Common Paleozoic Fossils of Wisconsin

Ross H. Nehm
Bryan E. Bemis

Wisconsin Geological and Natural History Survey
Educational Series 45 | 2002

Wisconsin Geological and Natural History Survey

James M. Robertson, *Director and State Geologist*

John W. Attig, *geologist*
William G. Batten, *geologist*
Kenneth R. Bradbury, *hydrogeologist*
Bill C. Bristoll, *information manager*
Bruce A. Brown, *geologist*
Lee Clayton, *geologist*
Michael L. Czechanski, *cartographer*
Donna M. Duffey, *Map Sales associate*
Timothy T. Eaton, *hydrogeologist*
Thomas J. Evans, *geologist*
Stephen J. Gaffield, *hydrogeologist*
Madeline B. Gotkowitz, *hydrogeologist*
David J. Hart, *hydrogeologist*
Ronald G. Hennings, *hydrogeologist (emeritus)*
Rilla M. Hinkes, *office manager*
Thomas S. Hooyer, *geologist*
Susan L. Hunt, *graphic artist*
Mindy C. James, *publications manager*
Marcia J. Jesperson, *Map Sales associate*
Kathy A. Kane, *network administrator*
Irene D. Lippelt, *water resources specialist*
Frederick W. Madison, *soil scientist*
M.G. Mudrey, Jr., *geologist*
Stanley A. Nichols, *biologist*
Deborah L. Patterson, *cartographer*
Roger M. Peters, *geologist*
Kathy Campbell Roushar, *cartographer*
Apichart Santipiromkul, *information processing specialist*
Curtis L. Thomas, *geotechnician*
Virginia L. Trapino, *program assistant*
Alexander Zaporozec, *hydrogeologist (emeritus)*
Kurt K. Zeiler, *GIS specialist*
Kathie M. Zwettler, *administrative manager*

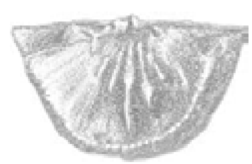
plus approximately 10 graduate and undergraduate student workers.

Research Associates

Gregory J. Allord, *USGS*
Mary P. Anderson, *UW–Madison*
Michael F. Bohn, *Wis. Dept. of Nat. Res.*
Stephen M. Born, *UW–Madison*
Philip E. Brown, *UW–Madison*
Charles W. Byers, *UW–Madison*
William F. Cannon, *USGS*
Douglas S. Cherkauer, *UW–Milwaukee*
Kevin Connors, *Dane Co. Land Conserv. Dept.*
Robert H. Dott, Jr., *UW–Madison (emeritus)*
C. Patrick Ervin, *Northern Ill. Univ.*
Daniel T. Feinstein, *USGS*
Robert F. Gurda, *Wis. State Cartographer's Office*
Nelson R. Ham, *St. Norbert Coll.*
Mark T. Harris, *UW–Milwaukee*
Karen G. Havholm, *UW–Eau Claire*
Randy J. Hunt, *USGS*
Mark D. Johnson, *Gustavus Adolphus Coll.*
Joanne Kluessendorf, *Weis Earth Science Museum*
James C. Knox, *UW–Madison*
George J. Kraft, *Central Wis. Groundwater Center*
James T. Krohelski, *USGS*
Michael D. Lemcke, *Wis. Dept. of Nat. Res.*
J. Brian Mahoney, *UW–Eau Claire*
Kevin McSweeney, *UW–Madison*
Christine Mechenich, *Central Wis. Groundwater Center*
David M. Mickelson, *UW–Madison*
Donald G. Mikulic, *Ill. State Geol. Survey*
William N. Mode, *UW–Oshkosh*
Maureen A. Muldoon, *UW–Oshkosh*
Robert E. Pearson, *Wis. Dept. of Transportation*
James O. Peterson, *UW–Madison*
Jeffrey K. Postle, *Wis. Dept. Ag., Trade & Consumer Protection*
Kenneth W. Potter, *UW–Madison*
Todd W. Rayne, *Hamilton Coll.*
Daniel D. Reid, *Wis. Dept. of Transportation*
Allan F. Schneider, *UW–Parkside (emeritus)*
J. Antonio Simo, *UW–Madison*
Kent M. Syverson, *UW–Eau Claire*
Jeffrey A. Wyman, *UW–Madison*

The Wisconsin Geological and Natural History Survey also maintains collaborative relationships with a number of local, state, regional, and federal agencies and organizations regarding educational outreach and a broad range of natural resource issues.

Common Paleozoic Fossils of Wisconsin



Ross H. Nehm
Bryan E. Bemis

2002

Wisconsin Geological and Natural History Survey
Educational Series 45

Cover art: Ross H. Nehm

Published by and available from

Wisconsin Geological and Natural History Survey
3817 Mineral Point Road • Madison, Wisconsin 53705-5100
☎ 608/263.7389 FAX 608/262.8086 www.uwex.edu/wgnhs/

James M. Robertson, *Director and State Geologist*

ISSN: 1052-2115

Mission of the Wisconsin Geological and Natural History Survey

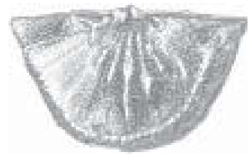
The Survey conducts earth-science surveys, field studies, and research. We provide objective scientific information about the geology, mineral resources, water resources, soil, and biology of Wisconsin. We collect, interpret, disseminate, and archive natural resource information. We communicate the results of our activities through publications, technical talks, and responses to inquiries from the public. These activities support informed decision-making by government, industry, business, and individual citizens of Wisconsin.

Figures

Table

Plates

Common Paleozoic Fossils of Wisconsin



Overview

Wisconsin's fossils

Many people view the Earth and its lifeforms as what we see today. However, both have changed dramatically through time; the evidence for this comes from something most of us see every day, but think little about: rock. Much of the rock in Wisconsin contains *fossils,* the remains of ancient organisms. After these organisms died, parts of their bodies were preserved in rock. Paleontologists—people who study ancient life on the basis of fossilized plants and animals—use them as clues about the Earth's past.

The fossils found in rock throughout Wisconsin were formed from creatures that lived in the warm, shallow seas that once covered the state. In this guide we introduce the fascinating *marine* (sea) creatures that existed in what is now called Wisconsin, discuss how they were preserved as fossils and what they tell us about the ancient Earth, illustrate common Wisconsin fossils, and suggest how and where to collect them.

Geologic time

When did the creatures that were to become fossils live? To appreciate fully just how long ago these organisms existed, it is helpful to develop an understanding of the concept of *geologic time*.

Scientific methods for determining ages indicate that the Earth is about 4.6 billion years old. It is difficult for most of us to imagine such a vast amount of time, so geologists have developed a timetable (see inside back cover) that breaks geologic time into major units. The most expansive units, covering the longest amounts of time, are called *eons*. The next unit of time is the *era,* which is further subdivided into *periods*.

Geologic time is divided into three eons. From oldest to most recent, these eons are the *Archean, Proterozoic,* and *Phanerozoic*. The Archean and Proterozoic (sometimes collectively referred to as the Precambrian) encompass geologic history prior to 570 million years ago. Fossils representing these two eons, when the earliest forms of primitive life developed, are uncommon. The oldest known single-celled organisms—bacteria that were beautifully preserved in rock that is 3.5 billion years old—were discovered in Africa. Fossils of soft-bodied multicellular organisms about 700 million years old have been found in Australia's Ediacara Hills.

The *Phanerozoic* has been divided into three principal eras; from oldest to youngest, they are the *Paleozoic* (upon which we focus in this booklet), *Mesozoic,* and *Cenozoic*.

Diversity of lifeforms and the complexity within them developed during the early part of the Phanerozoic, in the Paleozoic Era, 570 to 245 million years ago. This era has been divided into (from oldest to most recent) the *Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian,* and *Permian Periods.* Many major groups of *shell-bearing invertebrates* (animals with hard shells and no backbones) appeared throughout the oceans during an immense proliferation of lifeforms at the beginning of the Paleozoic. This era ended with the largest extinction in the Earth's history: 80 percent of all types of marine invertebrates became extinct at the end of the Paleozoic, during the Permian Period.

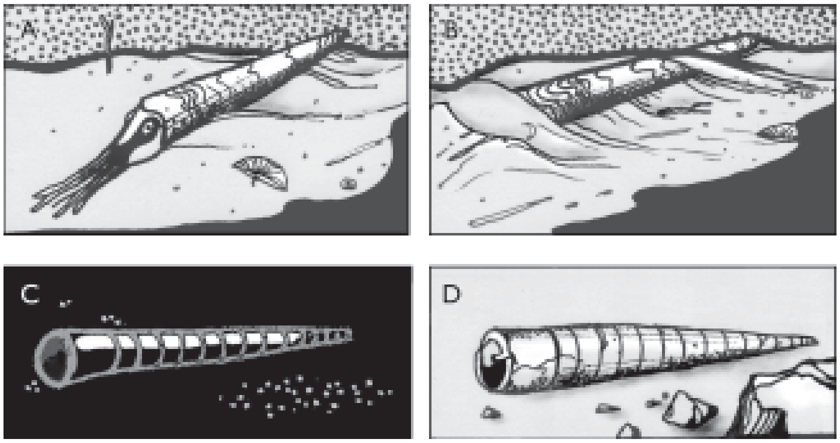


Figure 1. How fossils form. A: An animal dies and settles to the sea floor. B: Animal is buried and soft tissues decay. C: Hard parts are slowly replaced by minerals. D: Sediment becomes rock and erosion exposes fossil.

The Mesozoic Era (245 to 66 million years ago) is also called the Age of Reptiles because of the extensive proliferation of land and sea reptiles. Dinosaurs were one of the dominant animal groups during the Mesozoic Era. Although Wisconsin contains only a sparse geologic record of the Mesozoic, we know from the fossil record in other areas that many marine and terrestrial animals, including dinosaurs, became extinct near the end of this era. Mammals and flowering plants became common during about the last two-thirds of the Mesozoic.

The Cenozoic Era encompasses the past 66 million years of Earth's history. The most recent Ice Age began about 2.5 million years ago, during the Cenozoic.

How and where fossils form

Because fossils form under specific conditions, only a small percentage of organisms is preserved. Hard skeletal parts such as shells, bones, and teeth are the most commonly fossilized remains because they are more durable than the soft tissues, which decay rapidly.

Fossils are preserved in *sedimentary* rock, which is formed from what is essentially scrap material: Weathering processes break up and erode rocks at the Earth's surface, and wind and water carry away the scraps—pebbles, sand, silt, and clay. Many of these particles, called *sediment,* then settle on sea bottoms. As sea creatures die and also settle to the seafloor, they eventually are buried by sediment (fig. 1). Eventually, compaction of the sediment *consolidates* (solidifies) the sediment into layered rock, and, if conditions are right, the remains of organisms preserved in this rock become fossils (fig. 2).

Fossils can be preserved in such sedimentary rock types as *sandstone, shale, limestone,* and *dolomite.*

Sandstone, which is composed of sand-sized particles, forms in water in areas such as surf zones and beaches. Wave action is strong in these areas, and rock formed there contains few well preserved fossils—skeletal parts are easily shattered in these high-energy environments. Fossil-bearing Cambrian sandstone is exposed at the surface in central and northwestern Wisconsin. Middle Ordovician sandstone is found primarily along river valleys in southern Wisconsin, but it is generally devoid of fossils. Wisconsin sandstone can be white, tan, or iron-stained brown.

Unlike sandstone, *shale* forms in areas of slow-moving or still water; as a result, fossils in shale are generally better preserved than those in sandstone. Shale is composed of silt and clay and can be split into thin sheets. It is most common in the upper Ordovician and Devonian rock of eastern Wisconsin and is generally green, blue green, or black.

Limestone forms from the *precipitation* (settling out) of calcium carbonate from ocean water in warm, shallow environments away from the input of sand, silt, and clay. Limestone can also be composed of skeletal fragments and frameworks of organisms that built their shells with calcium carbonate from the water.

Limestone becomes *dolomite* when the element magnesium replaces some of the original calcium. Much limestone in Wisconsin has been altered to dolomite. Because of this alteration, fossils in dolomite are not as well preserved as those in limestone. Fossiliferous dolomite and limestone are found in southern and eastern Wisconsin. Limestone and dolomite range from buff or gray to dark gray or blue gray.

Conditions at a burial site determine how an organism is preserved. Fossils of marine invertebrates in Wisconsin are most commonly preserved as replacements or molds. *Replacements* are produced when minerals settle out of water and replace the original skeletal parts. *Molds* are three-dimensional impressions left in rock after the skeletal parts of an organism dissolve. A mold can be either internal or external. The impression of the outside of a preserved shell is called an *external mold;* if minerals or sediment fill the space between two shells, but the shells dissolve, an *internal mold* is formed.

Under certain conditions, the remains of some ancient plants and animals become *fossil fuels*. Coal is formed from the accumulation and burial of plant material under conditions lacking oxygen, such as in swamps. Over millions of years, high pressures and temperatures force oxygen and hydrogen out of the remains, leaving carbon, which we burn as fuel. Natural gas and petroleum form similarly, but they may include animal remains as well and form under higher pressures and temperatures. About 85 percent of the energy used in the United States comes from these fossil fuels.

What fossils tell us

About evolution and extinction

As you become familiar with Wisconsin's Paleozoic fossils, you may notice that fossils of certain organisms have different *morphologies,* or forms, through time. Some organisms develop new features (for example, shells that are thicker or shaped differently). These changes through time are known as *evolution*. How and why these changes come about, or why they don't, are the focus of much research.

Fossils also show us that many groups of creatures eventually become extinct. Trilobites, once plentiful in the Cambrian seas of Wisconsin, are extinct today, along with countless other creatures. Why are trilobites extinct, but direct descendants of other creatures that lived during the Paleozoic, such as snails, abundant today? Some creatures survive periods during which many other organisms become extinct. Does this happen because they are better adapted to their environment than those that became extinct, or are they just lucky? Paleontologists are working to answer these questions.

About ancient environments

What was the area we now call Wisconsin like 400 million years ago? It is possible to determine the environmental conditions of the past on the basis of the organisms that lived in an area at a certain time. Using information from living relatives of extinct creatures and assuming that similar, related creatures lived in similar habitats, we can make inferences about the past. For example, one indicator of marine environments is coral. Today, corals and coral reefs require specific conditions to flourish—warm temperatures (25°C to 29°C [77°F to 84°F]), shallow depths (less than 56 meters [165 feet]), and normal *salinity* (the total quantity of dissolved salts in water; normal salinity is approximately 35 parts per thousand). The abundance of coral fossils in Wisconsin's Silurian-age rock suggests that a warm, shallow sea of normal salinity covered Wisconsin during that time.

