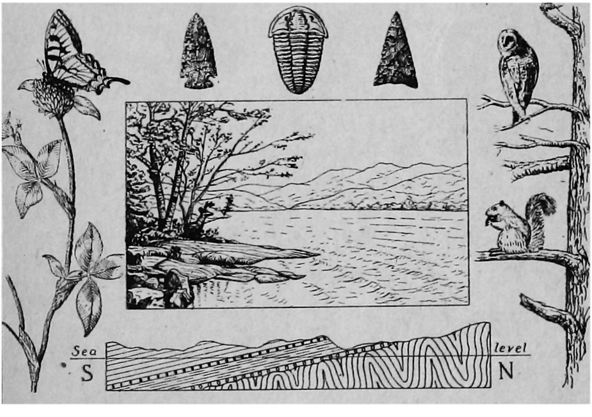
New York State Museum Handbook 9

NEW YORK STATE MUSEUM
CHARLES C. ADAMS, *Director*

HANDBOOK OF PALEONTOLOGY FOR BEGINNERS AND AMATEURS

PART 1 THE FOSSILS

BY WINIFRED GOLDRING
Associate Paleontologist, New York State Museum



ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1929

M205-D28-2000

New York State Museum Handbook 9

NEW YORK STATE MUSEUM

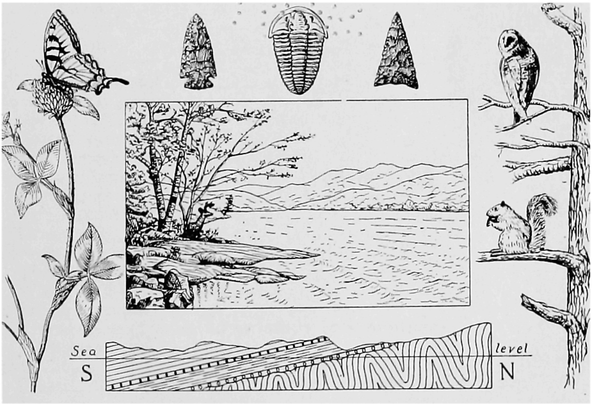
CHARLES C. ADAMS, *Director*

HANDBOOK OF PALEONTOLOGY FOR BEGINNERS AND AMATEURS

PART 1 THE FOSSILS

By WINIFRED GOLDRING

Associate Paleontologist, New York State Museum



ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1929

CONTENTS

LIST OF ILLUSTRATIONS

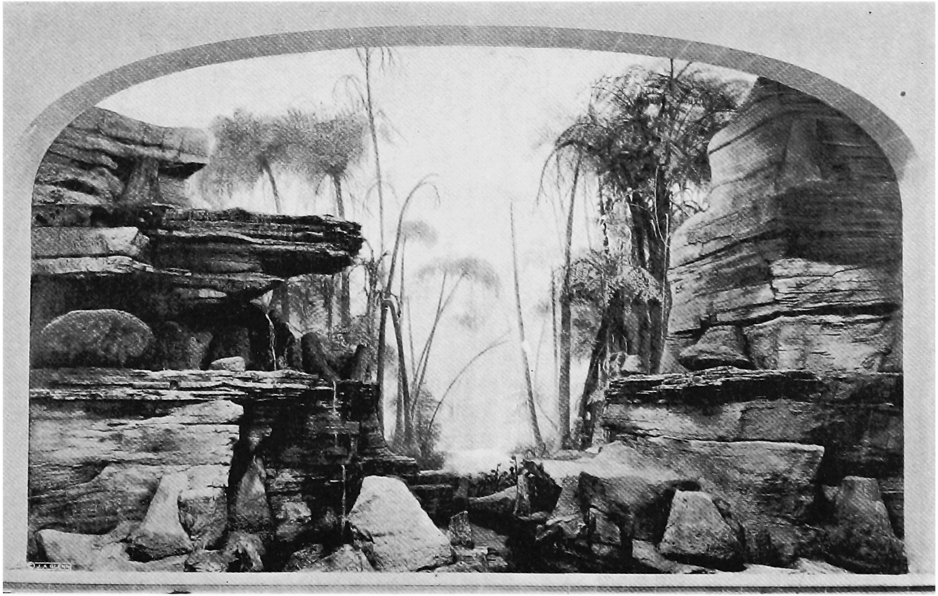


Figure 1 Restoration of the Upper Devonian forest of seed ferns found at Gilboa, N. Y. Restoration in the State Museum, executed by Henri Marchand and sons, Georges and Paul, and supervised by Winifred Goldring.

New York State Museum

HANDBOOK OF PALEONTOLOGY FOR BEGINNERS AND AMATEURS

PART 1 THE FOSSILS

By Winifred Goldring

Associate Paleontologist, New York State Museum

PREFACE

Numerous requests have come to the paleontological staff of the New York State Museum from visitors to the Museum and by mail from various parts of the State, for some treatise on paleontology simple enough to be understood by those who have had no previous training and yet full enough to give a comprehensive survey of the whole field. This handbook has been written in answer to such requests, *with special reference to New York State;* and is, in a sense, an amplification of two educational exhibition cases that have been on display in the Museum for several years now, namely, the "What is a Fossil?" and "What is a Geological Formation?" cases. The work is planned to be published in two parts: Part I The Fossils; Part II The Stratigraphy or Formations of New York State; and the present handbook constitutes Part I.

Part I: Fossils, serves not only as an introduction to paleontology but also, to a certain extent, as an introduction to zoology; for in order to give a proper understanding of the various groups of fossils it has been necessary to give descriptions of recent representatives. Wherever possible reference has been made to New York material and State Museum exhibits so that this work should have a special application to New York State. The invertebrates have been treated at greater length than the vertebrates or plants because they are the fossils found most abundantly in New York State. The chapter on plants is most briefly treated, and has been written with the idea of tracing the development of plant life from the earliest beginnings to the present, and thus giving a complete survey of the subject. Few specimens of fossil plants will come into the hands of amateurs, but they can be studied in museum collections.

Part II: Stratigraphy, as planned, will have an introductory chapter which deals with the different kinds of rocks and the conditions under which they are deposited and gives a general discussion of the geologic time scale. The remainder of the handbook will be entirely devoted to the formations in New York State with lists of characteristic fossils. The illustrations will comprise plates of characteristic fossils of the different formations, maps showing the distribution of the formations in the State and a number of photographs of type localities.

The material upon which this handbook (Part I) has been based has naturally been drawn from a great many sources, paleontological, zoological and botanical. Figures have been freely used since full illustration is essential in a work planned for beginners. The figures, with the exception of the photographs of the restorations in our Museum, are taken from various publications, wherever necessary; and proper credit is given under each figure to the author, work and publisher. Among the publications are: Cambridge Natural History; Bashford Dean: Fishes, Living and Fossil; A. W. Grabau: Textbook of Geology; A. W. Grabau and H. W. Shimer: Index Fossils; E. M. Kayser: Lehrbuch der Geologie; F. H.

Knowlton: Plants of the Past; E. Ray Lankester: Treatise on Zoology; R. S. Lull: Organic Evolution; F. A. Lucas: Animals of the Past; H. F. Osborn: Age of Mammals; T. J. Parker and W. A. Haswell: Textbook of Zoology; D. H. Scott: Extinct Plants and Problems of Evolution; W. B. Scott: History of Land Mammals in the Western Hemisphere; Charles Schuchert: Textbook of Geology, Part II, Historical Geology; H. W. Shimer: An Introduction to the Study of Fossils; A. E. Verrill and S. I. Smith: Invertebrate Animals of Vineyard Sound etc. Besides these, various publications of the New York State Museum and of other museums and reports of government and state surveys have been used.

In a work of this kind one has many acknowledgments to make. The author wishes first to express appreciation to Dr Charles C. Adams, Director of the New York State Museum, for the opportunity of undertaking this kind of work and for the interest he has shown. From Dr Rudolf Ruedemann, State Paleontologist, the author has had interest and encouragement, but she is likewise indebted to him for reading and criticizing the manuscript. The manuscript has also been read by younger and less experienced members of the staff, Clinton Kilfoyle, technical assistant in paleontology, Walter Schoonmaker, technical assistant in zoology, and Edwin J. Stein, draftsman and photographer, and has had the benefit of their viewpoints.

The majority of the pen and ink figures were made by Clinton Kilfoyle and the author herewith expresses her appreciation to him, not only for the work done but for the interest he has shown. The rest of the figures were made by the draftsman and photographer, Edwin J. Stein, who was too occupied with other duties to undertake the

entire work, and by Walter Schoonmaker. Special mention should be given to Mr Stein's pen and ink sketches of the heads of the three prehistoric men, based on the photograph of Professor McGregor's models in the American Museum Guide Leaflet.

For permissions, favors and courtesies the author is indebted to several individuals and institutions and herewith expresses her appreciation to the American Museum of Natural History, Professor E. W. Berry, Professor H. F. Cleland, the late Professor Bashford Dean, C. W. Gilmore, Professor W. K. Gregory, the late Dr F. A. Lucas, Professor R. S. Lull, Dr H. F. Osborn, Dr Charles Schuchert and Professor H. W. Shimer.

Prompt response and cooperation were received from most of the publishing houses approached. The author's acknowledgments are due, for permission to use illustrations, to the American Museum of Natural History, and to the publishing houses of A. & C. Black, Ltd; D. C. Heath & Co.; Macmillan & Co.; Princeton University Press; and John Wiley & Sons.

THE NATURE, PRESERVATION AND SIGNIFICANCE OF FOSSILS

What is a Fossil?

Fossils (from Latin *fossilis*, something dug up) *are the remains of plants or animals, or the record of their presence, preserved in the rocks of the earth.* The term in its narrower sense is applied to all remains or traces of plants and animals which have lived before the present geological period. This is an arbitrary distinction based upon the geological age of the formation in which the fossils occur and regarding as merely incidental considerations their mode and state of preservation or the fact of their belonging to extinct or to still living species. The Pleistocene formation is the youngest of the geologic deposits. In the postglacial sands and clays of this period in the Lake Champlain area in New York, in northern New England and Canada are found marine shells not at all different from those found in the deposits along the present coast, only the beds containing the former have been elevated several hundred feet. Even earlier than this in Tertiary times a large percentage of shells are found belonging to recent species, and often the changes which have taken place since they were buried are no greater than in shells found in recent deposits. In other words, the present life shades gradually into the past. The term "fossil," then, is by some extended, in a broader sense, to include all remains and traces of animals and plants from the time of the earliest fossil-bearing beds to the present, since no break divides the present from the past; geologic time is continuous and the development of life is progressive; the same natural laws are operative today as in the past. The use of the term "fossil" in the restricted sense is, however, the more commonly accepted.

Fossils, in the restricted sense, may be grouped into two classes, in the broader sense, into three: (1) organic remains and their impressions; (2) trails, tracks, burrows etc. of organisms; (3) artificial structures. The third group would include flint implements and other utensils of primitive man; the relics of the Swiss Lake Dwellers; Roman and other ancient coins buried in the peat bogs; and, in fact, all artificial productions of early man or the lower animals which have become entombed by natural agencies. This third group is not touched upon here as fossils are here treated in the more restricted sense.

How Fossils Are Preserved

To insure preservation it is necessary that organisms soon after death be imbedded in some protective material and, since soft parts of organisms are rarely preserved, that hard parts be present. Exposed to the atmosphere or hydrosphere (water) dead organisms, both plants and animals, soon vanish without leaving a trace, either through decay or through attacks by microscopic fungi and bacteria among the plants, which are found everywhere, and by scavenging animals of all sizes. The oxygen of the atmosphere assists in this process of disintegration in water as well as on land, although under water the process goes on much more slowly. Chemical and mechanical agencies also have a part in this disappearance of dead organisms. One who has collected along a sea-beach soon realizes that waves, with their undertow, constitute the strongest mechanical agency in the breaking up of marine organisms: shells, corals, starfishes, sea urchins etc. Perfect specimens are comparatively rare, especially after a heavy storm, and a close look at beach sands soon reveals the fact that they are filled with finely ground bits of shells, corals etc. A certain beach in the Bermuda Islands is known as Pink Beach because even from a distance it has a pinkish color due to the fact that the sands are composed to a large extent of broken pieces of a pinkish red coral washed in from deeper waters. The result of all this, one sees, is that the remains of most of the plant and animal life at the present time disappear completely after death. The same is true of the life of past ages. Probably 99 per cent or more of all life past and present has vanished without even leaving a trace. It is very evident, therefore, that the more quickly an organism is buried the greater are its chances for preservation.

Soft-bodied animals, without hard skeletal parts, suffer complete destruction and rarely is a mold of the body form or a trace found. Some occurrences are noteworthy, however. In the State Museum are three large slabs from some of our oldest fossil-bearing beds (the Lower Cambrian), Middle Granville, N. Y. The surfaces of these slabs are covered with star-shaped, black stains which are the casts of the lobed interior cavity of jellyfishes. One of the most remarkable discoveries of this nature was made by the late Dr Charles D. Walcott in beds of a little later age (Middle Cambrian) at Burgess pass near Field, British Columbia. The fossils found here are among the oldest and best preserved fossils discovered (figure 2). Remains of soft-bodied animals, such as sea cucumbers and worms, are preserved as well as crustaceans, etc. Because of burial in fine shale their preservation is so perfect that they retain all details of structure including stomach, intestines, and even the liver in the case of some of the crustaceans. These specimens have been distributed among various museums and some are now on exhibition in the State Museum (Cambrian case).

The kind of protective material in which any organism is buried after death depends largely upon its habitat while living. The protective materials include volcanic ashes, bog waters, ice, resin, incrustations from minerals carried in solution by water, and sediments of various kinds. Volcanic ashes at times of outbursts, are shot high into the air and carried by winds for greater or lesser distances. When the eruptions are extensive the ashes bury all living things in the area on which they fall. An example of such an occurrence is seen in the eruption of Mount Vesuvius in the year A. D. 79. Vesuvius burst into flame and poured forth destruction. Pompeii, a Roman summer resort, was deeply buried under a rain of ashes and stones that brought swift death to more than 2000 persons. Today during excavations in the city some of the bodies of men and animals have been found in the form of molds. Good casts of the people and animals, as they appeared in the flesh, have been obtained by filling the hollow spaces left in the fine ashes with plaster of Paris. Going back some millions of years into Miocene times we find another good example of entombment in volcanic ashes. In later Miocene times, near Florissant, Colo., there was a lake surrounded by active volcanoes. Ashes shot forth from these volcanoes in great quantities fell into the waters of this lake, burying large numbers of plants and insects. About 250 species of plants and more than 1000 kinds of beetles, ants, flies and other insects (figure 2) have so far been described.

Organisms decay very slowly in peat bogs and marshes because the waters there have antiseptic properties. During the last Glacial period or "Great Ice Age," bogs became frozen in the colder areas and plants and animals are well preserved there, as they act as natural refrigerators. Mammoths have been found frozen in the mud and ice of Siberia with hair, skin and flesh intact.

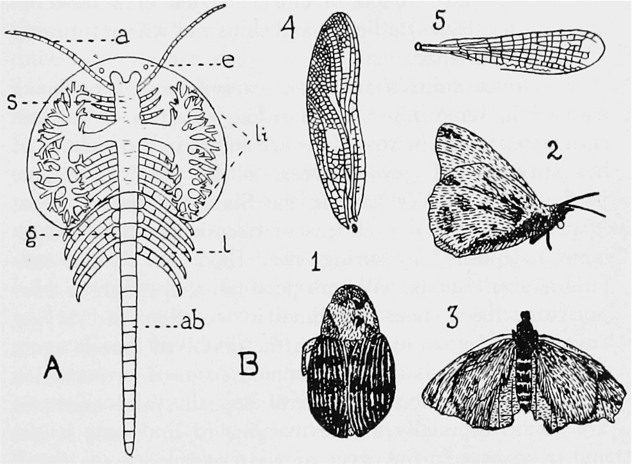


Figure 2 *A* A Cambrian crustacean (*Burgessia*) from British Columbia showing preservation of delicate parts. *B* Insects from Tertiary beds of Florissant, Colo.; 1 Beetle, x9; 2, 3 Butterflies, x¾; 4, 5 Dragon fly wings, x9/8 and x2. (*A* based on Walcott's figures; *B* from Grabau: Textbook of Geology, permission D. C. Heath & Co.)

Amber containing insects and other animals is found along the shores of the Baltic. Amber is simply a fossil resin. It occurs in sands and clays, from which it is washed out by the action of the sea or mined, and in beds of carbonized wood. The amber occurs in drops and globular masses which resemble the resin seen exuding from the bark of pine trees today. In early Tertiary times, many millions of years ago, this resin exuded from coniferous trees which formed an extensive forest in the Baltic region. Creatures were caught in the sticky resin and soon completely entombed. Seeds and other plant remains are also found in amber. This area now lies buried beneath the Baltic sea and ships sail where formerly a forest flourished.

Sometimes animals and plants are entombed by being encased in some mineral deposition, as silica or calcium carbonate. Such incrustations are found in the vicinity of hot springs and geyser areas, as in the Yellowstone National Park. We have in the State Museum ("What is a Fossil?" case) specimens of calcareous tufa ("horse-bone") deposited by springs near Ilion, N. Y., and containing small snails. Waters percolating through or over limestone beds take up lime in solution in varying amounts and upon evaporation the dissolved lime is again deposited. This is a more common form of preservation through incrustation by mineral deposits, and examples are found especially at the margins of limestone ledges and in caves. In the caves of western Europe are found remains of Pleistocene man and animals buried in this manner.

A former asphalt pool not far from Los Angeles, Calif., is a unique example of preservation of vertebrates. The asphalt deposit is remarkable not only because it is unusual but because it is the burial place of a large number of specimens. In the early stages of accumulation the gummy surface of this Pleistocene tar pool acted as a trap for unwary birds and other animals. Aquatic birds were entrapped in the soft tar around the margins of pools of water and mammals and land birds were caught while trying to reach the water. Numerous species have been identified, among them mammoths, horses, sloths, camels, saber-toothed tigers and many birds.

By far the greatest number of organic remains are buried in sediments and particularly in sediments brought by water. Wind-blown sands may or may not contain fossils. In the case of coarser wind deposits, such as sand dunes, fossils are not likely to be found. In southern Utah is a coarse-grained, white sandstone which is a dune deposit of Jurassic age and it is quite unfossiliferous. Prevailing winds which blow from a dry region to a moist region or from a region without vegetation to one with it carry a fine dust which accumulates in the latter region, forming deposits of great thickness. Extensive deposits of this fine, dustlike material, known as *loess,* have been formed in the eastern part of China, where it has been brought from the great deserts of the interior, particularly the desert of Gobi. In some sections its thickness is one or even two thousand feet. Terrestrial animals and seeds and other wind-transported parts of plants may be included in such deposits. Loess is also found in the United States, and here the material has been supplied by glacial streams during the ice age. Shells of land mollusks, such as snails, and occasionally those of river border type, are frequently found in such deposits. Loess deposits are especially abundant in Europe, Asia and North America from Pleistocene time to the present. Ancient rocks are known which are interpreted as altered loess deposits of a former time and, as might be expected, such rocks are free or fairly free from the remains of organisms.

Sediments carried and deposited by water may be roughly divided into two groups: those deposited upon the surface of the continent and those carried by rivers and streams into the sea. The first group includes lake, flood plain, alluvial fan and playa deposits. As surface deposits they are apt to be comparatively quickly worn away with all their organic remains because they are in the zone where the action of erosion is dominant. Deposits formed in the sea are more continuously covered with water and hence the included organic remains have a better chance of preservation. Lake, marsh and marine deposits favor the preservation of organisms more than those of flood plains, alluvial fans or playas because organic remains stand a better chance of preservation away from air and circulating waters. For the same reason clay or limestone materials are better than deposits of sand, pebbles or ash. The chances for preservation of animals and plants, therefore, vary with their habitat. Marine invertebrates are found in greatest numbers in the geological record; first, because they are the most numerous of all the animals and, second, because they live in a zone where there is low oxidation and prolonged sedimentation. Those forms living on the sea floor beyond the destructive action of the breakers but still in shallow water stand the best chance of preservation. Of the inhabitants of the land those living at lower levels stand a better chance of burial and preservation than those at high elevations where erosion is so rapid that it very greatly exceeds deposition. Remains of land life are carried by streams into the sea and buried in the delta deposits at their mouths. The materials of such deltas are worked over by the sea. The seaward portion is more continuously under water and the organic remains stand a much better chance of preservation than in the landward portion which is usually covered only in times of flood and thus leaves the inclosed organic material to the destructive action of the ground water and air circulating freely in the upper water-free layers.

The degree of consolidation of sediments is not dependent upon the time element alone. The time element does enter into it, but the firmness of the rock also depends in part upon the amount of the cementing material and its quality and in part upon the pressure. The cement is that which binds the particles of sediments together and changes loose material into more or less firm rock. The cementing material varies. Sometimes it is in solution and brought in from outside and deposited in the pores in the rock; sometimes the sediment itself may be dissolved and redeposited; or sometimes the cement is fine material which is mechanically inclosed in the sediments. Silica and carbonate of lime are commonly the cementing materials in the first two cases; clay or a claylike substance in the third. Iron oxide in various forms is also a cementing material. In the case of deposits of fine muds and clays a cement is not necessary but may be present. Such deposits may be consolidated into firm rocks under the pressure of the overlying masses. As a result of all this we have all gradations in the character of rocks from those which are so loose and friable that they can be easily rubbed to powder, as in the case of chalks and some of the sandstones, to those that are so hard, firm and compact, as in the case of some limestones and sandstones, that they take a high polish and break much like igneous rocks under the hammer. A discussion of the various kinds of sedimentary rocks will be included in part II.

The entombment of organisms in various kinds of materials may be regarded as the first stage in fossilization. A later stage is exemplified in Pleistocene deposits such as those seen in the Lake Champlain and St Lawrence region, both sands and clays. Although these beds have not been consolidated, the organic remains contained are truly fossils, but recent fossils. These fossils have been buried only some tens of thousands of years. so that they have not been greatly altered; but most of the shells have lost their epidermis and mother of pearl lining. The process of fossilization causes a darkening of shells etc. and likewise rapidly destroys the epidermis and pigment. Very little pigment or mother of pearl is found in the older shells. Sometimes the fossils form the nuclei of clay concretions, as in the Pleistocene clays near Green creek, Ottawa river, Canada. Neither the clays nor the fossils are much altered. In some concretions may be seen the impressions of the soft parts of fishes, which were probably killed by a sudden influx of very cold water. In contrast to this formation is a certain limestone found at Mount Lebanon, Syria, which represents deposits on the sea bottom in Cretaceous times, many millions of years before the Pleistocene period. There is a great abundance of small fossil fishes preserved in this rock just as in the Pleistocene clays, but there has been complete fossilization and the rock has been consolidated into a very hard, firm limestone.

A whitish fragile rock, known as *coquina* (Spanish for shell), is formed along the coasts of Florida. It is a recent deposit composed of shells and fragments of shells of all sizes slightly compressed and cemented together, and in its more compact form it is used to build houses. This formation if altered to a fossil state would form, by continued solution and redeposition, a solid, more or less crystallized limestone composed largely of shells. There are many examples of shell limestones showing all gradations in the abundance of shells in their composition. A formation of Silurian age (Clinton) in New York State, which is a hard limestone composed almost entirely of brachiopod shells, well illustrates what coquina might become in a later stage. The Clinton fossil iron ore beds (Silurian) of New York constitute another example of a rock composed largely of fossils, only in this case the rings of crinoid stems, bryozoans, brachiopods etc., have been replaced by iron ore (hematite). The Becraft limestone (Devonian) is virtually a consolidated coquina, and is made up chiefly of fragments of brachiopod shells and crinoids. The above are examples of differences in consolidation in rocks of different ages, with millions of years of time between. Rocks of the same age in different places show considerable difference in consolidation. The Devonian rocks are some two hundred million years or so old. In the State Museum are some collections of fossils from the Devonian of Brazil. The fossils in these rocks are much altered, but, although the rock is so old, it remained comparatively near the surface and is still soft enough to be loosened with the finger nail. Other deposits of this period have through the long ages been very thoroughly and closely cemented, as shown by the Devonian rocks in New York State, such as our Coeymans and Onondaga limestones, our Hamilton shales and flags, our Chemung sandstones, etc.

Fossils According to Nature of Preservation

As a rule only hard parts of organisms are preserved and these are usually altered in varying degrees. Fossils may therefore be divided into two main groups: *unaltered* and *altered* forms. The unaltered fossils include those in which the original soft parts are preserved and those in which only hard parts are preserved. One example of unaltered preservation of soft tissues, that of Tertiary insects inclosed in amber, has already been discussed (page 21). The most striking examples of the preservation of entire animals are seen in the entombment of the mammoth and hairy rhinoceros in the frozen tundras of northern Siberia, which have acted as a natural cold storage. The carcasses have been inclosed in these tundras for thousands of years, yet when the ice melted away the flesh was in such condition that it was devoured by dogs. The Natural History Museum of Petrograd, Russia, has the mounted skin and skeleton of two of these creatures and all of the internal organs preserved in alcohol. The hairy rhinoceros has been found preserved in the same state both in the tundras of Siberia and in the frozen ground of northwestern Alaska. Generally, soft tissues are preserved unaltered or only as impressions or molds; but occasionally the soft tissues may become impregnated with, and finally replaced by, mineral matter. In some Devonian fishes the muscle fibers are so perfectly preserved that they may be easily recognized under the microscope. A similar case is the preservation of muscle fibers in some Mesozoic reptiles. Even in recent times we have examples of preservation of bodies of animals and human beings, which have become impregnated with mineral matter from the ground in which they have been found. The American Museum of Natural History has on exhibition the body of a Peruvian miner which was buried during the collapse of a mine, probably several hundred years ago, and impregnated after death with blue vitriol (copper sulphate) and other mineral salts.

The majority of the different forms of organisms have hard parts of some kind, either internal or external. The higher animals (vertebrates) have developed an internal skeleton of bone and cartilage and besides have other hard parts, such as teeth, horns, spines or scales and dermal plates. Many of the lower forms of life (invertebrates) such as some of the Foraminifera, mollusks, brachiopods, some crustaceans etc., secrete shells of carbonate of lime. Animals such as starfishes and crinoids build up within the outer part of the body an armor of calcareous plates. Sponges, such as our common bath sponges, are protected or upheld by a more resistant organic substance than the fleshy tissues, to which is generally given the name of chitin; other sponges, such as the glass sponges have an internal, silicious skeleton. Some animals, such as the crustaceans, have a hard, skin-like covering composed of lime and a horny material which is shed each year to be replaced by a new and larger one. Hard parts are usually altered by infiltration in the process of fossilization but they may be preserved in a more or less unaltered state in the more recent formations, such as the various kinds of shells from the Tertiary of the James river, Virginia; the sharks' teeth from the Tertiary (Wando and Parrott creeks), North Carolina; the shells and fish skeletons found in the Pleistocene clays of New York and elsewhere. In the Cenozoic (Tertiary and Quaternary) deposits it is usual to find marine shells almost unaltered. Probably 50 per cent of all the fossils are still found in the original calcareous state or only slightly altered.

The older fossils are, geologically, the more altered they are apt to be. The alteration takes place through a process of mineralization, either at the time of burial when the ground waters were charged with solvents such as carbonic acid and other acids derived from organic decay; by infiltration of minerals from the surrounding rock, which may take place at any time after burial; or during weathering of the formations. It is to such fossils only that the term "petrifaction," that is, "turned to stone," should be applied. These petrifactions are divided into groups according to the material petrifying them, for fossils may be altered through calcification, silicification, pyritization, hematite replacement, carbonization etc.

Calcification. When the replacing material is calcite (lime carbonate) the alteration process is known as calcification. Examples in this group are found among the corals, brachiopods, echinoderms (crinoids, starfishes, sea urchins etc.) and less frequently among the mollusks. The corals, brachiopods and echinoderms, have calcite or lime carbonate in the original composition of the hard parts. Hence they are preserved in a calcified state in shales and sandstones, as well as in limestones. The mollusks (pelecypods, gastropods, cephalopods) have aragonite, an unstable form of lime carbonate, in their composition and the original shell is only found calcified in limestones or limy shales or in lenses of limestone in shaly or sandy beds. This matter will be discussed later under preservation of fossils according to composition.

Silicification. When the original material of a fossil is replaced by silica the alteration process is known as silicification. The first step may be just the filling of the cavities of a fossil with silica by percolating waters oversaturated with this mineral. The original composition of the fossil remains. The second step in petrifaction is a process of solution and deposition particle by particle due to the waters being undersaturated with the chemical substance of which the fossil is composed and oversaturated with silica. If the original composition of the fossil is calcite or carbonate of lime, the silica will replace the calcite because of the attraction offered by the silica already deposited in the pores, since carbonate of lime is much more soluble. Often such a replacement is marked by the development of a series of small concentric rings around a central nucleus or starting point. Where an object of calcareous composition is in the process of replacement of the calcite by silica many series of such concentric rings may be seen covering these objects. All stages in the replacement of other substances by silica may be found, and at times the replacement is very perfect, as in the case of the petrified tree trunks from the fossil forests of the Yellowstone National Park and Arizona. As a molecule of the original substance was removed a molecule of the replacing silica took its place, with the result that even rings of growth and the finer details of the structures of the wood have been preserved. Molecular replacement is most common with silica, lime and iron.

Often when silica replaces carbonate or phosphate of lime the original form of a fossil may be preserved, but many or all of the details of structure are lost. It frequently happens that the fossils in a limestone may become silicified, but the rock itself is not at all altered. When such a limestone is exposed to the action of the atmosphere or the solvent action of water, the rock will be weathered away and the silicified fossils will remain and accumulate in a layer on the surface of the weathered limestone. Such fossils make the best specimens for collectors, whereas those in the solid rock can be obtained only by careful work with needles and chisels or by etching with dilute acid, which tends to mar the specimens to some degree.

Sometimes silica is localized in fossils. It may be deposited along cracks in shells, or, as in the echinoderms, between the plates. This mode of deposition of the silica tends to distort the fossils because the large ridges of silica in the cracks push the fragments apart, and in the case of echinoderms the plates are pushed farther and farther apart as deposition continues. Sometimes hollow structures are developed which become lined with quartz crystals, just as in *geodes* (concretionary or nodular stones with a cavity lined with crystals).

Pyritization. Like silicification, pyritization is a process of molecular replacement. The replacing mineral may be pyrite or marcasite. Both are sulphides of iron, and marcasite turns over into pyrite under certain conditions. Both pyrite and marcasite occur as secondary impregnations in sedimentary rocks and are frequently found replacing fossils. It is common in coal seams. Its occurrence is considered due to reactions between the sulphur of decaying organic life and the iron in the rocks. Shells of various kinds, crinoids, crustaceans, graptolites and plants are among the various forms found in a pyritized state. While pyritized fossils are found in various beds, some occurrences are very striking. The Tully limestone (Devonian) in the western limits of New York is marked by a thin layer of iron pyrites containing a dwarfed fauna. Very beautiful, pyritized graptolites are found in the Deepkill graptolite beds (Ordovician) of New York. Very fine examples are seen in fossils, such as the crinoids and starfishes, from the Lower Devonian black shales of Bundenbach, Germany.

Hematite replacement. Iron in the form of hematite may be a replacing mineral. A good example of hematite replacement is seen in the hematite fossil ore from the

Clinton beds of New York. The original rock was largely composed of fossils—rings of crinoid stems, bryozoans, brachiopods etc. The fossils were centers around which the iron ore gathered until the mineral entirely replaced the original substance forming a fossiliferous iron ore. In cases like these where the original form has been retained, but not the original composition, the fossils are known as "pseudomorphs" (Gk. *pseudes,* false; *morphe,* form).

Cavity filling. Filling of cavities is one form of petrifaction, often the first step in the process, and may be a process of calcification, silicification, pyritization etc., according to the mineral filling the cavities. The original composition of the shell or other object remains. Good examples of this may be seen in some of the large coiled cephalopods from the Cretaceous. A longitudinal section reveals the various chambers of the shell filled with a deposit of calcite; or with calcite, often in crystalline form, lining the walls of the chambers.

Carbonization. Carbonization is a process by which vegetable or animal substances, cellulose or chitin (carbon, hydrogen, oxygen), are altered during fossilization by decomposition under water and pressure after burial. This results in the giving off of the hydrogen and oxygen in the form of marsh gas (CH_4), water (H_2O) and carbon dioxide (CO_2) and a consequent concentration of the carbon, thus giving us carbonized fossils. Chitin is used here in the general sense and does not imply chemical and structural identity with the true chitin of the arthropods. Carbonization is well shown among the plants. Good examples of carbonized fossil plants are found in the roof shales of coal mines. In the case of wood, continued carbonization would eventually yield anthracite coal. Carbonized animal remains are also abundant, and good examples are found among the graptolites, some corals, arthropods and fishes, such as those in the Upper Triassic beds of New Jersey and Massachusetts.

Preservation of Fossils According to Composition

The hard parts of different organisms vary considerably in composition and there is therefore a considerable variation in the preservation of the different forms as fossils. Calcite, aragonite, silica, lime phosphate, chitin and cellulose are the substances found composing the hard parts of animals and plants.

Calcite. Calcite is a lime carbonate and is found in the hard parts of many calcareous algae, almost all of the brachiopods, most of the bryozoans, most of the corals, and all of the echinoderms. It is also found in some of the Foraminifera, the calcareous sponges, the calcareous part of the skeleton of crustaceans, some pelecypods (bivalves), a few gastropods (snails) and a few cephalopods. Specimens whose hard parts are entirely of calcite are as a rule preserved as calcite in the fossil form. Our best examples here, and the most numerous, are found among the corals, brachiopods and echinoderms. Sometimes, as pointed out above, the calcite is dissolved away and is entirely replaced by some other mineral, as silica. This is usually a secondary process and takes place near the surface under conditions of weathering. Our numerous silicified corals are examples of this, and the occurrence is frequent also among the brachiopods. Because these fossils have the form but not the composition of the original specimens they may be termed "pseudomorphs." There may also be iron pseudomorphs of calcareous shells.

Aragonite. Aragonite is also a lime carbonate. It has the same composition as calcite but it crystallizes in a different manner and is more easily dissolved by percolating waters containing carbonic acid. Some of the Foraminifera and some of the corals have aragonite in their composition. Most of the mollusks (scaphopods, pelecypods, gastropods and cephalopods) have shells of aragonite. A few pelecypods (bivalves) such as *Mytilus* and *Unio,* have a shell with an outer layer of calcite and an inner layer of aragonite. In this case, as is found in many shells from the Pleistocene deposits, the aragonite is dissolved away and the calcite is preserved. As a result of this greater solubility of aragonite, brachiopods stand a much greater chance of whole preservation than the mollusks which, except perhaps in some limestones, are found as molds and casts. One finds all the markings of the shells beautifully preserved in the rock but the shell itself has been dissolved away.

Silica. Silica is an oxide of silicon (SiO_2), the mineral of which quartz is composed. In the form of quartz, silica is one of the most stable of minerals, but when it is secreted by an organism, plant or animal, there is water in its composition which renders it soluble in waters containing alkali. Among the plants, diatoms secrete silicious structures; more or less silica is present in the cell walls of horsetails, *Carex* (sedge) the margins of grass blades etc. Among the animals, silica is found in the skeletons of the Radiolaria and sponges. Since silicious skeletons of organisms are composed of a hydrous silica, the silica may become dehydrated into a form known as chalcedony or may be later crystallized into quartz. Since silica in the hydrous form is soluble with comparative ease the deposits of diatom skeletons (tripolite) are rarely known older than Tertiary time. The older deposits have been dissolved and redeposited as chert. The Radiolaria (protozoans) form a group of lowly marine forms that swarm in some parts of the ocean. These and the calcareous-shelled Foraminifera are the only protozoan forms found fossil. The group of sponges (Silicispongiae) having silicious skeletons contains most of the fossil and many of the recent sponges. These sponges have a skeleton made up of silicious rods or spicules which interpenetrate the other tissues and may project as glass fibers at the base of the sponges. Generally these silicious, or glass, sponges are shown only as impressions of the skeleton in the rock, the skeleton itself having been removed by solution. In the course of time, however, carbonate of lime may replace the silica. In some formations sponges have been found in which the original silicious skeleton is now entirely calcareous. These are calcareous pseudomorphs after silicious skeletons.

Lime phosphate. Lime phosphate is found in the shells of a few brachiopods (*Obolus, Lingula* etc.) and in the bones of vertebrates. About 40 per cent of the ash of bones is phosphoric acid. Bones may be found practically unaltered or carbonized. In our Catskill beds (Upper Devonian) fish bones are found showing the spongy bone structure and the leached out bone color. There has been no petrifaction. Some of the bones found in the phosphate beds of South Carolina are blackened, the black color being due to partial carbonization. If the bones are not leached out before burial the organic material left in them will cause carbonization.

Chitin. Chitin is here used in the general sense. It is a compound of carbon, hydrogen, nitrogen and oxygen. Chitin is found in a few Foraminifera, all graptolites, some corals (sea-fan etc.), some sponges, and forms the tests of crustaceans (trilobites etc.) and of insects etc. During fossilization the hydrogen, oxygen and nitrogen of the chitin are freed with a consequent concentration of the carbon which gives carbonized fossils.

Some animals, as the eurypterids, had chitinous skins of the pliable nature of leather. They are preserved as carbonized fossils and are generally reduced to a mere film, sometimes so thin that the segments of the under and upper sides appear in the same plane. Specimens as old as these carbonized forms are found in the Silurian beds, Isle of Oesel, Russia, which still retain the skin in uncarbonized condition. The scales of the skin show very plainly, and have been made transparent and studied under the microscope. Skins of reptiles have been found preserved in the Liassic (Jurassic) shales of England and Württemberg. In the Cretaceous of western North America (Wyoming) has been found similar preservation of the skin of a dinosaur.

Cellulose. Cellulose is a compound of carbon, hydrogen and oxygen. With few exceptions it is found in all plants from the algae up. Among the animals a few protozoans and the ascidians (tunicates) have cellulose in their composition. Carbonization takes place in the same way as with chitin.

Plant tissues are more frequently preserved because they resist decay better than animal tissues. Buried leaves are carbonized or they may leave only an impression, more or less iron stained or with a thin film of some mineral which has been precipitated by the decaying organic matter. Stems and other more woody tissues may be found carbonized, but woody tissues are often impregnated with silica or some other mineral carried in solution by the ground water. Petrified wood with the structure perfectly preserved is found entirely composed of agate, quartz or opal.

Objects Indicating Former Presence of Organisms

Besides the actual remains of animals and plants any evidence of their former existence found preserved is counted among fossils. These objects indicating the former presence of organisms include *molds* and *casts, trails, tracks, imprints, burrows* and *coprolites*.

Molds and casts. When shells are buried in sediments they leave the imprint of the external ornamentation on the surrounding material, and the finer the material the more perfect the impression. This is known as an *external mold* of the shell. Sometimes the shell becomes filled with sediments and the internal ornamentation or structure of the shell becomes impressed upon this filling, thus giving an *internal mold.* These external and internal molds (figure 3) may be well illustrated with a common clamshell and plaster of Paris, preferably; however, if this is not available, soft mud or modeling material of some kind may be used. Fill the clamshell (two valves) with soft plaster of Paris and allow it to harden. When this filling is removed one has a very perfect internal mold showing all the markings of the inside of the shell, such as the muscle scars. Then place the two valves of the clamshell in soft plaster of Paris and the imprint or external mold showing the surface markings is obtained. If *casts* are made from these molds, the internal and external surface may be obtained just as they appear on the shell. Fossil specimens show the same

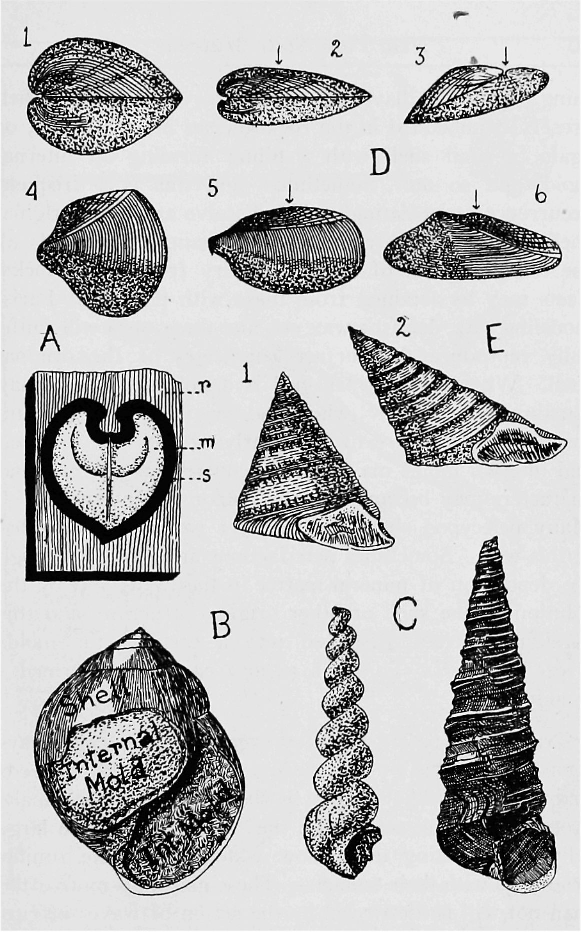


Figure 3 Molds and deformation. *A* Internal mold of a pelecypod shell: *r* Rocky matrix; *m* Internal mold; *s* Space occupied by shell. *B* Gastropod shell showing filling. *C* Gastropod shell and its internal mold. *D* Deformation of pelecypod shell: 1 Anterior view of perfect shell; 4 Left valve of perfect shell; 2, 3, 5, 6 Deformation by pressure. *E* Deformation of gastropod shell: 1 Perfect shell; 2 Depressed shell. (All from Grabau: Textbook of Geology, permission D. C. Heath & Co.)

thing. We may have the two valves of a bivalve shell preserved imbedded in the rock and an internal mold; or again, a snail shell with a filling forming an internal mold, and so on. Sometimes—and this is a frequent occurrence—percolating waters dissolve away the original shell or test and only the molds remain. The molds of the exterior form of shells are very frequent in rocks. Casts may be obtained from these with plaster of Paris, modeling clay, dentist's wax etc. and these casts will faithfully reproduce the surface characters of the original shell. When the original shell is dissolved a cavity may remain or, especially when the original shell is thin, through the pressure of the overlying rock the external and internal molds may come in contact and the external characters may become impressed upon the internal mold. Many pelecypod shells in the older rocks are preserved in this way. Sometimes petrifactions are formed through the deposition of mineral matter in the cavity left by the solution of the shell or other original structure, and this foreign material is shaped into a cast by the molds already formed. This is a *natural cast* and is termed a pseudomorph.

Trails. Trails are made by organisms in various ways upon the surface of soft sediments. Floating seaweeds that drag upon the bottom in shallow waters may make groovings on the surface of the sediments and the large jellyfishes floating in shallow water may make similar groovings with their tentacles. These markings more often than not will be destroyed by the action of waves or currents. Worms, snails etc. crawling over or just under the surface of soft sediments leave trails which are filled in by finer sediments and preserved. The relief mold on the underside of the covering layer is more largely repre-

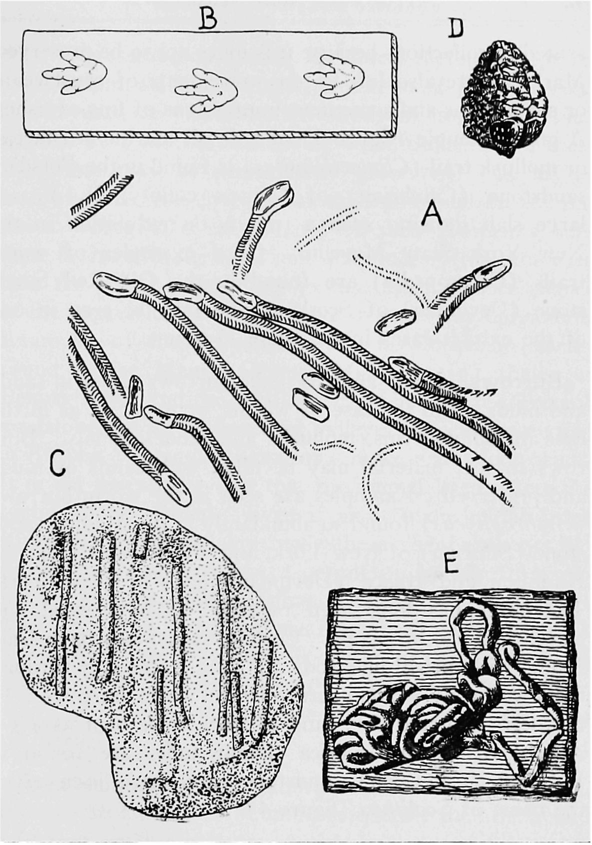


Figure 4. Trails, tracks, burrows, coprolites. *A* Fossil trail from Cambrian rocks (*Climactichnites*), about x1/35. *B* Three-toed dinosaur tracks, greatly reduced. *C* Vertical worm burrow (*Scolithus*) in Lower Cambrian sandstone. *D* Coprolite of fish. *E* Fossil worm casting (*Lumbricaria*), lithographic beds, Solenhofen. (*B* from Lucas: Animals of the Past, permission Amer. Mus Nat. Hist.; *A, C, D, E* from Grabau; Textbook of Geology, permission D. C. Heath & Co.)

sented in collections because it is more apt to be preserved. Markings are also left by the movements of crustaceans or sea urchins and sometimes impressions of fins of fishes. A good example (figure 4) of a fossil marine crustacean or mollusk trail (*Climactichnites*) is found in the Potsdam sandstone (Cambrian) of Clinton county, N. Y. A large slab showing such a trail is on exhibition in the New York State Museum. Good examples of worm trails (*Crossopedia*) are found in the Old Red Sandstone (Devonian) of Scotland, and may be seen in one of the exhibit cases in the State Museum.

Burrows. Many animals make burrows either in sands and muds, as in the case of worms, or in rocks, as in the case of echinoderms, mollusks and other animals. Burrows in soft material may be filled with sands or muds and preserved. Examples are seen in the worm burrows (*Arthrophycus*) found so abundantly in the Medina sandstone (Silurian) of New York, and in *Taonurus* from the Hamilton and Ithaca (Devonian) beds of New York. The latter has long been regarded as a seaweed and placed among the plants. Certain sandstones have been found with pencil-like rods of sand extending through them vertically. These are filled-in worm burrows. In northern Scotland this kind of rock is known as *pipestone.* In North America similar tubes are found in Potsdam (Cambrian) sandstones and have been given the name of *Scolithus* (figure 4).

Tracks. Tracks or footprints of animals are likewise preserved as fossils under favorable conditions (figure 4). When birds or other animals walk over the mud flats of rivers or seas they leave the impressions of their feet and if these tracks are covered with sediments they may be preserved as fossils. In desert regions footprints may remain without change for years. If the footprints are covered by wind-drifted sands or sand and mud washed over the surface during some sudden flood these footprints may be permanently preserved. As in the case of trails, the covering of sand and mud on solidification will give a relief mold of such footprints, and these layers with the relief molds are more often preserved than the actual impressions because there is more chance of the impression being destroyed in quarrying operations. Examples of fossil footprints are the amphibian tracks, found in the Mauch Chunk (Mississippian) shales of Pennsylvania, and the reptile tracks found in the Triassic sandstones of the Connecticut valley and New Jersey and in Europe. A single animal may make many foot prints. It is not necessarily true that the animal lived where the footprints are found. Even if animals die in the place where the footprints are made the skeletons do not remain intact long enough to permit of burial; so tracks are much more numerous than the remains of the skeletons. Also the footprints are more commonly preserved in regions where the climate is arid or semi-arid than in a moist climate, because there the muds or sands remain hard long enough to preserve the footprints until they are buried.

Impressions. Where animals have only soft parts, impressions are preserved more frequently than the actual soft parts. Impressions of soft-bodied jellyfishes are found; and sometimes, as in the case of the Cambrian fossils from British Columbia already mentioned, the embedding material is so fine that even records of the internal organs are preserved. Where structures are more resistant, as in the case of insect wings, bits of reptile skin, leaves etc., especially if buried in fine-grained materials, the impressions are stronger, and they may be strengthened by a thin film of carbon from the reduction of the organic tissue. Examples of leaf impressions are abundantly found in the Dakota sandstone (Cretaceous), Ellsworth county, Kans., and in the Mazon Creek (Carboniferous) beds of Illinois. Sometimes the imprints are so perfect that even the little veinlets are shown.

Coprolites etc. Coprolite is the term used for the excrementa of many ancient animals, such as fishes (figure 4) and some of the Mesozoic reptiles among the vertebrates and worms among the invertebrates, and the contents of the intestines. These coprolites are phosphatic in composition and are often found to contain bits of bone, teeth, scales and shells. Coprolites have a characteristic appearance which permits of their identification. The excrementa of sea fowl, while not of distinctive form, have a distinctive chemical nature. Recent deposits of this nature, called *guano,* are common on many of the Pacific islands, West Indies, and on ocean borders and their islands generally. One of the most extensive deposits on the islands off the Peruvian coast has largely been exhausted, and now deposits of another origin are more frequently used as the source of commercial phosphate of lime. On the sea beach at low tide, especially along sandy shores, one often meets with heaps of sand that look like twisted masses of heavy twine. These are castings left by marine worms, material that has been passed through the intestinal tract in order to extract the nutriment that may be present. We see similar castings made by our earthworms. There are rock formations, such as one of the Paleozoic limestones of northern Scotland, which give the appearance of the material of which they are composed having been passed through the bodies of worms, and to such formations the term "vermicular" (Latin; *vermis,* worm) rock has been applied (figure 4).

Gastroliths or stomach-stones have been found in the body cavities of fossil reptiles. These stones are supposed to have been of use in mastication, and they are so characteristic that they can be recognized even when they are found apart from the skeletons.

Preservation of Original Form and Color

The form in which fossils are preserved depends upon the conditions under which fossilization has taken place. A good illustration may be seen in some plants such as the specimens of *Calamites* or giant horsetails from the Carboniferous. In cases where the hollow trunks and stems have been filled with sediment during burial, they are preserved in the normal form instead of being compressed. Where such a filling is lacking, a trunk that has had in life a diameter of five or six inches may, through compression and carbonization, have a thickness of about a quarter of an inch. Fillings likewise help keep the original forms of animals. This is well illustrated in various types of shells, pelecypods, gastropods etc.

Sometimes fossils are so altered that it is difficult to ascertain what the original form was. The upheaval of great masses of sediments with the accompanying bending, twisting, slipping and crushing of portions of the strata causes more or less distortion of the included fossils (figure 3). Sometimes just the great weight of the overlying beds causes deformation. In the case "What is a fossil?" in the State Museum are three specimens of trilobites from the Ordovician of North Wales, all of the same species and all from the same beds, showing three different shapes. One specimen is long and narrow, the second is short and broad and the third is broadened diagonally. The three different shapes are due to different directions of compression. Examples of the same thing are seen in other forms, shells of various kinds, graptolites etc. Compression sometimes causes fossils to disappear gradually. Graptolites illustrate this very well. Pieces of slate, altered graptolite shale, from Hoosic Tunnel (Ordovician) show the graptolites but they are very faint, some of the specimens being scarcely visible. If the process had been continued further these fossils would have been eradicated.

Fossils are not always preserved entire. Anyone who examines sea or lake beach, river bank etc. will soon understand why. Because of the action of waves and currents, shells, tests etc. are more often than not found broken on beaches. Trilobites illustrate fragmentary preservation very well. We find many specimens preserved entire, though sometimes crushed or distorted, but mostly only parts or fragments are found; parts of the head, such as free cheeks, cranidia (glabella and fixed cheeks), glabella, or frontal margin; thoracic segments; thoracic segments with pygidia; pygidia alone etc. In a fossil condition fragments, if showing quite characteristic points, are very often quite sufficient to determine the species.

Many recent shells are lined with nacre or mother-of-pearl. Many fossils from the more recent geologic periods (Cretaceous-Pleistocene) retain this layer, especially well where the fossils occur in limy shales which have become impregnated with petroleum. The color in this mother-of-pearl layer is not due to pigment in the material but to the play of light in the prismatic (aragonitic) portion of the shell. In recent shells, corals etc., the calcium carbonate is white, except for the pigmented layer or epidermis (if present). Fossil shells are darker, and the older they are the darker they are liable to be. The aragonite of shells which is chalky in color, if not entirely dissolved away, becomes changed to the darker calcite. Darker color also results from the fact that the pores and interstices in the calcite gradually become filled; light is thus obscured with a resultant darkening in color. The shells are also stained by the surrounding sediment if it is darker, and the older the fossils are the deeper the stain will be. Where replacement has occurred the replacing material, calcium carbonate etc., may be stained by some impurities as iron, carbon, etc., giving another color to the fossils. In the case of vertebrate bones and arthropod remains there is likewise a darkening with time, but here the darkening is largely due to carbonization.

It is exceedingly rare to find a trace of former color among fossils; but former color patterns may be present in dark bands, especially where specimens are preserved in light-colored, shaly limestones. From earliest days of paleontologic investigations color markings on the shells of fossil mollusks and brachiopods have attracted the attention of scientists. The oldest record of color markings is that of a gastropod from the Chazy (Ordovician) of Valcour island, New York. The records include gastropods from the Carboniferous and cephalopods from the Silurian of England; brachiopods from the Triassic and cephalopods and gastropods from the Devonian of Germany; cephalopods from the Ordovician and Silurian of

New York, particularly, and elsewhere in the United States. Some of the cephalopods from the Trenton limestone (Ordovician) appear to retain even the original color.

Objects Due to Inorganic Agencies

Strictly speaking, the name "fossil" is used only for objects preserved in the rocks which have relation to an organism. The word is conveniently used, however, to denote objects preserved in the rock which are due to inorganic agencies, such as ripple marks, mud cracks, raindrop imprints. These markings occur most frequently in regions which are not favorable to the preservation of organic remains, such as mud flats of temporary lakes or aggrading streams which are periodically out of water with consequent oxidation of organic material. Ripple marks, mud cracks and raindrop imprints, on the other hand, stand a very good chance of preservation in such regions, and with them such fossils as tracks, trails and burrows.

Clay Concretions and Pseudofossils

Fossils may be the nuclei of clay concretions, such as the shells and fishes found in the clay concretions of the Pleistocene clays of Green creek, Ottawa river, Canada. Generally, however, clay concretions have no fossil nuclei but the concretions themselves assume fantastic forms resembling flowers and animals. Such concretions were formerly considered fossils and are still often mistaken for them.

Pseudofossils are inorganic forms presenting the appearance of fossils. Sometimes stains are produced on rocks due to the presence of decaying vegetable matter. These stains often resemble leaves. Dendrites are often mistaken by the uninitiated for fossil mosses or ferns. They are branching mineral incrustations, formed usually of manganese oxide or pyrite, and are found as surface markings, along cracks, or inclosed as in the moss agates. There are numerous other markings, some of mechanical origin, which are mistaken as fossils. Fractures in some rocks are of a conchoidal nature and give the appearance of molds of shells (pelecypod and others). Movements within a rock mass causing one face to move against another, as along a fault plane, produce a structure known as slickensides, which in some cases resembles trunks or stems of some of the plants of the Coal Measures. The distinction is easily made, however, for fossils always lie parallel with the bedding plane of the rock layers or beds, while the slickensides generally cut across the bedding plane.

Restorations, Models, Sections, "Squeezes" Etc.

Restorations of fossils, invertebrate and vertebrate, are seen now in many museums and there is a steady increase in this kind of exhibit (figures 5, 6). The experts use all their knowledge and skill to make the fossils live again for the general public, and more and more use is made of fossil habitat groups, just as habitat groups are used to present living plants and animals in an interesting and instructive way. In the field of group restorations of invertebrate fossils the New York State Museum has been the leader.

A reconstruction or restoration of a fossil to its appearance when living is made from the fossil remains and by comparison with other forms, living and fossil. The better preserved the condition in which the fossils are found, the truer will be the restoration. Impressions

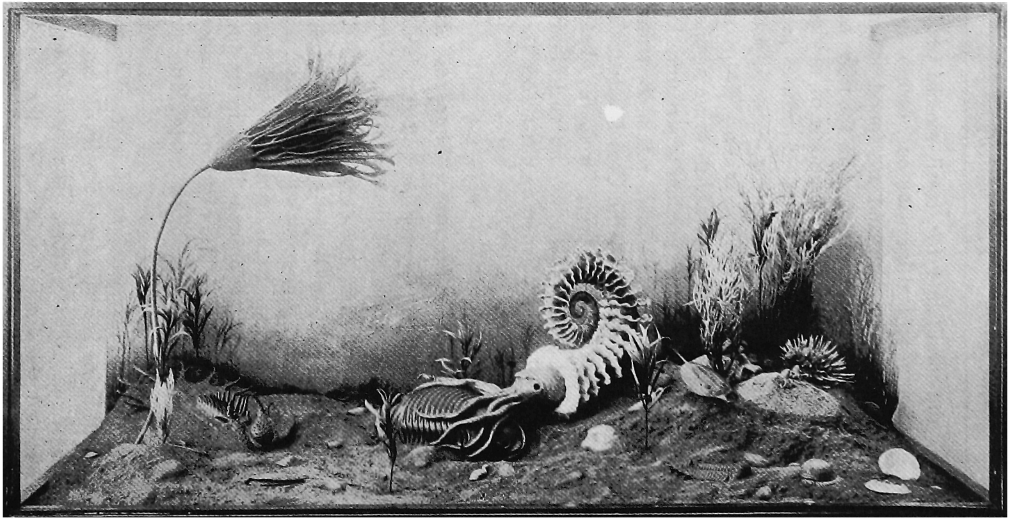


Figure 5 Restoration of early Devonian marine life of New York showing seaweeds, crinoids, trilobites, cephalopod, spiny gastropod, brachiopods etc. Restoration in State Museum, executed by Henri Marchand under the supervision of Rudolf Ruedemann.

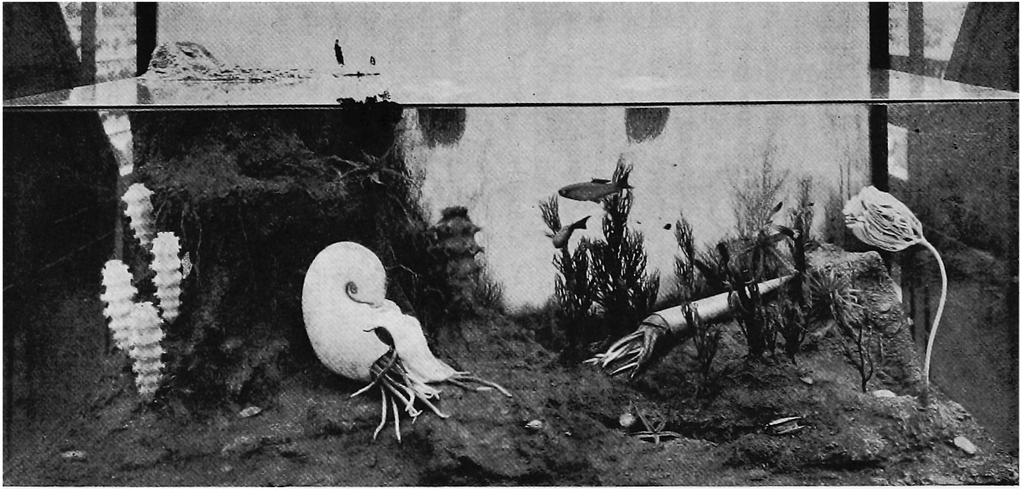


Figure 6 Restoration of Upper Devonian marine life of New York showing seaweeds, crinoid, starfishes, cephalopods, glass sponges, fishes. Restoration in State Museum, executed by Henri Marchand under the supervision of Rudolf Ruedemann.

of soft parts in fine-grained rocks, such as shales and limestones, are often preserved in minutest detail, as in the specimens of trilobites (*Triarthrus*) of the Utica (Ordovician) shales of New York State, which furnish legs, antennae, gills and traces of the digestive tube; and in the Cambrian fossils, already mentioned, discovered by the late Doctor Walcott in British Columbia. In vertebrate animals the muscle scars on the bones give grounds for an estimation of the number and size of the muscles; and, as vertebrates are mainly composed of muscles and bones, a restoration to living proportions is then possible. The shape of the teeth tells the character of the diet and hence the size of the digestive organs. Sometimes the superficial covering, such as the scales of fish and reptiles, are preserved; but where it is not found it is a matter of conjecture or comparison with fossil and living forms.

Models are placed in many cases in the Museum and are used to show enlargements of parts and particularly the internal structure; as, for example, the models of valves of brachiopod shells showing the internal calcareous arms which bear the respiratory apparatus. All such things, models, sections, "squeezes" etc., used in museums with exhibits of fossils are placed there to render fossils more understandable. Natural sections of fossils are quite often found in the field and these show internal structure, but where these are lacking sections are cut and polished, the high polish bringing out the structure to better advantage. Sections can be made in any direction—transverse, longitudinal or tangential. Thin sections, too, are used both in the museum and for study. They are primarily for the study of the detailed structure of specimens under the microscope; but they have been used very successfully in the State Museum for exhibition purposes, as in the case of thin sections of corals. In making a thin section, a slice is first cut from the specimen to be sectioned. The slice is fastened to a piece of glass by means of Canada balsam and then ground down (on plate glass, first with coarse, then with fine emery dust) until the required transparency is obtained.

When fossils are preserved only in the form of a mold, it is essential for a better understanding of the form to obtain a cast from the mold. It has been found that the best results have been obtained by the use of plasticene or gutta percha, which is squeezed or pressed into the mold, hence the term "squeeze." Plasticene is most easily handled and can be used in the field. "Squeezes" or casts of plasticene, gutta percha, plaster etc. are found in museums, particularly the State Museum, on exhibition with the fossils.

Naming of Fossils

The naming of fossils is based upon the binominal or two-name method introduced by the Swedish naturalist, Linnaeus (Linné) in 1735. Previous to this, simply a common name or a single technical name was used, often modified by a descriptive phrase. Under the Linnaean system the scientific name consists of a generic name and a specific name, the generic name usually taken from the Greek, the specific name from the Latin. The technical name therefore remains the same in all countries, no matter what the language spoken. The generic name indicates broader relationships; the specific name includes all individuals that are almost exactly similar. Generic names are written with an initial capital letter, specific names with a small letter, even when proper names are used. The technical name is followed by the name of the author, as *Spirifer arenosus* (Conrad). The author's name in parentheses indicates that the generic reference was later changed. Fossils have, for obvious reasons, no popular or English names.

Specimens which have been described and illustrated in various scientific publications are known as type specimens. In museums these specimens are marked in some special way and the label with them indicates where they were described. In the New York State Museum, for example, the number of the type is on green paper. A green star accompanies the small green square when the species was first described and figured from the specimen in question; a green disk accompanying the number indicates that this particular specimen served for later description and illustration.

Significance of Fossils

Fossils are to be found in general in all stratified (sedimentary) rocks, but they are especially abundant in rocks of marine origin, more so in lime rocks than in shales or sandstones. Calcareous shales and sandstones also carry a greater abundance of organisms. Among the stratified rocks shales comprise 80 per cent of the whole, sandstones 15 per cent and limestones 5 per cent. In red beds (other than limestones) such organisms as may have been there have disappeared through oxidation during subaerial sedimentation; it is exceptional to find fossils in such beds, although trails, tracks etc. may be found. Beds that are green, blue, black and yellow (subsequently oxidized) are apt to contain fossils. Thick beds of green and blue shales often have thin interbedded bands of limestone or sandstone which are quite fossiliferous. Conglomerates may be fossiliferous but here the collector must distinguish between the fossils of the pebbles and the fossils of the binding material or matrix. The pebbles contain fossils of other and older sediments.

Besides their enormous interest as records of progress of organic life in the past, fossils have been found very useful, indispensable in fact, in many ways in geological researches. They act as guides in geological chronology, so that rocks may be classified as to their relative ages and a connected record established of the geological facts in the earth's history. Fossils also throw light upon the physical geography, such as relations of land and water, changes in climate, the former distribution of animals and plants and their environment.

No absolute date can be fixed in geology for certain beds or formations, although calculations in round numbers as to the duration of the different periods and therefore as to the age of the earth can be and have been made. The relative ages of the different formations have also been determined. If one finds a succession of beds all dipping in the same direction, one knows that those at one end must underlie those at the other because we can trace all the beds in between. It is not possible to find a complete succession of beds in any one place and it is here that fossils help out. Mere external appearances and mineral character of the rock are not sufficient. One knows that the fossils in a certain deposit are older than those above and younger than those below. Fossils in the lower beds gradually disappear as one goes higher and new fossils come in, so that the assemblage of fossils in the upper beds are quite different from those in the lower beds. Every well-marked formation is distinguished by its own assemblage of species or genera, and one therefore identifies a formation, no matter where it occurs, or how isolated it is, by that characteristic assemblage of fossils. The assemblage of animals of any one locality at a given time constitutes the *fauna* of that period; a similar assemblage of plants constitutes the *flora*. In the absence of distinctive index fossils, the faunas and floras as a whole must be relied upon in distinguishing beds. *Index fossils*, or guide fossils, are fossils which are restricted in vertical range and represent organisms which lived for a comparatively short period of time only, giving place to later types, and therefore are satisfactory indexes to a certain period in earth history, serving to identify a particular horizon or formation. Index fossils are of the greatest importance in identifying the same formation in different localities, and those which have the greatest horizontal or geographic range with the smallest vertical or time range are of the most value.

Fossils tell us where there were seas in the past and where there was land so that the configuration of the continents in ancient times has been determined. They also show whether the seas were shallow or deep and what was the nature of the water. Beds of marl or lacustrine limestone full of fresh-water shells indicate the position of lakes of the past. Beds of marine shells and other organisms represent ancient sea bottoms and the character of the fauna indicates the character of the sea there, for there is a characteristic fauna for shallow waters, deep waters, clear waters, muddy waters etc. An impoverished or dwarfed fauna indicates that the previous favorable nature of the water has been changed, muddied or polluted in some way, as is seen in the dwarfed fauna of the Tully pyrite layer in western New York. The ancient coal forests of the Carboniferous period point to broadly swampy conditions, and so on. Just as fossils indicate how near the shore the sediments were deposited, so they show whether sediments were deposited on the land (continental deposits) or in the sea (marine deposits). Where the deposits contain only fragments of land plants it is generally safe to assume that the sediments were deposited on land, although in some cases they may be estuary deposits. Farther seaward in such deposits land and marine fauna and flora may be mingled and land life is also carried by currents into marine deposits. Some classes of animals are wholly marine and wherever they are found in rocks certain marine origin is indicated.

