statute law Burn includes 'the Thirty-nine Articles of Religion, agreed upon in Convocation in the year 1562; and in like manner the Rubric of the Book of Common Prayer, which, being both of them established by Acts of Parliament, are to be esteemed as part of the statute law.'"

The first principle of the ecclesiastical law is the assertion of the supremacy of the crown, which in the present state of the constitution means the same thing as the supremacy of Parliament. This principle has been maintained ever since the Reformation. Before the Reformation the ecclesiastical supremacy of the Pope was recognized, with certain limitations, in England, and the church itself had some pretensions to ecclesiastical freedom. The freedom of the church is, in fact, one of the standing provisions of those charters on which the English constitution was based. The first provision of Magna Charta is *quod ecclesia Anglicana libera sit*. By the various enactments of the period of the Reformation the whole constitutional position of the church, not merely with reference to the Pope but with reference to the state, was definitely fixed. The legislative power of Convocation was held to extend to the clergy only, and even to that extent required the sanction and assent of the Crown. The common law courts controlled the jurisdiction of the ecclesiastical courts, claiming to have "the exposition of such statutes or Acts of Parliament as concern either the extent of the jurisdiction of these courts or the matters depending before them. And therefore if these courts either refuse to allow these Acts of Parliament, or expound them in any other sense than is truly and properly the exposition of them, the king's great courts of common law may prohibit and control them."

The design of constructing a code of ecclesiastical laws was entertained during the period of the Reformation, but never carried into effect. It is alluded to in various statutes of the reign of Henry VIII., who obtained power to appoint a commission to examine the old ecclesiastical laws, with a view of deciding which ought to be kept and which ought to be abolished; and in the meantime it was enacted that "such canons, institutions, ordinances, synodal or provincial or other ecclesiastical laws or jurisdictions spiritual as be yet accustomed and used here in the Church of England, which necessarily and conveniently are requisite to be put in ure and execution for the time, not being repugnant, contrarient, or derogatory to the laws or statutes of the realm, nor to the prerogatives of the royal crown of the same, or any of them, shall be occupied, exercised, and put in ure for the time within this realm" (35 Henry VIII. c. 16, 25 c. 19, 27 c. 8).

The work was actually undertaken and finished in the reign of Edward VI. by a sub-committee of eight persons, under the name of the *Reformatio Legum Ecclesiasticarum*, which, however, never obtained the royal assent. Although the powers of the 25 Henry VIII. c. 1, were revived by the 1 Elizabeth c. 1, the scheme was never executed, and the ecclesiastical laws remained on the footing assigned to them in that statute,—so much of the old ecclesiastical laws might be used as had been actually in use and was not repugnant to the laws of the realm.

The statement is, indeed, made by Sir R. Phillimore that the "Church of England has at all times, before and since the Reformation, claimed the right of an independent church in an independent kingdom, to be governed by the laws which she has deemed it expedient to adopt." This position can only be accepted if it is confined, as the authorities cited for it are confined, to the resistance of interference from abroad. If it mean that the church, as distinguished from the kingdom, has claimed to be governed by laws of her own making, all that can be said is that the claim has been singularly unsuccessful. From the time of the Reformation no change has been made in the law of the church which has not been made by the king and parliament, sometimes indirectly, as by confirming the resolutions of Convocation, but for the most part by statute. The list of statutes cited in Sir R. Phillimore's *Ecclesiastical Law* fills eleven pages. It is only by a kind of legal fiction that the church can be said to have deemed it expedient to adopt these laws.

The terms on which the Church Establishment of Ireland was abolished by 32 and 33 Vict. c. 42 may be mentioned. By sect. 20 the present ecclesiastical law is made binding on the members for the time being of the church, "as if they had mutually contracted and agreed to abide by and observe the same;" and by section 21 it is enacted that the ecclesiastical courts shall cease after 1st January 1871, and that the ecclesiastical laws of Ireland, except so far as relates to matrimonial causes and matters, shall cease to exist as law. (E. R.)

ECCLESIASTICUS. See Apocrypha.