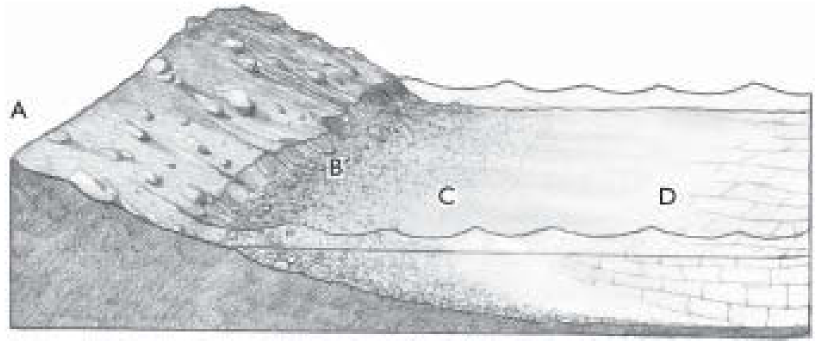


Figure 2. Block diagram of near-shore sedimentary environments. A: Eroding land is the source of sediment. B: Sand becomes sandstone. C: Silt and clay become shale. D: Farther from sediment sources, skeletal remains and calcium carbonate from ocean water become limestone.

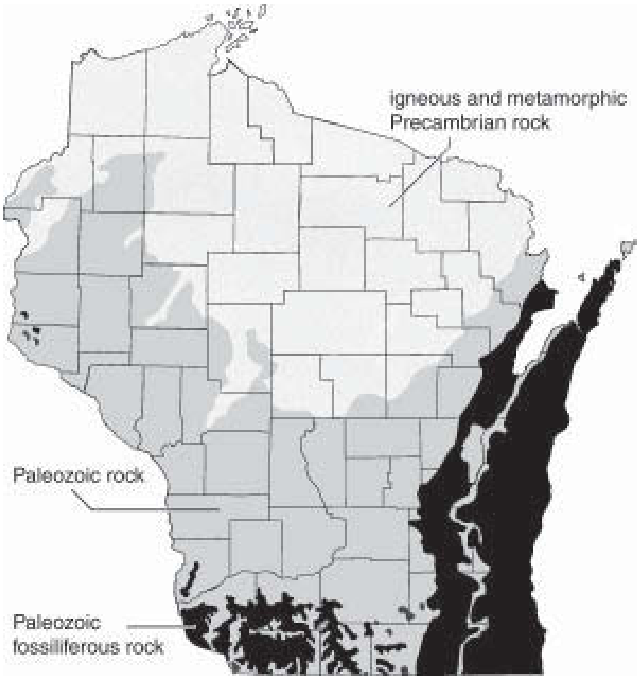


Figure 3. Where to find Paleozoic invertebrate fossils. Black areas are promising localities for collecting fossils.

Many other organisms can be used to reconstruct aspects of the Earth's ancient environment as well. Knowing how life has responded to environmental changes in the past may help us understand how future environmental changes, such as possible global warming, will influence life on Earth.

About the age of rock

Fossils can generally be considered the same age as the rock in which they are found. The age of rock can be determined *relatively* or *absolutely,* just as events can. For example, we know that Wisconsin became a state *relatively* later than the explorations of Marquette and Joliet. But when exactly did both events happen? Speaking in *absolute* terms, Marquette and Joliet's expedition began in 1673 and Wisconsin became a state in 1848.

Different rock layers can be dated relatively on the basis of their position in a "stack" of layers. For example, if you were to drop some sheets of paper on the ground, one on top of the other, it's obvious that the ones on the top got there more recently than the ones on the bottom. In the same way, rock layers (and the fossils they contain) on top of others are relatively younger than the rock layers below, if the rock has not been overturned by geologic processes.

One way you may be able to determine the geological period (age range) from which you are collecting is the presence of *index fossils* in the rock layers. Index fossils are fossil groups that lived for very short, specific periods of time. That makes them more useful for relative dating of rocks than long-lived fossil groups because they allow you to narrow down a rock's age range. Geologists can use several index fossils together to make determinations about relative rock ages.

The discovery of radioactivity provided a means of establishing absolute dates of rock. Radioactive *parent* (original) elements decay at a constant rate to produce *progeny* (decayed; also referred to as daughter) products. By knowing the *half life* (decay rate) and measuring the amount of parent and progeny products in a rock sample, it is possible to determine how much radioactive decay has occurred and therefore the time that has passed, which gives us the absolute age of the rock. Paleontologists can use a combination of relative and absolute methods to determine the age of rocks and fossils.

Collecting fossils

Finding fossils in Wisconsin

Fossils can be found in many places in the state. Fossil-bearing sedimentary rock covers much of Wisconsin, particularly the far southern and eastern parts of the state (fig. 3).

But you may not have to travel far to find fossils—the gravel in your driveway, the rocks in your garden, and the stone in buildings near you may have fossils in them. The most abundant and most easily collected fossils come from roadcuts, natural bluffs, and quarries. Roadcuts containing fossils can be found throughout Wisconsin, particularly in the southwest (fig. 4). Natural bluffs are along rivers and streams.

Quarries are excellent places to look for fossils as well, but falling rocks can make them dangerous. Do remember that many good collecting localities, such as quarries and roadcuts, are private property—***always secure permission with quarry and landowners before entering a collecting site. Use care along roadcuts.***

Here we list only general localities for fossil collecting: If we provided directions to specific sites, they might become overcollected. In many cases, the best finds are those that you discover on your own. This is part of the excitement of fossil collecting! *Refer to later sections of this guide for descriptions of specific fossil groups mentioned below.*

Eastern Wisconsin

■ Door County. Many bedrock exposures in Door County contain Silurian brachiopods (especially *Pentamerus*) and rugose and tabulate corals. Fragments of Silurian fossils are also found along the shore of Lake Michigan.

■ Oakfield, Wisconsin. An abandoned brickwork quarry southwest of Oakfield contains upper Ordovician orthid brachiopods. Many of these brachiopods have been eroded out of their matrix and can be picked from the ground. Above the shale in the lower quarry lie harder dolomite that contains layers packed with shell fragments of bryozoans and brachiopods. Fossils have been collected from this site for over a decade, but it still provides some good specimens.

■ Mayville, Wisconsin. The large quarries of the Mayville Lime Company near Mayville contain a few corals as well as casts and molds of abundant specimens of the brachiopods *Pentamerus* and *Virgiana*. ***Collecting permission is required.***

■ Washington County. In a quarry near Grafton, large blocks of reef material—including Silurian gastropods, brachiopods, and crinoid stems—are sometimes exposed. ***Collecting permission is required.*** Silurian corals can also be found on stone fences and rock piles throughout the county.

■ Cedarburg and Grafton, Wisconsin. Outcrops and quarries on the banks of the Milwaukee River between Cedarburg and Grafton contain Silurian fossils.

■ Waukesha County. Many of the best Silurian fossils from Wisconsin come from quarries in the metropolitan areas of eastern Wisconsin. Fossils in these quarries are rare but well preserved. Many beautiful specimens from these quarries are now in museums.

■ Green Bay, Wisconsin. Near Green Bay, outcrops of upper Ordovician Maquoketa Shale contain bryozoans and brachiopods, as does a roadcut on Highway 57 north of Green Bay. Other exposures along river banks in the area also contain Ordovician fossils.

Central and western Wisconsin

Middle Ordovician dolomite that is rich in virtually all types of invertebrate fossils is found in many localities in central and western Wisconsin. The most well preserved fossils come from the Platteville Formation of the Sinnipee Group. These fossils include brachiopods, bivalves (clams), gastropods (snails), trilobites, hyolithids, cephalopods, ostracods, crinoid columnals, and corals.

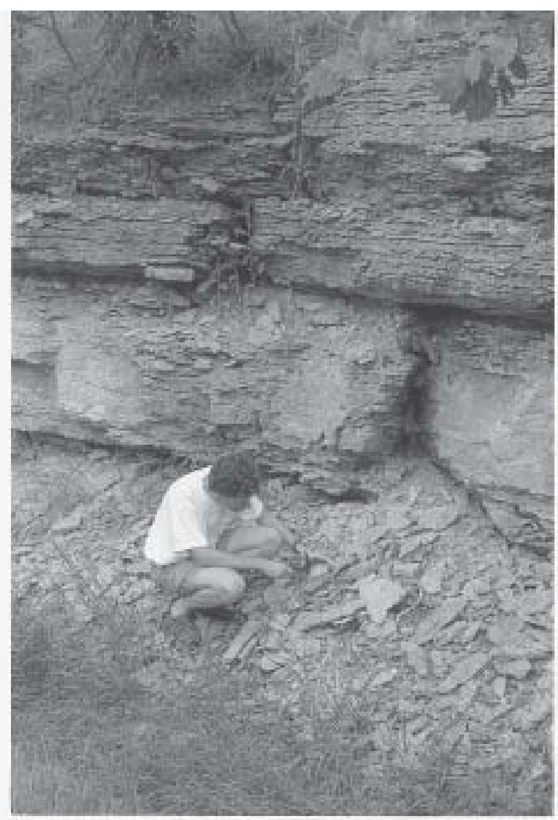


Figure 4. A paleontologist collecting Middle Ordovician fossils from a roadcut in southwestern Wisconsin.

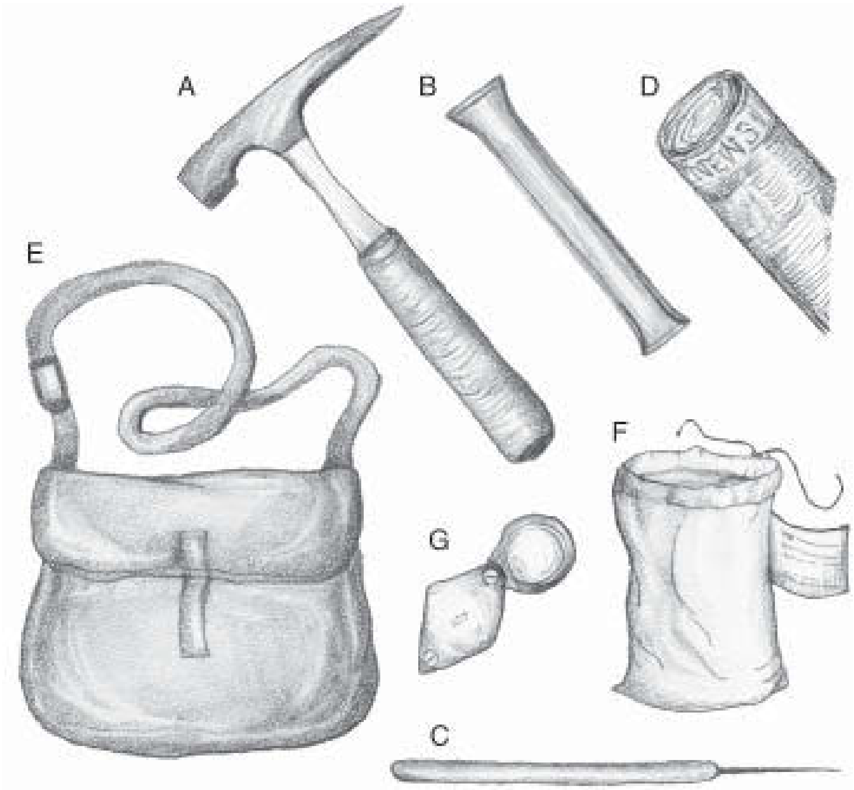


Figure 5. Tools for fossil collecting. A: Bricklayer's hammer. B: Chisel. C: Dental tool for removing delicate fossils. D: Newspapers for wrapping specimens. E: Backpack for storing tools and specimens. F: Specimen bag with label. G: Hand lens.

■ Sun Prairie, Wisconsin. Two quarries about 6.4 kilometers (4 miles) northeast of Sun Prairie off Highway 151 contain abundant Ordovician fossils from the Platteville Formation. These quarries have been active recently, and fresh rock has been exposed. In 1991 most of a cephalopod *(Endoceras)* approximately 4 meters (13 feet) long was discovered along with other excellent fossils. ***These are active quarries; secure permission from owners before entering.***

■ Dickeyville, Wisconsin. A roadcut about 6.4 kilometers (4 miles) northwest of Dickeyville in Grant County on Highways 35 and 61 contains weathered strophomenid brachiopods, bryozoans, ostracods, crinoid columnals, and other invertebrate fossils.

■ Platteville, Wisconsin. Roadcuts directly southwest of Platteville in Grant County are fossiliferous. A quarry off Highway 151 north of Dickeyville contains the brachiopod *Pionodema* and other common Ordovician fossils.

■ Mount Horeb, Wisconsin. Roadcuts along Highway 151 south of Mount Horeb occasionally contain *Receptaculites*, marine organisms that may be algae. Quarries and roadcuts just south of Mount Horeb contain Ordovician fossils, including strophomenid brachiopods, bryozoans, ostracods, and trilobite fragments.

■ Fennimore, Wisconsin. Roadcuts west and south of Fennimore contain well preserved Ordovician brachiopods, trilobites, ostracods, bryozoans, and cephalopods.

■ Roadcuts along Highways 18 and 35 east of Wyalusing State Park contain Ordovician fossils from the Platteville Formation of the Sinnipee Group, such as brachiopods, trilobite fragments, bryozoans, cephalopods, and clams.

Tools for collecting fossils

Fossil collecting is an inexpensive hobby. The following items are helpful when collecting (fig. 5):

■ **A bricklayer's hammer**. The long, flat, tapered end of a bricklayer's hammer is ideal for splitting sedimentary rock layers.

■ **A chisel**. Chisels are needed for chipping a fossil from a large piece of rock. Safety glasses should always be worn when removing fossils by this method.

■ **Dental tools**. Dental tools are useful in the removal of delicate fossils.

■ **Old newspapers**. Ensuring that a specimen is not damaged requires nothing more than a careful wrapping with newspapers.

■ **Pencil and paper**. These items are essential for labeling specimens and precisely recording where your fossil was found.

■ **A backpack**. A backpack provides a place to for tools, specimens, and maps.

■ **Specimen bags**. Use separate specimen bags for each locality.

■ **A magnifying glass or hand lens**. The details of many fossils cannot be seen with the naked eye, and magnification is helpful for identification.