The existence of different climates in past ages has been satisfactorily demonstrated through the study of fossils. When one finds in the rocks of a past age an assemblage of plants and animals of a tropical or subtropical nature, although the climate today may be temperate, we know that in this past age a climate of a warmer nature must have prevailed. Remains of arctic animals found in southern areas indicate that in the past there was a southern extension of a cold or arctic climate. Plants are the best indexes of climate upon the land. Cycads occur in Mesozoic rocks in northern United States, Canada, Alaska and Greenland, indicating for those times in these regions a climate as warm as our subtropics today. Rings of growth in fossil trees indicate seasonal changes, either of moisture or temperature. Reef-building corals, which can live only in warmer waters, are found in northern regions, as in the case of coral reefs in the Silurian beds of New Siberia, within the Arctic circle, suggesting a subtropical climate there in those times. Innumerable examples of this kind might be given. Caution must be used in interpreting climate by means of fossils, and it should be remembered that it is not individual species of fossils but whole assemblages of fossil plants or animals that give a clue to climatic conditions of the past.

Plants and animals now living on the face of the earth are the descendants of those that flourished in earlier times. In order to understand properly the present distribution one must know something of their ancestry and their own history. It is through the study of fossils that we obtain this knowledge even though the geological record is not perfect. The life of today shades gradually into the life of the geologic past. This is shown best among the marine invertebrates and land plants, because evolution has gone on more slowly in these groups than among the vertebrates, especially the land mammals where evolution has been rapid. A good illustration of transition between living and fossil forms is found among the mollusks (shellfish). In the Pleistocene formation, which comprises the youngest of the geologic deposits, the number of living species represented in different localities may be 75 to 100 per cent. In the latter part (Pliocene) of the preceding period, the Tertiary, about 50 per cent of the shells are living forms; 20 to 40 per cent in the middle Tertiary (Miocene); and rarely more than 5 per cent in the early Tertiary (Eocene). This is only one of the examples illustrating the fact that the life of today merges gradually into the life of the geologic past.

Literature

For collateral reading on the subjects covered by the preceding chapter, the student is referred to the following references found in the bibliography: Cleland

('16, p. 377–83); Geikie ('03, p. 824–49); Grabau ('99, p. 97–106; '09, v. 1, p. 1–6; '13, p. 1073–96; '21, p. 32–53); Schuchert ('24, p. 1–35); Scott ('24, p. 516–31); Shimer ('14, p. 1–28); Zittel ('13, p. 1–16).

HOW TO COLLECT AND PREPARE FOSSILS

Relatively few implements are needed for the collection of fossils, both invertebrates and plants. Collecting vertebrate fossils is an entirely different matter. It requires a much more elaborate outfit, and an amateur had best report his find to some trained man. Vertebrate collecting will not be discussed here since the amateur, particularly in this section, is likely to be dealing only with invertebrate fossils or, more rarely, with plants.

Equipment

The collector should provide himself with a collecting bag of some kind, a hammer, one or two chisels, a lens, labels, a notebook, soft tissue paper or cotton and newspapers. It is also sometimes convenient to have a small tube of glue, twine, a few rubber bands and small boxes for delicate specimens. A small basket with a handle may be used in place of a collecting bag, but a bag which can be carried from the shoulders is much more convenient. The common canvas hunting bag which may be obtained in a hardware or sporting goods store has been found to suit the purpose very well. It is provided with a leather strap for carrying it on the shoulder, there is a flap fastening with a buckle and there may be an additional pocket in which the notebook can be carried. In addition such a bag has the advantage of being light and inexpensive as well as durable. The hammer used by masons and bricklayers is very satisfactory. This has a square face and a cutting edge transverse to the handle. A small hammer with two square faces will be found useful in trimming up the material in the field or, preferably, in the laboratory after it has been brought home. The chisels used are the regular stonecutter's chisels, and both these and the hammer may be purchased in a hardware store. It is well to be provided with at least two sizes of chisels, one large and one small. In working out the material in the laboratory smaller chisels are necessary; and a stout needle or hatpin proves useful, also a stiff bristle brush and sometimes a wire brush. The lens used should be fairly good and have a large field. A magnification of seven times is satisfactory and even lower magnifications will do for field work. A lens may be obtained in any place that carries optical supplies. For labels one can use small scratch pads, or larger paper can be cut down to small size. It is better to have the labels of a uniform size. The notebook is more convenient if small enough to slip into the pocket of a coat or sweater, and it is handier to use if the pages are bound on the end rather than at the side. All specimens should be individually wrapped. Often the newspaper wrapping alone is sufficient, but smaller and more fragile things require cotton or tissue paper in addition. Small paper boxes are useful for carrying the more delicate specimens. Cigar boxes, too, are very handy, for smaller, fragile specimens can be thus protected from the heavier specimens. Twine or the rubber bands can be used to keep the paper from unwrapping and both are useful in holding together broken parts of specimens. In some cases where smaller pieces are broken off it may be more satisfactory to glue the broken specimen in the field.

Where and How to Collect

Old stone walls in fossiliferous regions make good collecting grounds. Often the rocks forming the walls have been exposed to weathering for such a long time that beautiful fossil specimens stand out in relief and are easily obtained. Quarries that are being worked, and the dumps of old quarries are good for collecting; also highway and railroad cuts, especially if they are fresh; in fact, any kind of excavation where rock is taken out and the dumped material is accessible. Sometimes broken rocks along railroads and roads afford good collecting, but in such cases one has to learn the source of the material and there is danger, too, of formations being mixed. Some of the best collecting is made in ploughed fields where the soil above the rock surface is thin. Fine specimens weathered entirely free from the rock may be obtained by careful examination of the soil. Weathered-out specimens may also be obtained from talus slopes at the base of rock exposures where the rock is weathering into soil. Some of the best weathered specimens have been found in the loose material filling in joint cracks. Collections may also be made from the solid rock beds, but such collecting is more difficult. Large pieces may sometimes be pried away and then split up into smaller pieces with the hammer and chisel. Specimens that occur on overhanging or jutting layers of rock may be broken off with a blow of the hammer or with hammer and chisel. Sometimes in certain limestones a sharp blow will separate a specimen from the mass of the rock. Specimens occurring on flat surfaces must be chiseled out. This is rather difficult, but is best done by chiseling a groove around the specimen and some distance from it. When the groove is deep enough the specimen with the surrounding rock is separated from the rock mass by one or more sharp slanting blows with the hammer and chisel, the chisel edge being held in the groove. Specimens should never be closely trimmed in the field.

Labeling Material

Specimens should be wrapped separately, and then all the specimens from one bed can be wrapped into one large package. With these specimens should go a label on which the locality and horizon is given and which bears a number corresponding to the notebook entry. Additional observations are made in the notebook under this number. The collector should never trust to his memory; only field notes are reliable. When the material is brought home or into the laboratory it should be ticketed in some way. The specimens may be put in trays and labeled with the name, horizon and locality, but they should also bear a number. A number may be given to each species from the same horizon and locality or to all specimens from that horizon and locality. This number is then entered in a record book or catalog, and if a specimen becomes separated from its label, the record can always be obtained. The numbers may be painted on the specimens or pasted on.

Preparation of Material for Study or Exhibition

Whether for study or exhibition, material brought in from the field must be worked up. Much of the unnecessary rock around the specimen can be removed with sharp blows of the trimming hammer, and here care should be taken not to strike too close to the specimen. Pliers are also useful in trimming, but not essential. Specimens may be worked out of the rock with small chisels and a small hammer. Only small pieces should be chipped away at a time. In working specimens out of limestone the rock can be worked away little by little with a stout needle or hatpin and the small blade of a knife. These implements are also useful in working on specimens in shale or sandstone. Stiff bristle brushes are used to clean and develop specimens; a long narrow brush of fine brass wire used with water is very good for helping cut away a shale or soft sandy matrix.

Literature

The above suggestions are sufficient for the ordinary amateur collecting. Many of the textbooks have a short treatment of the subject of collecting fossils. In Knowlton ('27, p. 9–12) there is a short discussion of fossil plant collecting. For the invertebrates the student is referred to Grabau ('99, p. 107–17), Kindle ('16, p. 117–24) and Schuchert ('95, Part K).

CLASSIFICATION AND DESCRIPTION OF ANIMALS

Classification. For convenience of study animals or plants are grouped together in some way. One way of grouping them is according to actual blood relationships or taxonomically (Greek *taxis,* arrangement; *nomos,* law). The taxonomic mode of classification is the one used here. A taxonomic classification depends to a large extent upon paleontology, or the study of ancient life, because a classification based only upon living organisms is apt to have errors. Groups of animals that stand isolated are seen to be related where their fossil ancestry is known.

The organic world is divided first into two kingdoms, the animal and plant kingdoms. The kingdoms in turn are divided into two subkingdoms: unicellular organisms on the one hand, and multicellular organisms on the other. The subkingdoms are then divided into phyla (singular, phylum from Greek *phylon,* race or tribe), classes, orders, families, genera (singular, genus), species and varieties. Classes may include subclasses; orders, suborders; families, subfamilies; genera, subgenera; etc. To illustrate this we may take for an example our house cat, which is classified as follows:

Kingdom: Animalia
- Phylum: Vertebrata or vertebrated animals
  - Class: Mammalia or mammals
    - Order: Carnivora or carnivorous animals
      - Family: Felidae or cats
        - Genus: *Felis,* a member of the cat family
          - Species: *Felis domestica,* the cat

The different kinds of individual cats are known as *varieties* and these are composed of individuals. Species are not always divided into varieties.

The classification used below is a modification after several authors, and only those groups are included, which are found fossil to any extent. This classification is simplified and takes up only phyla and classes, in general, although subclasses are given in a few cases.

Phylum	*Class*	
Vertebrata	Mammalia (Mammals including man)	
	Aves (Birds)	
	Reptilia (Reptiles: turtles, crocodiles, lizards, snakes etc.)	
	Amphibia (Amphibians: salamanders, frogs, toads etc.)	
	Pisces (Fishes)	
	Ostracoderma (Ostracoderms or aberrant sharks)	
Arthropoda	Insecta (True or six-legged insects: cockroaches, locusts, flies, beetles, bugs, butterflies, bees)	
	Arachnida	Subclass Embolobranchiata (Scorpions, spiders, mites etc.)
		Subclass Merostomata (Eurypterids, king or horseshoe crab etc.)
	Myriopoda	(Millipedes, centipedes)
	Crustacea	Subclass Malacostraca (Lobsters, crayfish, true crabs etc.)
		Subclass Cirripedia (Barnacles)
		Subclass Ostracoda (Ostracods)
		Subclass Branchiopoda (Branchiopods)
		Subclass Trilobita (Trilobites)
Mollusca	Cephalopoda (Cuttlefish, squid, octopus, nautilus etc.)	
	Pteropoda (Pteropods)	
	Conularida (Conularids)	
	Scaphopoda (Scaphopods)	
	Gastropoda (Univalved shellfish, such as periwinkles, whelks, land snails, slugs etc.)	
	Pelecypoda (Bivalved shellfish (Lamellibranchiata), such as mussels, cockles, oysters, etc.)	
	Amphineura (Chitons and allies)	
Molluscoidea	Brachiopoda (Brachiopods or lamp-shells)	
	Bryozoa (Moss-animals)	
Annulata (Annelids)	Chaetopoda (Earthworms, freshwater worms, marine annelids)	

Phylum	Class
Echinodermata	Holothurioidea (Holothurians or sea cucumbers)
	Echinoidea (Sea urchins)
	Ophiuroidea (Brittle stars)
	Asteroidea (Starfishes)
	Crinoidea (Crinoids)
	Blastoidea (Blastoids)
	Cystoidea (Cystids or cystoids)
Coelenterata	Actinozoa (Sea anemones and corals)
	Scyphozoa (Jellyfishes)
	Hydrozoa (Hydroids, jellyfishes, and hydrocorallines)
Porifera	Porifera (Sponges)
Protozoa	Rhizopoda (Foraminifera, Radiolaria)

Description. The various groups of animals will be treated beginning with the lowest forms—the Protozoa—but the Vertebrata will be less fully discussed. An attempt will be made only to give a short description of the different groups with such illustration as will be necessary to make it clear. This will enable the student at least to place any specimen he may find. For more detailed study there is plenty of literature of more advanced nature.

Since reference will be made throughout the discussions of the various groups of animals to the geological horizons in which they are found, it seems advisable to give here a simple geological time scale for reference. A more detailed time scale will be given in the second part of this work, which deals entirely with the different geological formations with particular reference to New York State.

The time scale used here has been adapted from Schuchert ('24, p. 100–6). Eras are defined as distinguished by worldwide revolutions and marked organic change; periods on the other hand, are separated by crustal disturbances and moderate changes in life. The duration of the different periods in percentages is taken from Schuchert, the duration in years is based upon the latest results (Holmes and Lawson, '27, p. 342) from

Geologic Time Scale

Eras	Major divisions	Periods		Age of the Earth (Over 1,000,000,000 years)	Dominant life
Psychozoic (Gr. *psyche*, soul; *zoe*, life)	Recent or postglacial time		Quaternary time	*17,000–20,000* years	*Age of Man*
Cenozoic (Gr. *kainos*, new; *zoe*, life) Modern Life	Late Cenozoic	Pleistocene or Glacial	= Quaternary time	2% or over *20,000,000* years (Pleistocene = 500,000 to over 1,000,000 years)	*Age of Mammals* and *Flowering Plants*
		Pliocene	Tertiary time		
		Miocene	Tertiary time		
	Early Cenozoic	Oligocene	Tertiary time	2% or over *20,000,000* years (Begins over 40,000,000 years ago)	
		Eocene	Tertiary time		
Mesozoic (Gr. *mesos*, middle; *zoe*, life) Middle Life	Late Mesozoic	Cretaceous (Upper Cretaceous)		5% or over *50,000,000* years (Begins over 90,000,000 years ago)	*Age of Reptiles*
		Comanchean (Lower Cretaceous)			
	Early Mesozoic	Jurassic		3.75% or over *37,500,000* years (Begins over 127,500,000 years ago)	*Age of Reptiles* and *Medieval Floras*
		Triassic		2.25% or over *22,500,000* years (Begins over 150,000,000 years ago)	

Eras	Major divisions	Periods	Age of the Earth (Over 1,000,000,000 years)	Dominant life
Paleozoic (Gr. *palaios*, ancient; *zoe*, life) Ancient Life	Late Paleozoic or Carboniferous	Permian	3% or over *30,000,000* years (Begins over 180,000,000 years ago)	*Age of Amphibians* and *Ancient Floras*
		Pennsylvanian	3% or over *30,000,000* years (Begins over 210,000,000 years ago)	
	Middle Paleozoic	Mississippian (Lower Carboniferous)	3% or over *30,000,000* years (Begins over 240,000,000 years ago)	*Age of Fishes*
		Devonian	4.5% or over *45,000,000* years (Begins over 285,000,000 years ago)	
	Early Paleozoic	Silurian	3% or over *30,000,000* years (Begins over 315,000,000 years ago)	*Age of Invertebrates*
		Ordovician	7.5% or over *75,000,000* years (Begins over 390,000,000 years ago)	
		Cambrian	6% or over *60,000,000* years (Begins over 450,000,000 years ago)	
Precambrian Eras	**Proterozoic** (Gr. *proteros*, former; *zoe*, life)		25% or over *250,000,000* years (Begins over 700,000,000 years ago)	*Age of Primitive Invertebrates*
	Archeozoic (Archean) (Gr. *archaios*, ancient; *zoe*, life)		30% or over *300,000,000* years (Begins over 1,000,000,000 years ago)	*Age of Larval Life*

Pre-geologic Time in the Earth's History.

the study of radioactive substances. The ages are given in round numbers in the time scale; but the age of the earth from the beginning of the Precambrian has been calculated as 1,336,000,000 years, from the beginning of the Cambrian, as 567,000,000 years. Geologists from a study of the rocks have estimated the age of the earth as at least 600,000,000 years. Of the two calculations the radioactive is the more dependable.

Phylum Protozoa

(Greek *protos,* first; *zoon,* animal)

This phylum represents the lowest, primary subdivision of the animal kingdom and comprises marine or fresh-water animals composed of a single cell or a small number of undifferentiated cells. Only individuals of two orders are found fossil—the Foraminifera and the Radiolaria. Most of the forms in both orders are very small, 1 millimeter or less in diameter, but some of them occur in such great numbers that they are quite important as rock formers. The class to which these two orders belong, the Rhizopoda or Rhizopods (Greek, *rhiza,* a root; *pous* (*pod*), foot) also includes the common fresh-water *Amoeba,* with which those who have had any course in biology are familiar, and which illustrates well the essential characters of a protozoan. The *Amoeba* (figure 7) is a single cell, an irregular mass of protoplasm, about one-sixth of a millimeter in diameter, which can be produced into irregular processes or *pseudopods* (Greek *pseudes,* false; *pous* (*pod*), foot) varying in size and capable of being protruded and retracted with considerable rapidity. These pseudopodia aid the Amoeba in changing its position and moving about although the process is a very slow one. The Amoeba feeds by the

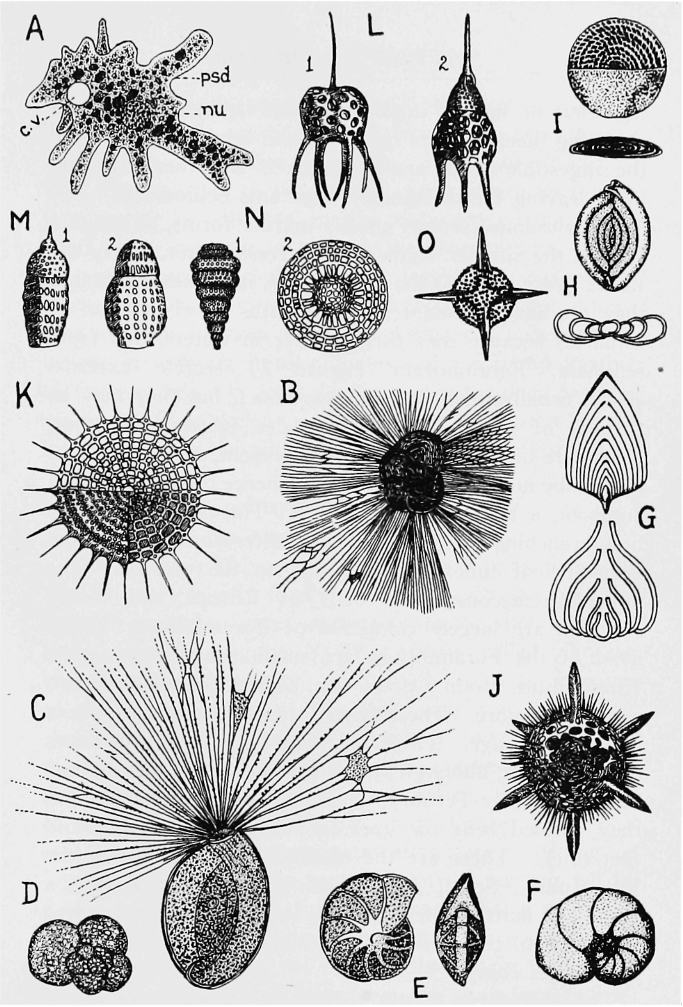


Figure 7 Amoeba Foraminifera, Radiolaria. *A Amoeba: psd* Pseudopod; *nu* Nucleus; *c. v.* Contractile vacuole. *B, C* Living Foraminifera (*B Rotalia; C Miliola*). *D—I* Shells of living Foraminifera (*D Globigerina; I Nummulites* with vertical section and half shell in horizontal section). *J, K* Recent Radiolaria. *L—O* Fossil Radiolaria (*L, M* Tertiary; *N* Devonian; *O* Ordovician), (*B, C* from Grabau: Textbook of Geology, permission of D. C. Heath & Co. *A, D—I* from Textbook of Zoology by Parker & Haswell; *J, O* from Textbook of Paleontology by Zittel-Eastman; published by The Macmillan Co.)

ingestion of minute organisms, that is, by entirely surrounding them with its substance and retaining them until the digestible parts are assimilated, and then crawling away leaving the undigestible remnants behind.

The *Foraminifera* are mostly marine forms, although a few of the simpler forms live in fresh water. They are found everywhere at the present day, in all seas, although they are less abundant at the mouths of rivers and in estuaries because they thrive better in waters free from sediment. Foraminifera (figure 7) secrete external shells, usually lime (calcite, aragonite), but they may be formed of chitin or sand particles fastened together. There are one or more chambers present, in many forms pierced by numerous fine apertures, hence the name (Latin *foramen*, a hole; *ferre*, to bear). The pseudopodia are fine, branching or netlike. Foraminifera have lived from very ancient times (Ordovician) to the present. The upper Cretaceous chalk beds of Europe and North America are largely composed of Foraminifera. While most of the Foraminifera are small, some, such as the Nummulites, attain a great size, having diameters of two inches and more. These giant forms are used as indexes of geological age. They occur from Carboniferous times to the present, although only a few forms are now living; but in the early Tertiary, when they were most abundant, they formed beds of limestone up to several thousand feet thick. These are the nummulitic limestones of the East Indies, South Asia, South Europe, North Africa etc. The flattened, lens or coin shape of the shells gives the name to this form (Latin *nummulus*, diminutive of *nummus*, a coin).

The *Radiolaria* (Latin *radiolus*, little ray) are protozoans that secrete a more or less internal skeleton of silica of a delicate, open lattice-like structure (figure 7). The pseudopodia are fine and raylike with a central axis. Radiolarians are marine organisms which range from possibly Precambrian to the present day and are an important source of silica in marine sediments, from which chert beds, concretions, such as the chert nodules of the Upper Cretaceous chalk, etc. are formed by segregation. Like the Foraminifera, the Radiolaria were not important as rock builders until the Tertiary. Today radiolarians are present in all climates and are found floating on the surface or at great depths, and in the deep parts of the oceans their skeletons accumulating on the sea bottom form a silicious deposit known as "radiolarian ooze."

Phylum Porifera

(Latin *porus,* pore; *ferre,* to bear)

The *Porifera,* or sponges, derived their name from the fact that they take in food not through a single mouth but through numerous pores scattered over the surface of the body. Sponges (figures 8, 9) are many-celled plantlike organisms, fixed, aquatic, and usually colonial. Because of their fixed mode of life they vary considerably in shape and often are of very indefinite form. Nearly all the sponges are marine; the green sponges (*Spongilla*) are the only ones found in fresh water. The simplest of the sponges is like a hollow attached vase. There is a central cavity which terminates in a large opening or *osculum* (mouth). The central cavity is surrounded by fleshy matter in which there are many canals or pores, through which water enters bringing in the food. In the more primitive forms the food is digested in the central cavity; in more complicated forms in secondary cavities surrounding the central one. The water with the undigested food passes out through the terminal opening of the central cavity. Where there is only one central cavity and one osculum one may consider that one is dealing with an individual; where there is more than one there is a colony.

The flesh of sponges is strengthened and supported by a skeleton of some kind, in the nature of a meshwork. This skeleton may be composed of chitinous or horny fibers or of calcareous or silicious spicules. The common bath sponge is one of the horny sponges, but in the form in which it is known to us, all the organic matter has been removed. If one examines such a sponge one may see the tubelike central cavities terminating in large, round oscula. This sponge is not an individual but a colony. Most modern sponges secrete a skeleton of horny fibers. Rods or spicules of silica are sometimes found in

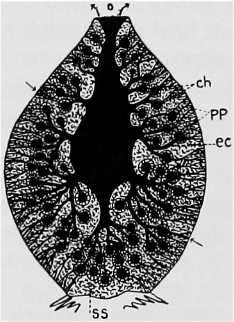


Figure 8 Diagrammatic figure showing the structure of a simple sponge in vertical section. *O* Mouth or *osculum; pp* Pores through which water enters into *inhalent canals* which carry it to *flagellated chambers, ch,* thence by *exhalent canals, ec,* into the general cavity. Arrows show the direction of the current. (Haekel, in Hall and Clarke)

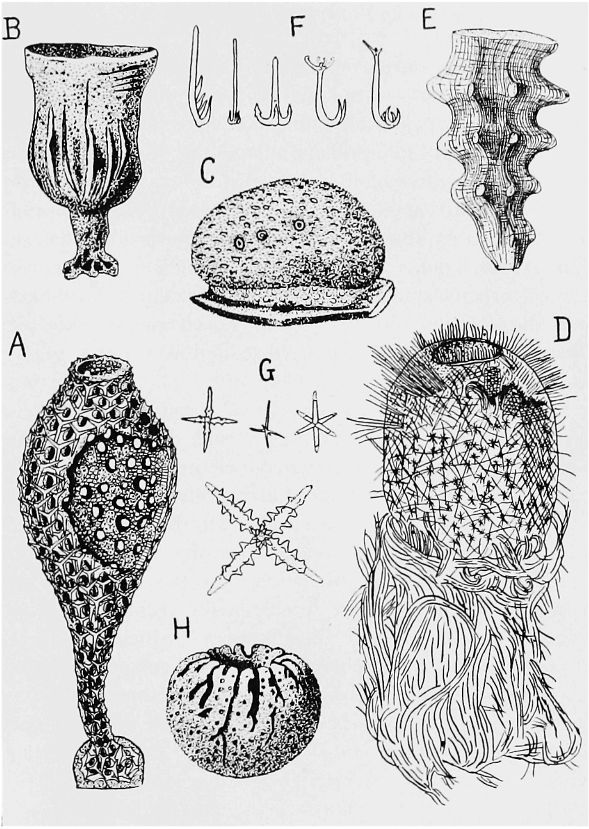


Figure 9 Recent and fossil sponges. *A* Simple modern sponge (*Olynthus*), reduced. *B* Recent cup sponge (*Poterion*), reduced. *C* Common bath sponge (*Euspongia*) greatly reduced. *D* Recent glass sponge (*Pheronema*), x¼. *E* Fossil glass sponge. (*Hydnoceras*) from the Chemung (Devonian) of New York (after Hall & Clarke, x⅙). *F*, *G* Fossil glass sponge spicules, enlarged (after Clarke). *H* Fossil sponge from the Silurian, much reduced (from Grabau & Shimer). (*A*, *B*, *C* from Textbook of Zoology by Parker & Haswell; *D* from Cambridge Natural History ed. by Harmer & Shipley, published by The Macmillan Co.)

horny sponges; but they make up the entire skeleton of other sponges and in the higher forms there is a union of their ends forming a rigid structure of silicious threads or fibers. Such sponges are known as "glass sponges." Recent glass sponges, such as Venus' Flower Basket, may be seen in Museums. A collection from the Philippine Islands is on exhibition in the State Museum near a large slab of fossil silicious sponges. One group of sponges has calcareous spicules, almost pure calcium carbonate; and the spicules do not form a continuous skeleton. These sponges today live in the shallower parts of the sea along the coast.

Sponges are known from the Precambrian on. As a rule they are poorly preserved and difficult to determine. Sponges with no skeletal elements or with only a skeleton of perishable fibers are rarely found preserved as fossils. Therefore, practically all the fossil sponges belong to the groups with calcareous or silicious skeletons and most of them to the latter. In the earliest forms with silicious spicules, the spicules were feebly united and so the form of the body is unknown. Silicious sponges attained their greatest abundance in the Cretaceous period. Large colonies of fossil sponges are sometimes found as, for example, the magnificent glass sponges of the Upper Devonian (Chemung sandstone) beds of New York State, which inhabited comparatively shallow water in contrast to the deep water habitat of the recent forms. As a matter of fact, New York State has furnished the richest fauna of Paleozoic sponges in the world: first, in the variety of forms obtained in the Utica shale (Ordovician) and, second, in the still richer faunas from the Upper Devonian of the southern part of the state. A restoration case (figure 10) in the State Museum shows some of these picturesque Devonian sponges.

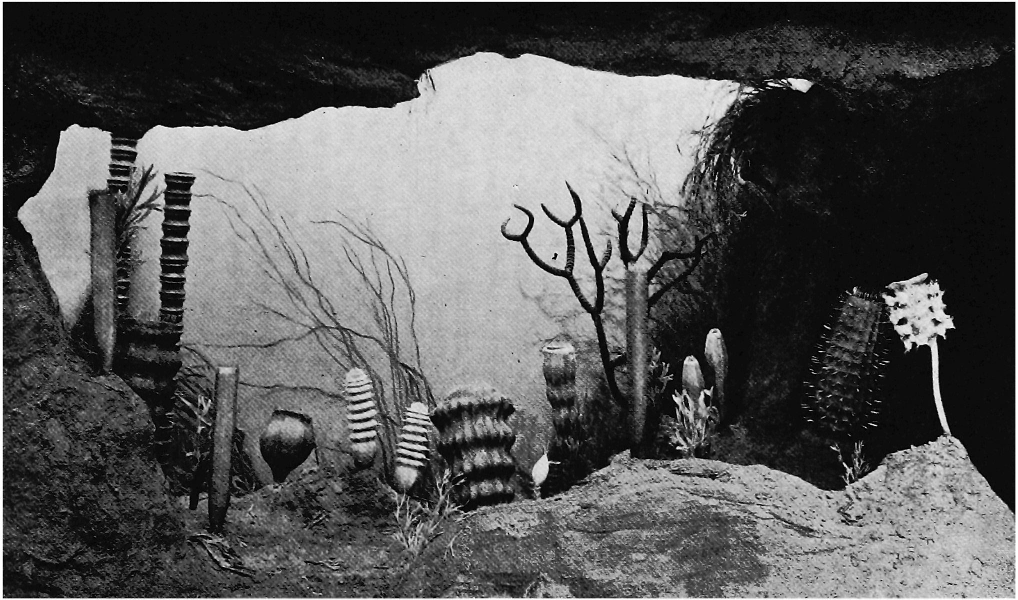


Figure 10 Restoration of Upper Devonian silicious sponges of New York. Restoration in State Museum, executed by Henri Marchand under the supervision of Rudolf Ruedemann.

The skeleton of fossil sponges may be preserved in the original state, altered or dissolved away so that only the shape of the fossil and the impression of the skeleton is seen. Silicious spicules may become crystallized during fossilization, or be dissolved away and replaced by calcite, pyrites etc. Likewise calcareous spicules may be replaced by silica, so that in the fossil state form rather than chemical composition must be depended upon. When silicious spicules are scattered through the sponge tissue, the decaying organic matter frees them, they collect in the sediments and if abundant form silicious beds. The dissolved silica of such spicules is often redeposited together with silica from other organisms and forms flint nodules, such as those found in the chalk beds (Cretaceous) of England and France.

Phylum Coelenterata

(Greek *koilos*, hollow; *enteron*, intestine)

The Coelenterata are animals of a low type of organization, with conspicuous radial symmetry, and generally with tentacles. They have one internal cavity, with only one opening, which serves both for digestion of the food and for circulation. The arms or tentacles are arranged about the opening of the internal cavity and are provided with special offensive weapons, the nettle or stinging cells. The body wall and tentacles are composed of three layers, an outer layer of cells, an inner layer of cells and a middle, rather stiff, structureless substance with few or no cells. There are four classes but only three are discussed here as the fourth is not represented in the fossil state. These classes are Hydrozoa, Scyphozoa and Anthozoa.

Class Hydrozoa (Greek *hydor*, water; *zoon*, animal). The hydrozoans are abundant from the Cambrian to the present. This class includes the hydroids, many jellyfishes

—mostly of small size—a few stony corals or hydrocorallines and possibly a group only known fossil, the graptolites.

The simplest form (figure 11) of the *hydroids* is the little fresh-water *Hydra,* but most of the hydroids are marine (figures 11, 12) and form more or less complex colonies, such as *Obelia* and *Sertularia,* which appear as delicate whitish or light brown, somewhat furlike growths on the wooden piles of piers and wharfs or attached to rocks or the rock weed, *Fucus.* Under a lens a hydroid colony is seen to consist of a common stem or axis, much branched and bearing two kinds of individuals (*zooids*). The large majority of the zooids are similar to the simple *Hydra,* which consists of a simple, cylindrical body with a circlet of a variable number but usually six or eight tentacles surrounding a conical protuberance at the tip of which is the mouth opening. They carry on all the functions necessary to the life of the colony. The food is captured by the tentacles and the nettle-cells paralyze any living prey and render it harmless. The other kind of zooid is specialized for reproduction. The *reproductive zooids* are usually found near the tips and are only present during the breeding season. These special polyps in some species form medusoid buds which break away and form minute, transparent free-swimming jellyfishes or *medusae* (Greek *Medusa,* Medusa), which bear sexual organs and give rise again to the asexual, plantlike colony. There is thus an alternation of generations. In other forms there are no free medusae; the reproductive zooids are fixed. The hydroids have been found from Mesozoic times to the present. Most marine hydroids are enveloped in a chitinous sheath or covering which often terminates in a cup or *hydrotheca* (Greek *hydor,* water; *theke,* box or

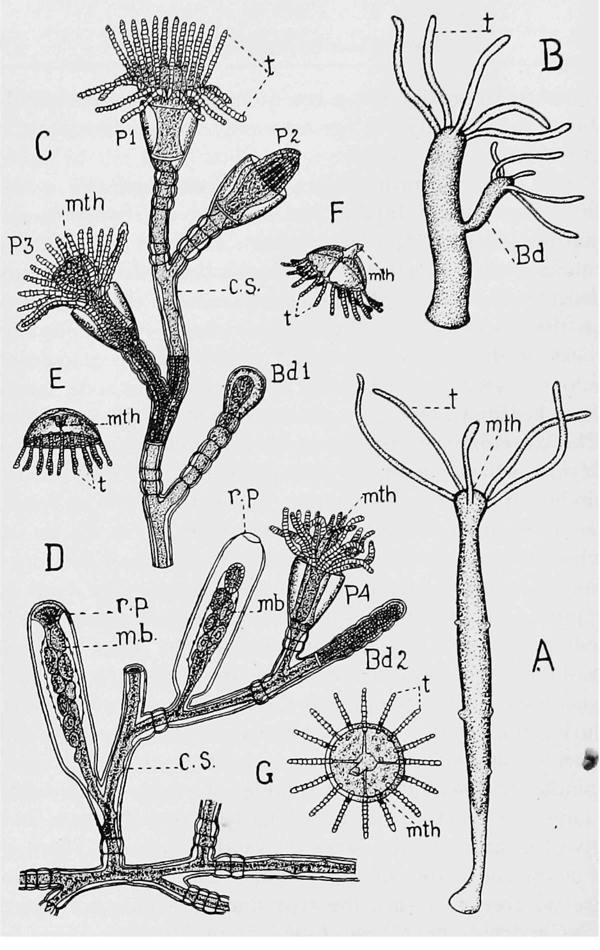


Figure 11 Hydroids. *A, B Hydra* sp., much enlarged; *A* expanded, *B* contracted, with bud (W. Schoonmaker). *C, D* Enlargements of parts of a marine hydroid colony (*Obelia* sp.). *E* Medusa of *Obelia*, side view. *F* The same with reversed umbrella. *G* The same, ventral or oral aspect. *P1–4* Polyps; *r.p.* Reproductive polyp; *Bd* Bud; *c. s.* Chitinous sheath; *t* Tentacles; *mth* Mouth; *mb* Medusa bud. (*C—G* from Textbook of Zoology by Parker and Haswell, published by The Macmillan Co.)

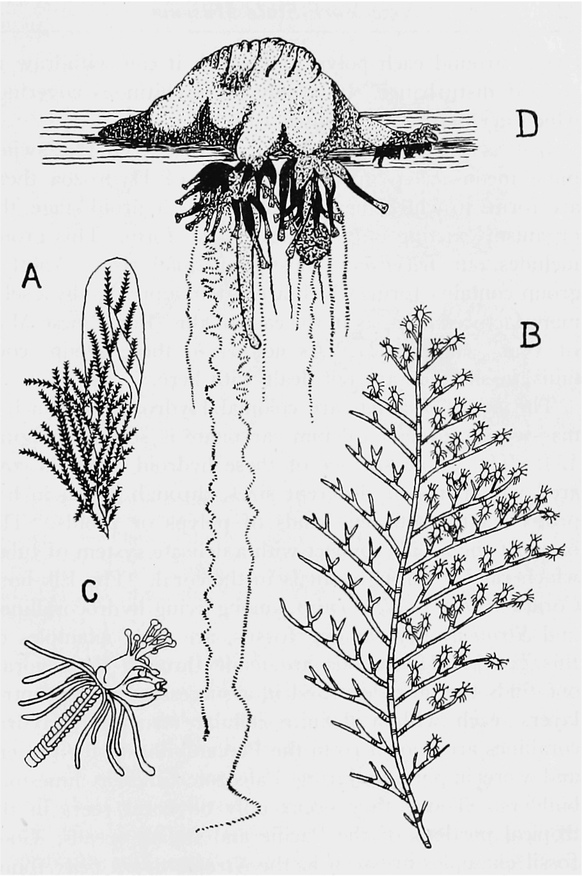


Figure 12 Hydroids. *A* Colony of *Sertularia* on a frond of seaweed, x1. *B* Branch of a colony of *Pennaria*, x1. *C* One of the hydroids of *Pennaria* showing medusae buds developing at the base of the proboscis, x8. *D* "Portuguese Man of War," *Physalia*. (*A—C* after Verrill and Smith; *D* from Textbook of Zoology by Parker and Haswell, published by The Macmillan Co.)

chest) around each polyp into which it can withdraw in case of disturbance. It is only these chitinous coverings which are preserved in fossil forms.

Just as there are hydroid colonies with no free-swimming medusae, so in another group of Hydrozoa there are forms in which there is no fixed or hydroid stage, the organism existing only in the medusa form. This group includes our *jellyfishes,* mostly of small size. Another group contains forms which are often supported by a self-manufactured float, as in the case of the "Portuguese Man of War" (figure 12). As neither of these groups contains fossils they are not dealt with here.

The *hydrocorallines* are colonial Hydrozoa in which a massive skeleton of calcium carbonate is secreted (figure 13). The whole surface of these hydroid corals is covered with pores of different sizes, through which in life protruded the different kinds of polyps or zooids. The bases of the zooids connect with a delicate system of tubes which ramify through canals in the coral. The Elk-horn Coral (*Millepora alcicornis*), among living hydrocorallines, and *Stromatopora,* among fossils, are good examples of this group. If sections are made through these corals one finds the lime deposited in a succession of concentric layers, each with a definite cellular structure. Hydrocorallines are known from the Precambrian to the present and were important during Paleozoic times as limestone builders. Today they occur only on coral reefs in the tropical portions of the Pacific and Indian oceans. Good fossil examples are seen in the *Stromatopora beds* found in the Manlius and Coeymans limestones of the Helderberg region and well shown in the John Boyd Thacher Park, Indian Ladder area. The individual Stromatoporas form masses or heads of large size.

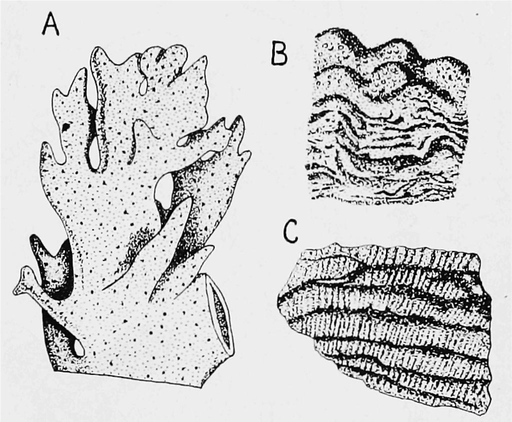


Figure 13 Hydrocorallines. *A* Recent form, the Elk-horn Coral (*Millepora alcicornis*), x¾. *B* Devonian form, *Stromatoporella,* showing undulating upper surface and concentric layers, x¾. *C* Vertical section of a Silurian form showing concentric layers, x3/2. (*A* from Textbook of Zoology by Parker & Haswell, published by The Macmillan Co.; *B, C* from Grabau & Shimer: Index Fossils)

The *graptolites* (Greek *graptos,* written; *lithos,* stone) are an extinct group of supposed colonial Hydrozoa which secreted a protecting and supporting skeleton of chitin with the separate individuals in cups or pits along the chitinous stalk (figures 14, 15). The chitinous covering is all that is fossilized. In fossilization the chitin became carbonized and these carbonized skeletons give the appearance of pencil markings or writing on the rock; hence the name of the group. Graptolites were either attached to objects on the sea bottom or, like the modern hydroids, to sea weeds which sometimes were torn from their anchorage and drifted; or they were free-floating,

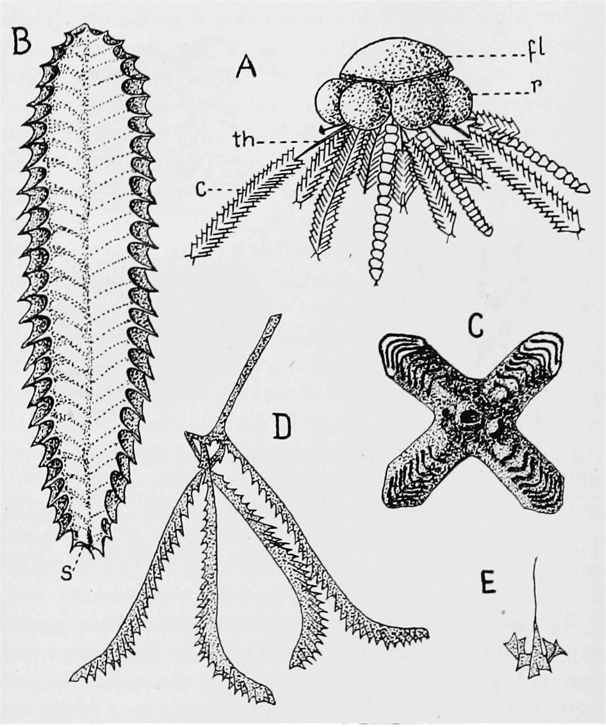


Figure 14 Graptolites. *A* A compound colony, *Diplograptus,* x1: *fl* Float; *r* Reproductive bladder; *th* Thread supporting the colony; *c* Side view of colony showing two rows of cups. *B Phyllograptus,* showing four rows of thecae and the earliest theca or sicula, x4. *C* View of same from sicular end, x6. *D Tetragraptus,* a four-branched form, x1. *E* Young form showing the long narrow sicula and the four thecae from which the four branches grow, x5. (All Ordovician forms from Ruedemann; *B, C* after Holm)

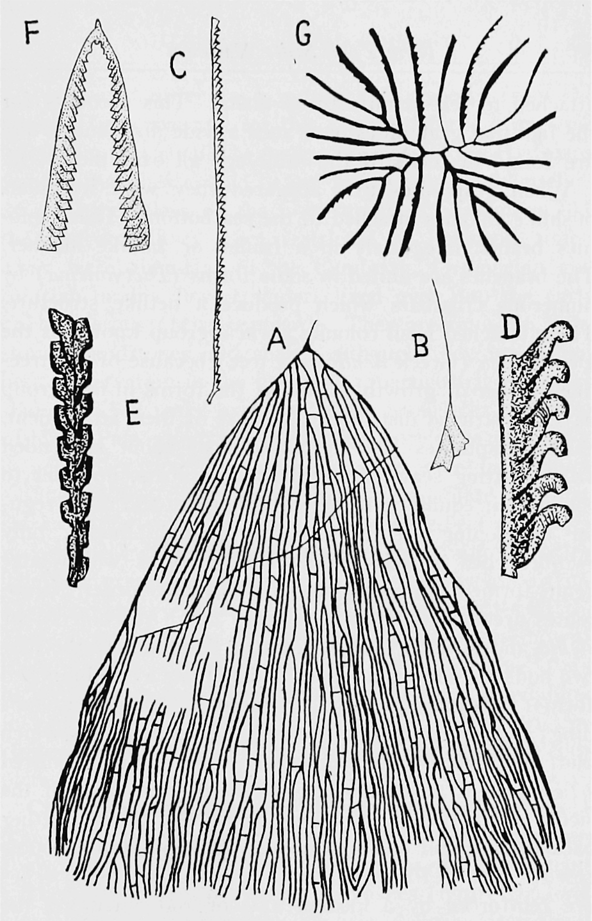


Figure 15 Graptolites. *A Dictyonema*, an attached, bushlike colony, x1. *B* Sicula of the same with budding first theca, x5. *C Monograptus*, a one-branched Silurian form with one row of thecae, x1. *D* The same, much enlarged. *E Climacograptus*, one-branched form with two rows of thecae, x7. *F Didymograptus*, a two-branched form, x2. *G Goniograptus*, with many branches, x1. (All Ordovician and Silurian forms, from Ruedemann)

attached to self-manufactured floats. This accounts for the fact that graptolites have such a wide distribution and are found in rocks of the same age all over the world.

When graptolites first appeared they were irregular, bushlike colonies attached to the sea bottom. These colonies branch irregularly in a funnel or fanlike manner. The branches are united in some forms (*Dictyonema*) by numerous crossbars which produce a netlike structure. These attached bush colonies form a group known as the Dendroidea (Greek *dendron*, a tree) because of the treelike manner of growth. Most of the forms in this group have a restricted distribution because of their attachment. When graptolites later began to float about suspended from drifting seaweeds or their own floats, in order to retain their equilibrium they became more and more regular developing 64, 32, 16, 8, 4 and, finally, only two-branched (rarely one-branched) forms which later again formed compound stocks of a higher order. Graptolites are derived from a primary cup (*hydrotheca*) or *sicula* and develop by a process of budding. If the first two buds are pointed in opposite directions a two-branched form (*Didymograptus*) is produced by continuous budding; if the first two buds each produce two buds which bud continuously a four-branched form is produced (*Tetragraptus*); and so on. If the original buds of the sicula are turned back upon themselves, grow together back to back and bud continuously, a form with a double row of cups (*Climacograptus*) is produced. Such types are reinforced by a median axis or rod extending the length of the branch and even beyond the last hydrothecae. In the development of graptolites the cups or thecae begin as simple straight tubes, then they become curved and finally recurved with protected apertures.

Graptolites differ in a number of respects from the typical Hydrozoa, and for this reason there is a growing belief that they should be made a subclass of the Hydrozoa or even that they should be put in a group by themselves as a distinct class of the Coelenterata. Graptolites like the hydrocorallines were restricted to Paleozoic times. They were abundant in the Cambrian, Ordovician and Silurian, and a few stragglers lived over into the early Carboniferous (Mississippian). They are found in limestones, sandstones and shales, although they have their best preservation in the fine shales, particularly the black shales. They make excellent index fossils for the rocks of lower Paleozoic times, permitting worldwide correlation of geologic formations, because of their wide distribution.

One of the cases in the New York State Museum shows, along with the slabs of graptolite-bearing shales, wax models of an interesting series of graptolite types. The first graptolites described in this country came from Kenwood, near Albany, N. Y. The black shales of the Hudson and Mohawk valleys in some places teem with these strange organisms, and they have furnished some of the finest material known to science, which is exhibited in various cases in the State Museum. This material includes growth stages of the graptolite colonies and complete colonies.

Class Scyphozoa (Greek *skyphos,* cup; *zoon,* animal). The forms in this class have no hydroid colony; they are coelenterates in which the medusae are large and dominant. The group includes our larger jellyfishes (figure 16), well exemplified by the common jellyfish, *Aurelia,* often found cast up on the seashore. This jellyfish is recognized by its gelatinous, saucer-shaped umbrella, three or four inches in diameter. The conspicuous, concavo-convex umbrella

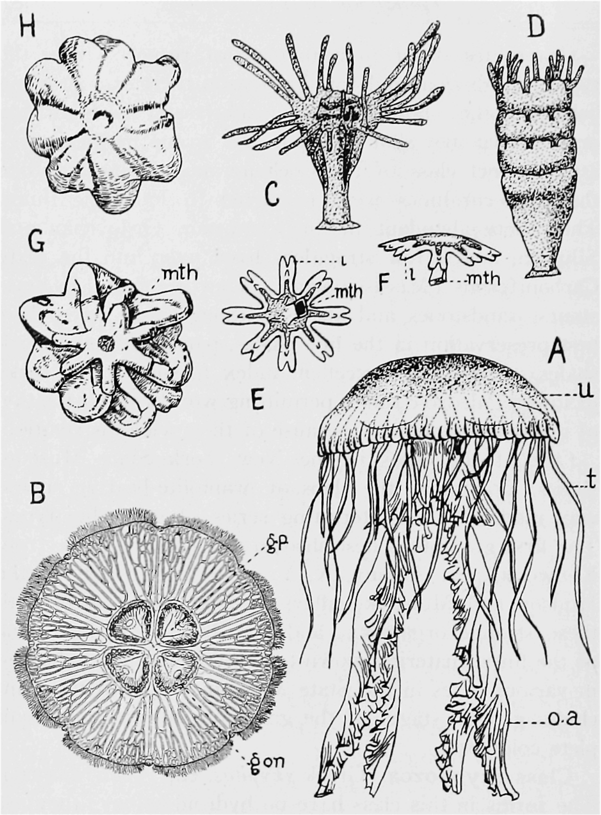


Figure 16 Scyphozoa. *A* Recent jellyfish, *Dactylometra*, from side, x1/5. *B* Recent jellyfish, *Aurelia*, seen from above, x1/5. *C—F* Development stages of an *Aurelia*, enlarged: *C* The polyp stage or *scyphula*; *D* Process of transverse fission; *E* Small jellyfish from beneath; *F* Same from side. *G* Fossil jellyfish (*Brooksella*) from the Middle Cambrian, top view showing nine lobes, x¾. *H* Undeview of the same. *gon.* Gonad; *g.p.* Gastral pouch, *l* Lobe of umbrella; *mth* Mouth; *o.a.* Oral arms; *t* Tentacles; *u* Umbrella. (*A*, *B* after Verrill and Smith. *C–F* from Textbook of Zoology by Parker & Haswell; *G*, *H* from Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

is slightly lobed and fringed with numerous, close-set, marginal tentacles. Near the center of the umbrella are four reddish or purplish horseshoe-shaped bodies, the gonads or sex organs. The upper or convex surface of the umbrella is known as the *exumbrella*; the lower or concave surface, as the *subumbrella*. In the subumbrella at the place where the handle of an umbrella would be attached is situated the mouth surrounded by four long, delicate processes, the *oral arms*. The mouth opens by way of a short gullet into a spacious stomach which occupies the whole middle region of the umbrella and is produced into four wide pouches, known as the *gastric pouches*. There is a muscular zone around the edge of the subumbrella, and the jellyfishes swim by rhythmically opening and closing their umbrellalike bodies.

The Scyphozoa are similar to the medusoid Hydrozoa, but they are of higher organization. In some Scyphozoa the medusa develops directly from the egg as in the Hydrozoa; in others, the egg produces a polyp form (*scyphula*), not unlike the *Hydra*, which becomes attached and undergoes a process of transverse fission, becoming divided by a series of constrictions which deepen until finally the polyp has the appearance of a pile of saucers. This process is continued until the saucerlike bodies are freed and swim around as small jellyfishes. The food of jellyfishes consists of small fishes and crustaceans and sometimes they feed upon their own kind. These creatures are short-lived, not living more than a year.

The Scyphozoa are known from the Cambrian to the present, but because of their lack of hard parts and delicate organizations (99 per cent water), they are rarely preserved. In very fine-grained muds, such as the lithographic slates of Bavaria (Jurassic), the impression of the bodies and trails of dragging tentacles are found. In other beds molds are found. The lobed digestive cavity sometimes became filled with fine sand or mud. Before the body of the jellyfish decayed it was covered with mud or sand, so that when decay finally took place the mold of the digestive cavity remained. Such molds have been found even in Cambrian rocks. The State Museum has three large slabs from the Lower Cambrian slates of Middle Granville, N. Y., which show star-shaped black stains representing such internal molds.

Class Actinozoa (Greek *aktis,* ray; *zoon,* animal). This group includes polyps with more or less complicated internal cavities and with no free-swimming form. They may be fleshy, as in sea anemones, or they may secrete a horny or calcareous skeleton, as in the corals (figure 17–19). All the animals in this group are marine forms. The group is also known as the Anthozoa (Greek *anthos,* flower; *zoon,* animal) because of the flowerlike appearance of the polyp when expanded. The tentacles correspond to the petals of a flower and the region about the mouth to the disk. The name is especially apt for the brilliantly colored tropical species.

Sea anemones are not found fossil and so will be discussed but briefly here. The sea anemone (figure 17) is a polyp formed on the same general lines as a Hydra or Scyphozoan scyphula, but differs from them in having numerous tentacles, in having a mouth flush with the tentacles, in its great size and bulk and in the comparative firmness of its substance. Sea anemones are among the best known and also the most abundant of the shore animals and are attached by a broad solelike base to rocks, seaweeds, shells etc. They are conspicuous for their flowerlike form and brilliant color and some of them measure several inches across.

The corals resemble the sea anemones in the general structure of the soft parts, but they secrete a skeleton. The coral polyp (figure 17) is sessile, with a barrel-shaped body, with the mouth at the center of the top surrounded by tentacles. Coral polyps differ from the hydroid polyp

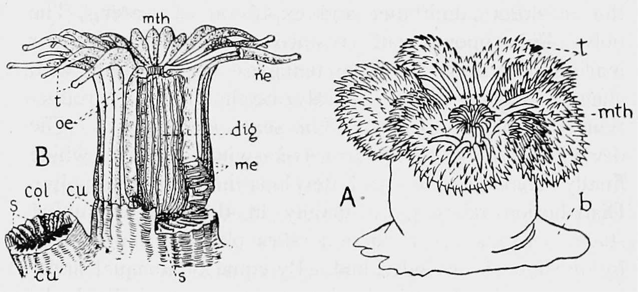


Figure 17 Anemone and coral polyp. *A* Common sea anemone of the North Atlantic. *Metridium marginatum*. *B* The common coral *Astrangia danae*, from Long Island Sound, showing polyp in feeding position upon the calcareous, cuplike base, x6. *b* Solelike base; *col* Spongy pseudo-columella; *cu* Cuplike calcareous base secreted by the polyp; *cu'* Part of the cup sectioned transversely; *dig.* Digestive cavity; *mth* Mouth; *ne* Clusters of nettle cells; *oe* Oesophagus; *s* Septa (which alternate with the mesenteries); *t* Tentacles. (*A* after Grabau: Textbook of Geology, permission D. C. Heath Co.; *B* from Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

in the invagination or inturning of the mouth region, which forms a sort of short oesophagus. The new mouth is surrounded by the edge of the inturned portion; the opening at the bottom of the oesophagus, or *stomodoeum* (Greek *stoma*, mouth, *daio*, divide), corresponds to the mouth of the hydroid. The oesophagus leads into a large digestive cavity or stomach, which is divided into radial compartments by fleshy partitions (*septa* or *mesenteries*) arranged in pairs. In general each radial compartment is continued into a hollow tentacle. There is a well-developed muscle surrounding the body at the top which draws in the tentacles and closes the mouth, and muscles in the septa which by their expansion and contraction cause the expansion and contraction of the animal and the resultant admittance and expulsion of water. The polyp lives upon small crustaceans, worms and other marine organisms, and the tentacles are provided with clusters of nettle-cells for paralyzing the prey. Reproduction is sexual or asexual. The sexes are distinct. The developing egg gives rise to a free-swimming form which finally becomes fixed and develops into a coral polyp. Distribution takes place mainly in the free-swimming stage. Asexual reproduction takes place by budding or by division of the individual. By equal or unequal division the coral polyp divides into two or more individuals, a portion of the mouth, some tentacles etc. going to each. Corals may be simple or compound, forming colonies. The solitary forms today are the deep-sea corals, while compound corals are very abundant on coral reefs. Most of the recent corals are colonial forms, but among fossils are a large number of types of single corals, popularly known as cup corals or horr corals.

Corals have a marvellously varied and gorgeous coloring during life. The stony corals (*Madrepores*) are pink, yellow, green, brown or purple. The organ-pipe coral (*Tubipora*) has green polyps with a crimson skeleton. In the precious red coral (*Corallium*), the polyps are pure white and the axis bright red. Another coral in the same group has a bright blue color (*Heliopora*). The Pennatulids or "Sea Pens," besides having vivid colors, are phosphorescent.

The skeleton of corals varies. One order, which includes the "Black Corals" has compound, treelike forms in which the skeleton is in the form of a branched, chitinoid axis. The Gorgonids or "Sea Fans" have compound, treelike forms with a calcareous or horny skeleton forming a branched axis throughout the colony. The Pennatulids or "Sea Pens" have a similar skeleton. In another group the skeleton usually consists of calcareous spicules. In some forms they remain detached. This is the simplest form of coral skeleton, and the common "Dead Men's Fingers" belongs here. In other forms the spicules become united to form a coherent skeleton: a branched axis, as in the "Red Coral"; a series of connected tubes, as in the "Organ-pipe Coral"; or a massive structure, as in the "Blue Coral."

Most corals have no spicules present but the outer surface of the lower part of the polyp secretes a calcareous skeleton (figures 17–19). Here belong most of the "Stone Corals" or Madrepores. The entire skeleton secreted by the coral polyp is known as the *corallum*. When there is more than one individual, the coral is compound and each individual is termed a *corallite*. The outer wall of the simple coral or corallite is known as the *theca* and the radiating vertical plates as *septa* (singular= *septum*). In some corals the theca is surrounded by another calcareous layer which shows concentric lines of growth. This is known as the *epitheca* (*epi*=upon). The outer ends of the septa are sometimes continued beyond the theca wall and appear as ridges or ribs, known as *costae* (singular = *costa*). At the broad end of the coral is a depression formed by the upper edges of the septa, which is known as the *calyx*. In some forms one of the principal or cardinal septa is sometimes partially or entirely

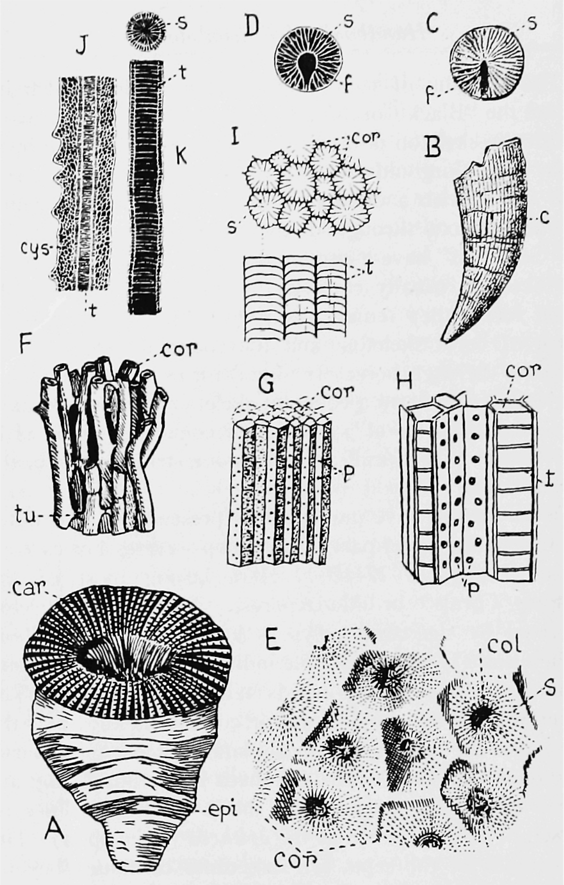


Figure 18 Corals. *A* Devonian cup coral, Heliophyllum halli. *B* Carboniferous cup or horn coral, *Zaphrentis calcareformis*. *C* Calyx of the same. *D* Transverse section of the same. *E* Portion of the surface of a Silurian compound coral, *Strombodes* with polygonal corallites. *F* Compound Devonian coral, *Syringopora*, composed of cylindrical tubes united by transverse tubular processes. *G*, *H* Groups of prismatic corallites of two species of the Devonian compound coral, *Favosites*. *I* Transverse and vertical sections of an Ordovician compound coral, *Columnaria*. *J* Silurian coral, *Eridophyllum*, with cystose structure. *K* Longitudinal and cross sections of a Devonian coral, *Synaptophyllum*. *c* Costae or ribs; *car* Carinae or septa; *col* Columella; *cor* Corallite; *cys* Cystose structure; *epi* Wrinkled epitheca; *f* Fossula; *p* Mural pores; *s* Septa; *t* Tabulae; *tu* transverse connecting tube. (*A*, *G* from Paleontology of N. Y.; *D*, *J*, *K* after Simpson; *B*, *C*, *E*, *H*, *I* from Grabau & Shimer: Index Fossils)

absent, which leaves a marked groove or depression known as a *fossula*. Union of secondary septa to each other or in groups produces apparent grooves known as *pseudofossulae*. In Tertiary forms septa often not reaching the center occur. At the center of the coral, projecting upward from the base, there is sometimes a central rod or *columella,* which is secreted by the center of the base of the polyp. Sometimes the septa are twisted near the center and give the appearance of such a column, which is then known as a *pseudocolumella.* Between the septa in the interior are *tabulae,* transverse partitions or floors extending across the whole coral; *dissepiments,* horizontal or oblique plates connecting adjoining septa but not extending across the whole coral; and *synapticulae* or cross bars. As the theca wall grows higher in some species the interior becomes too big for the polyp which draws itself upwards, and where it rests for a time a tabula is formed. The dissepiments are formed in the same way except that the base of the polyp is withdrawn in sections. Tabulae are generally well-developed when the septa are absent. In such corallites the walls are frequently pierced by more or less regular series of pores, known as *mural pores* (*Favosites*). Septa may be smooth or they may be reinforced with vertical beams which on cross section or in the calyx of the coral resemble short regular bars or *carinae* which extend a short distance on each side (*Heliophyllum*). Sometimes the septa are rudimentary and the interior consists of a spongy, cystose mass (*Cystiphyllum*).

Corals are classified in part according to the arrangement of the septa. In Palaeozoic corals the arrangement of the septa is often in cycles or groups of four. In the Mesozoic and later corals the septa occur in multiples of six.

In compound corals the corallites tend to lose their round outline and become prismatic in form (*Favosites*) when they are crowded. Sometimes the corallites are connected merely by strongly developed costae, or again by hollow, tubular connecting processes (*Syringopora*) etc. A compound coral may be a spherical or hemispheric "head," variously branching with cylindrical branches, or a platelike extension.

Corals are known from the Cambrian to the present (figures 18, 19). They have repeatedly formed coral reefs in the seas covering the present area of New York State, first in the Ordovician (Chazy of Champlain

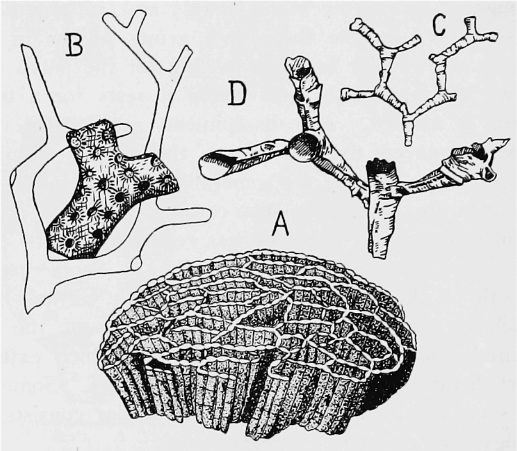


Figure 19 Corals. *A* Silurian chain coral, *Halysites*, x⅔ (N. Y. Geol. Surv.). *B* Devonian branching coral, *Trachypora*, with branch in outline, reduced (Paleontology of N. Y.). *C* Another type of Devonian branching coral, *Ceratopora*, x⅔. *D* The same, enlarged. (*C*, *D* from Grabau & Shimer: Index Fossils)

valley), then in the Silurian (Niagara of western New York; Cobleskill) and finally in the Devonian. Most extensive reefs were formed in the Devonian in Onondaga times (Onondaga limestone). These reefs are best known from the limestone quarries about Leroy, near Rochester. A variety of corals from this locality have been gathered together in the State Museum to form a reproduction group showing coral reef conditions. A number of special cases in the Museum are used for the exhibition of our wealth of fossil corals, many of which have been etched out with acid, restoring them to their original appearance except for color. A series of thin sections of corals have been mounted and are exhibited in the Onondaga and one of the Hamilton high cases. These are excellent for the study of structure.

Phylum Echinodermata

(Greek *echinos*, sea urchin (spiny); *derma*, skin)

The Echinodermata are spiny-skinned animals, entirely marine. All the forms show radial symmetry with the parts in multiples of five. This group is characterized by a water vascular system which functions in both locomotion and respiration. The Echinodermata form a more highly organized group than the Coelenterata. They have a digestive tube distinct from the body cavity, a more highly organized nervous system, a blood vascular system and exclusively sexual reproduction.

The Echinodermata are divided into seven classes, more or less closely related: Cystoidea, Blastoidea, Crinoidea, Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea. These are divided into two groups, according to their habit. The Asteroidea, Ophiuroidea and Echinoidea comprise the Eleutherozoa (Greek *eleutheros*, free; *zoon*, animal) or the free-swimming forms, and the Cystoidea, Blastoidea and Crinoidea, the Pelmatozoa (Greek *pelma(t)*, stalk; *zoon*, animal), or fixed forms. In the description of the various classes of Echinodermata it seems best to change the order somewhat and deal first with those classes which are most familiar to us through living representatives.

Class Asteroidea (Greek *aster*, star; *eidos (oid)*, form). The common starfishes along the Atlantic coast (*Asterias forbesii, A. vulgaris*) will serve in description as examples of the class. These starfishes live from high tide mark to a depth of a hundred feet. They seek deeper places in winter, but through summer and autumn are found in shallow rocky pools. *A. forbesii* is very common south of Cape Cod; *A. vulgaris*, north of Cape Cod. There are many tropical species of starfishes.