ECHIDNA, or Porcupine Ant-eater (*Echidna hystrix*), one of the four known species of Monotremata, the lowest order of Mammalia. It is a native of Australia, where it chiefly abounds in New South Wales, inhabiting rocky and mountainous districts, where it burrows among the loose sand, or hides itself in crevices of rocks. In size and appearance it bears a considerable resemblance to the hedgehog, its upper surface being covered over with strong spines directed backwards, and on the back inwards so as to cross each other on the middle line. The spines in the neighbourhood of the tail form a tuft sufficient to hide that almost rudimentary organ. The head is produced into a long tubular snout, covered with skin for the greater part of its length. The opening of the mouth is small, and from it the echidna puts forth its long slender tongue, lubricated with a viscous secretion, by means of which it seizes the ants and other insects on which it feeds. It is entirely destitute of teeth. Its legs are short and strong, and form, with its broad feet and large solid nails, powerful burrowing organs. In common with the other monotremes, the male echidna has its heel provided with a sharp hollow spur, connected with a secreting gland, and with muscles capable of pressing the secretion from the gland into the spur; but as the animal has never been observed to use this in defending itself, the spur probably serves some other purpose than that of offence or defence. It is a nocturnal or crepuscular animal, generally sleeping during the day, but showing considerable activity by night. When attacked it seeks to escape either by rolling itself into a ball, its erect spines proving a formidable barrier to its capture, or by burrowing into the sand, which its powerful limbs enable it to do with great celerity. "The only mode of carrying the creature," says Bennet (*Gatherings of a Naturalist in Australasia*) "is by one of the hind legs, when it may be removed to any place with great facility, for an attempt to seize it by any other part of the body, from its powerful resistance and the sharpness of the spines, will soon oblige the captor to relinquish his hold." They are exceedingly restless in confinement, and constantly endeavour by burrowing to effect their escape. From the quantity of sand and mud always found in the alimentary canal of the echidna, it is supposed that these ingredients must be necessary to the proper digestion of its insect food. The only other members of this family are the Short-spined Echidna (*Echidna setosa*), confined to Tasmania, and differing from the former species chiefly in the shortness of its spines, which are nearly hidden by the long harsh fur, and the Echidna Bruijnii—a new species discovered in 1877 in the mountains on the north-east coast of New Guinea, at an elevation of 3500 feet. By many naturalists the generic term *Echidna* has lately been abandoned in favour of *Tachyglossus* of Illiger.

ECHINODERMATA (from ἐχῖνος, a hedgehog or sea-urchin, and δέρμα, skin), a class of marine animals which constitutes with the class *Scolecida* the sub-kingdom *Annuloida* of Huxley, or, according to some authorities, is a distinct sub-kingdom of the Invertebrata. Familiar examples of the Echinodermata are the Sea-urchins, Star-fishes, Feather-stars, and Sea-cucumbers of the coasts of Britain. The characteristics of the group may be briefly summarized thus. The adult presents a more or less marked, although never perfect, radial symmetry of parts; the larva, in most instances, is bilaterally symmetrical. The perisome or dermis develops a calcareous skeleton of numerous interlocking plates or of detached plates or spicules. The muscular tissue consists chiefly of unstriped fibres. The intestinal canal terminates in a distinct anal aperture. An aquiferous or ambulacral system of organs, regarded as homologous with the water-vascular system of the Scolecida, is generally present; and there is a nervous system consisting of a ganglionated circular or polygonal cord, which surrounds the œsophagus, and sends off branches parallel with and superficial to the ambulacral canals. The sexes are in the majority of cases distinct, and the reproductive organs are generally placed symmetrically with respect to the radially disposed skeleton.

In all Echinodermata of which the life-history has been worked out, the larva, *echinopœdium*, or, as it has been termed by Sir Wyville Thomson, the *pseud-embryo*, produced from the egg is, with but one or two exceptions, ovoid, free-swimming, and provided with cilia, which become after a time confined to one or more bilaterally symmetrical bands running transversely or obliquely to the long axis of the body, and frequently borne on processes of the same. In the Asteridea and Holothuridea the larva is vermiform and devoid of skeleton; in the Echinidea, it is pluteiform (Latin, *pluteus*, a pent-house, or breast-work), and has a continuous calcareous skeleton, passing into and affording support to the body processes. A stomach, with an œsophagus and intestine, which make with each other an angle open towards the ventral side of the body, is early developed in the Echinoderm larva. The peritoneal cavity and ambulacral system of vessels are developed from diverticula of the alimentary canal. A tube formed by an involution of the integument of the pseud-embryo to one side of the dorsal line may remain connected with the ambulacral system of the adult as the madreporic canal. In the Echinidea, Asteridea, Ophiuridea, and Crinoidea the body-wall of the adult is formed from the blastema; the larval body, more or less of the intestine, and, when present, the skeleton are cast off or absorbed into the new organism, and another mouth appears in the centre of the circular vessel. It is by this peculiar metagenetic mode of development of the Echinoderm within its larva that the class Echinodermata is specially allied to the orders *Turbellaria* and *Tæniada* of the class Scolecida.

The Echinodermata may be divided into the following orders:—(I.) *Echinidea*, or Sea-urchins; (II.) *Asteridea*, or Star-fishes; (III.) *Ophiuridea*, or Sand-stars; (IV.) *Crinoidea*, or Feather-stars; (V.) *Cystidea*; (VI.) *Edrioasterida*; (VII.) *Blastoidea*; (VIII.) *Holothuridea*, or Sea-slugs. Of these orders V., VI., and VII. have been extinct since the Palæozoic period. By some authorities the Edrioasterida are included with the Cystidea.

