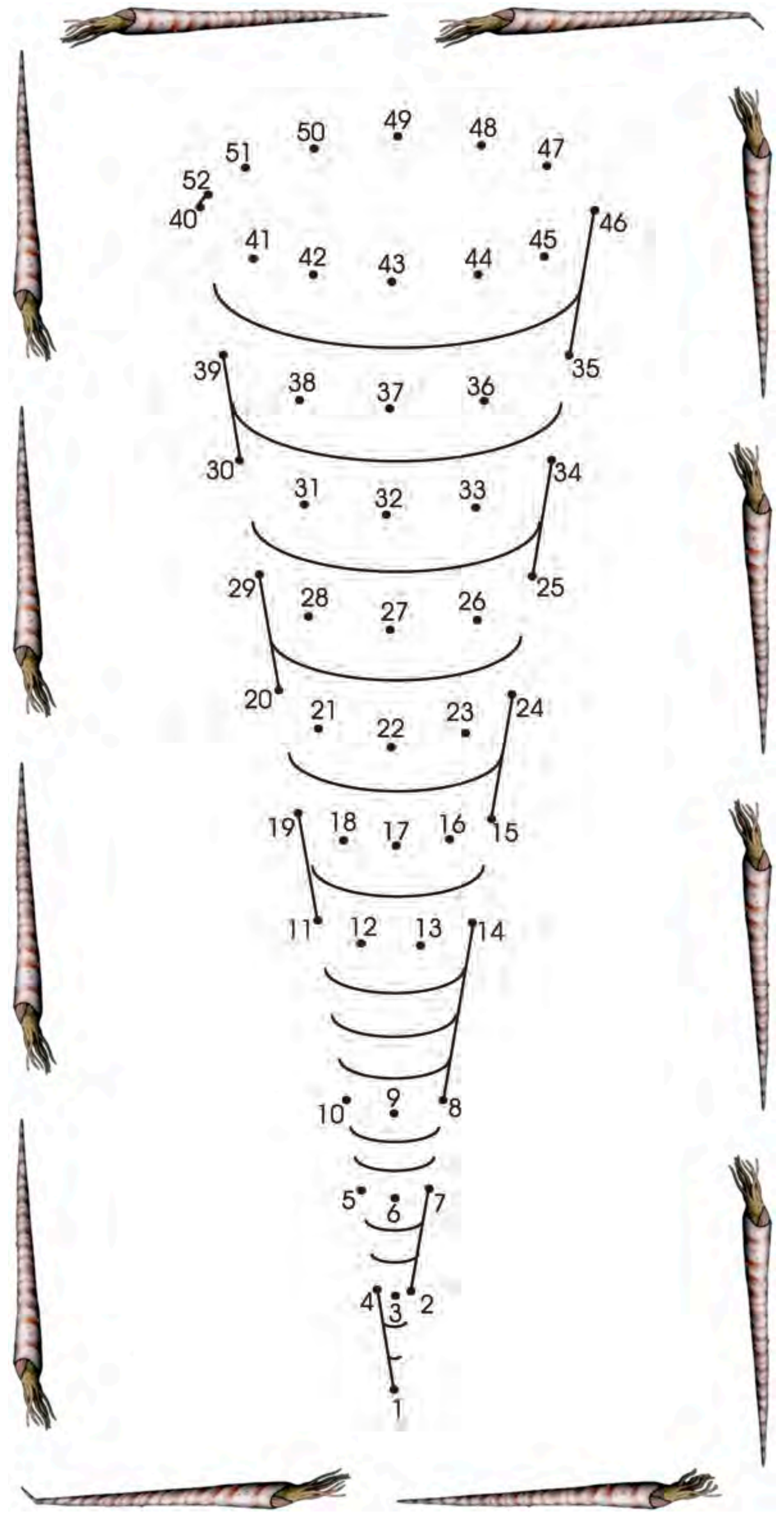
Nautiloids possessed heads with well–developed eyes, as well as grasping tentacles to seize and hold their food. They swam by squirting jets of water out of their body cavity by rhythmic muscular contractions.

Many nautiloids lived in shallow seas as scavengers, or preyed on small marine animals. They were active swimmers with the shell positioned horizontally in the water. Many adjusted their buoyancy by moving liquid along the margin of the shell from chamber to chamber or by altering the level of gas in their chambers. This allowed them to move up and down in the water column. Other nautiloids probably were poor swimmers, living on the seafloor feeding on small, bottom–dwelling animals. Mesozoic and Early Tertiary nautiloids, like the living *Nautilus*, had a strong beak with two parts resembling that of a parrot. Composed of the mineral calcite, this beak preserved well. The beak was adapted for either cutting fish or crushing crustaceans.

Modern relatives of fossil cephalopods include squids, octopods and cuttlefishes, all of which do not have shells.

The Buckhorn asphalt quarry south of Sulphur, Oklahoma contains one of the world's pristine preserved aragonitic molluscan faunas. As a result of asphalt impregnation, these molluscan faunas of Middle Pennsylvanian age (~300 million years ago), particularly the nautiloid–type cephalopods and gastropods, retained their original aragonite mineralogy, and their original color and iridescence.

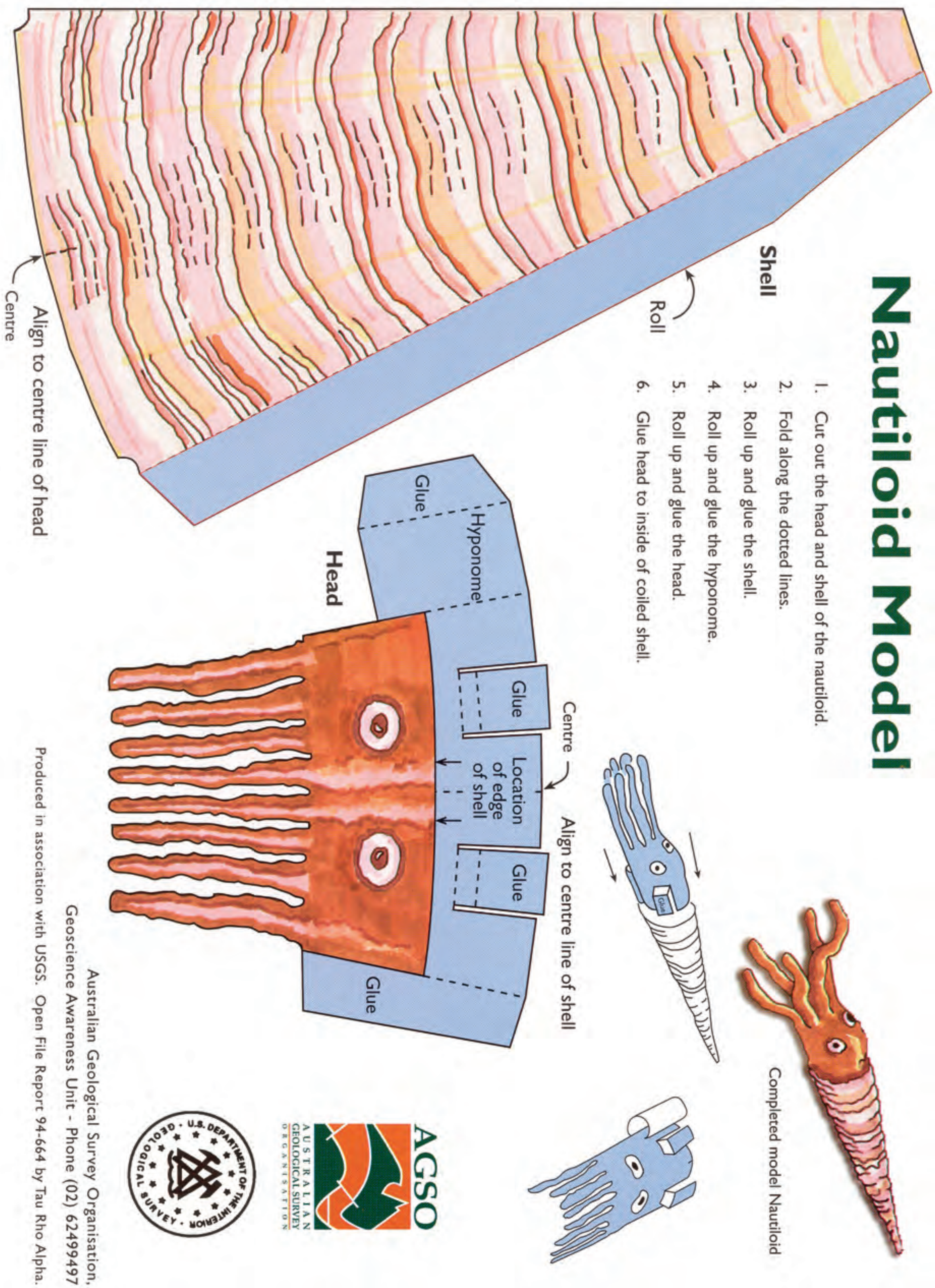
ACTIVITY 1ρ



I am related to the living Pearly *Nautilus*.

ACTIVITY SHEET

See page 45 for general information on nautiloid cephalopods.



ACTIVITY 1ς
FACT SHEET
Echinoids

Echinoids have been recognized longer than have most other fossils; indeed, they were prized for amulets by prehistoric inhabitants of Europe. Clues as to their probable values date from about the time of Christ, for Pliny recited a belief popular in his time that these creatures (then called *brontia*) fell from the sky during thunderstorms ("thunder stones") and thereafter would safeguard their bearer from being struck by lightning.

Irregular echinoids ("heart urchins" and "sand dollars") are members of the Phylum Echinodermata (spiny–skinned invertebrate animals), which include starfish, brittle stars, sea urchins and crinoids ("sea lilies"). Irregular echinoids are rarely circular in plan view like regular echninoids ("sea urchins"), but they may be subtly pentagonal (5–rayed); they are characteristically elongate, heart–shaped, and bilaterally symmetrical. Their skeleton ("test") is composed of aggregations of calcite plates surmounted by spines of various sizes and shapes.

Irregular echinoids first appear in the Jurassic Period (~205–135 million years ago) and consist of the furry, discoidal sand dollars and the bristling, burrowing heart urchins. Most of the irregular echinoids are burrowers, living at or under the surface of bottom sediments. They maintain an open channel to the surface, through which food and water (oxygen source) are brought down to the animal.