The Asteroidea, or starfishes, have a pentagonal or star-shaped body which consists of a central disk and five or more radiating arms or rays which taper slightly toward their tips (figure 20). There are two surfaces, an under or ventral surface (*oral* or *actinal:* Greek *aktis*, ray), in the center of which is situated the *mouth;* an upper or dorsal (*aboral* or *abactinal*) surface. The former is flat and is directed downward in the natural position of the living animal; the latter is convex. On the ventral side radiating out from the mouth are five grooves, one in the middle of each arm and extending to the extremity. These are the *ambulacral grooves* or *ambulacra* (Latin *ambulacrum*, walk), which are bordered on each side by two or three rows of movable, calcareous spines. Into the ambulacra project four rows of soft tubular bodies which end in suckerlike extremities; these are the *tube feet* which act as locomotive organs for the animal and

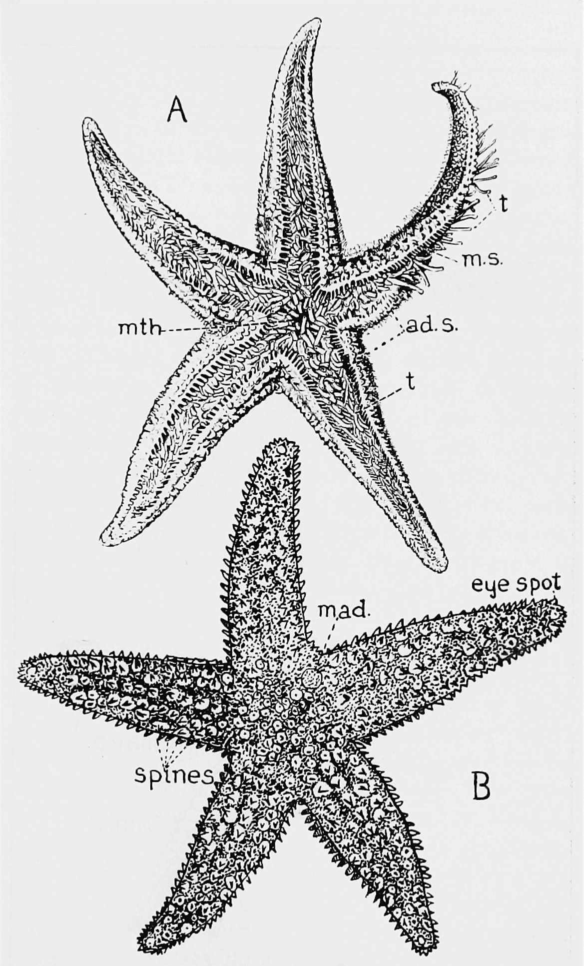


Figure 20 Living starfishes. *A Asterias rubens* of the North Atlantic, ventral side, x¾. *B* Dorsal side of four-months' old form, *Asterias forbesii,* from the Massachusetts coast, x1. *ad.s.* Adambulacral spines; *mad.* Madrepore; *m.s.* Movable spines; *mth* Mouth; *t* Tube feet. (*A* from Cambridge Natural History, ed. by Harmer & Shipley; *B* from Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

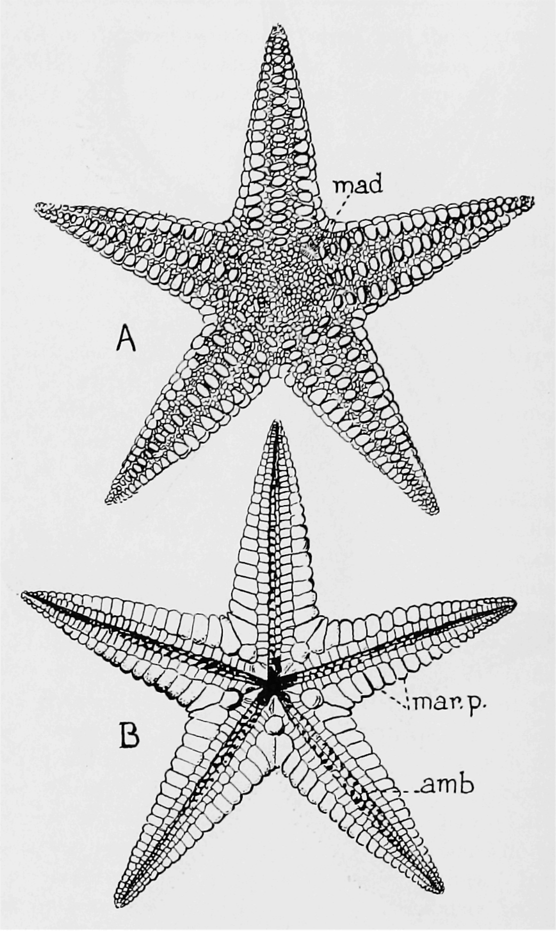


Figure 21 Devonian starfish, *Devonaster eucharis*. *A* Dorsal surface. *B* Ventral surface. *amb* Ambulacral groove; *mad* Madrepore; *mar.p.* Marginal plates. (After Hall)

form part of the water vascular system characteristic of the phylum. At the extremity of each ambulacral groove is a small, bright red speck, the *eye* or *eye spot,* which is so simple that it probably can distinguish only light and color, not form. Over each eye is a median process, or *tentacle,* similar to the tube feet, but smaller and with no terminal sucker. Experiments have shown that these tentacles are olfactory organs (organs of smell), and that the starfish is guided to its food more by these organs than by sight. The skeleton of the starfish is made up of numerous calcareous plates imbedded in the sub-epidermis, which, except for the mouth, completely surround the body. These calcareous plates, or ossicles, support protective spines which are covered only by the epidermis. Bands of muscular fibers extend between the neighboring plates, so that the arms and disk are movable.

In the soft interspaces between the ossicles are a number of *dermal pores* (Greek *derma,* skin) through which project short, hollow, threadlike processes, the dermal branchiae (Greek *branchia,* gills) which together with the ambulacral system carry on the respiration of the starfish. On the dorsal surface midway between the bases of two of the arms is a flat, nearly circular plate, the *madreporite* (Italian *madre* (L. *mater*), mother; Greek *poros,* pore) which is finely perforated. This connects with an S-shaped tube, the *madreporic* or *stone canal* which in turn connects with a five-sided, ringlike canal surrounding the mouth. Five straight ambulacral vessels radiate from this ring canal to the extremities of the arms and connect with the tube feet. Water enters the madreporite, passes through the stone canal to the ring canal and thence through the radial canals, the ambulacral vessels, into the tube feet, which become lengthened.

When the lengthened tube foot comes in contact with some solid object water is withdrawn and the tip is drawn inward forming a vacuum under it so that the end of the foot acts as a sucker. When water is again forced into the foot, its hold is released. By this process of attachment of the feet, contraction and pulling the body forward, locomotion is brought about. This is a very slow process, six inches a minute being considered fair speed.

The mouth of the starfish opens through a short passage, the oesophagus, into a five-lobed sac or ventral division of the stomach which has greatly folded walls and is capable of being erected through the mouth opening, wrapped around the object desired as food and retracted again. This division opens into a smaller chamber which in turn opens into a short intestine and thence out through the anal aperture near the center of the dorsal surface of the disk. The smaller chamber of the stomach is pentagonal and is drawn out at each angle into a pair of large appendages which extend to the tips of each arm and because they secrete a digestive fluid are looked upon as digestive glands. The food of starfishes consists of mollusks, particularly mussels such as clams and oysters; barnacles, small crustaceans, worms etc. In securing its food, such as a clam or oyster, the starfish wraps its arms about its prey, attaching itself to the shell by the tube feet, and exerts a steady pull until the muscles of the mollusk are tired and the valves open (figure 22). Between the opened valves the starfish rolls its stomach and spreads it as a thin sheet over the soft tissues of the prey which are digested with the aid of secretions from the digestive glands. Gastropods are opened and devoured similarly. A starfish can live for months without food. In the State Museum is a large slab from the Hamilton (Devonian) rocks of Mount Marion, N. Y., showing many starfishes (*Devonaster*) associated with mollusks, which they preyed upon then as now. They were apparently overwhelmed by a muddy current and thus preserved.

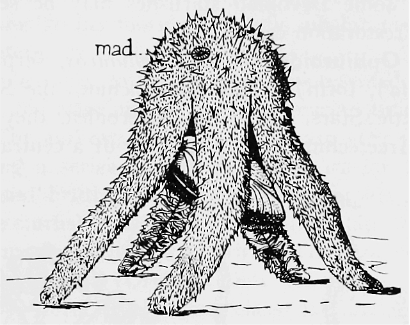


Figure 22 Starfish (*Echinaster*), devouring a mussel, x⅗. *mad* Madrepore. (From Cambridge Natural History, ed. by Harmer & Shipley, published by The Macmillan Co.)

Reproduction is exclusively sexual. Starfishes have the ability to regenerate arms and this is why starfishes, both recent and fossil, are found with one or more smaller arms. Sometimes an arm lost is replaced by two.

The Asteroidea are found fossil from Cambrian time to the present. Perfectly preserved starfishes are known only from a few localities, such as Bundenbach in Rhenish Prussia. Starfishes are usually preserved in the form of molds or detached plates. Pyritized specimens from the Devonian Bundenbach slates are on exhibition in special cases in the State Museum along with a very fine collection of New York material (figure 21) ranging from the oldest form of the true starfishes (*Hudsonaster*), consisting of a few heavy plates, to the later forms (*Urasterella*), consisting of many plates through which greater mobility of the arms is attained. Representatives of an extinct class leading to the later Ophiuroidea or Brittle Stars are also shown in one of the cases. Wax restorations of some Devonian starfishes may be seen in the Portage restoration case.

Class Ophiuroidea (Greek *ophiouros*, serpent-tailed; *eidos* (*oid*), form). This class includes the Sand Stars and Brittle Stars. Like the Asteroidea, they are star-shaped, free echinoderms consisting of a central disk and

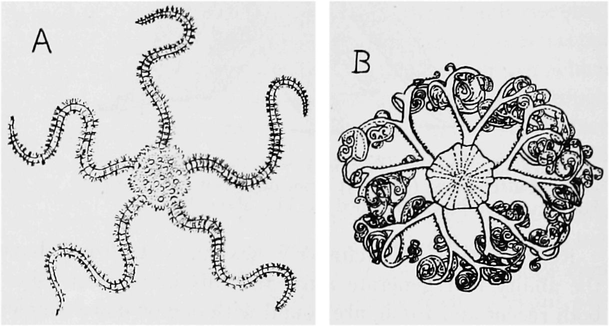


Figure 23 Living brittle star and basket starfish. *A* Brittle star (*Ophiopholis*) from the coast of New England, dorsal view, x½ (after Verrill & Smith). *B* Basket starfish (*Gorgonocephalus*), much reduced (from Grabau: Textbook of Geology, permission D. C. Heath & Co.)

five arms; but the arms are more sharply set off from the central disk than in the Asteroidea and the ambulacral and digestive systems are confined to the central disk (figures 23, 24). One fossil order occurring from

Ordovician to Devonian time has ambulacral grooves. There are no distinct oral and aboral surfaces; there is no anal opening present and the madreporite is on the oral side with the star-shaped aperture of the mouth. The arms are slender and rounded, tapering toward the free extremities; sometimes branched and intricately entwined as in the Basket Fish (*Astrophyton* and *Gorgonocephalus*). Living forms more commonly inhabit deep than shallow waters.

Ophiuroidea are rather sparsely represented among fossils, but the class ranges from Ordovician time to the present. The earliest Paleozoic forms are very interesting, forming a series intermediate in character between starfishes and brittle stars. A few ophiuroids may be seen in the starfish exhibition case in the State Museum, among them the earliest true brittle star (*Onychaster*).

Class Echinoidea (Greek *echinos*, sea urchin (spiny); *eidos* (*oid*), form). In this class are included Sea Urchins, Heart Urchins, Cake Urchins or Sand Dollars. They are free moving echinoderms with a body that is either globular or heart-shaped, or flattened and disklike. It is the shape of the last mentioned which gave to them the characteristic name of cake urchins or sand dollars (figures 24, 25). The globular forms are the regular sea urchins, represented by the common forms along our Atlantic coast (*Strongylocentrotus*). These forms are slightly compressed dorso-ventrally. The calcareous plates are firmly fitted together like a mosaic, forming a rigid shell or test, called the *corona*, which is supplemented near the center of the dorsal surface by a system of plates, the *apical system*, which usually consists of ten plates arranged in two alternating rows of five plates each. On the ventral side is the *mouth*, either central

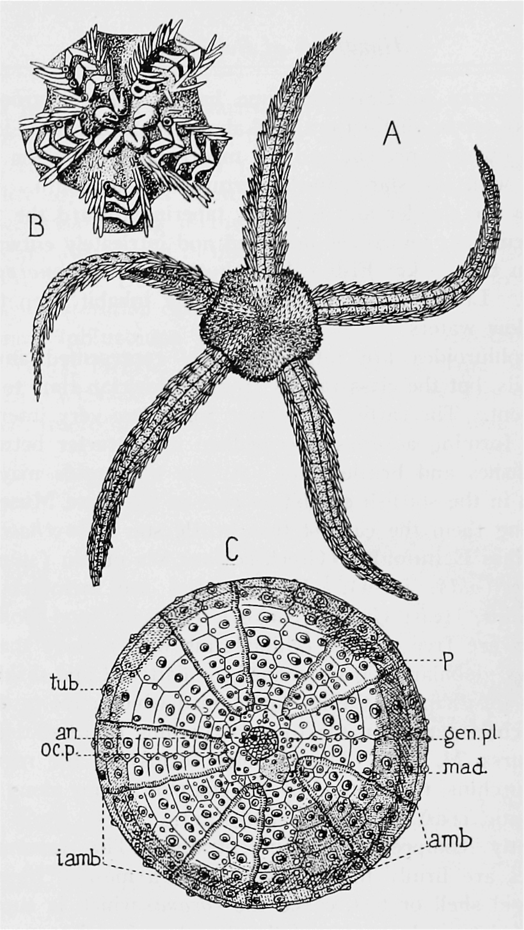


Figure 24 Brittle stars and sea urchins. *A* Lower Devonian brittle star (*Hallaster*), restoration of dorsal side, x3+. *B* Ventral surface of same, x3+ (both after Ruedemann). *C* Test or corona of recent echinoid (*Echinus*) from the dorsal or aboral surface x⅔, *amb* Ambulacral area; *an* Anus; *gen.pl.* Genital plate of apical system; *iamb* Interambulacral area; *mad* Madrepore; *oc.p.* Ocular or eye plate of apical system; *p* Pores for protrusion of tube feet; *tub* Tubercles. (From Textbook of Zoology by Parker & Haswell, published by The Macmillan Co.)

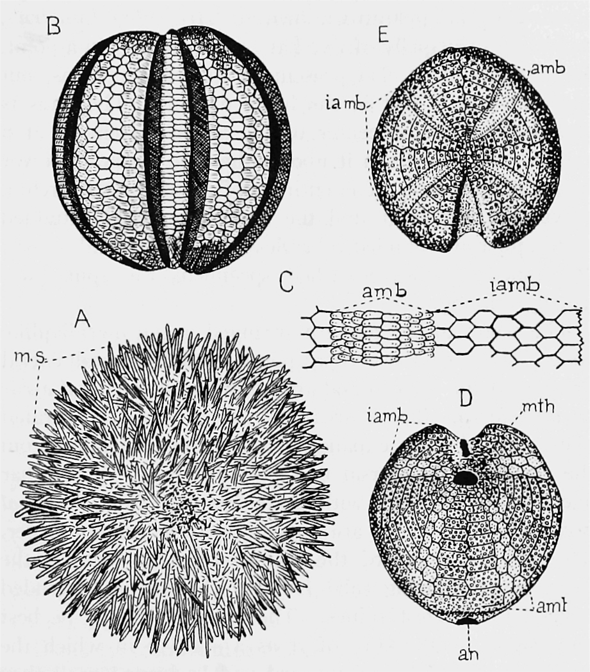


Figure 25 Sea urchins. *A* The common sea urchin of the North Atlantic, *Strongylocentrotus dröbachiensis,* top view. *B* Paleozoic (Mississippian) form, x⅞. *C* Detail of an ambulacral and interambulacral area of the same. *D* Cretaceous sea urchin, *Cardiaster,* ventral or oral view, x½. *E* The same from the aboral side, x½. *amb* Ambulacral area; *an* Anus; *iamb* Interambulacral area: *m.s.* Movable spines; *mth* Mouth. (*A—C* from Grabau: Textbook of Geology, permission D. C. Heath & Co.; *D, E* from Grabau & Shimer: Index Fossils)

or excentric in position, which contains in life a complicated dental apparatus known as *"Aristotle's Lantern"*, consisting principally of five hard teeth meeting in a point. This apparatus is also present in the cake urchins, but has been totally lost in the heart urchins. The anus is placed either at the center of the apical system or at a variable distance from it upon either the upper or lower surface of the test. The entire surface of the sea urchin, except the region around the mouth, is thickly studded with numerous rounded tubercles which bear solid, movable spines. In wave-washed specimens the spines are usually missing.

The plates of the test are arranged in ten meridianlike zones. Five of these correspond to the five ambulacral grooves of the starfish and are known as *ambulacral areas* or *ambulacra.* These areas consist of small perforated plates, are slightly expanding and extend radially from the center of the dorsal to the ventral side. The other five areas alternating with these are the *interambulacral areas* and their plates are imperforate and usually larger. Through the pores of the ambulacral areas project the long, sucker-bearing tube feet, which can be protruded beyond the longest spines. The sea urchin may be best understood by thinking of it as a starfish in which the arms have been turned upward and backward until they all meet at a point directly over the center of the disk and then are united at their edges.

Sea urchins are gregarious and in some places are so abundant that they pave the surface of rocks and bottoms of tide pools in sheltered places. Along exposed coasts some forms make cavities in calcareous or noncalcareous rocks either by absorption or with their teeth. Sea urchins are usually vegetable feeders. By means of the tube feet they slowly crawl over the rocks in search of the Algae and small organisms on which they live. When moving quickly the animal walks on its spines. Sand dollars are found on the sandy beaches northward from New Jersey and along the Pacific coast. Living echinoids have a vertical range from low water where they are sometimes uncovered to great depths (nearly 3000 fathoms).

Echinoids range in time from the Ordovician to the present and are well represented in the geological record, forming a characteristic element in many fossil faunas (figure 25). Fully 2500 fossil species are known as compared with 500 recent. They occur sparsely through the Paleozoic and those that are found are primitive in structure; but they multiply enormously in the Mesozoic. The tests are often perfectly preserved, but because of the regular arrangement of parts, even small fragments can be accurately determined. Some specimens may be seen in the Echinoderm cases in the State Museum. The collection includes the second oldest known sea urchin (*Lepidocentrus drydenensis*) from the Portage (Ithaca) beds of Dryden, N. Y. There is also shown a large slab with fossil sea urchins from the Lower Carboniferous (Mississippian) of Missouri.

Class Holothuroidea (Greek *holothourion,* zoophyte or water polyp; *eidos* (*oid*), form). The Holothuroidea comprise another group of free-swimming echinoderms. They are sausage-shaped, leathery-skinned forms popularly known as Sea Cucumbers (figure 26). Sometimes the shape is completely cylindrical, sometimes five-sided. The Greek name was originally given to an animal described by Aristotle and believed to belong to this class. The sea cucumbers differ from the other echinoderms not only in their elongated bodies, but also in having

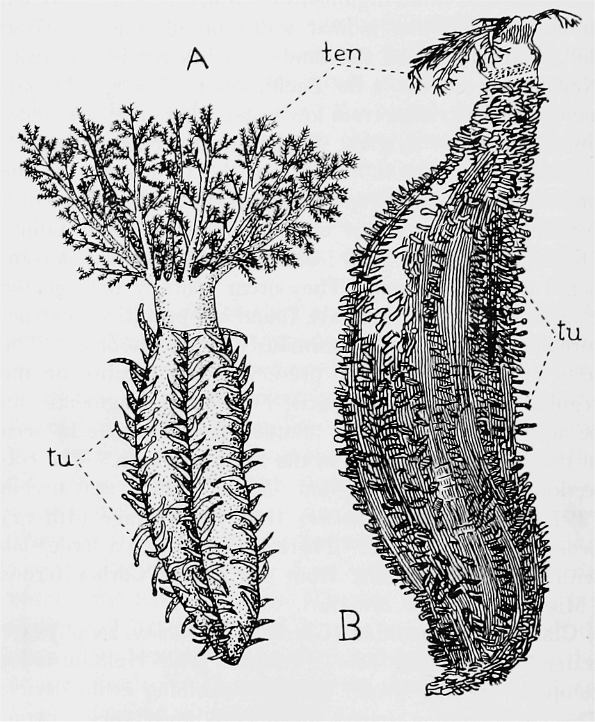


Figure 26 Living sea cucumbers. *A Cucumaria,* from ventral surface, x1. *B* Another form, *Phyllophorus,* x1. *ten* Tentacles; *tu* Tube feet. (*A* from Textbook of Zoology by Parker & Haswell; *B* from Cambridge Natural History ed. by Harmer & Shipley, published by The Macmillan Co.)

little or no skeleton. The skeleton is represented only by scattered calcareous spicules of various shapes, and in some species the skeletal particles are nearly or quite wanting. The mouth and anal opening are at opposite ends, and the former is always surrounded by a circle of branched tentacles, 8 to 30 in number. The ventral surface is parallel with the axis joining the mouth and anus, and is sometimes flattened and solelike. It bears rows of tube feet, well-developed and functional. On the dorsal surface the place of tube feet is taken by papillae lacking suckers and in some forms even those of the ventral surface may assume the form of papillae.

There are over 500 living species of holothurians, and they are distributed through all seas and range from shallow to deep water, in tide pools or in the sand or mud. Like some worms, the holothurians derive their nourishment from organic particles contained in the mud and sand which they devour and which is shoveled into the mouth through the aid of the surrounding circle of tentacles.

Holothurians are found from Cambrian to recent times. Usually the spicules from the leathery skin are all that is found fossil and these are known from the Upper Paleozoic on. Impressions or casts have been described from the lithographic limestone (Upper Jurassic) of Solenhofen, Germany. Recently in the remarkably well preserved fauna of the Middle Cambrian shales of British Columbia, the late Doctor Walcott found and described complete specimens of typical holothurians showing many details of the original animals. A specimen from this collection may be seen in the Cambrian case in the State Museum. Most of these species have been referred to a group the living representatives of which are confined to the deep sea.

Class Crinoidea (Greek *krinon,* lily; *eidos* (*oid*), form). This class includes the Sea Lilies or Feather Stars. They are stalked echinoderms with simple or many-branched arms; some (*Comatula, Antedon* etc.) become secondarily free in the adult stage. Crinoids, unlike the starfishes, have the mouth or ventral side up, while the stalk is attached to the opposite or dorsal side.

A normal crinoid (figure 27) consists of three principal parts: a globular body, the *theca* or *calyx,* from the upper surface of which are given off the *arms* (*brachia*) and from the lower surface the *stem* or *stalk* (*columna*). The calyx and arms together form the *crown.* The calyx is composed of the *dorsal cup* and the ventral disk or *tegmen.* The dorsal cup, or simply the cup, is the part of the calyx below the origins of the free arms and corresponds to the dorsal or apical system of other echinoderms; the tegmen (sometimes *disk* or *vault*) is the part above the origins of the free arms and corresponds to the ventral or oral system of other echinoderms. There is a radiate arrangement of the skeletal parts and many of the other systems, the dominant number being five. The five plates from which the *rays* (arms or arm trunks) may be traced are known as the *radials.* The plates composing the arms are known as *brachials.* The free arms may be simple or branching and often bear small lateral appendages or *pinnules.* The stem or column is composed of joints (*columnals*) of uniform or varying size and through the center of the stem passes an *axial canal* which is variously shaped. If lateral appendages are present on the stem they are known as *cirri.* When they are on the lower end they are *radicular cirri* or *roots.*

The ventral surface or tegmen bears the *mouth,* which is usually central and from which the *ambulacral grooves*

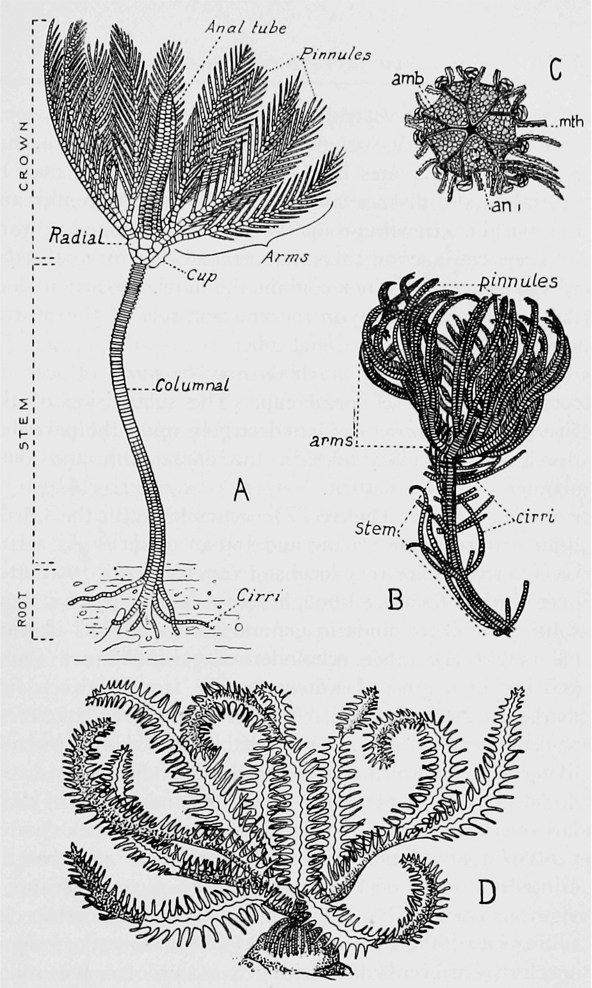


Figure 27 Crinoids. *A* Reconstruction of a simple type of crinoid from the Silurian, *Botryocrinus decadactylus.* (Bather in Lankester's Zoology; *A* & *C* Black, Ltd). *B* Recent stalked form, *Pentacrinus caputmedusae,* x2/3. *C* Oral surface or tegmen of calyx of the same, enlarged (after Springer): *amb* Ambulacral groove; *an* Anus; *mth* Mouth. *D* Free swimming form, *Antedon,* side view of entire animal, reduced. (*B* from Grabau: Textbook of Geology, permission D. C. Heath & Co.; *D* from Textbook of Zoology by Parker & Haswell, published by The Macmillan Co.)

extend over the ventral disk into the arms. In some forms the mouth, or the mouth and ambulacra, are covered by the plates of the tegmen. The *anus* may be central in the disk or anywhere between the center and the margin. In one group the disk is prolonged upward into a large sac or tube, the *ventral sac* or *anal tube,* which may or may not contain the anus. When it does the opening is usually on the anterior side of the ventral sac or at the end of the anal tube.

The arm plates or brachials may be more or less incorporated into the dorsal cup. The subdivision of the Crinoidea into orders is based largely upon the part that the lower brachials take in the dorsal cup and their manner of union with it.

Living crinoids (figure 27) occur chiefly in the Caribbean sea areas, the Pacific and Indian oceans. As a rule recent crinoids are very local and very unevenly distributed over the sea floor. Although a few forms are of a more solitary habit, crinoids in general are gregarious in their habits like the other echinoderms. Crinoids are found existing in depths of water ranging from between tide marks to 2900 fathoms. The great majority of recent stalked forms are deep-sea inhabitants. Until recently living crinoids were considered as the impoverished and decadent remains of a once numerous and powerful class. Discoveries in recent years have shown an unexpected profusion of crinoid life in the recent seas and that the crinoids, instead of being an expiring race, constitute a vigorous stock. They are represented by about 650 species falling into 100 genera. At Singapore a variety of crinoid species have been taken within a radius of a few miles, which is surpassed by but few localities of Paleozoic crinoids. Crinoids feed upon such things as diatoms, protozoans and microscopic crustaceans, which are carried down the ambulacral or food grooves of the arms to the mouth.

Fossil crinoids (figure 28) apparently were also gregarious in their habits. Paleozoic forms, in contrast to the recent, often characterize shallow water deposits and are especially numerous in the vicinity of fossil coral reefs. Crinoidal remains, consisting of stem joints only, have been detected in the Cambrian. Sometimes stems, detached joints of stems, roots and arms of crinoids are so abundant as to form crinoidal limestone beds of considerable thickness from the Ordovician to the Jurassic, being particularly characteristic in the Carboniferous and the Muschelkalk (Triassic of Germany). In North America the Ordovician (Trenton and later limestones) is locally very rich in crinoid remains; the Silurian, notably the Niagaran group (see Niagaran case in State Museum) also contains a large variety of forms. The best known American Devonian localities are in New York and Michigan and the region around the falls of the Ohio river. The New York State Museum has on exhibition in several special cases and in the synoptic cases, a remarkably fine collection of Devonian crinoids, including a large slab and individual specimens from one of the largest and finest colonies of Devonian crinoids ever found (Vincent, N. Y.). Wax restorations of some Devonian forms may be seen in the Portage and Lower Helderberg restoration cases. The most famous of all crinoid horizons is the Lower Carboniferous (Mississippian) limestone of North America, where the localities of Burlington, Iowa, and Crawfordsville, Ind., have acquired worldwide celebrity. Some specimens from these localities may be seen in the State Museum crinoid cases and

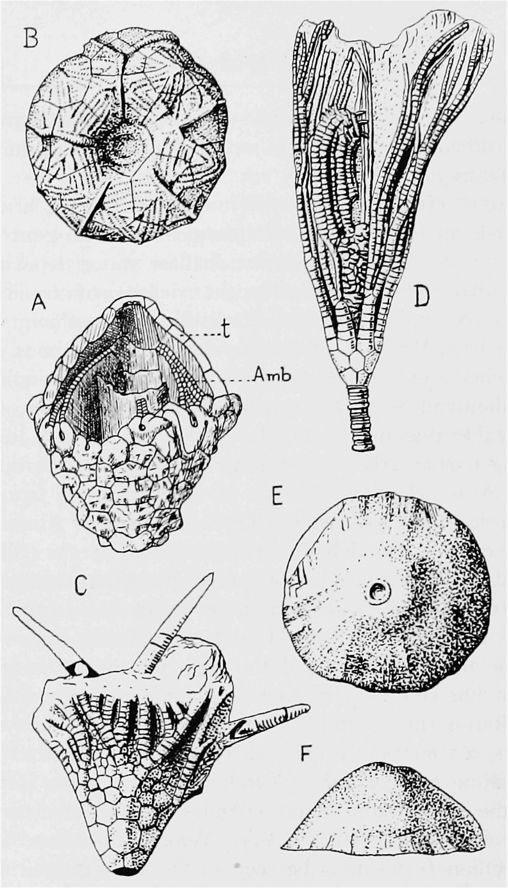


Figure 28 Fossil crinoids. *A* Lower Carboniferous form, *Cactocrinus* with the plates of the tegmen (*t*) partially removed to show the covered ambulacral passages (*amb*) leading from the arms to the mouth (after Meek & Worthen). *B* Basal view of the dorsal cup of a Middle Devonian form, *Dolatocrinus*, showing ornamentation of the plates. *C* The Middle Devonian *Thylacocrinus*, showing the spines ornamenting the tegmen. *D* Lower Devonian *Lasiocrinus*, showing the anal tube. *E*, *F* Top and lateral views of *Aspidocrinus*, the base or *scutella* to which the stem of some crinoid is attached. A Lower Devonian form very abundant in the Becraft ("Scutella") limestone. (*B*—*F* all New York forms after Goldring)

in two wall slabs showing crinoid colonies from Crawfordsville. One of the later free-swimming forms (*Uintacrinus*) is shown on a large and remarkable wall slab from the Cretaceous of Kansas. On the wall near this is a painted restoration of the animal as it looked in life. For a longer discussion of crinoid localities, particularly those abroad, the reader is referred to the literature.

Fossil crinoids are usually found in a fragmentary condition because of the looseness with which the plates and segments are bound together and the delicacy of some of the skeletal parts. Stems, detached joints of stems, roots and bases are found most frequently. Whole beds, such as the Becraft limestone in New York, are made up of these remains. The Becraft limestone because of the frequency of the shieldlike crinoid bases (*Aspidocrinus scutelliformis*) or Scutellas (Latin *scutella*, a little shield) is known as the Scutella limestone. Calyces or dorsal cups are found much more frequently than perfect crowns, which indeed are of rather rare occurrence.

Of all the Echinodermata, the crinoids, blastoids and cystoids are most intimately related. The crinoids are derived from the cystoids by way of the blastoids, according to some authors.

Class Blastoidea (Greek *blastos*, bud; *eidos* (*oid*), form). The blastoids have a clavate, ovate, globose, pyriform or budlike body (calyx), no arms and are short-stalked or stemless. They differ from crinoids, in general appearance, in the total absence of arms which exist only as pinnules. The name is derived from the bud-shaped calyx of many of the species (figure 29).

The calyx is composed of plates arranged in three successive cycles or rings. The *mouth* is in the center of the upper surface, is five-angled and is surrounded by

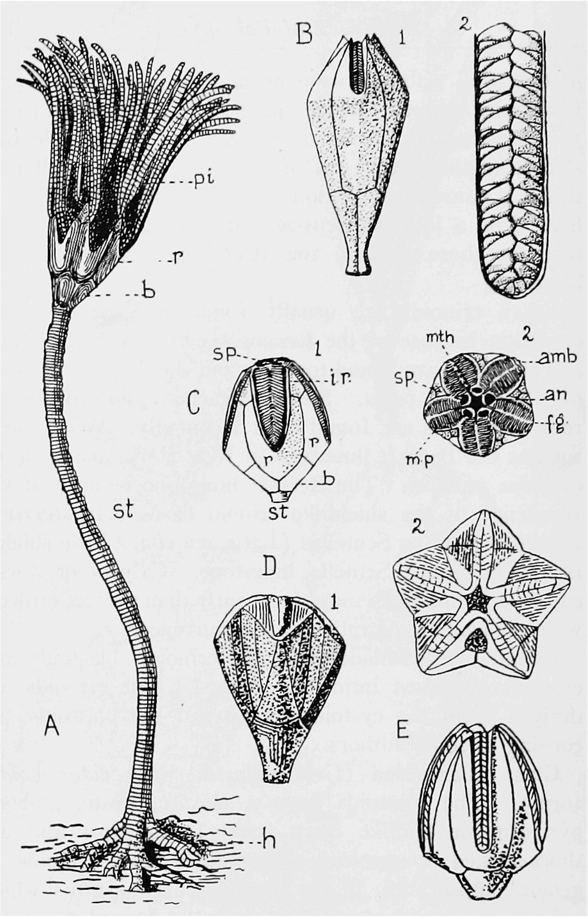


Figure 29 Blastoids. *A* Reconstruction of a Lower Carboniferous blastoid, *Orophocrinus*, x1: *b* Basal; *h* Root or holdfast; *pi* Pinnules; *r* Radial; *st* Stem (after Bather in Lankester's Zoology; *A* & *C* Black, Ltd). *B* Silurian form, *Troostocrinus*, x2, with the ambulacrum (2) much enlarged. *C* Lower Carboniferous *Pentremites*, x1: Side view; 2 Top view; *an* Anus; *b* Basal; *f.g.* Food groove; *i.r.* Interradial plate; *m.p.* Marginal pores; *mth* Mouth; *r* Radial plate; *sp* Spiracle. *D* Devonian *Codaster:* 1 Lateral view, x2; 2 Summit, x2 2/3. *E* Middle Devonian, *Pentremitidea*, side view, x2. (*B, D, E* from Grabau & Shimer: Index Fossils; *C* from Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

five single or five pairs of circular or slitlike openings, the *spiracles*. An additional opening, the *anus*, is sometimes present between two of the spiracles but in some types the anal opening is shared by one of the spiracles, then enlarged. From the angles of the mouth radiate the five *ambulacral areas*, which vary in shape from petaloid (wide in the middle and tapering toward each end) to narrow lanceolate. Each ambulacrum consists of a median groove running its entire length, from which branch off smaller side grooves, at the upper end of each of which is a small *marginal pore*. These pores open upon the inside of the calyx into a much-folded canal which connects with the spiracles and is respiratory in function. Around the marginal pores are long, jointed pinnules which function in straining out particles of food, probably similar to that of crinoids. When the pinnules are not preserved their former presence is indicated by minute pits and knobs. When, as rarely happens, the pinnules are completely preserved, they entirely conceal the ambulacral surface. The stem is rarely preserved, but is similar in structure to that of the crinoids. It is round, provided with a small central canal and composed of short joints.

The Blastoidea are an entirely extinct class being confined to Paleozoic times, ranging from Ordovician to Permian. The earlier forms occurring in the Ordovician are primitive. They represent transitions from cystoid-like ancestors and have the characters of the two groups mingled in varying degrees. Several genera are represented in the Silurian and Devonian both of Europe and America. Some of the forms more commonly met with in western New York State are the elongate to club-shaped *Pentremitidea* from the Hamilton (Devonian);

the olive-shaped *Elaeocrinus* (*Nucleocrinus*) from the Onondaga and Hamilton (Devonian) and the inverted, conical or ovoid *Codaster* from the Niagaran (Silurian) and the Onondaga and Hamilton (Devonian). Some New York State blastoids are exhibited in the State Museum in one of the echinoderm cases with the starfishes. One of the *Pentremitidea* has the pinnules present. The development of the blastoids reached its climax in the Lower Carboniferous (Mississippian) of North America in some of the beds of which the forms are numerous and as a rule excellently preserved. The pear-shaped *Pentremites* is a familiar form represented by many species from the Mississippian of the states of the Mississippi basin.

Class Cystoidea (Greek *kystis,* bladder; *eidos* (*oid*) form). The cystoïds, or cystids, derive their name from the globular shape of most of the species. They constitute the oldest division of the stalked echinoderms, are the least specialized group and probably most nearly represent the ancestral type of the three classes. It is possible that the ancestor of all the echinoderms is to be found in the most primitive division of the cystoids (figure 30).

Cystoids are mostly stalked forms with a calyx like the crinoids. The *calyx,* while often globular, varies in form and is composed of polygonal plates varying in number from 13 to several hundred and usually irregularly arranged. The *mouth* is a central or nearly central aperture on the upper or ventral surface but it is sometimes covered by small plates. From it radiate two or more simple or branching *ambulacral grooves* or ambulacra which may be roofed over with plates, and are sometimes extended into free branches or arms. *Arms,*

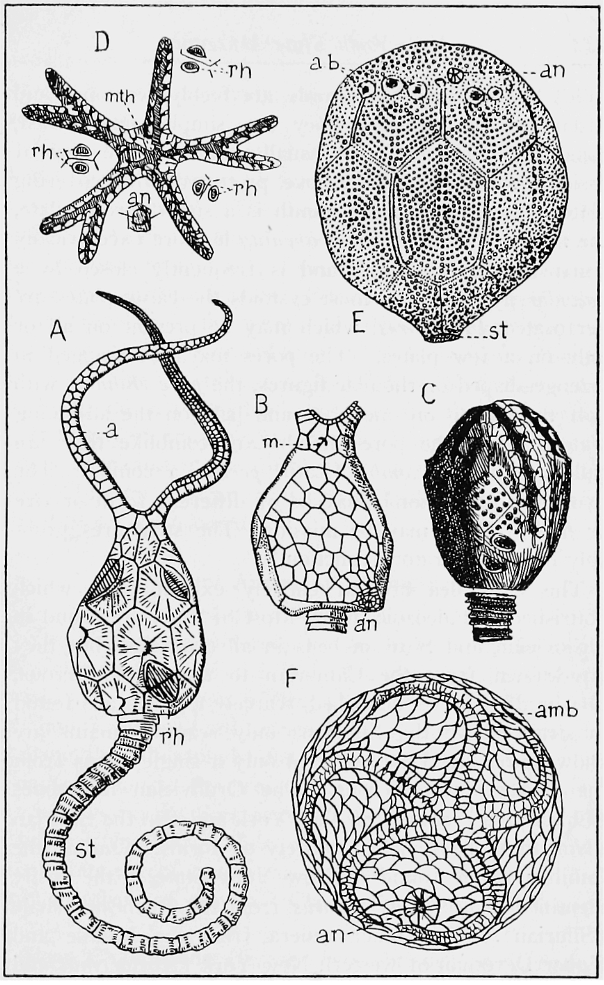


Figure 30 Cystoids. *A* Reconstruction of an Ordovician cystoid, *Pleurocystites*, x1. *B* The same from the anal side. *C* Silurian *Callocystites*, side view, x1. *D* Enlargement of ambulacral grooves and pectinated rhombs of the same. *E* Silurian *Caryocrinus*, side view, x1. *F*. Ordovician *Agelacrinus*, top view, x2. *a* Arms; *a.b.* Arm bases; *amb* Ambulacral area; *an* Anus; *m* Hydropore or waterpore; *mth* Mouth; *rh* Pectinated rhombs; *st* Stem. (*A* after Bather in Lankester's Zoology, *A* & *C* Black, Ltd; *C—E* after Hall; *F* after Meek)

called "fingers" in the cystoids, are feebly developed and often entirely absent. They are simple, unbranched, consisting of a single or, usually, of a double row of ossicles with a ventral groove protected with covering plates. Just beneath the mouth is a small porous plate, the *madreporite.* The *anal opening* is more excentrically situated than the mouth and is frequently closed by a *valvular pyramid.* In most cystoids the calyx plates are perforated with *pores,* which may be present on all or only on a few plates. The pores may be arranged in lozenge-shaped or rhombic figures, the *pore rhombs,* with half the rhomb on one plate and half on the adjoining plate. When the pore rhombs are comblike they are called *pectinate rhombs* (Latin *pecten,* a comb). The two parts of a rhomb may be of different form or size or one of them may be missing. The structures probably had a respiratory function.

The Cystoidea are an entirely extinct class which flourished in Paleozoic time. Most of them are found in Ordovician and Silurian beds in all countries; but they are known from the Cambrian to the Carboniferous. Of the 250 species described, scarcely a dozen are found in strata above the Silurian: only scanty remains are known from the Devonian and only a single genus from the Lower Carboniferous. The Ordovician limestones (Chazy and Trenton) of New York and also the Silurian (Niagaran) beds yield a variety of forms. One of the familiar forms found in New York State is the easily identified *Caryocrinus ornatus* from the Rochester shale (Silurian). Two other genera from the Middle and Upper Devonian of western New York (*Agelacrinus* and *Lepidodiscus*), while attached by the lower (dorsal) side of the flat, circular body, have a superficial resemblance to a starfish.

Cystoids are represented in the Cambrian by a number of poorly preserved forms whose affinities in some cases are doubtful. The most primitive of the cystoids, differing from the main division in the absence of arms and respiratory organs, are placed by some in one, sometimes two distinct classes (Edrioasteroidea, Carpoidea). It is probably in the primitive Edrioasteroidea that the ancestor of the Echinoderms is to be sought. Some representatives of this group from New York State are to be found in the synoptic cases in the State Museum, particularly in the Chazy, Trenton, Niagaran and Coeymans cases and in one of the special echinoderm cases. The Museum has no considerable collection of either the cystoids or blastoids.

Phylum Annulata (Annelida)

(Latin *annulus*, ring)

The phylum Annulata derives its name from the ring-like constrictions of the body of the organisms comprising it. It is one of the phyla into which the old phylum Vermes (Latin *vermis*, worm) has been divided. Among the other phyla, flat worms are found from the Pennsylvanian to the present and a specimen resembling a round worm has been found in the Middle Cambrian of British Columbia. Other worms are unknown in the fossil state except among the Annulata and in this phylum only members of the class Chaetopoda have been found fossil.

Class Chaetopoda (Greek *chaite*, bristle; *pous* (*pod*), foot). This class derives its name from the fact that the forms comprising the group have few or many bristles (setae) attached to the sides of the body. It includes earthworms and their allies and the marine annelids (figures 31, 32).

Worms resembling our earthworms have been described from the Ordovician of America and the Silurian of England and America. They are seen as ancestral representatives of our earthworms. In New York State specimens have been found in the Lockport limestone (Silurian) near Gasport and a form of doubtful affinities in the Bertie waterlime (Silurian) near Buffalo, N. Y. (figure 32).

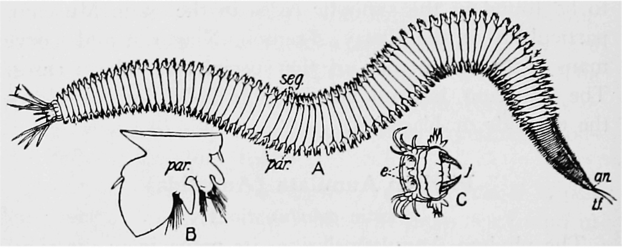


Figure 31 Worms. *A* The common carnivorous marine worm *Nereis* from Massachusetts Bay, x⅗. *B* One of the flapperlike gill feet (parapodium) used in crawling or swimming, much enlarged. *C* Head showing toothed jaws, x⅗. *an* Anus; *e* Eyes; *j* Jaws; *par* Parapodia or gill feet; *seg* Body segments; *t* Tentacles; *t.f.* Terminal feelers. (From Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

The marine annelids include the free-swimming forms, and the tube builders. As the amateur will rarely come upon these fossils it does not seem necessary to treat them in detail. Beautifully preserved specimens of marine annelids have been described by the late Doctor Walcott from the Middle Cambrian shales of British Columbia. The predatory free-swimming forms, as ex-

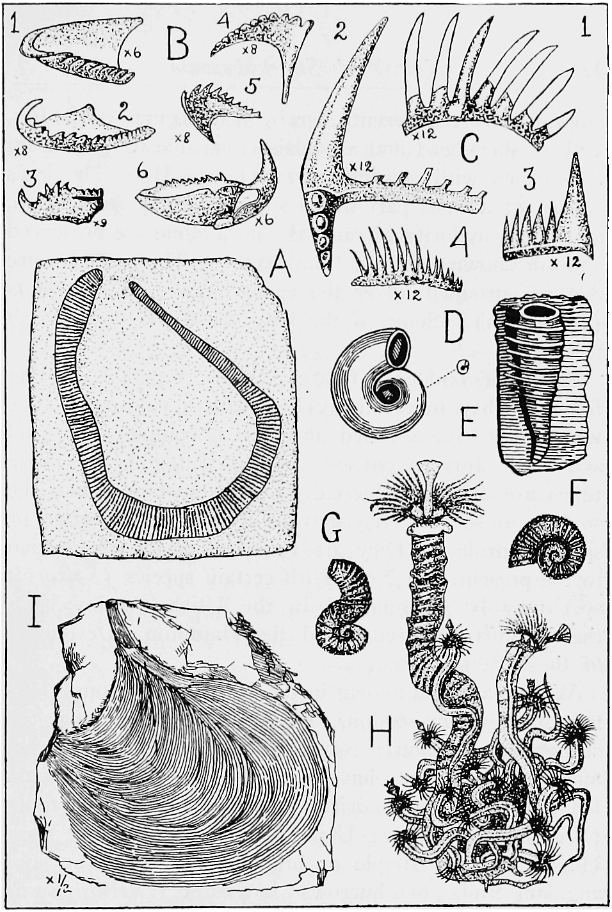


Figure 32 Worms. *A* Silurian earthworm (after Ruedemann), x7/8. *B* Annelid jaws: 3—6 Ordovician; 1, 2 Silurian. *C* Conodonts, 1—4 Devonian. *D* Devonian tube worm, *Spirorbis* sp., natural size and enlarged. *E* Devonian tube worm, *Ortonia* sp., greatly enlarged. *F, G* Silurian tube worm, *Spirorbis* sp., greatly enlarged; *F* Loosely coiled form; *G* Closely coiled form (after Paleontology of N. Y.). *H* Living tube worms, *Serpula*. *I* Worm burrow, *Taonurus velum* (after Vanuxem). *B—E* from Grabau & Shimer: Index Fossils; *H* from Textbook of Zoology by Parker & Haswell, published by The Macmillan Co.)

emplified by the recent *Nereis,* had segmented bodies, with distinct head and a proboscis capable of protrusion and armed with powerful jaws (figure 31). The jaws consist of a basal part which supports many small teeth, and in the majority of cases the jaws alone are preserved and are known from the Cambrian on. The teeth (figure 32) are grouped under the general name of *conodonts* (cone-tooth). Some of the latter however may be fish teeth.

The tube builders (figure 32) are vegetable-feeding forms. They invest themselves with a calcareous tube which they have secreted or which is composed of sand and other foreign particles cemented together. These tubes are free or adherent to some surface, often the surface of shells. They may be irregularly contorted or spirally inrolled. They are found from the Ordovician to the present. In New York certain species (*Spirorbis* sp.) may be encountered in the Utica (Ordovician), the Manlius (Silurian) and the Hamilton (Devonian) of the western area.

Worms are also known in the fossil state through burrows, trails, impressions, etc. The burrows may be straight or tortuous; sometimes they are hollow, but more commonly they have been filled in by solid matrix. Here belong the cylindrical or subcylindrical free tubes (*Scolithus*) from the Upper Cambrian of New York (figure 4); the simple or branching, rounded or subangular trails or burrows in relief (*Arthrophycus alleghaniensis*), so numerous in the New York Medina beds (Silurian) that they serve as index fossils; and the nearly horizontal, U-shaped, suboval or lobate, thin plates of ridged sandstone (figure 32) found in the Devonian rocks of New York (*Taonurus caudagalli* from the Oriskany sandstone and particularly the Esopus shale, the so-called Caudagalli grit; *Taonurus velum* from the Hamilton and Ithaca beds).

Phylum Molluscoidea

(Latin *molluscum*, mollusk; Greek *eidos* (*oid*), form)

The phylum Molluscoidea includes two classes, the Bryozoans or Sea Mosses and the Brachiopods or Lamp Shells. The Molluscoidea are aquatic; the Bryozoans, largely, and the Brachiopods, exclusively, marine animals. The typical Molluscoidea secrete a calcareous shell or else have a membranous or corneous covering. The bivalve shell of the Brachiopods gives them a resemblance to the true mollusks, and it is from this resemblance that the name of the phylum has been derived.

Class Bryozoa (Greek *bryon*, moss: *zoon*, animal). The Bryozoa or Polyzoa (Greek *poly*(*s*), many) are marine or fresh-water animals (usually marine), almost always occurring in colonies (figures 33, 34). They are small animals and arise from free-swimming larvae which become attached to foreign objects and give rise to the primary individuals which by repeated budding develop colonies of various shapes and sometimes considerable size. Each individual of the colony is known as a *zooid* and is inclosed in a membranous or calcareous double-walled sac or cup, the *zooecium*, into which it can withdraw for protection. The animal has a freely suspended, U-shaped alimentary canal so that the mouth and anus open and close together. Surrounding the mouth or the mouth and arms is a circular ridge, the *lophophore* (Greek *lophos*, a crest; *phoreo*, to carry), bearing a crown of hollow, slender tentacles which serve for respiration and for sweeping food toward the mouth. The food consists

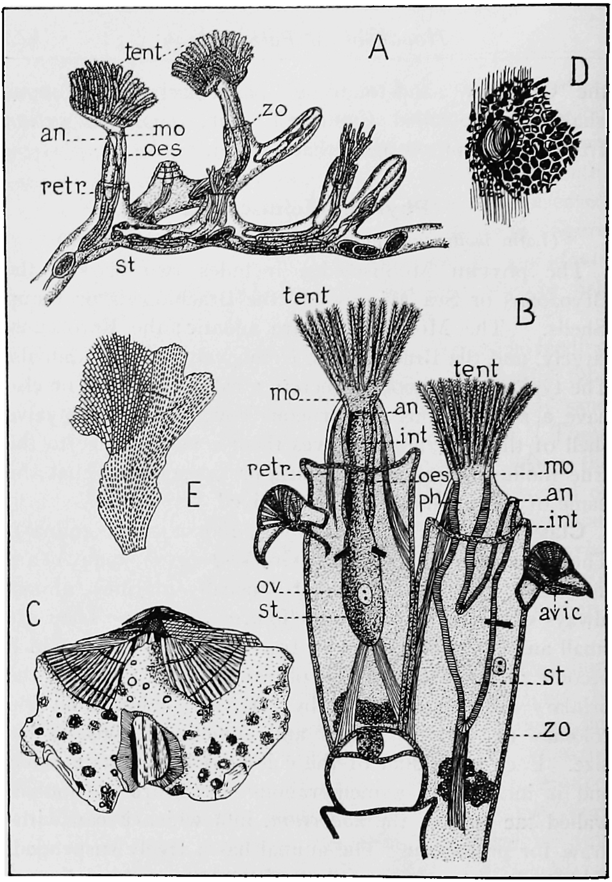


Figure 33. Bryozoans. *A Plumatella.* Portion of colony magnified. *B Bugula avicularia,* two zooids magnified. *an* Anus; *avic* Avicularium; *int* Intestine; *mo* Mouth; *oes* Oesophagus; *ov* Ovary; *ph* Pharynx; *retr* Retractor muscle; *st* Stomach; *tent* Tentacles; *zo* Zooecium. *C* Devonian bryozoan (*Monotrypa*) growing on a brachiopod shell to which are attached coral tubes, x⅔. *D* Enlargement, (x5) of surface surrounding mouth of coral tube. *E* Fan-shaped Silurian form (*Fenestella*), x⅔. (*A, B* from Textbook of Zoology by Parker and Haswell, published by The Macmillan Co.; *C—E* from Grabau & Shimer: Index Fossils)

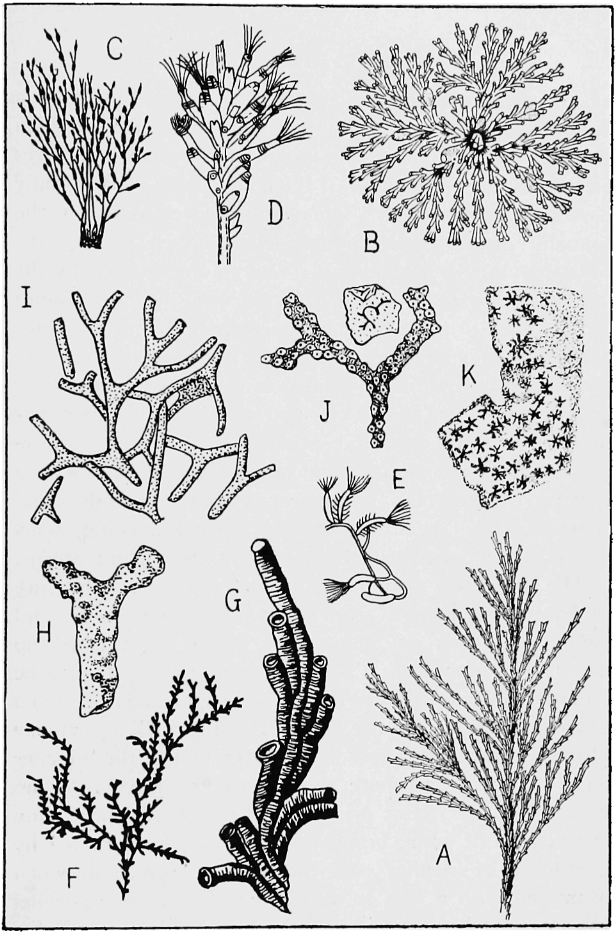


Figure 34 Bryozoans. *A—E* Living forms: *A Bugula,* extremity of branch, enlarged; *B Crisia,* cluster of branches enlarged; *C Bowerbankia,* colony, x⅔; *D* Portion of same, x10; *E Avenella,* x10, showing tubular stolons and erect zooecia. *F—K* Fossil forms: *F* Devonian (*Hederella*) x1; *G* The same, x12; *H* Silurian (*Trematopora*); *I* Lower Devonian (*Monotrypella*); *J* Ordovician (*Proboscina*), x½ and 4½; *K* Ordovician (*Constellaria*). (*A, B* after Verrill & Smith; *C—E* after Bassler; *F—K* from Grabau & Shimer)

of microscopic organisms, such as diatoms. There is a highly organized nervous system consisting of a ganglion or nerve center between the mouth and arms, which gives off nerves to various parts of the body. Each zooid usually possesses both sexes. The colony develops from the sexually produced individual, which gives rise to the colony asexually by budding. The colony formed by the individual zooids is known as a *zoarium*. These colonies are attached to some foreign object either by the greater part of their surface or basally, or they are attached to the bottom by rootlike appendages. Bryozoans frequently grow over shells, stones etc. and form delicate incrustations of exquisite patterns. Sometimes by repeated superposition of one incrustation upon another masses are formed of irregular nature, or globular, nodular and hemispherical. Again the colonies form branching stems or fronds, or open-meshed lace work of beautiful patterns.

The bryozoans are abundant in recent seas. They are probably best known from the mosslike structures and paperlike fronds or "sea mats" which are washed up along our seacoasts. The common forms along the Atlantic coast are species of *Bugula* (figure 33). *Bugula avicularia*, known as the Bird's Head Coralline, may be found in brown or purple bushy tufts, two or three inches long, along the seashore in all parts of the world, on rocks, piles of jetties or similar situations. The colony is made up of erect, branching, narrow stems, rooted by a number of slender root filaments. Each stem when examined with a lens is seen to consist of four parallel rows of closely arranged zooecia or individual cups. On each *zooecium* except on a few near the extremities of the branches is a remarkable appendage with the appearance of a bird's head supported on a short stalk. This organ is known as the *avicularium*. The jaws open and close with a snapping motion which has led to the belief that they are organs of defense. Their function is rather problematical. They are incapable of preservation in the fossil state, but their presence is indicated by the porelike excavations in which they were lodged.

Bryozoans are abundant in sedimentary rocks and are known from the Lower Ordovician to the present (figures 33, 34). The horny or calcareous skeleton which persists after the death of the animal is all that is capable of preservation in the fossil state. Bryozoans are practically wanting in sandstones, but there is scarcely a limestone bed in which they are not abundant, especially where there are shale alternations. The best specimens are usually obtained from the shale between limestone layers or the shale beds just above or just below. Most of the post-Paleozoic species occur in soft limestone or marls and are easily collected. The Paleozoic species usually belong to the so-called stony Bryozoa, and fragments are large enough to be visible. On weathered outcrops they occur as twiglike fragments or lacelike fronds. The Mesozoic and Cenozoic forms are usually so inconspicuous as to escape the notice of the average collector, yet they occur in the rocks literally by the millions, frequently in unconsolidated sediments.

In New York State Bryozoa may be looked for in limestones, such as the Niagaran (Silurian) and Onondaga (Devonian) limestones; but they are more particularly found in the shaly limestones and shales, such as the New Scotland shaly limestone and Hamilton shales in the Devonian, the Rochester shales in the Silurian and the Trenton shaly limestone in the Ordovician. Some of the forms are readily recognized.

Class Brachiopoda (Greek *brachion,* arm; *pous* (*pod*), foot). This class and the preceding are separated as phyla by some authors instead of being regarded as classes of the same phylum.

The brachiopods or Lamp Shells (figures 35, 36) are entirely marine and secrete a bivalved shell of lime carbonate (calcareous), lime phosphate or a horny substance, which resembles the shell of the lamellibranchs or pelecypods, to a certain degree. The shell may be entirely calcareous or alternately calcareous and horny. When the shell is entirely calcareous there are never more than three laminae or layers; an inner thick prismatic layer, a middle laminar layer, and an outer epidermal film. The shell sometimes consists of alternating layers of phosphate of lime admixed with lime carbonate and a lustrous, horny substance (*ceratin*). While the valves of mollusk shells are equal and lateral, the valves of brachiopod shells are unequal, and dorsal and ventral in position. Each valve is equilateral.

The majority of the brachiopods are attached in the adult stage as well as in youth by a fleshy stalk, known as the *pedicle,* which is the posterior prolongation of the animal body. Distribution therefore takes place in the free-floating larval stage. In some forms the pedicle is lost when adult, but in such cases the individuals are cemented to other objects or held together by spines or by other devices to foreign objects, or by social crowding (figure 35). The *ventral valve* is also known as the *pedicle valve* because through this valve the pedicle or peduncle is attached. It is larger than the *dorsal valve,* which is also known as the *brachial valve* because it bears the support for the armlike branches (*brachia*) of the lophophore or respiratory apparatus. The opening at the posterior end of the pedicle valve through which the pedicle passes is known as the *delthyrium* (Greek *delta,* Δ, delta-shaped; *thyra,* door) or in more restricted form, the *foramen* (Latin = opening), where the delthyrium is closed by a small double plate, the ***deltidium.*** The ventral or pedicle valve may be produced anteriorly into a ***beak.*** The rounded elevated portion of the valve which ends in the beak is known as the *umbo.* The line along which the two valves meet is known as the *hinge line.* In one subclass there are *teeth* on the posterior portion of the pedicle valve which fit into *sockets* on the brachial valve. The dorsal or brachial valve has no beak, but the posterior edge or hinge line has a short prolongation, the *cardinal process,* which fits between the teeth of the pedicle valve. At the posterior portion of each valve between the beak and the hinge line there is usually a flattened area, called the *cardinal area,* which extends to the *cardinal angles.* This area is higher in the pedicle valve. The *length* or *height* of the shell is the distance from the hinge line through the middle of the shell to the opposite or anterior edge or front. The *width* is the direction at right angles to this on a line extending from side to side of the shell. The thickness is in the direction at right angles to the plane of length and width through the center of the valves.

The interior of the shell is lined with a *mantle,* a membranous reduplication of the body wall, through which respiration is mainly effected. The pedicle valve is secreted by the ventral, and the brachial valve by the dorsal lobe of the mantle, and therefore any marked injury to the mantle is noticeable in the shell. Strong muscles open and close the valves of the shell, and the scars of these muscles may be seen on the inside of the valves. The

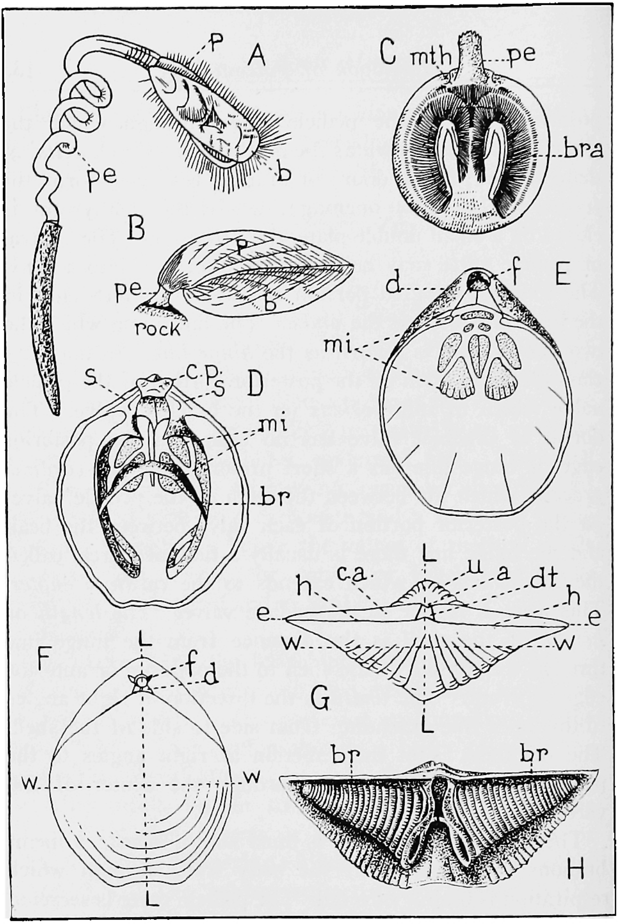


Figure 35 Brachiopods. *A—F* Living forms: *A Lingula* with pedicle; *B Terebratulina* from Maine coast, side view attached; *C* The same, soft body in brachial or dorsal valve; *D Magellania,* dorsal valve; *E* The same, ventral valve. *F, G.* Diagrams of brachiopods shells, showing parts. *H Spirifer* (Devonian) with spiral arms or brachidia (Paleontology of N. Y.) All x⅞. *a* Apex or beak; *b* Brachial or dorsal valve; *br* Brachidium; *bra* Lophophore; *ca* Cardinal area; *d* Deltidium; *c.p.* Cardinal process; *dt.* Delthyrium; *e* Cardinal extremities; *f* Foramen; *h* Hinge line; *m.i.* Muscle impressions; *mth* Mouth; *p* Pedicle or ventral valve; *pe* Pedicle; *s* Tooth socket; *u* Umbo; *L—L* Length or height; *W—W* Width. (*A, D, E* from Textbook of Zoology by Parker and Haswell; *B, C* from Introduction to Study of Fossils by H. W. Shimer, published by The Macmillan Co. *F* after Schuchert: Textbook of Geology, permission John Wiley & Sons; *G* from Grabau & Shimer: Index Fossils)

ventral valve which is firmly attached to the pedicle may be regarded as stationary. The body of the animal lies in the posterior portion of the shell and occupies only about one-third of the interior. Most of the interior is occupied by the respiratory apparatus, the tentacle-bearing *lophophore,* which is supported by a two-limbed, calcareous structure, the *brachidium.* The brachidium is variable consisting in its simplest form of two short or only moderately long, curved processes, in its more complex form of two thin, spirally coiled ribbons. The brachidium supports the *brachia* (Latin *brachium,* arm), fleshy processes of the lophophore which diverge armlike from the two sides of the mouth and bear tentacles. The tentacles help sweep food particles into the mouth. The food consists of diatoms, infusorians and microscopic organic fragments. There is a well developed digestive system; a blood vascular system which boasts a small, globular sac which may be considered a heart; and a nervous system consisting of a ring around the gullet with two ganglia or nerve centers from which nerves are given off.

Brachiopods are usually gregarious in habit and often grow in clusters attached to one another. This is true of Paleozoic forms as well as recent. While brachiopods are found in all seas and down to depths of 17,000 feet, they are largely shallow-water animals and are most abundant in warmer seas. Seventy-one per cent of living species are found between the strand line and 100 fathoms and 29 species are found in the warm waters of the Japanese province. Usually the forms occurring in colder waters do not occur in the warmer waters. Shallow water and littoral forms are much more abundant in numbers and have thicker and usually larger shells. Brachiopods,

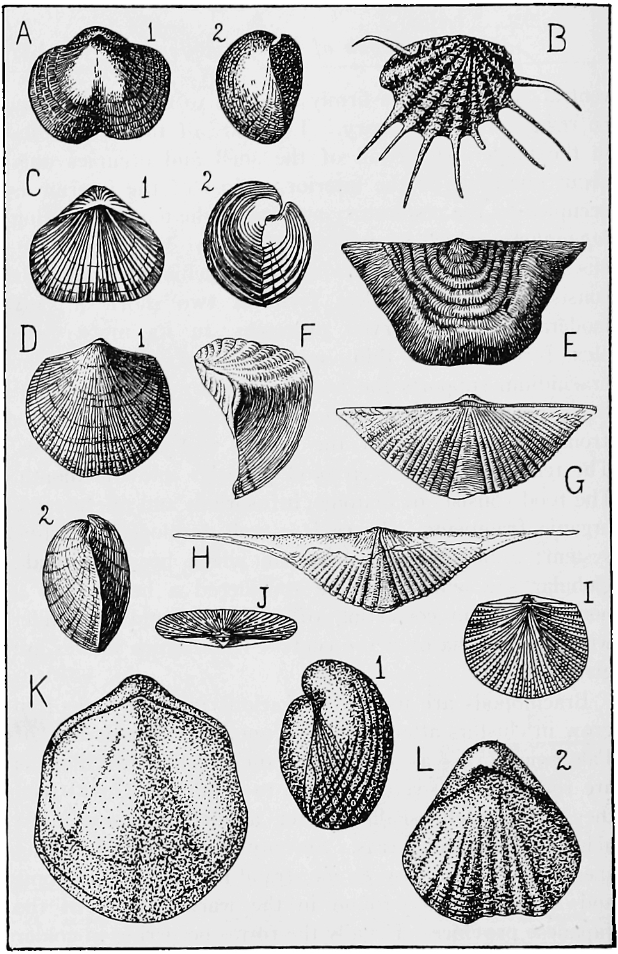


Figure 36 Fossil brachiopods. *A,* 1 and 2 Devonian, *Schizophoria,* (after Ind. Geol. Surv.). *B* Devonian, *Atrypa hystrix* (after Hall & Clarke). *C,* 1 and 2, Devonian, *Anastrophia* (after Can. Geol. Surv.). *D,* 1 and 2 Silurian and Devonian, *Atrypa reticularis.* *E, F* Ordovician—Lower Carbonic, *Leptaena rhomboidalis.* *G, H* Devonian, *Spirifer.* *I, J* Silurian *Schuchertella* (after Grabau & Shimer). *K* Silurian, *Pentamerus.* *L,* 1 and 2, Devonian *Gypidula.* All x¾. (*D, E—H, K, L* from Paleontology of N. Y.)

therefore, are important in the study of the geography of past ages. There are about 160 species and 33 genera of living brachiopods. Sixty per cent of the genera, but only 16 per cent of the species, have fossil representatives. There is a living species of brachiopod (*Terebratulina septentrionalis*) which is found from Massachusetts to Nova Scotia and is abundant off the Maine coast from low tide to a depth of 300 feet. The shells of most living species are of light or neutral color—white or horn color. Some have color in radiating bands or in solid tints: deep orange-red, light yellows, deep and light shades of green, black in bands or masses. Some traces of color are found even among fossil species.

