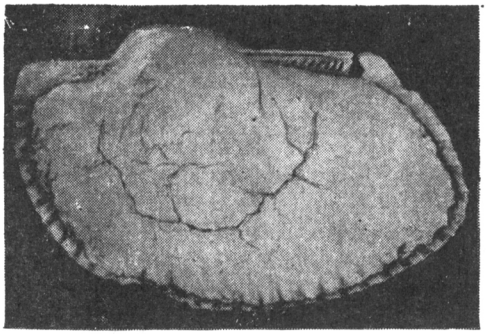

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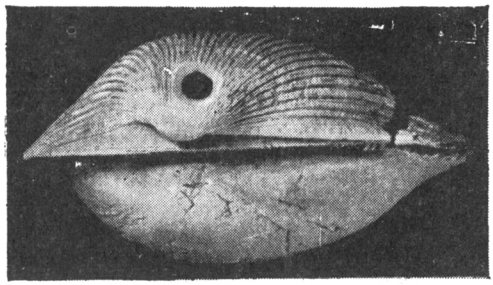

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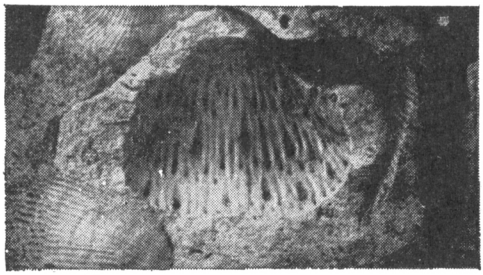

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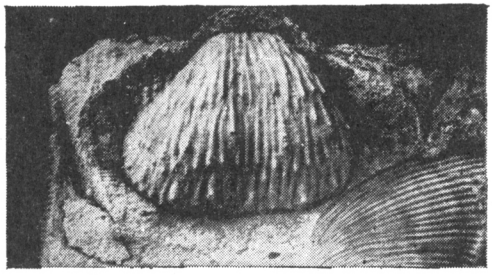

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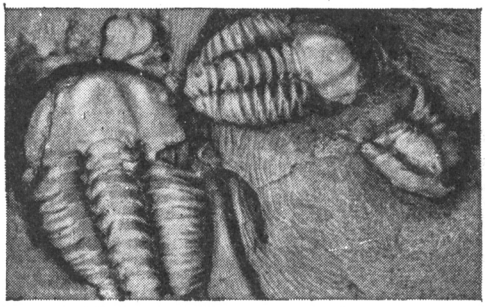

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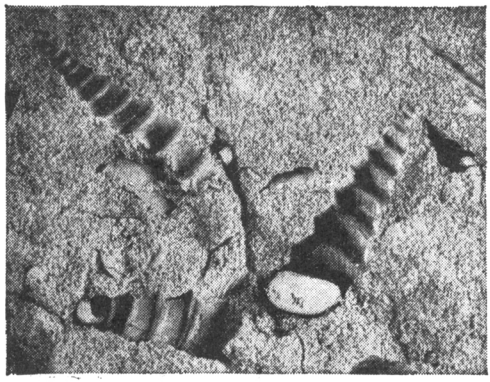

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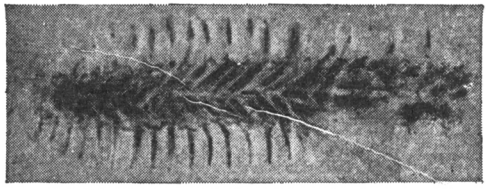

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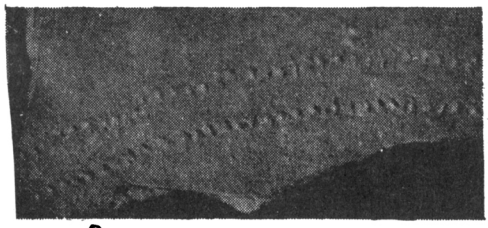

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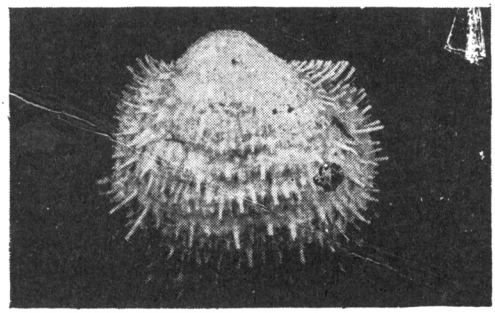

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FIG. 1-1.

Above families (or superfamilies) come successively higher and more inclusive ranks of classificatory assemblages (Fig. 1-6). In ascending series, these are **orders, classes,** and **phyla** (sing. **phylum**), each of which may be divided into lesser-rank parts by use of the prefix sub-, or combined in higher-rank units under names using the prefix super-. Rarely employed, but useful in some parts of classification, are terms such as tribe, clan, grade, branch, and others. Highest is kingdom, for the kingdom Animalia includes all animals.