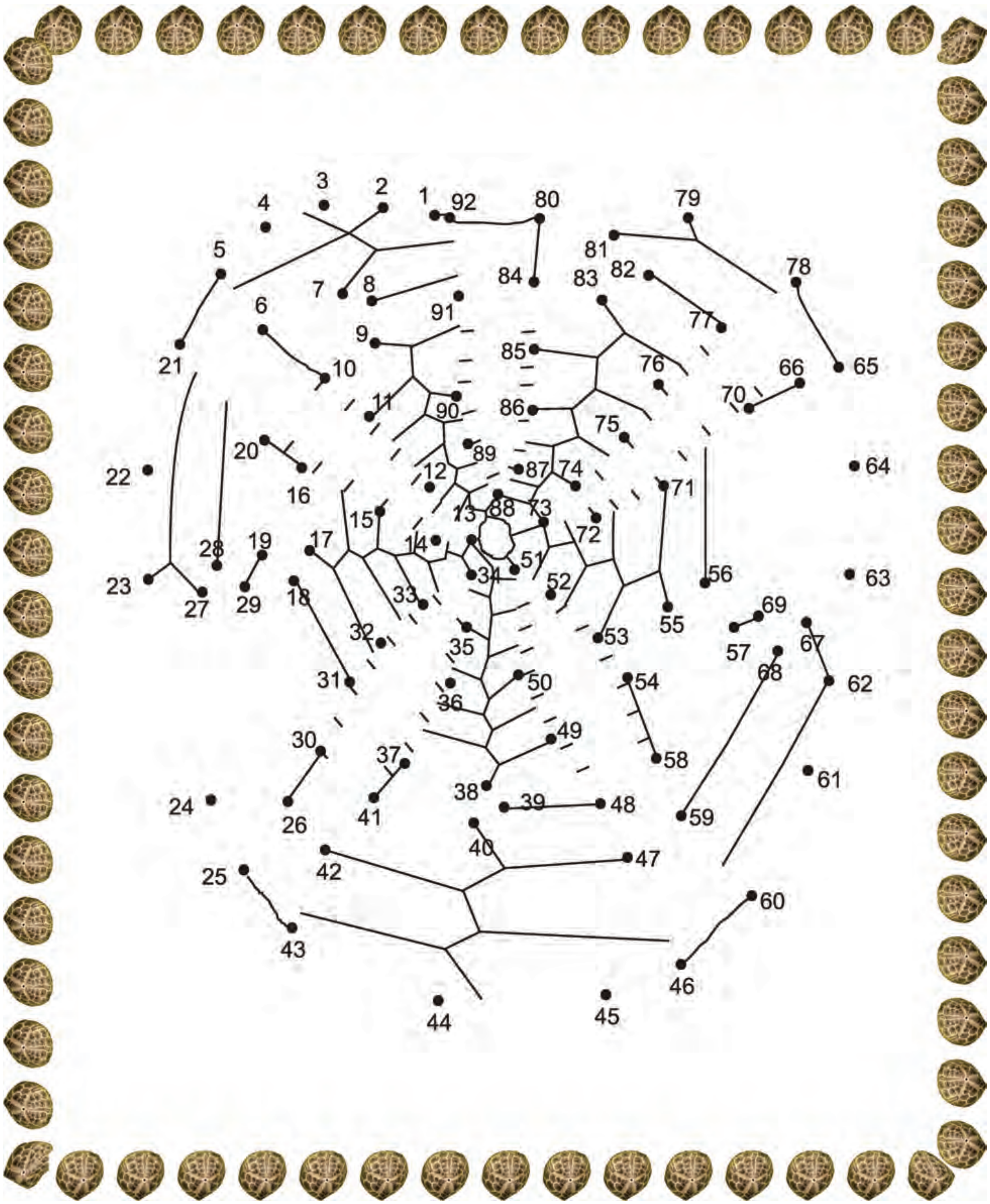
Sand dollars live in large colonies on sandy or muddy bottoms less than 700 ft deep. However, some sand dollars may extend to depths of ~6,000 ft. Most sand dollars live flat on the bottom, the aboral surface flush with the sediment or barely covered with a thin veneer of sand. Some burrow and move about by means of short fur–like spines. Food is obtained from the sediment, by selection of alga–covered sand grains and bits of organic matter, which are passed along the five food grooves (ambulacral) areas to the mouth.

Some specialized irregular echinoids called spatangoids (for example the genus *Echinocardium*) live in burrows up to 6 in deep. Fresh sea water is introduced, and stale water is expelled through a mucus–lined canal which extends to the sea floor. This canal also permits the long tube feet (prehensile branches of water vascular system), having finger–like branches at the end, to select choice morsels of organic matter and draw them into the burrow. *Echinocardium* burrows chiefly by means of its spines, many of which are shovel–shaped for this purpose.

Irregular echnoids are ruggedly constructed and, because of their burrowing habits, more readily preserved than regular echinoids.

Irregular echinoids are very common in the lower part of the Duck Creek Member of the Caddo Formation of Cretaceous age (~135–65 million years ago). These rocks are found (outcrop) along the shores of Lake Texoma in southern Oklahoma. The echinoids are commonly found in association with oyster–like clams and ammonoid cephalopods.

ACTIVITY 1ς



I am related to starfish, brittle stars, sea urchins and crinoids.

ACTIVITY 1σ

FACT SHEET

Archaeopteris

This tree–size, spore–producing plant has fernlike leafy branches carried on the top half to one–third of its trunk. It is similar to some conifers and is called *Archaeopteris*. *Archaeopteris* is thought to be the earliest known modern tree. Evidence supporting this theory is based on four characteristics that compare this tree with early seed plants.

1. Branches were composed of leafy shoots that were opposite each other (“lateral branching”).
2. It was capable of producing roots from stem cuttings as do modern trees.
3. It possessed nodal zones or areas where new branches might develop.
4. It used “wood anatomy strategies” to facilitate the yearly growth of branches as evidenced by woody growth under branch attachment areas similar to trees living today.

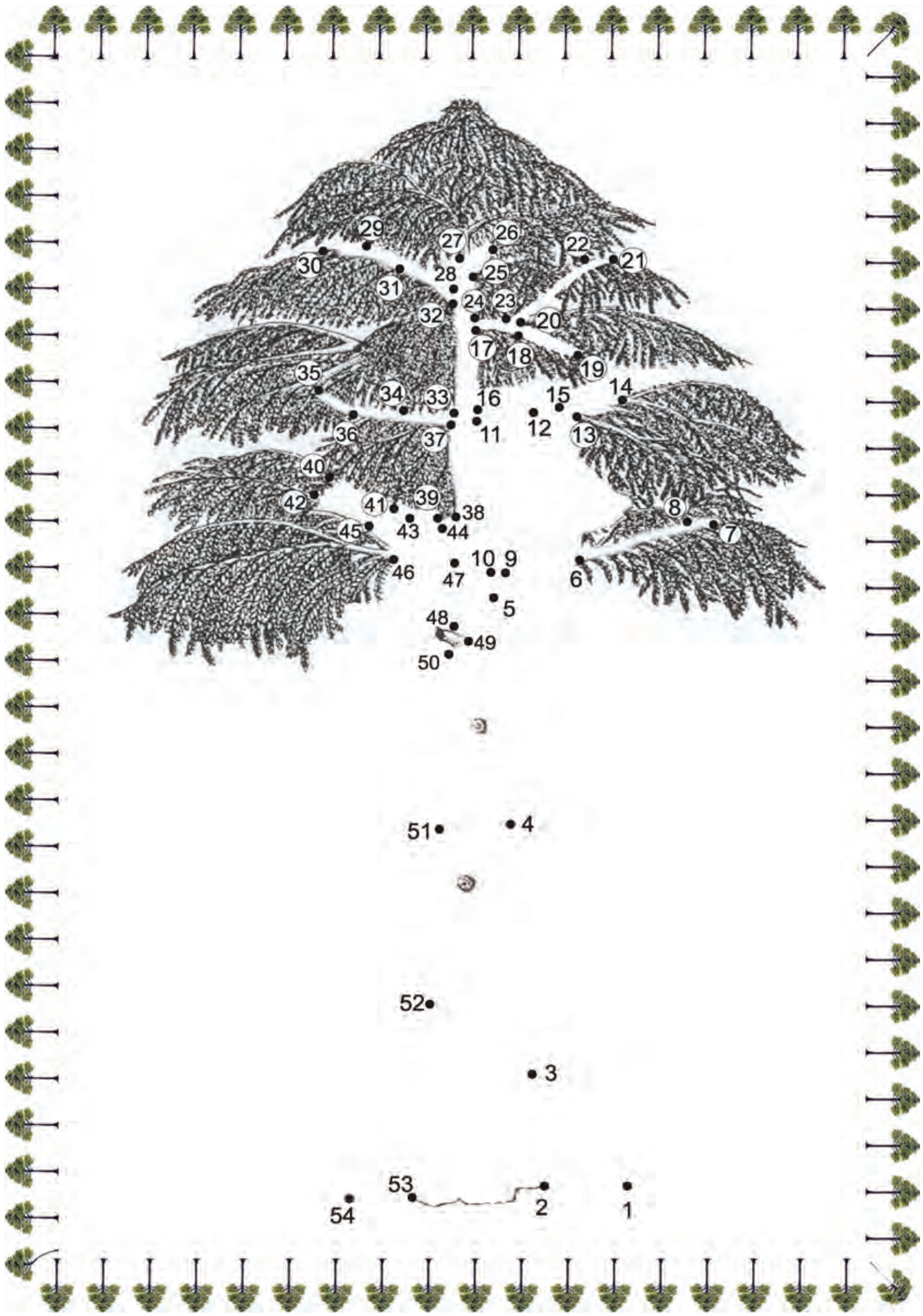
Fossil conifer–like wood identified as *Callixylon* has been identified to represent the roots, woody trunk, and branches of *Archaeopteris*.

Archaeopteris is assigned to the progymnosperm—intermediate between true ferns and gymnosperms (naked seed plants). The longest single trunk segment of *Callixylon* known to date is 27.8 ft in length and was found in Texas.

Specimens of *Callixylon* are found preserved in the black, organic–rich Woodford Shale of Late Devonian (~370 million years ago) to Early Mississippian (~340 million years ago) age throughout Oklahoma. The specimen with the largest trunk diameter is 5.0 ft across, and is a petrified stump reconstructed at the entrance of East Central State University in Ada, Oklahoma. These trees formed an extensive forest during the Devonian Period (~420–355 million years ago) in the vicinity of Ada, Oklahoma.

Specimens have also been found in southeastern Morocco. Specimens typically are found associated with a floodplain woodland environment.

ACTIVITY 1σ



I am considered to be the earliest known modern tree.

ACTIVITY ρτ

FACT SHEET

Plant fossil (*Pecopteris*)

The Carboniferous Period was a time of warm temperatures, and extensive lush forests and swamps that were densely populated with a great variety of plants (the parent material of coal). American scientists divided this period into two smaller, distinct periods—the Mississippian and the Pennsylvanian that lasted from ~360–300 million years ago. Ancient Carboniferous forests probably resembled modern–day coastal swamps such as the Florida Everglades, Okefenokee Swamp in Georgia, Snuggedy Swamp in South Carolina, and the Great Dismal Swamp in North Carolina.

Many primitive vascular plants grew during the Carboniferous Period in Earth's history including lycopods such as *Lepidodendron*, also known as a scale tree, that could grow to 100 ft tall, and sphenopsids like *Calamites*, which are the ancient cousins of modern–day horsetails (e.g. *Equisetum*), with jointed stems and whorls of leaves at the intersection of the stem segments, and seed ferns.

As vegetation died and fell into the swamp, much of the plant debris was submerged and buried rapidly. This process excluded oxygen, and prevented decay and attack by decomposer organisms except for anaerobic bacteria. Over considerable periods of time, the vegetation was compacted by the weight of subsequent overlying sediments to form peat, a mat of unconsolidated partially decayed plant material. The typical ratio of noncompacted peat to coal thickness is about 10:1. Therefore, to form any sizable commercial coal seam requires a very large quantity of vegetation. Through the gradual escape of volatile hydrocarbon compounds (such as methane CH_4) from plant tissues, peat is converted to coal, which is more compact and contains a higher percentage of carbon. Increased burial and compaction over time produced better grades of coal (e.g. bituminous and anthracite), that is, coal with greater heating values and less polluting soot. Coal formation is a continuous ongoing process in modern–day swamps. The lush vegetation that grew in Carboniferous swamps and forests formed vast coal beds that are mined today in Pennsylvania, Ohio, Kentucky, West Virginia, eastern Oklahoma, Missouri, and Kansas.