Brachiopods appeared in the Lower Cambrian, reached their maximum development in the Silurian and Devonian and continued to the present (figure 36). The class is tending slowly toward extinction. There are more than 6000 fossil species so far described in contrast to the 160 living species. Some of the fossil species formed large shell banks as the oysters do today. This is well illustrated by the large brachiopod, *Pentamerus oblongus*, so characteristic of the Clinton beds (Silurian) of New York. The wide distribution and vast abundance of the brachiopods through the whole series of geological formations give them especial importance in the study of the past history of the earth. Because of the large number of species and great abundance of the brachiopods, the beginner will meet them frequently in his fossil collecting. For this reason and the fact that many of them characterize definite stratigraphical horizons and are important as index fossils the brachiopods have been treated in detail here. The beginner can soon become familiar with the more common and striking forms of the New York formations, particularly the Devonian. Some of these forms are of very large size, measuring several inches in breadth. This is a contrast to living forms, few of which reach a large size.

Phylum Mollusca

(Latin *mollis,* soft)

The phylum Mollusca is here treated under seven classes: Amphineura, Pelecypoda, Gastropoda, Scaphopoda, Conularida, Pteropoda and Cephalopoda. The names in most cases have reference to the form assumed by the foot. Only three classes—Pelecypoda, Gastropoda and Cephalopoda—will be of importance to the beginner, because of the large numbers in which they are found in the fossil state; and they will be treated first and in greater detail. These classes are familiar through their recent representatives, which are numerous in the first two groups.

The Mollusca include marine, fresh-water and land animals. Most of them have an exoskeleton or shell of some kind secreted by the mantle. They are all free-moving and swim, crawl or burrow. The body consists of head (except in the Pelecypoda), foot and a dorsal portion which includes the viscera and is covered by the mantle. The various systems have a higher organization than in the preceding group. The liver is an important digestive gland, which pours its secretion into the stomach. There is a well-developed excretory system. The circulatory system is composed largely of closed tubes and a heart consisting of one ventricle and usually two (sometimes four) auricles. The blood serves both a nutritive and respiratory function. The nervous system consists essentially of a nerve ring around the oesophagus, from which are given off a pair of nerves to the dorsal region and another pair to the ventral region. Respiration is carried on by gills, specialized expansions of the ventral surface of the mantle through which nearly all the blood passes before entering the auricles on its way back from circulating through the body. The sexes are usually separate, and most of the mollusks (except Cephalopods) have a free-swimming larval stage.

Class Pelecypoda (Greek *pelekys*, ax; *pous* (*pod*), foot) or Lamellibranchiata (Latin *lamella*, plate; Greek *branchia*, gills). This class, which includes Mussels, Cockles, Oysters, Clams, etc., is also referred to as the bivalved Mollusca or the Acephala division of the Mollusca (Greek *a*, without; *kephale*, head) from the fact that they are headless. The pelecypods are compressed, usually symmetrical, marine or fresh-water mollusks which have a calcareous shell of two valves, that are usually equal, and a ventral, often hatchet-shaped, foot capable of burrowing (figures 37–39).

The pelecypods may be distinguished from the brachiopods by the equal but unequilateral valves of the shell, one being the complement or mirror image of the other. The valves are lateral, whereas in the brachiopods they are dorsal and ventral. Each valve has an initial point or beak from which spread out the concentric lines of growth marking successive growth stages. The rounded, elevated portion of each valve ending in the beak is the *umbo*. Under the beak and anterior to it is a depression called the *lunule*. The shell is oriented by holding it with the *hinge line* uppermost and the beaks pointing away from the observer. The end farthest away from the observer is the anterior end; the nearer end, the posterior. The upper border is dorsal; the lower, ventral; and the valves are respectively designated as right and left. Length, height and thickness are measured as in the brachiopods. The valves are held together by the contraction of one or two strong *adductor muscles* and are opened, upon relaxation of the muscular tension, by external or internal *hinge ligaments.* Some forms have a special, spoon-shaped projection from the hinge which lodges the internal ligament. Commonly *teeth* are borne on the hinge or cardinal margin of the valves and aid in their articulation. They are various in size and arrangement and have a special classification. There are various scars on the inside of the shell. Scars mark the attachment of the adductor or closing muscle or muscles.

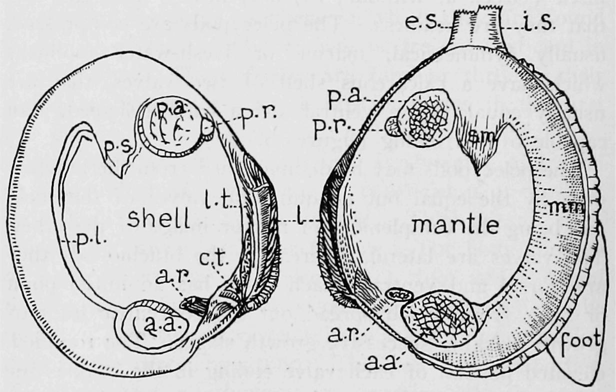


Figure 37 Living pelecypod. The quahog, *Venus mercenaria*, in feeding position with left valve separated, x⅔: *a.a.* Anterior adductor muscle and scar; *a.r.* Anterior retractor muscle; *c.t.* Cardinal teeth; *m.m.* Mantle muscle; *e.s.* Excurrent siphon; *i.s.* Incurrent siphon; *l* Ligament; *l.t.* Lateral teeth; *p.a.* Posterior adductor muscle and scar; *p.l.* Pallial line, *p.s.* Pallial sinus; *p.r.* Posterior retractor muscle and scar; *s.m.* Siphonal muscle. (From Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

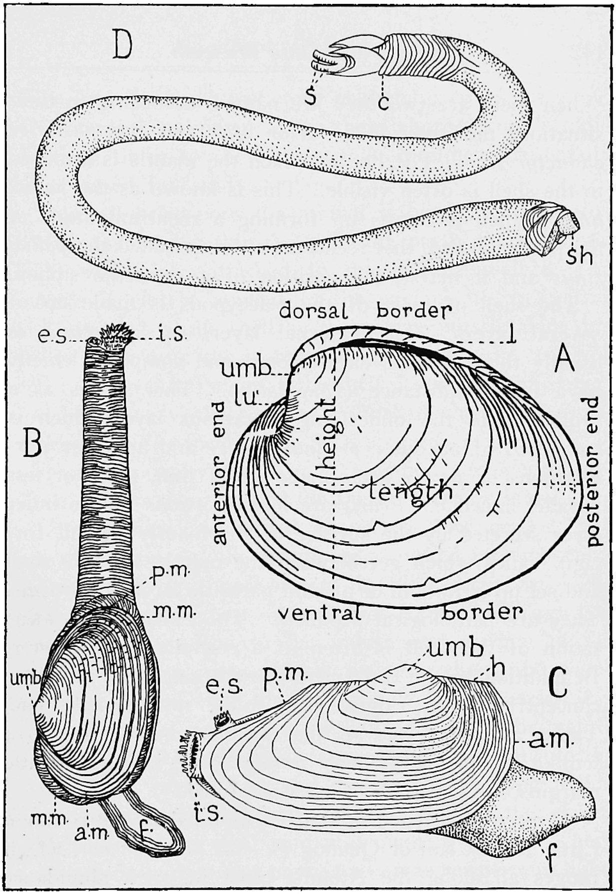


Figure 38 Living pelecypods. *A* Quahog, *Venus mercenaria*, three inches long, three and one-half years old. Age reckoned by prominent growth lines, indicated by notches. *B* Common clam, *Mya*, reduced (after Verrill & Smith). *C* Fresh-water mussel, *Anodonta*, x⅓ (after Simpson). *D* "Ship-worm," *Teredo*, a boring form (after Verrill & Smith). *a.m.* Anterior margin; *c* Collar; *e.s.* Excurrent siphon; *f* Foot; *h* hinge line; *i.s.* Incurrent siphon; *l* Ligament; *lu* Lunule; *m.m.* Mantle margin; *p.m.* Posterior margin; *s* Siphon; *sh* Shell; *umb.* Umbo. (*A* from Introduction to the Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

When there are two they are named, according to their situation, the *anterior adductor scar* and the *posterior adductor scar*. The line at which the mantle is attached to the shell is often visible. This is known as the *pallial line*. When it curves up forming a reentrant angle at the posterior end, this reentrant curve is called the *pallial sinus* and it marks the position of a retractile siphon.

The shell of most of the pelecypods is made up of several layers. The external layer, or *epidermis*, is usually thin, flexible, dark-colored and composed chiefly of a horny substance (*conchiolin*). This serves as a protection to the underlying calcareous layer which is composed of an outer *prismatic layer* and an inner porcellanous or *pearly layer* made up of thin, more or less parallel lamellae. *Pearls* are loose portions of the inner layer secreted by the surface of the mantle around foreign bodies which get between the mantle and the shell and set up irritation, or around parasitic larvae of worms. They are pathological products. The external ornamentation of the shell is often of a conspicuous character. In addition to the concentric growth rings are radial or concentric striae, ridges, ribs, folds, spines, nodes etc. These, as in the case of the brachiopods, are due to a temporary or permanent modification in the mantle margins, by which the shell is secreted.

A recent pelecypod is well exemplified in the common Little Neck Clam or Quahog (*Venus mercenaria*), which ranges all along the Atlantic coast in great abundance from the south side of Cape Cod to Texas (figures 37, 38). North of Cape Cod it occasionally occurs up to the Gulf of St Lawrence. This form ranges from high tide to a depth of more than 50 feet, although it is found most abundantly on sandy or muddy flats, where it burrows into the mud just deep enough to cover the shell. This species is known along these shores from Middle Tertiary times to the present. A specimen may easily be obtained for study.

Like all pelecypods the animal is headless. The soft body is inclosed within the two thin, partly fleshy mantle lobes which are attached to the body dorsally. The mantle is closely applied to the surface of the valves and attached to the shell by the *mantle muscle* along the pallial line near the ventral edge. From the anterior end of the ventral edge of the shell protrudes a muscular, tonguelike body, the *foot,* by means of which the animal moves. A few pelecypods as the oyster (*Ostrea*) have no foot; in many forms it is modified for special use. From the posterior end of the shell project two tubes, the *siphons,* which are united almost to their ends. They are projections of the mantle edge united into muscular tubes. They are not present in all pelecypods. The lower is the *incurrent* or *branchial siphon* and draws in water bringing food to the mouth and oxygen to the gills; the upper carries off the waste products and water that has passed over the gills and is known as the *excurrent* or *anal siphon.* A specialized part of the mantle muscle, the *siphonal muscle,* serves to draw them into the shell. The margins of the mantles beyond the pallial line are free and thickened. They contain the glands which secrete the shell, and also pigment glands. There are no definite eyes, but pigmented areas sensitive to light. *Eyes* are present in some forms of pelecypods, such as the scallop (*Pecten*). The *gills* consists of two thin, curtainlike folds which hang free on each side of the body just beneath the mantle. Each of the four gills is double, having the form of a very narrow bag, which opens dorsally. The union of the gills with each other, with the mantle and with the main body divides the mantle cavity into two chambers. Into the lower opens the inhalent siphon; from the upper passes the exhalent siphon.

The *visceral mass,* including the digestive tract, the heart, the generative organs, the excretory and other glands, lies in the upper or dorsal portion of the shell. The digestive system consists of a mouth provided with two triangular flaps, the labial palps, (Latin *labium,* lip) which sweep the food into the mouth; an oesophagus, stomach and intestine with anal opening. There is also present the large digestive gland or "liver" which pours into the stomach a fluid to aid in the digestion of the food. The liver is a paired, dark brown mass surrounding the stomach. The excretory system consists of two dark, V-shaped tubes, one serving as the kidney, the other as the bladder. The heart in the case of *Venus mercenaria* has one ventricle and two auricles. The nervous system consists of three pairs of large ganglia or nerve centers: a ganglion on either side of the oesophagus, connected by a nerve cord and connected by other nerve cords with two ganglia in the base of the foot and two visceral ganglia near the posterior adductor muscle. Besides the *mantle, siphonal, posterior* and *anterior adductor muscles,* there are *anterior* and *posterior retractor muscles* which draw the foot into the shell and a single *protractor muscle* by which the foot is extruded. The attachment of the foot muscles is marked by three faint scars on each valve. The anterior retractor and protractor muscle scars are near the adductor muscle impression; the posterior retractor just dorsal to the posterior adductor muscle impression.

The sexes are separate. The reproductive elements are extruded into the mantle cavity and thence through the excurrent siphon into the surrounding water, where fertilization takes place. Fertilization, therefore, is a matter of chance. The larval form is free-swimming. The shell gland soon secretes a tiny shell which envelops the embryo. After a period of development, the animal attaches itself by a *byssus*, a fine, tough thread secreted by a gland in the foot. It travels from one place of attachment to another but remains attached until large enough to make its way in the sand. Certain forms as the Horse Mussel and Sea Mussel (*Modiola* and *Mytilus*), so abundant between tide marks on the rocks along our shores, remain attached by a byssus even in adult life.

There are other forms available for study, among them the fresh-water mussels (figure 38), such as the *Anodontas* or *Unios* found in rivers and lakes in most parts of the world. Great varieties of shells of the dead animals can be collected in quantities along most sea beaches. A large number of the genera of pelecypods living today are represented among fossils and have a long vertical range. This is also true of some species. A number of the common living genera are listed here to give a better idea of their range. Of the river mussels, *Unio* (Pearl Mussels) is known from the Jurassic; *Anodonta* from the Cretaceous. Among the marine forms, *Nucula* (Nut Shells) and *Pteria* are known from the Ordovician; *Leda*, from the Silurian; *Solemya* (Razor Shells) and *Modiola* (Horse Mussels), from the Devonian; *Ostrea* (Oysters) and *Pecten* (Scallops), from the Carbonic; *Astarte*, *Isocardia*, *Cucullaea* (Cowl Shells), *Venus* (Hard-shelled Clams or Little Necks or Quahogs), *Teredo* (Ship-worms: borers), from the Jurassic; *Cardium*

(Cockles), *Corbula* (Basket Clams), *Lucina, Mytilus* (Sea Mussels or Edible Mussels), from the Triassic; *Yoldia, Corbicula, Venericardia,* from the Cretaceous. The class Pelecypoda comprises about 5000 recent and twice as many fossil forms. These mollusks are next to the univalves or gastropods in variety and importance and though they are less numerous in species, they are far more abundant in individuals. Except for a few genera, they are all marine forms, and they are found on every coast, in every climate, ranging from low water mark to a depth of more than 200 fathoms. They likewise have a considerable range in size, from the minute *Nucula,* about 4 mm long to the Giant Clam (*Tridacna gigas*) which is sometimes two feet (60 cm) in length and 500 pounds in weight. Many of the pelecypod shells are white or dull brown in color, but there are several genera which have brilliant tints, such as the various species of Scallop (*Pecten*). Beautiful, iridescent tints are found on the inner surface of the shells of some species, such as the so-called Pearl Oyster (*Meleagrina margaritifera*) and the fresh-water mussels. Some of the pelecypods are free-swimming, as the scallops which swim by clapping the valves together; some are permanently attached by the byssus, as the horse mussels and sea mussels; but most of them are sluggish in habit, progressing by slow contractions of the foot. One group includes boring forms (figure 38), such as the ship-worm (*Teredo*), and they are specially modified for this mode of life. There is one parasitic genus (*Entovalva*) which lives in the gullet of a sea cucumber.

Pelecypods are known from the Lower Paleozoic (Cambrian) to the present (figure 39). They are very rare in the Cambrian, where they are represented by a few

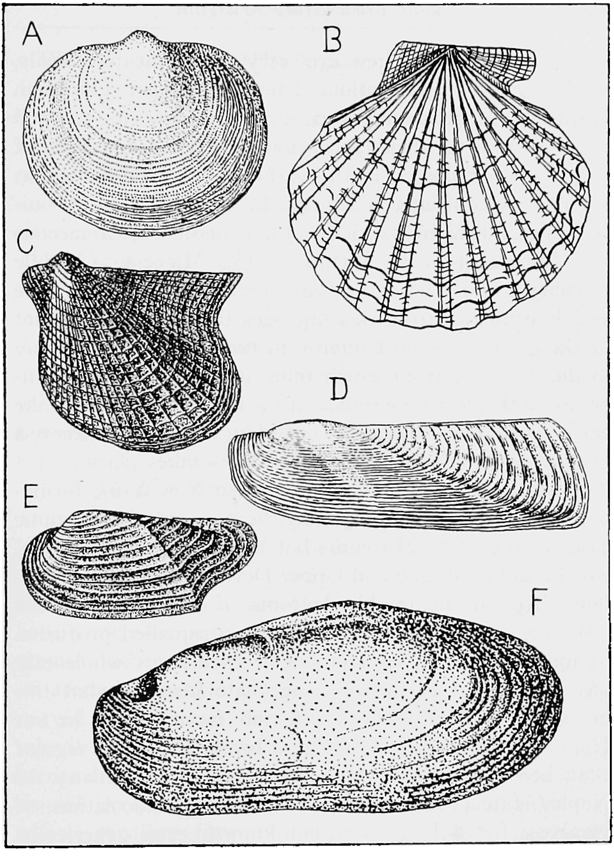


Figure 39 Fossil pelecypods. *A* Devonian *Ontario* (N. Y. State Mus. Mem. 6). *B* Tertiary (Miocene), *Chlamys* (Md. Geol. Surv.). *C—F* Devonian: *C Actinopteria; D Orthonota; E Paleoncilo; F Anodonta*, fossil fresh-water mussel of Upper Devonian (all from Paleontology of N. Y., slightly reduced).

doubtful genera. They are very abundant as fossils, occurring in all formations from the Upper Cambrian upwards, and frequently form extensive deposits, or shell beds, owing to their gregarious habits. Families of pelecypods originated in the various geological epochs as follows: Ordovician 9, Silurian 11, Devonian 9, Carboniferous 3, Permian 1, Triassic 13, Jurassic 14, Cretaceous 18, Eocene (Early Tertiary) 15, Miocene (Middle Tertiary) and Pliocene (Late Tertiary) 3, Pleistocene and Recent 6. From this one sees that the development of the group was most intense in the Silurian, decreasing to the Triassic, from which time there was a gradual increase until the Cretaceous, with a rapid decline after the early Tertiary. With the beginning of the Tertiary a gradual approach to present conditions takes place.

Pelecypods are found in any of the New York formations, and representatives may be seen in the synoptic cases in the State Museum; but they are especially noteworthy in the Middle and Upper Devonian beds. Bivalves flourished on the muddy bottoms of the Hamilton sea (Middle Devonian) and attained an unequalled profusion of individuals and development of forms. A whole case has been given to them in the State Museum, but this gives but a faint idea of the rich fauna found in our Hamilton beds. In places these bivalves formed regular clam beds. In the Portage beds (Upper Devonian) the Naples fauna has afforded a strange association of bivalves, for a large part not known, even generically, from other regions. Fresh-water clams (*Archanodon catskillensis*) are found in the Catskill beds (Upper Devonian). These beds were in an estuary of a large river coming from the north into Albany Bay.

Class Gastropoda (Greek *gaster,* stomach, *pous* (*pod*), foot). The gastropods or Snails (figures 40–42) are univalved or single-valved mollusks, and include marine, fresh-water and land forms. The shell, as in the pelecypods, is secreted by the mantle. It may be conical or saucer-shaped, but is usually coiled into a spiral which is either right-handed (*dextral*) or left-handed (*sinistral*). The coiling is the result of the more rapid growth of one side of the body with its mantle, and as it is usually the left side which grows more rapidly than the right, the dextral coil is the more common type. The shell is oriented by holding it, so that the apex (posterior end) is above and the aperture (anterior end) below facing the observer. In a right-handed shell the opening is on the right side; in a left-handed shell, on the left.

The shell begins with minute embryonic whorls (the *protoconch*), which in many types is quite distinct from the rest of the shell. The protoconch (Greek *protos,* first; *konche,* shell) is missing in many of the shells that are picked up. The shell is to be considered as a gradually widening cone which is wound either around an axial pillar, the *columella,* or around a central tubular cavity. The outside of the curved shell is the dorsal portion. Each coil of this tube is known as a whorl. The whorls gradually increase in size from the apex down. The last whorl, in which the animal lives, is known as the *body whorl;* all the other whorls together form the *spire* (figure 40). Normally the whorls are circular or elliptical in section, but from compression and other causes they vary. As a rule the whorls are in contact with each other, each in succession partly, sometimes entirely covering the preceding; but there is sometimes formed a loose spiral in which the whorls are separated from one another. The spire may be high or low, broad or slender, according to the nature of the enrolment and this causes a variation in the *apical angle*. The contour of shells varies with the manner of enrolling, requiring descriptive names, such as conical, turbinate, cylindrical, oval, pyramidal etc. The line between two neighboring whorls is known as the *suture*. When an angulation occurs on a whorl, the space between it and the suture above is called the *shoulder*, which may be simple or keeled or furnished with nodes or spines. The columella is formed by the coalescence of the inner parts of the whorls. When they do not unite but leave a central tubular cavity, the opening of the cavity below is termed the *umbilicus*. In some cases the inner edge of the mantle is turned back over the inner edge of the aperture, and secretes a shelly growth, the *callus*, which partially covers the umbilicus. The aperture varies in form, being most commonly rounded, half-round, oval or crescentic. Its margin is known as the *peristome* (Greek *peri*, around; *stoma*, mouth), the outer part of which forms the *outer lip* and the part next the columella the *inner lip*. As a rule the inner and outer lips are separated by an *anterior notch*, which may be drawn out into an anterior canal serving for the lodgment of the siphon. The outer lip may be entire or incised, thin and sharp or thickened, curved outward or inward, even or crenulate etc., according to the character of the mantle margin.

Since the shell is formed by the mantle the surface irregularities of the shell merely reflect corresponding irregularities in the mantle. The shell shows the growth lines and in addition is usually marked with lines or grooves, or elevated ridges, ribs, folds, nodes, spines etc. When the markings run parallel with the suture they are called *spiral markings;* when they meet the suture at right

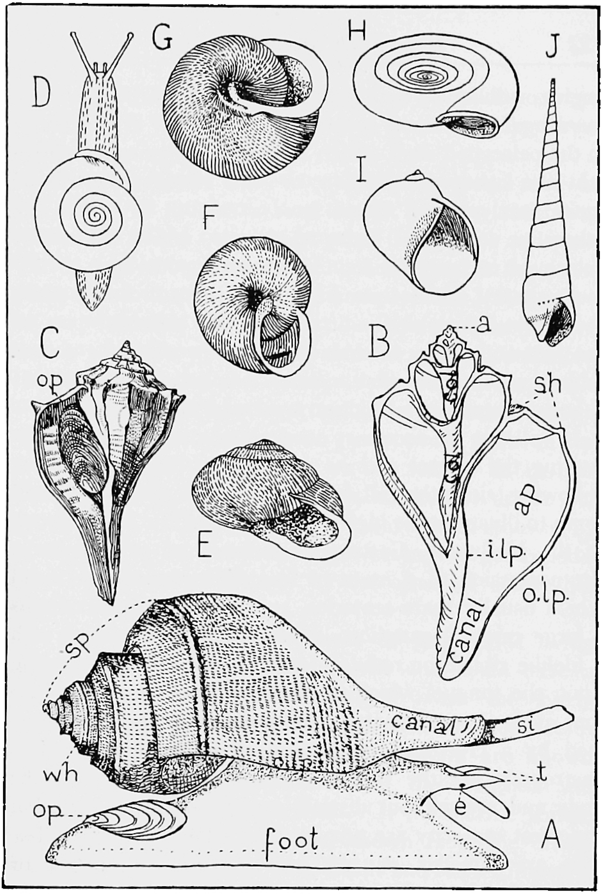


Figure 40 Living gastropods or snails. *A* Marine snail, *Buscyon* of Atlantic coast in feeding position, about x½. *B* Shell of same with portion broken away, x⅝. *C* Marine snail, *Fulgur*, with operculum in place, x½. *D—G* Land snails, x⅞: *D Helix (Polygyra)*, crawling; *E* Shell of same, side view; *F Helix (Campylaea)*, with central cavity or umbilicus; *G Helix (Polygyra)* with callus covering umbilicus. *H—J* Types of spires: flattened (*H*); globose (*I*); greatly produced (*J*). *a* Apex of spire; *ap* Aperture; *col.* Columella; *e* Eye; *i.lp* Inner lip; *o.lp* Outer lip; *o.p.* Operculum; *sh* Shoulder; *si* Siphon; *sp* Spire; *t* Tentacles; *wh* Whorl. (*A*, *B* from Introduction to the Study of Fossils by H. W. Shimer; *C*, *F*, *H*, *I*, *J* from Cambridge Natural History; published by The Macmillan Co. *D*, *E*, *G* after Simpson)

angles or obliquely they are known as *axial* or *longitudinal markings*. The shell consists essentially of aragonite, as in the pelecypod shell, which forms a homogeneous, porcelain like layer. In addition, in some families there is an inner pearly layer. Some have a smooth or rough and others a velvety or hairy epidermis, which is usually destroyed in fossilization. Many gastropods have a variously shaped, variously marked, calcareous or horny plate, the *operculum,* which is attached to the posterior part of the foot and serves to close the aperture when the animal withdraws into the shell. Since it is most commonly of a horny nature it is seldom preserved as a fossil.

It will not be necessary to go into much detail in discussing the animal and its anatomy in this class or the following, since the full description of the pelecypods will serve to illustrate the high organization of the whole group of the Mollusca. Gastropods differ from pelecypods in the possession of a more or less distinctly marked head which usually bears tentacles, eyes and ears and contains a large cerebral ganglion. The mouth is furnished with a filelike ribbon or *radula* (Latin *rado,* to scrape) resting upon the tongue, which is merely a swelling at the bottom of the buccal cavity. Gastropods are also characterized by a creeping foot and a single mantle. A few gastropods breathe through the general surface of the body and are without distinct organs of respiration; but the great majority are provided with gills or lungs. The gills are lamellar or tuftlike, sometimes branched or feathered lobes. The water for respiration passes in through a fold of the mantle which lies in the anterior notch, or through the canal when one is present. The air-breathing snails, which are mainly terrestrial or of fresh-water habitat, have the gills replaced by a saclike cavity, the *lung,* which occupies the place of the gill cavity. The sexes are separate in some of the groups and united in others; and there is a free-swimming larval stage.

Gastropod shells like those of pelecypods, may be found in large numbers along the sea beaches, and living forms such as the common limpets (*Crepidula*) and periwinkles (*Littorina*) may be found clinging to the rocks between tide marks. The land snail *Helix* (*Polygyra*) has a worldwide distribution; and fresh-water forms, such as *Lymnaea* and *Planorbis* are easily obtainable. Gastropods are both herbivorous and carnivorous, but a large percentage are herbivorous. The vegetable feeders among the marine forms have many small teeth on the radula; the carnivorous, few, strong teeth. In carnivorous forms the lip of the shell is notched or drawn out into a canal. *Touch* and *smell* have been shown by experiment to be the most acute senses of gastropods, and it is almost exclusively by the sense of smell that food is found.

A great number of the genera of gastropods living today are represented among fossils and some have a long vertical range. *Helix* ranges from the Early Tertiary to the present; and, among the common fresh-water forms, *Physa, Lymnaea* and *Valvata* are known from the Jurassic, *Planorbis* from the Triassic and *Campeloma* from the Cretaceous. Of the marine forms, *Pleurotomaria* (Slit Shells) are known from the Ordovician; *Patella* (Common Tent Shells and Rust Limpets), *Acmaea* (Tent Shells), *Trochus* (Top Shells), *Eotrochus* (Top Shells), from the Silurian; *Fissurella* (foss. *Fissuridea,* Key-Hole Limpets), from the Carboniferous (?); *Solarium* (Sundial Shells), *Cypraea* (Cowry Shells), *Bulla* (?) (Bubble Shells), *Littorina* (Periwinkles), from the Jurassic; *Turritella* (Screw or Tower Shells), *Calliostoma* (Top Shells), *Capulus* (Hungarian Cap, etc.) and *Natica* (Moon Shells), from the Triassic; *Calyptraea*, (European Cup and Saucer Shells), *Crepidula* (Slipper Shells), *Conus* (Cone Shells), *Haminea* (Bubble Shells), *Margarita* (Wavy Top Shells etc.), *Murex*, *Nassa* (Dog Whelks, etc.), *Oliva* (Olive Shells), *Pleurotoma* (Notch-side Shells), *Strombus* (Conch Shells), *Typhis* (Smoke Shells), from the Cretaceous; and *Buccinum* (Edible Whelks), *Crucibulum* (Cup and Saucer Limpets), *Fulgur* (Giant Whelks, Pear Conchs), *Fusus* (Spindle Shells), *Marginella* (Margin or Rim Shells), *Mitra* (Mitre Shells), *Sigaretus* (Ear Shells), *Sycotypus* (Channeled Whelks), *Terebra* (Augur Shells) and *Vasum* (Chank Shells), from the Tertiary.

Gastropods excel all classes of mollusks in variety and importance, and are at present enjoying their maximum vigor. More than 30,000 species have been described, of which over 20,000 are recent species, three-fifths of them gill breathers. They are essentially aquatic. Some species are especially adapted to brackish water. Gastropods crawl on the bottom of the water or on land, a considerable number are swimmers and some are jumpers. Some families burrow in sand or mud. Some genera, while able to move from place to place, have taken up a more or less sedentary life; others are completely sedentary when adult; and some are parasitic, generally in or upon echinoderms, a habit acquired in Paleozoic times. Some marine species are found at a depth of over 2500 fathoms, and air breathers live in the Himalayas at a height of 17,000 feet above sea-level. Some gastropods are found in lakes, 180 fathoms below the surface; others live in subterranean waters and some are found in caverns where daylight does not penetrate. In size gastropods vary from a fraction of a millimeter to more than 15 centimeters (over six inches). Some of the living gastropods are very brilliantly colored, but color is rarely seen in the fossil state. The carnivorous habit of some of the gastropods is due to specialization. Various forms live and feed on colonial invertebrates, such as Hydrozoa, Anthozoa etc., and mimic them to a certain extent.

As fossils, gastropods are known from the Cambrian upward (figures 41, 42). The great majority of the genera of the Early Tertiary are still living, although the species, with few exceptions, have become extinct. In the Middle Tertiary more species made their appearance than are still living; 80 to 90 per cent of the Late Tertiary species are living today. Land snails are first met with in the Devonian, where they are very sparse, and were initiated in still smaller numbers in the Carboniferous, but fresh-water snails do not come in until some time between the Jurassic and Cretaceous. Both land and fresh-water forms become highly developed and widely distributed during the Tertiary. The most generalized forms of gastropods appeared first in geological history, and the more specialized forms later.

Fossil gastropods may be studied in the series of synoptic cases in the State Museum, and even an amateur collector should not fail to find them in almost all of the New York formations. With the cephalopods they form the most prominent fossils of the lower Ordovician beds and they are abundant in the upper beds (Trenton) as well. The Guelph fauna (Middle Silurian) is notable for its strange and beautifully preserved gastropods. The Devonian beds have numerous representatives of

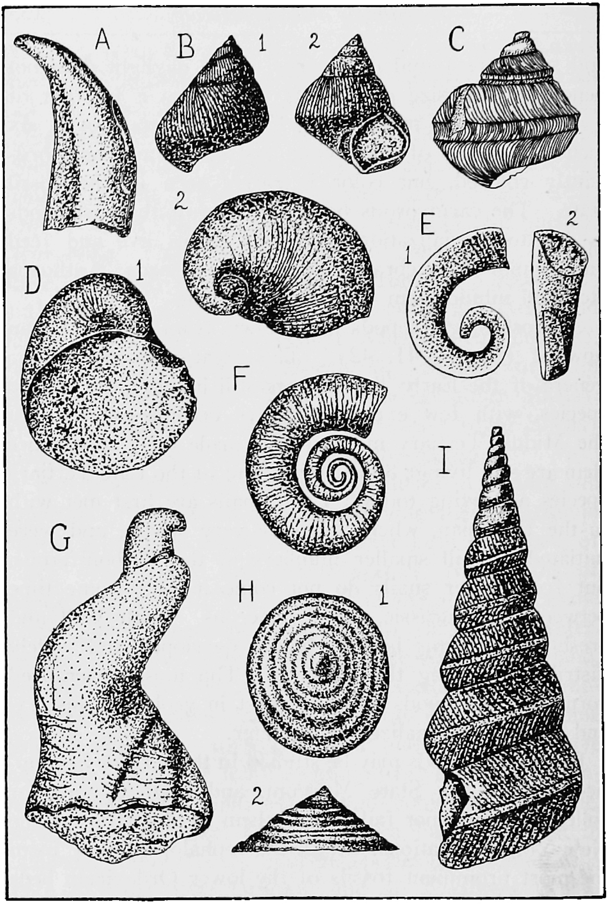


Figure 41 Fossil gastropods. *A—D* Devonian: *A Orthonychia; B Callonema; C Euryzone, x2*; *D,* 1 and 2 *Platyceras.* *E,* 1 and 2 Ordovician, *Eccyliomphalus* (after Ulrich). *F* Devonian, *Phanerotinus.* *G* Devonian, *Platyceras spirale.* *H,* 1 and 2 Cambrian, *Palaeacmaea* (after Hall and Whitfield). *I* Silurian, *Coelidium* (after Clarke & Ruedemann). All x7/8. (*A—D, F, G* from Paleontology of N. Y.)

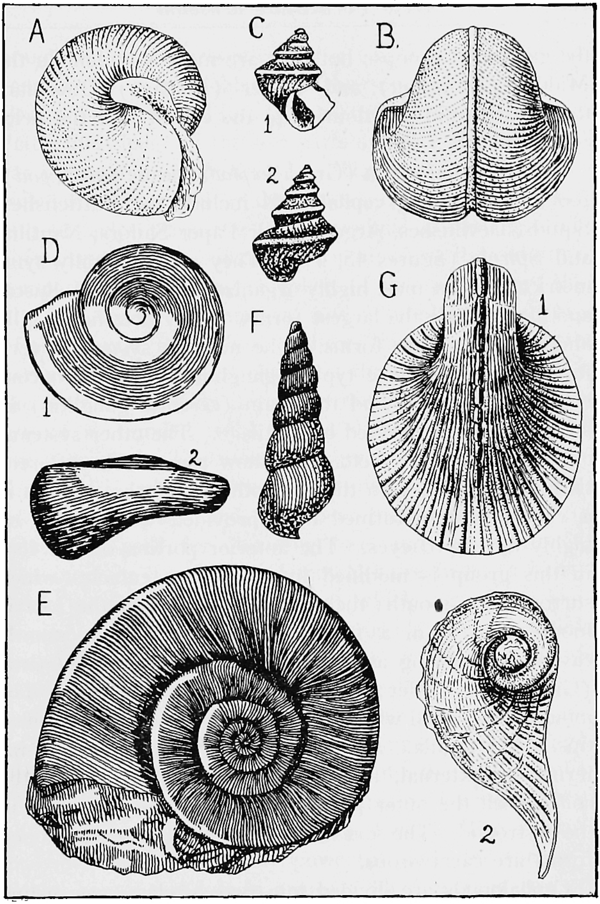


Figure 42 Fossil gastropods. *A, B* Devonian, *Bellerophon. C,* 1 and 2 Ordovician, *Lophospira* (after Ulrich). *D,* 1 and 2 Ordovician, *Raphistoma. E* Ordovician *Maclurea magna,* x⅔. *F* Devonian, *Loxonema. G* 1 and 2 Silurian, *Trematonotus,* x⅔ (after Clarke & Ruedemann). (*A, B, D—F* from Palentology of N. Y.)

the gastropod groups; but they are most abundant in the Middle (Hamilton) and Upper (Portage) Devonian, though they did not flourish to the extent that the pelecypods did.

Class Cephalopoda (Greek *kephale,* head; *pous* (*pod*), foot). The living cephalopods include the Cuttlefishes, Squids, Devilfishes, Argonauts or Paper Sailors, Nautilus and Spirula (figures 43, 44). They are bilaterally symmetrical and the most highly organized of all the Mollusca, and also include the largest forms. They breathe by gills and are all marine forms. The nervous system is very highly developed; the typical ganglion pairs are concentrated in the head, and the brain (cerebral ganglion) in some forms is protected by cartilage. The other systems, circulatory, digestive etc., also show remarkable differentiation compared with those of other mollusks. There is a very definitely formed head provided with a pair of highly developed eyes. The anterior portion of the foot in this group is modified into arms or tentacles which surround the mouth; the posterior portion of the foot is modified to form a funnel leading out of the mantle cavity and serving as a swimming organ, the hyponome (Greek *hypo,* under; *nome,* feeding place or food). The mouth is provided with horny, beaklike jaws with calcified tips, and a radula. A shell may be present or absent, internal or external, and it has various forms. In the coiled shell the outer portion is ventral, not dorsal as in the gastropod. The sexes are separate. All the cephalopod forms are carnivorous.

Cephalopods are divided into two subclasses according to the number of the gills: *Tetrabranchiata* (Greek *tetra,* four) and *Dibranchiata* (Greek *dis,* two). The Tetrabranchiata are represented by a single genus *Nautilus,* familiar to us particularly in the species known as the *Pearly Nautilus,* and it is from a study of this genus alone that a knowledge of the soft parts of the Tetrabranchiates has been obtained (figure 43). The body is inclosed in a coiled shell, secreted by the mantle, from which the head and tentacles project when the animal is moving. The soft parts of the animal are contained in the outermost compartment, or living chamber, of the shell, where they are held by strong muscles; and a tubular prolongation of the mantle, the *siphon,* connects this chamber with the earlier and unoccupied chambers through perforations in the septa. The body is roughly oblong in shape, consisting of a rounded trunk and a distinct head with eyes and tentacles. The mouth is surrounded by a series of fleshy lobes, which represent the anterior part of the foot of other mollusks, and these bear the 60 or 90 *tentacles* which are used for obtaining food and for attachment. The inner or dorsal pair of tentacles are fused to form a thick, muscular lobe, the *hood,* which serves the same function as the operculum of gastropods when the animal withdraws into the shell. On the ventral side of the head is the funnel or *hyponome.* This swimming or ambulatory funnel here has the appearance of a muscular leaf rolled into a tube by the infolding of its free edges. It widens posteriorly and opens into the gill chamber. The animal is enabled to eject a stream of water through the hyponome and propel itself backward. The mouth is provided with remarkably powerful *jaws,* the tongue is fleshy and the *radula* is armed with numerous rows of plates and hooks. Besides eyes, there are organs of hearing, and a pair of small tentacles near each eye, so-called *ocular tentacles,* which are supposed to be olfactory in

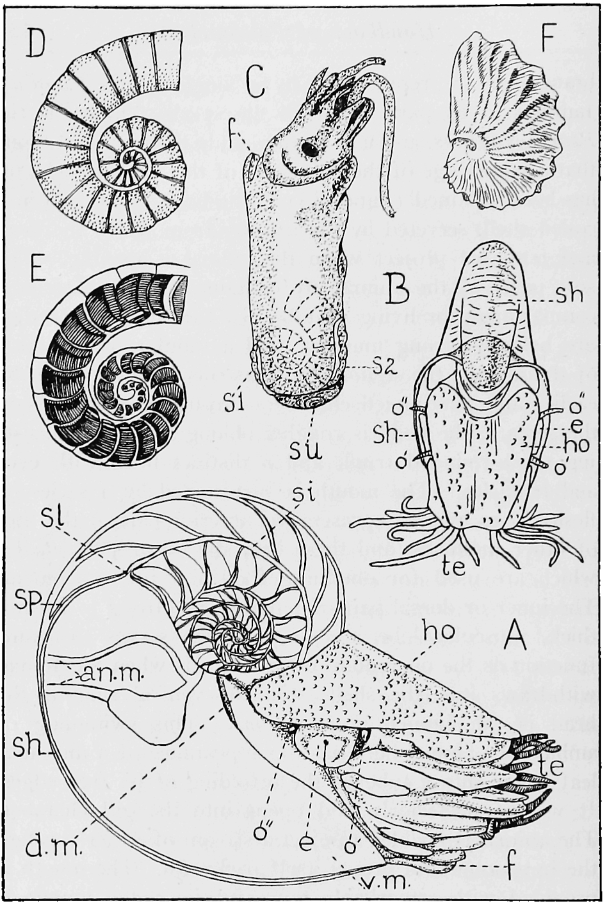


Figure 43 Living cephalopods. *A Nautilus* from Philippine Islands, x7/16. Right half of shell cut away. *B Nautilus* creeping upon horizontal surface (much reduced). *C Spirula*, lateral view (reduced). *D, E* Shell of same, outside view and in section (reduced). *F* Shell of paper argonaut, *Argonauta*, x7/16 (after Woodward). *an.m.* Annular muscle holding body in shell; *d.m.* Dorsal portion of mantle; *e* Eye; *f* Funnel; *ho* Hood; *o',o''* Ocular tenacles; *s1, s2*. Projecting portions of shell; *sh* Shell; *si* Siphon; *sl* Siphuncle, shelly covering of siphon; *sp* Septum; *su* Terminal sucker; *te* Tentacles; *v.m.* Ventral portion of mantle. (*A, B* from Introduction to the Study of Fossils by H. W. Shimer; *C—E* from Textbook of Zoology by Parker & Haswell; published by The Macmillan Co.)

function. *Nautilus* finds its food chiefly by the sense of smell.

The shell of the *Nautilus* is coiled in a single plane and consists of two and a half whorls. Internally the shell is divided by septa into a series of *chambers* (*camerae*) filled with gas and connected by the *siphuncle,* the calcareous wall secreted about itself by the siphon. The septa are secreted by the mantle as the animal moves forward in the living chamber when it has outgrown its quarters. The lines formed by the union of the septa with the shell are *suture lines.* The gas-filled chambers are supposed to act as a support to the shell in the water, relieving the animal of its weight in swimming or floating. When the animal creeps on the sea bottom it applies its tentacles to the surface over which it is traveling and movement is effected. In the creeping position the soft body is nearly horizontal, curving upward posteriorly. The coil of the shell is dorsal, the funnel is ventral, the head is anterior and the siphuncle is posterior. The Nautilus shell is calcareous and is lined with mother-of-pearl. Externally it is smooth and in the *Pearly Nautilus* marked with alternating bands of reddish-brown and white. *Nautilus* is known from the Tertiary to the present. The three living species are inhabitants of moderately shallow water about the shores and coral reefs of the South Pacific. In contrast to living forms fossil Tetrabranchiates are represented by over 2000 species.

The Dibranchiates include the Cuttlefishes, Squids, Argonauts, Octopus or Devilfishes etc. They differ from the Tetrabranchiates in the possession of two gills; the shell is internal or wanting or, exceptionally, external but not coiled, as in the argonauts; the foot here is modified into eight or ten arms around the mouth and these are furnished with suckers; the hyponome is a complete funnel; there is an *ink sac* present which discharges its contents through the funnel; the eyes are remarkably perfect, next in development to those of vertebrates, and food is found chiefly by their aid rather than through the sense of smell.

The Dibranchiates are further divided into two groups according to the number of arms. Those forms with eight arms belong to the *Octopoda* (Greek *okto,* eight), those with ten arms to the *Decapoda* (Greek *deka,* ten). The Octopods include the devilfishes and the argonauts (figure 43). The eight arms have sessile suckers and the eyes are fixed, incapable of rotation. The devilfish has no internal shell. The shell of the argonaut or paper sailor is thin and translucent and is not attached to the body of the animal in any way. It is peculiar to the female and its special function is the protection and incubation of the eggs. It is not analogous with the shell of other cephalopods.

The Decapods are represented by the squids, cuttlefishes etc. (figures 43, 44). The arms have stalked suckers. Two of the arms are elongated, with expanded ends, and are known as tentacles. The eyes are movable in their orbits. The shell is internal, lodged loosely in the middle of the dorsal aspect of the mantle. In most forms this internal shell is a *horny "pen"* or a *calcarcous "bone"*; in one genus (*Spirula*) it is a delicate *spiral tube* divided by septa into air chambers. The common American squids (*Ommastrephes* and *Loligo*) found along the Atlantic coast and worldwide in distribution are good examples of the group. They are free-swimming animals with an elongated, shield-shaped trunk bordered laterally by a fleshy fin. The head is distinct and separated from the

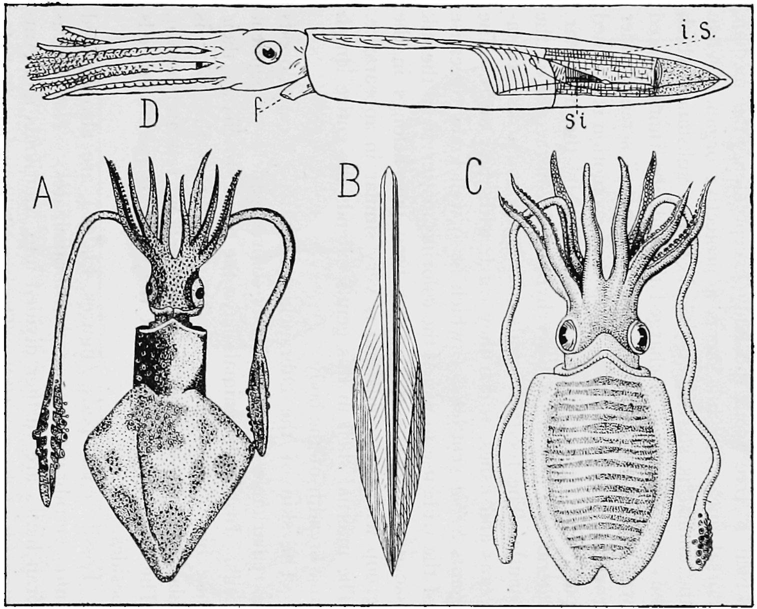


Figure 44 Cephalopods, living and fossil. *A* The common squid, *Loligo vulgaris*, x1/7. *B* Internal shell or pen of same, x¼ (after Woodward). *C* The cuttlefish, *Sepia officinalis*, x1/7. *D* Restoration of the fossil *Belemnites* (*Jurassic*), x1/3, *i.s.* Internal shell; *f* Funnel; *si* Siphuncle. (*A* from Textbook of Zoology by Parker and Haswell; *D* from Introduction to the Study of Fossils by H. W. Shimer; published by The Macmillan Co.)

trunk by a constricted region, known as the *neck*. The whole body is surrounded by a thick, muscular mantle, which is free from the body except along the median, dorsal line. The ink sac is a protective organ. When the animal is startled, the dark brown substance which this sac secretes is discharged through the funnel mixed with water, and creates a sort of "smoke" screen, under cover of which the animal escapes. Locomotion is attained partly by the use of the arms, partly by the muscular, lateral fins and largely by rhythmical contraction of the mantle. The food of squids consists of mollusks, crustaceans and fishes, which they catch with their arms. The genus *Sepia* (cuttlefish), which is so well known because of the wide use to which the coloring matter from the ink sac of one of its species has been put, belongs in the group with the squids and is very similar in appearance. The internal shell in this genus extends the entire length and breadth of the body.

The skin of the Dibranchiates or naked cephalopods is remarkable for its variously colored vesicles or pigment cells. In life the animals have the power to change their hue like a chameleon. In the cuttlefishes the color is black and brown; in the squids yellow, red and brown. The argonauts and some of the octopods have blue cells besides.

Fossil cephalopods (figures 45, 46) are also divided into Tetrabranchiates and Dibranchiates. The Tetrabranchiates are further divided into Nautiloids and Ammonoids (*Ammonites*). The nautiloid group includes forms with shells straight (*Orthoceras*), slightly curved (*Cyrtoceras*), loosely coiled (*Ryticeras*) to closely coiled (*Nautilus, Centroceras*). In some cases the coiling may be in an asymmetric spire, resembling a gastropod shell

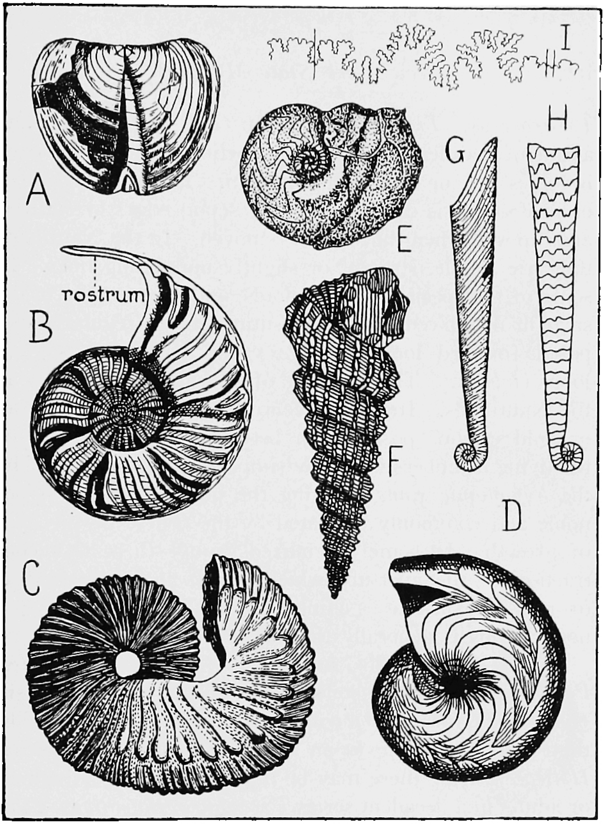


Figure 45 Fossil cephalopods. Ammonoid types: *A Aptychus* of *Scaphites* (Up. Cretaceous). *B* Aperture with ventral rostrum (*Schloenbachia*, Cretaceous). *C* Type with last whorls loosely coiled (*Scaphites*, Cretaceous). *D* Goniatite (*Goniatites*, Lower Carboniferous). Internal mold with shell removed, showing sutures with simple lobes and saddles. *E* Goniatite (*Manticoceras*), x½, from Devonian (after Hall). *F* Form with turret-shaped cone (*Turrilites*, Cretaceous). *G* Uncoiled form (*Baculites*, Cretaceous). Young shell, x4½. *H* Specimen of same with outer shell broken away, showing sutures, x4½. *I* Condition of suture in adult shell. All, except *E, G, H*, x⅞. (*C, D* from Grabau: Textbook of Geology, permission D. C. Heath & Co. *A, B, F* from Textbook of Paleontology by Zittel-Eastman; *G, H, I* from Introduction to Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

(*Mitroceras, Trochoceras*). In old individuals and adults of decadent series, the last portion of the whorl often becomes free or even straight again. The initial chamber or *protoconch* is calcareous. The septal edges or sutures, are exposed when the shell is removed. In the Nautiloids they are simple, straight or slightly undulating lines. In some of the specialized Nautiloids, and occasionally in the straight or curved forms the suture shows regularly disposed forward loops (*saddles*) and backward bending loops (*lobes*). The position of the siphuncle varies in the Nautiloids. It may be central, subventral, subdorsal, or hold various positions in between. The aperture of the living chambers is mostly simple and modified only by the *hyponomic sinus* marking the position of the hyponome and commonly indicated by the course of the lines of growth. In some specialized groups there is a contraction of the aperture which results in the formation of narrow, slit-like openings or *sinuses*, but the hyponomic sinus is generally the longest.

The Ammonoids also include close-coiled (*Agoniatites, Perisphinctes*), loose-coiled (*Mimoceras*) and straight (primitive) forms (*Bactrites*); and, as in the Nautiloids, there may be coiling in an asymmetric spire (*Turrilites, Helicoceras*) or there may be uncoiling in old individuals or adults in a decadent series (*Scaphites, Baculites*). The initial chamber or protoconch is noncalcareous. The Ammonoids are characterized by complex suture lines with well-developed lobes and saddles. The siphuncle is subventral, although in one group it is subdorsal and in some primitive forms more nearly central. The living chamber is contracted toward the aperture in many forms, and in old individuals. The Paleozoic Ammonoids commonly retain the hyponomic sinus, but in more specialized forms,

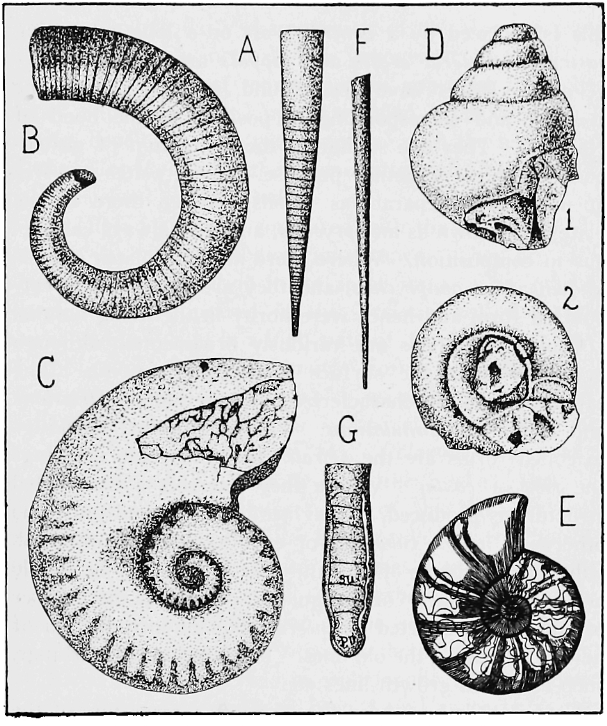


Figure 46 Fossil cephalopods. *A—D* Nautiloid types: *A* Straight form (Devonian, *Orthoceras*) x⅓; *B* Loosely coiled form (Devonian, *Ryticeras*), x⅓; *C* Closely coiled type (Devonian, *Centroceras*), x¼; *D*, 1 and 2 Type with high turbinate spire (Silurian, *Mitroceras*), x⅜; Side and umbilical views of mold. *E—G* Ammonoid types: *E* Jurassic form (*Ceratites*) showing sutures, x¼; *F* Final straight form in uncoiling of ammonoid series (*Bactrites*, Upper Devonian), x⅜; *G* Apex of shell, x10, showing protoconch (pr) and sutures (su). (*A*, *D* after Grabau; *B* after Hall; *C* after Meek; *F*, *G* after Clarke; *E* from Grabau: Textbook of Geology, permission, D. C. Heath & Co.)

this is replaced by a *ventral crest* or a long projecting *rostrum*. *Lateral crests* and *lappets* are sometimes developed. Plates have been found, *in situ*, closing the aperture and corresponding in position to the hood of Nautilus. They are similar to the operculum of gastropods and serve a similar purpose. These plates are frequently found separate as fossils. When there is one plate it is known as an *aptychus*, and it is always calcareous in composition. Where there are two plates each is known as an *anaptychus*, and they are preserved in carbonized form and hence were horny in the living animal.

Cephalopod shells are variously ornamented, although in many forms the surface is perfectly smooth. The earliest forms are characterized by longitudinal *striations* and transverse *annulations*. The longitudinal markings in coiled forms are the *spirals*; the transverse markings the *ribs* or *costae*. Where they intersect a cancellated structure is produced, if they are both fine and uniform; otherwise, *nodes*, *tubercles* or even *spines* are produced. Ribs may be coarse or fine and sharp; they may be simple or divide regularly or irregularly. Increase in number of ribs is also effected by *intercalation* or introduction of new ribs between the old ones. There are other markings, such as frilled growth lines etc.

Cephalopods have been the strongest competitors of the vertebrates in the oceans from Silurian times to the present. The Nautiloids are first known from the Cambrian, reached their maximum development in the Silurian, declined from the Devonian to the Triassic and are represented today by only one genus, *Nautilus*. The Ammonoids are twice as rich in forms as the Nautiloids, far more than 5000 species having been described, whereas there are about 2500 described species of Nautiloids. The group was particularly characteristic of the Mesozoic and is now entirely extinct. It is a younger group than the Nautiloids; the oldest representatives appeared from the Upper Silurian to the Upper Devonian. The true Ammonites developed with great rapidity with the beginning of the Mesozoic era; they constitute rich faunas and make excellent index fossils.

The Dibranchiates as compared with the Tetrabranchiates are of minor geological importance. They are less adapted for preservation in the fossil state. The earliest representatives appeared in the Triassic, and they appeared suddenly and in a high state of development. One of the more commonly known forms is *Belemnites,* (Greek *belemnos,* a dart) which as an index fossil of the Jurassic and Cretaceous is scarcely less important than the Ammonites (figure 44). *Belemnites* is closely allied to the squid. Usually only the internal shell is found, but sometimes impressions of the tentacles and arms are preserved, showing suckers with horny hooks, and the jaws and ink sac are at times found. The ink is preserved in the form of solid carbon particles. The shell is more complete than in the squid. The genus *Sepia* is known from the Tertiary to the present.

Color is rarely preserved in cephalopods, but specimens showing color patterns have been found as early as the Ordovician, and the distribution of the coloring has been used to interpret the mode of life. Among cephalopods in general, the possession of a hyponomic sinus indicates swimming habits while the possession of a crest or lappets seems to suggest sedentary, crawling or even floating habits. The larger, straight forms of the Paleozoic were probably stationary, resting upon the sea bottom, although there may have been swimmers among these. Many of the living Dibranchiates are gregarious and swim in the open sea in hordes; some lead a separate existence along rocky shores; still others creep on the bottom. Some of the Dibranchiates attained gigantic size.

Cephalopods may be studied in the State Museum in the synoptic cases and in a number of special exhibition cases, and these cases are supplemented by models showing structure and restorations. Both the Portage and Helderberg restoration cases show cephalopods, two coiled forms and one straight (*Manticoceras, Ryticeras* and *Orthoceras*). A large floor slab from Manlius, N. Y., shows a profusion of straight and coiled forms of Devonian age (Agoniatite limestone of Marcellus shale). In beds of Ordovician age in New York State cephalopods may be found abundantly in the Chazy and Trenton limestones and the Black River beds; in the Silurian, in the Lockport and Shelby dolomites and Cobleskill limestone; in the Devonian, in the Schoharie grit, Onondaga limestone, Cherry Valley (Agoniatite) limestone of the Marcellus, and the Hamilton and Portage (Naples) beds. Some gigantic coiled forms measuring about a foot across have come from the Hamilton and Portage beds. Large goniatites, far surpassing in size those obtained in other countries, have been found in concretions along the shore of Lake Erie and in other places in western New York. The straight forms, too, attained gigantic size. Specimens nine feet long or more have been found in the Trenton limestone. Large forms are also found in the Agoniatite or Cherry Valley limestone. Some forms of peculiar character (*Gonioceras, Actinoceras, Ryticeras* and *Mitroceras*) have become known principally from the rocks of this State. The special exhibition cases in the Museum show, among other things, beautifully preserved pyritized specimens, occurring as nuclei of concretions; specimens with color bands; and growth stages of one of the coiled forms (*Manticoceras pattersoni*).

Class Amphineura (Greek *amphi*, on both sides; *neuron*, nerve) The Amphineura are marine mollusks, formerly grouped with the gastropods. The commonest and most highly organized of the living representatives of this group are the *Chitons* (figure 47), which are sluggish, limpetlike mollusks with a shell composed of eight pieces. They are bilaterally symmetrical with mouth and anus at opposite ends. They possess a foot adapted for creeping, and the mantle surrounds the body dorsally. The other members of this group are of low organization and comprise the most primitive forms of the whole phylum, all devoid of the shell. Along the Atlantic coast Chitons are abundant from Cape Cod to Florida. Chitons occur at all depths, though most abundant on the shore between tidal limits, where they may be found adhering to the surface of rocks etc. by means of the suckerlike foot. They are vegetable feeders, their food consisting of minute algae and diatoms.

Amphineura have existed since Ordovician times; but all fossil forms are members of the group to which the chitons belong, since the members of the other group have no hard parts that would be recognizable in the fossil condition. The amateur is not likely to meet with any fossils of this group, particularly in New York State.

Class Scaphopoda (Greek *skaphos*, spade; *pous* (*pod*), foot). The Scaphopoda or Elephants' Tusk Shells are aberrant, marine mollusks and are represented today by only three genera. For the most part they inhabit deep water; but there are a few littoral species. They live embedded in mud or sand with the smaller end of the shell projecting above the surface. The food consists chiefly of Foraminifera.

Scaphopods have an elongate, bilaterally symmetrical body, inclosed in a tubular, calcareous shell, somewhat curved and tapering and open at both ends (figure 47). The shell is secreted by the mantle. The concave side is dorsal, and the large end is the anterior end. The shell increases by successive additions at the larger end, and at the same time loses at the smaller end by wear and resorption. These shells may be distinguished from similar shells of gastropods and cephalopods by the fact that the latter are always closed at one end.

Scaphopods are known from the Ordovician to the present. The fossil species described probably lived in moderate depths. A characteristic example is the genus *Dentalium,* with smooth or sculptured shell. About 275 fossil and 150 recent species are known. A few species occur in the Ordovician and the number increases slowly until the Cretaceous.

Class Conularida (Latin *conulus,* little cone, from Greek *konos*). The members of this group are placed by some with the gastropods. They are known only in the fossil state, chiefly from the Paleozoic (Cambrian to Permian), and are of problematic relationship. The shells in general shape resemble some of the recent pteropods, such as *Styliola;* but they are usually much larger, with thicker walls and variable in form, and generally have transverse septa toward the apical or posterior end.

There are a few forms that the collector will be apt to meet with in the field. Of particular note is the genus *Tentaculites* which is extremely abundant in the Silurian and Devonian (figure 47). The shells are conical, straight or slightly curved, elongate, tapering.

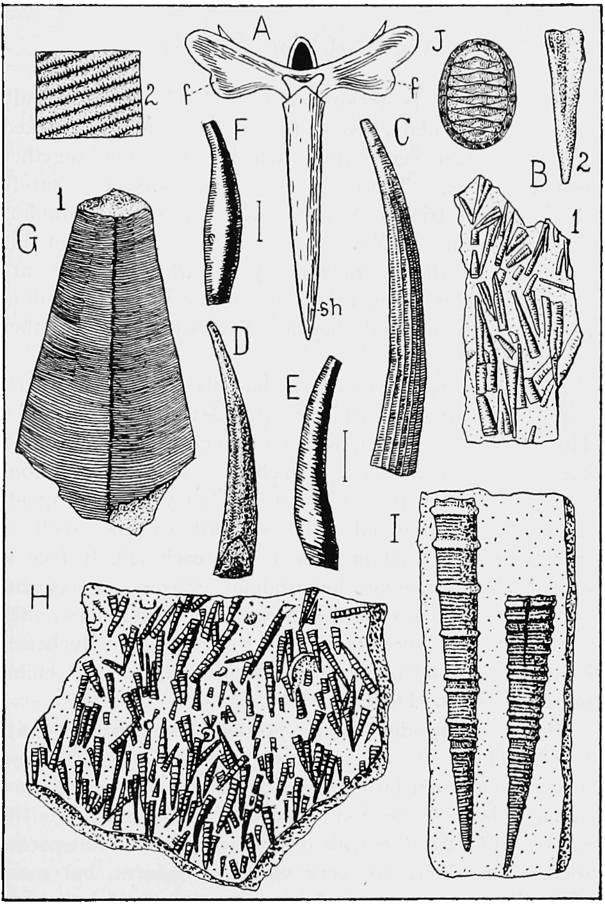


Figure 47 Pteropods, scaphopods, conularids, amphineuran. *A* Recent pteropod, *Styliola*, enlarged: *f* Foot; *sh* Shell. *B* 1 and 2 Devonian form (*Styliolina*) with enlargement. *C—F* Scaphopods or Elephants' Tusk Shells: *C* Miocene, *Dentalium*, x2; *D* Devonian, *Dentalium*, enlarged; *E*, *F* Eocene and Miocene, *Cadulus*. *G—I* Conularids: G 1 and 2 Devonian, *Conularia*, x⅔, with enlargement of surface; *H*, *I* Silurian (Manlius), *Tentaculites gyracanthus* with enlargement (x4). *J* A chiton or amphineuran, *Chaetopleura*, from Atlantic Coast. (*A*, *C—F* from Grabau & Shimer; *B*, *G—I*, after Hall; *J* after Verrill & Smith)

They terminate posteriorly either acutely or in a bulb and have a circular cross section. The surface is marked by strong transverse rings which are closer together near the apex. There are also fine transverse, rarely longitudinal, striae. Anyone collecting in the Manlius beds (Silurian) of New York is sure to come upon this form (*Tentaculites gyracanthus*), for whole surfaces are covered with it. Several species occur in the Hamilton beds (Devonian) and they are likewise found in other formations.

Another genus, *Conularia,* has its maximum distribution from the Ordovician to the Devonian (figure 47). This is a larger form, which in some regions attains a length of 20 cm (about 8 inches). The shell is elongate-pyramidal with a cross section varying from quadrangular to octagonal. The surface of the shell is transversely striated or ribbed, and each lateral face is marked by a median longitudinal groove. Specimens may be looked for in the New York formations, such as the Trenton limestone in the Ordovician, the Rochester shale in the Silurian and the Helderbergian and Hamilton beds in the Devonian.

Class Pteropoda (Greek *pteron,* wing; *pous* (*pod*), foot). These are free-swimming mollusks, moving about in the open ocean by flapping movements of the anterior, finlike lobes of the foot, which give the name to the class. They may be with or without a thin, transparent shell. The shells are very variable in form, but more often they are symmetrical, conical or pyramidal, straight or sharply bent. Pteropods lead a pelagic life, rising to the surface in vast numbers toward nightfall. The accumulation of shells on the sea floor forms pteropod ooze (figure 47).

A living form, known from the Tertiary, is the little *Clio,* which occurs in immense swarms in both northern and southern seas. The shell is a thin tapering tube about an inch long. *Styliola* is another living form. As fossils the pteropods are most typically represented in the Mesozoic and later deposits. They are represented in the Devonian by one family to which the genus *Styliolina* belongs. One species (*S. fissurella*) is especially abundant in the lower Genesee (Upper Devonian) of New York, where the minute shells make up the *Styliolina limestone.* It is found in other Upper Devonian beds in New York and is also abundant in the Marcellus shale (Middle Devonian).