Order I.—Echinidea.—The body in the Echinidea is spheroidal, oval, discoid, or heart-shaped, and the shell, test, or perisome bears numerous spines. A common European type of the group is the species *Psammechinus* (*Echinus*, L.) *esculentus* (see fig. 1). In certain forms (*Scutellidæ*) the test is perforated by slit-like apertures, and curiously lobed or digitate (fig. 2). With few exceptions the test is a rigid structure of numerous plates united by their edges. In the *Echinothuridæ*, however (*Calveria*, *Phormosoma*, and the extinct *Echinothuria* and *Lepidocentrus*), and also in the Palæozoic genera *Archæocidaris*, *Lepidesthes*, and *Lepidechinus*, the plates of the corona overlap, so as to resemble the peristomial plates of *Cidaris*.

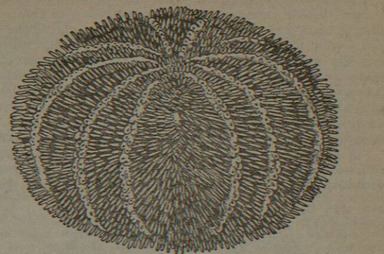

Fig. 1.—Psammechinus esculentus.

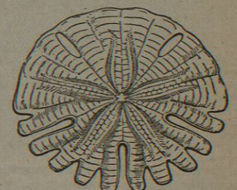

Fig. 2.—Rotula augusti.

The plates are composed of a dense calcareous network, consisting chiefly of calcium carbonate. As the test is invested with an epidermis, and is produced mainly by calcification of the mesoderm, it is to be regarded as an internal shell or endo-skeleton. In the typical recent echini the walls of the corona or main body of the shell, when freed from spines, are seen to consist of five zones or areas, the *ambulacra* (Latin, *ambulacrum*, a walk), composed of double rows of pentagonal plates, and alternating with five other double rows, the *interambulacra*. In the Palæozoic forms, which constitute the sub-order *Perischoechinidæ* of M'Coy, the interambulacrum is made up of more than two rows of plates, of which the intermediate and central are hexagonal in form (see figs. 3 and 4). In the genera *Melonites* and *Oligoporus* there are extra ambulacral as well as interambulacral plates. The ambulacra, which

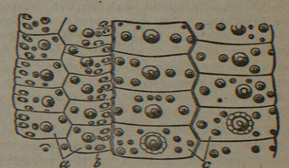

Fig. 3.—Echinus gracilis.

a, ambulacral plates; b, poriferous zone; c, interambulacral plates. (After Agassiz.)

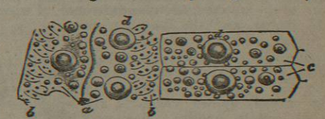

Fig. 4.—Stomechinus intermedius.

a, portion of ambulacral area; b, poriferous zones; c, two interambulacral plates; d, primary tubercles. (After Wright.)

are usually narrower than the interambulacra, have near their outer edge small shield-like spaces, *umbones*, bounded by a more or less elevated wall, and perforated by pairs of small orifices or pores for the protrusion of the feet or *pedicels*, each pair of pores corresponding to one of the pore plates—the primitive ossicles which commonly unite to form the ambulacral plates. The ambulacra are either homogeneous, *i.e.*, composed of similar elements gradually diminishing in size towards the poles of the test, or (as in the *Spatangoida* and most of the *Clypeastroida*) are heterogeneous, having the upper portion petaloid in shape, and the lower with pores scattered in areas not always confined to the ambulacral plates, or arranged in ramifying fasciæ. In the *Spatangoida* the anterior unpaired ambulacrum is commonly obsolete (see fig. 5). In the Oolitic genus

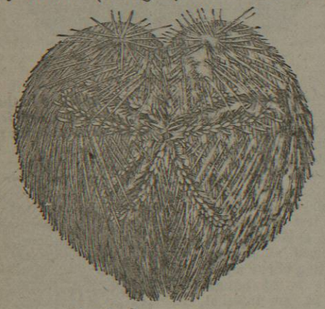

Fig. 5.—Spatangus purpureus.