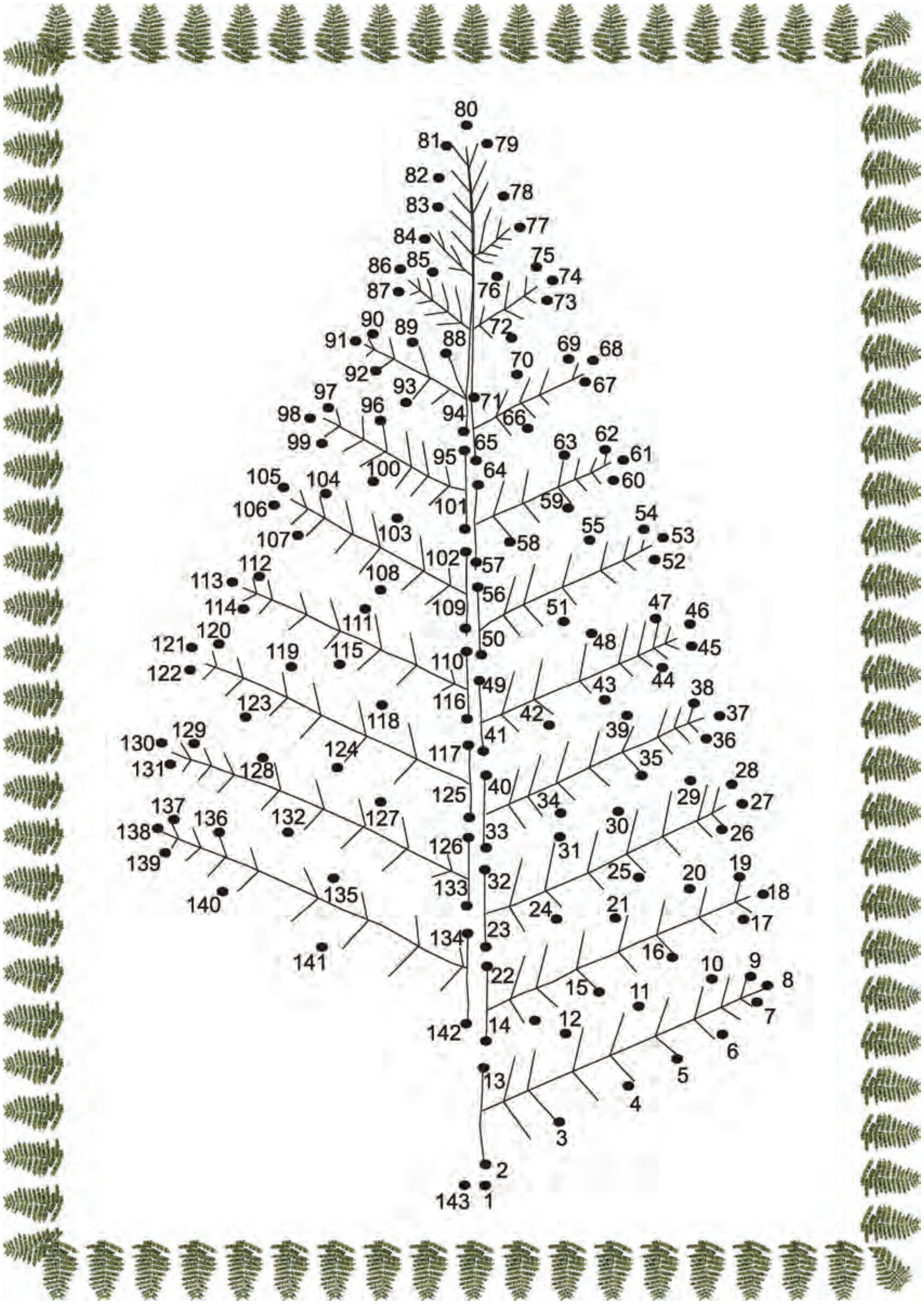
These forested swamps and mires that became peat–producing ecosystems stretched across the paleoequator. All of these primitive vascular plants, such as seed ferns, horsetails and scale trees, consumed massive amounts of carbon dioxide from the atmosphere to fuel photosynthesis and released much oxygen as a by–product. The oxygen–rich atmosphere during the Carboniferous Period reached 30–35% (compared to 21% today). Some scientists believe that this high oxygen content, along with the warm temperatures and moist conditions, favored some plants and arthropods, such as insects (e.g. dragonflies) and millipede–like forms, to reach gigantic sizes.

Near the end of the Carboniferous Period, Africa collided with eastern North America, an event that formed the Appalachian Mountains. Vast lowland forested swamps, with plants like giant club mosses, true ferns, horsetails and *Cordaites* (conifer–like plant), stretched across the lowlands to the west of the rising Appalachians. By the end of the Carboniferous Period, the Earth's continents were moving toward a single landmass called Pangaea.

Paleozoic land plants have contributed directly or indirectly to the Industrial Revolution, and the overall general well being of Western civilization for more than 200 years. Coal beds still constitute one of the Earth's great reservoirs of stored energy. Coal is abundant in the United States and will continue to play a major role as an energy source as our reserves of petroleum are consumed. Along with petroleum and natural gas, coal is considered a nonrenewable fossil fuel; that is, an energy source that formed from plant materials over millions of years of geologic time.

This dot–to–dot activity shows a single frond of a true fern, *Pecopteris*, one of the common plants inhabiting ancient coal swamps. The fronds (compound leaves divided into leaflets) commonly were 5–6 ft in length. True ferns produced spores, not cones or seeds. The spores developed in cases called sporangia. True ferns similar to those living in today's woodlands were common in Carboniferous forested swamps. These true ferns formed the middle story of vegetation in the coal swamp forests reaching heights of 10–14 ft below the taller canopy composed of the scale trees and scouring rushes. The fronds (compound leaves) are often found associated with coal deposits in eastern Oklahoma. They are preserved as black carbon films on the bedding plane surfaces of shales, just above or below a coal bed.

ACTIVITY ρτ



I am one of the most common plants living around ancient forested coal swamps.

REFERENCES

American Paleontologist, 2003, Fossil focus—Algerian ammonites, v. 11, no. 2, p. 16.

_____, 2004, Fossil stuff—Trilobite body plan, v. 12, no. 4.

_____, 2005, Fossil stuff—Inside an ammonoid, v. 13, no. 2.

Australian Geological Survey Organization, Nautiloid and trilobite models, produced in association with United States Geological Survey, Open–file Report 94–664 by Alpha, T.R.

Balducci, S., 2009, Carboniferous plants: American Paleontologist, v. 17, no. 1, p. 9.

Black, R.M., 1970, The Elements of Paleontology: Cambridge University Press, 339p.

Colbert, E.H., 1961, Evolution of the Vertebrates: John Wiley & Sons, Inc., 479p.

Heaton, M.J., 1979, Cranial anatomy of primitive Captorhinid reptiles from the Late Pennsylvanian and Early Permian–Oklahoma and Texas: Oklahoma Geological Survey Bulletin 127, 84p.

Kessler, S.E., 1994, Mineral Resources, Economics, and the Environment: Pearson Education, 391p.

Kissel, R., 2009, A sale of a tale: American Paleontologist, v. 17, no. 3, p. 22–23.

Moore, R.C., (ed.), 1957, Treatise on Invertebrate Paleontology, Part L–Mollusca 4, Geological Society of America and University of Kansas Press, 490p.

_____, 1959, Treatise on Invertebrate Paleontology, Part O–Arthropoda, Geological Society of America and University of Kansas Press, 560p.

_____, 1965, Treatise on Invertebrate Paleontology, Part H–Brachiopoda, v. 1, Geological Society of America and University of Kansas Press, 521p.

_____, 1965, Treatise on Invertebrate Paleontology, Part H–Brachiopoda, v. 2, Geological Society of America and University of Kansas Press, 404p.

Moore, R.C., Lalicker, C.G., and Fischer, A.G., 1952, Invertebrate Fossils: McGraw–Hill Book Co., 766p.

Olson, E.C., 1967, Early Permian vertebrates: Oklahoma Geological Survey Circular 74, 111p.

Olson, E.C., and Barghusen, H., 1962, Permian vertebrates–Oklahoma and Texas: Oklahoma Geological Survey Circular 59, 68p.

Prothero, D.R., 1998, Bringing Fossils to Life: An Introduction to Paleontology: McGraw–Hill Book Co., 457p.

Suneson, N., 1999, The GEE(whiz!)OLOGY of Oklahoma: Oklahoma Geological Survey, Information Series 7, 20p.

_____, 2000, “Is this dinosaur dung?”: Oklahoma Geological Survey, Information Series 8, 36p.

U.S. Department of Energy—Office of Fossil Energy, 1992, Dinosaurs and power plants—Teacher’s guide: Paleontological Research Institution, 2004, Kid’s Newsletter, v. 9, no. 1.

Whitely, T.E., 2004, Spininess in trilobites: American Paleontologist, v. 12, no. 4, p. 18–20.

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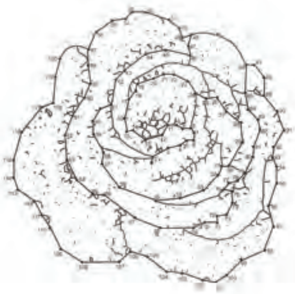
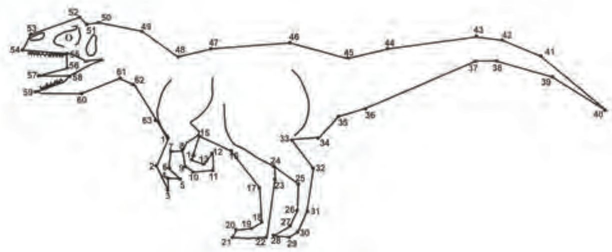
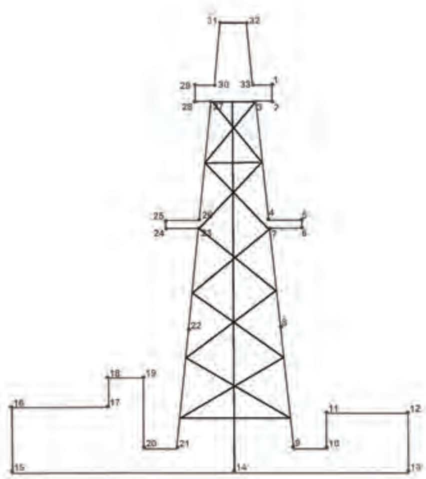
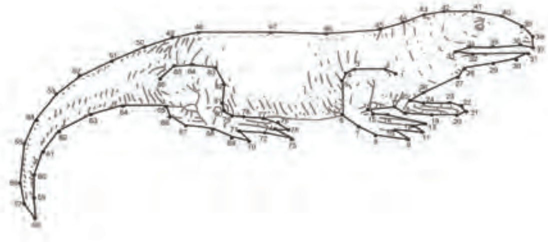
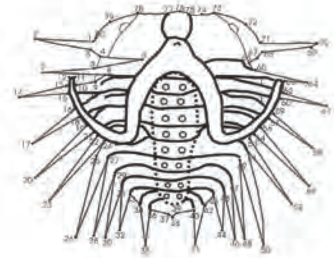