Principal Divisions of Animals

Linné in 1758 recognized six main divisions of the animal kingdom, which he called Vermes (worms), Insecta, Pisces (fishes), Amphibia, Aves (birds), and Mammalia. All kinds of creatures now collectively known as invertebrates were included under Vermes. Distinctions of the sort which have come to be recognized as fundamental in modern zoological classification were first grasped by Lamarck in 1809 and Cuvier in 1816, for the work of these great French naturalists established characters of the phyla named Mollusca, Annelida, Arthropoda, and Vertebrata, and of their main divisions. Subsequent studies, especially by the zoologists Ehrenberg (1838), Leuckart (1848), Vogt (1851), Haeckel (1874), Hatschek (1888), and Lankester (1900), have shown that definition of the principal divisions of animals needs to be based on consideration of groups of characters, rather than on any one sort of evidence consisting of anatomical or embryological facts. Among the chief characters having significance in classification are (1) grade of body construction, cellular or with organized tissues and organs; (2) type of body symmetry, primarily radial or bilateral; (3) presence or absence of a body cavity (coelom) distinct from the digestive tract, and mode of origin of such cavity; (4) presence or absence of an anus; (5) segmentation of the body or lack of it; and (6) nature of circulatory, respiratory, excretory, and nervous systems, if present. Using these bases, the animal kingdom may be divided into main parts shown in the outline of classification opposite, in which an asterisk (*) indicates that representatives occur among fossils, and numbers in the column at right designate chapters of this book in which members of the phyla are described.

ADAPTATION TO ENVIRONMENT

Animals are greatly influenced by the surroundings in which they live. In the struggle for existence, many species become specially fitted for particular modes of life. They obtain food, adapt themselves to all aspects of their environment, find ways of protection from enemies, and successfully reproduce their kind. They become established under various conditions of depth, temperature, and bottom conditions in the seas; become differentiated for floating freely or swimming; invade hypersaline, brackish, and fresh waters; achieve ability to move about on land; and even take to the air. Many burrow in sediment at the bottom of water bodies or in the earth on land. Virtually no place on or near the earth's surface is uninhabited by some kind of animals.

This adaptation of the animal kingdom to all sorts of environments has importance in paleontological study, for what is true of the present is equally true of the past. Knowledge of the mode of life of modern animals of all kinds therefore is helpful in understanding adaptations of ancient invertebrates and vertebrates, because most ecologic adaptations of animal groups seem to have been acquired early in their history and retained tenaciously. Thus, the fact that modern corals build reefs only in shallow warm seas, correlated with observation that Mesozoic and Paleozoic coral reefs occur chiefly in low latitudes and in deposits having signs of shallow marine origin, strongly suggests that the pre-Tertiary reef corals, like modern ones, thrived in warm shallow waters.

at depths of less than 200 m., are grouped in (*a*) the so-called **neritopelagic** environment, comprising shallow waters above the continental shelf areas, and (*b*) the **oceanopelagic** environment, including near-surface parts of open ocean basins. In these parts of the sea live perhaps 99 per cent of all nektonic and planktonic marine animals. (2) Deep waters include (*a*) the **bathypelagic** environment, between depths of 200 and 2,000 m., and (*b*) the **abyssopelagic** environment, below 2,000 m. A few sorts of peculiarly modified fishes are chief inhabitants of these waters.

Land Environments

Ecologists recognize numerous major and minor types of environments on land, the differences between them consisting chiefly of conditions controlled by climate and topography. Classification of these environments has little meaning for study of invertebrate fossils, and hence may be neglected. Most invertebrates of the land which are found preserved in Tertiary and older sedimentary deposits are animals adapted for life in fresh water, as in ponds, lakes, and streams. The environment in which they lived is indicated partly by physical characters of the rocks containing them and partly by the nature of the fossils themselves, including zoological affinities to known types of nonmarine animals and absence of marine organisms.

Air-breathing invertebrates, adapted to dry-land environments, include insects, spiders, scorpions, and other kinds of jointed-leg animals (arthropods), and the pulmonate snails. These have acquired the ability to thrive in almost all sorts of ecologic surroundings, even deserts and high mountains.

Facies Fossils

The term facies is used in stratigraphy to designate areally segregated sedimentary deposits which have significant characters differentiating them from contiguous strata of equivalent or partly equivalent age Thus, rocks which are divisible into two or more facies comprise diverse kinds of contemporaneous sedimentation in different areas. A facies intergrades or interfingers with neighboring ones, and at some places rocks of one facies may rest on another.

Because animals generally are adapted to particular modes of life and environments most favorable for them, different facies of rock formations almost invariably are characterized by more or less unlike assemblages of fossils (faunas). It is natural to distinguish such environment-controlled dissimilar assemblages as fossils of facies, or more simply, **facies fossils.** Examples of facies fossils are so numerous in all parts of the geologic column and in all regions that it is more difficult to cite species which lack impress of facies (environment) than those which do. From this comes the untrue but near-true dictum that "all fossils are facies fossils," meaning that virtually all reflect environments to which they are specially suited or restricted. Thus, in Middle Ordovician rocks of the Appalachian region we find limestones containing many brachiopods and bryozoans, which interfinger eastward with graptolite-bearing black shale which lacks the brachiopods and bryozoans. This and many similar occurrences express the influence of environment.