Dysaster, the two postero-lateral ambulacra, forming the *bivium*, are separate from the rest, and converge over the anal opening; while the three anterior, the *trivium*, unite at the apical disk (see fig. 8). The growth of the urchin in length is effected by the formation of new plates at the apical end of the corona, and in breadth by additions to the margins of the plates. On the surface of the plates are tubercles of different sizes, each with a knob or elevation, sometimes crenulated, by which the acetabulum of the spine is attached (see figs. 4 and 5). The presence or absence in the tubercle of a central perforation for the passage of a ligament for the spine is an important distinguishing character in various groups of fossil echini. The spines in the young state are ciliated; like the plates of the test they are composed of a calcareous network, and are interpenetrated and covered by the perisome, which contains the muscular fibres by which they are moved. They are short in the *Clypeastroida* and *Spatangoida*, and of various lengths in the *Echinoida*, and offer a considerable diversity of form and ornamentation. Dr Gray (*Ann. of Nat. Hist.*, i. p. 414) mentions the discovery in Sicily of the fragment of a spine of an echinus, the circumference of which was nearly 1½ inches, and the length more than 8 inches. In *Porocidaris purpurata*, a deep-sea form, the spines are paddle-shaped, and very flat, and are serrate on the edges; in *Cœlopleurus* the long curved spines resemble the antennæ of certain beetles. Scattered over the surface of the test, and more especially on the oral membrane, are the pedicellariæ, generally regarded as peculiarly modified spines; these, when well developed (fig. 6), consist of a long flexible stem, furnished at the summit with a forceps of three pincers or prongs, which snap together, and seize firm hold of any object that comes in their way. They serve for the removal from the neighbourhood of the shell of dirt of all kinds, and apparently also for defence. *Calveria fenestrata* has pedicellariæ with four valves. In some Spatangoid genera the corona bears symmetrical bands of minute tubercles with attached spines, the *semitæ* or *fascioles*, distinguished, according to their position with respect to the anus or to the apical or the marginal terminations of the petaloid ambulacra, as *sub-anal*, *circum-anal*, *intrapetalous*, and *peripetalous*. The spines of the semitæ have a thick integumentary covering, and except at the enlarged apex, are closely studded with cilia. Lovén has shown the occurrence, in all Echinidea but *Cidaris*, of another kind of appendages of the test, possibly sensory organs, to which he has given the name of *sphæridia*. These are button-like, spheroidal bodies, seldom above $\frac{1}{10}$th inch in length, furnished with a short stalk, and normally articulated with small projecting tubercles on the plates of the ambulacra and peristome. Sometimes they become concealed by a layer of the test, in which there remains only a fine external fissure. At the summit or apical pole of the test is a space occupied by the ocular and genital plates, which in the *Echinoida* (Endocyclica) encircle the anus with its anal plates. The five genital plates, which are opposite the interambulacra, or interradial in position, are perforated by apertures for the exit of the reproductive products. In the *Clypeastroida* and *Spatangoida* (Exocyclica), in which the anus is eccentric, and exterior to the apical disk, one of the genital plates is usually imperforate (fig. 7). The five ocular plates are situated radially, crowning the apical ends of the ambulacra; on the surface of each is a depression, having a pore for an ocellus or eye-spot. Always, except in the *Clypeastridæ*, the right antero lateral genital plate, or, in other words, that situated to the right of the anterior ambulacrum of the trivium, is larger than the others, and bears the convex, perforated *madreporic tubercle* or *madreporite*. In the *Clypeastroida* this is most frequently extended over the other apical plates. The hinder genital plate, with apparently one exception, is wanting in the *Spatangidæ*, its place being occupied by the madreporite. The Palæozic Echinidea differ from the more modern forms by the greater number of perforations of their ocular and genital plates. At the base of the test is the mouth with its buccal membrane and plates. The species *Leskia mirabilis* (the type of the sub-family *Leskiadæ*, family *Spatangidæ*) has both mouth and anus closed by converging triangular valves In the *Echinoida* and *Clypeastroida* the mouth is central in position, and provided with teeth; in the *Spatangoida* it is eccentric and edentulous. The teeth resemble those of Rodents in form, and are arranged in hard wedge-shaped sockets or *alveoli*, which by their union form a pentagonal cone. As the outer substance of the tooth is harder than the inner, it is less readily worn away, and thus always presents a sharp edge. Each alveolus is composed of two halves united in the middle line, and each half, again, consists of a superior and inferior portion. The alveoli are inter-radial in position, or opposite the interambulacra. They are connected by transverse muscular fibres, and alternate with superiorly placed, thickish, radial structures, the *rotulæ* or *folces*, which, in the *Echinoida*, bear each a bifurcated piece, the *radius*. This skeletal mouth-apparatus is commonly known as

Fig. 6.—Pedicellaria of *Echinus saxatilis*. *a*, open; *b*, closed. (After Gegenbaur.)

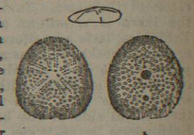

Fig. 7.—Echinocyamus pusillus. Upper surface (*a*), showing four genital pores, and lower surface (*b*), with anus half-way between mouth and posterior border.