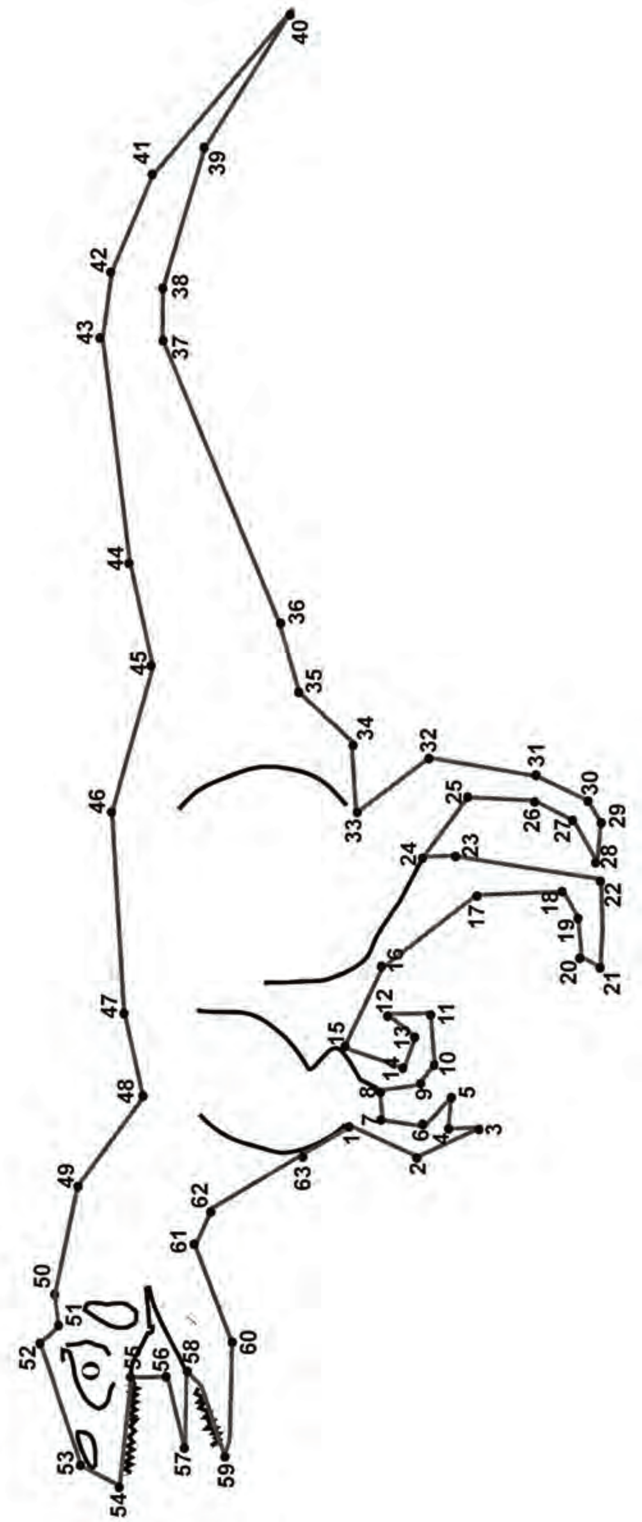
Activity Answer Key





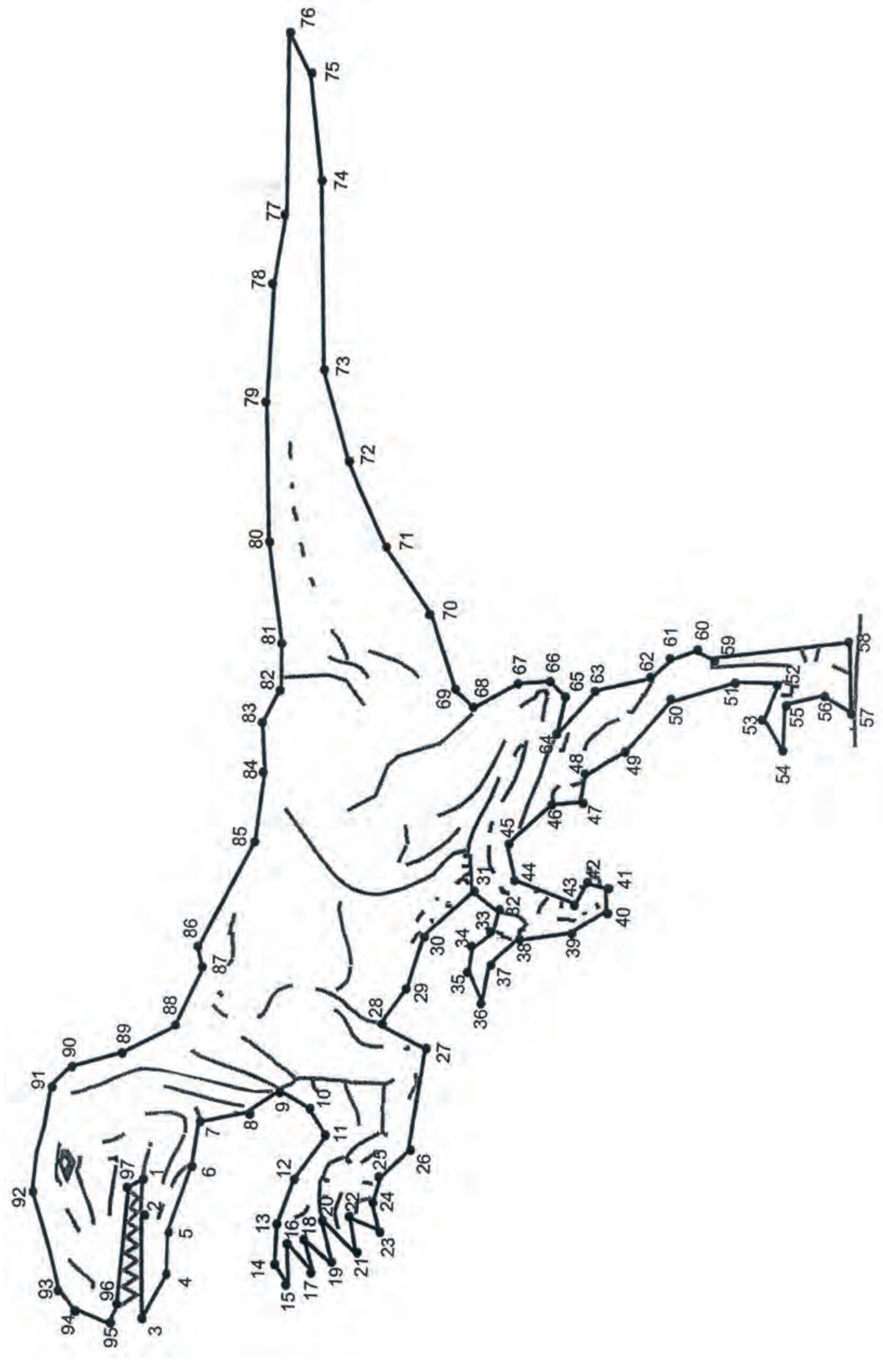


ACTIVITY ρ



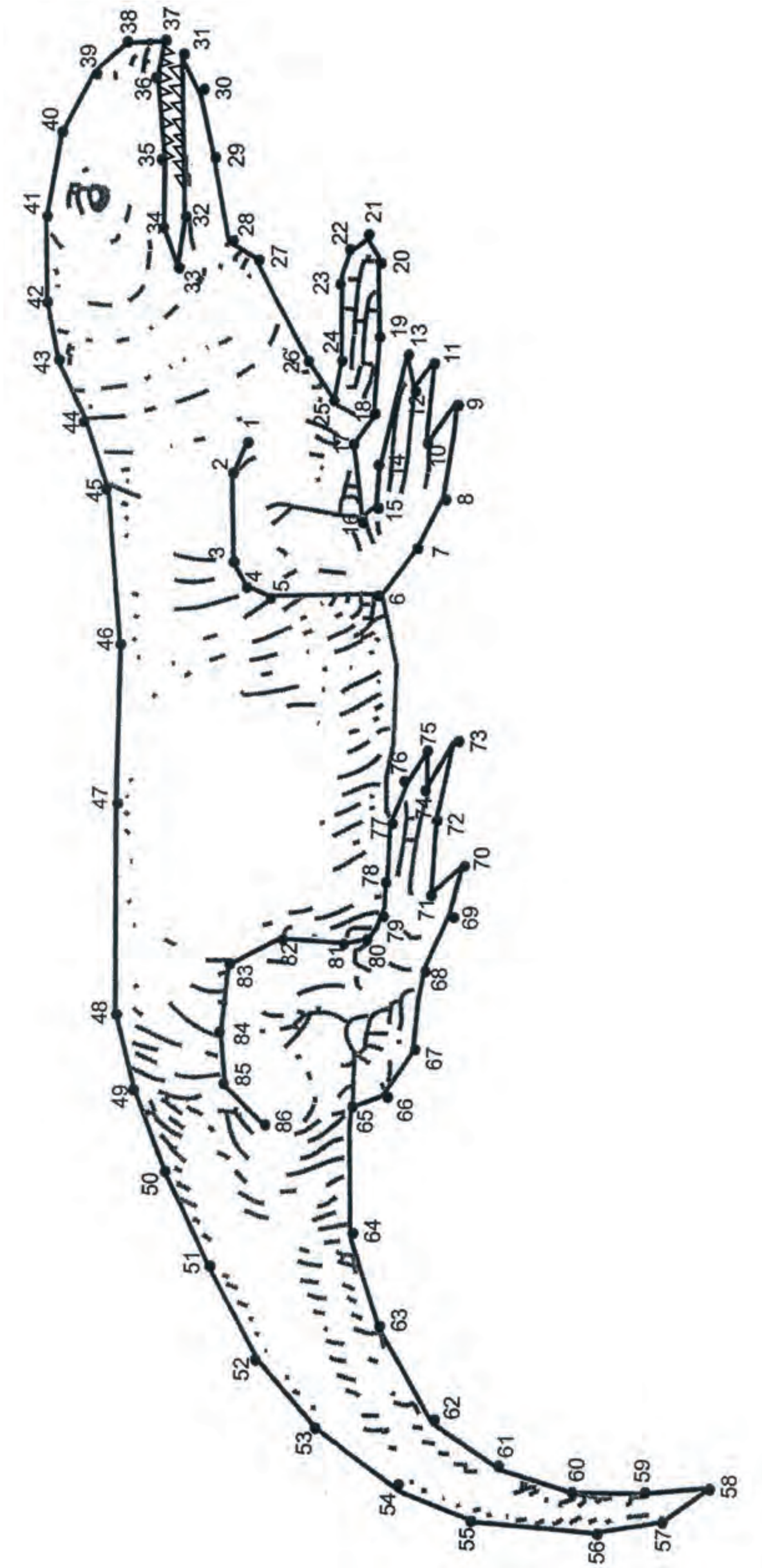
I am *Saurophaganx maximus*,
a carnivorous dinosaur.