Phylum Arthropoda

(Greek *arthron,* joint; *pous (pod),* foot)

The phylum Arthropoda is a large and important group of animals, including lobsters, crabs, spiders, insects etc. (figures 48–62). The forms grouped here have elongate, transversely segmented bodies with more or less perfect bilateral symmetry; the mouth and anus are at opposite ends of the elongated body, and there is a central nervous system consisting of a dorsal brain above the oesophagus, connected by nerves around this with a double ventral chain of ganglia, segmentally arranged. The important advance in this group over the segmented worms is the presence of a pair of jointed appendages on a few or most of the body segments. Eyes are simple or compound, and are nearly always present. The skin secretes an outside skeleton (exoskeleton) of a horn-like substance, chitin, which may be reinforced by calcareous deposition. Since this exoskeleton is rigid, growth can take place only through shedding or molting of the chitin. The body cavity between the exoskeleton and the internal organs is in free communication with the circulatory system from which it is developed. It consists largely of space, the blood sinuses (Latin *sinus*, hollow). The heart, which is usually present and elongate, is situated in a blood sinus from which the blood enters through valvular openings.

The phylum is divided into two subphyla according to whether they are mostly water breathers or air breathers. The Crustacea belong in the first division; the Arachnida, Myriopoda and Insecta in the second division. Of all the divisions, the subclass Trilobita of the class Crustacea and the subclass Merostomata (Eurypterids) of the class Arachnida contain the forms which are of most importance to the beginner in paleontology and particularly to the student of New York paleontology. Therefore the trilobites and the eurypterids will be treated more fully here.

Class Crustacea (Latin *crusta*, shell). This group includes the Trilobites (only found fossil) Crayfishes, Lobsters, True Crabs, Shrimps, Wood-lice, Barnacles, Water Fleas, etc. The forms belonging in this class are usually aquatic and carnivorous. The body is divided into three regions: head, thorax and abdomen; and the whole with the appendages is covered externally with a chitinous cuticle or exoskeleton. Sometimes more or fewer of the thoracic segments are fused with the head to form a *cephalothorax* (Greek *kephale*, head; *thorax*, thorax) which is covered by a chitinous shell or carapace. Where there is no movement the crustacean skeleton becomes thickened and sometimes calcified. Where movement is necessary, as between the segments of the body and appendages, the chitin is thin and flexible. The head, thorax and abdomen bear appendages of various kinds. Respiration takes place either by the general surface of the body or by gills, which are hollow offshoots of the thoracic wall or of the thoracic and abdominal appendages. The digestive canal in the anterior and posterior portions is lined with chitin which is continuous with that of the exoskeleton; the middle unlined portion gives rise to digestive glands. The nervous system is typical of the phylum. The vascular system includes a contractile heart which forces the blood through the arteries to the surface of the body whence it is returned through sinuses and veins passing through the gills on the way. Sexes are separate or united. The young pass through a series of larval stages. The young animal increases in size through successive molts. The food of crustaceans consists largely of decaying animal matter.

The common *crayfish* is usually taken as the type of the class in the study of this group (figure 48). It lives in fresh-water lakes, rivers and pools. Two genera are found in the northern hemisphere. One (*Cambarus*) occurs in North America east of the Rockies; the other (*Astacus*) is found in North America west of the Rockies and in Europe and Western Asia. Either genus is typical; but the one described here is *Cambarus,* the genus found in the east.

The body of the crayfish is divided into two regions: an anterior, the cephalothorax, which is unjointed and covered by a *carapace;* and a posterior, the abdomen, which is divided into distinct, movable segments. The cephalothorax is again divided into two regions, head and thorax, by a transverse depression known as the *cervical groove* (Latin *cervix,* neck). The carapace is composed of chitin but is so strongly impregnated with carbonate of lime as to be hard and but slightly elastic. It is free only over the sides of the thorax where it forms a flap or *gill-cover* on each side, and it is produced in front into a large median spine, the *rostrum*. Immediately below the rostrum is a plate which bears two movably

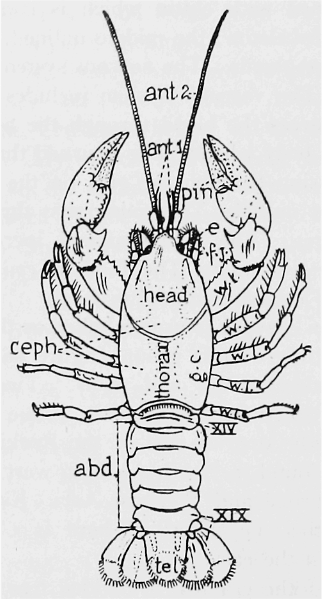


Figure 48 Crustacean. Dorsal view of the common crayfish (*Cambarus bartoni*), x⅗. *abd.* Abdomen; *ant 1* Anterior antennae; *ant 2* Posterior antennae; *ceph* Cephalothorax; *e* Eye; *f.j.* Foot jaws; *g.c.* Gill cover; *pin* Movable arm of pincer; *tel* Telson; *wl* Walking legs; *xiv* Fourteenth body segment (first abdominal segment); *xix* Nineteenth body segment. (From Introduction to Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

articulated cylindrical bodies, the *eye-stalks*, at the ends of which are the eyes. The body is composed of twenty segments which bear nineteen pairs of appendages on the under side. The head consists of five segments, the thorax of eight and the abdomen of seven.

The appendages are greatly differentiated. The head bears a pair each of *antennules* and *antennae*, one of *mandibles* or *jaws* (Latin *mando*, to chew) and two of *maxillae*, (Latin *maxilla*, the jaw). The thorax has eight pair of appendages; three small anterior pairs, the *maxillipeds* or *foot-jaws*, which have their bases toothed to aid in passing the food obtained by them forward to the mouth; five large posterior pairs, the *walking legs*, of which the first (anterior) pair are very large and terminate in huge claws or *chelae* (Greek *chele*, claw) which give to them the name *chelipeds*. The abdomen bears appendages on six segments, the last or seventh being known as the *telson*. In the female the first five pairs of appendages are small *swimming feet* or *pleopods* (Greek *pleo*, to swim). The sixth pair are much larger and consist each of two flattened parts which form with the telson the five-lobed *tail-fin* which is capable of being spread out in the manner of a fan. These appendages are called *tail-feet* or *uropods* (Greek *oura*, tail). In the male the first two pairs of swimming feet are modified into special sexual appendages. The typical appendage consists of one or more basal joints which divide into two branches, a ventral or inner, a dorsal or outer. The latter is largely respiratory in function and is not present in the walking legs, the mandibles or first maxillae.

The muscles are attached to and supported by the external skeleton. The muscular system is well-developed.

In the abdomen the muscles are of great size and are divisible into a smaller dorsal and a larger ventral set. The respiratory, blood circulatory, nervous and digestive systems have been touched upon in the description of the group and need not be taken up here. The food of the crayfish varies. It may be plant or animal, living or dead; but largely it is decaying animal matter. Crayfish eat the stonewort (*Chara*) a fresh water alga, because of their need for lime. The food is torn to bits by the toothed edges of the mandibles. A single plate, the upper lip, *labrum* or *hypostome* (Greek *hyper*, above; *stoma*, mouth) bounds the mouth anteriorly; a pair of delicate lobes, the *lower lip* or *metastome* (Greek *meta*, after, behind) bounds it posteriorly.

The sense organs include those of touch, sight and possibly smelling and hearing. Setae on the antennae and in many other parts of the body have the sense of touch. The eye is compound, composed of many four-sided facets. The antennules contain two sensory organs to which are attributed the functions of smell and hearing. The organ of smell is constituted by a number of extremely delicate setae borne by the antennules. The organ of hearing is formed by a saclike inbending of the surface chitin in the proximal segment of the pair of antennules. It has been shown that one function of this organ is the maintenance of equilibrium.

The sexes are separate in the crayfish. The adult sheds its exoskeleton about once a year but molting occurs more often during the rapid growth of youth. In molting, not only is the external chitinous covering shed, but also the chitinous lining of the oesophagus, stomach and intestine. Some of this internally shed chitin is redigested.

Crustaceans are abundant in the fossil state, and are known from the earliest formations to the present. The class is divided into the following subclasses: Trilobita, Branchiopoda, Ostracoda, Copepoda, Cirripeda, Malacostraca and Stomatopoda. The Copepoda and Stomatopoda will not be treated here. The former subclass has no fossil representatives; the latter is known from the Carboniferous (Pennsylvanian) to the present and is represented today by *Squilla,* the Mantis shrimp (Jurassic to present), which is known from Cape Cod to Florida.

Subclass Trilobita (Greek *treis* (*tri*), three; *lobos,* lobe). The trilobites are an extinct class of primitive crustaceans entirely incased in a protective, chitinous skeleton, which consists of a thick dorsal shield, a very thin ventral membrane and the covering of the body appendages (figures 49–51). The body is depressed, more or less oval in outline and divided into three parts; the *head, thorax* and *abdomen.* A median elevated ridge and the depressed lateral portions give the trilobation from which the group derives its name (figure 49).

The anterior portion of the dorsal shield or carapace is the headshield, also known as the *cephalon* or *cephalic shield.* It consists of three pieces: a medium raised region, the *glabella,* with the *fixed cheeks* and two *free cheeks;* all three united by thin chitinous joints. The glabella is of varying outline; it is bounded on each side by a *dorsal furrow* and more or less divided by *transverse furrows* or pairs of furrows which probably indicate the presence of four or five segments. The free cheek is separated from the fixed cheek by the *facial suture.* The *compound eyes* are situated on the *free cheeks.* At the anterior margin the cephalon is folded down and back,

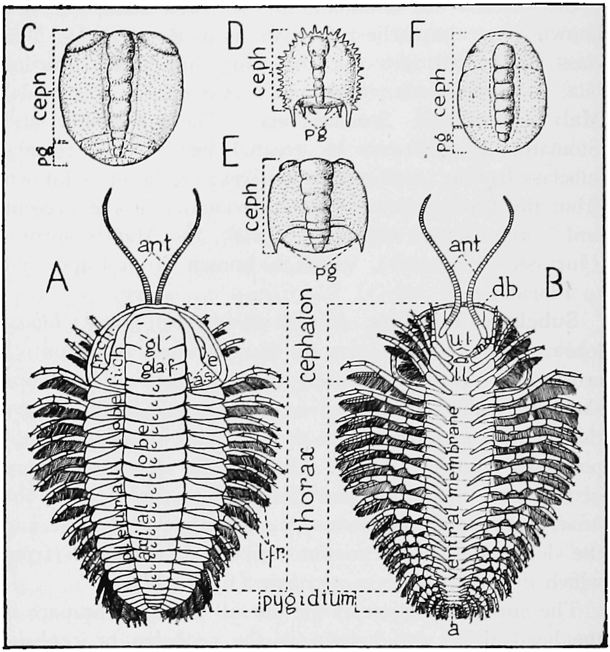


Figure 49 Trilobites. *A, B* Dorsal and ventral views of the Middle Ordovician *Triarthrus becki* (*catoni*), xl. *C—E* Larval stages of trilobites, much enlarged: *C* Ordovician (*Proëtus*) ; *D* Devonian (*Acidaspis*) ; *E* Ordovician (*Dalmanitina*). *F* Ordovician *Triarthrus becki* (*catoni*), *a* Anus; *ant* Antennules or feelers; *ceph* Cephalon or head segment; *db* Doublure; *e* Eye lobe protecting compound eye; *fa.s.* Facial suture; *fi.ch.* Fixed cheeks; *fr.ch.* Free cheek; *gl* Glabella; *gla.f.* Glabellar furrows; *l.fr.* Limb fringe for swimming and respiration; *l.l.* Lower lip or metastome; *mo.* mouth; *pg* pygiddium; ; *u.l.* Upper lip or hypostome. (After Beecher from Textbook of Paleontology by Zittel-Eastman, published by The Macmillan Co.)

forming the *doublure*, to which is attached the upper lip or *hypostome*. Posterior to this is the lower lip or *metastome*. The doublure continues backward and is often produced into solid or hollow *genal spines* (Latin *genae*, cheeks).

The middle portion of the carapace, the *thoracic shield*, consists of a variable number of divisions or *segments*; from two in *Agnostus* to twenty-nine in *Harpes*, all united by chitinous joints and commonly permitting the power of enrolment. Each segment is divided by two furrows into a middle, often-raised portion, the *axis*, and two lateral divisions or *pleura* (Greek *pleuron*, rib), so that the shield is divided into an *axial lobe* and two *pleural lobes* which are continued into the abdominal shield.

The abdomen is covered by a *caudal shield* (Latin *cauda*, tail) or *pygidium* (dim. from Greek *pyge*, rump). The pygidium consists of a single piece due to the welding together of a number of similar segments, and comprising a *central axis* and *lateral lobes*. *Transverse furrows* are commonly shown on the axis and lobes, and sometimes they are so strongly marked that it is difficult to make a division line between the thorax and pygidium. The pygidium is sometimes prolonged into a *caudal spine*.

Probably all trilobites had jointed appendages consisting of *antennae*, *mouth parts*, *legs* and *gill fringes*, comparable in general with the appendages of some of the lower orders of modern crustaceans. The appendages are known in only a few cases (*Isotelus*, *Ceraurus*, *Calymene*, *Neolenus* etc.), but they have been elaborately worked out in the case of *Triarthrus becki* (=*eatoni*), which has been called the daddy-long-legs of the trilobites because of its unusually long legs (figure 49). They are shown in the restoration. There is a single pair of antennae, the *antennules* or *feelers,* and four pairs of two branched (biramous), leglike cephalic appendages. Each segment of the thorax bears a pair of slender, biramous legs bearing ~~spiral~~ gills, and similar limbs are present on the abdomen. The legs have one branch adapted to crawling and another, less jointed and fringed along its posterior border by lamellaelike setae, adapted both to swimming and respiration.

The organs of sight vary greatly in trilobites. Most of the trilobites have compound eyes (figure 50) of varying size, situated on the free cheeks. The facets composing the compound eyes vary greatly in size and numbers. The compound eyes are of two kinds: those in which each separate facet is covered with a horny, protective layer or cornea, and those in which the whole visual area is covered with a continuous horny layer. In the first type the number of facets vary in the different genera from a few to 600; in the second type there may be as many as 4000, 12,000 or even as high as 15,000 facets. In some genera of trilobites the eyes are so imperfectly shown that for a long time they were unrecognized. Certain genera lack the ordinary compound eyes and have only simple eyes, represented by one to three elevations or granules on the fixed cheeks at the ends of the eyelines. A median, simple eye is present on the glabella of some genera, in the majority of cases appearing as a single tubercle (figure 50). This tubercle has been found in upward of thirty genera and in most of the families of trilobites. Some genera of trilobites were long considered blind, and it is interesting to note that these genera are apt to show the median eye tubercle most distinctly. There is a direct relation between the character of the eyes and the habits of the trilobites. Swimming and crawling

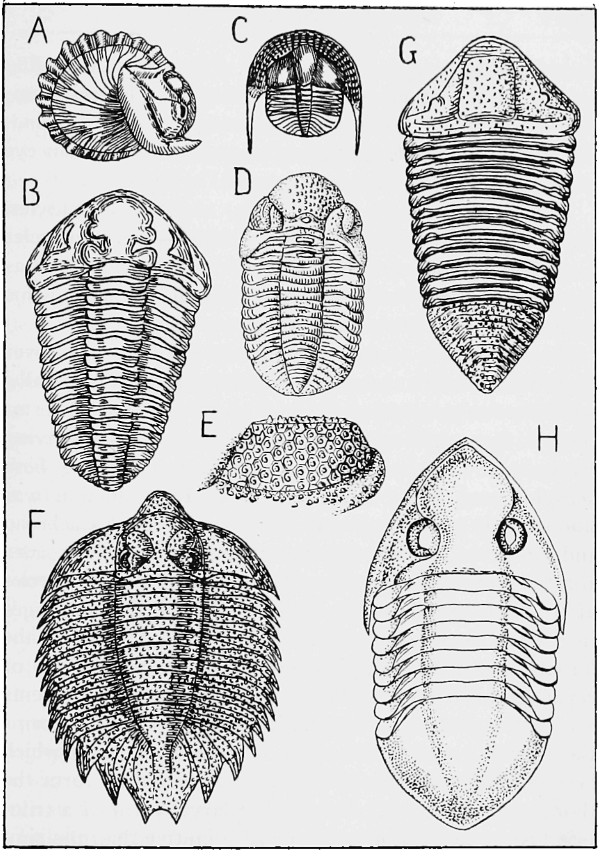


Figure 50 Trilobites. *A, B* Silurian *Calymene,* showing enrolled form. *C* Ordovician *Trinucleus,* lacking compound eyes. *D* Devonian *Phacops.* *E* Compound eye of the same, x3. *F* Silurian *Lichas* (*Arctinurus*), x½. *G* Devonian *Homalonotus,* x½. *H* Ordovician, *Isotelus.* (*A* from Geol. Ohio; *B, D, E* from Paleontology, N. Y.; *C, H* from Grabau & Shimer; *F* after original; *G* from Schuchert: Historical Geology, permission John Wiley & Sons)

forms had large eyes (*Dalmanites, Phacops*); burrowing forms, on the other hand, often lost their lateral, compound eyes and became either entirely blind (*Conocoryphe, Elliptocephalus*) or still retained the median eye on the glabella (*Trinucleus, Agnostus*).

Trilobites possessed paired dorsal and ventral muscles. Many forms by the contraction of the ventral muscles had the power of enrolment (figure 50), which served as a means of protection to the soft ventral surface. Some forms possessed this power only to a limited degree.

The alimentary canal begins at the mouth, curves over backward beneath the glabella and then extends parallel with the dorsal shield to the anal opening in the posterior end of the pygidium. Judging by the food of living crustaceans the trilobites were carnivorous, eating both decaying and living animal matter. Reproduction was undoubtedly sexual. Frequently a species shows a broad and a narrower form, and it is probable that the broader form represents the female. The larvae of several species of trilobites have been found fossil and the various stages in growth have been studied (figure 49). Some of the larval forms, in the youngest stages, consist only of cephalic shield and pygidium and the thoracic segments are subsequently added in regular order. In other forms the earliest stage is like a rounded plate in form which becomes elongated posteriorly and segments to form the thorax and abdomen. The earliest larval form of a trilobite (from the Cambrian) is more primitive than the simplest larval form of living crustaceans. Species of trilobites vary greatly in form and size, some of them attaining giant size. The group includes some very peculiar forms; partly monstrous shapes, partly highly ornamented, spinose forms.

The dorsal shield is the part of the trilobite usually found fossil, and even this is comparatively seldom found whole, as the parts are easily separable. The appendages and ventral membrane are seldom preserved because of their delicate nature. Many of the trilobite remains found are molted skins.

As already stated, the trilobites were undoubtedly marine animals, since their remains are only found in salt-water deposits associated with such typically marine forms as brachiopods, cephalopods, crinoids etc. Trilobites are primitive crustaceans, and they show their primitive nature in the great number of segments and in the fact that each segment bears a pair of appendages, as illustrated by *Triarthrus becki*. Like crabs they were in part crawlers and in part swimmers and many also burrowed in the mud. This difference in habit caused a great variety in form and also affected the development of the eye, as noted above. Some forms are abundant in calcareous or argillo-calcareous deposits associated with thick-shelled brachiopods, reef-building corals etc. and so could not have lived at any considerable depth. The bottom crawlers frequented sandy or muddy bottoms, while the burrowers lived partly buried in the soft mud. The absence of eyes in some species indicates comparatively deep water habitat. Species that both crawl and swim are restricted neither to the shore nor to the bottom, which explains their occurrence in very different sediments.

Trilobites had their origin in Precambrian times. Their remains are very abundant in the Cambrian, the oldest known fossiliferous strata. During this time they were the dominant form of animal life, exceeding all others in number and diversity. Trilobites are restricted to Paleozoic times. The fact that there have been over two

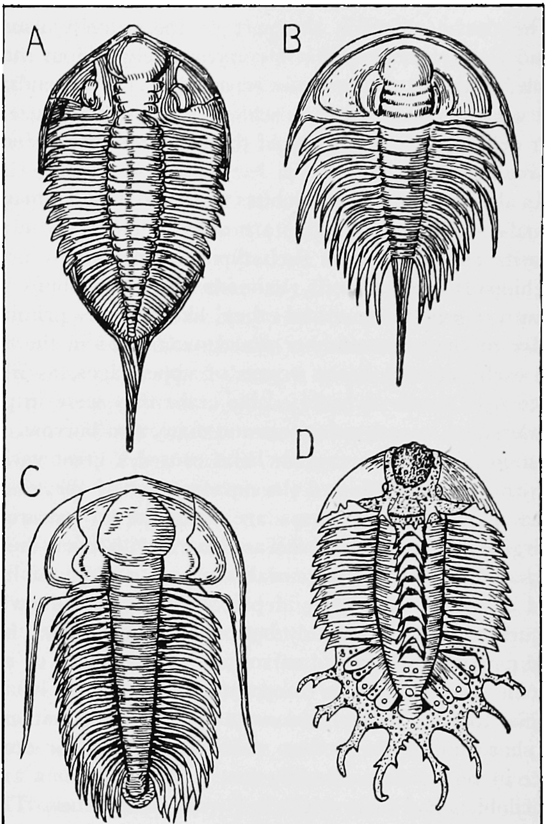


Figure 51 Trilobites, including some of the largest and most grotesque forms. *A* Silurian *Dalmanites*, x5/6. *B* Cambrian *Olenellus*, x1/3. *C* Cambrian *Paradoxides*, x1/5. *D* Devonian *Terataspis*, x1/12. (*A* from Textbook of Paleontology by Zittel-Eastman, published by The Macmillan Co.; *B—D* from Schuchert: Historical Geology, permission John Wiley & Sons)

thousand species and nearly two hundred genera will give some idea of the amount of differentiation and specialization in the group. The greatest development of the trilobites occurred in the Cambrian and Ordovician; they were plentiful in the Silurian but declined in the Devonian, and a few last survivors are found in the Carboniferous and Permian. Some of the genera are of cosmopolitan occurrence, but for the most part the different forms have an extremely limited distribution.

Some of the largest and also most grotesque trilobites are found in the rocks of New York State and natural size models of these (*Terataspis grandis, Dalmanites myrmecophorus,* and *Homalonotus major*) are exhibited in special cases in the State Museum. Two of them (*T. grandis* and *H. major*) are also shown in the Lower Helderberg restoration case (figures 5, 51). Trilobites are also exhibited both in the synoptic cases and in special exhibition cases. The exhibit of trilobite material is very complete and covers the primitive forms; peculiar forms, partly of monstrous shapes and partly of extreme spinosity; enrolled forms; forms with genal and caudal spines especially developed and with a peculiar frontal extension of the head shield. *Triarthrus becki* is shown with appendages, and growth stages of this and other species are exhibited. There is also a special exhibit of species showing the median or parietal eye on the apex of the glabella together with a compound eye showing the numerous lenses. Trilobites may be collected from most of the New York formations, shales and limestones particularly, from the Cambrian upward.

Subclass Branchiopoda (Greek *branchia,* gills, *pous* (*pod*), foot). This subclass with the two following, Ostracoda and Cirripedia, are by some placed together

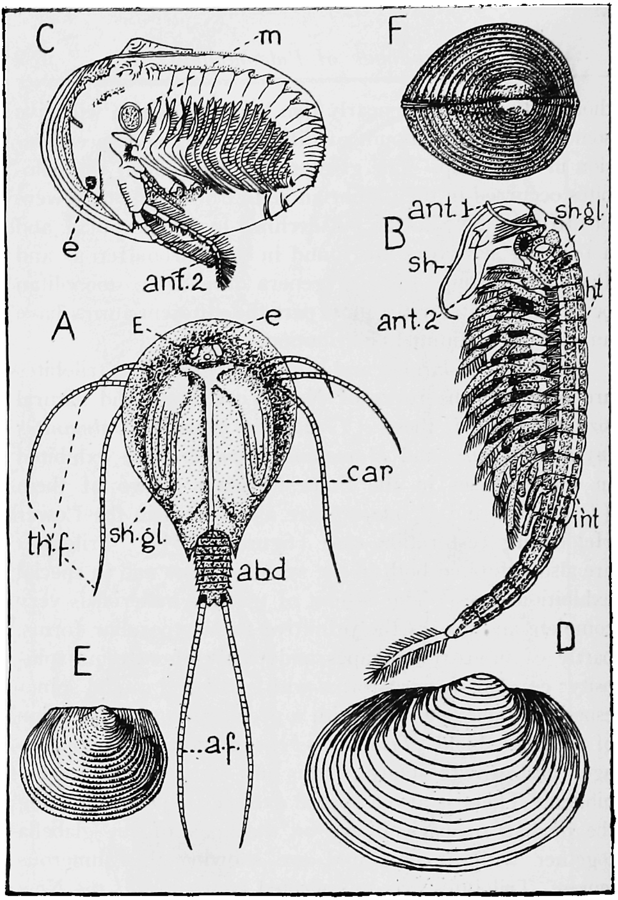


Figure 52 Branchiopods. *A Apus,* dorsal aspect. *B Branchipus,* lateral view. *C Estheria,* Animal in the shell with one valve removed, x5. *D* Exterior of one valve of same, x5. *E* Fossil *Estheria,* x4; Upper Devonian (after Clarke). *F Schizodiscus,* x2; Middle Devonian (after Clarke). *abd* Abdomen; *a.f.* Caudal styles (abdominal furca); *ant. 1* Antennule; *ant. 2* Antenna; *car* Carapace; *e* Eye; *e'* Median eye; *E* Paired eye; *int* Intestine; *ht* Heart; *m* Adductor muscle; *sh* Shell; *sh.gl.* Shell gland; *th.f.* Thoracic foot. (*A, B* from Textbook of Zoology by Parker & Haswell; *C, D* from Introduction to Study of Fossils by H. W. Shimer; published by The Macmillan Co.)

in one subclass (Entomostraca) as orders or super-orders. By others the name Phyllopoda (Greek *phyllum*, leaf) has been used for the subclass, but usually it is used as the name of a division of the Branchiopoda or it has been split up into several divisions. This is a primitive group and the forms included here are usually crustaceans of small size (figure 52), such as *Branchipus*, *Apus*, the Brine Shrimps (*Artemia*) and the Water Fleas (*Daphnia*). The carapace may be absent (*Branchipus* and *Artemia*), shield-shaped (*Apus*, *Lepidurus*) or a bivalve shell (*Estheria*, *Daphnia*). There are long-bodied forms with at least ten pairs of postcephalic limbs and short-bodied forms with not more than six pairs of postcephalic limbs. The legs are generally leaflike and lobed and usually carry gill plates, hence the name Phyllopoda or Branchiopoda. The posterior part of the body is without limbs and usually ends in a *caudal furca* or *tail fork*, the branches of which may be filiform, flattened or clawlike. The segmentation of the body in the larger forms is very distinct, but in the water fleas is usually quite incomplete. The sexes are distinct in these forms, but the males are often much less numerous than females, sometimes not appearing over a period of several years, and the females reproduce largely by *parthenogenesis* (Greek *parthenos*, virgin; *genesis*, origin).

These crustaceans live mostly in fresh water or salt lakes, although some are marine. Some species of *Branchipus* and *Estheria* occur in salt pools but the brine shrimps (*Artemia saliva*) are even found in the south of Europe in swarms in shallow brine pans from which salt is commercially prepared. The water fleas belong to the floating fauna of fresh waters and seas; a few live near the bottom at considerable depth and a few are littoral in habits, clinging to water weeds near the shore. The great majority of the Branchiopoda inhabit fresh water, however, many of the forms living in stagnant shallow waters, especially ponds which are formed during spring rains and dry up in summer. The eggs dry up in the mud and hatch out in the next rainy season. They may be carried great distances by wind, on the legs of birds etc. Two kinds of eggs are produced by many of the forms: thin-shelled, parthenogenetically produced eggs; thick-shelled, sexually produced eggs which alone can survive cold and drought.

Branchiopoda are known in the fossil state (figures 2, 52) from the Cambrian to the present. Very beautiful material has been collected in the Middle Cambrian of British Columbia by the late Doctor Walcott and some of these specimens are on exhibition in the Cambrian case in the State Museum. Branchiopods are not found abundantly in the fossil state. The soft-bodied forms are not known fossil. *Apus,* which is one of the most primitive of living crustaceans, is known from the Permian to the present. Today, though not common. it is present in the fresh waters of nearly every portion of the world. The most numerous fossil remains are of those forms having hard shells or carapaces and they are known in beds of all ages from the Devonian to the present. Two genera may be met with in the Devonian beds of New York. *Estheria* in the Upper Devonian (Oneonta-Catskill) beds and *Schizodiscus* in the Middle Devonian (Hamilton) beds. *Estheria* has a horny shell of two thin. rounded, inequilateral valves. The surface of each valve is covered with concentric ridges. *Schizodiscus* has a bivalved. shield-shaped carapace. Each valve is nearly a semicircle, with concentric ridges marking the surface.

Subclass Ostracoda (Greek *ostrakon,* a shell; *eidos* (*oid*), form). These are small to minute crustaceans, indistinctly segmented and completely inclosed in a horny or calcareous bivalve shell which corresponds to the carapace of other crustaceans (figure 53). The valves may be of equal size, but they are usually unequal and, as a rule, fit closely with the edge of one valve within a groove at the margin of the other. An eye tubercle, situated antero-dorsally, is often present. The surface of the shell may be smooth or modified by nodes, tubercles, lobes or furrows; it may be pitted or sculptured etc. The posterior part of the shell is usually thicker than the anterior and sometimes of less height. The minute size, the unequal valves, external sculpturing, the absence of concentric growth lines and the presence of the eye spot distinguish the ostracod shell from the pelecypod shell. Ostracods, except for one or two families, are restricted to marine or brackish waters. The common *Cypris* of our ponds is a fresh-water representative. Ostracods are gregarious. They usually prefer shallow depths. They may be found creeping over the bottom or swimming near the surface in vast hordes.

Fossil ostracods (figure 53) are found in nearly all the principal formations and are abundant from the Ordovician to the present. Often they are important as rock builders. They are difficult to identify on account of their size and the similarity of form and ornamentation. These fossils are to be found in beds of all the periods in New York State. One species, *Leperditia alta,* is abundant in the Manlius (Silurian) of New York and there will be no difficulty in the identification of this form. Several genera and a number of species may be obtained from the Hamilton beds (Devonian), some of them not too difficult of identification.

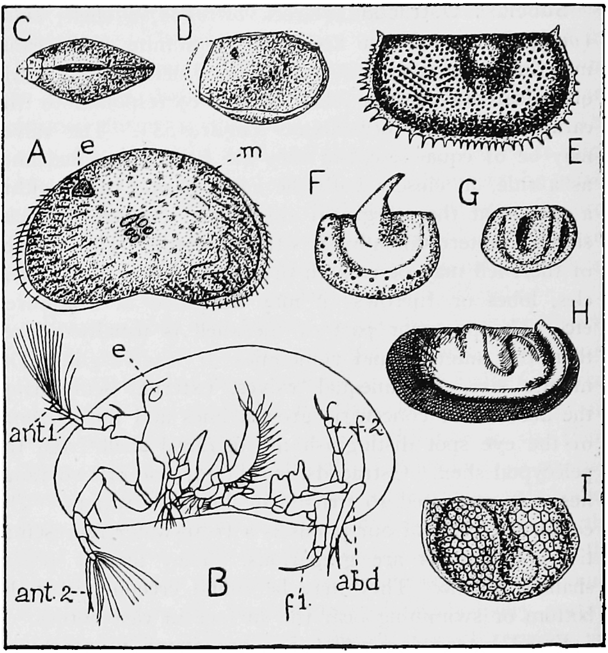


Figure 53 Ostracods. *A Cypris,* external view. *B* The same, with left shell removed. *abd.* Abdomen; *ant. 1* Antennule; *ant. 2* Antenna; *e* Eye; *f1, f2* Thoracic feet; *m* Adductor muscle. *C—I* Fossil forms: *C, D* Silurian (*Leperditia*) x2; *E* Devonian (*Kloedenia*), left valve, x14; *F* Silurian (*Aechmina*), right valve, much enlarged; *G* Silurian (*Bollia*), x7; *H* Ordovician (*Drepanella*), left valve, x10; *I* Devonian (*Primitia*), left valve, x18. (*E—I* from Grabau & Shimer. *A, B* from Textbook of Zoology by Parker & Haswell; *C, D* from Introduction to Study of Fossils by H. W. Shimer; published by The Macmillan Co.)

Subclass Cirripedia (Latin *cirrus*, fringe; *pes* (*ped*), foot). The cirripedes are medium-sized marine crustaceans which are all either attached in the adult stage or parasitic. The forms in this group most familiar to us are the Goose Barnacles and the Acorn or Sessile Barnacles (figure 54). The *Goose Barnacle* (*Lepas*) is attached by a long stalk or pedicle which is covered with a wrinkled skin. The body proper is covered by a bivalved carapace consisting of a fold of the skin strengthened by five calcareous plates: one medium and dorsal, two lateral and proximal, and two lateral and distal. During life the carapace is partly open and through this ventral aperture protrude the six pairs of thoracic feet, delicate and fringelike in appearance, which keep up a constant grasping movement and are used both for respiration and gathering food. There is an old legend to the effect that the barnacles attached to pieces of floating timber hatched out into barnacle geese, hence the name of this form. Goose barnacles may live at some depth attached to corals etc., but large numbers float on the surface of the sea attached to logs and wreckage of various kinds. The *Acorn Barnacles* (*Balanus*) have no stalk. The whole animal is surrounded by a sort of parapet of six calcareous pieces. Acorn barnacles are familiar to everyone as the hard sharp objects found covering rocks and piles near high water mark on all sea-coasts. Probably the best known form is the *Balanus balanoides* which grows over the whole north Atlantic coast in such enormous numbers and covers the rocks with a white incrustation.

Barnacles are degenerate forms. The young larva is free-swimming. By several molts it passes into a bivalved shell stage, known as the Cypris stage in which it resembles an ostracod. Later it attaches itself to some object by the antennules through a secretion from a gland at their base, and after profound changes becomes transformed into the adult form. The body of the cirripede is imperfectly segmented and the posterior part of the body is vestigial. Many of the living families are naked. A number of cirripedes are parasitic, one form living embedded in the skin of whales, another in the skin of sharks, and still another is entirely parasitic on crabs etc. Most barnacles inhabit shallow water, but certain genera occur at great depth, 1900 to 2000 fathoms.

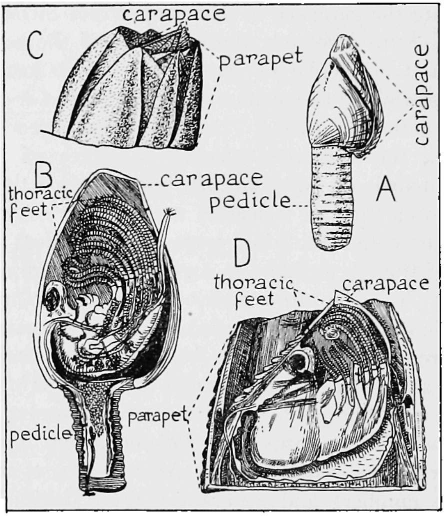


Figure 54 Cirripedes. *A* The Goose Barnacle, *Lepas*, external view (after Darwin). *B* The same, showing anatomy (after Claus). *C* The Acorn Barnacle, *Balanus*, external view. *D* The same, showing anatomy (after Darwin and Claus; from Textbook of Zoology by Parker & Haswell; Cambridge Natural History ed. by Harmer & Shipley; published by The Macmillan Co.)

Only those forms are found fossil which possess shells. Including supposed fossil barnacles they are known from the Ordovician to the present, but they occur sparingly in the older strata. The acorn barnacle (*Balanus*) is known from the early Tertiary (Eocene) to the present. Supposed ancestral acorn barnacles have been described from the Ordovician. From the Ordovician also (Trenton; Snake Hill shale) has been described, as the earliest barnacle known, *Eopollicipes siluricus*. The goose barnacle (*Lepas*) is known from the Late Tertiary (Pliocene). Species of barnacles in the New York formations have been described from the Ordovician (Utica and Trenton beds), Silurian (Rochester shale) and Devonian (Helderbergian, Onondaga limestone, Hamilton shales). Several species have been described from the Hamilton shales including an early spiniferous barnacle (*Strobilepis spinigera*). *Balanus* is fairly abundant in the Pleistocene deposits of the Champlain and St Lawrence Valleys. The barnacle nature of all the above forms, except *Balanus* and *Lepas,* has recently been questioned, and it is even believed that there is no real evidence that they are cirripedes at all. They have been placed together in a new group, suggesting no relationship, to which the name Machaeridia has been given because of the saber or blade-shaped form of the fossils (Greek *machairidion,* diminutive of *machaira,* saber).

Subclass Malacostraca (Greek *malakos,* soft; *ostrakon,* shell). This group comprises marine, brackish water, fresh-water and terrestrial forms (figure 55). Among the smaller forms are the Phyllocarids, Fresh-water Shrimps, Sandhoppers, Wood Lice, Pill Bugs; among the larger forms are Prawns, Shrimps, Lobsters, True Crabs, Hermit Crabs, Coconut Crabs, Fresh Water Crayfishes,

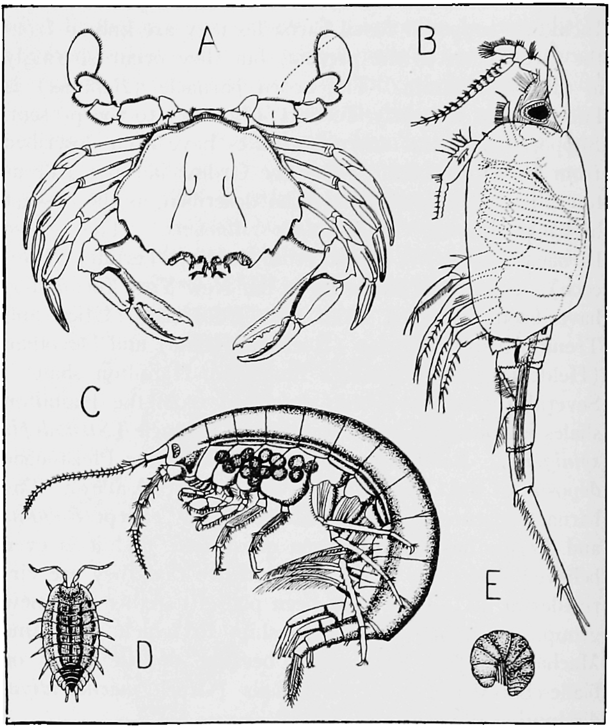


Figure 55 Living Malacostracan crustaceans. *A* Crab (*Platyonichus*), much reduced (after Verrill & Smith). *B* Shrimplike marine form, (*Nebalia*), enlarged. *C* Fresh-water shrimp, *Gammarus*, enlarged. *D* Wood louse, *Oniscus*, x1. *E* "Pill bug," *Armadillidium*, x1. (*B—E* from Textbook of Zoology by Parker & Haswell, published by The Macmillan Co.)

Sea Crayfishes etc. It will be unnecessary to go into a description of this group. The description of the crayfish *Cambarus* given above will serve here, and most readers are familiar with the appearance of the larger representatives of the group. The phyllocarids, which include the little shrimplike, marine crustacean *Nebalia,* are linking forms between the Branchiopods and the Copepods on the one hand, the higher Crustacea on the other. The shrimplike fresh-water crustaceans, while probably not familiar, are easily recognized as such when found, and sandhoppers soon become familiar to anyone who knows the beaches. Pill bugs or common garden wood lice (*Armadillidium*) are found in damp places under boards and stones. They derive their name from the fact that they roll up into a ball, when disturbed, like an Armadillo. Wood lice (*Oniscus*) are allied forms and are found in woods under pieces of wood, stones etc., that have lain undisturbed on the ground for some time. They are almost unique among the Crustacea for their perfect adaptation to terrestial life. The highest degree of specialization among the Crustacea is reached in the true crabs with their large and broad cephalothorax and reduced abdomen which is often quite hidden from view as it is flexed into a groove on the ventral side of the thorax.

The Malacostraca are found in varied situations. The terrestrial forms have been touched upon. Although air breathers, they are dependent on moisture and are found only in damp situations. Some forms are found inland but always in the neighborhood of water or under trees in damp moss. Terrestrial forms were probably derived from marine forms. Related forms, more generalized, are found in damp caves and crannies in the rocks along coasts. Sandhoppers have deserted the waters entirely and live in the sand and under rocks on the shore. One peculiar species in England and northern Europe lives in ants' nests. They are supposed to serve as scavengers for the ants.

Fresh-water forms are found in all manner of situations: weed-growing ditches, small ponds, mud of slowly moving streams, deeper pools in swifter streams, shores of lakes, depths of lakes etc. The mountain shrimp lives in deep pools of rivers and tarns on the mountains of southern and western Tasmania at altitudes from 2000 to 4000 feet.

Though other crustaceans are found along seashores, it is the Malacostraca which give the character to the coastal waters. There are shore crabs of various kinds on rocky coasts which hide at low tide in rock pools and under stones. They can live out of water for an astonishing time. Lobsters and the edible crab are dependent on rocks but they prefer depths of a few fathoms and rarely come close in shore. Sandy coasts are preferred by shrimps and prawns and spider crabs are found on muddy shores and bottoms. Coral reefs support a characteristic crustacean fauna. Latitude as well as the geological nature of the coast has a very important bearing on the distribution of littoral forms. The Malacostraca are found in warm and cold waters, from the littoral zone to abyssal regions of the sea. Many of the smaller species are found in the littoral zone wherever rocks are covered with a rich growth of Algae, Polyzoa etc., and others swim in the open sea, under the surface of the water and sometimes at great depth. Some forms burrow and in some the legs are modified for this life and furnished with spines for digging. The hermit crab lives in large gastropod shells, such as the whelk, and the body is modified accordingly. There are a large number of parasitic species, some parasitic only in the larval stage, others parasitic as adults and greatly modified. Some forms are parasitic in the gill chambers of other Crustacea.

The largest living crustacean is the Japanese spider crab which has a spread of legs of 11 feet and more. These creatures do not burrow but clamber among the weeds upon the sea-bottom. The edible blue crab of the Atlantic coasts of America ranges from Florida to Cape Cod. This crab lives along muddy shores, largely upon decaying animal matter. When it molts during the summer it becomes the "soft-shelled crab" of our markets.

The Malacostraca have been found fossil from the Cambrian to the present (figure 56). Some divisions are not known in the fossil state. The phyllocarids are known from the Cambrian; the group to which our pill bugs and wood lice belong is known from the Devonian; but the group to which the crayfishes, lobsters and crabs belong was not differentiated until the latter part of the Triassic. The family to which our crayfish *Cambarus* belongs has existed since the Cretaceous. The crayfish is descended from marine, lobsterlike ancestors. The genus to which the American lobster (*Homarus americanus*) belongs is known from the Cretaceous to the present. This species ranges today from North Carolina to Labrador, from near shore to a depth of 100 fathoms. Little lobsters start in rather deep water, gradually crawl towards the shore where adolescence is passed, and migrate again into deep water on coming to maturity. The body of a lobster increases in size from 13 to 15 per cent with each molt. It has been roughly estimated that a lobster 10 inches long is four years old. Normally a

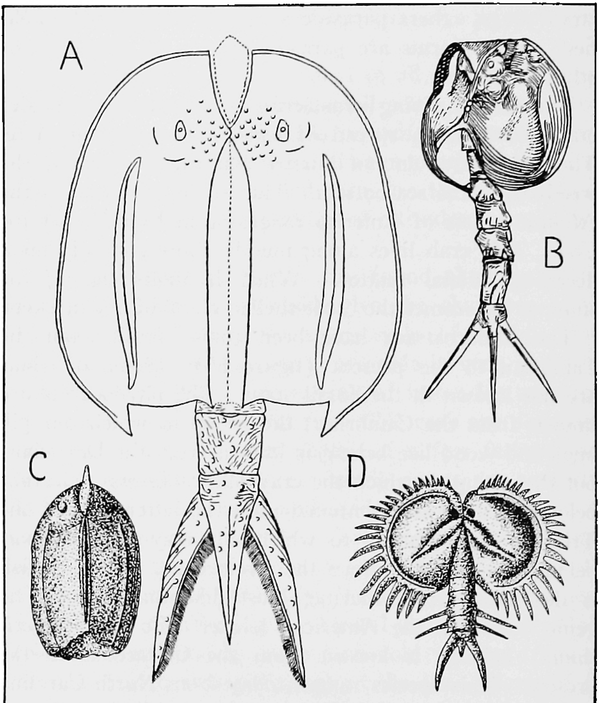


Figure 56 Devonian Malacostracan crustaceans. *A Mesothyra*, x3/8, (after Hall & Clarke). *B Echinocaris*, x3/4 (after Beecher). *C Rhinocaris*, x3/2 (after Clarke). *D Pephricaris*, x3/4 (after Clarke).

female breeds once in two years, and it has been estimated that a 17-inch female will lay about 60,000 eggs at one time.

The rocks of New York State can not offer such enticing catches as crayfishes, lobsters, crabs etc., but other forms of the Malacostraca are present. Our rocks, aside from the trilobites, have afforded a wonderful collection of crustaceans, among them the phyllocarids (figure 56). A special case is given over to the crustaceans in the State Museum and here are found the large carapaces of a strange, crablike phyllocarid (*Mesothyra occani*) from the Devonian rocks. Larger specimens of this species and a restoration of the animal are shown in neighboring cases. Another strange, double-shelled Devonian crustacean (*Echinocaris*) is exhibited in the same case. The gastric teeth of this form have been found and are exhibited still in their proper place. This exhibit also includes the unique and picturesque species (*Pephricaris horripilata*) from the Upper Devonian (Chemung). Other crustaceans are shown in the synoptic cases, particularly in the Salina (Silurian) and Hamilton (Devonian) cases. Several genera and species of phyllocarids are found in Middle and Upper Devonian rocks (Hamilton, Portage, Chemung beds).

Class Myriopoda (Greek *myrios*, countless; *pous* (*pod*), foot). This class comprises the Millipedes, or thousand-legged worms, and the Centipedes, or hundred-legged worms. They are air-breathing arthropods, wormlike in appearance. They have a distinct head bearing a pair of eyes, one pair of antennae and three pairs of jaws, and some are armed with poison fangs. There are numerous similar body segments, each furnished with one or two pairs of legs, hence the name (figure 57).

Myriopods are found fossil from the Devonian to the present. The amateur collector is not apt to meet with these forms. No representatives have been found in New York rocks.

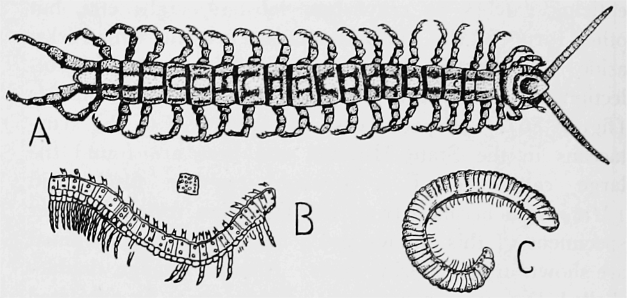


Figure 57 Myriopods. *A* Living form (*Scolopendra*). *B* Carboniferous species (*Euphoberia*). *C* Tertiary (Oligocene) form (*Julus*). All x¾. (*A* from Textbook of Zoology by Parker & Haswell; *B, C* from Textbook of Paleontology by Zittel-Eastman; published by The Macmillan Co.)

Class Arachnida (Greek *arachne,* a spider). The name of this class is taken from one of the typical representatives, the spider. The class is divided into two divisions or subclasses: a water-breathing division (Merostomata: Greek *meros,* thigh; *stoma,* mouth) which includes the Eurypterids, the King or Horseshoe Crab and fossil members of the same order, and fossils of an imperfectly known order from the middle Cambrian of British Columbia; an air-breathing division (Embolobranchiata: Greek *embolos,* inserted; *branchia,* gills) covering all the other orders and including the Scorpions, Spiders, Mites, Ticks etc. This class by some has been given a different nomenclature, but the nomenclature used here is the more generally accepted (figures 58–62).

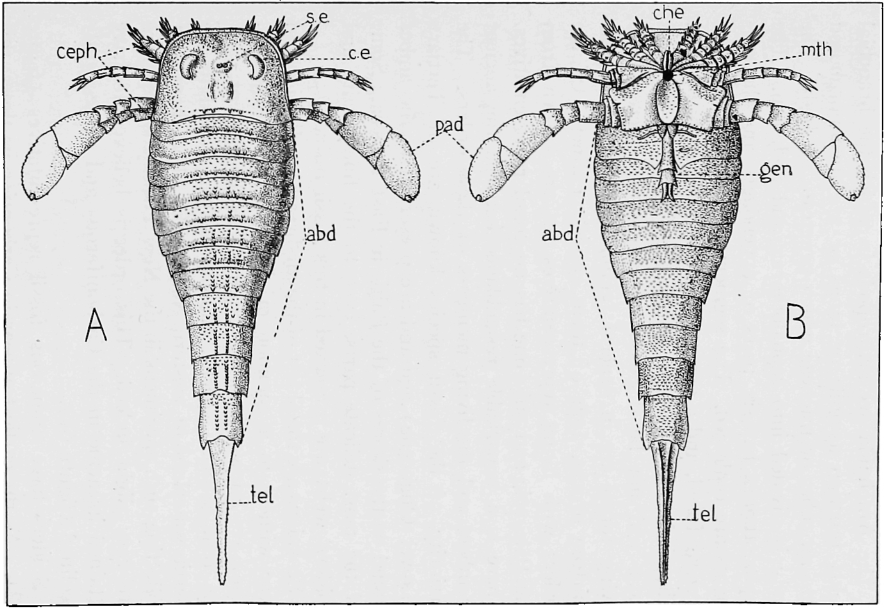


Figure 58 Silurian eurypterid. *Eurypterus remipes,* about x⅖. *A* Dorsal. *B* Ventral aspect. *abd* Abdomen; *ceph* Cephalothorax; *c.e* Compound eye; *che* Chelicerae; *gen* Genital appendage; *mth* Mouth; *pad* Paddle; ***s.e*** Simple eye; ***tel*** Telson. (After Clarke & Ruedemann)

The Arachnida are arthropods in which the branchial folds function as gills or lungs or are metamorphosed into air-tubes or tracheae which penetrate the body. The body is divided into cephalothorax and abdomen. The cephalothorax has six pairs of appendages and the segments are coalesced. The segments of the abdomen are free or fused, and a postanal spine is frequently present. The air-breathing section of the class (spiders, scorpions etc.) will not be discussed to any extent here. The living forms are in general familiar. This subclass has thirteen orders, four of them entirely extinct. Of the orders with living representatives six are known from the Paleozoic and only one has no fossil representatives. There is a remarkable resemblance between the ancient members and the living members of these orders. The majority of the fossil species known are of Tertiary (Lower Oligocene) age and are preserved in the amber found on the shores of the Baltic in East Prussia. Some of the most delicate parts, even to the finest hairs and spiders' webs, are preserved in this fossil resin.

Scorpions are the oldest of the air-breathing division and bear witness to a common origin with the eurypterids. They are known from the Silurian to the present. Of the four Silurian species known one was found in the Bertie waterlime of western New York. The chances of collecting such specimens in the New York beds therefore are very slight indeed. This order is believed to have attained its acme in the Carboniferous and subsequently declined (figure 61).

Spiders have numerous fossil representatives (figure 62). As the earliest appear in Carboniferous times, this group is beyond the scope of the collector in New York rocks. The majority of forms are known from the Baltic amber and examples may be seen in a small collection of this material in the State Museum. In addition, specimens have been found in Tertiary fresh-water marls in France and Germany, in Tertiary lignites of Germany and in Tertiary fresh-water strata of Florissant, Colorado. Earlier Tertiary material has been collected in the Green River beds of Wyoming and in the beds at Quesnal, British Columbia. About 250 species of fossil spiders are known at present.

Subclass Merostomata (Greek *meros,* thigh; *stoma,* mouth). This water-breathing division derives its name from the arrangement of the appendages around the mouth and the fact that the basal joints aid in mastication. It contains the order Eurypterida, the Arachnida of most interest to the student of New York paleontology because, among other things, they are most available for collection.

There are two other orders. The first order contains *Limulus,* the king or horseshoe crab (figure 59). *Limulus* is known from the Trias to the present. The body is covered with a chitinous skeleton, is longer than broad and consists of cephalothorax and abdomen. The cephalothorax, which is arched dorsally, has the central portion separated from the sides by longitudinal grooves and there is a large flat marginal area. Six segments of the abdomen are consolidated to form a subtriangular shield and the seventh forms a very long, slender caudal spine or telson. The cephalothorax has six pairs of appendages. In front of the mouth is a pair of short, three-jointed, chelate or pincer-ended appendages, the chelicerae (Greek *chele,* claw; *keras,* horn). Behind these are five pairs of legs, four chelate and with the bases covered with spines and having the action of jaws. The sixth pair of appendages is surrounded with whorls of

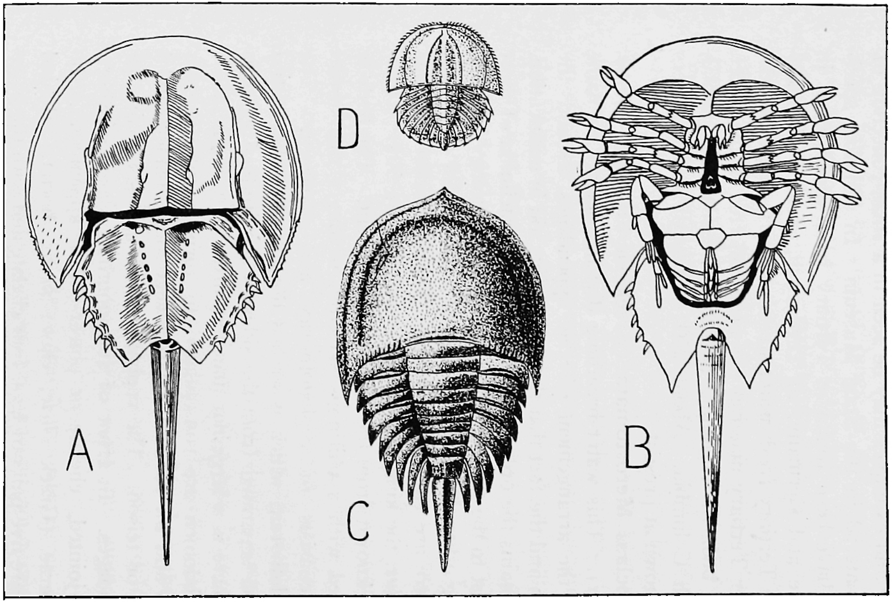


Figure 59 Merostomes. *A, B* Dorsal and ventral views of the horseshoe crab, *Limulus*, x1/3. ***D*** Embryo of Limulus, trilobite stage, x2/3. ***C*** Silurian form, *Pseudoniscus*, x2 1/2 (after Clarke). (*A, B* from Textbook of Zoology by Parker & Haswell; ***D*** from Textbook of Paleontology by Zittel-Eastman; published by The Macmillan Co.)

plates which aid in pushing the animal over or through the mud. The six pairs of abdominal appendages are flat plates, the first pair united in the middle line and forming an operculum (Latin=a cover) bearing the genital opening; the other five pairs bear the gills. There are over a hundred pairs of gill leaves in all. Our species of *Limulus* lives in shallow water, grubbing in the mud for its food, and it ranges from Yucatan to Maine. The young embryo of *Limulus* presents a strong resemblance to a trilobite. It has no elongated caudal spine and swims freely by means of its abdominal appendages. There are marked lateral eyes, and the abdomen and body are segmented and divided by longitudinal grooves into a median and two lateral regions. *Limulus* is the last surviving marine member of the ancient arachnid subclass Merostomata and the order to which it belongs is known from Upper Devonian times. A *Protolimulus,* resembling the recent *Limulus* to some extent, has been found in the Upper Devonian (Chemung) of Pennsylvania, but no species, so far, has been found in New York State.

The second order contains forms belonging to the Silurian with the exception of one genus found in the Cambrian. The forms belonging here have a semicircular cephalothorax, with the median axis more or less well-defined. The abdomen has free segments and is trilobed, bearing a resemblance to the thorax of a trilobite; and the pleura which are flat and extended generally terminate in lateral spines. Compound eyes are generally present. Two genera (*Pseudoniscus, Bunaia*) and three species have been found in the Silurian rocks (Salina: Bertie waterlime and Pittsford shales) of western New York and representatives may be seen in the State Museum. *Pseudoniscus* (figure 59) was formerly known only from Russia. A natural size model of a similar form (*Bunodes*) from the Silurian of the Island of Oesel, Russia, is shown in one of the crustacean cases in the Museum. It is well for the student to keep these forms in mind, but they are very rare.

Eurypterida (Greek *eurys,* broad; *pteron,* wing; reference to the broad winglike pair of legs). The eurypterids are an extinct order of marine arachnids or scorpionlike spiders. Although living in the water they have a superficial resemblance to crabs and, like crustaceans, they breathe through gills. Their anatomical structure is that of arachnids, and living land spiders and scorpions have no doubt originated from them. Practically all of the arachnids have gone from the sea to the land by way of fresh water. The eurypterids were, undoubtedly, originally marine forms; then they became gradually adapted to brackish water and finally possibly even to fresh-water conditions at the end of the Paleozoic (Permian). The earlier species are found associated with marine forms, cephalopods, trilobites, phyllocarids, ostracods, brachiopods, graptolites etc., while the later forms are found in beds along with land plants, insects, scorpions and fresh-water amphibians (figures 58, 60, 61).

The eurypterids and *Limulus* and the eurypterids and scorpions present a number of points of common resemblance. The body in eurypterids is elongate, somewhat like that of a scorpion, but relatively broader and shorter. The cephalothorax or *prosoma* (Greek *pro,* before, forward; *soma,* body) is comparatively small and consists of six fused segments covered by a more or less quadrate carapace with the front angles rounded. The abdomen consists of thirteen segments, including the post-anal *telson* or caudal spine. The first six segments of the

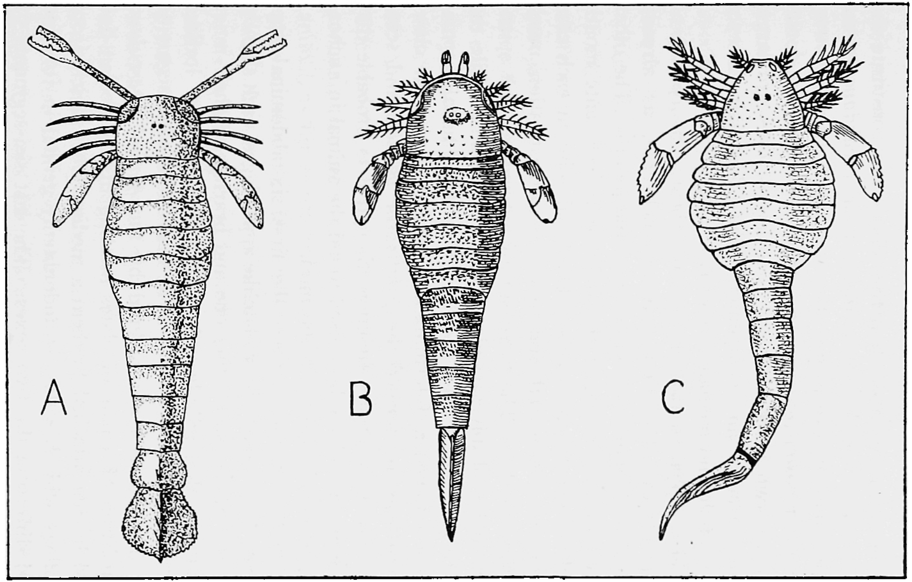


Figure 60 Silurian eurypterids. *A Pterygotus*, x1/25. *B Hughmilleria*, x½. *C Eusarcus*, x1/12. (After Clarke & Ruedemann, from Schuchert: Historical Geology, permission John Wiley & Sons)

abdomen are broader than the others and constitute the *mesosoma* (Greek *mesos,* middle) or *preabdomen;* the remaining six constitute the *metasoma* (Greek *meta,* after) or *postabdomen.* The carapace bears on the dorsal surface two pairs of eyes. The lateral eyes are large, kidney-shaped and compound. The other pair of eyes are simple and median in position.

The cephalothorax or prosoma bears six pairs of appendages. The first pair or chelicerae, as already noted in *Limulus,* are in front of the mouth. The other five pairs are found at the sides of the elongate mouth and are developed as legs. The basal joint in each case is provided with teeth and functions in mastication, much as in *Limulus.* The fifth pair of appendages are spineless and probably served as balancing organs, while the sixth pair is of greater size than the others, usually somewhat flattened and terminating in an oval plate or claw. These legs are termed the *palettes* or *paddles* and seem to serve a swimming function, though it is probable that they may also have been used to aid the animal in anchoring or burying itself in the mud.

On the ventral surface, the first six abdominal segments (mesosoma) bear platelike appendages, each slightly overriding the succeeding one and bearing on their inner surfaces the gill leaves, comparable to the leaflike external gills of *Limulus.* The first and second segments of the abdomen are covered by the *genital operculum,* consisting of a pair of plates meeting in the median line and having attached to them a median lobe, which from analogy with *Limulus,* is undoubtedly genital in function and differs in the two sexes. The last six segments of the abdomen have no appendages.

Growth stages of many of the eurypterids are well known. The larval forms have bigger heads, immense eyes situated nearer the margin, smaller number of segments and broader bodies, as compared with the full-grown animals, and the swimming legs are usually larger. The eurypterids led a varied mode of life: swimming, crawling and burrowing; and they reached a size far surpassing that of all later arachnids. One of the largest species (*Pterygotus buffaloensis*), as found in the Silurian rocks around Buffalo and in Herkimer county, attained a length of nine feet or more.

Eurypterids are known from the Cambrian to the end of the Paleozoic (Permian). The rocks of New York State have furnished a more complete representation of eurypterids than those of any other part of the world, and the collection in the State Museum therefore is unique in its completeness. This collection contains all the Ordovician eurypterids known, with the exception of two, and contains specimens from the Normanskill beds, Catskill, N. Y., and the Schenectady beds, Schenectady, N. Y. The most common Silurian eurypterid, *Eurypterus remipes,* has become almost as fully known as a recent animal, as far as the integument is concerned; and a complete series of this form is shown in two of the eurypterid cases. In this series of cases are shown not only specimens in all stages of growth, but also all organs separately. The shale layers of the Shawangunk grit (Silurian), Otisville, Orange county, N. Y., have furnished a wonderful assemblage of eurypterids, and among them the earliest growth stages of the most important genera: *Eurypterus, Stylonurus, Hughmilleria* and *Pterygotus,* which are exhibited in several of the cases, with the published drawings for clearness. One case shows a fine series of Ordovician species of *Eurypterus* from the graptolite shales, and other cases show a fine series of

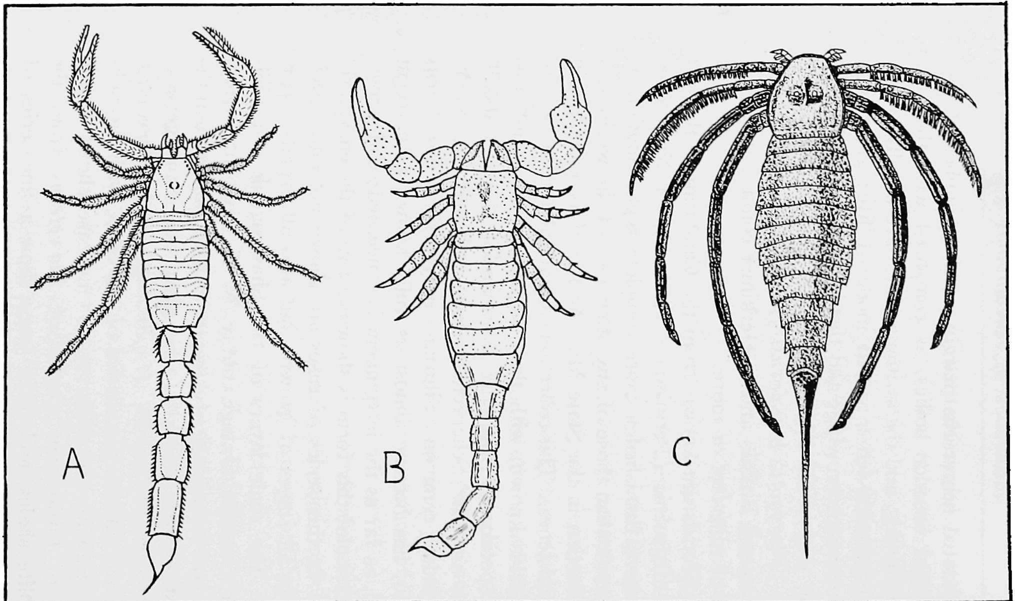


Figure 61 Scorpions and eurypterid. *A* Old world scorpion, *Buthus*, about x1⅓ (after Kraepelin). *B* Silurian scorpion (*Palaeophonus*), x1 (after Pocock). *C* Upper Devonian eurypterid, *Stylonurus*, x1/20 (after Clarke & Ruedemann). (*A* from Cambridge Natural History ed. by Harmer & Shipley; *B* from Textbook of Paleontology by Zittel-Eastman; published by The Macmillan Co. *C* from Schuchert: Historical Geology, permission John Wiley & Sons)

fossils from the Pittsford shale (Silurian) at Pittsford, N. Y., among them a group of *Hughmilleria socialis,* the small, fish-shaped eurypterid. Life-size restorations have been made of a number of forms. The wall specimens include the giant *Pterygotus buffaloensis* restored from a jaw and body joint found in the Bertie waterlime (Silurian), near Buffalo, N. Y.; another large, stately, spider-like creature, *Stylonurus excelsior,* restored from a head found in the Catskill sandstone (Upper Devonian) at Andes, N. Y.; and the strikingly scorpionlike eurypterid, *Eusarcus scorpionis* restored from Bertie waterlime (Silurian) specimens. Inside the special eurypterid cases are natural-size restorations of *Strabops thacheri* (a Cambrian species from Missouri); *Eurypterus remipes,* dorsal and ventral sides; *Stylonurus cestrotus,* dorsal side; *Hughmilleria socialis,* dorsal and ventral sides. On top of these cases are models of growth stages of three forms: *Hughmilleria shawangunk, Eurypterus maria,* and *Pterygotus* (*Erettopterus*?) *globiceps.* There is also a habitat restoration case showing two specimens of *Eusarcus scorpionis* in their natural submarine surroundings. Specimens of an *Eurypterus* from the Silurian of the Island of Oesel, Russia, are also shown in the State Museum collection. These specimens show the uncarbonized skin with scales. Two examples of the king or horseshoe crab, *Limulus polyphemus,* the only marine arachnid and living relative of the eurypterids, are also exhibited for comparison with the fossil forms.

There are many localities where the collector may look for specimens of eurypterids. Ordovician forms have been found in the *Normanskill beds* of Greene county (Catskill, N. Y.), the *Utica shale* of Oneida county, and the *Schenectady beds* of Schenectady and Schoharie counties; Silurian forms have been collected from the *Clinton sandstone* of Cayuga county, *Shawangunk grit* of Orange county (Otisville, N. Y.), *Pittsford shale* of Monroe county (Pittsford, N. Y.), *Bertie waterlime* of Erie county, particularly, also Herkimer, Oneida, Madison and Cayuga counties, *Manlius limestone* of Herkimer, Onondaga and Otsego counties, *Rondout waterlime* of Seneca and Genesee counties; and Upper Devonian specimens from the *Chemung-Catskill* beds of Delaware (Andes, N. Y.) and Schoharie (Gilboa, N. Y.) counties, and the *Portage sandstone* of Yates county.