Removing fossils from rock

Considerable care must be taken when removing fossils from rock. Many fossils are fragile and cannot be removed without damage. It is generally best to take a large sample home and there carefully and patiently work the specimen out. Many superb specimens have been destroyed by impatient collectors attempting to remove them quickly in the field. Chiseling a shallow trough around the fossil and then popping it out usually works well (fig. 6). Large rocks can be trimmed to smaller sizes by hanging the excess area over the edge of another rock and striking the large rock firmly.

Recording information about fossils

Amateurs have found many important fossil specimens. However, without detailed locality information, fossils are virtually useless to paleontologists. When collecting fossils, label specimens and record the following information:

■ **Locality**. Be sure to record the county, nearby roads, and distinguishing features of your collecting site.

■ **Rock description**. Include a description of the fossil-bearing rock type (that is, sandstone, shale, or limestone/dolomite), including color.

■ **Layer in rock**. It is useful to describe the specific fossil location in relation to layering visible in the rock. For example, you may notice that rock in some outcrops is punctuated by thin, horizontal layers composed primarily of fossil fragments. Describing the location of fossils relative to such layers allows you (and others) to find your exact collecting locality again.

■ **Interesting features**. It may be helpful to include a sketch or description of any other interesting features of the quarry or outcrop, such as unique layering patterns.

Identifying fossils

Throughout time, humans have sought to name things in the world; in biology and paleontology, this naming process is called *taxonomy.* Taxonomy involves naming groups of organisms, and a taxon (plural, taxa) is a unit of any rank in this naming process. Grouping organisms by shared characteristics is known as *systematics.* Organisms described within large groups, such as kingdoms, contain organisms with general similarities; those within smaller groups, such as families, have specific similarities.

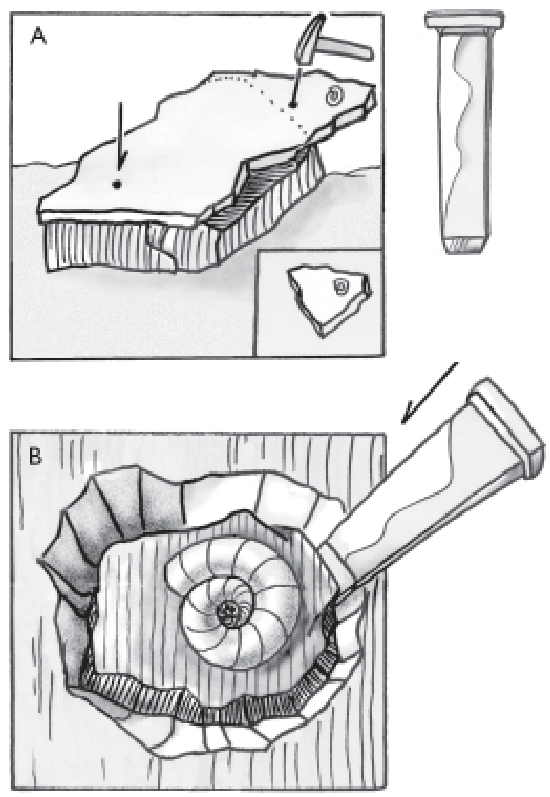


Figure 6. Removing fossils from rock.
A: Trimming a large rock to a smaller size.
B: Close-up of chiseling out a fossil.

The most precise way to identify a fossil is by its two-part scientific name. The first part of the name is the *genus* (plural, genera); the second, the *species.* A genus includes species that are related to each other; the members of a species are usually morphologically similar and are able to breed with each other and produce fertile offspring. The scientific name is usually written in italics. For example, in the case of *Calymene celebra,* Wisconsin's state fossil, *Calymene* is the genus and *celebra* is the species.

This complete hierarchy is shown in the example of trilobites in column two of table 1, in

Figure 7. Reconstruction of stromatolite mounds in the Cambrian Period (500 million years ago) of Wisconsin.

which *Calymene celebra* is a member of a larger group, the trilobites. Trilobites are themselves members of the animal kingdom.

In this guide, we use scientific and common names (such as lamp shells for brachiopods) to describe the major fossil groups in Wisconsin. We discuss how, where, and when these intriguing organisms lived and illustrate the common genera found within these groups.

Many other types of invertebrate fossils also lived, died, and were preserved in Wisconsin rock; therefore, further sources of information may be necessary to identify the fossils you find. Two of the most complete sources are the *Treatise on Invertebrate Paleontology*, a series of more than forty volumes containing descriptions of all known invertebrate genera, and Shimer and Schrock's *Index Fossils of North America*. These and other references are listed in the *Sources of information* section at the end of this guide.

Stromatolites

Approximately 3 billion years ago, long before multicellular organisms roamed the earth, lush mounds of algae began to thrive along warm, shallow shorelines (fig. 7). These algal mats trapped sediment, which built up layer by layer into dome-shaped mounds (fig. 8). Such mounds are called *stromatolites.* Although they are not animals, stromatolites may have been a food source for some of the animal groups we describe. Stromatolites were abundant in the Precambrian and Cambrian, but their numbers decreased in later times. A few stromatolites are still forming today. Shark Bay, Australia, is well known for its abundant living stro-

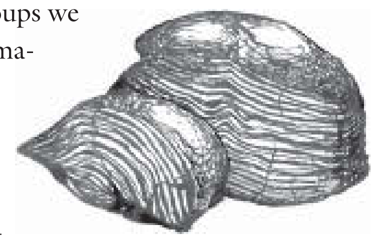
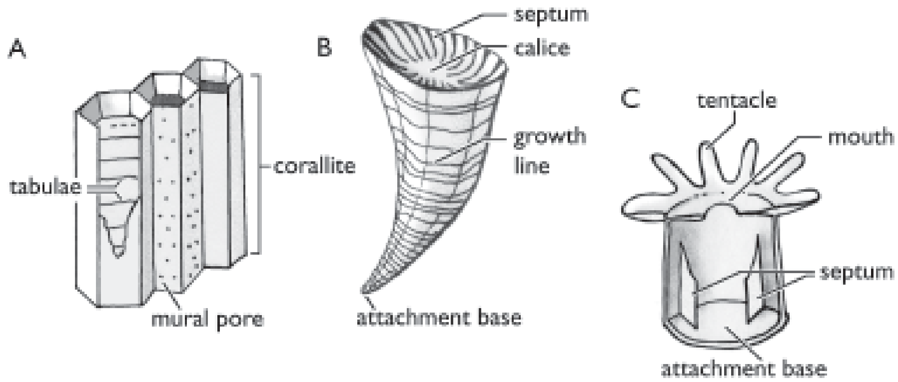


Figure 8. A stromatolite, showing the characteristic layered and domed structure.

Table 1. A classification of three specimens (after Easton, 1960).

Taxon	**Trilobite**	**Human**	**Car**
Kingdom	Animalia	Animalia	machine
Phylum	Arthropoda	Chordata	transportation
Class	Trilobita	Mammalia	automobile
Order	Phacopida	Primatida	gas-powered
Family	Calymenidae	Hominidae	sedan
Genus	*Calymene*	*Homo*	four door
Species	*celebra*	*sapiens*	brand of automobile
Individual	specimen number	social security number	registration number

Figure 9. Coral anatomy. A: Tabulate coral. B: Rugose, or "horn coral." C: Living coral animal.



matolites. In Wisconsin, stromatolites were most common in Cambrian and Ordovician seas, and therefore are most common in rock of those ages.

Corals

Corals are marine animals with simple body structures (fig. 9; plate 1). The mouth of a coral's sac-like body is surrounded by a ring of tentacles. The living coral animal, the polyp, secretes a cup-like skeleton called the *corallite*. Many corallites cemented together make up the entire skeleton, or *corallum*. Inside the corallite, a radial divider, called a *septum* (plural, *septa)* grows vertically from the attachment base and helps support the soft tissues. Many coral polyps contain algal cells, which use photosynthesis to produce food for themselves and the coral.

Corals can live together in large colonies, or reefs, which can be hundreds of miles across. Coral reefs are among the most complex ecosystems on Earth because many thousands of species other than corals make the reef their home. Corals themselves require specific living conditions, so fossil coral reefs tell us a great deal about the environmental conditions at the time of reef formation. Living coral reefs are confined to subtropical regions in shallow waters that are warm and clear. Thus, Wisconsin's Silurian reefs provide evidence that the state was once covered by a warm, subtropical sea. Although ancient corals formed the reef itself, many other organisms flourished in the small habitats the reef provided. Brachiopods covered the reef structure, gastropods fed on the abundant algae and detritus, cephalopods hunted for prey, and crinoids swayed in the agitated waters.

Two groups of reef-forming fossil corals are found in Wisconsin: the tabulates and rugosans (fig. 9). Tabulate corals grow upward, depositing horizontal plates known as *tabulae*. Tabulates formed mounds that appear similar to honeycombs; the distinctive rugosan corals resemble cow horns.

Tabulate corals

Tabulate corals are the most abundant coral fossils in the Silurian rock of Wisconsin and are usually the largest reef corals. They form massive colonies, about 0.3 meter (1 foot) wide or larger. They can be identified by the presence of tabulae. Fieldstones, commonly found in fencerows along the edges of farm fields in eastern Wisconsin, in many cases contain well preserved tabulate corals. Beach pebbles and gravel along the Lake Michigan shoreline also abound with coral fragments.

Favositid tabulates: Honeycomb corals. The favositid corals are quite common. They usually formed large colonies. The corallite is prismatic in shape, resembling honeycombs. Favositids have *mural pores,* tiny holes in the wall of the skeleton, which connect different corallites. These pores are distributed in characteristic patterns and numbers, which are useful for distinguishing the various types of favositids. Favositids lived from the Ordovician to the Permian, at which time they became extinct. They are most abundant in middle Silurian to lower Devonian rock. *Favosites* is the most common fossil coral in Wisconsin.

Halysitid tabulates: Chain corals. Halysitids resemble interlocking strings of delicate chains. *Halysites* is a common chain coral in Wisconsin, and it is used worldwide as an indicator of Silurian rock. *Halysites* is best seen in weathered rock because the rock between the chains dissolves, leaving the chains beautifully exposed.

Syringoporid tabulates: Tube corals. Syringoporids are easy to identify because of the

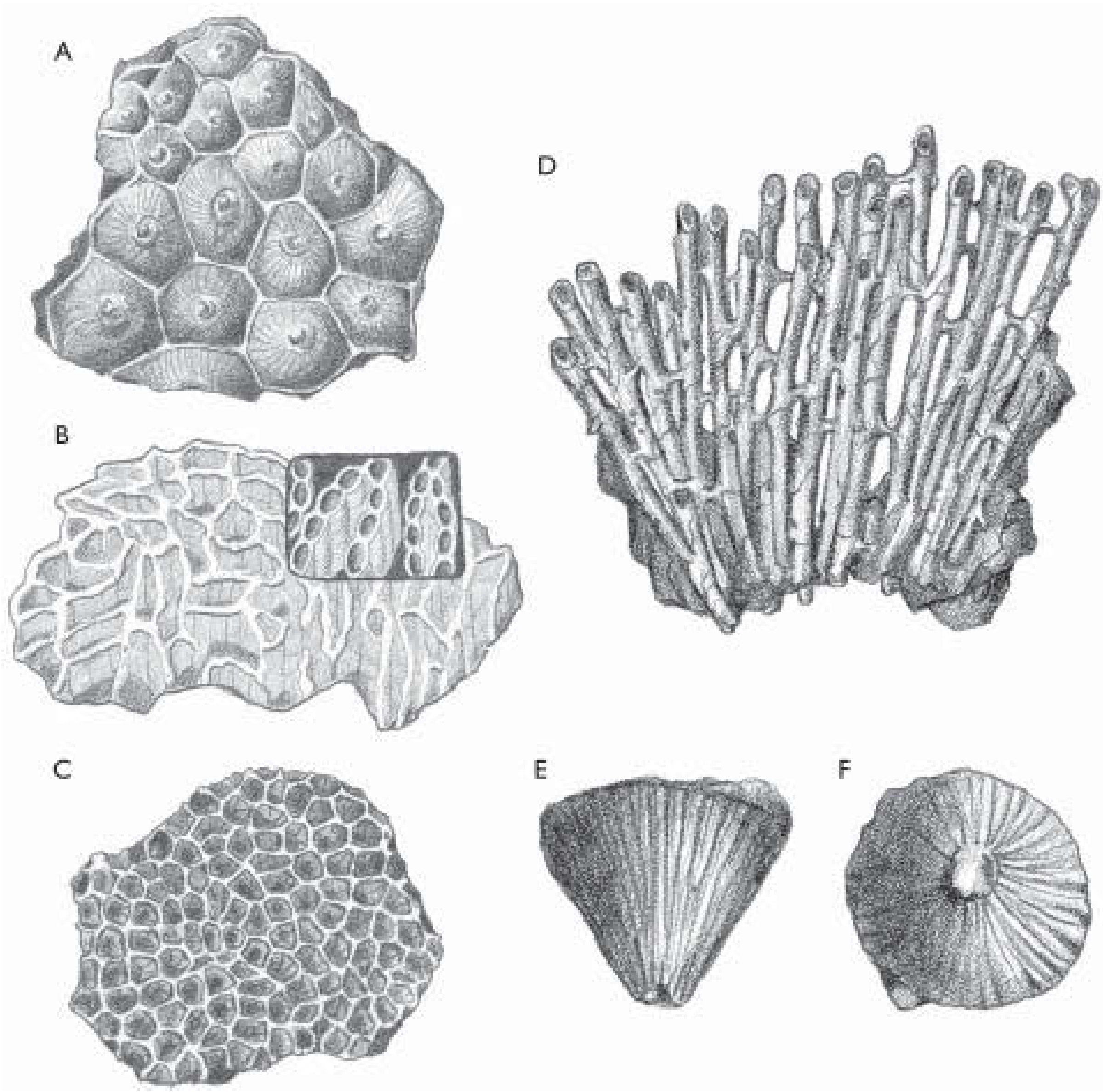
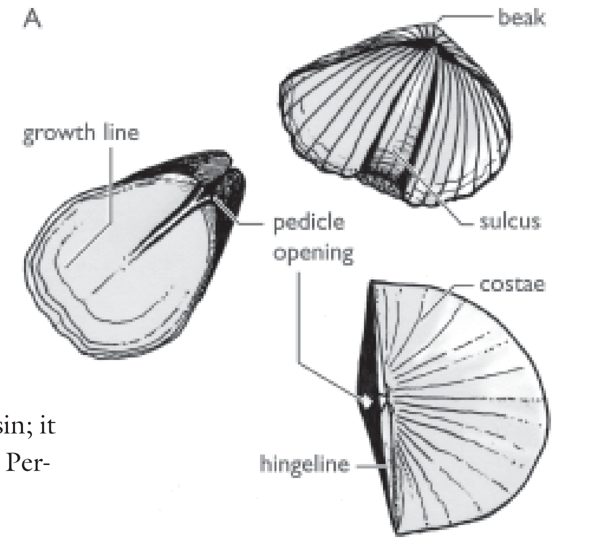


Plate 1. Coral fossils. A: Top view of large, prismatic corallites of *Strombodes*, a common coral in Silurian rock of eastern Wisconsin [8.5 cm]. B: Closeup of the chains of *Halysites*, also common in Silurian rock [7 cm]. C: Top view of small, prismatic corallites of *Favosites*, the honeycomb coral, a common fossil in Silurian rock [7 cm]. D: Side view of *Syringopora* (common in Silurian rock), showing the lateral collecting tubes [6.5 cm]. E: *Lambeophyllum*, a common coral in Ordovician rock. [2 cm]. F: *Streptelasma*, an Ordovician rugose coral that has a deep calyx and is taller than *Lambeophyllum* [4 cm].