"Aristotle's lantern." The calcified internal arched processes termed *auriculæ*, at the oral end of the ambulacra in the *Echinoida* (of the interambulacra in *Cidaris*), regarded as homologous with the internal ambulacral ossicles of the Asteridea and Ophiuridea, are formed each of two pieces. From the top of the auriculæ pass retractor muscles to the outer edge of the alveoli. The oral skeleton is provided also with protractors proceeding from the alveoli to the lower interambulacral edge of the corona, besides special muscles connected with the radii. In the *Clypeastroida* arched (in *Cidaris* unarched) processes are given off from the ambulacral plates, at the sides of the ambulacral canals; and in the Clypeastroid genus *Scutella* the dorsal and ventral walls of the corona are connected by vertical calcareous plates or trabeculæ. None of the above-mentioned internal calcareous processes is developed in the *Spatangoida*. The mouth communicates by a tortuous œsophagus with the stomach. The intestine forms a sort of festoon on the inner side of the shell, and is attached to it by a mesentery.

Of the internal organs of the Echinidea the most important and characteristic are those constituting the ambulacral system. These are (1) a circular or slightly pentagonal vessel placed around and traversed by the œsophagus, on the inside of the alveoli, and between the nervous and blood-vascular rings; (2) cæcal appendages of this vessel, called Polian vesicles (absent in the *Clypeastroida* and *Spatangoida*), answering to the racemose appendages of the Holothuridea; (3) the membranous or calcareous madreporic canal, termed also the sand-canal, which runs nearly vertically through the axis of the body, and, communicating with the exterior by the madreporic tubercle, supplies water to 1; (4) vessels radiating from 1 along the parietes of the body, and opening eventually into basal sacs, or *ampullæ*, proceeding from the canals of the pedicels shortly above their origin. In the vessels of the ambulacral system is contained a watery fluid strained from the perivisceral cavity. The pedicels, which may vary considerably in shape, are tubular structures, usually terminated by a sucking-disk; they have contractile, muscular walls, and are capable of being protruded beyond the extremities of the spines. They subserve locomotor, tactile, or branchial functions. The corpusculated perivisceral fluid is kept in motion by the cilia clothing the lining membrane of the body and the viscera. Where modified pedicels or ambulacral gills are absent, as in the *Echinoida*, the *Cidaridæ* excepted, aeration of that fluid is apparently promoted by branchial developments from the peristome, the hollow stems of which communicate with the body-cavity. The nervous system consists of a slender, pentagonal, red or violet hoop around the gullet, superficial to the circular ambulacral vessel, with five ganglia sending off as many cords, which, passing out between the alveoli, take a course similar to that of the ambulacral radial canals, giving off fine side branches which pass in their course through the ambulacral pores, probably supplying the pedicels, spines, and pedicellariæ, and terminate eventually in the pigmented eye-spots. The principal vessels of the pseud-hæmal or blood-vascular system of the Echinidea appear to be two trunks, the one on the dorsal, the other on the ventral side of the alimentary canal; these, according to Hoffmann, communicate either directly or by a distinct trunk with the water-vascular ring.

From an examination of *Echinus sphæra*, *Psammechinus miliaris*, *Toxopneustes lividus*, and *Amphidetus cordatus*, Perrier determined that, as maintained by Hoffmann, the circulatory and aquiferous systems are identical; that the so-called "heart" is only a gland, which opens by a canal into a funnel-shaped space bounded by the lining membrane of the test and the madreporite; that the artery proceeding from the water-vascular ring is distributed upon the first loop of the intestine, forming there ramifications which unite with those of the intestinal vein; and that the vein has no communication with the water-vascular ring, but is connected by ten branches and by its two extremities with a collateral canal, which floats freely in the perivisceral cavity beneath the intestine. Further, he found that the ambulacral vessels and their branches terminate blindly, the circulation consisting simply in a to-and-fro movement of their contents.

The reproductive organs are large racemose glands, situated beneath the upper termination of the interambulacra, and opening externally by the genital pores. The sexes are distinct. The spermatozoa have vibratile filaments; the egg is fecundated after leaving the body of the female, and in about eight hours undergoes complete yelk-division.