ACTIVITY ς



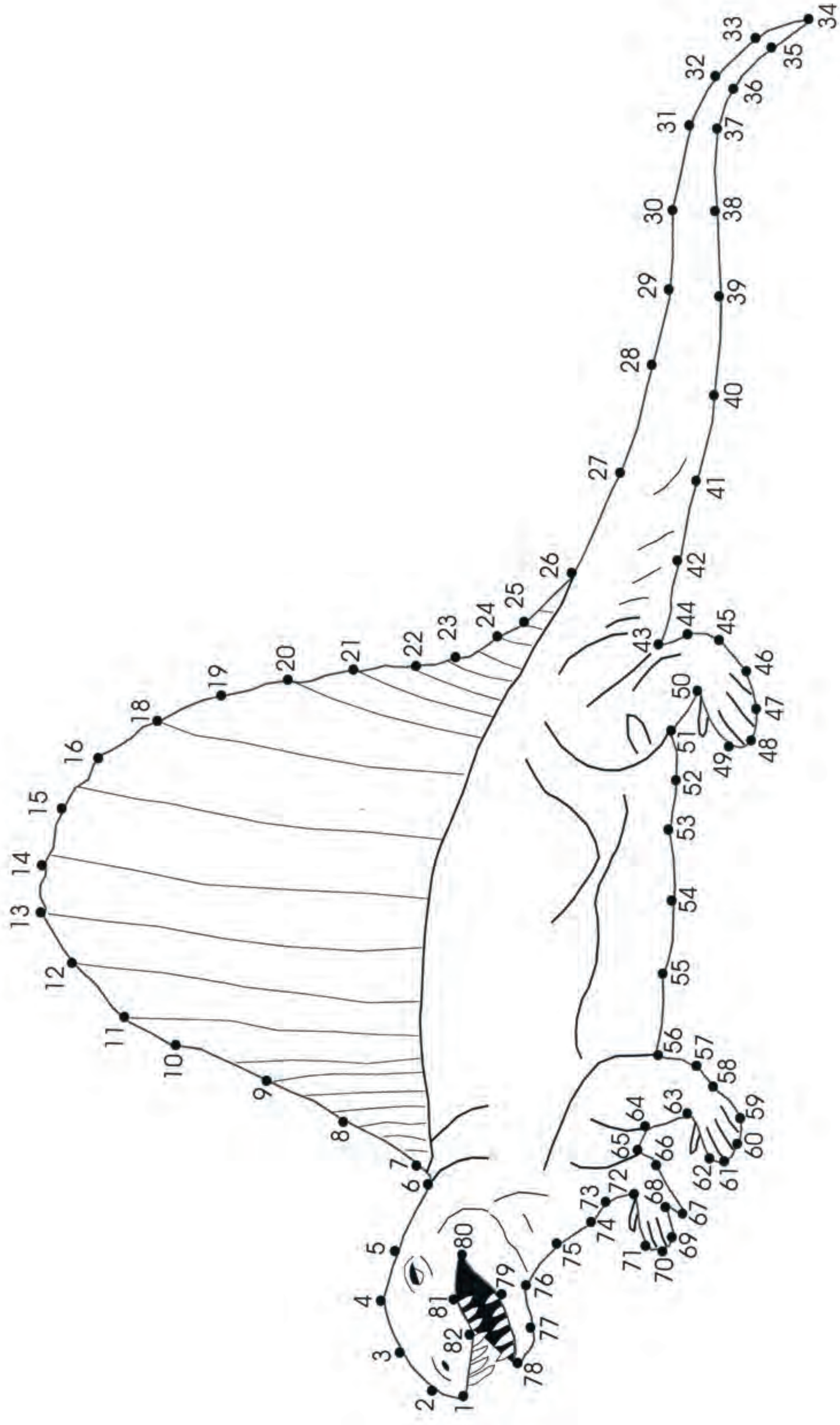
I am *Deinonychus*

ACTIVITY σ



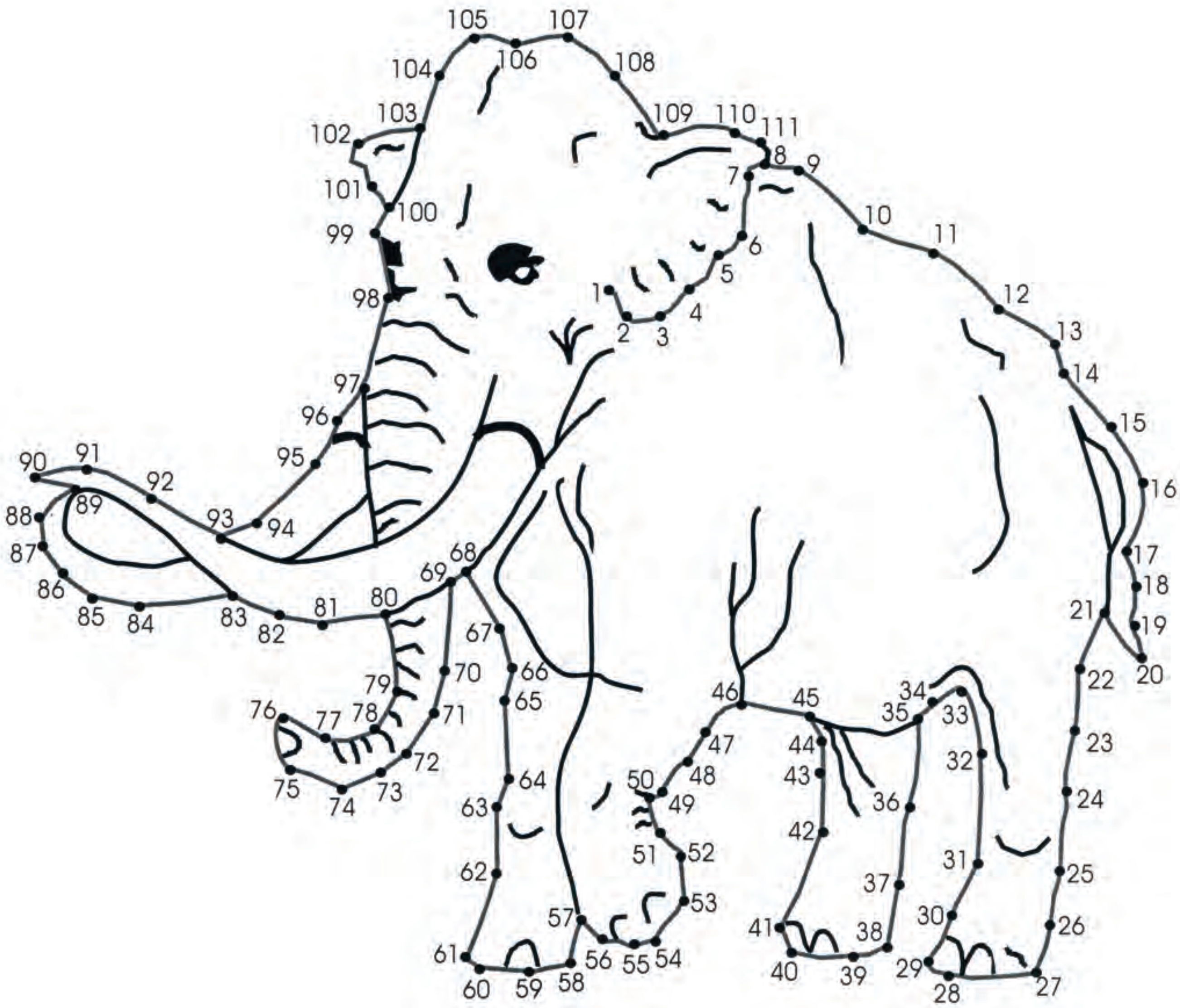
My name is *Captorhinus*.

ACTIVITY τ



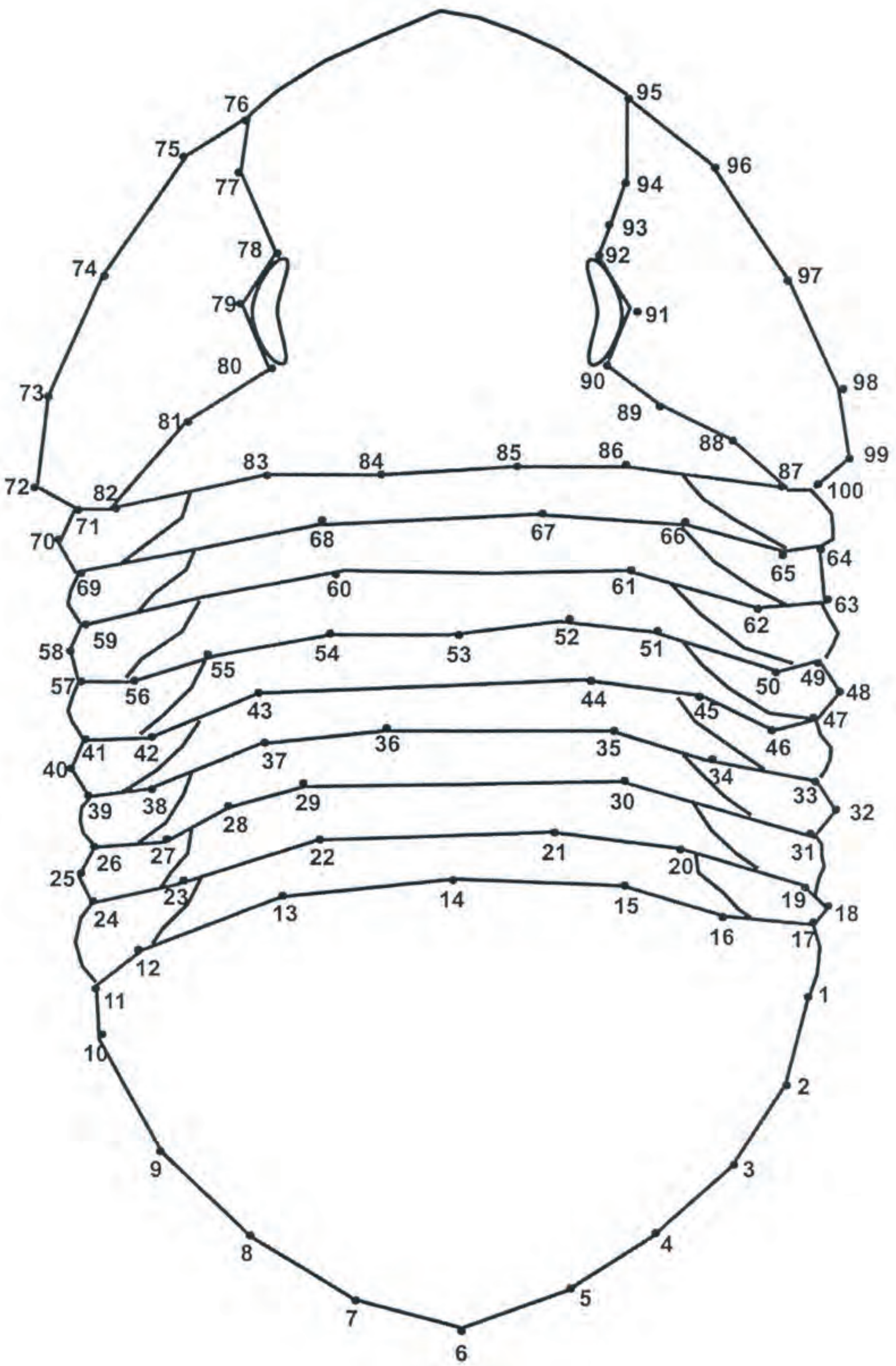
I am called *Dimetrodon*.