Please note that in all the plates that the numbers in brackets following each genus refer to the general length of the longest dimension. These measurements are in the metric system because that is the system that paleontologists use. One centimeter equals about 0.39 inch.

presence of distinct tubes connecting the corallites. They are quite delicate, but in many places they have been preserved in astonishing detail. *Syringopora* is a common syringoporid in Wisconsin; it lived from the Silurian to the Permian.



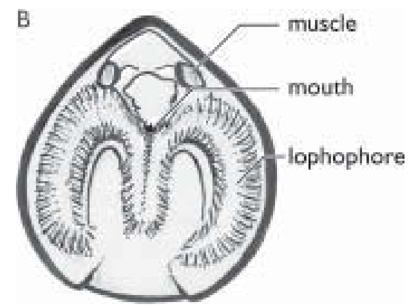
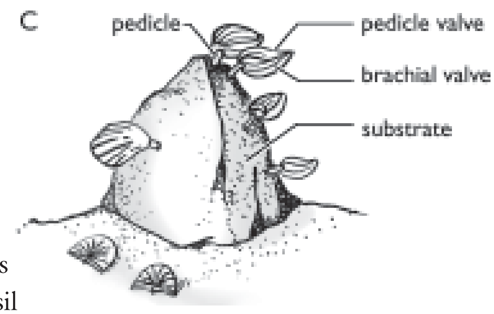


Figure 10. Brachiopod anatomy. A: External anatomy. B: Internal anatomy. C. Living brachiopods attached to rocks by their pedicles and two animals living on soft sediments.



Rugosans: Horn corals

Rugosans (plate 1) are cone-shaped corals that resemble cow horns. The polyp lived in a space in the center of the cone, known as the *calice*. Rugosan corals first appeared in the Ordovician and are the second most common type of coral in Wisconsin. Because most horn corals appear to be similar, they can be difficult to identify.

Rugose corals can be colonial or solitary. Colonial rugosans formed bunches attached to one another. Solitary rugose corals commonly were dislodged and then tipped over. If they survived, in many cases they grew upward again. Such rugosans have *geniculations* (contortions) caused by the change in growth direction. Solitary and colonial rugosans are characterized by external growth bands, which formed much like tree rings.

Rugose corals declined after the Silurian and eventually died out at the end of the Paleozoic Era.

Brachiopods: Lamp shells

Brachiopods (plates 2 and 3) are the most abundant fossils in Wisconsin. Most people are not familiar with living brachiopods because modern species inhabit extremely deep regions of the world's oceans, and their shells are rarely found on modern seashores. But during the Paleozoic, thousands of different species of brachiopods teemed in the near-shore and deep-sea environments of Wisconsin. The number of brachiopod species has decreased since the extinction at the end of the Permian (about 245 million years ago). Now, only about 250 living species of brachiopods exist; more than 30,000 fossil species have been identified in the fossil record.

Brachiopods have two *valves* (shells) that are generally of unequal size and shape (fig. 10A), but the right and left halves of each valve mirror each other. Near the tip of the bottom shell (the *pedicle valve),* a fleshy stalk (the *pedicle)* emerges through a hole (the *pedicle opening)* and attaches the animal to the sea bottom (fig. 10A, C). The other shell is known as the *brachial valve,* which contains the *brachidium*. The brachidium supports the gill-like *lophophore,* which has many filaments and *cilia* (hairs) that create currents to bring microscopic food particles to the mouth (fig. 10B). The large surface area of the filaments is used to obtain oxygen from water and eliminate carbon dioxide. The two valves join at the hinge line, which is on the shell near the pedicle (fig. 10A). Muscles hold the two valves together so that the soft parts are protected. The two valves meet at the *commissure*.

Other shell features are useful for identifying brachiopods. A *sulcus* (a groove-like depression) is present on many brachiopod shells, and a *fold* (a raised ridge) can be found on the op-

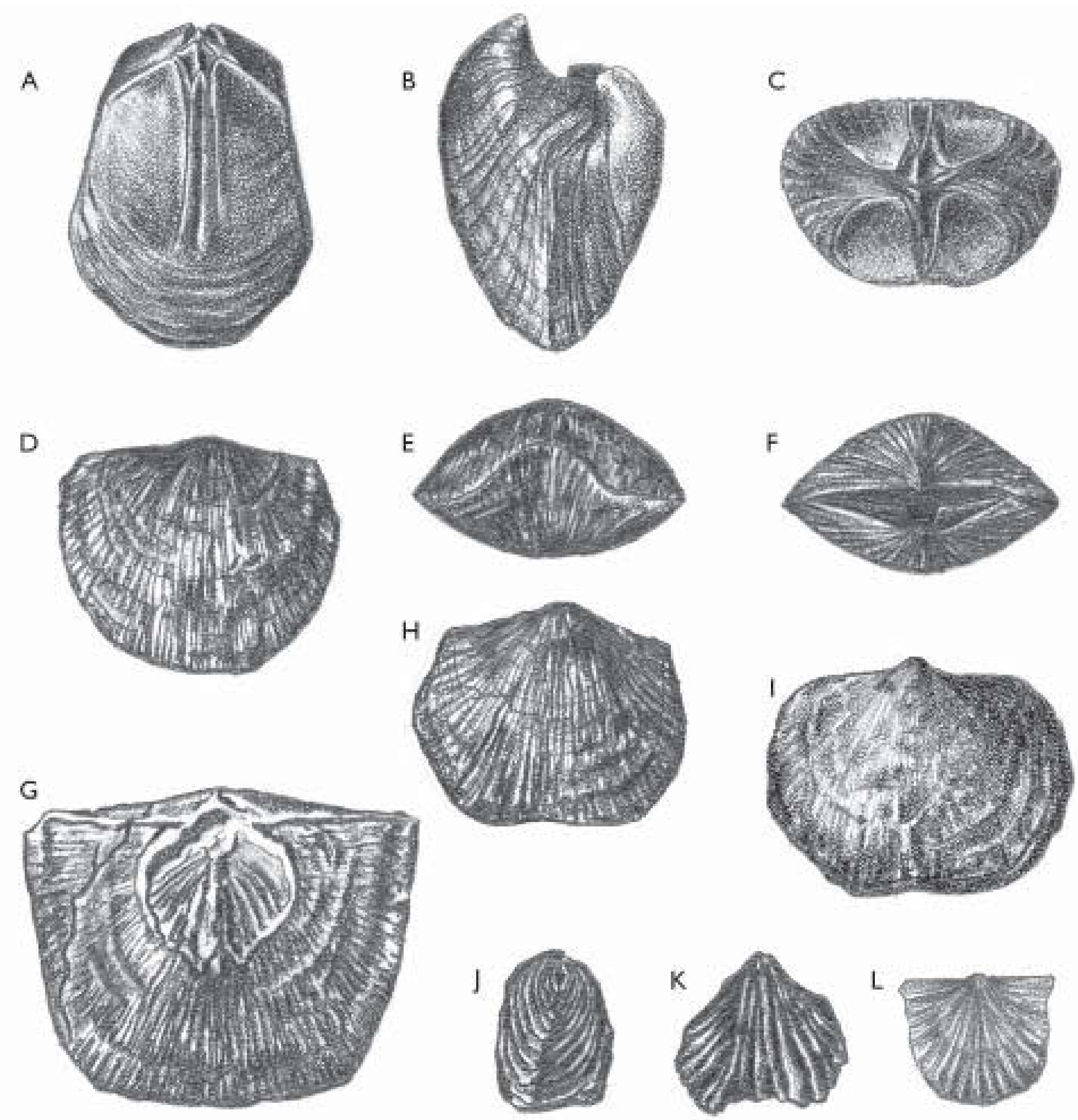


Plate 2. Brachiopod fossils. A, B, and C: Top, side, and back views of *Pentamerus*, an exceptionally common and distinctive pentamerid brachiopod in Silurian rock of Wisconsin [4.5 cm]. D: *Valcourea*, a flat Ordovician orthid brachiopod [2 cm]. E and F: Front and back views of *Pionodema*, an orthid brachiopod with a strong sulcus. It is found in large concentrations within specific layers in Ordovician rock [2 cm]. G: Interior view of *Strophomena*, an abundant Ordovician strophomenid brachiopod that is flat and broad [4.5 cm]. H and I: Two examples of *Doleroides*, a Middle Ordovician orthid brachiopod with a shallow sulcus [2 cm and 3 cm, respectively]. J and K: Side and pedicle valve views of the common Ordovician rhynchonellid brachiopod *Rhynchotrema*, showing the zig-zag commissure and sulcus [1 cm]. L: *Rafinesquina*, a Middle Ordovician strophomenid brachiopod. It is similar to *Strophomena,* but with pointed, lateral projections of the shell near the hingeline [3 cm].

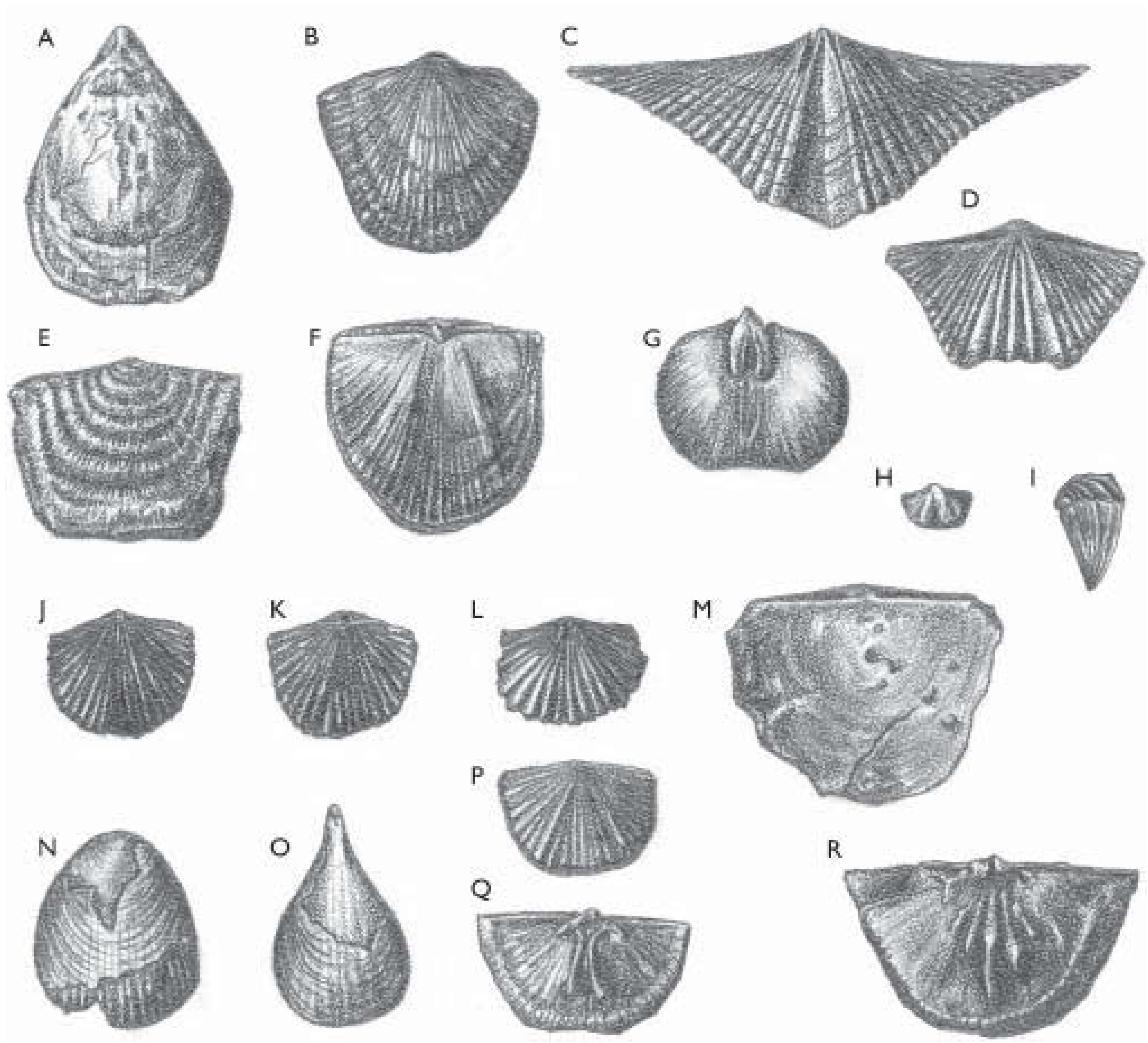


Plate 3. Brachiopod fossils. A: *Westonia*, a raindrop-shaped inarticulate brachiopod found in Cambrian rock [1 cm]. B: *Atrypa*, a common spiriferid brachiopod found in Devonian rock along the margin of Lake Michigan [2.5 cm]. C: *Spirifer*, a Devonian spiriferid brachiopod with wing-like extensions of the shell [6 cm]. D: *Platystrophia*, an Ordovician orthid brachiopod that looks like a spiriferid with a squared front end [3 cm]. E: *Leptaena*, a square-shaped Devonian strophomenid brachiopod that has concentric ridges [2.5 cm]. F: Bottom view of the flat Silurian pentamerid brachiopod *Stricklandinia* [3 cm]. G: A cast of *Orthis*, a rounded orthid brachiopod found in Ordovician rock [2 cm]. H and I: Top and side views of *Cyrtina*, a small spiriferid brachiopod found in Silurian rock [1 cm]. J and K: Pedicle valve and brachial valve views of *Hesperorthis*, an abundant orthid brachiopod in Middle Ordovician rock. It is more egg-shaped than *Eoorthis* (shown on this plate as L) and has a larger interarea [2 cm]. L: Pedicle valve view of *Eoorthis*, an upper Cambrian orthid. It is more square-shaped than *Hesperorthis* and has more pronounced costae than *Billingsella* (shown on this plate as *P*) [1.5 cm]. M: *Protomegastrophia*, a spade-shaped Devonian strophomenid brachiopod that resembles the Ordovician strophomenid brachiopod *Strophomena* (plate 2G), but is more rounded [3.5 cm]. N and O: *Lingulepis*, an inarticulate brachiopod that can be found in Cambrian rock [1.5 cm]. P: *Billingsella*, a square-shaped orthid brachiopod with fine costae that is found in upper Cambrian rock [1 cm]. Q: Interior view of *Sowerbyella*, a common strophomenid brachiopod in Middle Ordovician rock, showing the raised, π-shaped structure near the hinge [1.5 cm]. R: Interior view of *Oepikina*, a Middle Ordovician strophomenid brachiopod, showing strong ridges that diverge from the hinge [2 cm].