The pseud-embryo or echinopædium, at first ciliated and spheroidal, becomes after a time wedge-shaped, at its broad end appears the mouth or *pseudostome*, and at the other the anus or *pseudoproct*. Simultaneously with these the skeletal rods and ciliated bands of the pluteus begin to be produced. The development of the ambulacral system commences with the formation of a sac which lies to the left of the junction of the pseud-embryonic gullet and stomach, and is prolonged into a canal opening by a pore on the dorsal surface of the larva. The blind end of the sac becomes a quinque-petaloid rosette, from which radiate the ambulacral vessels; a new mouth is formed in the centre of this, at the bottom of a depression in the integument of the pseud-embryo, and the canal of the sac becomes the madreporic tube. The skeleton of the pluteus separates, as development proceeds, into several pieces, and is by degrees discarded, whilst its processes atrophy, and the body assumes the rounded form of the embryo urchin. This, however, has in many cases to undergo sundry important changes before its resemblance to the adult is complete. Thus in the young of species of *Spatangus* the peristome is almost central, and is pentagonal in form. In the *Echinoida*, before the appearance of the anus in the embryo, its place is occupied by a single plate, the *sub-anal*, and the anus appears near its border, towards the posterior right ambulacrum. It lies within a circle formed by five imperforate pieces, the future genital plates, and these again are surrounded by five imperforate ocular plates, with intervening ambulacral plates. The central anal plate persists in the family *Salenidæ* among the *Echinoida*. If it be considered as homologous with the dorso-central plate of *Marsupites*, or the basalia of the calyx in other Crinoids, the genital plates correspond to the parabasalia, and the ocular to the first radialia.

The food of the Echinidea consists either of seaweed, and small shell-fish and crustaceans, which are conveyed to the mouth by the pedicels, or, as in the case of the edentulous forms, of sand and earth containing nutritive material. In the species *Anochanus sinensis*, one of the *Cassidulidæ*, Grube discovered the presence of an incubatory chamber at the apical pole of the test, containing embryos in various stages of their growth. Certain species, as observed by Cailliaud, Deshayes, and Lory, have the power at a very early age of drilling for themselves burrows in the hardest rocks, such as granite and grit.

Allusion is made to the echinus in the writings of Aristophanes, Horace, Martial, and other classical authors. By the ancients it was considered a delicacy, and the common species *Psammechinus* (*Echinus*, L.) *esculentus*, Ag., especially in spring, when the ova are matured, is still eaten in some parts of Europe. Sir Thomas Browne, in his *Vulgar Errors*, mentions a notion formerly current that the spines of the echinus were a remedy for the stone, and "films in horses' eyes." They are put to practical use in some countries as slate-pencils.

Various systems of classification have been adopted for the Echinidea. In the following scheme the principal groups are arranged chiefly according to the position of the anal opening and the nature of the ambulacra.

Sub-order I.—Tesselata. Echinidea with interambulacra of more than two rows of plates.

Sub-order II.—Typica. Echinidea with interambulacra of but two rows of plates.

Group I.—Regularia or Endocyclica. Mouth central or subcentral; anus usually central and opposite the mouth, and never exterior to apical disk.

A. Anus central.

1. Shell round.

Cidaridæ. Tubercles smooth, perforate, peristome unnotched; anal plates ten; auriculæ unclosed; buccal branchiæ absent.

Diadematidæ. Tubercles crenulate, perforate, peristome notched, spines hollow. Allied forms are the fossil *Hemicidaridæ*.

Arbaciadæ. Tubercles smooth, imperforate; four large anal plates; auriculæ closed.
Echinidæ. Tubercles imperforate, or perforate and crenulate; anal plates numerous; pairs of pores in ranks of three, four, or more.

ii. Shell oval or elliptical.
Echinometridæ. Pores in ranks of five or six pairs.

B Anus eccentric through intervention of one or several supernumerary apical plates.
Salenidæ. All fossil forms, with exception of *Salenia varispina*.

Group II.—IRREGULARIA or EXOCYCLICA. Anus eccentric, not within the apical disk.

A Ambulacra simple, not petaloid.
Galeritidæ. Mouth central: shell globular or subpentagonal; a single apex at which the ambulacra converge.
Dysasteridæ. Mouth eccentric: shell ovoid or heart-shaped; two apices, at which the bivium and trivium respectively converge.

B Ambulacra more or less petaloid.
i. Dental apparatus present.
Clypeastridæ. Shell more or less flattened, sub-pentagonal.
Scutellidæ. Shell depressed, discoidal, often digitate or perforated; lower surface with ramifying grooves.
ii. Dental apparatus absent.
Cassidulidæ. Mouth central or nearly so; peristome sub-pentagonal.
Spatangidæ. Mouth eccentric, transverse or reniform.

To the group Regularia must be added the Cretaceous and Recent family of *Echinothuridæ*. The Echinidea are represented in Palæozoic strata by the Tesselata or Perischoechinidæ, *Palechinus* (see 1 in fig. 8), *Perischodomus*, *Lepidechinus*, *Eocidaris*, *Archæocidaris* (2 in fig. 8), *Melonites*, *Oligoporus*, and *Lepidesthes* (see *Quart. Jour. Geol. Soc.*, xxx. 307). The *Echinidæ* and *Dysasteridæ* occur first in the Trias, and are represented by numerous species in Mesozoic strata; the *Salenidæ*, *Galeritidæ*, and *Cassidulidæ* make their earliest appearance in rocks of Jurassic, and the *Spatangidæ*, including the sub-family *Ananchytidæ*, in rocks of Cretaceous age. The accompanying figures represent fossil forms of Echinidea characteristic of various strata. Some account of the distribution in space of the Echinidea, together with that of other classes of the Echinodermata, will be found at page 278 of the present volume. See also Sir Wyville Thomson, *Proc. Roy. Soc.*, xx. 1872.