ACTIVITY υ



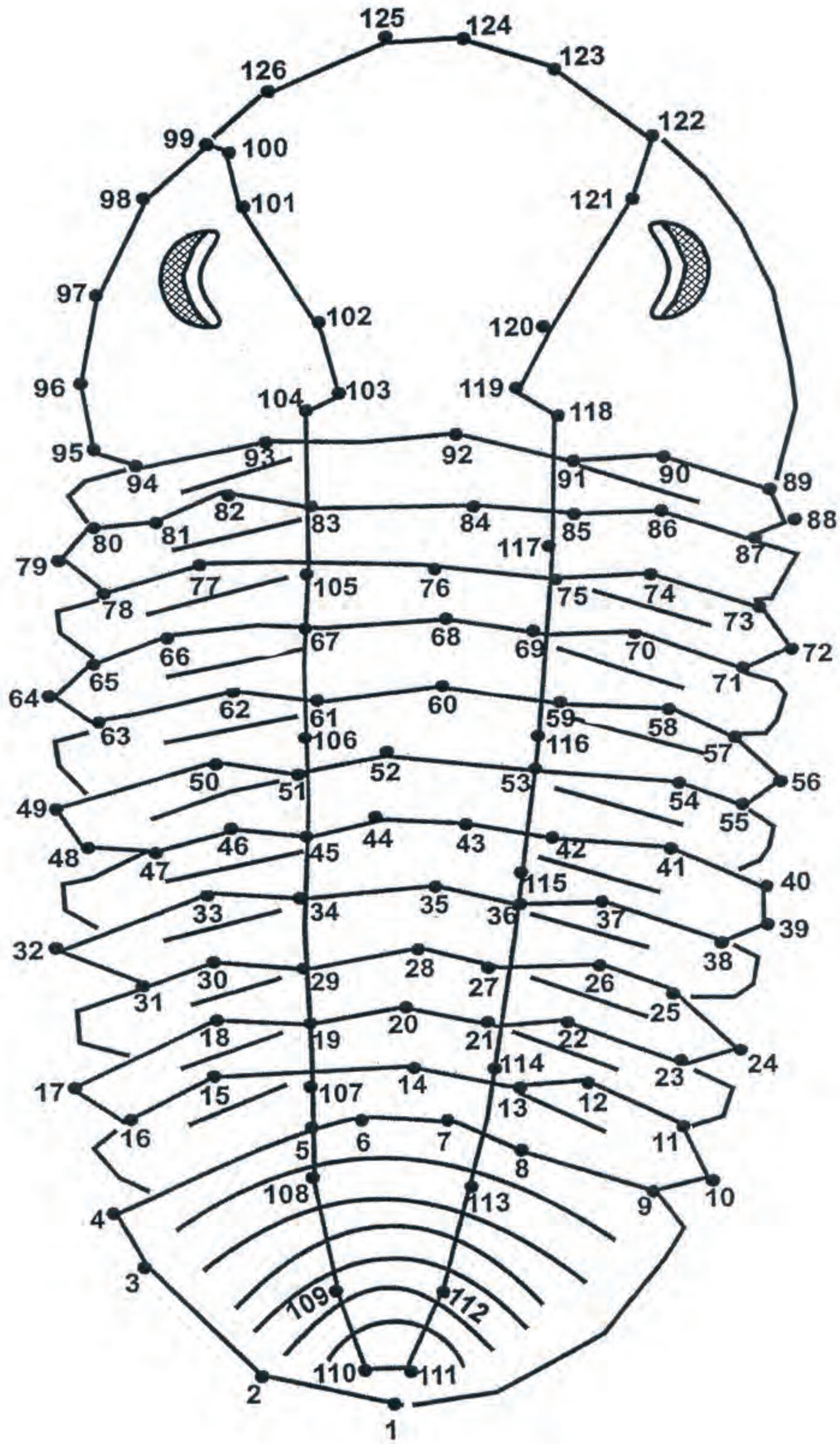
I am a Columbian mammoth.

ACTIVITY φ



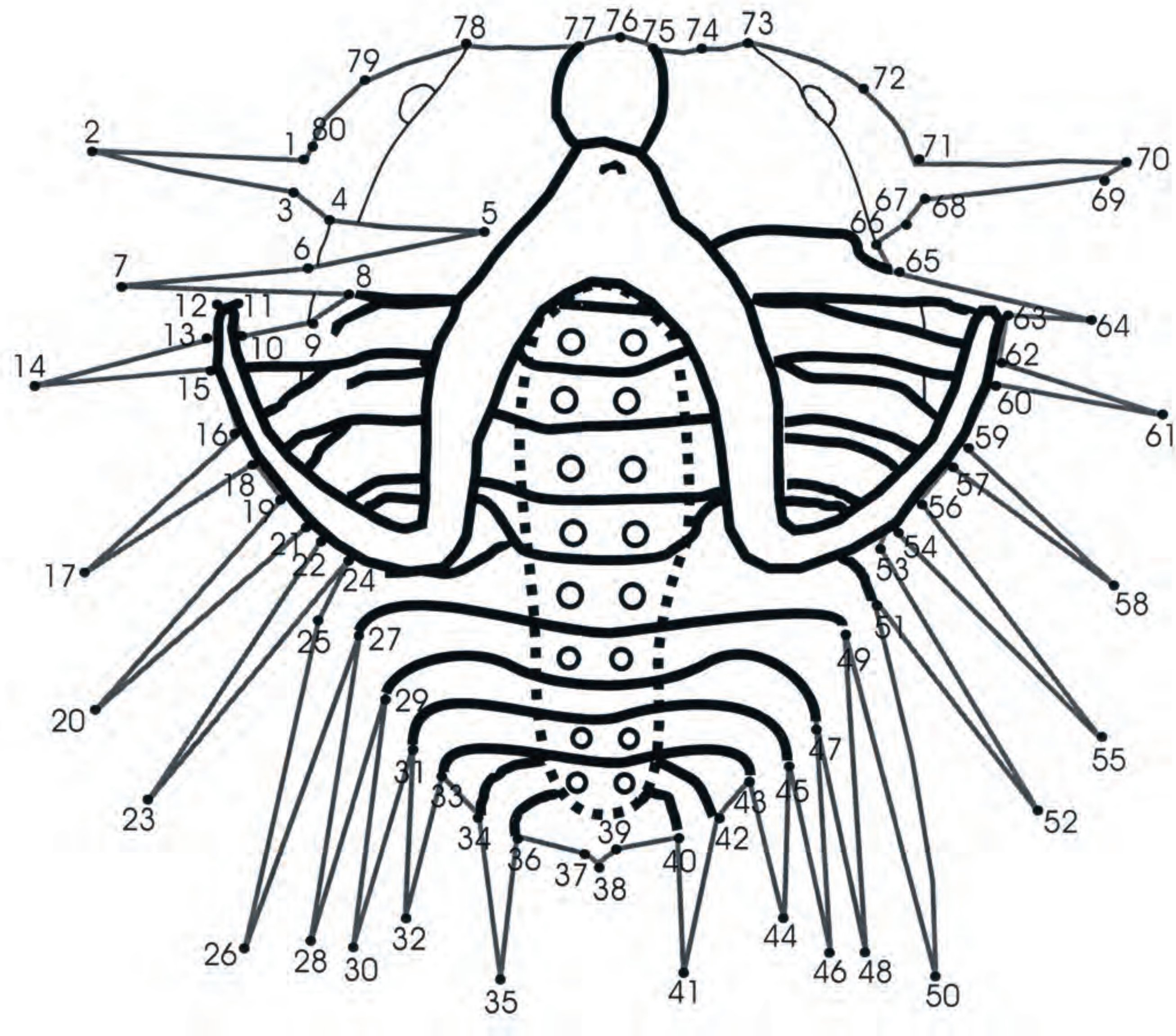
My name is *Isotelus*.

ACTIVITY χ



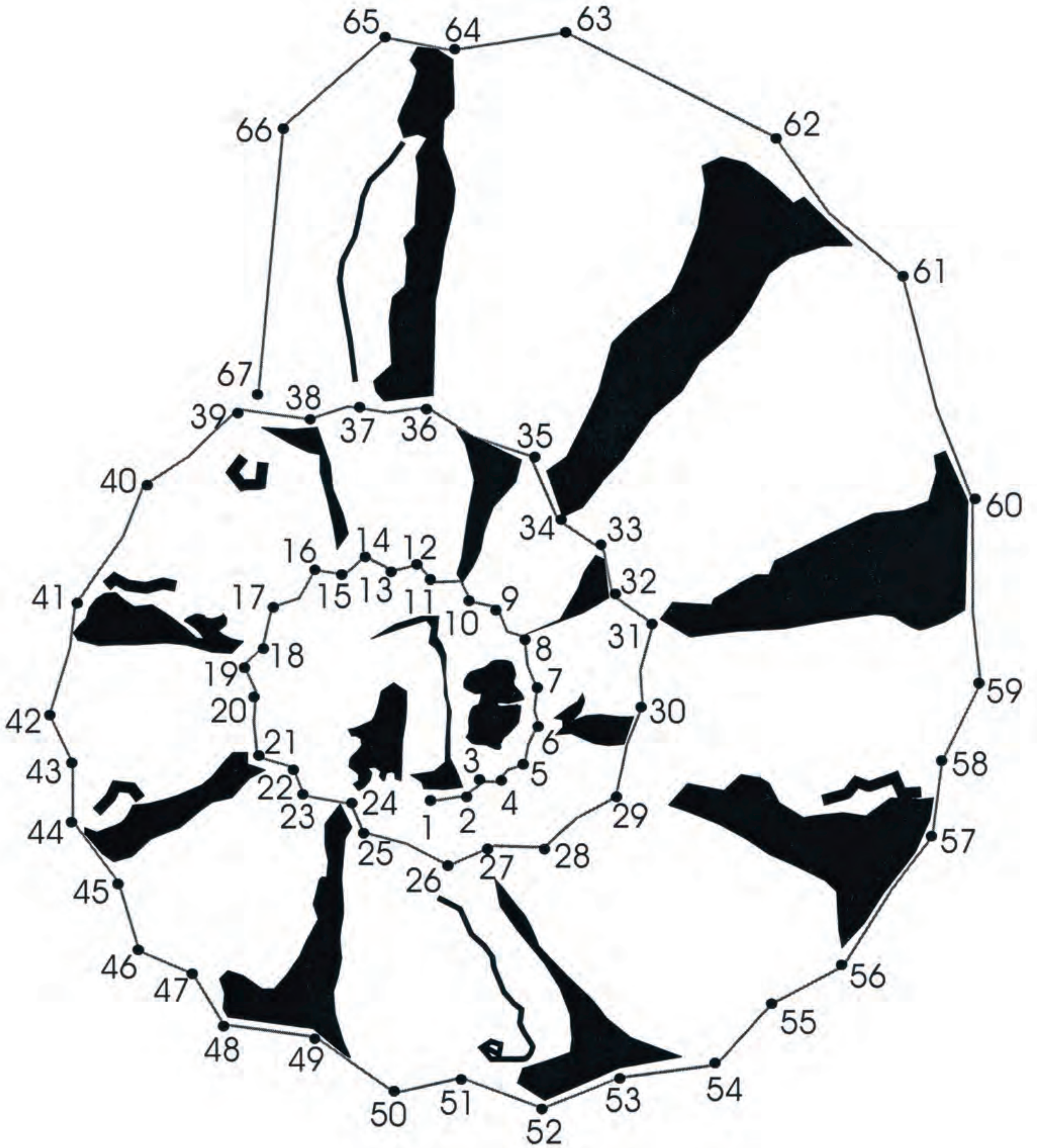
My name is *Phacops*.