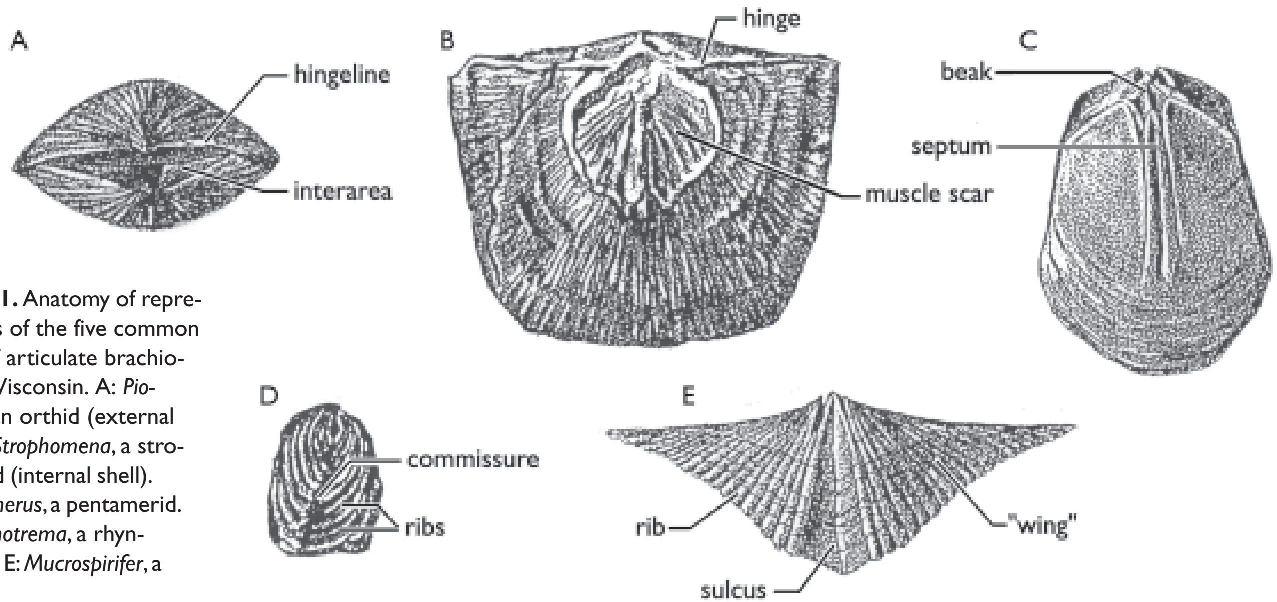


Figure 11. Anatomy of representatives of the five common groups of articulate brachiopods in Wisconsin. A: *Pionodema*, an orthid (external shell). B: *Strophomena*, a strophomenid (internal shell). C: *Pentamerus*, a pentamerid. D: *Rhynchotrema*, a rhynchonellid. E: *Mucrospirifer*, a spiriferid.

posite valve. *Costae* are elevated ribs on the shell. *Growth lines* are concentric rings representing successive periods of growth.

Brachiopods are divided into two main groups: the *articulates* and the *inarticulates*. Articulates have hinge structures on their shells; inarticulates do not. Because articulates greatly outnumber inarticulates in Wisconsin, we focus on the five orders of articulate brachiopods found in Wisconsin: Orthida (orthids), Strophomenida (strophomenids), Pentamerida (pentamerids), Rhynchonellida (rhynchonellids), and Spiriferida (spiriferids).

Orthids

Wisconsin's Ordovician rock holds many orthids (fig. 11A). Several characteristics of orthids distinguish them from other brachiopods. Both valves of orthid shells are convex, and one valve is larger and deeper than the other. Most orthids have costae. The hingeline of the orthid shells is normally straight and somewhat long and is bordered by a large *interarea,* a flat, shelf-like region. Orthids lived from the Cambrian to late Permian, and most Ordovician rock contains diverse assemblages of these brachiopods.

Strophomenids

Strophomenids (fig. 11B) were especially abundant during the Ordovician. Strophomenids usually have large, semicircular shells, with one concave and one convex valve. A short, flat interarea borders the hinge region, and the hingeline is straight, like that of the orthids, but may contain a row of small teeth. Muscle scars are conspicuous features of the internal shell. The strophomenids in Wisconsin, particularly the genus *Strophomena*, commonly cover entire *horizons* (layers) of rock. Strophomenids were devastated along with other groups during the Permian extinction, but managed to survive a little longer, into the Triassic, before becoming extinct.

Pentamerids

Pentamerid shells (fig. 11C) are extremely abundant in the Silurian rock of eastern Wisconsin. These brachiopods are large and egg-shaped, with curved hingelines and pronounced shell beaks. They possess a unique internal structure found near the hinge; it is called the *spondylium,* a raised, spoon-shaped platform used for muscle attachment. Pentamerids arose in the Cambrian, were most common in the Silurian, and became extinct in the Devonian. Some quarries in Dodge County contain Silurian rock with millions of large pentamerid molds and casts.

Rhynchonellids

Most rhynchonellids (fig. 11D) in Wisconsin are small and marble-like in shape. The commissure is zig-zag in outline. These small shells have prominent ribs, and a fold and sulcus are usually present. Rhynchonellids arose in the Ordovician. This group is still present in some of the Earth's oceans.

Spiriferids

Spiriferids (fig. 11E) are among the most beautiful brachiopods. They are somewhat triangular; many possess shell extensions that give them the appearance of having wings. The spiriferids have a unique spiraling support for the lophophore as well as a fold and sulcus. This group arose in the late Ordovician, but can be found mostly in Devonian rock in the Milwaukee metropolitan area. Two main groups of spiriferids are found in Wisconsin: spiriferidinids and atrypids.

Spiriferidinids have straight hingelines and lateral wing-like shell extensions. Some members of this group, such as *Eospirifer*, are superficially similar to pentamerids. *Platyrachella*, because of its interarea, looks suspiciously like an orthid. For the most part, however, triangular-shaped spiriferids are found in Wisconsin.

Atrypids are triangular, and they do not have the wing-like shape of some other spiriferids. These spiriferids have curved hingelines and two convex valves. Most atrypids have ribs and a small beak. *Atrypa* is a common Devonian brachiopod.

Bivalve mollusks: Clams

Bivalves (plate 4) are aquatic mollusks that possess two valves (fig. 12) that protect the soft body parts. The valves are secreted by the *mantle,* a soft tissue that leaves a scar (the *pallial line)* where it connected to the inside of the shell. The muscles that hold the two valves together also leave scars on the inside of the shell, as do the *siphons,* through which food passes in and out of the body. The length and shape of the siphon scar, or *pallial sinus,* is helpful for interpreting the burrowing habits of a bivalve. Different scars are also characteristic of different bivalve species.

Unlike the valves of brachiopods, clam valves are typically of similar size and shape. The two shells are hinged together by a strong ligament. Small teeth and sockets may also be present in the hinge area, which add strength to the hinge and prevent the two valves from slipping apart.

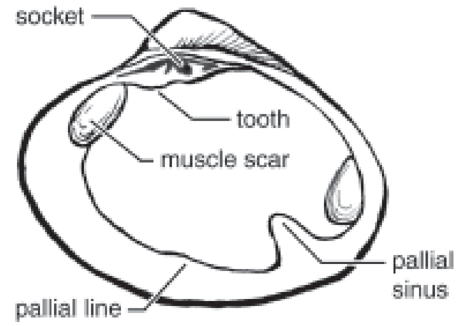


Figure 12. Bivalve mollusk anatomy. Internal view of the right valve of a clam.

Bivalves are filter feeders: They strain small food particles from water. Water enters through the *inhalent siphon,* passes through the gill, which takes in oxygen from the water, and exits through the exhalent, the *outcurrent siphon*. The gill traps food particles and transports them to the mouth. Bivalves live in a variety of habitats: Some live *epifaunally* (on top of seafloor sediment); others live *infaunally* (in seafloor sediment), using their muscular foot to burrow within the bottom sediments. The shape of the shell can be related to the environment in which the animal lives.

Bivalves originated in the Cambrian, but did not become abundant until the Ordovician. They are not particularly common in Paleozoic rock of Wisconsin, but they sometimes can be found within large groupings of other Ordovician fossils.

Gastropod mollusks: Snails

Once confined to the oceans, gastropods (snails; plate 5) now live in streams, lakes, and even on land. Gastropods are the most abundant mollusks: There are approximately 40,000 living species and 50,000 fossil species. Some modern species are voracious predators equipped with poison. However, the snails that lived in Wisconsin's Paleozoic seas were probably peaceful grazers.

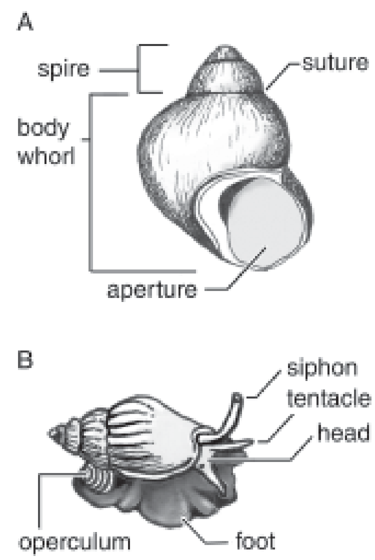


Figure 13. Gastropod mollusk anatomy. A: Apertural view of gastropod shell. B: Anatomy of a living gastropod.

The shell of a gastropod is usually coiled and is used for protection, as it is for most mollusks (fig. 13A). Gastropods can retreat into

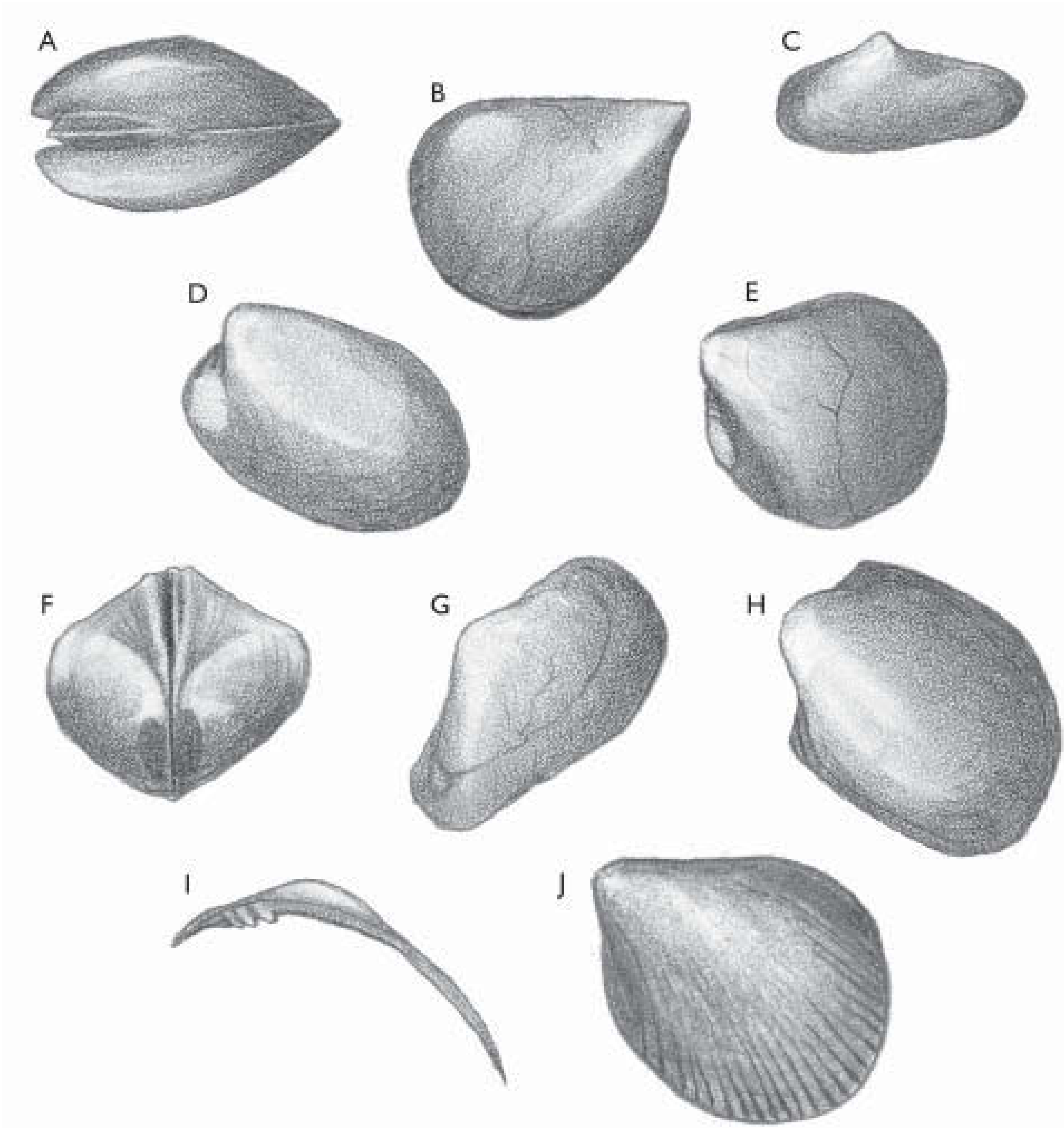


Plate 4. Bivalve mollusk fossils. A: Side view of *Saffordia*, an Ordovician clam [3.5 cm]. B: *Ambonychia*, a raindrop-shaped Ordovician clam [3.5 cm]. C. The elongate Ordovician clam *Ctenodonta* [3.5 cm]. D, E, and F: Two top views and one back view of casts of the egg-shaped Ordovician clam *Cypricardites* [3.5 cm]. G: *Tellinomya*, an Ordovician wedge-shaped clam [3.5 cm]. H and I: Top view of a cast and internal view of the hinge structure of the square-shaped *Cyrtodonta*, a clam found in Ordovician and Silurian rock [4 cm]. J: *Amphicoelia*, a Devonian clam [3.5 cm].