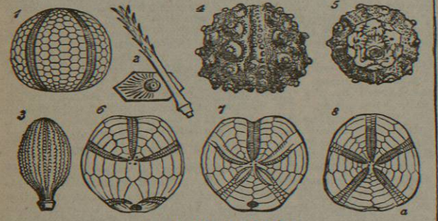

FIG. 8.—Fossil Echinidea.

1 Palæchinus sphæricus, Scouler: *Carboniferous*. Ireland.
2 Archæocidaris Urii, Flem (spine and intermediate plate); *Carboniferous*, Ireland.
3 Cidaris glandifera, Goldf (spine); *Jura*, Mount Carmel.
4. Hemicidaris intermedia, Flem.; *Corallian*, Calne.
5. Salenia petalifera, Desm. *U. Greensand*, Wilts.
6. Dysaster ringens, Ag. *Inferior Oolite*, Dorset.
7 Hemipneustes Greenovii, Forbes. *U. Greensand*, Blackdown.
8. Catopygus carinatus Goldf. *U. Greensand*, Wilts.

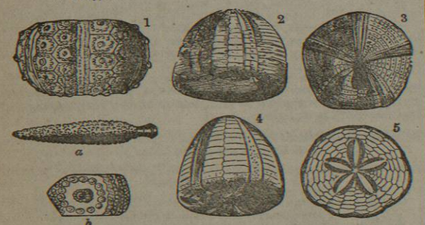

FIG. 9.—Fossil Echinidea.

1. Cidaris florigemma, with spine, *a*, and single ambulacral plate, magnified, *b* (after Wright); Coral Rag.
2 Annechytes ovatus, Lam.; *U. Chalk*, Europe.
3. Pygaster semisulcatus, Ph.; *Inf. Oolite*, Cheltenham.
4. Galerites albogalerus, Lam.; *U. Chalk*, Kent.
5. Scutella subrotunda; *Miocene*, Malta.

Order II.—ASTERIDEA.—The Asteridea, or Star-fishes, have mostly a star-shaped body, composed of a central disk and five or more rays. The common British species of *Solaster*, *S. papposus* (fig. 10), has ordinarily 13 rays;

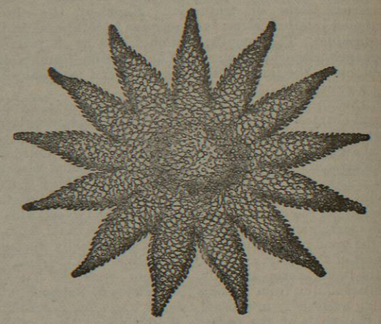

FIG 10.—Solaster papposus (upper surface).

S. helianthoides, a South American species, has as many as 34, the extinct *S. Moretoni* of the Great Oolite had 33, and another fossil species, of Devonian age, *Helianthaster Rhenanus*, had 16 rays. The rays are sometimes very short (fig. 11), or altogether wanting, the body having

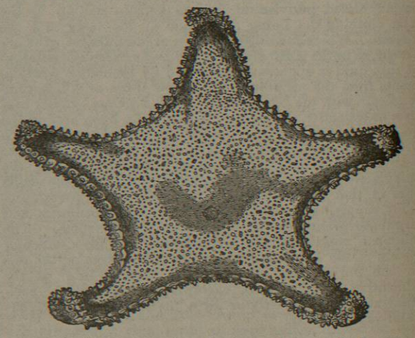

FIG. 11.—Astrogonium phrygianum (upper surface).

the form of a pentagonal disk. In the *Brisingidæ* they may attain a length of many feet. The perisome in the *Asteridea* is coriaceous, and consists of an ectoderm with a thin ciliated cuticle, a muscular mesoderm which contains calcareous skeletal plates or ossicula, and an

internal ciliated epithelium. Studding the perisome are numerous spines, attached to the ossicula on the dorsal surface and to those bordering the ambulacral grooves; sometimes also there are tufts of bristles, the *paxillæ*. The pedicellariæ are attached to the perisome and spines, and are either sessile or provided with short foot-stalks. Except in one group, they have two blades only, which are moved by divaricator and adductor muscles.