ACTIVITY ψ



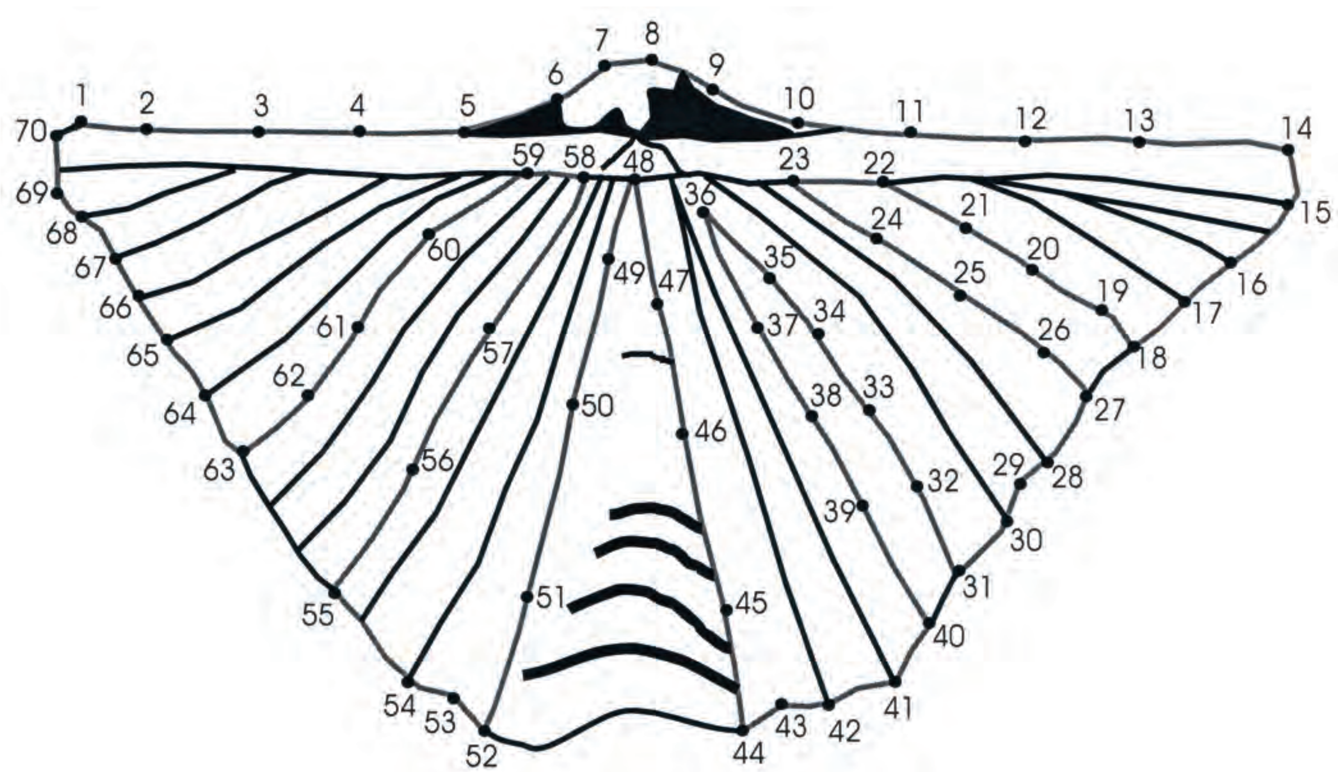
My name is *Dicranurus*.

ACTIVITY ω



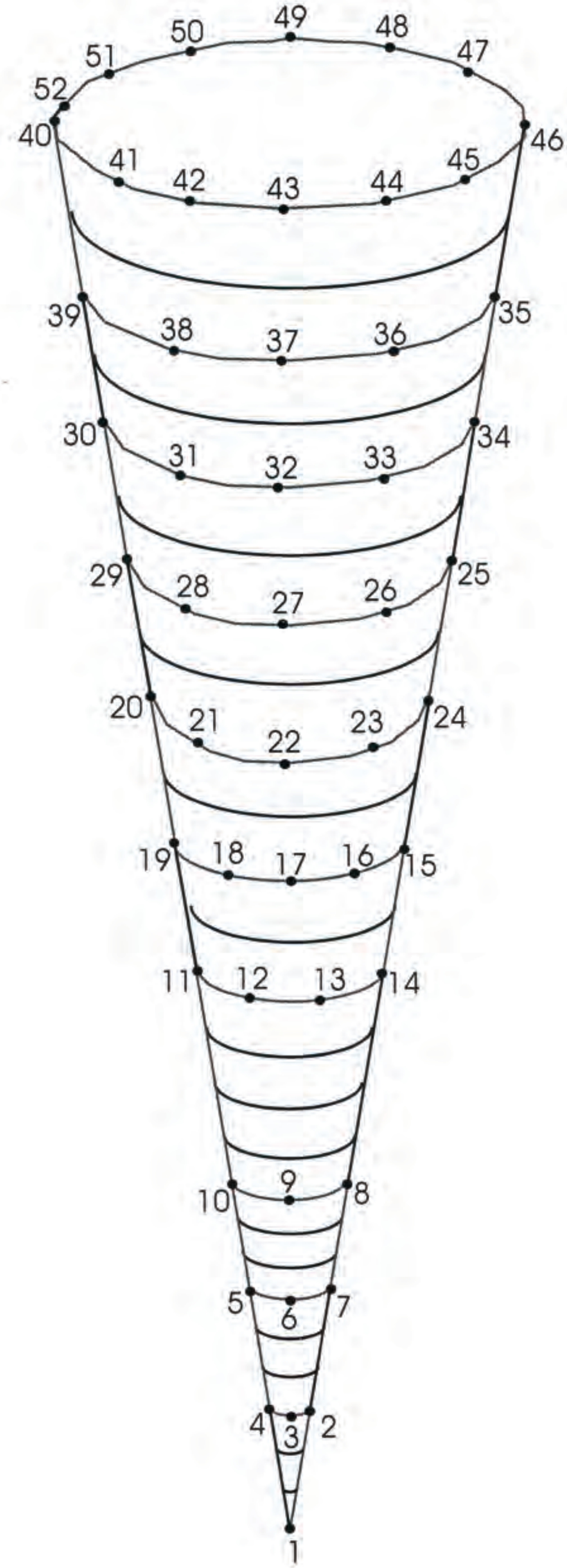
I am an ammonoid–type cephalopod.

ACTIVITY ρπ



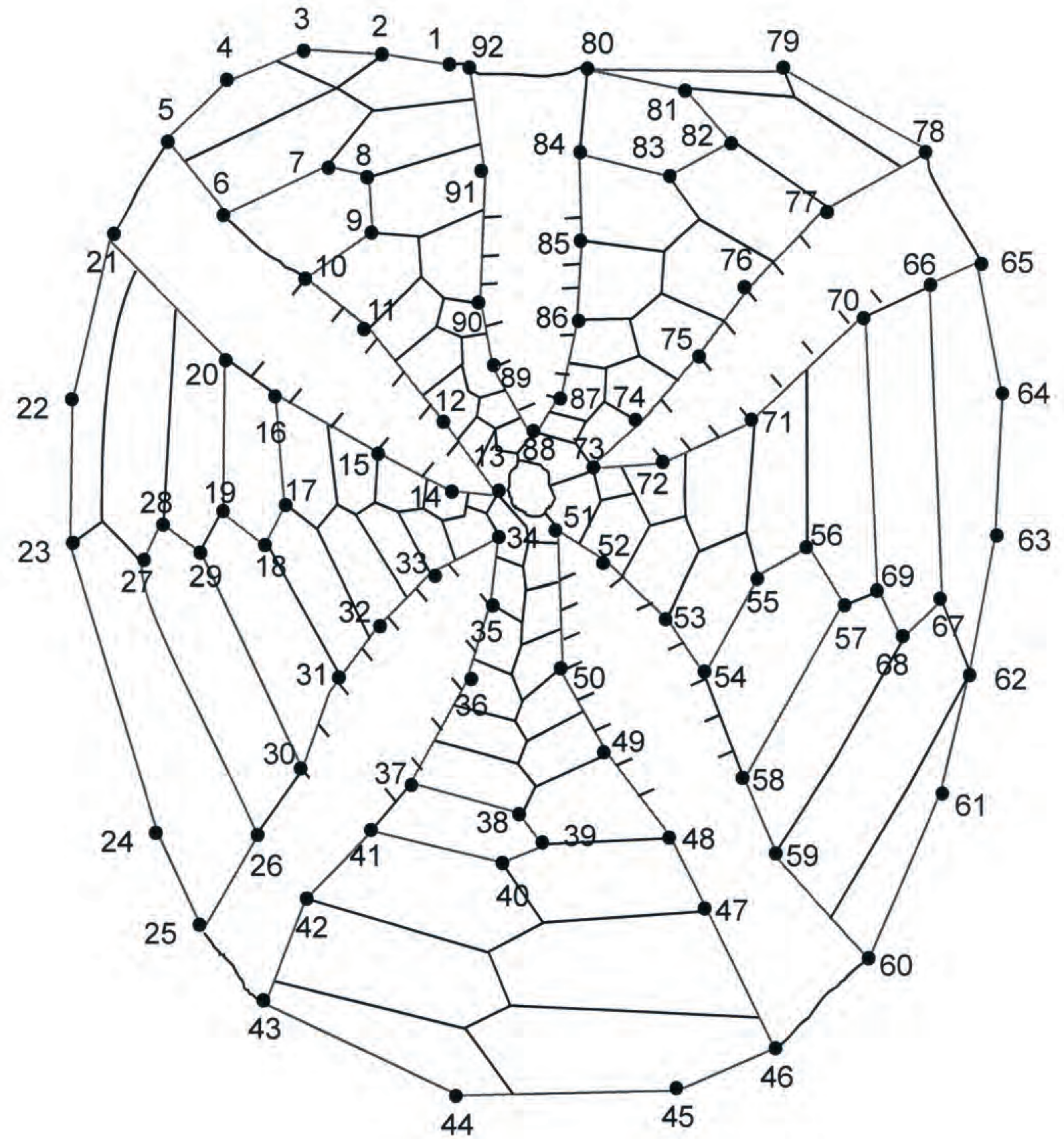
I am called a brachiopod.