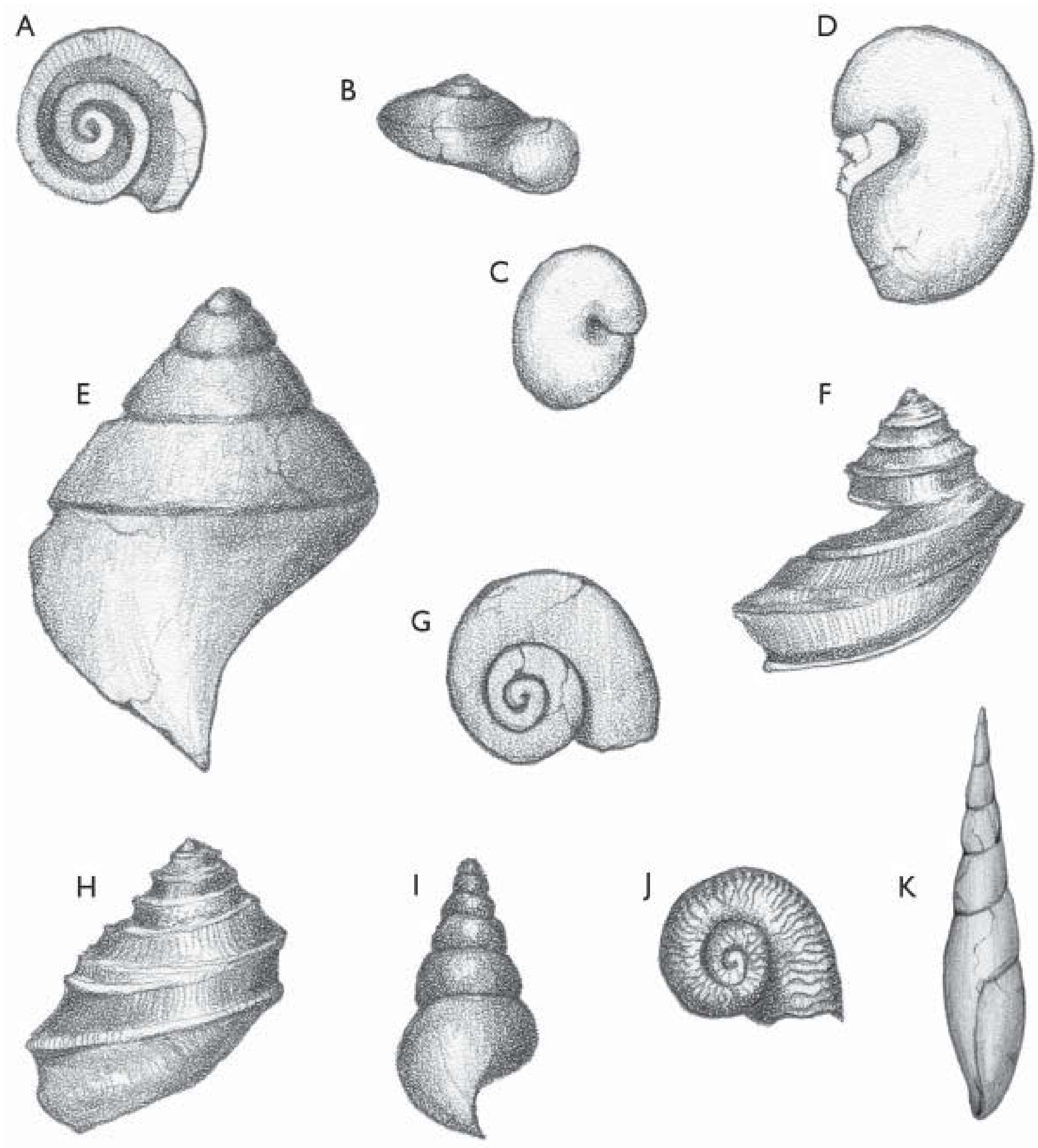


Plate 5. Gastropod mollusk fossils. A: *Helicotoma*, an Ordovician gastropod with raised, angular sutures [2 cm]. B: *Liospira*, an Ordovician gastropod with a flattened shell [1.5 cm]; C and D: *Sinuites*, a common Middle Ordovician gastropod with a large, smooth shell [2.5 cm]. E: *Clathrospira*, a large and common Ordovician gastropod with a cone-shaped spire [4.5 cm]. F: *Lophospira*, a gastropod with angular ridges. It is similar to *Trochonema* (shown on this plate as H), but taller and with an unwound body whorl [4.5 cm]. G: Bottom view of *Maclurites*, an Ordovician gastropod with one side flattened where it rested on the sea floor [4.5 cm]. H: *Trochonema*, an Ordovician gastropod with angular ridges [3.5 cm]. Several different types can be found in Wisconsin. I: *Hormotoma*, a high-spired gastropod found in Ordovician rock [2 cm]. J: *Phragmolites*, an Ordovician gastropod possessing suture-like ornamentation [1.5 cm]. K: *Subulites*, a tall, high-spired Ordovician and Silurian gastropod [5 cm].

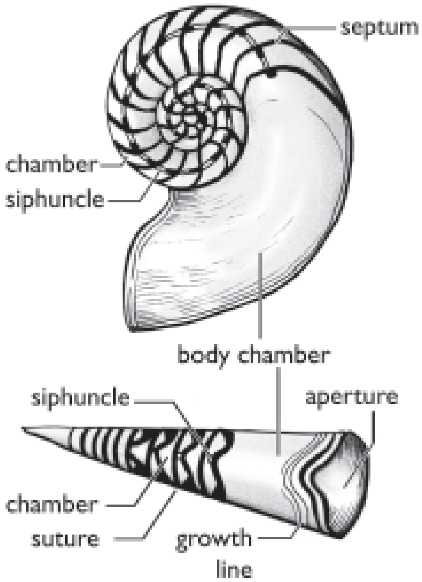


Figure 14. Cephalopod mollusk anatomy: coiled and straight cephalopod shells (after Boardman and others, 1987).

their shells and close the opening with a cover called the *operculum*. The shape of the shell can be highly varied because of the way it coils. Each 360° revolution of the shell is called a *whorl*. The body whorl is the bottom and largest whorl; it contains the *aperture*, the opening of the shell. The shell *spire* includes the whorls above the body whorl. Whorls come in contact with one another at the shell *sutures*.

Gastropods have highly developed sensory organs, including tentacles and eyes (fig. 13B). The head is attached to the foot, a muscular organ used for creeping and feeding. Many gastropods have a *radula*, a rasp-like structure used for scraping algae and other food off the seafloor. Some carnivorous gastropods use the radula for boring through the shells of other animals.

Gastropods originated in the Cambrian, but few are found in rock of that age in Wisconsin; more are found in Silurian and Devonian rock. Our Ordovician rock contains abundant and beautiful gastropod fossils.

Cephalopod mollusks: Squid and octopus

Cephalopods (plate 6) are a group of swimming mollusks, including the living squid, octopus, and the chambered *Nautilus*. Although most living cephalopods have somewhat reduced shells, fossil shells were well developed. Cephalopod shells have evolved into many astonishing and beautiful forms (fig. 14), exhibiting a variety of shapes, such as straight, slightly curved, crescent, and coiled (fig. 15).

The shell of a cephalopod is normally tube- or cone-shaped with many dividers. These dividers are called *septa*, and they partition the inside of the shell into chambers. Each septum intersects the shell wall at a suture, which can be seen as a pattern on the outside of the shell. Sutures are characteristic of cephalopod groups and are therefore helpful for identification. The body chamber, which lacks sutures, is the area where the animal lived. A small tube called the *siphuncle* runs the length of the shell, and passes through the septa. The siphuncle contains liquid that helps maintain the buoyancy of the animal in the water.

Like their clam and snail relatives, cephalopods possess typical molluscan features: a shell, a muscular foot, and a mantle. They also have highly developed sensory organs. The eye of a cephalopod, for example, is similar to that of a human. Unlike the brachiopods and clams, cephalopods are mobile predators, and some can swim at speeds of approximately 64 kilometers (40 miles) per hour by jetting water from the mantle cavity through a fleshy funnel.

Cephalopods originated during the Cambrian and are common as fossils in Ordovician and Silurian rock in Wisconsin. Fossil cephalopods from Wisconsin can exceed 4 meters (13 feet) in length. They are exciting to find because of their large size, but they can be preserved as molds and casts and can be difficult to identify.

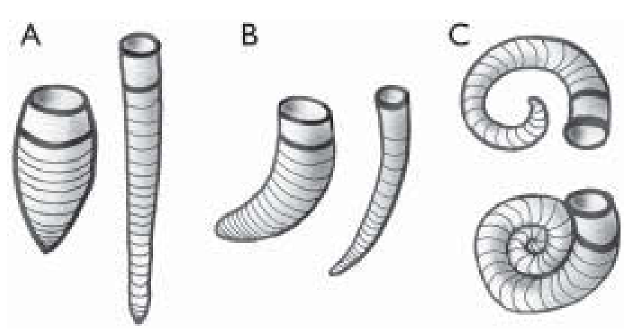


Figure 15. Morphologies of fossil cephalopods.
A: Straight.
B: Crescent-shaped.
C: Coiled.

Extinct arthropods: Trilobites

Trilobites (plates 7 and 8) were a group of crab-like animals with hard *exoskeletons* (outer skeletons) similar to those of modern insects. Trilobites have a three-lobed body (fig. 16B): Two grooves divide the body lengthwise into

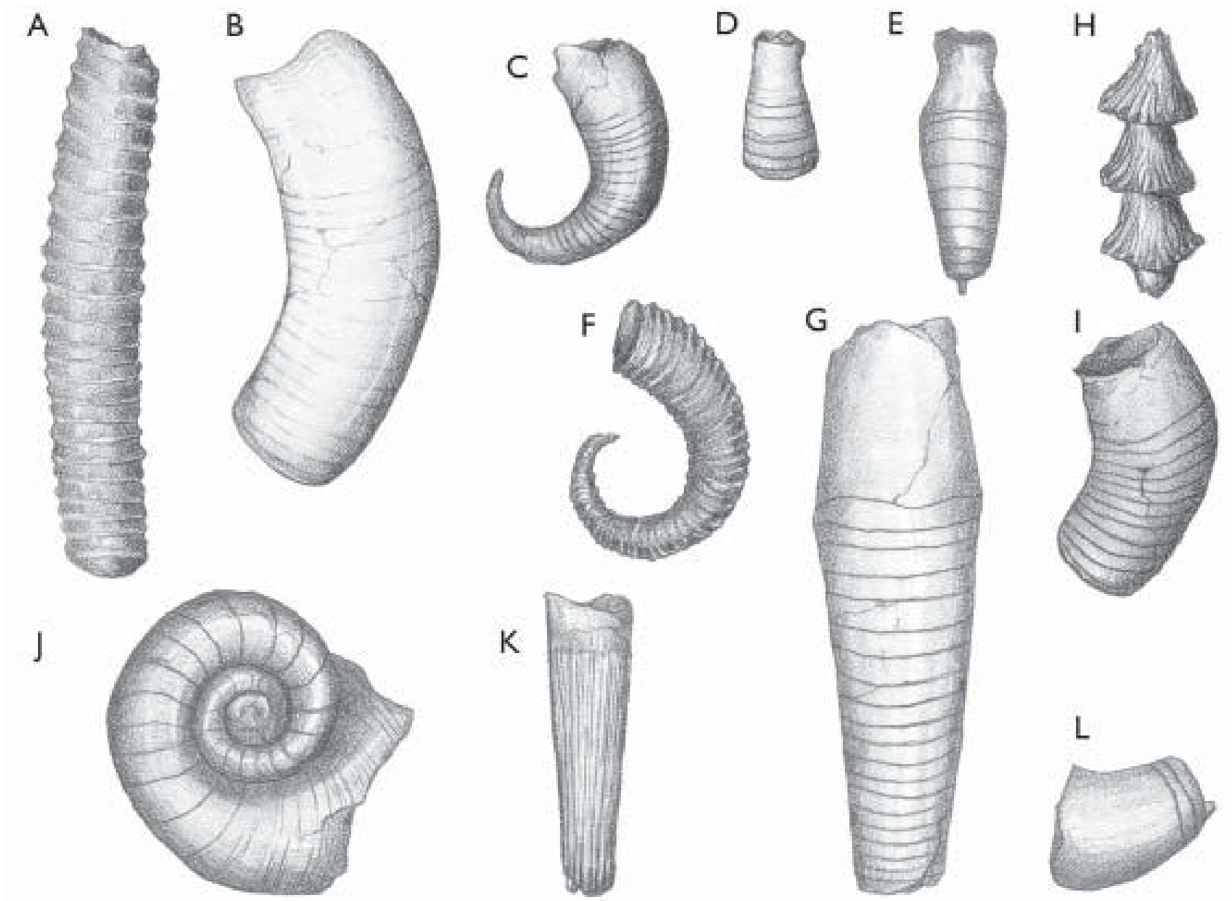


Plate 6. Cephalopod mollusk fossils. A: *Spyroceras*, a common Ordovician and Silurian cephalopod with a straight and ridged shell [10 cm]. B: *Richardsonoceras*, common in Ordovician rock [11 cm]. C: Crescent-shaped *Richardsonoceras*, similar to *Gyroceras*, but lacking a ribbed shell [5.5 cm]. D and E: Two examples of *Whitfieldoceras*, an Ordovician cephalopod with a constricted body chamber [2.5 cm and 5 cm, respectively]. F: *Gyroceras*, a Silurian crescent-shaped cephalopod [6 cm]. G: *Actinoceras*, a large, straight cephalopod common in Ordovician rock [35 cm or more]. H: Enlarged siphuncle of *Actinoceras*, a cephalopod common in Ordovician rock and sometimes found in lower Silurian rock [4.5 cm]. I: *Beloitoceras*, a short and stout Ordovician cephalopod [5 cm]. It is similar to *Richardsonoceras*, but smaller. J: *Trocholites*, a coiled cephalopod occasionally found in Ordovician rock [8.5 cm]. K: *Kionoceras*, a Ordovician cephalopod possessing longitudinal ribs [8.5 cm]. L: *Cyrtorizoceras*, an Ordovician cephalopod possessing a large body chamber [4 cm].

three sections. The middle section is the *axial lobe;* the other two sections are the *pleural lobes.* The body can also be divided into three sections from head to tail: the front section is the head, or *cephalon,* the middle section is the *thorax,* and the tail section is known as the *pygidium.* These marine animals had a series of small, *bilobate*

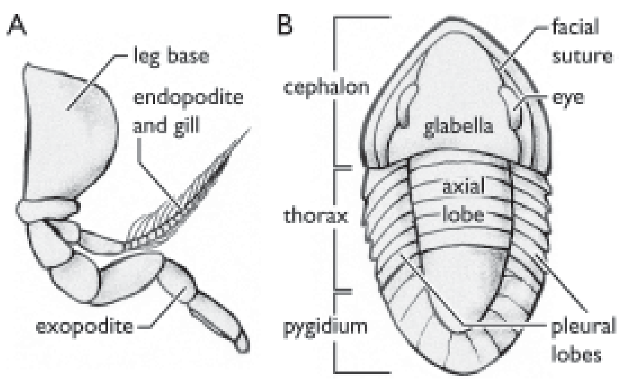


Figure 16. Trilobite anatomy. A: Bilobate appendages of a living arthropod, similar to that of trilobites. B: Exoskeleton of trilobite.