The lower or oral surface of the star-fish with the ambulacra corresponds to the ambulacral, the aboral or antambulacral surface to the interambulacral areas of the echinus. The deep ambulacral grooves which occupy the middle of the lower face of each ray are formed each by a series of plates, the *vertebral ossicles*, articulated to one another by their inner opposed ends, and united by their lower or outer ends to

FIG. 12.—Section of ray of *Astropecten aurantiacus*.
a, vertebral ossicles; *b*, adambulacral ossicles; *c*, *d*, marginal ossicles; *e*, paxillæ. (After Gaudry.)

rows of plates, the *adambulacral ossicles*, which form the margins of the grooves, and are themselves succeeded by one or more series of *marginal ossicles* (fig. 12). The outer ends of the innermost pairs of ambulacral ossicles unite round the mouth to form five crests, which bear spines and pedicellariæ. On the aboral surface of the body are the *tergal* plates (fig. 13). Transverse muscular fibres unite the lateral halves of the arm-segments; similar fibres supply the floor of the ambulacral groove; besides these there are intervertebral and interambulacral longitudinal muscles. The ambulacral grooves are nearly filled with the tube-feet or pedicels, which have a nervous external and muscular internal layer, are usually cylindrical in form and furnished with terminal sucking-disks, and communicate by ducts through the ambulacral pores with vesicles lying above the ambulacral ossicles and opening into the ambulacral canal of the ray. In the common star-fish, *Asterias* (*Asteracanthion*) *rubens* the pores form a zig-zag line on each side of the ambulacral groove, and the pedicels passing through them thus come to be four-ranked (fig. 14). They are formed by notches or semi-

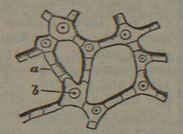

FIG. 13.—Tergal skeleton of *Asterias rubens*.
a, connecting pieces; *b*, spine-bearing plates. (After Gaudry.)

FIG. 14.—Asterias rubens.
a, 4-ranked pedicels; *b*, end of pedicel magnified.

pores incised one on the distal and the other on the oral surface of each ambulacral ossicle, and lying alternately external and internal to one another in position on successive ossicles (fig. 15). The mouth, which is devoid of dentary apparatus, is situated in the middle of a membranous disk in the centre of the oral surface. It leads by a short gullet into the stomach. The stomach in most star-fishes is produced into five sacculated prolongations (*cardiac sacs*); above these it contracts, but again widens to form the *pyloric sac*; this gives rise to five tubes, which open out in each ray into a pair of parallel diverticula having numerous cæcal dilatations, and connected by a mesentery with the antambulacral perisome. The pyloric sac in most cases leads into a short intestine terminating in an anus situated in the left posterior interradial space. In *Astropecten*, *Ctenodiscus*, and *Luidia* there is no anus. The madreporic tubercle is situated dorsally in the body disk, near one of the interradial angles; it is oval or slightly pentagonal in form, and the surface is marked with undulating grooves, and is finely perforated (fig. 16). In some genera

FIG. 15.—Ossicles of ambulacral groove of *Asterias rubens*, viewed from above. *a*, pore for pedicel.

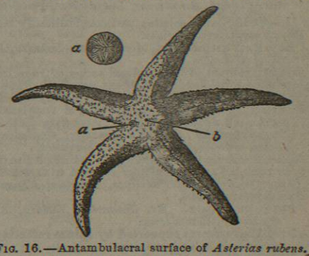

FIG. 16.—Antambulacral surface of *Asterias rubens*.
a, madreporite; *a'*, the same magnified; *b*, anus.

(*Ophidiaster*, *Echinaster*) there are several interradially placed madreporic tubercles. The doubly involuted madreporic canal is invested by the peritoneal membrane, which incloses a sinus, or "heart," as it has been termed; it passes downwards into a pentagonal circum-oral ring which gives off the five radial canals occupying the uppermost part of the ambulacral grooves. The circum-oral ring may or may not possess Polian vesicles. A dorsal or aboral ring has been described as communicating with the "heart," and sending off interradial branches to the genital glands, the products of which, in the case of star-fishes devoid of external genital apertures, it has been supposed they are the means of removing. The genital glands are racemose masses placed interradially in pairs; their processes sometimes extend a considerable distance into the arms. The nervous system consists mainly of a circular canal around the gullet, with five ambulacral trunks opening into it at their inner ends. The ambulacral neural trunk in each ray underlies a strong band of transverse fibres, by which it is separated from the ambulacral canal above. At the extremity of the ray the nerve terminates in an eye and its tentacle. The eyes are small processes of the ectoderm, having a convex surface or cornea containing a large number of simple, conical, pigmented ocelli. In the peritoneal cavity and ambulacral vessels is a watery fluid containing corpuscles. Respiration appears to be effected by means of water supplied