Class Insecta (Latin *in,* into; *secare* to cut). This group derived its name originally from such forms as the bees and wasps which are almost completely cut into two or three parts. The class is also known as the *Hexapoda* (Greek *hex,* six; *pous* (*pod*), foot), because the thorax bears three pairs of legs. This class includes the most highly diversified and by far the most numerous of all the animals. Forms belonging here live under almost every conceivable condition of life. This class includes Cockroaches, Bugs, Beetles, Bees, Flies, Dragon Flies, Butterflies and Moths etc. There are over forty orders. Some of them are only known fossil, but the majority have living representatives (figure 62).

Insects are characterized by a body divided into three distinct parts; head, thorax and abdomen, and with a skin hardened with chitin to which the muscles are attached. The head bears normally a pair of feelers or antennae, usually a pair of compound sessile eyes and the jaws, a pair of mandibles and two pairs of maxillae. The compound eyes are made up of facets or individual eyes which number thousands (4000 in the house fly; 28,000 in the dragon fly). The thorax bears three pairs of legs and

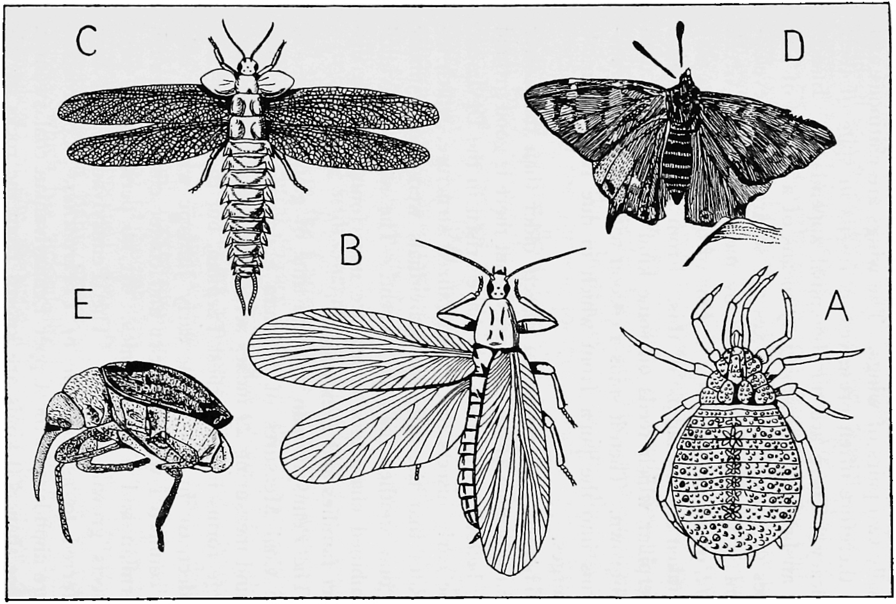


Figure 62 Spiders and insects. *A* Ancestral spider (*Euphrynus*), Carboniferous, x4/3. *B* Ancestral cockroach (*Eucaenus*), Carboniferous, x2/5. *C* Carboniferous primal insect (*Stenodictya*), about x½. *D* Butterfly (*Prodryas*), Tertiary, x⅞. *E* Beetle (*Teretrum*), Tertiary, 3 mm long. (*A* from Schuchert: Historical Geology, permission John Wiley & Sons; *B*, *C* from Textbook of Paleontology by Zittel-Eastman, *E* from Introduction to Study of Fossils by H. W. Shimer, published by The Macmillan Co.; *D* from Grabau & Shimer: Index Fossils)

usually two pairs of wings. The wings are chitinous and are therefore often preserved as fossils in spite of their delicacy. There are no abdominal appendages. Insects are air-breathers, breathing by means of a system of air-tubes or tracheae. The sexes are separate and development is usually accompanied by metamorphosis (Greek *meta*, over; *morphe*, form). One of our large moths may be taken as an example of this. From the egg hatches a caterpillar which feeds on some kind of vegetation until full grown. Then it spins a cocoon within which it transforms into the pupa from which in due time the moth emerges.

There is no evidence of insects older than the Lower Pennsylvanian (Coal Measures), but there is good ground for believing that they may have arisen in the Devonian. The early insects had a generalized structure, which indicates that the different individuals were more similar to one another than at present. The same individual combined characters which are now found only in distinct families and even orders.

The Pennsylvanian was the time of giant insects. In the Coal Measures of Belgium a dragon fly type was found measuring 29 inches across the wings. There were large forms in the earliest Permian, but then there came a decrease in size in the early Jurassic which can only be connected with the drier and colder climates through Permian and Triassic times. At no period since have insects grown so large. The Pennsylvanian has been referred to as the *Age of Cockroaches*. Cockroaches were abundant in the Upper Pennsylvanian coal swamps. More than 800 kinds are known from the rocks of this period and they were mainly carnivorous and large, some of them having a length of three to four inches. Thirteen hundred species of insects have been described from the Pennsylvanian and Lower Permian. The oldest forms were especially prevalent in the Pennsylvanian and all died during the Permian. They were large in size and primitive in structure and gave rise to transitional forms, which in turn gave rise to modern insects. While cockroaches are known from the Pennsylvanian to the present and May flies from the Permian to the present, grasshoppers, crickets, beetles, bees, ants, bugs, modern dragon flies, lace-wing flies, butterflies, moths and flies are all known from the Jurassic to the present. Other living forms such as the fleas, book lice etc., had their origin much later, during the Tertiary. Besides the thousand odd species described from Paleozoic rocks, it is estimated that about 1000 Mesozoic and upwards of 8000 Cenozoic species have been described by various authors; and this is only a fragment of the insect fauna of past periods.

Insects, along with arachnids and myriopods, are found well preserved in the Carboniferous (Pennsylvanian) of Commentry, central France. This is the richest deposit of Carboniferous insects in the world. Some of the other Carboniferous localities are southwestern Rhenish Prussia (Saarbrücken); Mazon Creek, Illinois; Rhode Island. Insects are well represented in the lithographic limestone (Jurassic) of Solenhofen, Bavaria; in fresh-water Tertiary (Oligocene) deposits of Aix in Provence, France, and in Baltic amber of the same age in East Prussia, which has yielded the largest and most varied assemblage; in the Miocene (Tertiary) lacustrine deposits of Oeningen, Baden, on Lake Constance, and in similar deposits of the same age of Florissant, Colorado; and in the Green River Eocene (Tertiary) of Wyoming, western Colorado and eastern Utah. There are other localities but this list includes many of the most noteworthy. There is considerable reason to suppose that there were more species of insects living during Tertiary times than there are at the present day.

No insects have been found in the New York rocks, since formations above the Devonian are but slightly represented.

Literature

The references given here cover the classification of Animals and the description of the Invertebrates. On the whole the references are general but some special references are given for the New York fauna. Many of the references carry good bibliographies which will aid the student who wishes to carry his studies further, and such bibliographies are indicated. Any good zoology may be studied for the classification and description of the different groups, keeping in mind, however, that the various authors differ somewhat as to details of classification. Parker and Haswell ('10) will be found to be a good, general textbook. Very excellent but lengthy zoological treatises are to be found in the Cambridge Natural History ('09–'20), edited by Harmer and Shipley, and Lankester ('00–'09). The student is also referred to various textbooks of historical geology, such as Schuchert ('24), Schuchert and LeVene ('27), Cleland ('16), Grabau ('21), Scott ('24), Chamberlin and Salisbury ('09), Geikie ('03). Treatises of a particularly paleontological nature are Shimer ('14), Davies ('20), Zittel ('13), Grabau and Shimer ('10). Shimer ('14) and Schuchert and LeVene ('27), are particularly recommended to the beginner. To these general references may be added Grabau ('13, p. 1007–39) and Lull ('17).

For New York State fossils the student is referred to the Paleontology of New York (Hall and others, '47–'94) and to memoirs and treatises on special groups, published by the State Museum: Beecher and Clarke ('89), Hall and Clarke ('91–'94; 1898), Ruedemann ('05, '08), Clarke and Ruedemann ('12), Goldring ('23). There are numerous State Museum publications dealing with the fossils and stratigraphy of New York, some of which are still available. An index to these publications may be obtained from the Museum.

Phylum Vertebrata

(Latin *vertebra,* a joint)

The name of this group is derived from the presence of a jointed backbone, which in the lower forms consists mainly of cartilage, while in the higher forms the cartilage is replaced by bone. By some authors the Vertebrata are considered a subphylum and with two other subphyla, not known in the fossil state, constitute the phylum Chordata (Latin *chorda,* a cord), named from the presence of a notochord (primitive backbone) at some stage in development. The Vertebrata are the typical Chordata. The Vertebrata show their main advance over the Invertebrata in the development of a second body cavity dorsal to the one in which are lodged the digestive system, heart and lungs. This second body cavity lodges the spinal column and the brain, which together form the central nervous system.

The classes of Vertebrata to be discussed here are the Ostracoderma (aberrant sharks), Pisces (fishes), Amphibia (amphibians), Reptilia (reptiles), Aves (birds), Mammalia (mammals, including man). All these groups are found fossil. None of them will be discussed very fully. The amateur is not likely to meet with many vertebrate fossils, particularly in the New York rocks; but if he should do so, it would be well to consult with some authority in that field.

Class Ostracoderma (Greek *ostrakon,* shell; *derma,* skin). This class, also given by some as a subclass of the Class *Pisces,* takes its name from the wonderful development of the external (dermal) armor of plates or scales with which its representatives were provided. They are known only fossil and are the lowest of the primitive fishes (figures 63, 64). Since no trace of a backbone has been found in the fossil state they probably had only a soft notochord or primitive backbone. There were no jaws and no proper paired fins. For these reasons these forms have been separated from the fishes in a distinct class. They are possibly a group of highly aberrant sharks. By some they have been placed in the phylum Arthropoda. They have sometimes been considered as transitional forms from the Arthropoda (sea scorpions etc.) to the fishes. Most of the ostracoderms were of small size. The head and anterior part of the body was large, broad and depressed, and covered with plates or scales which were sometimes fused into thick body plates. The head was provided with a pair of eyes either dorsally or laterally placed. The posterior part of the body was either naked or covered to a greater or less degree with scales or plates. The class is divided into two groups: one including the most primitive forms with head shield only (*Cephalaspis*), the other comprising more complicated forms with a shield surrounding head and trunk and composed of a number of overlapping plates (*Pterichthys, Bothriolepis* etc.). The older

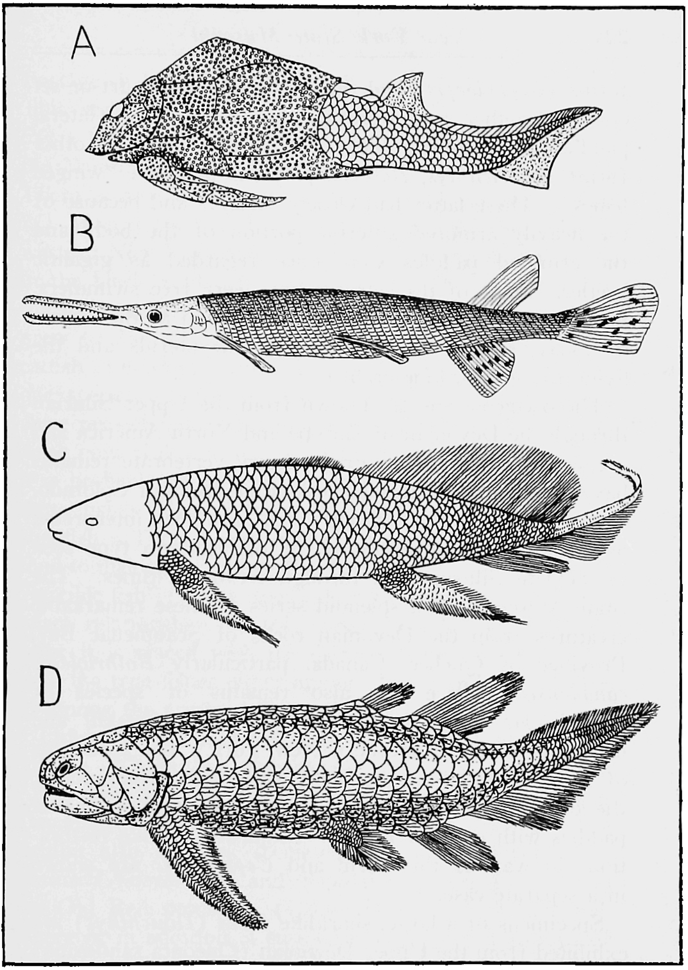


Figure 63 Ostracoderms, lung fish, ganoids. *A Pterichthys* or winged fish Upper Devonian of Scotland, x4/9 (from Kayser after Traquair). *B* Living garpike (*Lepidosteus*) of New York State, x1/7. *C* Upper Devonian lung fish, (*Scaumenacia*) from Scaumenac Bay, Canada, x4/9, (after Hussakof). *D* Upper Devonian ganoid (*Holoptychius*) from Scotland, x4/9 (after Woodward).

forms (*Cephalaspis*) had the eyes either far apart or set closely together and were without the pair of lateral paddles or swimming limbs which have given to other forms (*Pterichthys, Bothriolepis*) the name of "winged fishes." These latter had closely set eyes and because of the heavily armored anterior portion of the body and the armored paddles were once regarded as gigantic beetles. Some of the ostracoderms were free swimmers, but many lived on the mud of the bottom as the catfish of today, as the contemporaneous eurypterids and the living *Limulus* or king crab.

The ostracoderms are known from the Upper Silurian through the Devonian of Europe and North America and are widely distributed. Fragmentary vertebrate remains have been found in Middle Ordovician rocks of Colorado, Wyoming and South Dakota which have been interpreted as armor bones of fishes of the ostracoderm type seen in the late Silurian and through Devonian times. The State Museum has a splendid series of these remarkable creatures from the Devonian rocks of Scaumenac Bay, Province of Quebec, Canada, particularly *Bothriolepis canadensis*. There are also remains of species of *Bothriolepis* from the Upper Devonian (Catskill and Chemung) beds of southern New York. The specimens of *Bothriolepis* show the finely sculptured armor plates, the orbits with the eye plates and the anterior fins or paddles with exterior armor. Exquisite, lifelike restorations in wax of this form and *Cephalaspis* are shown in a separate case.

Specimens of a large, sharklike form (*Dinichthys*) are exhibited from the Upper Devonian (Oneonta sandstone) beds of Delaware county. There is a reproduction of the head bones (*Dinichthys magnificus*) found in the black

Portage shale (Upper Devonian) of the Lake Erie region. This creature must have been 15 to 20 feet long and had a head covered with bony plates. The original is in the Museum of the Buffalo Society of Natural Sciences. There is also a complete restoration of another species (*D. intermedius*). These fishes lived in the seas of western New York and Ohio and their remains are found in the black muds of those regions. They were among the most remarkable fishes of the Devonian seas. They grew to 25 feet in length and resembled an overgrown catfish in external form. The head was six feet broad in one species. Both the head and the front of the body were protected by an armor of heavy plates. The jaws were powerful and adapted for tearing and cutting, but it is probable that instead of being fierce and predaceous these fishes lived on the ocean bottom and existed on shellfish. Their heavy armor and clumsy shape would tend to make them sluggish. The name *Dinichthys* means "terrible fish" (Greek *deinos,* terrible; *ichthys,* fish). The exact relationships of this species are not known. By some it is placed with the ostracoderms, others place it with the true fishes either among the armored lung fishes or among the armored fishes (Arthrodira).

Other ostracoderm remains have been found in the Middle (Onondaga limestone) and Upper Devonian (Portage) beds of western New York and the Upper Devonian (Chemung) beds of Delaware county. The exhibit also includes specimens from the Devonian of Maine (*Asterolepis*) and Scottish representatives from the Old Red sandstone (Upper Devonian) of Scotland. There is, in addition, a case of models or restorations of Devonian fishes which include a number of ostracoderms found here and abroad; such as *Dinichthys, Pterichthys, Pteraspis, Drepanaspis* etc.

Class Pisces (Latin *piscis,* fish). This class includes all the true fishes, both marine and fresh water. They are cold-blooded aquatic vertebrates. There is a well-developed skull and the notochord, or primitive backbone, is more or less completely replaced by a cartilaginous or bony backbone. Locomotion is by means of the paired fins and the tail, and respiration by means of gills, for the most part, or gills and lungs. Most fishes lay eggs but in some forms, as the dogfish, the young are brought forth alive. Although fishlike animals are known as far back as the Middle Ordovician, the primitive fossil ancestors are yet undiscovered. All that can be said is that the oldest fossil vertebrates are fishes of ostracoderm and primitive sharklike types. The class Pisces is divided into a number of subclasses and includes the Elasmobranchs (gristle fishes or sharks); the Lung Fishes; the Ganoids or enamel-scaled fishes; the Armored Fishes (Arthrodira); and the Teleosts or bony fishes.

The *elasmobranchs* (Greek *elasmos,* a plate; *branchia,* gills) or gristle fishes include the ancient and modern sharks, sawfishes, sea cats or chimaeras, skates and rays. The subclass is known from the Silurian to the present. Sharks lived in the Devonian in considerable numbers, but the fossil evidence of their existence consists largely of teeth, spines and the spinous dermal plates, since the skeletons were cartilaginous. The best known and most simple in structure of these ancient sharks is the well-known genus *Cladoselache* from the Upper Devonian (Cleveland shale) of Ohio (figure 64). This shark was two to six feet long. It had a short blunt snout with the mouth situated on the lower side, farther forward than in the modern shark, and provided with teeth in clusters and arranged in six or seven rows, one behind

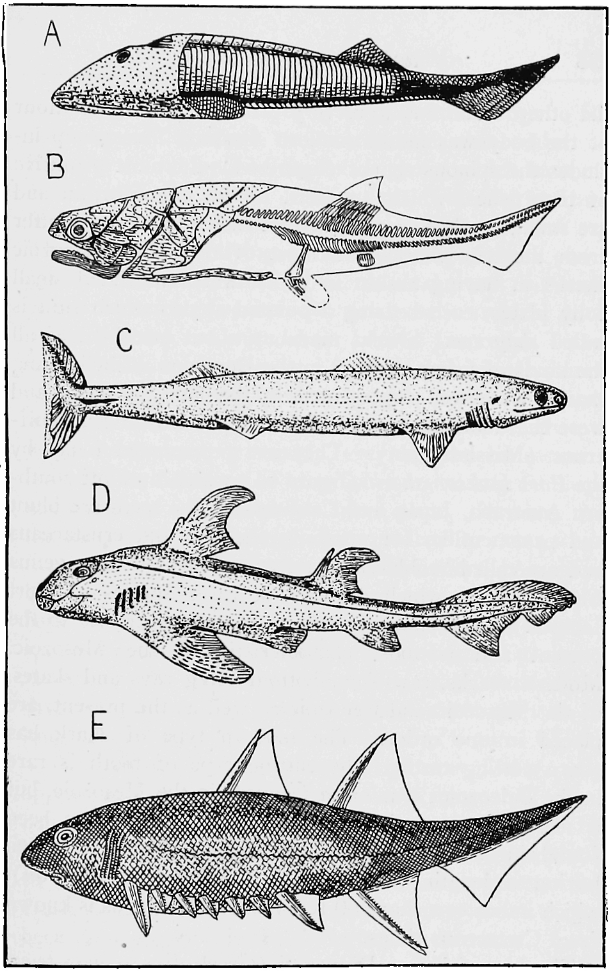


Figure 64 Ostracoderms, arthrodires, sharks. *A* Silurian and Devonian ostracoderm (*Cephalaspis*), x2/5 (after Woodward). *B* Upper Devonian arthrodire or armored fish (*Coccosteus*) from Scotland, x2/5 after Woodward). *C* Upper Devonian shark (*Cladoselache*) from Ohio, x1/7 (after Dean). *D* Living Port Jackson shark (*Cestracion*), Australia, about x1/12 (after Garman). *E* Lower Devonian spinous shark (*Climatius*) from Scotland, x¼ (after Woodward). (*A, C, D* from N. Y. State Mus. Mem. 10; *B* from Textbook of Paleontology by Zittel-Eastman, published by The Macmillan Co; *E* from Schuchert: Historical Geology, permission John Wiley & Sons)

the other. The fins were very primitive and the contour of the body was unlike modern sharks. This group includes the spinous sharks (figure 64), the most primitive of true fishes, which appeared in the late Silurian and are small, rarely exceeding a foot in length. They differ from the true sharks and most of the other Paleozoic sharks in having a skin in which were embedded small bony plates, each bearing a pointed spine. Such skin is called *shagreen*. Sharks made up about one-third of all the kinds of fishes existing in the Devonian. Shell-eating sharks were well represented in the late Paleozoic and were the dominant marine fishes in the Lower Carboniferous (Mississippian). They are represented today by the *Port Jackson shark* (figure 64) which lives off southern Australia, Japan and California. The teeth are blunt and pavementlike for crushing shellfish and crustaceans and are called "cobblestone pavement" teeth. The genus *Cestracion,* to which the two or three species of Port Jackson shark belong, is known from the Jurassic to the present and is most characteristic of the Mesozoic. Modern sharks, sawfishes, bottom-living rays and skates, of the Mesozoic and Cenozoic as well as the present, are placed in one order. The modern type of shark has sharp cutting teeth. The cutting type of tooth is rare in the Paleozoic; it is more frequent in the Mesozoic, but is not common until the Cretaceous. Teeth have been found in Tertiary (Miocene) beds of South Carolina having a length of nearly six inches (*Carcharodon*), which indicates a shark 60 feet long. This genus is known from Cretaceous times.

The *lung fishes* or Dipneusti (Greek *di(s)*, two; *pneo,* to breathe=double breathing) are known from the Devonian to the present and receive their name from the fact that they breathe by both gills and lungs. They were heavily armored or covered with thin scales, and it is the descendants of the latter group which have succeeded in living to the present day. The lateral fins of lung fishes were leaflike with an elongate, central axis. There are three living genera of lung fishes: one in Queensland, Australia (*Neoceratodus*); one in central South America (*Lepidosiren*); and one in tropical Africa (*Protopterus*). *Ceratodus* is known from the Triassic and Jurassic to the present. These fishes are also known as mudfishes. They breathe by gills in the wet season when the water is purer; in the dry season, or when the water is stagnant or muddy, they breathe by means of lungs. The skeletons of lung fishes are mostly cartilaginous but some ossification has taken place. In many ways the lung fishes appear to be intermediate in structure between the lower fishes and the salamanders (Amphibia) but they are not to be considered as a connecting link between the two. The oldest lung fishes (about 15 species) occur in the Devonian rocks of both Europe and America. By some the Dinichthys or "Terrible Fish" discussed under the Ostracoderma, is placed with the lung fishes in the "armored" division. (Figures 63, 66.)

The *ganoids* (Greek *ganos,* brightness; *eidos,* (*oid*) appearance) or enamel-scaled fishes (figure 63) are so named from the glossy surface of most of the fish. This is due to the bright enamel covering of the scales, similar to the outer covering in teeth. Ganoids are essentially fresh-water fishes, though marine forms seem to have been more common in the geologic past than now. Living representatives of this subclass are the more or less familiar garpikes and sturgeons (Tertiary [Eocene] to present) and two species from Africa (*Polypterus* of the

Nile valley and equatorial Africa; *Calamoichthys* from western Africa). The African species belong to an ancient order of the ganoids beginning in the Devonian. They were the common fishes of the Lower Devonian. This order is represented in the fossil state by the genus *Holoptychius,* a form widely spread in the Devonian of North America and Europe, and the genus *Eusthenopteron* from the Upper Devonian of Scaumenac Bay, Province of Quebec, Canada. In Eusthenopteron ossification of the notochord sheath has taken place anteriorly but no such ossification has taken place in the other genus. In this group the lateral and tail fins are primitive. The paired fins have a basal fleshy lobe and are leaflike with an elongate, segmented central axis; the tail fin is somewhat equally lobed with the spinal column extending nearly to its end. The groups to which the sturgeons and garpikes belong lack the basal fleshy lobe to the paired fins and the tail fin is either unequally lobed or nearly equally lobed with the backbone extending into the upper lobe.

Ganoids constitute one half the fish fauna known from the Old Red sandstone (Devonian) of Scotland. They are abundant in the Triassic of Europe, North America and South Africa and remain abundant until early Cretaceous times. The skeleton of ganoids is more or less bony though in some forms it is entirely cartilaginous. The perfected fish mouth, that is the lower jaw working against the teeth of the perfected upper jaw, is seen for the first time in this subclass. An air bladder is present which aids in respiration but is not like the lung found in the lung fishes. This group forms a connecting link between the spinous sharks and the bony fishes.

The *Arthrodira* (Greek *arthron,* joint; *deire,* neck), or highly armored fishes, were the most striking fishes of the

Devonian seas (figures 64, 65). They have been placed by some in a division of the ostracoderms; by others they are considered as armored lung fishes; and they have even been removed entirely from the class Pisces and elevated to the rank of an independent class. One of the well-known representatives is *Coccosteus,* known from the Lower Old Red sandstone (Devonian) of Scotland; the Upper Devonian of England, Ireland, Germany, Russia and Canada; and the Middle Devonian of Ohio. The "terrible fish," *Dinichthys,* discussed here with the ostracoderms, is by some placed in this division.

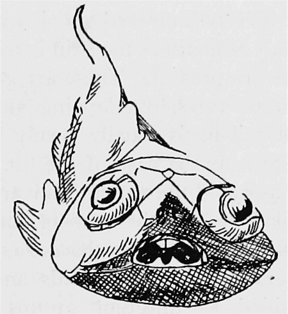


Figure 65 Arthrodire or armored fish (*Rhinosteus*), Upper Devonian of Germany, much reduced (from Grabau: Textbook of Geology, permission D. C. Heath & Co.).

The arthrodires are rather heavily armored fishes reminding one of the armored lung fishes and the earliest amphibians. The name is derived from the fact that an up and down movement of the head is permitted by the armor of the head sliding to some extent over that of the body. There was little internal skeleton, the vertebral column being without ossification. There were no true teeth but the dental plates were provided with cusps of dentine and functioned as large cutting shears or crushing plates. Almost 40 per cent of all the Devonian fishes belong here. The oldest forms were fresh-water (Early Devonian, Germany), but the Middle and Upper Devonian forms of North America were marine. They were the largest and fiercest fishes of their time, dying out in the Lower Carboniferous (Mississippian) when the shell-feeding sharks came into dominance.

The *Teleosts* (Greek *teleos,* perfect; *osteon,* bone), or true bony fishes, are the modern fishes such as trout, perch, cod, mackerel etc., with the highest organization in the class. They are merely improved ganoids with a typically ossified backbone. Sometimes the skin is naked and slimy, but usually scales are present. These are generally round, arranged in oblique rows, overlapping and usually thin and elastic. The tail fin is usually evenly lobed, with the backbone stopping near the base of the fin. The gills are covered with a movable operculum and an elongated air or swimming bladder may be present, but it does not function as a lung. Many of the characters of the teleosts are seen less perfectly in the ganoids and the two are sometimes classified as different groups of the same subclass.

Teleosts or bony fishes are not known until the Mesozoic (Jurassic). Herrings are known from the Lower Cretaceous (Comanchean); eels from the Cretaceous; perch, catfish, mackerel, cod, etc., from the (Eocene) Tertiary; pike from the (Miocene) Tertiary; and salmon from the Upper Tertiary. In nodules in the Pleistocene clays of Greenland and eastern Canada (Green creek, Ottawa river) are found skeletons of a small smeltlike fish, the caplin (*Mallotus villosus*). This fish lives today in the lower waters of the St Lawrence and in general in the shoal waters of northern seas, and is used as bait for cod.

No Silurian fishes have been described from New York State, but Upper Silurian (Salina) specimens have been found in Perry county, Pennsylvania. The State Museum has quite a representative collection of true fishes from the Devonian rocks. The Devonian shark, *Cladoselache,* which has been found in Ohio with the muscle fibers preserved, is represented in the Museum by a restoration. The restoration shows well the primitive character of these early sharks in the many gill slits, the uneven lobed structure of the tail fin and the absence of scales. To the elasmobranchs or sharks belong also a species (*Acanthodes? pristis*) from the Portage (Upper Devonian) beds. One specimen in the museum collection shows well the shagreen. A number of large fin spines indicate the presence of sharklike fishes of considerable size (*Machaeracanthus* and *Gyracanthus*).

The Museum contains some of the best preserved lung fishes found on this continent in *Scaumenacia curta* from the Upper Devonian of Scaumenac Bay, Canada. This fish shows the primitive form of the lateral fins, which are leaflike with a long axis, and the tail fin which is unevenly lobed as in the sharks. One of the three living genera of this once flourishing subclass of lung fishes, the Australian *Neoceratodus,* is exhibited with these fishes for comparison. Fossil specimens of some of the armored lung fishes are also shown. There are armor plates of a Portage (Upper Devonian) species from Western New York (*Glyptaspis abbreviata*) which show the fine sculpture. The head shield of another armored form (*Macropetalichthys*) is also shown. It is of uncertain position, but has been placed with the armored lung fishes. This all indicates that big armored fishes once plowed through the seas covering the present New York State.

The ganoids are now nearly extinct. Living representatives, as the sturgeon and gar pike, may be seen in the fish exhibits of Zoology Hall. *Polypterus,* the living representative from the Nile region, is exhibited with the fossil specimens for comparison. An especially notable example of a very early ganoid is seen in the splendidly preserved *Eusthenopteron foordi* from the Upper Devonian of Scaumenac Bay, Canada. The best preserved specimen shows the beginning of the ossification of the spinal column anteriorly. Posterior to this only the upper and lower spines of the column are ossified. This same specimen also shows the ganoid scales, the internal, cartilaginous supports of the lateral fins (front) and the still primitive tail fin with the extension of the tail into it. Another fine ganoid is represented in the same case with this. It is a splendidly preserved specimen of *Holoptychius nobilissimus,* a genus that lived in the Upper Devonian lakes and estuaries of Scotland, Russia, Canada and the estuary marking the site of the present Catskill mountains in New York, where it has been collected (Delaware co.). This ganoid is remarkable for its large scales. Another Devonian ganoid (*Rhadinichthys devonicus*) may be seen in one of the Portage cases of the synoptic series; and a restoration of one genus (*Palaeoniscus*) may be found in the case of models of Devonian fishes. Another case contains an exhibition of a good series of younger ganoid fishes (*Semionotus, Catopterus*) from the Triassic rocks of Boonton, New Jersey, and the Connecticut valley. They show well the character of the rhombic scales and the lateral and tail fins.

The arthrodires or armored fishes are represented by the large *Coccosteus*. In the case with the large ganoids is exhibited *Coccosteus canadensis* from the Upper Devonian of Scaumenac Bay, Canada. This specimen shows well the jaws, the head armor and the impression of the notochord or spinal column still lacking ossification. A restoration of a species of *Coccosteus* from the Devonian of Scotland is shown in the case of models. As pointed out above, *Coccosteus* is placed by some students among the armored lung fishes.

The teleosts or true bony fishes are not represented in the New York rocks and the Museum has little fossil representation of this subclass. The living forms may be studied in the fish cases in Zoology Hall. In one of the Pleistocene cases is quite a representative exhibit of the smeltlike caplin (*Mallotus villosus*) in clay nodules from the Pleistocene clays in the vicinity of Green creek, Ottawa river, Canada. A slab of limestone from the Upper Cretaceous of Mount Lebanon, Syria, is on exhibition in one of the cases explaining "What is a fossil?" The surface of the rock is covered with a large number of very small teleost fishes (*Diplomystus*). The abundance of fossil fishes in the rock indicates that some great change, probably a sudden influx of cold water, must have taken place in the life conditions in the sea of that time in order to cause the death of the fishes in such great numbers.

Class Amphibia (Greek *amphi*, both; *bios*, life). The class takes its name from the fact that most of the members pass their larval life in water and, for the most part, are land dwellers during adult life. They differ from the fishes in the possession of five-toed limbs instead of the paired fins, and the limb is of the pattern characteristic

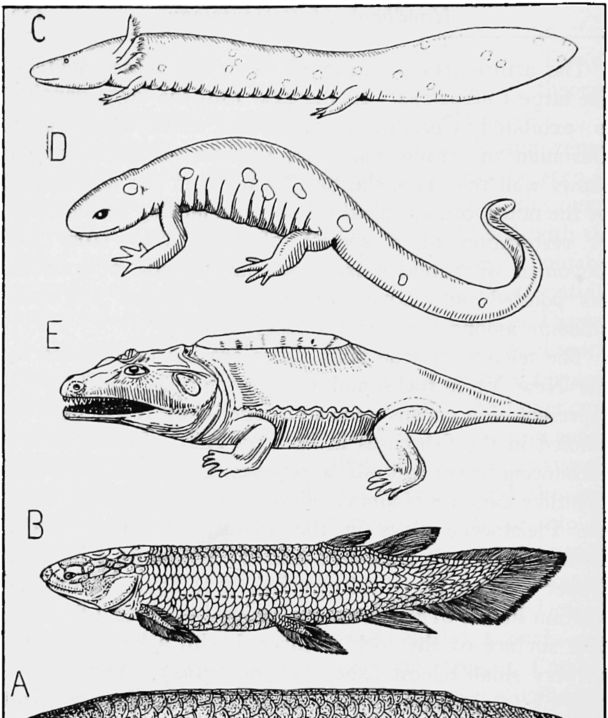


Figure 66 Lung fishes and amphibians. *A* Living lung fish (*Neoceratoduse*), Queensland, Australia, x1/28 (after Woodward). *B* Upper Devonian lung fish (*Dipterus*), Scotland, x⅜ (from N. Y. State Mus. Mem. 10, after Woodward). *C* Mud puppy (*Necturus*), a living amphibian, 8—17 inches long. *D* Land amphibian, the spotted salamander (*Ambystoma*), 6 inches long. *E* Stegocephalian or armored amphibian (*Cacops*), Permian of Texas, 20 inches long (after Williston). (*C*, *D*. by W. Schoonmaker; *A*, *E*. from Schuchert: Historical Geology, permission John Wiley & Sons)

of higher vertebrates. There is an absence of fin rays in the median fin when present, as in the tadpole. The amphibian in the tadpole stage is physiologically a fish. Amphibians breathe by gills in the larval condition and, for the most part, by lungs in the adult stage, although some retain gills and are water dwellers throughout life. They also breathe through the skin which is kept soft by glands secreting mucus and is usually without scales. There are distinct organs of hearing in this class in contrast to a lack of functional ears in fishes. The skeleton is bony. There are 900 living amphibia, and they are all cold-blooded animals (figure 66).

Four orders are recognized in this class. The first includes the tailed forms (Urodela, from Greek *oura,* tail; *delos,* distinct) such as the eellike Sirens, Mud Puppies, Hellbenders, land Salamanders, Newt or Efts etc. The second order of tailless forms (Anura, from Greek *a,* without; *oura,* tail) comprises the Frogs and Toads. The Coecilians, burrowing, snakelike tropical forms, compose the third order (Gymnophiona, from Greek *gymnos,* naked; *ophis,* serpent); and the fourth order, Stegocephalia (Greek *stegos,* cover; *kephale,* head), represents an extinct group of tailed and armored amphibians (figure 66). Except for the Stegocephalians, fossil remains of amphibians are rare. The group to which the coecilians belong is not known fossil. Fossils belonging to the tailless amphibians, including remains of both toads and frogs, are known from the Tertiary (Eocene). The tailed forms, salamanders etc., are known from the Jurassic but probably had their origin in the Paleozoic Stegocephalia.

It is believed now that the primitive amphibians were derived from the fringe-finned fishes by way of an older stock which gave rise also to the reptiles. Toward the end of the Devonian there were fishes present which were so constructed that slight modification would make them adaptable to life on land, and the extensive swamps of the Devonian and Carboniferous and the changing seas supplied the impetus or urge for development along these lines. One four-inch long footprint of a supposed amphibian is known from the Upper Devonian of western Pennsylvania. This indicates a salamanderlike amphibian or stegocephalian which must have been three feet long. In the Lower Carboniferous (Mississippian) of North America only footprints are known. Footprints found in the Mississippian (Mauch Chunk shale) of Pottsville, Pennsylvania, indicate an amphibian with a stride of 13 inches and a breadth between the outer toes of 8 inches. Nearly complete specimens of amphibians have been found in the Lower Carboniferous of Scotland.

These *Stegocephalia*, roof-headed or armored amphibians, were sluggish animals that lived around or in water or on dry land and were protected by an external body armor which covered the chest as well as the head. This armor distinguishes the Paleozoic and Triassic forms from the modern forms. In some forms the body was practically naked; in others it was entirely covered with overlapping scales. Stegocephalians reached their greatest importance in Carboniferous times (Pennsylvanian and Permian) and constituted the amphibian fauna of the coal swamps. Thirteen skeletons were taken from a single Sigillaria stump in Nova Scotia and represent small, active types that lived in hollow logs in the Pennsylvanian period. The Coal Measures of North America have yielded 90 species which range in size from one inch to 10 feet or more. Today the largest representatives of the Amphibia are found among the hellbenders or giant salamanders which in Japan and China attain a length of five feet. During Carboniferous (Pennsylvanian) times the amphibians of the different continents were so similar that there must have been great freedom of communication and migration which ceased with the close of that period.

The Stegocephalia began to give way to the reptiles in the Pennsylvanian and by Triassic times held a very subordinate place, although they attained their greatest size then. One specimen had a skull four feet long, and therefore must have attained a length of fifteen to twenty feet. This group was extinct before the close of the Triassic, probably due to competition with the reptiles. In the Cretaceous have been found a few salamanders of modern form; with the Tertiary come the salamanders, newts, frogs, toads; and there are numerous impressions of tadpoles preserved.

Nothing much is known of the life habits and food of the early amphibians but it has been inferred from the teeth that the great majority were probably carnivorous and fed on shellfish, worms, water invertebrates of various kinds, fish, small reptiles and even small forms of their own kind.

No amphibians have been found fossil in New York State. In the State Museum is a cast of the skeleton of a stegocephalian amphibian (*Eryops*) which inhabited the coal-forming swamps of Pennsylvania and no doubt also lived in the southwestern part of the present New York State near the edge of the great coal jungle.

Class Reptilia (Latin *reptilis*, creeping). This class derives its name from the crawling habit of some of its best-known representatives, the snakes. The members of this class are all cold-blooded animals, terrestrial or aquatic and breathing entirely by means of lungs. They are scaly or armored. Reptiles lay eggs as a rule, although some snakes bring forth the young alive as did also one extinct group (ichthyosaurs). In external appearance reptiles resemble amphibians, but as a class they show a decided advance over the latter and are a great deal more differentiated. The limbs are variously modified for habits of walking, swimming and flying, and some members, as the snakes, are without limbs. Whenever legs were present there were claws on the fingers and toes, a rare feature among the amphibians. The integument is tougher than in amphibians and the external skeleton (exoskeleton) of horny scales or horny or bony plates often forms a complete covering which is characteristic of the group and almost peculiar to it. The horny exoskeleton of living reptiles is cast off either as a whole or partially. Reptiles and birds are more closely allied with each other than with the mammals, but these three classes are grouped together because there are certain features common to them which separate them from the lower vertebrates (most important being the presence of embryonic membranes). The living representatives of the reptiles include the Lizards, Chameleons, Snakes, Turtles, Tortoises, Crocodiles, Alligators etc., and over 3500 species have been described, a number which is far in excess of the fossil forms known. Fossil forms, however, show a diversity of structure far greater than in living forms. The majority of fossil reptiles were land forms. (Figures 67–69).

Most modern authorities recognize nine independent orders of reptiles, living and fossil; some, as the Cam-

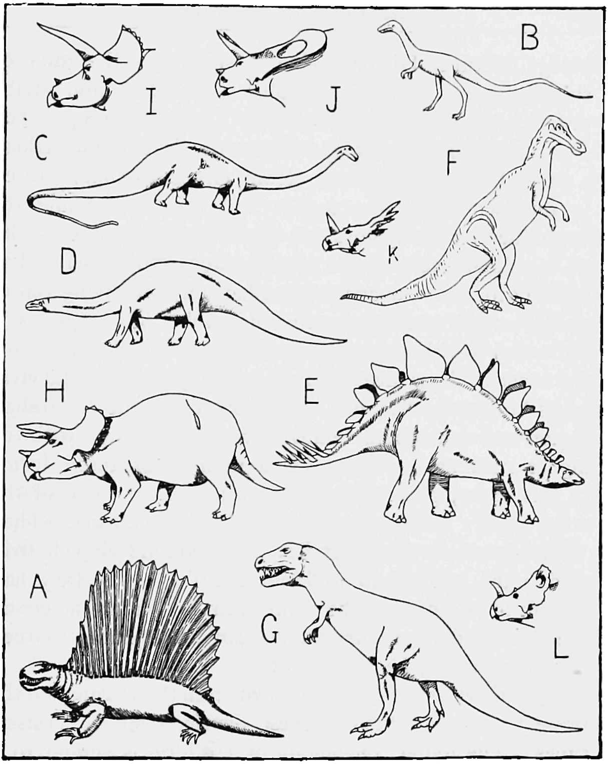


Figure 67 Land reptiles. Permian (*A*); Triassic (*B*); Jurassic (*C—E*); Cretaceous (*F—L*). *A* "Finbacked" lizard, *Dimetrodon,* 8—10 feet long x1/50 (after Williston). *B—L* Dinosaurs; *B Podokesaurus,* 4 feet long, x1/32 (after Lull's model); *C Diplodocus,* 80—87 feet long, x1/360. *D Brontosaurus,* 65 feet long, x1/360; *E Stegosaurus,* 20 feet long, x1/120; *F Trachodon,* 30 feet long, 15 feet high, x1/144 (after Gilmore's model); *G Tyrannosaurus,* 47 feet long, 18—20 feet high, x1/120; *H Triceratops,* 20—25 feet long, x1/120; *I Triceratops* head; *J* Head of another form, (*Torosaurus*); *K* Older, much horned form (*Styracosaurus*); *L* Another older form (*Monoclonius*). (*C—E, G—L* after Lull. *A, C—E, G—L* from Schuchert: Historical Geology, permission John Wiley & Sons)

bridge Natural History, give these orders the rank of subclasses and recognize 11 subclasses. Only four of the orders have living representatives. One order (Squamata, from Latin *squama,* scale) includes the lizards and snakes; a second order (Chelonia, from Greek *chelone,* turtle) is represented by the turtles and tortoises; while the crocodiles and alligators are grouped into a third order (Crocodilia, from Greek *krokodeilos,* crocodile). The fourth order is very ancient and has only one living representative, the small primitive lizardlike *Sphenodon* (or *Hatteria*) which lives on two or three small islands off the coast of New Zealand and probably owes its survival to its burrowing life and to its isolation in the Australian region and consequent removal from competition with the higher mammals. There are a number of fossil forms in this order, generalized types which unite some of the other orders (Squamata, Crocodilia, Dinosauria). They were lizardlike, scaly reptiles, with well-developed, five-toed limbs adapted to walking, and frequently they had a beak at the end of the skull from which characteristic the order derived its name, Rhyncocephalia (Greek *rhynchos,* snout; *kephale,* head).

The *Rhyncocephalia* are known from the Permian to the present, but had their highest development in Triassic times. The living *Sphenodon* or *Hatteria* is similar to a fossil form (*Paleohatteria*) found in the Permian of Europe and this fossil in turn shows much similarity to the Stegocephalian amphibians. The *Squamata* (snakes and lizards) are geologically the most recent of the existing orders of reptiles. While fossil remains of lizards are found in beds as early as the Jurassic and Cretaceous, most of the families are not represented as fossils earlier than the Tertiary; and all fossil remains of snakes are found in

Tertiary formations except for an imperfectly known specimen from the Cretaceous. The *Chelonia* (turtles, tortoises) are known from the Triassic onwards. The *Crocodilia* (alligators, crocodiles) also date back as far as the Triassic; and some of the fossil forms grew to an immense size.

The earliest undoubted reptilian remains were found in Carboniferous beds (Upper Pennsylvanian and Lower Permian) and while they are not plentiful in formations of these ages they are known in numbers from the Upper Permian in North America, Europe and South Africa. The high specialization of the oldest reptiles known, suggests an origin even earlier than the beginning of the Pennsylvanian. Through all Mesozoic time reptiles were very abundant and were the rulers of the earth, sea and air. As a class they reached their culmination during Jura-Triassic times and then steadily declined. There are five orders of reptiles which have only fossil representatives: the *Theromorpha,* or mammal-like reptiles; the *Ichthyosauria* and *Plesiosauria,* or marine reptiles; the *Pterosauria* or flying forms; the *Dinosauria* or land forms. Most attention will be given here to the last four orders which contain the most striking and noteworthy representatives.

The *Theromorpha* (Greek *ther,* wild beast; *morphe,* form) was a highly specialized group of wholly land animals with limbs adapted to the habitual support of the body. They possessed both amphibian and mammalian features and in the character of the skeleton held a position intermediate between a group of the stegocephalian amphibians and the lowest mammals, the egg-laying monotremes. Probably a primitive reptile of this type gave rise to the mammals. The theromorphs varied greatly in appearance and in habit. Some were herbivorous, some carni-

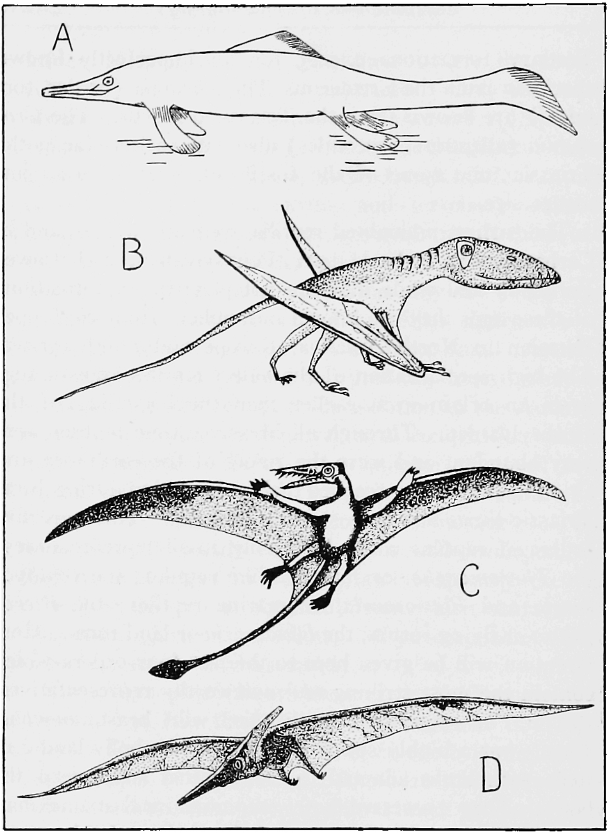


Figure 68 Swimming and flying reptiles. *A* Ichthyosaur (*Cymbospondylus*) of Middle Triassic of Nevada, 30 feet long. x1/120. *B* Jurassic *Dimorphodon*, 2 feet high, wing spread 4 feet, about x1/27. *C* Jurassic *Rhamphorynchus*, 2 feet long, wing spread 4—5 feet, about x1/19. *D* Upper Cretaceous, *Pteranodon*, 8—12 foot wing spread, x1/40. (*A*, *C* from Schuchert: Historical Geology, permission John Wiley & Sons; *B*, *D* from Lucas: Animals of the Past, permission Amer. Mus. Nat. Hist.)

vorous; and in size they ranged from small, agile forms to massive forms about ten feet long. Some of the large herbivorous forms are believed to have had tortoiselike habits. In this order, too, belong the fiercely carnivorous "fin-backed" lizards represented by the eight to ten foot long *Dimetrodon* (Greek *dimetros,* two measures; *odous* (*odont*), tooth) from the Permian of Texas (figure 67). As this form shows, the popular name is derived from the more or less high bony crest or fin borne on the back. These reptiles are found in the greatest numbers in Carboniferous (Upper Pennsylvanian and Lower Permian) beds in North America, Europe and South Africa, occurring in greatest abundance in the Texas-New Mexico area of North America. They lived in Triassic times but died out before the Jurassic, probably because they were not fitted for competition with the better-organized reptiles that lived during Triassic times.

The *Ichthyosauria* (Greek *ichthys,* fish; *sauros,* lizard) and the *Plesiosauria* (Greek *plesios,* near; *sauros,* lizard) were among the monsters of the sea. Reptiles became adapted to a life on land and then as air-breathers again took to the sea, probably partly from the overcrowding and great competition on the land, partly because of the ease of obtaining food in the shallow waters bordering the land. Not one group, but members of several groups, became perfectly adapted to life in the sea. There were developed as well as the ichthyosaurs and plesiosaurs, marine crocodiles and turtles and gigantic sea lizards.

The *ichthyosaurs,* represented by *Ichthyosaurus,* were fishlike in appearance and among the reptiles in ancient times paralleled the whales among the mammals today, only they were not so large (figure 68). They had a large head with large eyes and with an elongated, slender

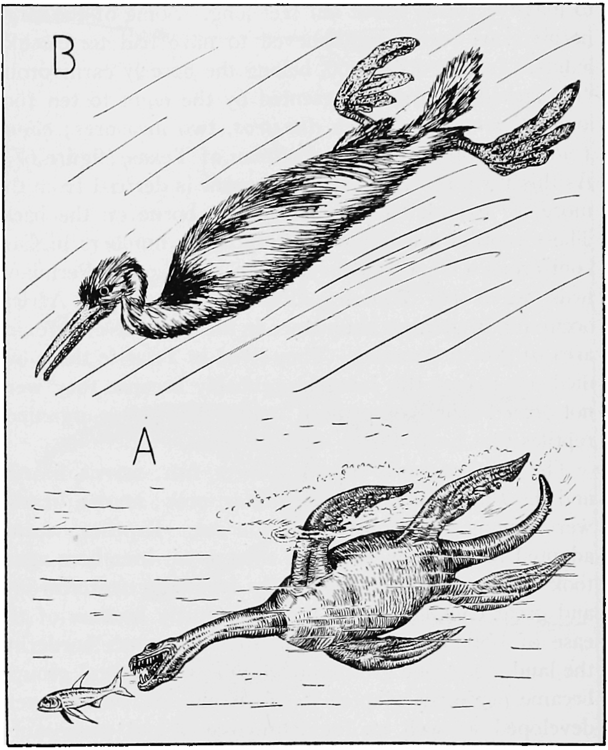


Figure 69. Swimming reptile and bird. *A* Jurassic *Plesiosaurus,* 20 feet long, x1/90 (from Schuchert: Historical Geology, permission John Wiley & Sons; pen sketch by E. J. Stein). *B* Upper Cretaceous diving bird, (*Hesperornis*), 6 feet long, 4½ feet high, x1/18 (from Lucas: Animals of the Past, permission Amer. Mus. Nat. Hist.)

snout provided with numerous sharp teeth, the jaws sometimes having a length of five feet. There was no neck and the body was heavy and provided with a long, powerful tail. A dorsal fin was present and a vertical tail fin designed for rapid propulsion. The two pairs of limbs were modified into true paddles which, in the earlier forms, were less paddle-shaped and more like legs, thus indicating the derivation of this group from land animals. These creatures were 20 to 30 feet long and some even attained a length of 40 feet. The ichthyosaurs lived on fishes and cephalopods, such as the squids, as shown by the contents of the abdomen. The young were brought forth alive and specimens have been found with the embryos preserved. In some fossils the impressions of the outline of the body and limbs are preserved and the nature of the skin is recognizable. It was smooth and without scales. The ichthyosaurs lived from the Triassic to the Cretaceous but they had their highest development during the Jurassic at which time they were very abundant and seem to have occupied every sea. Their place in the Upper Cretaceous seas was taken by the giant sea lizards (Squamata), scaled reptiles known as *mosasaurs* (Greek *mosa,* river; *sauros,* lizard) which in some cases attained a length of 50 feet. These forms were entirely confined to the Upper Cretaceous.

The *plesiosaurs* or "near-lizards" formed another group of marine reptiles. They are also termed by some sauropterygians (Greek *sauros,* lizard; *pterygia,* fins). Plesiosaurs (figure 69) had a short, stout body, two pairs of paddlelike limbs and a short tail probably most useful for steering. They differed from the ichthyosaurs in the possession, usually, of a long neck and a small head provided with large, sharp teeth. The skin, as with the ichthyosaurs, was smooth and without scales. In size they varied considerably, some reaching the extreme length of 40 feet, others not longer than 6 feet. The *Plesiosaurus* of Jurassic times attained a length of 20 feet or thereabouts, but the majority of the species were smaller. One species reaching a length of 40 feet had a small head and a neck 22 feet long, very useful in catching prey. Some forms just as large had a short neck of not more than a foot and a half, with a head several times as long. As in the ichthyosaurs the limbs were less paddlelike in the earlier (Triassic) forms, showing a like origin from land forms. Species of *Plesiosaurus*, likewise, must have produced their young alive as, in some specimens, there have been found in the abdomen objects which appeared to be embryos. From the remains, such as bones and shells, found in the neighborhood of the body where the stomach should be located, the food of plesiosaurs must have been similar to that of the ichthyosaurs and consisted of fish and cephalopods with an added diet of pterodactyls or flying reptiles. With these remains, in complete skeletons, have been found a large number of pebbles, some of large size, which are known variously as "gizzard stones," "stomach stones" or "gastroliths" (Greek *gaster*, stomach; *lithos*, stone) and which assisted in grinding the food, probably devoured whole. Plesiosaurs lived throughout the entire Mesozoic. While they were most abundant in the Jurassic, they reached their greatest size in Cretaceous times, during which period some forms became adapted to a fresh-water environment.

The *pterosaurs* (Greek *pteron*, wing; *sauros*, lizard) or pterodactyls (Greek *pteron*, wing; *dactylos*, finger) were the dragons of the air in Mesozoic times. They, like the marine forms, may have been driven into the new element, in part, because of overcrowding and competition on the land. From fossil remains it has been inferred that these forms were common and showed considerable variety. Flying reptiles (figure 68) had long necks, rather large but light heads, and were birdlike in general build, with hollow, light bones and the front limbs modified for flying. Tails were long or short; some forms were tailless. In the beginning the jaws were provided with teeth but in later genera the jaws were toothless (*Pteranodon*) and sheathed with horn as in modern birds. As in birds, there was a strong shoulder girdle and a large, keeled breastbone for the attachment of the muscles of flight. The most striking characteristic of these reptiles was the large, batlike leathery wings which stretched from the body, hind limbs and tail to the greatly elongated fourth or little finger of the forelimbs. The other three fingers bore claws, and there was no thumb. Flying reptiles had not the power of flight of birds; the flight probably was more batlike. In size they varied greatly; from the size of a sparrow to large forms with a wing spread of 20 to 25 feet. The largest, living sea bird, the albatross, has a wing spread of only twelve feet.

One of the least specialized of the flying reptiles, and at the same time one of the best known, is *Dimorphodon* (Greek *dimorphos,* two formed; *odous* (*odont*), tooth). This Jurassic pterosaur had a height of less than two feet when standing on its hind legs and had a wing spread of something more than four feet. The wing membrane was naked. As implied by the name, the jaws bore two kinds of teeth; those in front strong, sharp and fitted for tearing; those in back small, sharp and sawlike. Another Jurassic form is *Rhamphorynchus* (Greek *rhamphos,* curving beak; *rynchos,* beak), a long-tailed pterosaur that had a length of about two feet and a wing spread of four to five feet. On the whole the Jurassic pterosaurs were small but the later forms attained a wing spread of a score or more feet (*Pteranodon*). *Pteranodon* (Greek *pteron,* wing; *a,* without; *odous* (*odont*), tooth), the largest pterodactyl known, lived in Upper Cretaceous times when it sailed over the chalk seas of Kansas. It was also probably the most highly specialized animal that ever existed; everything possible was sacrificed toward its adaptation to flight. There was a highly developed head, 30 to 45 inches long and very narrow, with a daggerlike beak and toothless jaws as in modern birds. The body was little longer than the head; and in fact was so light, comparatively, that it might be looked upon as an appendage of the wings. It is believed from the structure of the body that even the largest individuals could not have weighed more than 25 to 30 pounds, while the majority must have weighed less than half this. The body was built strongly in front as to wings, shoulder girdle and breastbone, but the rear end and the hind legs were weak. The wings had a length of 8 to 12 feet and over, giving a wing spread more than twice that of the largest living bird. Pterosaurs were carnivorous, feeding upon both land and sea animals; some are even believed to have been insect feeders. They probably laid eggs, as is the general habit of reptiles. Pterosaurs have been reported from the latest Triassic of Europe and as the earliest forms were highly specialized when they appeared, the time of their origin has been placed back in the Permian. Birds have not been derived from these flying reptiles but it is thought possible that birds, flying reptiles and carnivorous dinosaurs, as well, may trace their origin back to a common ancestor. Pterosaurs reached their greatest development in the Jurassic and died out in the Cretaceous.

The *dinosaurs* (Greek *deinos,* terrible; *sauros,* lizard) or terrible saurians were the dragons of the land, the reigning reptilian dynasty of the Mesozoic (figure 67). These animals appeared first in the Triassic, and even then they were numerous and quite varied, although they were at first generalized types becoming more specialized later. They varied from species small and delicate in structure to forms of gigantic size, up to 100 feet in length. It is probably due to the early discovery of remains of these large reptiles, without knowledge of their meaning, that gave rise to tales of dragons, such as the dragons of our fairytales. These "dragons" were either lizardlike or birdlike in form and some even approached birds in certain features of their structure, such as hollow limb bones. They had long powerful tails suggesting that, although they were land animals, they were also good swimmers. The surface of the body in some was protected by a bony armor, sometimes with spines and highly ornate; in others there was a covering of scales, while some were probably naked. In some the fore and hind limbs showed about equal development; in others the hind limbs were much more powerful, the fore limbs being small and short. The hind legs alone therefore were used in walking and gave rise to the three and four-toed tracks such as those (*Anchisaurus, Podokesaurus*) found in the Triassic sandstones of the Connecticut valley which when first discovered were interpreted as the tracks of gigantic birds. Some of the tracks of dinosaurs are an inch long, while others are as long as two feet, which also gives some idea of the variation in size. Most of the dinosaurs, like most of the other reptiles, laid eggs. A nest of eggs was found in the Gobi Desert by the Mongolian Expedition of the American Museum of Natural History. Dinosaurs were both carnivorous and herbivorous. All the Triassic forms were carnivorous, not especially large, and upright-walking, with the reduction of the toes which gave the three-toed tracks. All carnivorous forms had a bipedal or two-footed mode of progression; they reached their highest development in the Jurassic. The herbivorous forms developed later than the carnivorous ones and include Jurassic species (as *Brontosaurus*) which were the largest land animals that ever lived on the earth. These massive forms walked semi-flatfooted. They had long snakelike necks and long tails and the heads were very small proportionally. Another group includes herbivores with horny beaks, birdlike or tortoiselike. Some of these (*Iguanodon, Trachodon*) walked on their hind legs and were unarmored; while others walked on all four feet, had a bony armor and were variously ornamented with bony plates (*Stegosaurus*) or horns and bony frills (*Triceratops*).

Podokesaurus (Greek *podokes*, swift-footed) was one of the small carnivorous dinosaurs which inhabited the area of the Connecticut valley in Triassic times and its skeleton and three-toed imprints are found in the sandstones of that valley. This little creature was something less than four feet long from the head to the tip of the 30-inch tail and stood about 18 inches high. Associated with this form was one (*Anchisaurus*, from Greek *anchi*, near) about twice as large, with a proportionally shorter tail. These were primitive types with light bodies, long necks and long tails from which were developed the later flesh-eating carnivores, some of them, as *Tyrannosaurus*, being very ferocious. *Tyrannosaurus rex* (Greek *tyrannos*, tyrant; Latin *rex,* king) from the Upper Cretaceous of Montana and Wyoming was the king of the tyrant dinosaurs, having a length of 47 feet and a bulk equal to the mammoth, mastodon or the largest of the living elephants. This creature stood 18 to 20 feet high and had a head over four feet long, over three feet deep and about three feet wide, with powerful jaws equipped with teeth three to six inches long. The feet were provided with large, sharp claws; the forefeet are shown in the reconstruction as relatively very small.

Brontosaurus (Greek *bronte,* thunder) was one of the massively built herbivorous dinosaurs. One of the largest specimens from the Upper Jurassic of the Rocky Mountain region measures over 65 feet in length and had an estimated living weight of 38 tons. Another genus from the same region had a still greater size, standing 20 to 25 feet high and measuring about 80 feet in length; and East Africa has produced still huger forms (*Gigantosaurus*: Greek *gigas* (*gigant*), gigantic). These immense creatures had small heads with brains weighing less than a pound. *Diplodocus* (Greek *diploos,* double; *dokos,* beam —referring to the character of the vertebrae) was a more slender form, and the last ten feet of the tail was like a whiplash and may have been used as a weapon of defense. This creature grew to a length of at least 80 feet, and a specimen 87 feet long was obtained in the Comanchian (Lower Cretaceous) of Wyoming. Even with this length they were not as heavy as the Brontosaurus because of the lighter build and the fact that a large proportion of the length was in the slender neck and tail. All these huge herbivorous forms must have been protected to a certain extent by their size and also by their habits. While they were land animals, they must have been able to swim easily and probably lived as much in water as on the land, getting their food from floating plants or foliage growing along the water's edge which their long necks enabled them to reach.

Trachodon (Greek *trachys,* rough; *odous* (*odont*), tooth) was one of the herbivorous dinosaurs with birdlike beak. This creature has been found in the Upper Cretaceous of the Rocky Mountains region. It walked or ran on two feet and was unarmored but specimens of skin have been found showing that it was covered with small, tuberclelike scales. This was a duck-billed dinosaur which had a length of not more than 30 feet, stood about 15 feet high and possessed a powerful, flattened crocodile-like tail very useful in swimming, since it led an amphibious existence. The hands were webbed but it is not known whether the feet were also.

Stegosaurus and *Triceratops* are armored representatives of the herbivorous dinosaurs, the former from the Lower Cretaceous, the latter from the Upper Cretaceous. *Stegosaurus* (Greek *stegos,* cover, roof) was about 20 feet long and must have weighed at least ten tons. The head was very small in proportion to the size and the brain has been estimated to have had a weight of two and one-half ounces, while that of an elephant is about 50 times that, although the elephant is smaller in size. Above the hips was an enlargement of the spine twenty times larger than the brain, and this was a nerve center controlling the huge hind limb and tail muscles. These dinosaurs had turtlelike beaks and were protected by bony plates embedded in the skin of the throat and two rows of large bony plates, varying in size from a few inches to two feet, which ran from the head along the middle of the back and over nearly two-thirds of the tail. The rest of the tail bore spines ranging from six inches to over three feet in length. *Triceratops* (Greek *treis* (*tri*), three; *keras*, horn) was a huge creature, 20 to 25 feet in length, rhinoceroslike in aspect, and with a large head one-quarter to one-third the length of the body. One skull has been found measuring eight feet over all. The body was very large and barrel-shaped and the legs were short and stout. The skull is expanded backward into a large bony frill or crest which protects the neck. Above each eye is an enormous horn three to four feet long, with a diameter of six inches at the base, and there is a shorter horn over the nose. In a closely related genus this condition is reversed, the long horn being on the nose. In addition, in *Triceratops* there are smaller horns along the edge of the frill or the frill may be drawn out into long horns. The mouth completed the armament of this creature, for it was armed anteriorly with a sharp cutting beak like that of a turtle. This armament protected *Triceratops* in combats with other creatures. Marks from such combats are preserved in the fossils today. These creatures had to depend upon their bulk and their armament for protection because they had very small brains, probably the smallest for their bulk of any of the reptiles, and therefore must have been very stupid. Their career began and ended in the Cretaceous period.

Dinosaurs are known from the Triassic through the Cretaceous; not a single trace of them remains in the rocks of Tertiary age. Various theories have been offered to account for their sudden extinction, such as warfare amongst the dinosaurs themselves, destruction of the young possibly in the egg by small, carnivorous mammals, and change in climate. We do know, however, that there were changes of elevation of the land at the end of the

Mesozoic era which brought about the drainage of the big, inland seas, thus restricting the old reptilian haunts and sounding the doom of these strange creatures.

These old reptiles lived and wandered over the area now occupied by New York State, but this territory was then dry land, so they failed to leave a trace of their existence. Traces of these reptiles are found in neighboring areas. They walked the mud flats of the estuaries then in existence in the Connecticut valley, leaving the imprints of their birdlike feet. Some of them, from their tracks, must have been animals of gigantic size. The Museum has some of these slabs from Turner's Falls and South Hadley Falls, Mass., on exhibition in Vertebrate Paleontology Hall. The tracks and a restoration of the little *Podokesaurus* from the Connecticut valley may be seen in the "What is a Fossil?" exhibition case. In Vertebrate Paleontology Hall is a case of Gilmore's models of extinct reptiles, among them *Dimetrodon, Diplodocus, Trachodon, Stegosaurus* and *Triceratops.* Specimens of the different types of ancient reptiles may be seen in the larger museums in the country.

Class Aves (plural of Latin *avis,* bird). The birds show less variation in character than any other group of vertebrates and are remarkable for the compactness and lightness of their skeletons. They are feathered, warm-blooded, egglaying vertebrates. The head is small, the neck long and flexible, and the fore limbs are modified to form wings. The hind limbs have four toes; the wings show three reduced fingers upon the tips. There is a well-developed keel on the breastbone for the attachment of the muscles of flight in all flying birds. The bones are light and hollow or may be completely filled with spongy bone. This is true of the skull and the upper wing and leg bones, particularly, in the majority of birds. The vertebrae have peculiar saddle-shaped articulations which allow great freedom of movement. The exoskeleton or protective skeleton in birds consists of the feathers, the claws on the feet (sometimes on the wings), reptilianlike scales on the feet and lower legs, and a horny beak. Over 25,000 recent species of birds have been described but there are only about 700 known fossil forms and most of these have been found in the Miocene (Middle Tertiary) beds or later and are referable to existing families, often to existing genera. The reason for the small number of fossil birds, even in the periods when birds were abundant, must be in large part that the dead bodies fell upon the ground or in the water and were eaten or decayed before there was a chance for the burial necessary to fossilization. There are places such as Allier in southern France, Fossil Lake, Oregon, and Rancho la Brea, California, where fossil bones of birds occur in considerable numbers. Fossil eggshells or their casts have been found in Cretaceous formations and in various Tertiary beds. The saddle-shaped articulation of the vertebrae is characteristic of post-Jurassic species; teeth have not been present in adult birds since Tertiary times.