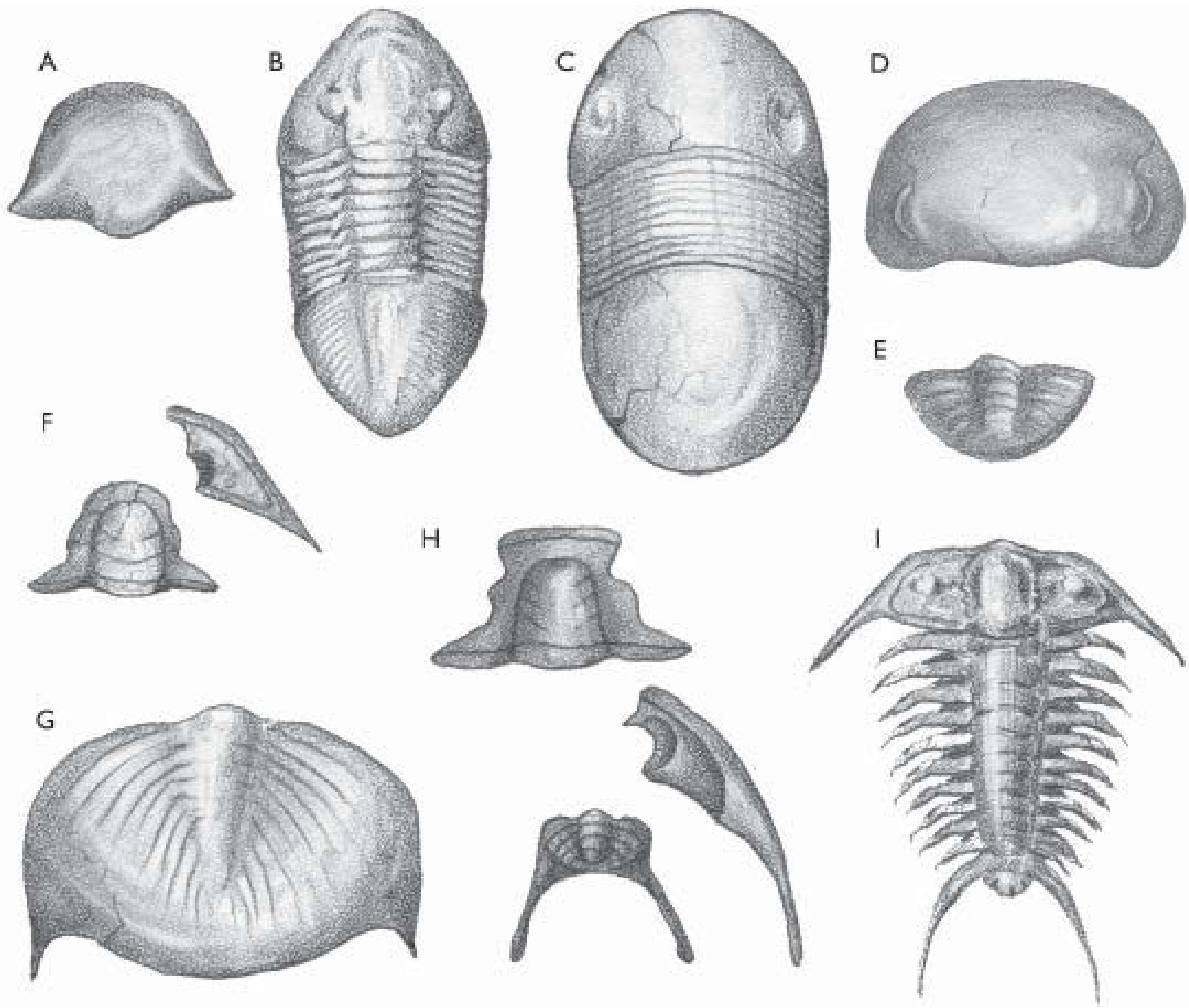


Plate 7. Trilobite fossils. A: Cephalon of *Illaenus*, a common trilobite in Ordovician rock. The cephalon is similar in shape to a strophomenid brachiopod [2.5 cm]. B: Complete specimen of the Ordovician trilobite *Isotelus*. It has a more triangular cephalon and pygidium than *Bumastus*, and a more pronounced axial lobe [5 cm]. C: *Bumastus*, a Ordovician mud-burrowing trilobite with a broad, rounded cephalon and pygidium [6.5 cm] D: Large cephalon of *Bumastus* [4 cm]. E and F: Stubby, rounded pygidium and disarticulated cephalon of the Cambrian trilobite *Conaspis*. The glabella is more rounded than that of *Crepicephalus* (shown on this plate as H) [3 cm]. G: Large, egg-shaped pygidium of the upper Cambrian trilobite *Dikelocephalus* [6 cm]. The pygidium looks similar to a fish tail. H: Molted parts of the Cambrian trilobite *Crepicephalus*. The glabella is more squared than that of *Conaspis*. Extensions of the pygidium make it look similar to a swallowtail butterfly wing [3 cm]. I: The Ordovician trilobite *Ceraurus*, showing the characteristic tail spines and pronounced "ribs" of the pleural lobes [4 cm].

(two-pronged) legs beneath their exoskeleton (fig. 16A). One part of the leg, the *exopodite,* was used for walking; the other, the *endopodite,* was used for gas exchange or "breathing."

On the cephalon, a series of lines, or *facial sutures,* are present. These sutures opened when trilobites molted their skeletons. The trilobite pushed itself out of its old skeleton and grew a new one; most trilobite fossils are *instars,* or molted skeletons. The region of the cephalon between the eyes and bounded by the sutures is called the *glabella*.

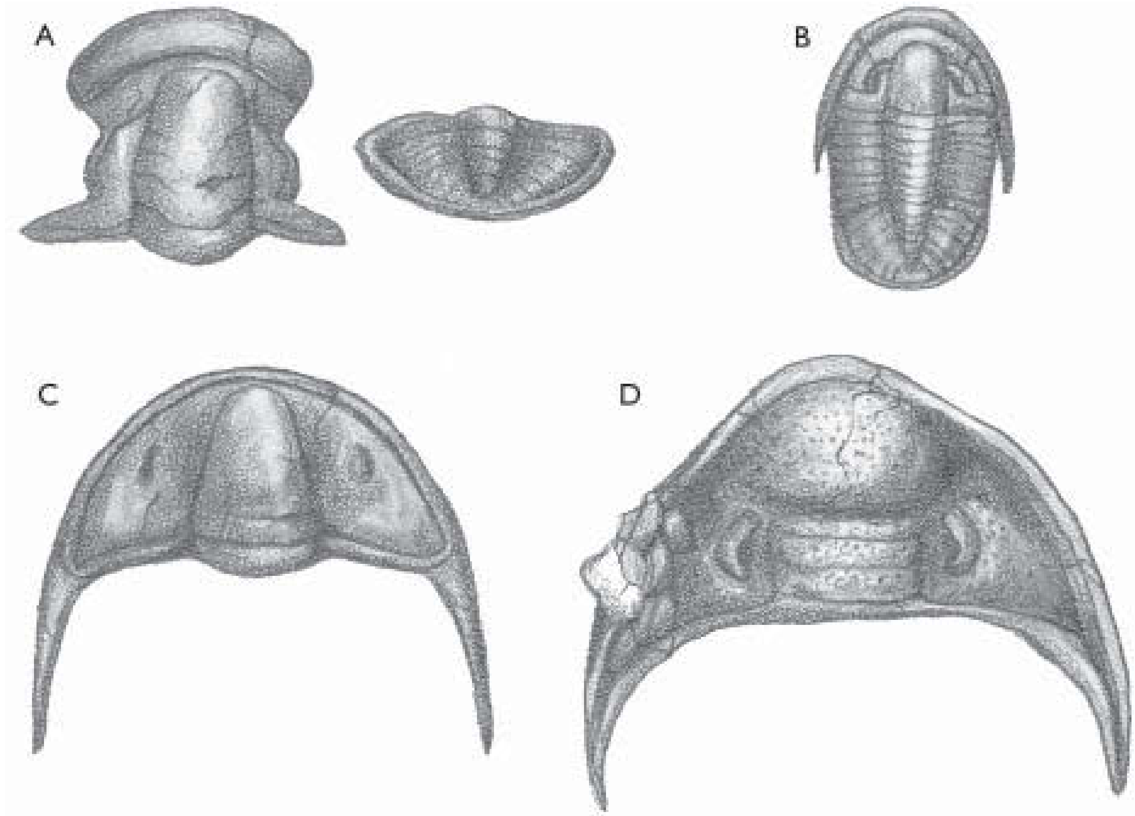


Plate 8. Trilobite fossils. A: Cephalon and pygidium of the Cambrian trilobite *Wilburnia*. The glabella is similar to that of *Conaspis* (shown on plate 7 as F), but with a pronounced flared lip along the outer margin [1.5 cm]. B: Articulated specimen of *Cedaria*, found in Cambrian rock. It is similar to *Wilburnia*, but smaller and with a narrower pygidium and lip [3 cm]. C: Cephalon of *Ptychaspis*, a Cambrian trilobite. It is similar to *Cedaria*, but much larger and with more widely spaced eyes [3 cm]. D: *Dalmanites*, a Silurian trilobite possessing bumps on the cephalon [4.5 cm].

Trilobites had compound eyes, much like those of insects. Some trilobites were adapted to mud-burrowing, and possessed *vestigial,* or nonfunctional, eyes. Mud-burrowing trilobites had smooth, streamlined bodies.

Trilobites first appeared in the Cambrian, but after a diversification they dwindled and eventually became extinct during the Permian. Trilobite fossils are not common in Wisconsin. Generally, they form a large component of Cambrian fossil assemblages, and Ordovician rock commonly contains trilobite fragments. In Silurian rock, trilobites may be associated with reef-like habitats. Devonian trilobites are not particularly abundant. Fossil tracks of trilobites can be found on rock that was once the Paleozoic seafloor. The trilobite *Calymene celebra* is Wisconsin's state fossil.

Crinoids: Sea lilies

Crinoids (plate 9A, B) are echinoderms, a group that includes the starfish, sea urchins, and sand dollars. Sometimes called sea lilies, crinoids resemble long-stemmed flowers, but they are marine animals. A *holdfast* at the base of the animal's stem functions like a root that holds the animal in place (fig. 17). The animal's cuplike body, or *calyx,* is composed of a mosaic of geometric plates. The calyx has many arms that open into a fan-like net so the crinoid can feed on microscopic food particles. The flexible stem is

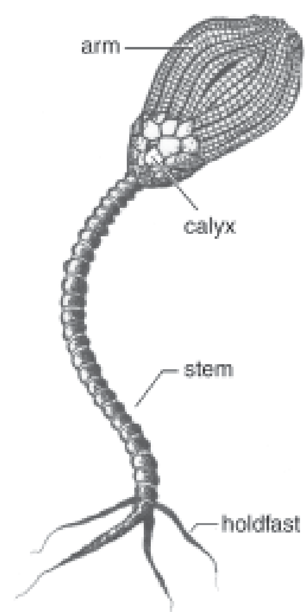


Figure 17. Crinoid anatomy.

composed of a series of button-like discs called *columnals.* When crinoids die, their stems fall apart, or *disarticulate,* into columnals. The *lumen,* a hole in the middle of the stem, contained a tube for carrying nutrients to the stem and holdfast. The mouth of the crinoid is on the top of the calyx.

Crinoids first appeared in the Cambrian and diversified until the Permian extinction, when their numbers were greatly reduced. Complete crinoid fossils may occasionally be found in Wisconsin's Silurian and Devonian rock, but most crinoid fossils consist of scattered columnals. In the Paleozoic, crinoids lived in colonies in shallow waters, but today they live in deeper regions of the world's oceans.

Bryozoans: Moss animals

Bryozoans (plate 9C, D) are small, mostly marine animals that form skeletons of a variety of shapes: tiny twigs, nets, domes, and mossy crusts (fig. 18). The *zooecium* (skeleton) houses highly structured colonies of *zooids,* or cuplike animals. Bryozoans, like brachiopods, contain a tentacle-bearing lophophore used in feeding

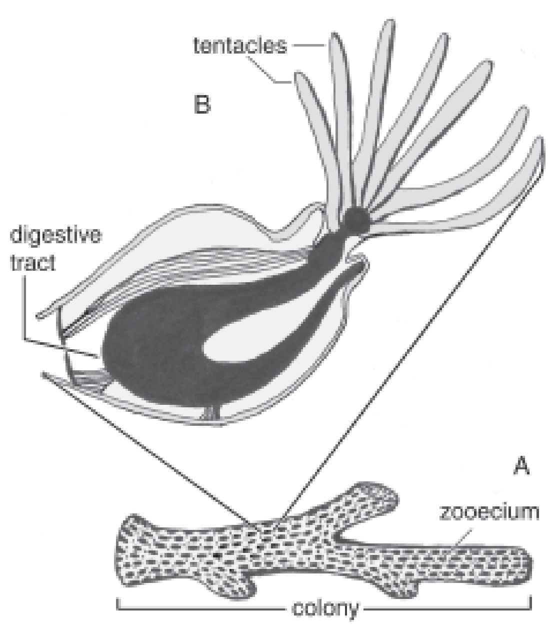


Figure 18. Bryozoan anatomy. A: Skeleton of a bryozoan colony. B: A zooid living in the skeleton.