Study of the kinds of fossils occurring in some successions of sedimentary deposits has shown numerous specimens of a distinctive marine invertebrate in certain rock layers, whereas none are found in adjacent strata until a zone is reached 200 ft. or so higher in the section; here are many shells identical to the distinctive fossils previously noted. They are called a **recurrent fauna,** because the assemblage makes a new appearance after seeming extinction in the region. Observation of the fossil-bearing rocks indicates that the two zones under discussion are closely similar in lithologic features and different from associated strata. The temporary disappearance of the recurrent fauna in the area of study undoubtedly is correlated

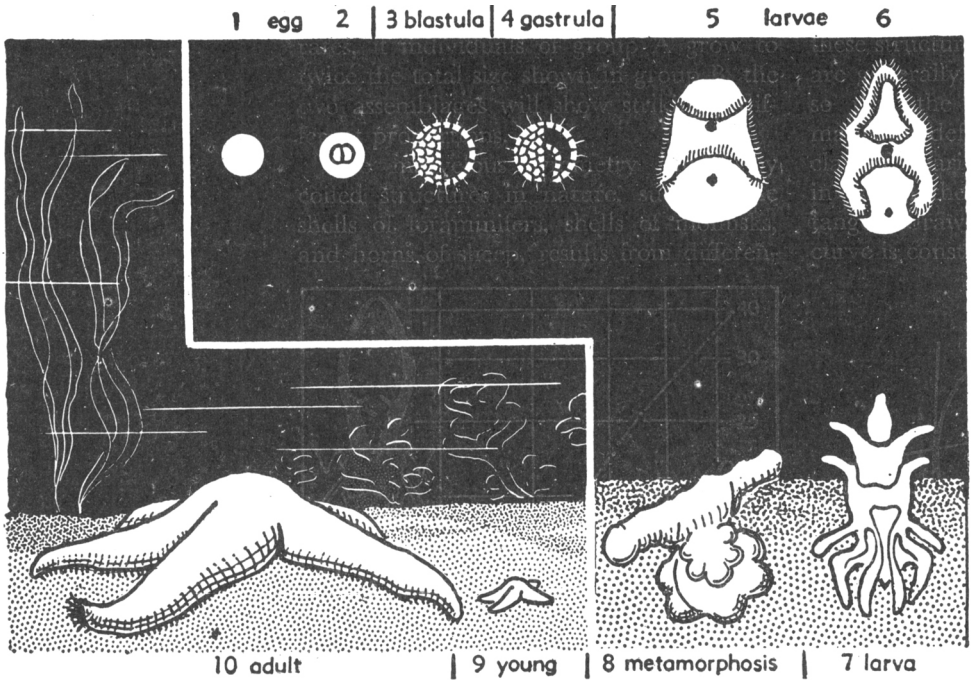

FIG. 1-13. **Life history of a starfish.** A starfish begins life as (1) a single-celled fertilized *egg*, which passes into (2) multicellular stages and develops into (3) a *blastula*. Invagination of one side forms (4) a double-walled *gastrula*, which develops into a feeding and growing *larva*. Larval stages are (5) the free-swimming *dipleurula* (common to most echinoderms), (6) the free-swimming *bipinnaria* (restricted to starfishes), and (7) the attached *brachiolaria*. (8) Metamorphosis changes the larva radically into (9) a baby starfish, which grows into (10) an adult.

The life histories of animals may be divided generally into five stages: **embryonic,** growth before the organism reaches independence; **larval** (**nepionic**), independent early development, in which structure and function differ markedly from those of the adult; **neanic,** close to the adult in structure but small in size; **adult** (**ephebic**), normal in size and able to reproduce; and **old age** (**gerontic**). Embryos and larvae are rarely encountered as fossils, because most lack hard parts or their delicate skeletons are very minute. Most fossils represent the preadult (neanic) and adult stages. Gerontic specimens are generally rare, for few animals survive to a ripe old age; the majority are killed at or before the height of life.

The life history of higher organisms passes through stages which recall to some extent the adult organization of lower phyla. The single-celled egg recalls the protozoan; the blastula, a protozoan colony (*Volvox*); and the gastrula, the coelenterates. The embryos of mammals and birds develop gill arches and gill slits, well supplied with blood. These fishlike structures evidently serve no useful purpose, and are resorbed during further development. The heart develops from a two-chambered (fishlike) to a three-chambered (amphibian) condition before reaching the final four-chambered stage. Thus, an individual mammal passes through stages which are comparable in a general way to structures of protozoans, coelenterates, higher invertebrates, fishes, and amphibians. There is much evidence that during geologic time mammals have indeed developed in this manner. Thus, traces of