The earliest-known bird, *Archaeopteryx* (Greek *archaios*, ancient; *pteryx*, wing), was found in Upper Jurassic beds in the lithographic limestone quarries of Solenhofen, Bavaria (figures 70, 71). Conditions here were very favorable for preservation and yet only two well-preserved specimens and a single feather have been found. One specimen, headless, is in the British Museum, London; the other is in Berlin. This early bird type was about the size of a crow and, while it shows an advanced

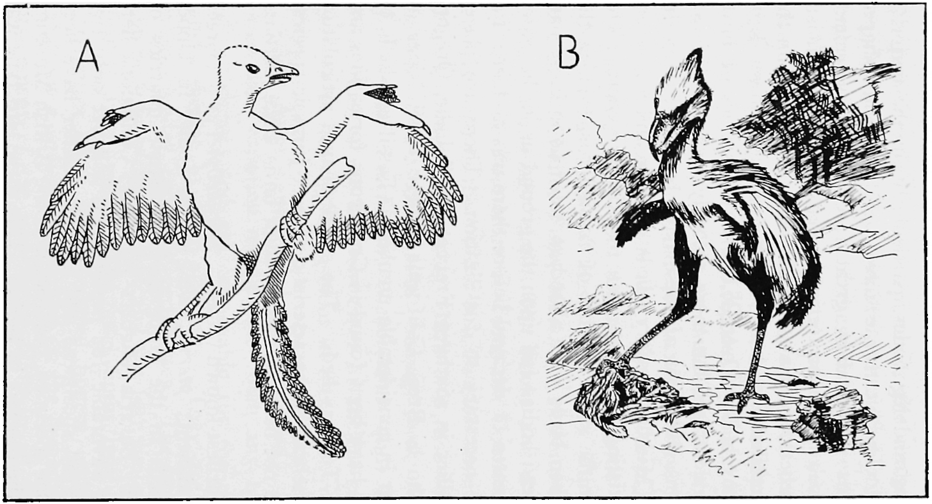


Figure 70 Birds. *A* Earliest known bird, (*Archaeopteryx*), from Upper Jurassic of Solenhofen, Bavaria; size of pigeon (after Pycraft, from Introduction to Study of Fossils by H. W. Shimer, published by The Macmillan Co.). *B* Middle Tertiary bird (*Phororhacos*) from Argentina, 8 feet high, x1/45 (from Lucas: Animals of the Past, permission Amer. Mus. Nat. Hist.

stage of evolution, in a number of characters it is more reptilelike than modern birds; in fact, if the feathers had not been preserved the remains would have been classed as reptilian. Both jaws bore sharp teeth; the neck was short; the wings bore three reptilelike claws at their tips, the fingers not having yet been fused into the modern wing form; the hind limb bore four toes as in modern birds; there was a long, vertebrated tail with a pair of feathers to each vertebra. The shoulder girdle was small for a flying bird, but the breastbone had a small keel showing that these birds did fly. They probably confined themselves to short, occasional flights, more of a soaring nature. This bird is not known from America.

The differentiation of true birds was contemporaneous with the evolution of the flying reptiles. There is no evidence that pterosaurs are the ancestors of birds, but rather that pterosaurs, carnivorous dinosaurs and birds may have descended from a common stem. Several theories as to the origin of birds have been put forward and hypothetical ancestors reconstructed. Among these is *Tetrapteryx* (Greek *tetra,* four; *pteryx,* wing), the ancestral four-winged reptilian bird, the reconstruction of which (by C. W. Beebe) is based upon certain characteristics found in newly hatched birds and also in the Berlin specimen of *Archaeopteryx* (figure 71). This bird is supposed to have had its origin somewhere in the Lower Jurassic and the feathered limbs were used as planes in gliding rather than wings, as true flight had not yet been acquired.

After *Archaeopteryx* the next bird remains known are from the marine beds of the late Cretaceous of the Kansas region. Between the *Archaeopteryx* of the Jurassic and the late Cretaceous birds important changes had taken

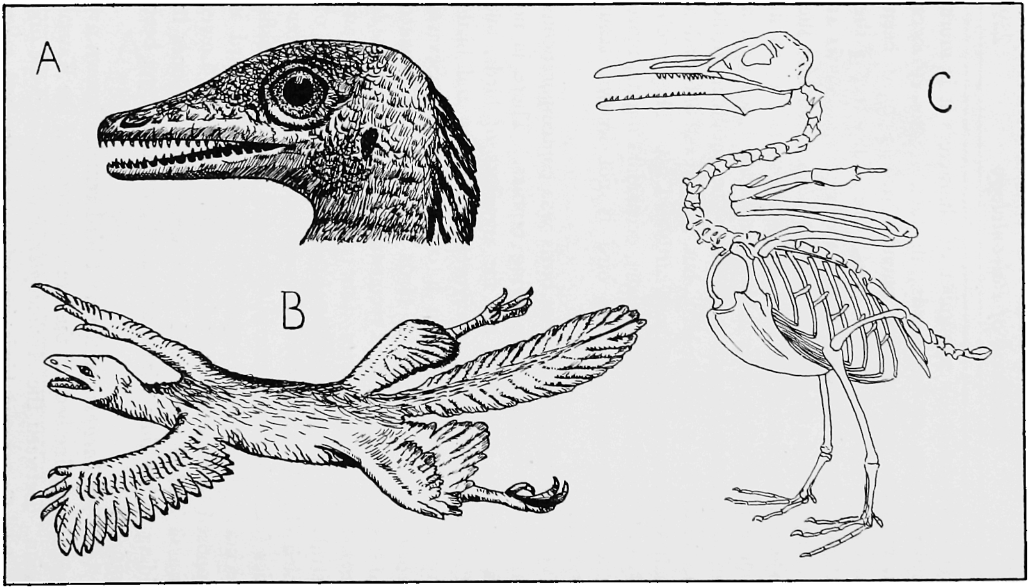


Figure 71 Birds. *A* Head of *Archaeopteryx* (after Heilmann; from Schuchert: Historical Geology, permission John Wiley & Sons. *B Tetrapteryx*, hypothetical ancestral four-winged reptilian bird (after Beebe, from Organic Evolution by R. S. Lull published by The Macmillan Co.). *C* Upper Cretaceous *Ichthyornis*, about size of pigeon, x½ (after Marsh).

place, among them the loss of the long, vertebrated, bilaterally feathered tail. The birds of Jurassic times were terrestrial; Cretaceous birds mainly aquatic. There were terrestrial types but the fossil record here is meager. About 30 species of Cretaceous birds are recorded which may be grouped into two widely divergent types represented by *Hesperornis* and *Ichthyornis.*

Hesperornis (Greek *hesperos,* western; *ornis,* bird) was named from the fact that the remains were found first in our western Upper Cretaceous, and the first species was named *Hesperornis regalis* or regal western bird (figure 69). This was the largest bird of its time, for it had a length of six feet in some cases and stood about four and one-half feet high. *Hesperornis* was an aquatic bird, a highly specialized diver, and was so modified in adaptation to the life which it led that it was unfitted for life anywhere but in the sea. The shape of the body, head and neck were suited to this life. The wings were so reduced as to be practically wanting and of no use either in the air or water; but along with this was an extraordinary development of the legs. The feet were webbed and the bones of the feet were joined to the legs in such a manner that they could be turned edgewise in the water when brought forward, increasing their efficiency as paddles. The legs were joined to the body nearly at right angles, resembling a pair of oars and suggesting that walking, too, had been abandoned. The jaws were provided with teeth, and the tail while vertebrated was intermediate between that of *Archaeopteryx* and modern birds. *Hesperornis* probably frequented somewhat widely the shallow seas over the continent during these times. Because of their size they would be formidable to sea life, feeding upon fish and reptiles, even of considerable size.

Ichthyornis (Greek *ichthys,* fish; *ornis,* bird) was a small, gull-like bird, not much larger than a pigeon, and while an aquatic bird of a similar habitat, in contrast to *Hesperornis* it was endowed with great powers of flight as shown by the well-developed wings and the strongly keeled breastbone (figure 71). It must have resembled a modern bird very much. While the wings had lost the reptilian claws and the tail was less vertebrated than in *Archaeopteryx,* the jaws were toothed as in *Hesperornis* and the vertebrae were biconcave, unlike modern birds but like fish and many of the extinct reptiles. This bird, too, was a flesh feeder.

Tertiary birds were essentially like those of today. In early Tertiary beds are found fossils of ancestral gulls, terns, flamingoes, albatrosses, buzzards, falcons, eagles, owls, woodcock, quail, plover etc., showing the great expansion of this class. Besides forms of doubtful interpretation there have also been found ostrichlike flightless birds of great size. Both these and the water-loving birds descended from flying types. These large, flightless birds lived on all the continents at some time during the Cenozoic era and were only exterminated in New Zealand 500 or 600 years ago. These *Moas* of New Zealand were the tallest and heaviest of this type of bird, and some of them stood ten feet high. On the island of Madagascar have been found subfossil eggs of one of these birds (*Æpyornis:* Greek *aipys,* tall) which measure 9 by 13 inches and are the largest eggs known. It has been estimated that one of these would hold the contents of six ostrich eggs. About 30 eggs have been discovered. The State Museum has a plaster model of one of them. One of the fiercest and most powerful of these flightless, running birds (*Phororhacos*) lived in the

Argentina region (Patagonia) in Middle Tertiary (Miocene) times. *Phororhacos* (Greek *phoros,* bearing; *rachos,* rags, tatters) stood about eight feet high and had a decidedly beaked skull as large as that of the largest horse (figure 70). When the first fragment of one of these birds was found it was thought to belong to one of the large ground sloths, hence the error in the name.

From the Tertiary on, birds continued their rapid evolution, but they have not shown the variety in size and adaptation that is shown among reptiles. No fossil birds have been found in New York State and none are exhibited in the State Museum. Specimens of *Archaeopteryx* may be seen only in the British Museum, London, and the Royal Museum of Natural History, Berlin; but a large collection of the toothed birds such as *Hesperornis* and *Ichthyornis* may be seen in the Peabody Museum, Yale University. There are also specimens in the National Museum, Washington, and the American Museum of Natural History, New York.

Class Mammalia (Latin *mamma,* the breast). This class derives its name from the fact that for the most part the young are brought forth alive and nourished for a time with milk from the mother's breast. The mammals are the highest of the vertebrates; warm-blooded, breathing entirely by air, though many are aquatic. Usually they have a protective covering or exoskeleton of hair which replaces the scales of reptiles and the feathers of birds and usually develops in such quantities that it forms a thick soft fur. Most of the mammals, as we know, live upon the surface of the earth but there are several variations from this mode of life. There are flying forms, as the bat; arboreal forms or tree-dwellers, as the squirrel and monkey; and some as the mole, lead a burrowing life.

Other forms pass an aquatic life either in fresh water, as the beaver and muskrat, or in the ocean, as the whale and seal. (Figures 72–75).

There is some variation in the classification of the mammals, but there are recognized, generally, eleven orders of living forms. Three orders are only known fossil. The eleven orders of living forms are: Monotremata, Marsupialia, Edentata, Insectivora, Chiroptera, Rodentia, Carnivora, Cetacea, Ungulata, Sirenia, Primates. These orders are grouped by some into two, by others into three, subclasses. The first includes all egg-laying mammals (*Prototheria:* Greek *protos,* first; *therion,* wild beast) and has the one order, Monotremata; the second includes all forms in which the young are brought forth alive (*Eutheria:* Greek *eu,* well, good; *therion,* wild beast) and comprises the remaining orders. When a third subclass is recognized it covers the order Marsupialia which includes forms in which the young are brought forth alive but in such an undeveloped condition that they are nourished and sheltered in a ventral pouch, such as in the kangaroo, until they are able to take care of themselves (*Metatheria:* Greek *meta,* between, intermediate; *therion,* wild beast).

The *Monotremata* (Greek *monas,* single; *trema,* perforation) are very primitive, reptilelike forms that are characterized by the egg-laying habit. The two living genera are confined to the Australian region, and are the Duck-bill or Platypus (*Ornithorhynchus*) and the Spiny or Porcupine Anteater (*Echidna*). With the exception of a doubtful Upper Triassic form which may prove to be no mammal at all, this group is known only since the Pleistocene or Glacial Period.

The *Marsupialia* (Latin *marsupium,* pouch) receive their name from the integumentary ventral pouch in which the young, born in a rudimentary condition, develop until able to take care of themselves. They are represented by the Opossums of North and South America and the so-called Opossum-rats of Ecuador and Columbia. Outside of these types the marsupials are confined to the Australian region and include the Tasmanian Wolf, Bandicoots, Marsupial Moles, Kangaroos and their allies, Wombats and the flying and climbing Phalangers; but representatives of the two groups into which these types fall lived in South America during Tertiary times. Opossums lived in Europe during the Lower Tertiary; in America they are known from the Cretaceous. The order is known from the Jurassic to the present.

In the *Edentata* (Latin *edentatus,* toothless) the teeth are absent or of imperfect development, hence the name which is somewhat inappropriate. The order includes terrestrial, partly subterranean or arboreal creatures and they vary from quite small forms to those of gigantic size. To this order, among living forms, belong the Sloths, Anteaters, Armadillos, Scaly Anteaters, Cape Anteaters and Aard-varks. Fossil forms include the giant ground sloths and armadillos. One of the largest species (American) of giant sloths (*Megatherium*) reached a length of 20 feet and one of the fossil armadillos (*Glyptodon*) of North and South America attained the extreme length of 15 feet. True edentates are known from the Tertiary (Eocene) to the present and, with the exception of Australia, from all the continents. They attained their greatest importance in Late Tertiary (Pliocene) and Pleistocene, particularly in South America, where some of them were the largest creatures on the continent.

The *Insectivora* (Latin *insectum,* insect; *vorare,* to devour) are a rather generalized group of small mammals whose habit of living upon worms and insects has given the name to the group, which includes Moles, Shrews and Hedgehogs. The nose is usually prolonged into a short, soft proboscis or snout. The brain is simple, of a low type. It has been suggested that this, more than any other living group, reproduces the characters and habits of the primitive true mammals. Primitive insectivores are known from the Jurassic; representatives of the living families are known from the Lower Tertiary (Eocene) to the present. The insectivores occupied an important place in Eocene times but have dwindled in numbers to the present.

The *Chiroptera* (Greek *cheir*, hand; *pteron*, wing) include the ordinary Bats abundant all over the world and the so-called Flying Foxes of tropical and subtropical parts of the Eastern Hemisphere. The members of this order have the fore limbs modified to form wings and a keeled breastbone for the attachment of the flying muscles. The bats are small and mostly insect feeders, with a short snout; the flying foxes are large, fruit-eating bats, with an elongated snout. Bats are known from the Lower Tertiary (Eocene) to the present. It is believed that they are descended from primitive insectivores.

The *Rodentia* (Latin *rodens*, gnawing), or rodents, form a larger order of small, fur-bearing, vegetable-feeding forms and include Rats, Mice, mouselike Jerboas of the Old World, Rabbits, Hares, Squirrels, Marmots, Pocket Gophers, Beavers and Porcupines. They are provided with elongated, chisel-like incisors which serve a gnawing function and give the name to the group. Rodents are first known from the Early Tertiary (Eocene) and they were then very much as they are today, having always

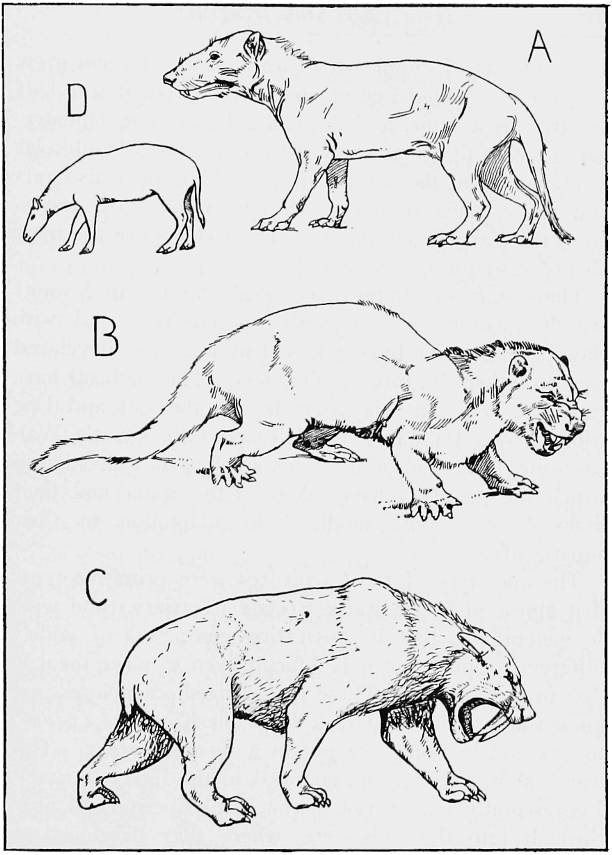


Figure 72 Mammals. *A Hyacodon,* one of the last of the Lower Tertiary creadonts. Size of fox, about x1/20 (after Osborn). *B* Ancestral cat, a creodont (*Patriofelis*) from Lower Tertiary, about x1/25 (after Osborn). *C* Saber-toothed tiger, *Smilodon,* of Pliocene and Pleistocene (after Osborn from Lull). *D* Four-toed horse, *Eohippus,* from Lower Eocene. Size of small dog (after Lull). (*A—C* Knight restorations; *C, D* from Organic Evolution by R. S. Lull, published by The Macmillan Co.)

been animals of simple structure. Some of them grew to great size. One Eocene species of a rodent was half as large as a tapir, and from the Pleistocene (Quaternary) comes the giant beaver (*Castcroides*). The beaver is known from the Late Tertiary (Pliocene), also rats and mice; while squirrels and true rabbits are known from the Early Tertiary, etc. The rodents are the most abundant of the mammals today.

The *Carnivora* (Latin *carnis,* flesh; *vorare,* to devour) are flesh-eating animals, with fur covering and with clawed feet, never having less than four well-developed toes on either the fore or hind feet. The teeth all have cutting edges. In this order belong the Cat and Dog tribes, Civets, Hyenas, Bears, Weasels, Otters, Seals, Walruses etc. The seals and walruses belong in a division in which the members have taken to the water and their limbs have become modified in adaptation to their aquatic life.

The ancestors of the Carnivores were primitive types that appeared in the Early Eocene (Tertiary) and were so generalized, that is, possessing characters of widely different groups, that it is difficult even to place them in the proper order. These generalized carnivores are known as *creodonts* (Greek *kreas,* flesh; *odous* (*odont*) tooth) and by some are put in a separate order. This was a short-lived group, confined to the Early Tertiary. Representatives appeared in the basal Eocene and lived through into the Oligocene, where they developed to larger size. Some of the creodonts were larger, some smaller, than a fox (figure 72).

Before the close of the Oligocene (Middle Tertiary) many of the families of true carnivores had appeared and they had entirely replaced the creodonts before the end of that period. The dog tribe made its appearance in the Eocene; the cat tribe had a somewhat later development, being first known from the Oligocene. The fossil cats form a very interesting group. Among them are included not only the ancestors of the modern forms, but huge saber-toothed tigers or stabbing cats (Middle Tertiary to Pleistocene) that are now extinct but whose effective weapons made them the most formidable and most efficient beasts of prey among the carnivores. The bear tribe came in with the Middle Tertiary (Miocene) in Eurasia. The great cave bears of the Pleistocene or Glacial Period were hunted for food by primitive man. By Middle Tertiary (Miocene) times, the *"Mammalian Golden Age,"* the carnivores were very abundant, some of them not differing much in appearance from modern types. There were hyenas and bears as well as the wolves, foxes, pantherlike forms, saber-toothed tigers, weasels, martens, otters, ancestral raccoons etc. The dog tribe went through the greater part of its development in North America. True cats appeared here for the first time in the Miocene, while true bears were not known in America before the Pleistocene. South America had only carnivorous marsupials during these times but was later populated from North America. During the Late Tertiary (Pliocene) the carnivores throve and gained upon herbivorous forms forcing them to further development along the lines of alertness, speed, defense etc. The saber-toothed tigers had their best development in the Pliocene and Pleistocene. The great saber-toothed tiger *Smilodon* spread over North America and travelled over the land bridge into South America during Pliocene time (figure 72).

The *Cetacea* (Greek *ketos,* whale) are aquatic forms with large heads and fishlike bodies without hairy covering. The fore limbs are modified into paddles, the hind limbs are absent and there is a horizontal tail fin and a vertical dorsal or back fin. The snout is long. The brain is large, a contrast to the condition in the Sirenia or sea cows. To this order belong all the Whales, the Killers, the Porpoises and Dolphins. The order is represented from the Early Tertiary (Eocene) to the present. These forms were descended from land forms, probably the clawed division of mammals, and having taken to an aquatic life became modified to fit the environment of their adoption.

The *Ungulata* (Latin *ungula,* hoof) include land animals which are herbivorous and have abundant or scanty fur. The weight of the body usually rests upon the ends of the toes which are nearly always invested with a solid, horny nail or hoof. The Ungulata comprise ten suborders but only four have living representatives. One suborder includes Horses, Asses, Zebras, Tapirs and the Rhinoceroses; forms in which one toe is larger than the others which tend toward reduction. Another comprises the ruminants or cud-chewers, such as Camels, Oxen, Sheep, Goats, Antelopes, Giraffes, Deer; and non-ruminants, such as Pigs, Peccaries, and Hippopotami. In this group two toes are symmetrically developed and the others absent or reduced. There is also a suborder of small, furry forms in which there may be five functional toes and the animals walk on the flat of the foot. These are harelike creatures, such as the Conies (*Hyrax*) mentioned in the Bible, belonging to Africa and neighboring Asiatic regions. A fourth suborder includes, among living forms, only the Elephants which have five complete toes, united by the skin but each terminating in a distinct hoof, and are further characterized by a proboscislike extension of the nose and a pair of enormous tusks on the upper jaw.

The most primitive of the ungulates, which are known from the basal Eocene, are with difficulty separated from the creodonts, the ancestral carnivores. They were generalized types, flat-footed, five-toed animals with clawed toes intermediate between the typical claws of the carnivores and hoofs (figure 73).

One extinct group of the ungulates is of much interest. They are the *titanotheres* (Greek *titan,* giant; *therion,* wild beast) or "giant beasts" which formed a group of characteristic mammals of the North American Cenozoic (figure 73). They had their origin in the Lower Eocene, the ancestral form having a resemblance to a tapir and being about the size of a sheep. This group lived only in the Early Tertiary, dying out in the Oligocene. During Oligocene times there were representatives of this group attaining the size of small elephants. These animals had heavy bodies, heavy, columnar legs and short feet supported by thick pads as in the recent elephants. Some of the forms had tusks; knobs or horns on the head were also present, in some being situated on the nose. The brain of the titanotheres was no larger than a man's fist, so they must have been very stupid creatures. This tribe is distantly related to that of the rhinoceros.

Horses are known from the Lower Eocene (Early Tertiary) in both North America and Eurasia. Their ancestry has been traced from an animal less than a foot in height, unhorselike in appearance and about the size of a fox. The earliest American horse, *Eohippus* (Greek *eos,* dawn; *hippus,* horse) had four well-developed toes with a rudimentary first toe on the fore-foot and three well-developed toes with rudimentary first and fifth toes on the hind-foot (figure 72). A series of fossil forms

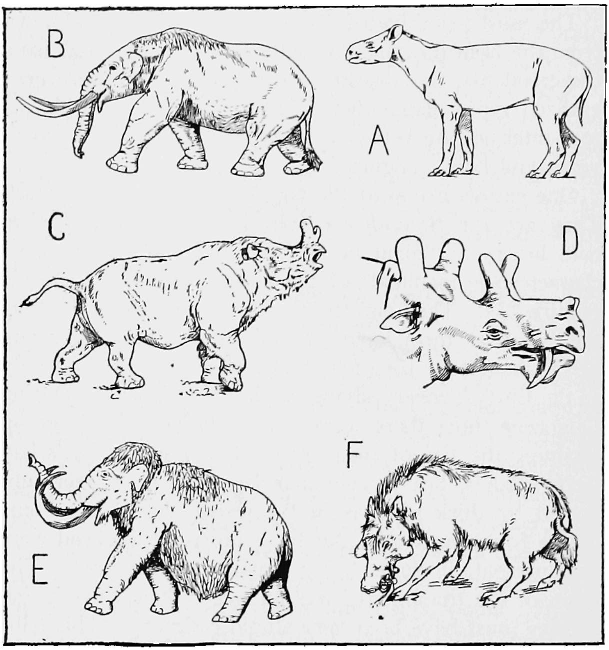


Figure 73 Mammals. *A Hyrachus* x1/40, one of hyracodonts, ancestral hornless animals; ancestors of titanothere, rhinoceros, and possibly horse group; Tertiary (Eocene). *B* Mastodon, *Mastodon* (*Mammut*) *americanus*, Pliocene and Pleistocene (Tertiary), height 7–9 feet. *C* Titanothere (*Brontotherium*), from Tertiary (Oligocene); size of small elephant. *D* Upper Eocene titantothere, *Eobasilius*. *E* Pleistocene mammoth, *Elephas primigenius*, size of Indian elephant. *F* Ancestral giant pig, *Archaeotherium*, Tertiary (Eocene and Oligocene). (*A—E* after Osborn; Knight restorations. *C* from Schuchert; Historical Geology, permission John Wiley & Sons. *B*, *E* from Organic Evolution by R. S. Lull; *F* from History of Land Mammals in Western Hemisphere by W. B. Scott, published by The Macmillan Co.)

has been found tracing the horse through various stages of development from this earliest horse type to the one-toed modern horse. The horses of the Early Tertiary lived in a moist climate, in forest-covered lands with abundant lakes, marshes and streams. The development in the Miocene or Middle Tertiary of the extensive grasslands or prairies favored the rapid evolution of horses suited to speed on the plains. After the Miocene horses became more and more like modern types and they were very abundant during the early Pleistocene or Glacial Period. During late Tertiary and Pleistocene they migrated from America into all the other continents, becoming extinct in North and South America by the end of the Glacial Period, probably due to some epidemic. Our wild horses now are descendants of those brought in by European explorers.

The *elephant tribe* is known from the Early Tertiary (Upper Eocene) to the present and includes some interesting forms. The earliest remains are known from Egypt and southern Asia. By Pleistocene time their distribution had become world-wide due to the fact that the group had taken to the forests and grassy plains. There are only two well-defined species of elephants living, the Indian or Asiatic elephant and the African elephant; and prediction has been made that they are doomed to extinction unless protected by law. To the African species belong the tallest living elephants; but the Imperial Elephant (*Elphas imperator*) which ranged from Ohio to Mexico City during the Pleistocene was larger, attaining a height of over 13 feet, two feet or more above the tallest African individuals. Elephants are characterized by their long, pillarlike limbs, a short neck supporting the huge head with proboscis and a pair of tusks. The proboscis is perhaps the most distinctive feature of the elephant. The earliest forms had no proboscis and many of them were provided with two pairs of tusklike incisors, one pair in each jaw. The development of the proboscis went along side by side with the development of the tusks and the true proboscis is found in the Pleistocene or Glacial Period.. The brain of the elephant is twice the size of man's and second only to that of the great whales but its intelligence has often been overestimated.

Two extinct representatives of the elephant tribe, the mastodon and the mammoth are fairly well known. The *mastodon* (Greek *mastos,* breast; *odous* (*odont*) tooth) differs from true elephants principally in two respects: the character of the teeth and the greater length of the lower jaw. It lived through Pliocene and Pleistocene times and ranged from Europe across Asia to Alaska and southward through the United States, outliving the elephant in North America. Mastodons (*Mastodon* (*Mammut*) *americanus*) are the best known of the American representatives of this group (figures 73, 74). They were about the size of the living Indian elephants, having a height of seven to nine feet, but were more robust in build, and the brain cavity was relatively larger. The tusks are sometimes more than nine feet in length. Mastodons dwelt more exclusively in forests than the true elephants. Their food consisted of twigs of evergreens, such as hemlock and spruce, and possibly herbaceous vegetation, according to the contents of the stomach. One specimen found in New York State (Ulster co.) showed, along with the bones, quantities of dense, shaggy hair, dark golden brown in color. Remains of mastodons are found in swampy and boggy lands where the animals were mired and conditions were favorable to preservation.

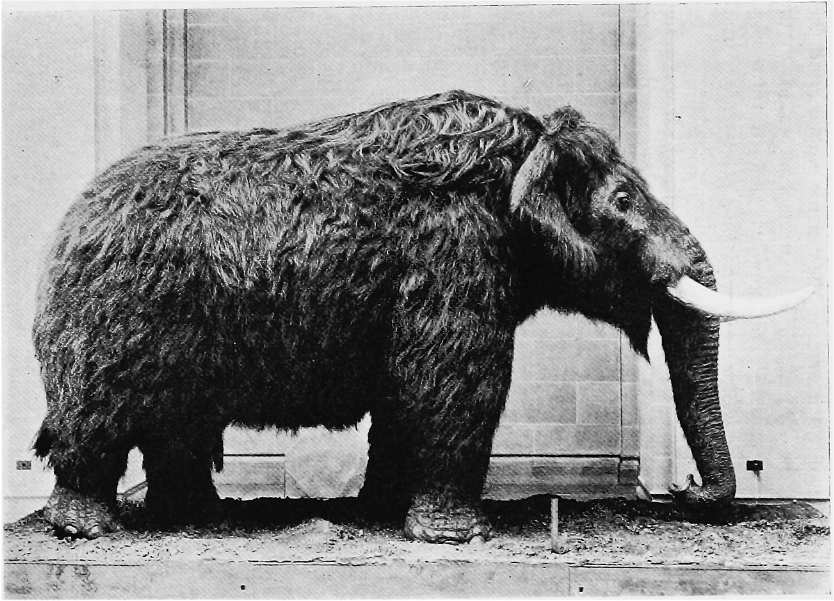


Figure 74 *Mastodon americanus.* Restoration of the Cohoes Mastodon in the State Museum, executed by Noah T. Clarke and C. P. Heidenrich.

The *mammoths* were true elephants (figure 73). They were not of great size as their name implies, but were of about the size of the Indian elephant to which they are closely related. The popularly known form is the Hairy or Wooly Mammoth (*Elephas primigenius*) of the Pleistocene. It differed from the living elephants in having a coat of coarse, black hair beneath which was a thick coat of brown wool, which protected it against the Arctic climate. This species was circumpolar in range, extending over the greater part of the northern hemisphere in both the Old and New World. Frozen carcasses, complete even to the hair, have been found in the Siberian tundras and delta gravels. The food of mammoths, according to the contents of the stomach, consisted of grasses, sedges, birches, alders, poplars etc., prevailing in the north today. The tusks were very long and curved. It has been estimated that so far, through the centuries, there must have been found over 40,000 individual mammoths, because their tusks constitute one-half the annual output of commercial ivory. Pictures of these mammoths made by prehistoric man are found on the walls of caverns in the Upper Paleolithic Age; paintings and carvings on the ivory of mammoths are also found. Man and the mammoth were contemporaneous in Eurasia during the Pleistocene.

A few other ungulates can be just briefly touched upon here. *Camels* originated in North America and are first known from Upper Eocene (Tertiary) times when they were the size of our house cats. Like the horse they developed and became diversified in North America and thence spread southward into South America and northward across Alaska and Siberia into Asia and Africa. In North America they became extinct during Pleistocene times. The *deer tribe* dates back to the Early Tertiary (Oligocene). The bovine family (*cattle, sheep* and *goats*) is known first from the Late Tertiary (Pliocene) but as a family has its greatest development today. True *pigs* belong to the Old World and were brought to the New World by European settlers. While the family is known from the Early Tertiary, the true pig is known first from the Middle Tertiary. Giant pigs appeared in the Upper Eocene and Oligocene; the last were known from Lower Miocene (Middle Tertiary), one of them being over six feet tall. *Peccaries* are related to the pigs and they were abundant in parts of both North and South America. Peccaries were numerous in the Early Tertiary (Oligocene) and abounded in the Middle Tertiary (Lower Miocene) of North America, radiating into South America in Late Tertiary (Pliocene). They were also abundant during the Pleistocene or Glacial Period.

The order *Sirenia* (Greek *seiren,* Siren, the sea cow), the so-called Sea Cows, includes among living forms only the Dugongs of the Indian Ocean and the Manatees found in the fresh waters and along the coasts of South America and Africa. The members of this order are derived from land forms, an off-shoot of the ungulates or hoofed mammals. Sea cows and elephants derive their origin from the same ancestral stock, and the great differences between the present representatives are due merely to environmental adaptation. Sea cows, like the cetaceans, are highly modified. The head is of moderate size and, as among the cetaceans, there is a fishlike body which has but few scattered hairs, paddlelike fore limbs and no hind limbs. There is a horizontal tail fin but no vertical dorsal fin. The brain is small. Sea cows are known from the Early Tertiary (Eocene) of Egypt and the

West Indies but they occur in Europe and America in later beds. During the Late Tertiary and Pleistocene they were abundant in North America on both the Atlantic and Pacific coasts. One recently extinct genus known as Steller's Sea Cow was seen alive up to nearly the end of the last century along the shores of Bering's Straits, and its remains occur in the peat on the shores of those seas. They were much like the other recent sirenians, huge beasts reaching lengths of 20 to 30 feet.

The *Primates* (Latin *primus,* first) by their name signify headship in the animal kingdom, but their superiority lies in mental development, not physical. While there are bipedal walking forms in this order, it includes mainly arboreal forms. Two suborders are recognized: Lemuroidea and Anthropoidea. To the first order, which has representatives since the Lower Eocene (Tertiary) of both North America and Europe, belong the living Lemurs which are strictly arboreal. The Lemurs are the oldest of the living primates. The second order includes the New World Monkeys, such as Marmosets or Squirrel Monkeys, Spider Monkeys, Howler Monkeys and Capuchins, some of which have been found fossil in the Pleistocene; the Old World monkeys, such as the Baboons, Macaques and Langurs; the anthropoid apes, such as the Gorilla, Chimpanzee, Orang-utan and Gibbon; and Man. Monkeys and lemurs have not lived in North America since the beginning of the Middle Tertiary (Miocene). Anthropoid apes are known from Lower Miocene (Middle Tertiary) to the present. The family to which man, *Homo sapiens* (Latin *homo,* man; *sapiens,* wise), belongs, the Hominidae, bears close relationship to the family of the anthropoid apes. There is only one living genus of man and but one species which is divided into several races or varieties: Caucasian, Mongolian (including North and South Americans), Negroid and Australian (Lull). Recent evidences point to Central Asia as the ancient home of man and the forerunners of man. The oldest known remains of the human family are those of the Java ape-man, *Pithecanthropus* (Greek *pithekos,* ape; *anthropos,* man), found on the island of Java, in the earliest Pleistocene (figure 75). Man, as man, probably dates back to the Pliocene or Late Tertiary, so that the age of man may be reckoned in terms of hundreds of thousands of years. The oldest remains of man in Europe are those of the "dawn man," *Eoanthropus* (Green *eos,* dawn; *anthropos,* man), found in the early middle Pleistocene of Sussex, England. Also from the Pleistocene are the Heidelberg man (*Homo heidelbergensis*) found near Heidelberg, Germany; and the Neanderthal man (*Homo neanderthalensis*) found in the Neanderthal ravine, near Düsseldorf in Rhenish Prussia. These were men of the Old Stone Age; and here also belongs the Rhodesian man recently (1921) discovered in a cave in Northern Rhodesia, Africa, related to the Neanderthal man but not nearly as old. The division of man's early history into Old Stone Age (Paleolithic: Greek *palaios,* old; *lithos,* stone) and New Stone Age (Neolithic: Greek *neos,* new; *lithos,* stone) is made on the degree of perfection of the stone implements made by him. The Old Stone Age is the time of late Pliocene and most of the Pleistocene and is marked by very crude stone implements. Neolithic man dates back to the latest Pleistocene. The oldest known Neolithic people belonged to *Homo sapiens,* and lived in western Europe at about the close of the Glacial Period (about 17,000 B. C.). They were a magnificent race known as the Aurignacian-race or Crô-Magnon race

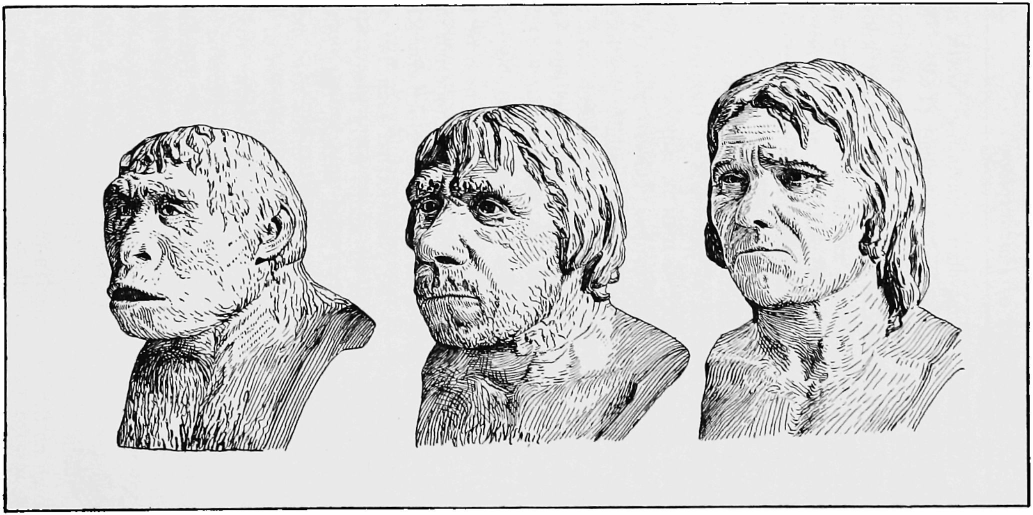


Figure 75 Three Great Races of Prehistoric Man. Left to right: *Pithecanthropus erectus*, the Ape Man; *Homo neanderthalensis*, Neanderthal Man; *Homo sapiens*, Crò-Magnon Man (after McGregor). (Pen sketches by E. J. Stein, from Fig. 1 Guide to the Hall of the Age of Man, permission Amer. Mus. Nat. Hist.)

because their remains have been found at Aurignac and Crô-Magnon in France. Evidence points to the Orient as the cradle of human civilization, and these people had spread westward from Asia Minor. Their remains are found in most of the Mediterranean countries and throughout a large part of central and western Europe. So far as present fossil evidence shows, man was not living in North America during Pleistocene times, but it is becoming more certain that he must have lived here between 10,000 and 20,000 years.

The earliest mammalian remains are known from the Upper Triassic. These were the reptilian mammals, obscure forms often referred to as the archaic mammals. American and European species were much alike and probably were mainly egg-layers pretty well through the Mesozoic. Evidences of many kinds of mammals are found in the late Cretaceous formations. With the decline of the reptiles the mammals came into possession of, and during the Cenozoic they dominated, the organic world. Most of the living orders of mammals are not known fossil earlier than the earliest Tertiary (basal Eocene), but this means that the origin of some of them at least is to be looked for back in the Cretaceous. At the end of the Mesozoic there came a great change in the plant world. Herbaceous plants and grasses came in, bringing open plains and meadows. The great variety of habitats and the increased chance of spreading out advanced the evolution of the mammals. The Miocene or Middle Tertiary is known as the "Mammalian Golden Age." The change in climate at this time to cooler and semi-arid conditions brought great changes in both plant and animal life. The climax of development, however came during Late Tertiary (Pliocene) times and continued into the Pleistocene. Then came the Ice Age, and the magnificent types of animals that had developed disappeared one after the other. The extinction of mammals through the ages may be due to several causes, among them changes of climate and epidemics. Over-specialization, too, may be looked upon as a cause; also excessive bulk, foot or tooth structure not well adapted, relatively small brain etc.

No large number of fossil mammals have been found in New York State. The preservation of a land mammal would be accidental rather than otherwise. Of the carnivorous mammals, only a fox, two species of bears and a seal have been reported in New York State; the rodents are represented by the giant beaver, *Castoroides;* the ungulates by the mastodon and mammoth, peccary, deer, elk, caribou, moose, American bison and the horse. These are all Pleistocene fossils and all are rare except mastodons and mammoths, of which 115 finds have been listed for New York State. Fifteen of these have been determined without question as mammoth remains and with the exception of one in Warren county have all been found in central and western New York. New York has proved rich in mastodon remains. They have been found in eastern New York, central New York and westward. There has been a localization of mastodon remains in southeastern New York, particularly Orange county, due to the large swampy areas in this section. It is the peat bogs, marl ponds and beds of extinct ponds in this area which now contribute mastodon remains.

Specimens of mammals of the different groups may be seen in the large museums. The New York State Museum has on exhibition in Vertebrate Paleontology Hall the Cohoes Mastodon skeleton, a life size restoration based upon this, the Temple Hill (Newburgh) Mastodon skeleton and the skeleton of an Indian elephant for comparison. In addition to these fairly complete skeletons are parts of both mastodons and mammoths, such as tusks, jaws with teeth, separate teeth, parts of skulls, leg bones, vertebrae. The hairy mammoth is shown on top of one of the cases in miniature restoration. There is also a model of the pothole in which the Cohoes Mastodon was found, and another model showing the Cohoes falls area with this and other potholes located. The museum has the original skull of the giant beaver, *Castoroides ohioensis,* from Clyde, N. Y., and with this a life-size restoration of the animal. There are parts of two skeletons of an extinct peccary with a pictured restoration, and an adjoining case shows a mounted specimen of a living species. The Irish Elk (Pleistocene) from Limerick county, Ireland, a gift of the British Government to the Museum, constitutes one of the striking exhibits of the Hall.

Literature

The references given here cover the classification and description of the Vertebrates. They are general, on the whole, but some special references for the different classes will also be given. Those who wish to make a more extended study, will find numerous references in the literature listed. Any good zoology will cover the ground as to classification and description of the various groups, and, as with the Invertebrates, minor differences are to be found among different authors as regards details of classification. Parker and Haswell ('10) is a good general textbook. A lengthier treatment will be found in the Cambridge Natural History ('09–'20), edited by Harmer and Shipley. The student is also referred to any of the good textbooks on historical geology, such as Schuchert ('24), Schuchert and Le Vene ('27), Cleland ('16), Grabau ('21), Scott ('24), Chamberlin and Salisbury ('09), Geikie ('03) etc. Of a strictly paleontological nature are Shimer ('14), and Zittel ('02). Shimer ('14) and Schuchert and LeVene ('27) are particularly recommended to the beginner. To these general references may be added Lull ('17), Osborn ('17), Lankester ('06), Hutchinson ('10), and Lucas ('22) which is of a popular nature.

For New York State Vertebrates the only two publications that require mention are Eastman ('07) on fishes, and Hartnagel and Bishop ('22) on Pleistocene mammals.

A few additional special references are given here for the various classes of vertebrates. For the *fishes* the student is referred to Dean ('95) ; for *amphibians,* to Cunningham ('12) ; for *reptiles,* to Seeley ('01), Osborn ('04–'05), Williston ('02), Matthew ('15) and Cunningham ('12) ; for *birds,* to Marsh ('83), Wetmore ('28) ; for *mammals,* to Osborn ('10, '26), Scott ('13) ; for *man* to Osborn ('10, '15), Duckworth ('12), Scott ('13), Tyler ('23), Wilder ('23), Whitnall ('24; especially recommended to beginners), Cleland ('28) and Encyclopedias, under Anthropology and Archaeology.

CLASSIFICATION AND DESCRIPTION OF PLANTS

Plants will not be discussed at great length in this chapter. They are not particularly abundant in New York State as fossils and the amateur is not likely to collect many specimens. Many of the specimens of plant fragments are unidentifiable and where they can be identified it is better to consult some authority. The description of the plants will be treated in a different manner than in the case of the animals. Each group or phylum will be briefly characterized and then the development of the plants will be traced through the different periods of geologic time. It is believed that this treatment, in view of the shorter discussion of the plants, will give a much better grasp of the subject.

Classification

Plants, living and fossil, are divided into several groups or phyla. Many systems of classification have been proposed. The simplest gives four divisions or phyla: Thallophyta, Bryophyta, Pteridophyta and Spermatophyta. It is now recognized that the Thallophyta represent several phyla, but they are often treated under the old term for convenience and also because of their lack of importance as fossils. The Pteridophyta and Spermatophyta are split up into several phyla. This classification is given below and is the classification used in this chapter.

Thallophyta (Greek *thallus,* branch, twig; *phyton,* plant)
Bacteria, diatoms, slime molds, fungi, algae or seaweeds

Bryophyta (Greek *bryon,* moss)
Mosses and liverworts

Pteridophyta (Greek *pteris,* fern). Ferns

Arthrophyta (Greek *arthron,* joint)
Fern allies, such as the living horsetails and the fossil calamites etc.

Lepidophyta (Greek *lepis* (*lepid*), scale)
Fern allies such as the living quillworts, club mosses etc., and the fossil Lepidodendrons, Sigillarias etc.

Pteridospermophyta (Greek *pteris,* fern; *sperma,* seed)
The extinct seed ferns

Cycadophyta (Greek *kykas,* Cycas)
Cycads and allied fossil forms

Coniferophyta (Latin *conus,* cone; *fero,* to bear)
Conifers, such as the pine or spruce, cypress, ginkgo, larch etc. among living plants; the fossil Cordaites etc. (Corresponds almost exactly to the Gymnospermae of authors)

Angiospermophyta (Greek *angeion,* capsule; *sperma,* seed)
All the flowering plants (Corresponds to the Angiospermae of authors)

The various phyla of plants are grouped into two divisions: the Cryptogams, or spore-bearing plants, and the Phanerogams or seed-bearing plants. The lower Cryptogams comprise the Thallophyta and Bryophyta; the higher Cryptogams, the Pteridophyta, Arthrophyta and Lepidophyta; while the Phanerogams comprise the remaining phyla.

Description

Thallophyta. The thallophytes include a variety of plants ranging from microscopic unicellular bacteria to seaweeds of huge size and with a differentiation of the plant body into parts which correspond to root, stem and leaf of the higher plants. This group includes the *bacteria*, one-celled plants of microscopic size—one ten-thousandth of an inch or less in diameter. They are known in variety even from the Precambrian. These with the fungi, such as molds and toadstools, the seaweeds and the lichens are probably the representatives of this group best known to the student who is not a botanist. In this group also belong the *slime molds* of doubtful classification, which live on decaying matter and form sticky masses on decaying leaves and logs in woods; and the *blue green algae*, unicellular plants which form slimy appearing thin mats on damp wood or the ground, or floating mats or scum on the water. While usually bluish green in color they may be purplish, red or brown in some species, and where they occur in large numbers they often give color to the water, as in the case of the Red Sea. Some are lime-secreting and are responsible for hot spring deposits, such as those in the Yellowstone National Park; and both in the past and present they have been important as rock builders through the accumulation of oolitic grains (rounded, concentric limestone grains) secreted by them. The Jurassic of England formerly was known as the Oolitic system because of large beds of oolites of such an origin. *Slime molds* are not known fossil and *fungi* are rarely known fossil, though fungal threads have been found in Carboniferous trees and, even in Silurian beds, shells occur which show perforations or borings apparently made by tubules of species of fungi (figure 79). *Lichens* are known only from recent formations. They are formed by fungi and algae living together to the mutual benefit of each in what is known as a symbiotic relationship or *symbiosis* (Greek *syn,* together; *bios,* life). These thallophytes are familiar to all as the gray, gray-green or brownish, dry fronds spread over rocks and tree trunks and also found on the ground. *Diatoms* (figure 76) form another group of thallophytes, possibly related to the algae, and they are found in fresh, brackish and salt water and damp soil. They are microscopic, one-celled plants which are inclosed in a silicified, boxlike skeleton consisting of two halves or valves, one fitting over the other like the lid of a box. They live singly and free, or several individuals are joined together into long threads and are attached. They are so abundant that the skeletons form, on the bottom of oceans, marshes and ponds, silicious deposits known as diatomaceous earth. Such deposits have accumulated in the geologic past even to thousands of feet in thickness and are known from Jurassic times to the present.

The *algae* are known from Precambrian times to the present (figure 76). They are water-loving plants occurring both in fresh and salt water, the marine forms being popularly known as seaweeds. Algae are primitive plants ranging from simple, unicellular species to large forms of complex structure. All have green coloring matter or chlorophyll, which in some groups is masked by red or brown coloring matter, thus giving a basis for the division into the green, brown and red algae. The simpler forms of algae reproduce through the development of special cells or spores which develop into new

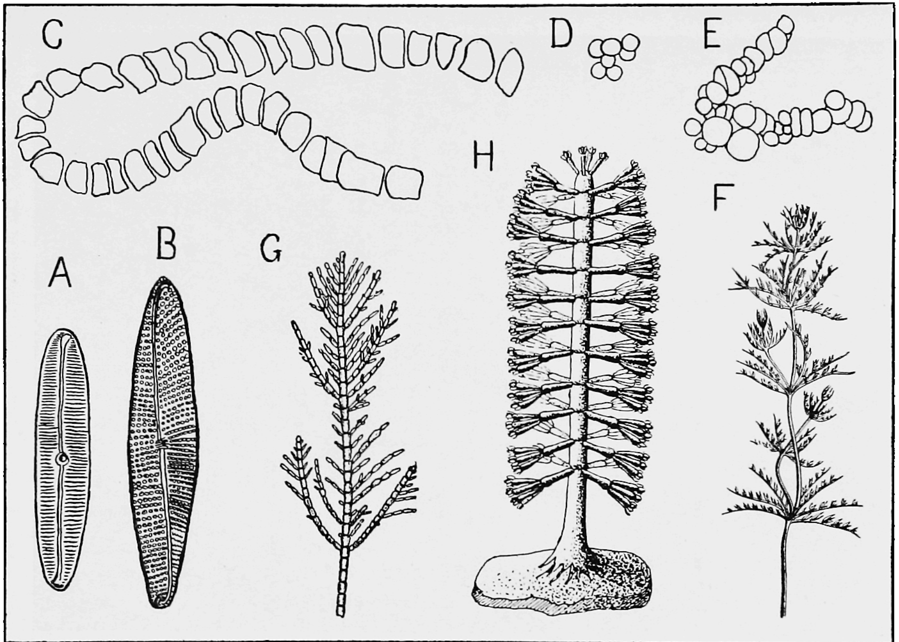


Figure 76 Diatoms and algae. *A, B* Recent diatoms (*Navicula*). *C E* Precambrian blue-green algae (after Walcott): *C Schizothrix*, x1200; *D, E Camasia*, x350. *F* Recent lime-secreting green alga (*Chara*), reduced. *G* Recent lime-secreting red alga (*Corallina*). *H* Silurian lime-secreting alga (*Primicorallina*), x5 (after Ruedemann). (*A, B, F, G* from Grabau: Textbook of Geology, permission D. C. Heath & Co.)

Figure 77 Cambrian calcareous algae. Glaciated exposure of the Cryptozoön reef beds, Lester Park, Saratoga Springs, N. Y.

plants. This is known as asexual reproduction. The more advanced forms have developed special male and female cells which by their union give rise to new plants. This is known as sexual reproduction. Some algae are lime-secreting and both in the geologic past and in the present have been more important than the corals themselves in building up coral reefs. Some forms cause the calcareous and siliceous deposits of hot springs and the beautiful colors are due to these plants which comprise the green as well as the blue-green algae. The algae inhabiting these hot springs are known as thermal algae and they live in temperatures between 90° F and 185° F.

The *green algae* are found in both fresh and salt water. They are perhaps most familiar to us in *Spirogyra* which forms masses or mats of long green threads floating on ponds, known as pond "scums." The threads are made up of cylindrical cells attached end to end. The green algae include some of the lime-secreting marine forms, some of these showing a high per cent of lime (90 per cent), which enter into the formation of reefs. The fresh-water stonewort (*Chara*) is probably familiar to some readers (figure 76). By some it is placed with the green algae, although others consider it as belonging in a distinct group standing near the mosses. This form today inhabits fresh-water lakes of the temperate zone. It secretes lime with which it encrusts itself, forming upon disintegration a limy mud; and in the geologic past it has formed extensive fresh-water limestones.

The *brown algae* are best known to most of us through the *Fucus* or "rockweed," the common seaweed of our coasts, growing on the rocks between tide marks or rolled in on the sandy beaches in great quantities by the waves, particularly after a storm. The *Sargassum* of the Sar-

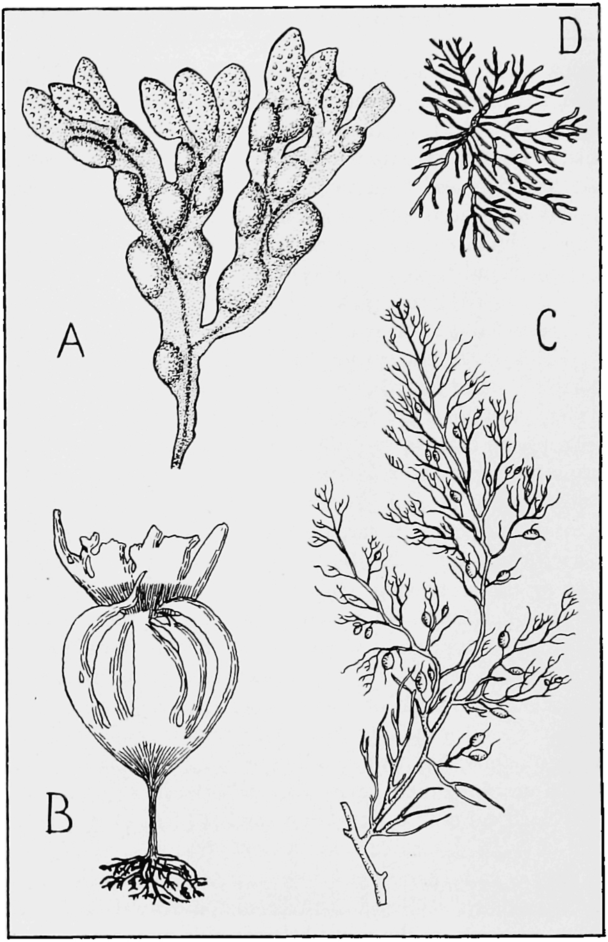


Figure 78 Algae or seaweeds. *A* Brown alga (*Fucus*), showing the fruiting tips and vesicular swellings. *B* Brown alga (*Laminaria*), about x¼. *C* Brown alga, the *Sargassum* of the Sargasso sea (from Engler-Prantl). *D* Tertiary (Oligocene) so-called fucoid, *Chondrites* (from Grabau: Historical Geology, permission D. C. Heath & Co.).

gasso Sea also belongs here and the giant kelps or *Laminarias* which are sometimes washed in after a storm (figure 78). There is a stout stem or stalk attached by rootlike outgrowths or holdfasts and at the free end extending into one or many large, long blades. Some of them have highly developed tissues. Among the Laminarias are found some of the largest plants known, with huge, trunklike stalks, and reaching a height of several hundred feet (200–300 meters). The fossil genus *Nematophycus* found in the Silurian and Devonian beds bears some resemblance to these giant laminarian seaweeds. No members of the group of brown algae are of any importance as lime-secreting forms.

The *red algae* include fresh and salt-water forms. To this group belong the coralline algae or "corallines" which have a coral-like appearance because of the lime incrustation. An example of these forms is the delicate living *Corallina* which forms whitish tufts on rocks and seaweeds in the tide pools along the North Atlantic coast, and the related *Primicorallina* known from the Ordovician (figure 76). Forms are also found forming incrustations on rocks, shells etc. (*Lithothamnion*). *Lithothamnion* has been important as a reef builder since the Cretaceous period. In this division also may belong the Upper Cambrian species of *Cryptozoön* which formed large reefs (figure 77) and are beautifully shown in "Cryptozoön Ledge" or Lester Park and other areas in the neighborhood of Saratoga Springs, N. Y. These calcareous seaweeds deposited thick layers of lime in their tissue, and some species formed cabbagelike heads which have been cut through by the great glacier that levelled the rocks down, giving beautiful cross sections which show the con-

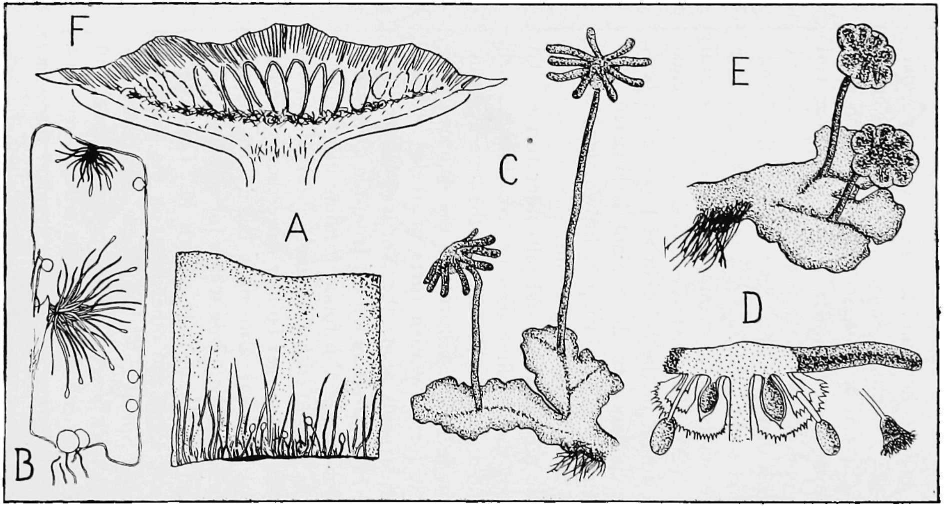


Figure 79 Fungi and liverworts. *A* A *fungus* (about x190) in Silurian brachiopod shell. Round swellings probably spore sacs. *B* Fungus, (*Cladosporites*) in wood of Tertiary age, x300 (after Berry). *C—E* Liverwort (*Marchantia*): *C* Female plant or gametophyte; *D* Section (magnified) through female receptacle showing the spore cases developed from the fertilized egg, each spore case with the stalk constituting the sporophyte; *E* Male plant or gametophyte. *F* Section (magnified) through male receptacle showing the oval bodies bearing the male elements. (*A* from Introduction to Study of Fossils by H. W. Shimer, published by The Macmillan Co.)

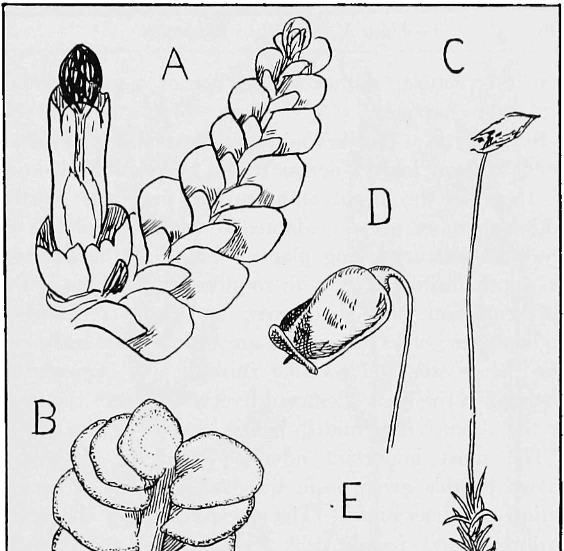


Figure 80 Liverworts and mosses. *A* Foliose liverwort (*Radula*); branch with fruit, x8. *B* Foliose liverwort (*Odontoschisma*), x18. *C—E* Common hair-cap moss (*Polytrichum commune*): *C* Leafy plant or female gametophyte bearing the stalked capsule or sporophyte; *D* Mature capsule, x5; *E* Male plant or gametophyte.

centric structure. Other species are of a more undulating, wavy character.

Bryophyta. The bryophytes, *liverworts* and *mosses*, are not of any importance as fossils and nothing is known of them in the fossil state earlier than the Tertiary. Although more or less adapted to a terrestrial life they are still moisture-loving plants. Some of the liverworts have a thalluslike body with rootlike rhizoids but with no differentiation into root, stem and leaf, recalling the thallophytes; other liverworts are foliose with leafy stems like the mosses and rootlike rhizoids. A beginner may distinguish the leafy stemmed liverworts from the mosses by the absence of a midrib in the leaves (figures 79, 80).

The most important advance over the thallophytes shown by this group is in the establishment of an alternation of generations. The organs bearing the specialized male and female cells are borne by the thallus or foliose phase, which is known as the sexual or gametophyte stage. The fertilized female or egg cell does not develop directly into the same phase of the plant but produces a new phase which has for its function the development of spores, and is known as the sporophyte or asexual stage. These spores develop in turn into the thallus or foliose stage bearing the sex organs, the gametophyte. The common mosses illustrate this very well. The plant consists of a stem or stalk which bears the small leaves. From the top of this in the fruiting season extends a very slender stalk ending in a capsule which contains the spores. The sexual organs in the mosses are borne at the tips of the leafy plants (gametophyte) and the fertilized egg of the female gametophyte develops into the stalked capsule (sporophyte).

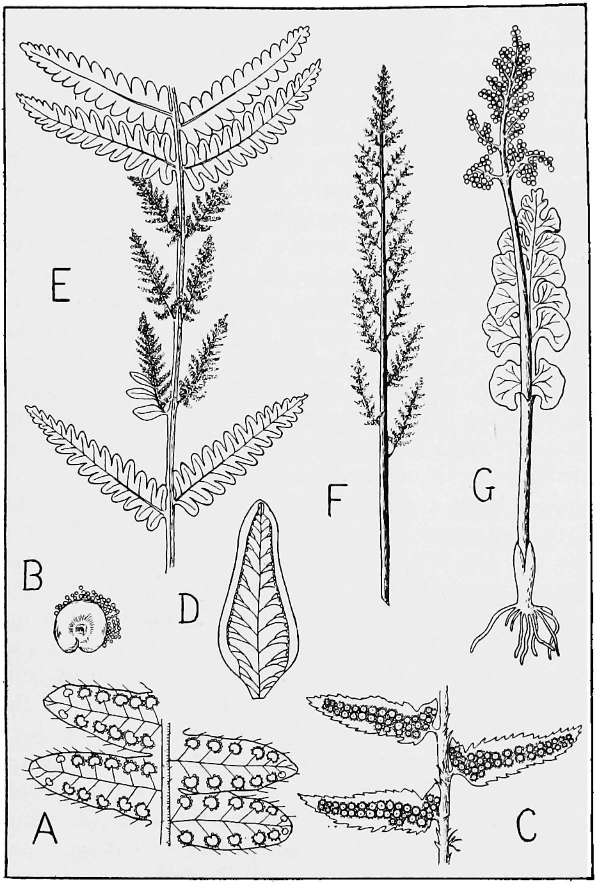


Figure 81 Ferns. *A* Portion of fern frond showing fruit-dots or sori with covering or indusium. *B* Enlarged sorus of same. *C* Portion of a frond with crowded fruit-dots. *D* Pinna or leaflet of fern with edge of leaf inrolled over sporangia. *E—G* Specialized spore-bearing: *E* Interrupted fern (*Osmunda claytoniana*) with specialized leaflets; *F* Fertile frond, Cinnamon fern (*Osmunda cinnamomea*); *G* Grape fern (*Botrychium*) with specialized fertile shoot. All reduced, except *B*.

Sphagnum which has been put to many commercial uses belongs in this group. It is one of the peat mosses.

Pteridophyta. The pteridophytes as now defined include only the *true ferns,* which vary in size from the tiniest ferns to the impressive tree ferns of the tropics or subtropics which are sometimes seen in greenhouses. They show a far more complex structure than the bryophytes, having developed, like the higher flowering plants, a vascular system or systems of vessels for the conduction of food and sap. Like the liverworts and mosses, the ferns show an alternation of generation, but with a difference. In the mosses, as we have seen, the leafy plant, or gametophyte, is the most conspicuous phase; in the ferns the conspicuous leafy phase is the spore-bearing stage or sporophyte. On the under side of some fern leaves are small dots, in rows or scattered, which are formed by clusters of spore-bearing organs. When the spores are ripe the dots are brown and quite conspicuous. These dots are known as fruit dots or sori (sing., sorus). The fruit dots may be naked or protected by a covering or the edge of the leaf may be rolled over to protect them, as in the maidenhair fern. There are various kinds of fruit dots. Sometimes the entire frond bears them on the under side, as in the common Christmas fern; or there may be certain leaflets of the frond specialized for spore-bearing, as in the Interrupted fern; or certain whole fronds are given up to spore-bearing, as in the Cinnamon fern; or there may be a specialized fertile shoot, as in the Sensitive fern, Grape fern and Ostrich fern. In any case, when the spores are shed from the microscopic spore-bearing organs (sporangia) they germinate and produce tiny, thin, green, heart-shaped growths which are known as fern prothallia. The fern prothallium, or gametophyte, bears on the under side the threadlike rhizoids for attachment and obtaining nourishment and the sexual organs. Close examination will sometimes disclose these tiny fern prothallia in damp places in the woods, particularly on old decaying logs or decaying wood; and they may be seen in greenhouses where ferns are grown. (Figures 81, 82).

Ferns are known from Devonian times on, and therefore must have had their origin before the close of the Silurian (figures 87, 97). They were not common as fossils until the time of the Coal Measures (Pennsylvanian). There are today about 6000 species of ferns which vary in size from very small delicate forms to the tree ferns of the tropics and subtropics which grow as high as 50 feet.

This phylum corresponds to the Order Filicales (Latin *filix* (*filic*), fern) of the division Pteridophyta as formerly defined.

Arthrophyta. This group includes the Paleozoic *calamites,* Greek *kalamites,* reedlike), and the *living rushes* or *horsetails*, so-called because of the resemblance of the branching stems to a horse's tail (figures 83, 87). All the living rushes belong to one genus, *Equisetum,* and are characterized by simple or branching, hollow stems which are divided into sections by joints and strongly ribbed longitudinally. They are usually of small size, except for a giant form living in Cuba and South America. They are found early in the year in moist places and the best known form is very familiar to all, growing in sandy places and along gravelly railroad banks. This is the common horsetail. There is a fertile shoot and a sterile shoot. The buff-colored fertile shoot appears above the ground early in the spring and is from about four to eight inches high.

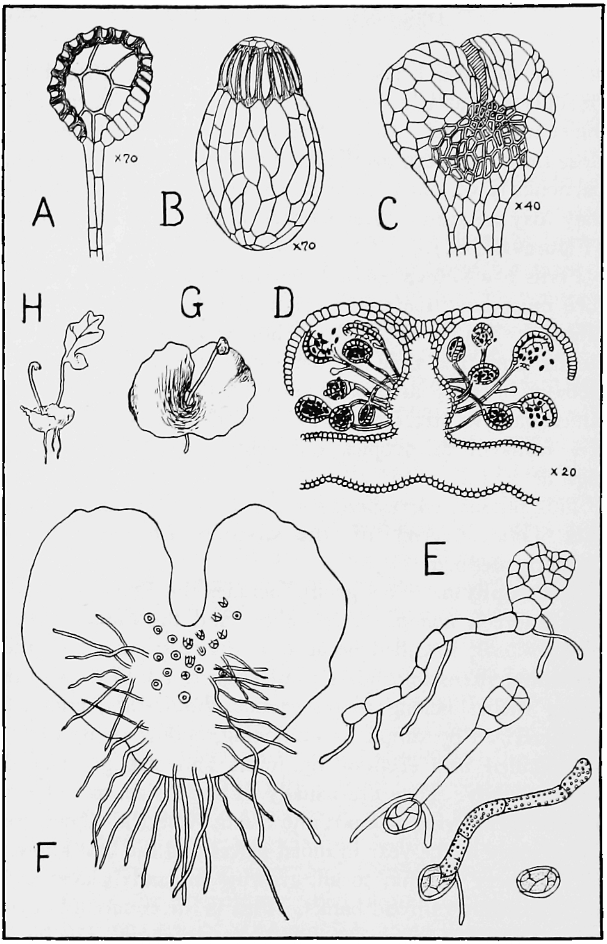


Figure 82 Ferns. *A—C* Various types of spore-bearing organs or sporangia. *D* Section through a sorus with covering or indusium, showing sporangia. *E* Stages in germination of the spore (enlarged). *F* Heart-shaped prothallium or gametophyte from underside, showing rhizoids and sexual organs (enlarged). *H, G* Gametophytes with attached small fern plants or sporophytes.