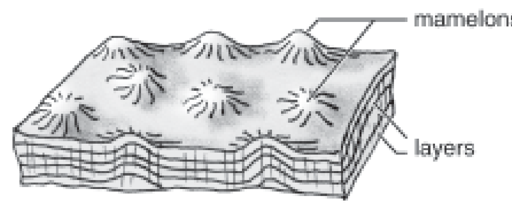


Figure 19. Stromatoporoid anatomy.

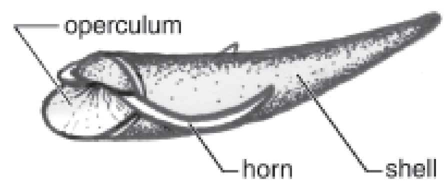


Figure 20. Hyolithid anatomy.

and gas exchange. They also contain a u-shaped gut with a distinct mouth and anus.

Bryozoans are inconspicuous fossils, but can be seen most easily on slabs of Ordovician limestone or dolomite with the aid of a magnifying glass or hand lens. Bryozoans are difficult to distinguish from one another. In most cases you may not be able to identify your fossil more specifically than as a bryozoan.

Bryozoans were able to live almost anywhere: on a brachiopod shell, the side of a cephalopod, coating sea plants, or in an individual colony on the sea floor. Many fossils have patches of bryozoans on them. Bryozoans first evolved in the Ordovician and have persisted to the present day; they live in ocean habitats that are similar to those of Paleozoic seas.

Other fossils

Stromatoporoids: Laminated reef builders

Stromatoporoids were colonial marine organisms related to sponges. They formed skeletons composed of thin layers called *laminae*. Small bumps called *mamelons* were present on their surface (fig. 19). Stromatoporoids formed reefs in the shallow Silurian seas of Wisconsin. They became extinct 65 million years ago.

Ostracods: Bivalved arthropods

Ostracods (plate 9E) are small, two-valved arthropods that resemble small, dark, polished

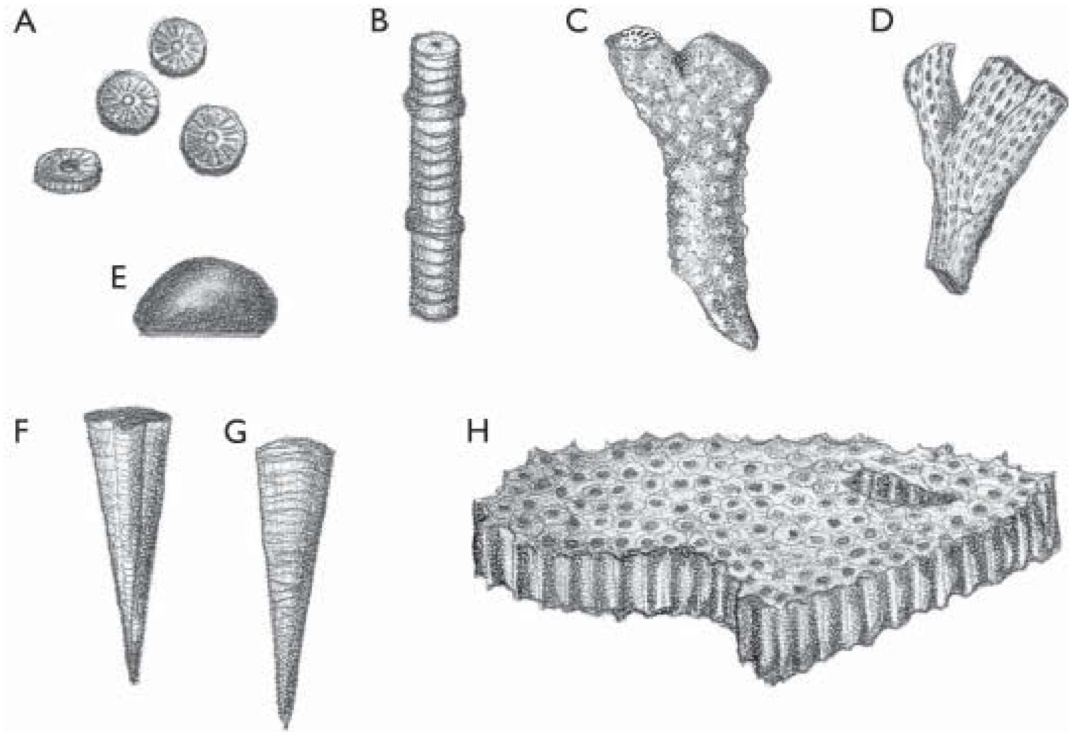


Plate 9. Miscellaneous fossils. A: Crinoid columnals, or plates, which make up the stems [0.5 cm]. B: Crinoid column section, or stem [3.5 cm]. C and D: Fragments of bryozoan colonies found in Ordovician, Silurian, and Devonian rock [3 cm]. E: *Eoleperditia*, an Ordovician ostracod. [1 cm]. F and G: Two views of the Ordovician hyolithid *Hyolithes* [3 cm]. H: An Ordovician colony of *Receptaculites*, believed to be a skeleton-secreting algae [10 cm].

beans. Ostracods first appeared in the Cambrian and still exist today in freshwater, marine, and terrestrial environments. Like other arthropods, ostracods molt their skeletons as they grow. Although they are not very common, ostracods are occasionally found in Wisconsin's Ordovician and Silurian rock.

Hyolithids: Animals of unknown affinities

Very little is known about these mysterious animals. Hyolithids (plate 9F, G) are an unusual, extinct group of marine animals that had a conical shell with an operculum (fig. 20). They are sometimes found in the digestive tracts of fossil marine worms. Middle Ordovician rock in Wisconsin commonly contains hyolithids.

Receptaculitids: Skeleton-secreting algae

Receptaculitids (plate 9H) are another extinct group of marine organisms that scientists have had difficulty classifying. Receptaculitids have been classified as corals and sponges, but they are now thought to be colonial algae. They superficially resemble favositids, the honeycomb corals. Receptaculitid fossils are most common in Ordovician rock.

Trace fossils: Trails, borings, and burrows

Trace fossils (plate 10) are the preserved paths of animals that crawled on and bored or burrowed into the seafloor. A variety of paths representing behaviors—such as feeding, moving, and resting—can be found in sedimentary rock. Certain burrowing behaviors are specific to certain environments, so paleontologists can reconstruct ancient environments from the shape of trace fossils. Trace fossils are common in the Paleozoic rock of Wisconsin and are still being formed in ocean sediments today.

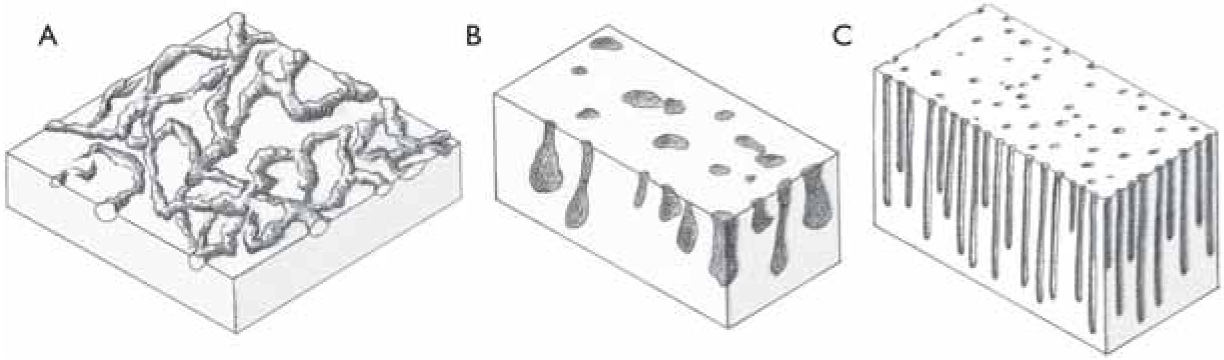


Plate 10. Trace fossils. A: Large, worm-like feeding traces parallel to rock layers [diameter can be as much as 1 cm]. B: Large, variably shaped borings perpendicular to rock layers [diameter up to 1 cm or more; length up to 4 cm or more]. C: Long, thin burrows perpendicular to rock layers [diameter less than 0.5 cm; length up to 5 cm or more].

Sources of information

Societies

Wisconsin abounds in groups that are devoted to all aspects of the earth sciences, including paleontology. One way to find out if there is a club near you is to check with the Midwest Federation of Mineralogical and Geological Societies, a regional member of the American Federation of Mineralogical Societies. The Midwest Federation maintains a directory of its member societies. (Note that not all of these societies focus on paleontology.) The Internet address for the Midwest Federation at the time of the printing of this publication is **<www.amfed.org/mwf/>.**

One of the largest groups in Wisconsin is the Wisconsin Geological Society. It is a nonprofit organization, located in Milwaukee, that conducts study groups, meetings, and field trips on geology and paleontology. Its monthly publication, *The Trilobite*, contains articles of local interest on rocks, minerals, and fossils. This group is an excellent place to learn more about fossils and geology and meet others interested in Earth history.

Books

You may be interested in learning about fossils in more detail. Many books have been written for the interested layperson; check your local public library for the various titles available. The following books provide detailed technical information about fossils and the principles of paleontology. They are usually available at university libraries.

Boardman, R.S., Cheetham, A.H., and Rowell, A.J., 1987, *Fossil Invertebrates:* Blackwell Scientific Publications, Palo Alto, 713 p.
A detailed, college-level textbook intended for paleontology students.

Chamberlin, T.C., 1882, *Geology of Wisconsin: Survey of 1873–1879*, Volume IV, 779 p.
A classic work on the geology and paleontology of Wisconsin.

Easton, W.H., 1960, *Invertebrate Paleontology:* Harper and Row, New York, 701 p.
A detailed and extensively illustrated college-level textbook.

Moore, R.C. (director and editor), 1953—, *Treatise on Invertebrate Paleontology*: The University of Kansas Press/The Geological Society of America.
A multi-volume, professional-level treatise containing every described fossil genus.

Moore, R.C., Lalicker, C.G., and Fischer, A.G., 1952, *Invertebrate Fossils:* McGraw–Hill Book Company, Inc., New York, 766 p.
A general text on invertebrate fossils.

Rhodes, F.H.T., Zim, H.S., and Shaffer, P.R., 1962, *Fossils:* Western Publishing Company, Inc., Racine, 160 p.

An inexpensive, superbly written, and extensively illustrated book.

Schrock, R.R., and Twenhofel, W.H., 1923, *Principles of Invertebrate Paleontology:* McGraw-Hill Book Company, Inc., 816 p.

A classic text written by Wisconsin paleontologists.

Shimer, H.H., and Schrock, R.R., 1945, *Index Fossils of North America:* John Wiley & Sons, New York, 837 p.

A book that will help you identify fossils not illustrated in this guide.

Acknowledgments

We thank those who reviewed earlier drafts of this guide, especially Maureen Muldoon, M.G. Mudrey, Jr., and the late Juergen Reinhardt, of the Wisconsin Geological and Natural History Survey, who provided many useful comments. We also thank Susan Lawton Hunt and Ronald Hennings of the Wisconsin Geological and Natural History Survey, for assistance and encouragement throughout this project. Paula Sumpter of the Milwaukee Public Museum and Klaus Westphal of the University of Wisconsin–Madison assisted with museum collections. We thank David Clark and Dana Geary of the University of Wisconsin–Madison for sharing their knowledge of fossils and paleontology with us. RHN thanks Wayne Schaefer, of the University of Wisconsin Center–West Bend, Lloyd and Ellen Brown, Dan and Ellen Dettwiler, and his parents for support during the early periods of this project.

About the authors

Ross H. Nehm and Bryan E. Bemis grew up in Wisconsin and collected fossils before pursuing undergraduate degrees at the University of Wisconsin–Madison. Both received their doctorates from the University of California—Nehm at Berkeley, and Bemis at Davis. Nehm is now an assistant professor at The City College, City University of New York, in New York City. Bemis is a research associate at the U.S. Geological Survey, Menlo Park, California.

Reconstruction of Silurian reef. (Photograph of diorama © Milwaukee Public Museum.)

Eon	Era	Period	Million years ago
			0
Phanerozoic	Cenozoic	Quaternary	2
Phanerozoic	Cenozoic	Tertiary	66
Phanerozoic	Mesozoic	Cretaceous	144
Phanerozoic	Mesozoic	Jurassic	208
Phanerozoic	Mesozoic	Triassic	245
Phanerozoic	Paleozoic	Permian	286
Phanerozoic	Paleozoic	Pennsylvanian	320
Phanerozoic	Paleozoic	Mississippian	360
Phanerozoic	Paleozoic	Devonian	408
Phanerozoic	Paleozoic	Silurian	438
Phanerozoic	Paleozoic	Ordovician	505
Phanerozoic	Paleozoic	Cambrian	570
"Precambrian" Proterozoic		Soft-bodied organisms (single and multi-celled) develop; first invertebrates appear.	900 1,600 2,500
"Precambrian" Archean		Oldest known fossils: bacteria and single-celled organisms.	3,000 3,400 3,800-4,400

Extensive sea present. Fishes become abundant; some invertebrate animals develop spines and boney frills on shells. Trilobites and pentamerid brachiopods decline; coral reefs diminsh. Crinoids and spiriferid brachiopods are common.

Plants and animals invade land. Tabulate and rugose coral reefs are extensive; they are covered with crinoids, bryozoans, and pentamerid brachiopods. (See reef reconstruction, above.)

Sea level rises and falls several times. New animal groups (bryozoans and corals) appear. Mollusks and strophomenids and orthid brachiopods dominate shallows; trilobites become less common.

Much of what is now the United States is covered by water. Many groups of marine animals, such as trilobites, mollusks, crinoids, and inarticulate brachiopods, appear.

Geologic time scale. Shaded area indicates time periods for which there is only sparse evidence in Wisconsin.

E.S. 45

Common Paleozoic Fossils of Wisconsin

2002

UW Extension

Wisconsin Geological and Natural History Survey
3817 Mineral Point Road • Madison, WI 53705-5100
TEL: 608/263.7389 FAX: 608/262.8086 www.uwex.edu/wgnhs/
James M. Robertson, *Director and State Geologist*