ACTIVITY 1ρ



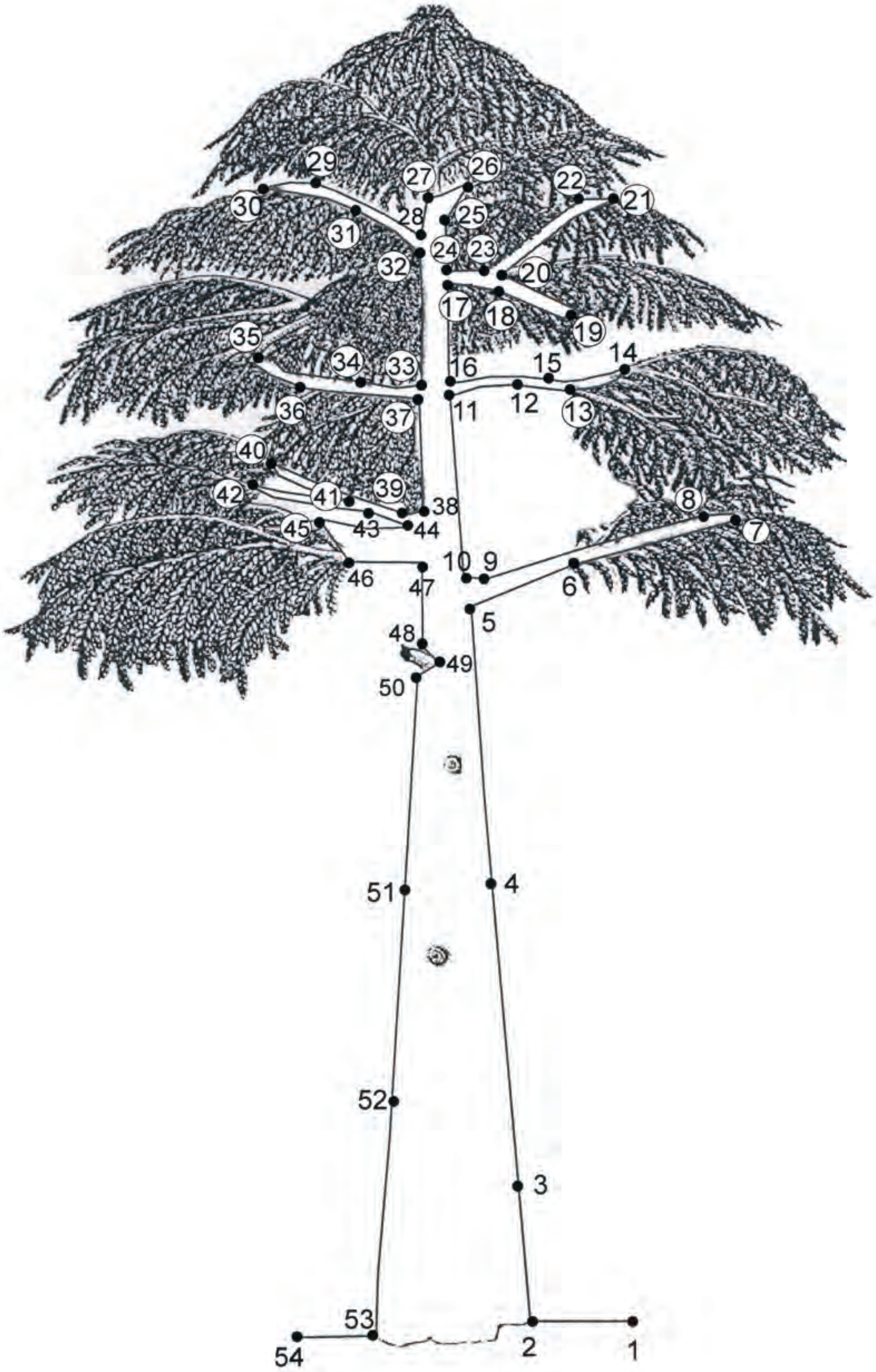
I am a nautiloid–type cephalopod.

ACTIVITY 1ς



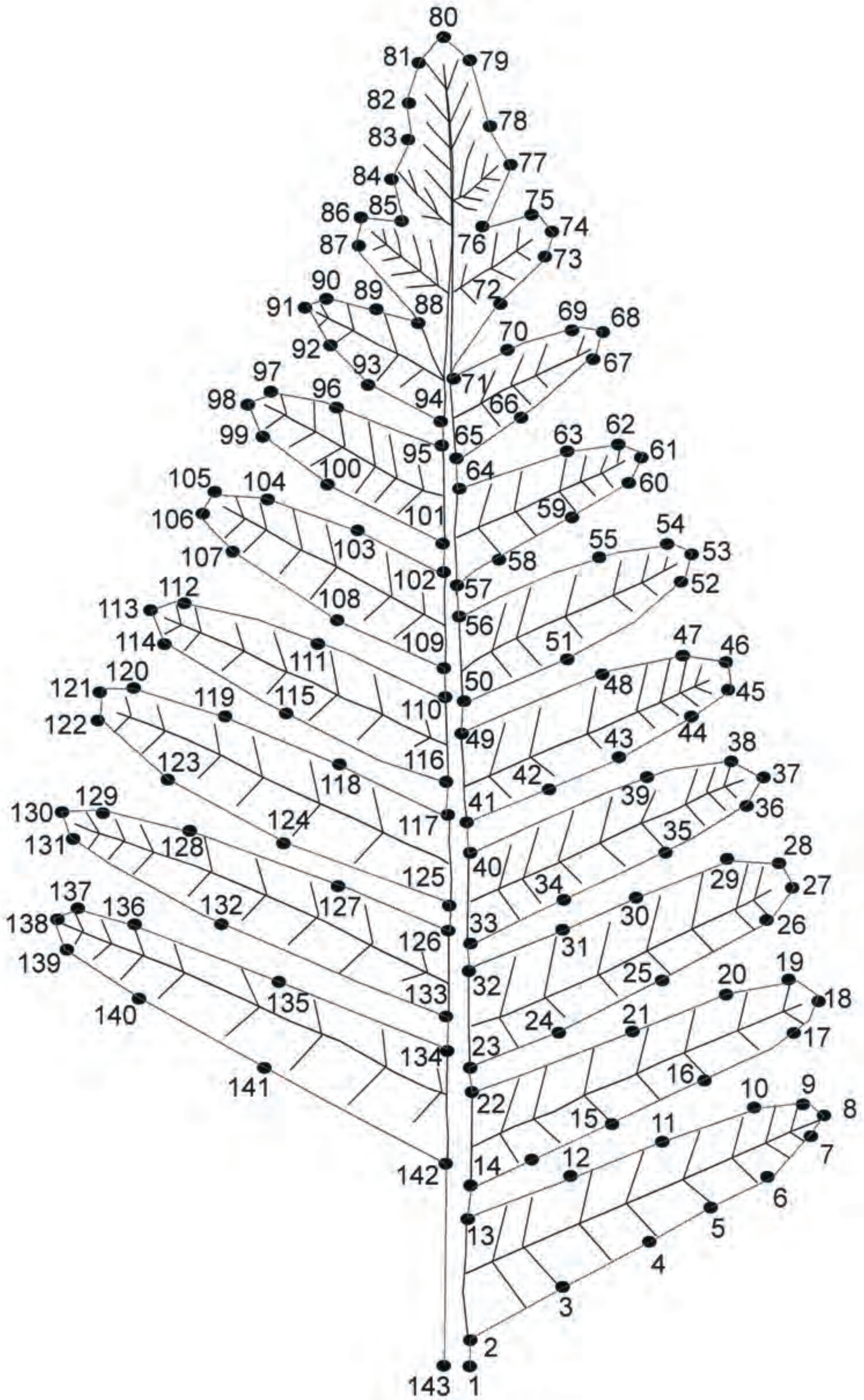
I am called a “heart urchin”.

ACTIVITY 1σ



My name is *Archaeopteris*.

ACTIVITY ρτ



My name is *Pecopteris*.

Appendix 1

Some Sources for Minerals/Rocks/Fossils and Teacher Classroom Materials

D. J. Minerals, Inc.
P. O. Box 761
Butte, Montana 59703–0761
406–782–7339
www.djminerals.com
(Both classroom and museum quality mineral/rock specimens available for purchase)

Geological Enterprises, Inc.
P. O. Box 996
Ardmore, Oklahoma 73402
508–223–8537
geoent@ardmore.com
(Both classroom and museum quality fossil specimens available for purchase)

Scott Resources–Hubbard Scientific
National Teaching Aids
401 Hickory Street
P. O. Box 2121
Fort Collins, Colorado 80522
1–800–289–9299
www.amep.com/cat_home_earthsci.asp

NIE Educational Programs by the Oklahoman
Site includes earth science activities for students in grades 6–8
Oklahoma Rocks
Oklahoma Rocks—Energy
www.nie.newsok.com/Programs

Ward's Natural Science Establishment
5100 west Henrietta Road
P. O. Box 92912
Rochester, New York 14692–9012
1–800–962–2660
www.wardsci.com
(Mineral/rock fossil specimens and earth science materials to purchase)

Joe and Nancy Stine
Timberlake Rose Rock Gallery & Museum
419 S. Highway 77
Noble, Oklahoma 73068
405–872–9838
www.roserockmuseum.com
(Rose rock specimens of all sizes to purchase, as well as jewelry made with rose rocks)

Oklahoma Petroleum Information Center
2020 Industrial Blvd.
Norman, Oklahoma 73069
405–360–2886
www.ogs.ou.edu/
(Addition to the Oklahoma Geological Survey—free selected mineral, rock, and fossil samples for teachers when available. Also lists programs and activities for teachers.)

Oklahoma Geological Survey
Publication Sales Office
2020 Industrial Blvd.
Norman, Oklahoma 73069–8512
Phone: 405–325–1299
Fax: 405–366–2882
E–mail: ogssales@ou.edu
(Site lists educational publications for sale and other materials for classroom use)

Appendix 2

Some Fossils on the Web

Fossil safari in southwest Wyoming with Warfield fossils—Dig your own fossil fish.
www.fossilsafari.com

Discovery Channel's Web site—Kids can learn about all the dinosaurs that roamed their neighborhood. — dsc.discovery.com/dinosaurs

Awesome Library web site has an endless supply of resources for teachers with topics ranging from weather on Mars to dinosaur fossils.
www.awesomelibrary.org/Classroom/Science/Earth_Sciences/Earth_Sciences.html

Two Guys Fossils provides a general list and photos of both invertebrate and vertebrate fossils with brief descriptions. Cost to purchase specimens is included.
http://www.twoguysfossils.com

Fossils! Behind the scenes at the Royal Ontario Museum describes how fossils are formed and prepared, who studies them, where they are collected, how scientists identify and classify fossils, and a fossil game. — http://www.rom.on.ca/programs/activities/fossils/

Trilobites.com displays photos of trilobites worldwide with several specimens shown from Oklahoma and other U.S. States. Cost to purchase specimens is included on web site.
www.Trilobites.com

Website includes pictures of various invertebrate fossils, answers to questions about fossils, locations of places across the U.S. where you can go to collect fossils, and much more. It also has many cool links to fossil information including some awesome games and activities.
www.fossilsforkids.com

Information about fossil plants and animals. Site includes numerous links to fossil coloring pages, printable fossil word searches and crossword puzzles, and extreme fossil facts.
www.surfnetkids.com/fossils.htm

This site is all about fossils. It is especially for teachers, students, and homeschoolers who want to put some fun into their earth science classes. Includes facts on fossils, fossil lesson plans, earth science activities (word searches and crossword puzzles) and a link to buying fossils online.
www.fossils–facts–and–finds.com

Learn about fossils on public lands and National Fossil Day activities at:
www.nature.nps.gov/geology/nationalfossilday

Site includes a 62–page full–color catalog of fabulous fossils from the Triassic, Jurassic, and Cretaceous Periods. — www.trieboldpaleontology.com