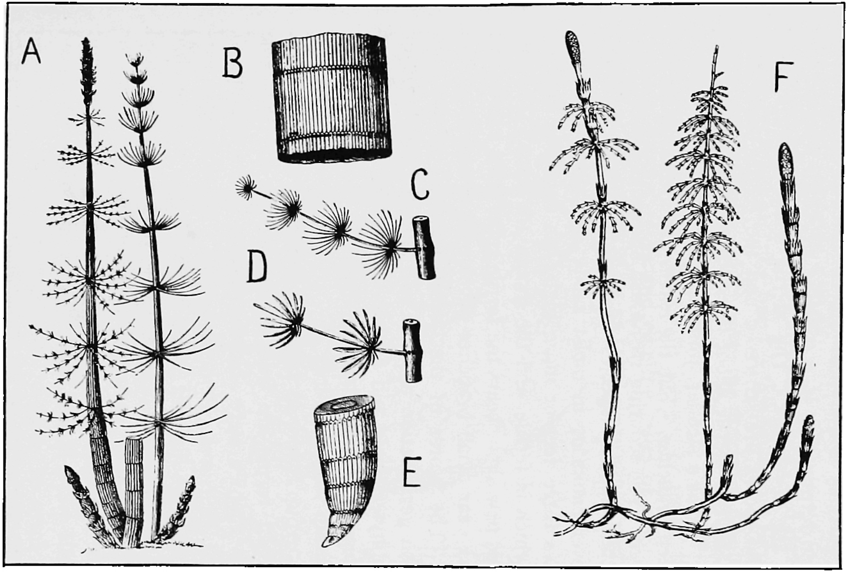


Figure 83 Calamites and horsetails. *A—E* Carboniferous *Calamites*: *A* Restoration of tree; *B* Portion of stem; *C, D* Hypothetical twigs; *E* Lower end of stem (all reduced, after Schenk). *F* Modern horsetail or scouring rush (*Equisetum arvense*). Spore-bearing stalks at right and left (from Haas). (All from Grabau: Textbook of Geology, permission D. C. Heath & Co.)

It consists of a jointed stem, ribbed lengthwise, with a ring of partially united membranous scales at each joint or node and terminating in a conelike structure wherein the spores are developed. The sterile shoot appears soon after the spores are scattered and the fertile shoot dies down, and this sterile shoot lives for a great part of the season. It has a slender, jointed, green stem with numerous green branches, while the leaves are membranous and not green. The scouring rush, also known as shave grass, is another common species of horsetail which is found along wet banks or in moist sandy soil along railroads. It grows three feet or more high, has only one kind of shoot which is fertile, and the shoots are stout. The unbranched new shoot bears the fertile spike at its extremity; the next year small branches develop at a number of the nodes. The spores of the horsetail are all of one kind but upon germination produce two kinds of prothallia or gametophytes, male and female. In the development of an independent gametophyte stage the horsetails show relationship with the ferns.

This group is known from the Devonian to the present. The fossil forms are well exemplified by the Paleozoic *Calamites* which were abundant plants in the swamps of the Coal Measures (Pennsylvanian). In general appearance they were like our living horsetails but they reached heights of a hundred feet, and bore narrow, lance-shaped leaves which were arranged in whorls at the nodes or joints of the branching stems. The stems of these giant horsetails were hollow, and so they are often preserved in the form of casts of the interior. Cones have been found in a few cases with specimens of stems. These forms disappeared before the end of the Paleozoic.

This phylum corresponds in general to the Order Equisetales (after *Equisetum*) of the division Pteridophyta as formerly defined.

Lepidophyta. These are the scale plants and include the *living lycopods* and the *fossil lepidophytes*, as *Lepidodendron* and *Sigillaria*, which were the dominant plants of the Pennsylvanian or Coal Period (figures 84–87). The living lycopods are the plants known to us as the club mosses, ground pines and running pines of some of our woods and familiar to us in floral decorations such as the

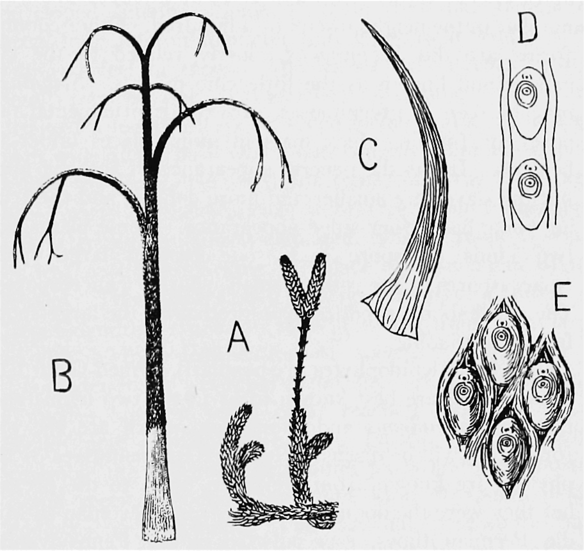


Figure 84 Club mosses. *A* Living club moss or lycopod (*Lycopodium*). *B—E* Upper Devonian lepidophyte or giant club moss (*Protolepidodendron*); *B* Restoration of tree, x1/80; *C* Scale leaf; *D, E* Leaf scars. (*B—E* after Berry.)

Christmas roping. They are largely creeping plants and many-branched with small, simple leaves, spirally arranged, which gives a mosslike appearance to the plants. Certain leaves, known as fertile leaves, are set aside for the function of spore bearing and form spikes or heads which sometimes have the appearance of club-like cones, well illustrated in our common club moss (*Lycopodium clavatum*). The spore case is borne in the axil of the fertile leaf and may be seen by bending back the leaves or tearing off a few. There are four living genera in this phylum, and the best known are the species of *Lycopodium* which number in the neighborhood of a hundred. Other common forms are the *Selaginellas,* closely related to the club mosses and known as the little club mosses. *Selaginella* may be seen in greenhouses, grown for ornamental purposes, or forming thick mats in moist places under the benches. It has the general appearance of the club moss but the leaves are smaller and more delicate and the fruiting spike has a four-sided appearance. These plants bear two kinds of spore cases, one bearing large spores (macrospores), the other small spores (microspores). The small spores produce male prothallia; the large spores female prothallia.

The fossil lepidophytes are popularly termed Giant Club Mosses, and are best known to us in the two main types, the *Lepidodendrons* and *Sigillarias,* which are the only forms that will be discussed here. Representatives of this phylum are known from Devonian times to the present, but they were the dominant plants from Devonian to Middle Permian times, especially so in the Pennsylvanian. They reached the climax of their evolution at this time, attaining gigantic size in comparison with their lowly living relatives.

Lepidodendrons (Greek *lepis,* scale; *dendron,* tree) derive their name from the scalelike leaves that clothed their trunks and branches (figures 85–87). The Devonian forms, of smaller size and of a more primitive character, are now known as *Protolepidodendrons* (Greek *protos,* first) and a restoration of one of these species has long been familiar to visitors to the New York State Museum (figure 84). The Lepidodendron trunk tapered gradually. It did not branch until near the top and the branching was of a forking nature, though the two branches of the fork, or dichotomy, were not always developed equally. Some of these trees had trunks at least four feet in diameter and grew to a height of a hundred feet or more. The leaves were needlelike and small for the size of the trees. In some forms they attained a length of six or seven inches and were half an inch wide at the base which was roughly diamond-shaped. While the leaves persisted for some time, the trunk and older parts of the branches were free from foliage and characterized by closely arranged, oblique rows of scars or leaf cushions marking the place of attachment of the leaves. These scars will always identify a piece of Lepidodendron trunk or stem and are used to a large extent in the identification of species. The cones in Lepidodendrons were borne on the tips of the slender branches, and in some cases reached a length of 20 inches and a diameter of two inches. They roughly resemble the cones of the ground pines and club mosses. Some species produced only one kind of spores in the cones; some two kinds. The fact that these spores have entered so largely into the formation of beds of coal indicates that a great number of cones were borne on each tree. The trunks were woody, either with a pith sur-

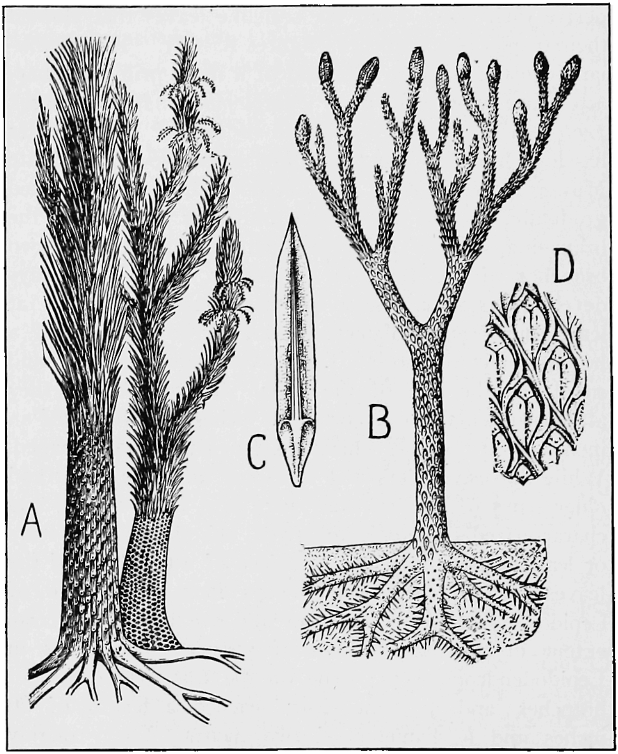


Figure 85 Carboniferous lepidophytes or giant club mosses. *A Sigillaria* restorations, showing stigmarian roots, x1/60. *B Lepidodendron* restoration, x1/120. *C* Scale leaf of same. *D* Leaf scars of same. (All from Schuchert: Historical Geology, permission John Wiley & Sons)

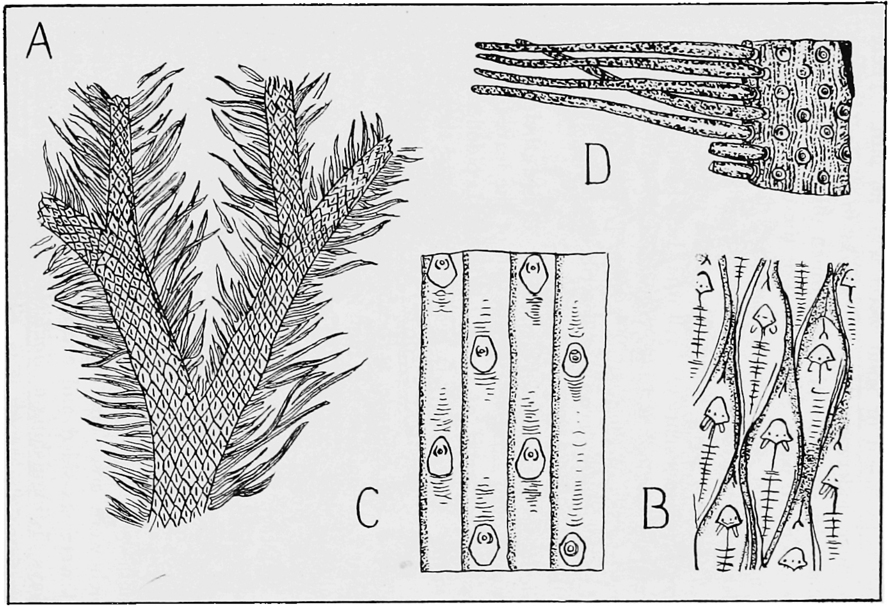


Figure 86 Lepidophytes or giant club mosses. *A* *Lepidodendron* twig showing leaves and scars. *B* Leaf scars of *Lepidodendron* (after Lesquereux). *C* Leaf scars of *Sigillaria* (after Lesquereux). *D* Part of a root-stock (*Stigmaria*), x⅓ showing scars and adhering rootlets. (*A*, *D* from Grabau: Textbook of Geology, permission D. C. Heath & Co.)

rounded by wood or solid wood with no pith. There were huge underground parts, rootlike in appearance but without the structure of roots, which divided or forked into two equal parts, each branch of the dichotomy forking again, and so on to the smallest divisions. These underground parts are marked with circular scars where the "rootlets" were borne, hence the name *Stigmaria* (Greek *stigma,* mark). All the Lepidodendrons had stigmarian "roots," and they constitute some of the commonest fossils of the Coal Measures. About 100 species of Lepidodendron have been described. The genus lived into the Permian.

Sigillarias (Latin *sigillum,* seal) derive their name from the deep scars, left by the fall of the leaves, which have the appearance of a seal. Like the Lepidodendrons, these trees grew to very large size but most of them were unbranched (figures 85–87). Some were short and stocky, as for example, a specimen that was six feet in diameter and only 18 feet high. Other specimens reached heights of 100 feet and had a diameter only of two or three feet; one unbranched form was found with a length of 200 feet. The leaves varied in size, some bearing a close resemblance to the leaves of Lepidodendron, others being long and grasslike or sword-shaped and in some cases three feet long. The leaves persisted longer than in the Lepidodendrons; sometimes for several years. In general about ten feet or so, at the tip, bore the leaves which were erect and rigid. The scars left when they fell were six-sided and arranged in vertical rows, thus always distinguishing a *Sigillaria* from a *Lepidodendron.* Sometimes the trunk was ribbed, each rib bearing a single row of scars. Sigillarias also bore cones, not at the tips of the small branches as in the Lepidodendrons

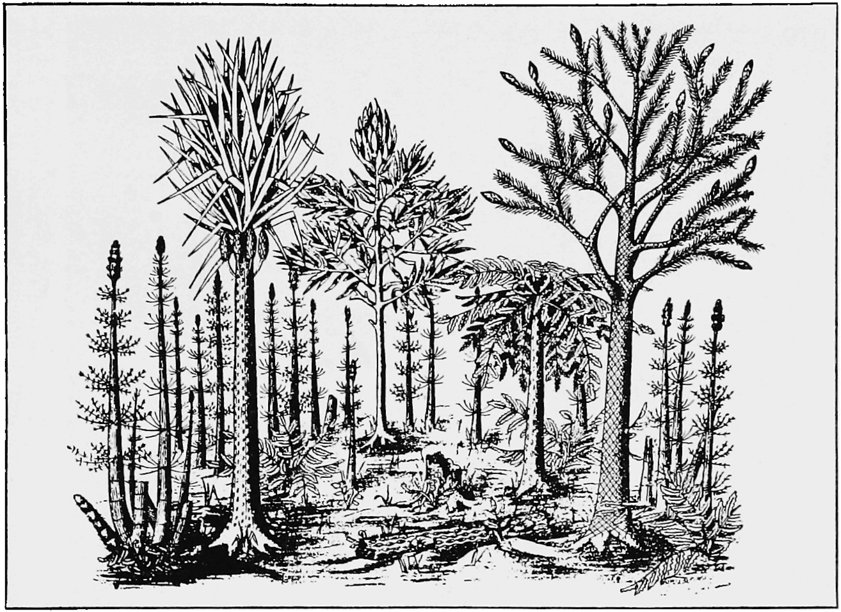


Figure 87 Composite restoration of Carboniferous trees: *Lepidodendron*, right foreground; *Sigillaria*, left foreground; *Cordaites* and *tree fern* in background; *Calamites* in outer circle (after Chamberlin and Salisbury's Geology from Knowlton: Plants of the Past, permission Princeton University Press).

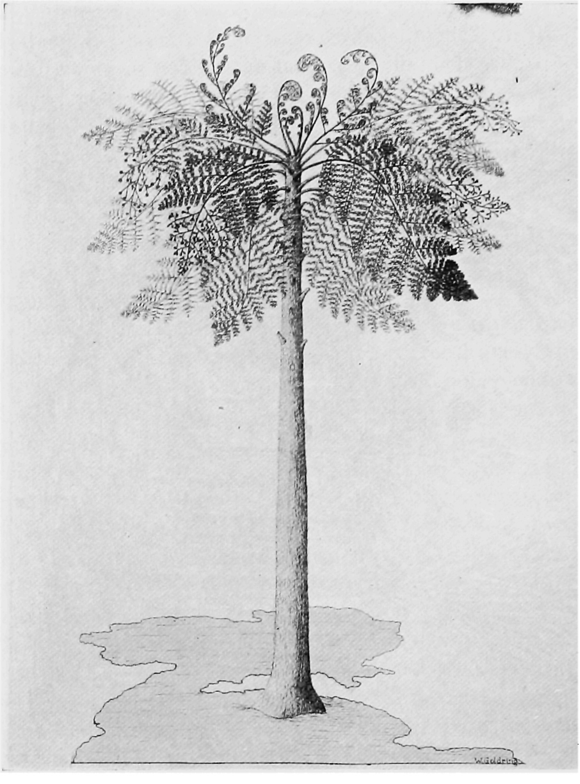


Figure 88 Upper Devonian seed fern. Restoration of *Eospermatopteris* by Winifred Goldring. Restoration in New York State Museum.

but in vertical rows or in a whorl around the stem. The cones do not reach the size of those of *Lepidodendron* but have been found up to 12 inches in length and two or three inches in diameter. Only one kind of spore has been found, though probably both kinds existed, at least in some cones. Like the spores of *Lepidodendron,* they must have been very abundant because of the part they play in coal formation. Sigillaria also possessed stigmarian "roots," and the trunk was similar to Lepidodendron in structure. About 100 species of Sigillaria have been described and they are confined to the Pennsylvanian or Coal Period, so that this type of tree was shorter lived than the Lepidodendron type.

The phylum Lepidophyta corresponds to the Order Lycopodiales (after *Lycopodium*) of the Pteridophyta as formerly defined.

Pteridospermophyta. These plants, characteristic of the late Devonian and Carboniferous, had fernlike leaves and were *fernlike* in habit, including *climbing* and *herbaceous forms* and *trees.* One of the earliest recorded types comes from the fossil forests in the Devonian beds of eastern New York, and a life-size restoration group of these oldest known forests has been on exhibition for several years in the State Museum (figure 1). This is a tree form (*Eospermatopteris*) with a height of 25 feet and upwards, bearing at its summit a crown of long, fernlike leaves, some of which bore *seeds* at the tips, others the pollen bearing organs (figure 88). These plants differ from the true ferns, which also have tree forms, in the higher organization of the trunk, approaching that of the cycads, as well as in the fact that they bore seeds. The seeds are borne variously in different species of seed ferns, sometimes being attached to the midrib of the

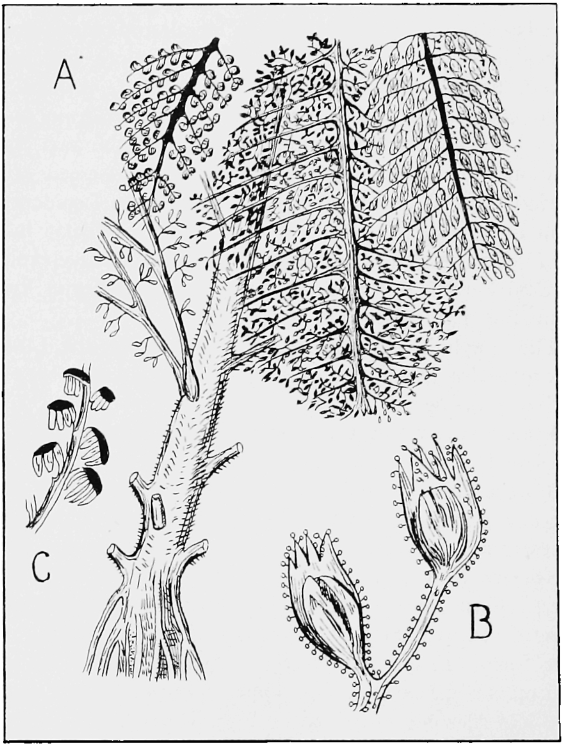


Figure 89 Carboniferous seed fern. *A* Restoration of *Lyginopteris:* frond on left bears pollen-sacs; on right seeds; vegetative frond in middle. *B* Two seeds, enlarged. *C* Peltate leaflets, bearing pollen-sacs, enlarged. (From Extinct Plants and Problems of Evolution by D. H. Scott, published by The Macmillan Co.)

frond, but they were in no cases borne in cones (figure 89). This group holds a position between the ferns and the higher seed plants and shows ancestral relationships with the cycadophytes. Seed ferns must have had their origin earlier than the Middle Devonian in primitive fern types, and they reached their greatest development in Carboniferous times (particularly the Pennsylvanian), dying out before the end of the Paleozoic. A number of forms that were formerly thought to be true ferns have been found through more recent studies to be seed ferns and future discoveries will undoubtedly add many more of the so-regarded tree ferns to this number. It has been estimated that fully half of the known plants of the coal deposits of the Carboniferous were seed ferns. Some of these seed ferns grew to huge size, having a diameter of two feet and rising to heights of 60 or 70 feet; and must have been even more impressive than the living tree ferns. The development of the seed habit was an important advance in the evolution of plants, giving those plants bearing them immense advantages, as evidenced by the fact that the dominant existing plants bear seeds.

The phylum Pteridospermophyta corresponds to the Order Cycadofilicales (Greek *kykas,* Cycas; Latin *filix* (*filic*), fern), also known as the Pteridospermeae, of the Gymnosperm (Greek *gymnos,* naked; *sperma,* seed) division of the phylum Spermatophyta in the older classification.

Cycadophyta. This phylum includes the *living cycads* (for example *Cycas*) or sago palms and two *extinct* orders of *cycadlike plants.* This group of seed plants are believed to have been derived from the pteridosperms, probably some time during the Devonian; and while they were not common in Paleozoic times they were dominant in

Figure 90 Cycads. Tall unbranched and branching trunks of a living cycad (*Cycas revoluta*), Japan (after Wieland from Knowlton: Plants of the Past, permission Princeton University Press).

the plant life of the earlier part of the Mesozoic (Triassic, Jurassic). There are 110 species of living cycads, all belonging to the warmer regions of both hemispheres (figure 90). The cycads are characterized by a columnar trunk which may be dwarfed or reach heights of 30 to 60 feet. The trunk, branched or unbranched, is crowned with whorls of leaves (figure 91) sometimes numbering over a hundred and reaching lengths up to nine feet. The leaves usually have a central midrib with a row of leaflets or pinnules on each side, sometimes numbering 250; however, sometimes the leaves are further divided giving a fernlike appearance to the leaf. The trunk has a large pith and is encased in an armor formed by the old leaf bases. There is a primary taproot, probably also characteristic of most of the fossil forms, which approaches the trunk in size. Plants of the genus *Cycas* may be seen in many greenhouses and the fronds are familiar through their use by florists in funeral pieces. The genus *Cycas* is known from the Lower Jurassic.

The nature of the "flower" in the cycads is of great interest. In living cycads the fructifications are in the form of cones in nearly all genera. There are two kinds of cones, male and female, which are borne on separate plants. The female cone is the larger and is sometimes of great size, reaching a length of three feet. The genus *Cycas* is an exception to this. In this genus the male flowers are produced in a cone but the female flowers consist of leaflike bodies which form a whorl around the summit of the stem, just as the leaves do, and bear the unprotected bright scarlet seeds on their edges. The cycadeoids, one of the fossil cycad groups, had a true flower (figures 91, 92). The male and female organs were borne on the same axis and had the same arrangement as is found in the later flowering plants — the angio-

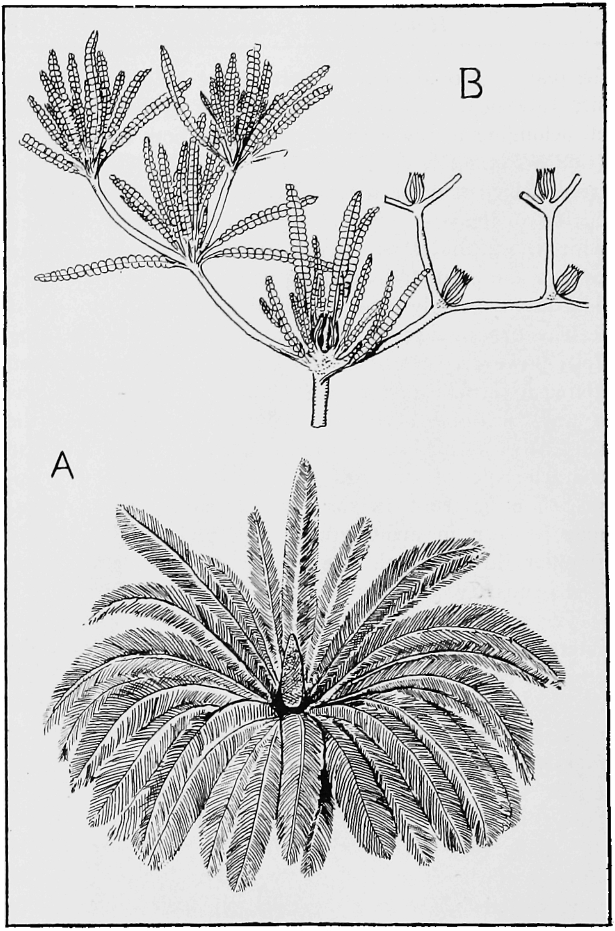


Figure 91 Cycad and cycadeoid. *A* Crown of male plant (*Cycas revoluta*) with a single terminal cone. *B* Cycadeoid (*Wielandiella*) from the Triassic, one of the oldest cycadeoids known, showing the bisexual flowers (after Nathorst). (From Extinct Plants and Problems of Evolution by D. H. Scott, published by The Macmillan Co.)

sperms. On the outside of this flower is a sheath of overlapping, hairy bracts which incloses the circle of pollen-bearing organs that correspond to the stamens of the modern flower. Centrally situated is an elongate, pear-shaped axis which bears the stalked seeds and corresponds to the pistillate portion of the modern flower.

The phylum Cycadophyta corresponds to the Order Cycadales of the Gymnosperm division of the phylum Spermatophyta in the older classification.

Coniferophyta. This phylum corresponds to the Gymnosperms of older classifications, without the pteridosperm

Figure 92 Cycadeoid. Restoration of flower (*Cycadeoidea dacotensis*) in longitudinal section, showing outside hairy bracts, great incurved stamens with numerous pollen-sacs, and conical ovule-bearing receptacle in the middle. (From Extinct Plants and Problems of Evolution by D. H. Scott, published by The Macmillan Co.)

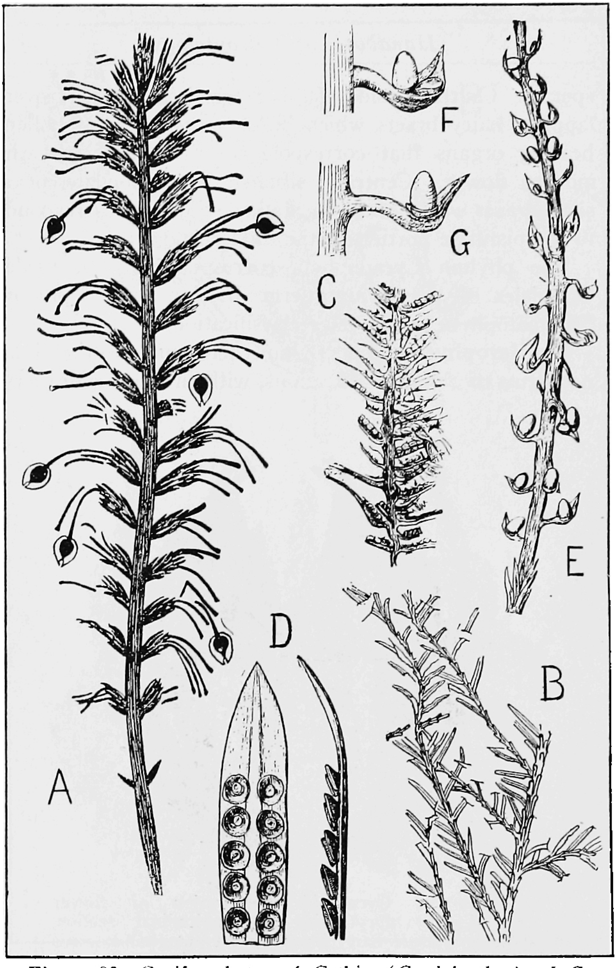


Figure 93 Coniferophytes. *A* Catkin (*Cordaianthus*) of *Cordaites,* showing the pollen-sacs. The female cones are similar to the staminate or male cones, with short-stalked ovules in the axis of the bracts. *B, C* Twig and cone of Triassic conifer (*Palissya*). *D* Enlarged cone scales of same showing seed cupules (after Nathorst). *E—G* Fructifications of Triassic conifer (*Stachytaxus*) with yewlike leaves. (All from Berry)

and cycad groups. All of the members are woody plants in which growth rings are developed, the majority of them are cone-bearing (*conifers*), and nearly all are trees. Their outstanding characteristic is the possession of "naked" or unprotected seeds, hence the name gymnosperms (Greek *gymnos,* naked; *sperma,* seed). With the exception of a few forms, such as the larch, ginkgo and bald cypress, all the existing species have evergreen foliage. The male and female cones are borne on the same plant except in the groups containing the Araucarias and the yews, and the pollen from the male cones is carried to the female cones through the agency of the wind.

Here belongs an extinct order of gymnosperms that had a world-wide distribution from the Devonian to the end of the Paleozoic, and is represented by the genus *Cordaites,* named in honor of one of the early paleobotanists, Corda. *Cordaites* (figures 87, 93) is the best-known genus of this order. These trees were tall, relatively slender, rising to heights of 30 to 100 feet and branched only at the crown. The dense crown of branches bore spirally arranged leaves which were simple with conspicuous parallel veins and sometimes attained a length of three feet and a width of two or three inches. Some of the leaves were blunt tipped, others pointed, and there was variation in their width and the character of the veins. The stem had a large pith more like the cycads, but otherwise had the general features of the modern conifers. There were male and female catkins. The seeds recall the pteridosperms, while the male or staminate catkins resemble those of the ginkgos to which, among living forms, this group shows the closest relationship.

Another isolated order of the gymnosperms is represented today by one genus and species, the *Ginkgo* or maidenhair tree, which has recently been reported in a wild state in western China (figure 94). It has long been cultivated by the Chinese and Japanese and now is becoming a common cultivated plant here, where it may be seen on lawns or in gardens or along the streets of cities. In the structure of the stem and general appearance the ginkgo resembles the gymnosperms, but the leaves are fanlike in outline having the appearance of enlarged leaflets of the maidenhair fern. Ginkgo appeared as far back as the Permian (late Paleozoic) and was abundant in the Triassic, Jurassic and Lower Cretaceous.

These first two orders show relationships with the pteridosperms and ferns.

A third order (Gnetales), not yet known fossil, forms a group of small trees, shrubs and climbers included in three genera, two of which (*Welwitchia, Ephedra*) are characteristic of desert areas. The third genus (*Gnetum*) represented by trees and climbers belongs both to the eastern and western tropics and shows angiospermous tendencies. The Gnetales are chiefly of interest because they seem to form a connecting link with the angiosperms through the character of the wood structure and the flower.

The relationships of the other three orders are not so certain, though it is thought by some that they probably were derived from the Paleozoic Cordaitales. They include all the conspicuous gymnosperms or conifers of the north temperate regions, both trees and shrubs. Here belong the yews (Taxales) with their fleshy seeds, known from the Lower Cretaceous; the Araucarias or monkey-trees (Araucariales) which were widely distributed in Mesozoic times but now are restricted to a small region of the southern hemisphere; all our well-known, more

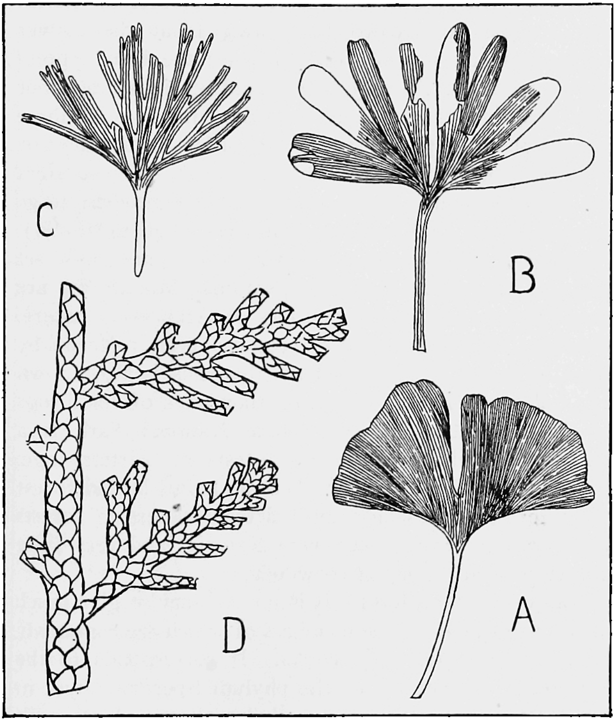


Figure 94 Coniferophytes. *A, B Ginkgo* leaves of Jurassic and Cretaceous time (after Berry). *C* A related extinct form (*Baiera*) from the Triassic (after Berry). *D* Scale-leafed conifer (*Brachyphyllum*) from the Lower Cretaceous (after Fontaine, from Knowlton: Plants of the Past, permission Princeton University Press).

common evergreens, such as the pines, spruces, cedars, hemlocks etc., recorded from Lower Cretaceous times; the Sequoias or redwoods, known from the Lower Cretaceous and possibly the Jurassic; the bald cypress known from the Upper Jurassic; and the junipers, arbor vitae etc., known doubtfully from the Jurassic. All these last named groups constitute the order Coniferales or Pinales (Pinaceae of older classifications). The conifers are familiar enough in general so that it is needless to go into a lengthy discussion of them here (figures 93, 94).

In the Triassic rocks of Arizona, in an area now set aside as the Petrified Forest National Monument, are fossil forests of silicified conifers of Araucarian nature. Because the wood of these trees has been replaced by silica in the form of chalcedony, this park is also known as Chalcedony Park. There are thousands of fossil logs in these forests. In Yellowstone National Park is a series of fossilized coniferous forests of Tertiary age. Volcanoes of Pliocene (Late Tertiary) time buried forest after forest under ashes until fifteen successive forests were buried. These trees were *Sequoias* and very little different from the living redwoods.

Angiospermatophyta. It is unnecessary to give much space to this phylum, the members of which are commonly known as the *flowering plants.* It corresponds to the division Angiospermae of the phylum Spermatophyta in the older classification, and includes all the plants with the seeds inclosed in a protecting ovary, as the core of apples, the shucks of nuts and the chaff of grains. They include certain water plants, the majority of the forest trees, palms, grasses, flowering herbs, shrubs etc. The flowering plants represent the climax of the plant kingdom and are the most perfectly adjusted of plant life to

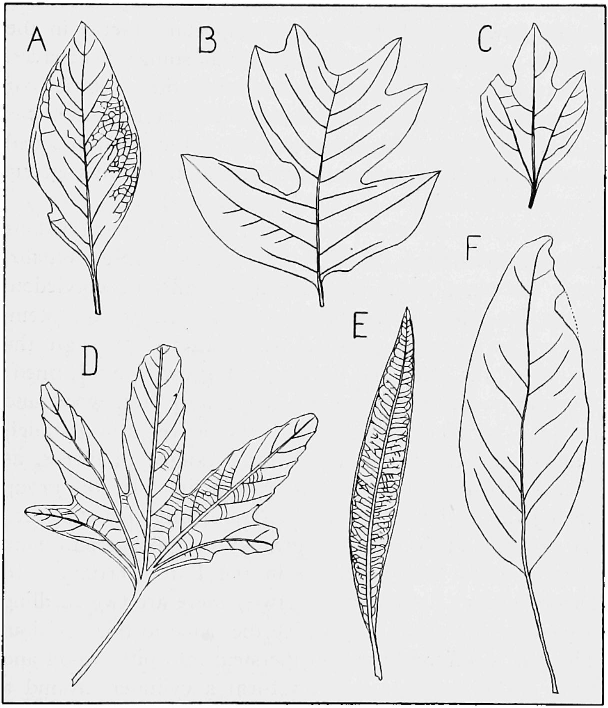


Figure 95 Angiosperms. Leaves (reduced) of various Upper Cretaceous plants: *A* Persimmon tree; *B* Tulip tree; *C* Sassafras tree; *D* Aralia; *E* Moonseed; *F* Magnolia. (All from Knowlton: Plants of the Past, permission Princeton University Press)

their terrestrial existence. The sea margin has been invaded by them, as well as the lakes and the streams. The fruits in this group show as great variety as is seen in the flowers, and this was an important factor in the success of the angiosperms in establishing themselves. It has been pointed out (Berry) that the evolution of the storage of foods in the seeds of the angiosperms was contemporaneous with the evolution of the warm-blooded animals and that without the evolution of this group human civilization could not have evolved.

Two divisions are recognized: the Monocotyledons and Dicotyledons. In Monocotyledons (Greek *monos,* one) the plant starts with a single leaflet or cotyledon, hence the name. The bundles of vessels of the stem, known as vascular bundles, are scattered through the tissues of the stem and no rings of growth are formed; there is no distinction in the stems into pith, wood and bark. The roots are fibrous; the leaves are parallel-veined; and the flower parts are arranged in threes, as exemplified in the well-known Easter lily. In this group belong the various lilies, the various palms, bananas etc., the sedges and the grasses (grains) so important to man. True grasses first appeared in the Late Tertiary. In Dicotyledons (Latin *dis* (*di*), two) there are two seedling leaves or cotyledons which give the name to this division. There is a differentiation in the stem into pith, wood and bark. The vascular bundles form a cylinder around a central pith and the formation of a new layer of wood each year produces the characteristic growth rings seen in cross section. The leaves are usually net-veined. There is a taproot present and the flower parts are arranged in fours or fives, as in the common mustard and the wild rose. Here belong the bulk of the plants with which we are familiar: our forest trees, such as the oaks, chestnuts, ashes, maples etc.; our shrubs and herbs and most of our garden plants etc.

Angiosperms appeared during the Lower Cretaceous. They have been the dominant plants since Tertiary (Eocene) times and are represented by about 125,000 living and several thousand fossil species. Between three and four thousand fossil species have been described from the Mesozoic and Cenozoic floras of North America (figure 95).

THE DEVELOPMENT OF PLANTS THROUGH THE AGES

Reckoning the whole of geologic time as 100 per cent, it has been estimated that the Archeozoic period represented 30 per cent of the total length of time and the Proterozoic 25 per cent. In the Archeozoic no recognizable trace of life has been found and it has been called the age of probable unicellular life. In the Proterozoic, the age of primitive plants, only algae and bacteria are known to have existed; and these two eras together form 55 per cent or 700,000,000 to 750,000,000 years of geologic time.

During Cambrian, Ordovician and Silurian times only seaweeds are known with certainty to have lived, although animal life at this time was wonderfully developed and varied. The abundance of animal life argues for an abundance of plant life, which was their food either directly or indirectly. Both animals and plants were confined to the water. Air-breathing animals (scorpions) appeared in the Upper Silurian; but the evidence for land plants in the Upper Silurian has not been generally accepted, although specimens thought to be land plants have been reported from several places. The Cambrian, Ordovician and Silurian periods have been estimated to have covered 16.5 per cent of geologic time so that over 70 per cent or nearly 1,000,000,000 years of geologic time had elapsed before the appearance of land plants. Land plants, therefore, have evolved to their present high state of development in considerably less than one-third of the total length of geologic time.

The Devonian period is considered the time of the earliest, certainly known, land plants; and it is believed that they first came into existence in the early Devonian. These earlier Devonian plants were very strange and unnatural looking (figure 96). One form (*Psilophyton*) described first from the Lower and Middle Devonian of Canada and later from Scotland, Norway, Bohemia, Germany, Maine etc. was a plant with a mat of creeping stems from which arose, to a height of about two feet, woody stems about half an inch thick. The stems were forked, and in the case of the younger branches, coiled at the tips. Some of the stems were smooth and have been regarded as belonging to another plant; others were provided with spines or prickles which have been interpreted as rudimentary leaves. The fruiting bodies were naked oval spore cases which were borne in pairs on the smaller branches, either lateral or terminal. Other primitive types of plants have been found, some from the Lower Devonian, some from the Middle Devonian, of Canada, Scotland, Bohemia, western Norway etc. Among these is an interesting form (*Rhynia*) from the Rhynie Chert beds (Middle Devonian) in Aberdeenshire, Scotland, which represent an ancient, silicified, peat bed. There are two species based on size; the smaller one, eight inches high and as thick as a small lead pencil

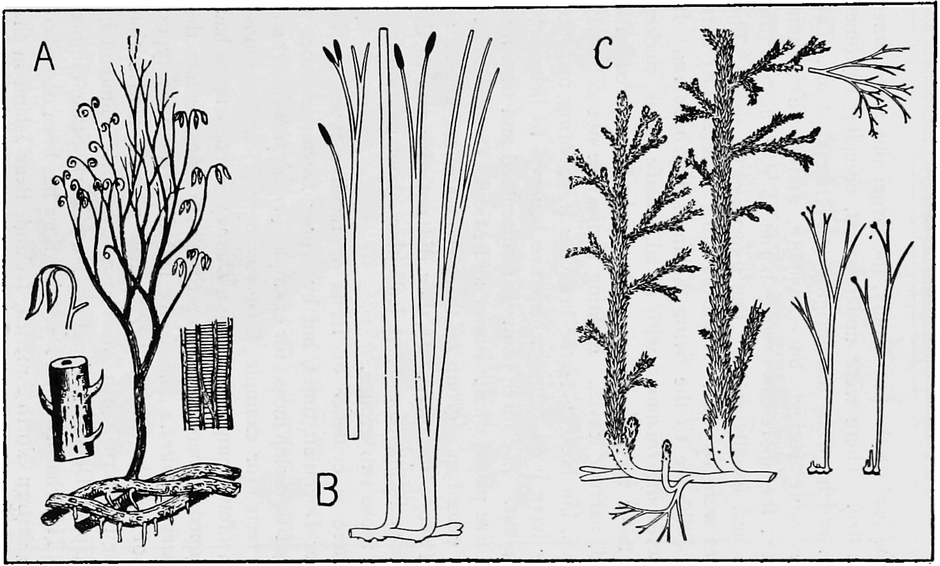


Figure 96 Early Devonian plants of the *Psilophyton* flora. *A Psilophyton;* enlargements of branch with spore cases, stem with "spines" and wood cells showing ladder-shaped thickenings. *B Rhynia major,* with terminal spore-cases. *C* ***Asteroxylon*** *mackiei.* Fertile branch in upper right corner; *Hornea lignieri* in lower right corner. (*A* after Dawson; *B, C* after Kidston and Lang. All from Knowlton: Plants of the Past, permission Princeton University Press)

or the lead of the pencil only, the larger one three times that size. There were underground, creeping rhizomes from which sprang the upright, woody aerial stems. The stems were forked, but sparingly, and were without leaves; the spore-cases were borne at the ends of the branches, usually solitary but sometimes in pairs. The spores were fernlike. A third form (*Asteroxylon*) bore a resemblance to the living clubmoss, *Lycopodium*. It had creeping rhizomes, with aerial, woody stems, thicker and taller than in *Rhynia* and completely covered with small, narrow leaves. Fruiting bodies are not definitely known, but leafless, fertile branches terminating in spore cases have been found which are believed to belong to this plant. The three plants here discussed and the other primitive plants of the Lower and Middle Devonian have been placed in a group by themselves and are known as the *Psilophyton flora*. If they did not give rise to the ferns and club mosses, at least they show relationships with those two groups.

There is evidence of ferns or fernlike types in the earlier Devonian times, but by Upper Devonian times a flora of fern, club moss (for example, *Protolepidodendron*), seed fern (for example, *Eospermatopteris*) and gymnosperm (for example *Callixylon, Dadoxylon* etc.) types had developed. There were also arthrophyte types, such as the *Archaeocalamites*. The ferns included tree fern types, one of which (*Achaeopteris*) had a wide distribution through eastern North America and is fairly abundant in the Upper Devonian rocks of New York State (figure 97). This characteristic Devonian flora has been described from eastern North America, Ireland, Bear Island in the Arctic region, Donetz Basin of southern Russia, Bohemia, Germany etc.

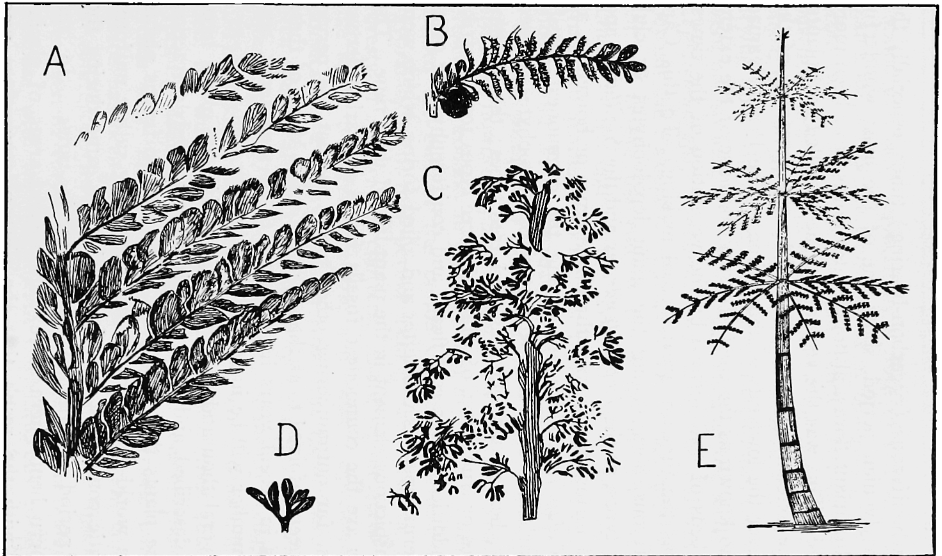


Figure 97 Tree ferns and calamites. *A* Foliage of a species of the common Devonian tree fern, *Archaeopteris.* *B* Fertile pinna of same. *C* Fertile pinnae of another species. *D* Enlargement of group of sporangia of same. *E* Upper Triassic calamite type, *Neocalamites,* x1/30. (*A, B* after Schimper; *C, D* after White; *E* after Berry. All from Berry)

Carboniferous (=carbon-bearing) times, especially the Pennsylvanian period, show one of the most wonderful and luxuriant floras, although later floras have been more varied. This was the vegetation, the so-called coal plants, of the extensive swamps formed by the spreading of the sea over the lowlands of those times. The Pennsylvanian is also known as the *Coal Measures* because of the extensive beds of coal formed by the vegetation of the times. It was the time of greatest coal making. To this Carboniferous flora belong the giant lepidophytes or club moss types, as the *Lepidodendrons* and the *Sigillarias* and allied forms; the giant arthrophyte types or horsetails, as the *Calamites,* which are among the commonest fossils in Carboniferous rocks; the pteridospermophytes or seed ferns, herbaceous, climbing and tree types; the pteridophytes or true ferns, of which the tree types form a striking addition to the coal flora; and coniferophyte or gymnosperm types, as *Cordaites* and allied forms, which were a conspicuous element in the plant life of their time. The ferns are the commonest fossils found in Carboniferous rocks, far outnumbering other types, so that the period has been referred to as the *Age of Ferns.* Many of these ferns in recent years have proved to be seed ferns, and the number will be increased with further study.

Several thousand species of Carboniferous plants have been described, and they probably represent only a fraction of the plants that lived then. The Carboniferous plants had a world-wide distribution, suggesting rather uniform climatic conditions. Profound changes came during the last period (Permian) of Paleozoic times. In the southern hemisphere there were several areas of glaciation, with the result that the Carboniferous flora was almost entirely blotted out in the southern hemisphere and became gradually replaced by a flora of coarse, fernlike plants known as the *Glossopteris* or *Gangamopteris flora* from two of the most abundant types. The Carboniferous flora continued little changed in the northern hemisphere but before the close of the Paleozoic era with the drying up of the swamps and climatic changes, conditions were not so ideal. Certain types, such as the seed ferns, *Lepidodendrons, Sigillarias* and *Calamites* did not live beyond the Paleozoic. *Cordaites* had disappeared almost entirely before the end of the Paleozoic, but lived on almost to the end of the Triassic. Most of the great groups of plants lived on, but their representatives were smaller and were overshadowed by the Mesozoic flora.

The Mesozoic was the age of the cycads, conifers and primitive flowering plants. Not many Triassic plants are preserved, probably in part due to a dry climate, although toward the end of the period conditions became more favorable. To this period belong the Arizona fossil forests of Araucarian conifers. Some of the ferns were like small tree ferns in size and habit. Specimens of horsetails not distinguishable from true *Equisetums* have been found; also a calamitelike type, known as *Neocalamites* (figure 97); and cycad remains, mostly foliage.

The Jurassic flora had an almost world-wide distribution, but was not particularly rich. The most abundant types of plants were ferns, cycads and conifers; and the cycads were so abundant and so characteristic that the period has been called the *Age of Cycads*. The conifers or coniferophytes were abundant; but none appear to have been of very large size. Thus there was nothing to compare with the magnificent Carboniferous forests or with the forests of Tertiary or modern times. The Araucarianlike types of conifers show closer relationship to the modern types. *Sequoias* also lived during this period and the *Ginkgo,* or maidenhair tree, was abundant and had a wide distribution.

The Cretaceous marks the appearance of the so-called flowering plants. Ferns were abundant, of comparatively small size, and some approached modern types. Types of ferns, cycads and conifers that lived on from Jurassic time died out before the beginning of the Upper Cretaceous. Cycads reached their culmination in early Cretaceous times; conifers at this time were the largest and most conspicuous plants and were represented by several kinds of sequoias. There were also cedarlike and juniperlike conifers and species of *Araucaria;* the yew family was represented; forerunners of the cypresses were present, and the ginkgos and an extinct form closely related (*Baiera*). The coming of the flowering plants or angiosperms in the latter part of the Lower Cretaceous marked the most important step in the evolution of plants. These first angiosperms, most of which can be referred to living families and some even to living genera, were so characteristic and modern in appearance that they must have had their origin much farther back in geologic time. Some of the other groups had disappeared, others had become smaller in size and number and taken the minor place that they hold today. Among the angiosperms were representatives of the willow family, the birch family, the elm family, the mulberry or fig family, the laurel family, the grape family, the water lily family etc. By Upper Cretaceous time the angiosperms had spread widely over the earth and, before the end of this period, had become the dominant group of plants; many new and modern types had come in, such as the sassafras, tulip tree, walnuts, persimmons, maples, oaks, dogwoods, sycamores, the eucalyptus etc. Some floras were made up entirely of flowering plants but there were also, in places, mixed floras of hardwoods and conifers, such as sequoias, junipers, cypresses, pines, ginkgos etc.

The Cenozoic, including the Tertiary and Quaternary or Ice Age, was the time of modern life. The wide distribution and development of the floras toward modern character continued into the Tertiary. Eocene or Early Tertiary times show rich floras. Species of palms that only grow in the tropics today grew in our southern states and there were bread-fruit trees in the Colorado flora. There was a wonderfully rich Eocene flora in Greenland, consisting of ferns, horsetails, tall grasses, the bald cypress, cedars, ginkgos, junipers, willows, poplars, sweet gums, elms, birches, hickories, walnuts, dogwoods, persimmons, magnolias, grapevines etc. Mosses formed part of this flora which was a typically temperate one. Miocene or Middle Tertiary plants are not as well known and the knowledge comes from a few localities, but undoubtedly a considerable number of these species are still living. There was a lowering of temperature in late Pliocene (Upper Tertiary) times forcing migrations and bringing about considerable changes in the distribution of plants. Comparatively few species are known from the beds of this time. The Pleistocene or Great Ice Age forced a further southward migration of plant types. Some were able to migrate successfully; others were overwhelmed; still others were left stranded on southern mountain tops; and from this flora has developed the plant life existing today. It has been estimated that over 90 per cent of the plants now living in the area covered by the ice were in existence throughout all of Pleistocene time.

Estimations have been made (Wieland) as to the number of species of plants that may have existed in the different periods of geologic time, with due regard to the fossil record. In the Devonian there were possibly 12,000 species; in the Carboniferous, 27,000; in the Permo-Triassic, 43,000; in the Jurassic, 60,000; at the base of the Cretaceous 100,000. Over 200,000 species of living plants have been described, and the total number of living species would probably amount to over 300,000.

Collections of fossil plants may be found in a number of the larger museums and in university collections. The United States National Museum, with more than 500,000 specimens, has the largest collection of fossil plants in this country and perhaps in the world. The Yale University collection is particularly rich in cycads; the Colorado University and the University of California collections, in Tertiary plants. Both The Johns Hopkins University and the University of Chicago have good Carboniferous collections, etc. The Devonian plants in this country and Canada are almost entirely located in three museums: the United States National Museum, the New York State Museum and the Redpath Museum of McGill University, Montreal.

The New York State Museum includes in its plant collection beautiful specimens of the Cambrian calcareous alga, *Cryptozoön;* Ordovician and Silurian plants, including a few specimens of possible Silurian land plants; and some Cretaceous plants. The bulk of the plant material is from Devonian beds and constitutes the largest and finest collection of Devonian plant material in the world. It includes the rare and valuable Gilboa collection of seed fern material. The greater part of this collection is on exhibition in the State Museum together with a life-size restoration of the Upper Devonian club moss, *Protolepidodendron,* and a restoration group of the Upper Devonian forests of seed ferns (*Eospermatopteris*).

Literature

Only a few references need be given for plants. Any good textbook of botany may be consulted, as Atkinson's *Botany for High Schools* ('10) or his more advanced *College Botany* ('05); also Bailey ('12), Clements ('07), Coulter ('99, '11), Coulter, Barnes, Cowles ('10, '11). For fossil plants the student may consult any of the textbooks of historical geology and Shimer ('14); but they are particularly recommended to *Plants of the Past,* a popular book on fossil plants by the late Dr F. H. Knowlton. For the student who wishes to go further, may be added Berry ('18), Campbell ('11), Scott ('09, '11, '20). References to other works will be found in those cited above.

BIBLIOGRAPHY

Atkinson, G. F.

1905 College Textbook of Botany. 737p. 2d ed. rev. New York

1910 Botany for High Schools. 463p. New York

Bailey, L. H.

1912 Botany. An Elementary Text for Schools. 413p. New York

Beecher, C. E. & Clarke, J. M.

1889 Development of Some Silurian Brachiopoda. N. Y. State Mus. Mem. 1:1–96. 8 pls.

Berry, E. W.

1920 Paleobotany: A Sketch of the Origin and Evolution of Floras. Smith. Inst. Ann. Rep't for 1918, Pub. No. 2549:289–407

Campbell, D. H.

1911 Plant Life and Evolution. 360p. New York

Chamberlin, T. C. & Salisbury, R. D.

1909 A College Textbook of Geology. 978p. New York

Clarke, J. M. & Ruedemann, R.

1912 The Eurypterida of New York. N. Y. State Mus. Mem. 14, v. 1 (text) p. 1–440; v. 2 (plates) p. 1–188. 88 pls. (Full bibliography)

Cleland, H. F.

1916 Geology, Physical and Historical. 718p. New York (Bibliographies)

1928 Our Prehistoric Ancestors. 379p. New York

Clements, F. E.

1907 Plant Physiology and Ecology. 315p. New York

Coulter, J. M.

1899 Plant Structures. A Textbook of Botany. 348p. New York

1911 Plant Studies. An Elementary Botany. 392p. New York

——— **Barnes, C. R. & Cowles, H. C.**

1910, 1911 A Textbook of Botany for Colleges and Universities. V. 1. Morphology, Physiology, p. 1–484; v. 2. Ecology, p. 485–964. New York

Cunningham, J. T.
1912 Reptiles, Amphibians and Fishes. 510p. London

Davies, A. M.
1920 An Introduction to Paleontology. 414p. London. (Bibliographies)

Dean, Bashford
1895 Fishes, Living and Fossil. 300p. New York

Duckworth, W. L. H.
1912 Prehistoric Man. 156p. New York

Geikie, A.
1903 Textbook of Geology. V. 2, p. 705–1472. London

Goldring, Winifred
1923 Devonian Crinoids of New York. N. Y. State Mus. Mem. 16:1–670. 60 pls. (Full bibliographies)

Grabau, A. W.
1899 The Paleontology of Eighteen Mile Creek and the Lake Shore Sections of Erie County, New York. Buffalo Soc. Nat. Sci. Bul. 6:97–403
1913 Principles of Stratigraphy. 1185p. New York. (Bibliographies)
1921 Textbook of Geology, Part II. Historical Geology. 976p. New York

——— & Shimer, H. W.
1909, 1910 North American Index Fossils. V. 1, p. 1–853; v. 2, p. 1–909. New York. (Bibliographies)

Hall, James
1847 Natural History of New York. Organic Remains of the Lower Division of the New York System. Paleontology, 1:1–338. 99 pls.
1852 Natural History of New York. Organic Remains of the Lower Middle Division of the New York System. Paleontology, 2:1–362. 104 pls.
1859, 1861 Natural History of New York. Organic Remains of the Lower Helderberg Group and the Oriskany. Paleontology, 3 (part 1, text) :1–532; (part 2, plates), 142 pls.
1867 Natural History of New York. Fossil Brachiopoda of the Upper Helderberg, Hamilton, Portage and Chemung Groups. Paleontology, 4 (part 1) :1–428. 69 pls.
1879 Natural History of New York. Gasteropoda, Pteropoda and Cephalopoda of the Upper Helderberg, Hamilton, Portage and Chemung Groups. Paleontology, 5 (part 2, text) :1–492; (part 2, plates), 120 pls.

Hall, James

1884 Natural History of New York. Lamellibranchiata I, Monomyaria of the Upper Helderberg, Hamilton and Chemung Groups. Paleontology, 5 (part 1):1–268. 45 pls.

1885 Natural History of New York. Lamellibranchiata II, Dimyaria of the Upper Helderberg, Hamilton, Portage and Chemung Groups. Paleontology, 5 (part 1):269–561. 51 pls.

——— **& Clarke, J. M.**

1888 Natural History of New York. Trilobites and Other Crustacea of the Oriskany, Upper Helderberg, Hamilton, Portage, Chemung and Catskill Groups. Paleontology, 7:1–236. 46 pls.
(With supplement to v. 5, part 2. Pteropoda, Cephalopoda and Annelida. 42p. 18 pls.)

1892, 1894 Natural History of New York. Paleozoic Brachiopoda. Paleontology, 8 (part 1):1–367, 44 pls.; 8 (part 2): 1–394. 64 pls.

1892*a*, 1894*a* Handbook of the Brachiopoda. Part I, Report of State Geologist for 1891, p. 133–300. 22 pls., map; part II, Report of State Geologist for 1893, p. 749–943. Pls. 23–54. (Also in Mus. Rep'ts 45 and 47, without plates, and published separately in two parts, with plates)

1898 Paleozoic Reticulate Sponges. N. Y. State Mus. Mem. 2:1–350. 70 pls.

——— **& Simpson, G. B.**

1887 Natural History of New York. Corals and Bryozoa of the Lower and Upper Helderberg and Hamilton Groups. Paleontology, 6:1–298. 67 pls.

Harmer, S. F. & Shipley, A. E.

1909–20 Cambridge Natural History. V. 1 Protozoa, Coelenterates, Echinoderms, etc. p. 1–671 (1909). V. 2 Worms, Rotifers and Polyzoa, p. 1–560 (1910). V. 3 Molluscs and Brachiopods, p. 1–535 (1913). V. 4 Crustacea and Arachnids, p. 1–566 (1920). V. 5 Peripatus, Myriapods and Insects, part I, p. 1–584 (1910). V. 6 Insects, part II, p. 1–626 (1918). V. 7 Fishes, Ascidians etc., p. 1–760 (1910). V. 8 Amphibia and Reptiles, p. 1–688 (1920). V. 9 Birds, p. 1–635 (1909). V. 10 Mammalia, p. 1–605 (1920). London. (Volumes written by various authors; edited by Harmer and Shipley)

Hartnagel, C. A. & Bishop, S. C.

1922 The Mastodons, Mammoths and Other Pleistocene Mammals of New York State. N. Y. State Mus. Bul. 241–42:1–110

Holmes, Arthur & Lawson, Robert W.

1927 Factors Involved in the Calculation of the Ages of Radioactive Minerals. Amer. Jour. Sci. (5th ser.), 13:327–44. (Age of the Earth)

Hutchinson, H. N.

1910 Extinct Monsters and Creatures of Other Days. 329p. London. (Popular)

Kindle, E. M.

1916 Fossil Collecting. Ottawa Naturalist, 29:117–24

Knowlton, F. H.

1927 Plants of the Past: A Popular Account of Fossil Plants. 275p. Princeton. (Bibliography)

Lankester, E. Ray

1900–09 A Treatise on Zoology. Part I Introduction and Protozoa. Fasc. 1, p. 1–451 (1903); fasc. 2, p. 1–296 (1909). Part II The Porifera and Coelenterata. 368p. (1900). Part III The Echinoderma. 344p. (1900). Part IV The Platyhelmia, the Mesozoa and the Nemertini. 200p. (1901). Part V Mollusca. 355p. (1906). Part VII Crustacea. 346p. (1909). Part IX Vertebrata, Craniata, Cylostoma, Fishes. Fasc. 1, p. 1–518 (1909). London. (Full bibliographies. Volumes written by various authors, edited by Lankester.)

1906 Extinct Animals. 331p. New York

Lucas, F. A.

1922 Animals of the Past. Amer. Mus. Nat. Hist. Handbook Ser. No. 4:1–207. New York. (Popular)

Lull, R. S.

1917 Organic Evolution. A Textbook. 729p. New York. (Bibliographies)

Marsh, O. C.

1883 Birds with Teeth. U. S. Geol. Surv. 3d Ann. Rep't, 1881–82, p. 45–88

Matthew, W. D.

1915 Dinosaurs. Amer. Mus. Nat. Hist. Handbook Ser. No. 5:1–162. Plate, 48 text figs. (Popular)

1920 Flying Reptiles. Amer. Mus. Nat. Hist. Jour., 20:73–81. (Popular)

——— & Chubb, S. H.

1927 Evolution of the Horse. Amer. Mus. Nat. Hist. Guide Leaflet Ser. No. 36:1–67. 38 figs. (Popular)

Osborn, H. F.
1904 The Evolution of the Horse in America. Century Mag., November, v. 69 (no 1) :3–17. (Popular)
1905 Ichthyosaurs. Century Mag., January, 69 (no. 3) :414–22. (Popular)
1910 Age of Mammals. 635p. New York
1915 Men of the Old Stone Age. 545p. New York
1917 The Origin and Evolution of Life. 322p. New York
1926 Mammoths and Mastodons of North America. Amer. Mus. Nat. Hist. Guide Leaflet Ser. No. 62:1–26. (Popular)

Parker, T. J. & Haswell, W. A.
1910 A Textbook of Zoology. V. 1, p. 1–839. London

Ruedemann, R.
1905 Graptolites of New York, Part I. N. Y. State Mus. Mem. 7:1–350. 17 pls. (Full bibliographies)
1908 Graptolites of New York, Part II. N. Y. State Mus. Mem. 11:1–584. 31 pls., 2 tab. (Full bibliographies)

Scott, D. H.
1909 Studies in Fossil Botany V. 2, Spermophyta. p. 355–675. London
1911 The Evolution of Plants. 256p. New York
1920 Studies in Fossil Botany. V. 1, Pteridophyta. p. 1–434. 3d ed. rev. London

Scott, W. B.
1913 A History of Land Mammals in the Western Hemisphere. 693p. New York
1924 An Introduction to Geology. 816p. 2d ed. rev. New York.

Schuchert, C.
1895 Directions for Collecting and Preparing Fossils. U. S. Nat. Mus. Bul. 39 (part K) :1–31
1924 Textbook of Geology, Part II. Historical Geology. 724p. New York. (Bibliographies)

——— & Le Vene, C. M.
1927 The Earth and Its Rhythms. 410p. New York

Seeley, H. G.
1901 Dragons of the Air. 239p. London

Shimer, H. W.
1914 An Introduction to the Study of Fossils. 450p. New York. (Full bibliography)

Tyler, J. M.
1923 The Coming of Man. 147p. Boston

Wetmore, A.
1928 Prehistoric Ornithology in North America. Wash. Acad. Sci. Jour., 18:145–58

Whitnall, H. O.
1924 The Dawn of Mankind. 278p. Boston

Wilder, H. W.
1923 Man's Prehistoric Past. 463p. New York

Williston, S. W.
1902 Winged Reptiles. Popular Sci. Monthly, February, 60: 314–322. (Popular)

Zittell, K. A. von. (*Ed. by C. R. Eastman*)
1913 Textbook of Paleontology. V. 1, Invertebrates. p. 1–839; V. 2, Vertebrates. p. 1–283. New York. (Bibliographies)

INDEX

HANDBOOKS OF THE NEW YORK STATE MUSEUM

No. 1 **Lobeck, A. K.** A Popular Guide to the Geology and Physiography of Allegany State Park. 281p., illustrated. 1927 $1.00

No. 2 **House, Homer D. & Alexander, William P.** Flora of the Allegany State Park Region. 212p., illustrated. 1927 75c.

No. 3 **Bishop, S. C.** The Amphibians and Reptiles of Allegany State Park. 134p., illustrated. 1927 50c.

No. 4 **Shaw, William T.** The Spring and Summer Activities of the Dusky Skunk in Captivity. 100p., illustrated. 1928 30c.

No. 5 **Taylor, Norman.** The Vegetation of the Allegany State Park. 121p., illustrated. 1928 40c.

No. 6 **Felt, E. P.** A Popular Guide to the Study of Insects. 140p., illustrated. 1929 50c.

No. 7 **Saunders, Aretas A.** Bird Song. 202p., illustrated. 1929 50c.

No. 8 **Harper, Francis & Harper, Jean S.** Animal Habitats in Certain Portions of the Adirondacks.
Harper, Francis. Notes on Mammals of the Adirondacks.
Fraleigh, Lucy B. The Habits of Mammals at an Adirondack Camp. 176p. 1929 50c

No. 9 **Goldring, Winifred.** Handbook of Paleontology for Beginners and Amateurs, with Special Reference to New York State. 356p. 1929 $1.50