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Echinodermata

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Echinodermata

by

A. A. Shorygin

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The echinoderms are exclusively marine organisms. The majority of adults lead a benthic, the larvae a free-floating mode of life. The adult echinoderms usually have a radial symmetry, whereas the larvae are bilaterally symmetrical. The present echinoderms are divided into the subphylum Pelmatozoa, which includes the class of sea lilies (Crinoidea), and the subphylum Elentherozoa, which comprises the classes of starfish (Asteroidea), the ophiurids or brittle stars (Ophiuroidea), the sea urchins (Echinoidea) and the holothurians or sea cucumbers (Holothuroidea).

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The echinoderms have a skin, a calcareous skeleton, a coelom, a water-vascular, digestive, vascular, nervous and sexual systems. A special excretory and respiratory system is lacking, although some groups have special respiratory organs such as dermal gills in starfish and a respiratory tree in some holothurians. Sensory organs are poorly developed.

*The figures in the right-hand margin indicate page numbers in the original (Tr.).

The most distinguishing features of the echinoderms are a calcareous skeleton and a water-vascular system. The skeleton consists of calcareous corpuscles localized in the intermediate layer of connective tissue. Skeleton development is highly varied in different classes. In sea urchins the plates have intergrown into a solid immobile shell. In the starfish and ophiurids the plates are situated alongside each other or overlie each other, like tiles, without growing together. This enables these animals to change their form, to bend their radial arms. An even weaker skeletal development is found in holothurians, in which the corpuscles, which frequently resemble little wheels or perforate plates, are far apart or absent altogether. Forming part of the skeleton are the spines that cover the body, the pedicellariae, which are special moveable forceps used for catching food morsels, for protection and removal of dirt, and the sphaeridia, which are spines thickened at the end and serve a balancing function.

The ambulacral or water-vascular system is peculiar only to echinoderms. This system has a motive, excretory, respiratory and tactile function. It consists of a circular and radial canals (usually five). Branching off from the radial canals are side canals terminating in tube feet with ampullae. The circular canal connects with the external environment by way of a calcareous canal terminating on the dorsal side in the shape of a perforate madreporic plate. In holothurians and in sea lilies the calcareous canal opens into the body cavity. The tube feet are organs for locomotion and apparently also serve as tactile organs.

The digestive system consists of a mouth and an alimentary canal. Holothurians, sea urchins and sea lilies and most of the starfishes also have an anal opening which is usually situated on the side of the body opposite to that containing the mouth. In sea lilies the anal opening is

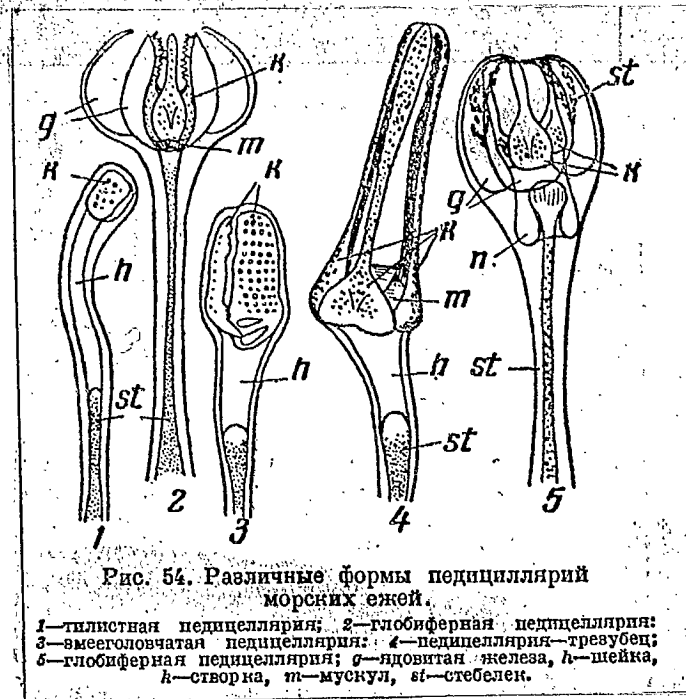


Fig. 54. Different forms of pedicellariae of sea urchins.

1—trifoliate pedicellaria; 2—gemmiform pedicellaria*; 3—snake-head pedicel.; 4—tridactyle pedicel.; 5—gemmiform pedicellaria; g—poison gland; h—neck; k—valve; m—muscle; st—shaft.

on the same side as the mouth. The ophiurids and some of the starfishes lack an anal opening. The mouth is usually on the underside and sometimes it is on the forward side (in holothurians). In sea lilies the mouth is turned upward.

In most sea urchins the alimentary canal begins with a special masticatory apparatus (Aristotle's lantern) consisting of special calcareous plates furnished with muscles. The alimentary canal itself is shaped either like a cul-de-sac (in ophiurids), or like a sac with two protuberances connected with the arms (in starfishes), or like a coiled canal (in sea

*"gemmiform pedicellaria": suggested rendition of globifernaya peditsellyariya (Tr.).

urchins, holothurians and sea lilies). Special alimentary glands are lacking, and the alimentary secretions are secreted by the walls of the intestine.

The general structure of the blood circulatory system and of the nervous system resembles somewhat the water-vascular system. These systems consist mainly of one or a pair of shafts with radial side branches. The sensory organs are very poorly developed; but some of these organs have a tactile function, others have a balancing function, perceive light or perhaps function as an olfactory organ.

Echinoderms, with the exception of some holothurians, are dioecious. The reproductive system (except in holothurians and irregular sea urchins) has a radial construction. The adults have 5 gonads (sea urchins) or 5 pairs of gonads (starfishes) lying at the base of the arms, or 5 pairs of pouches which receive numerous gonads (ophiurids). In the sea lilies numerous gonads are located in the arms and in their lateral branches called pinnules. Holothurians have only one gonad. Most of the echinoderms are egg-laying. The sex products are deposited in the water either through excretory ducts or by way of breaching the body walls in areas designed for this purpose.

The fertilized eggs usually develop in the water, but in the ophiurids the embryo develops partly in pouches inside the female's body. Finally there is a whole series of viviparous species such as Pteraster pulvillus, P. obscurus, Hymenaster pellucidus, Poraniomorpha.

The larvae of echinoderms are bilaterally symmetrical. At the initial stages of development all echinoderm larvae resemble each other (dipleurulas) (Fig. 55, I). Later the external form begins to differentiate according to the various groups (Fig. 55, II—VI). But all of them bear little resemblance to the future "adult" echinoderms. The metamorphic

change into an "adult" animal involves only part of the larva's body even though extensive alterations in body form, position and structure of organs do occur.

The echinoderms are a sufficiently peculiar and closed group so that their links to other types of animals remained obscured for a long time. They used to be compared to the coelenterates and sponges, based on their radial symmetry. It was only at the beginning of this century that echinoderms, as deuterostomes, were assigned to one general group of enteropneusts, urochordates and chordates. Based on the structure of their larvae, the echinoderms, especially the holothurians, approximate especially the enteropneusts.

The radial symmetry of echinoderms, which previously was considered to be very important, represents a secondary development, which is linked to the fact that, in their evolution, most of the adult echinoderms led a sessile mode of life. That the ancestors of the present echinoderms at one time must have been bilaterally symmetrical animals is suggested by the bilateral symmetry of the larvae of the present forms as well as by the fact that the oldest echinoderm fossils—the Carpoidea—were also bilaterally symmetrical. At present, only sea lilies—a class that is dying out—have retained a sessile mode of life. The members of the other classes lead a motile mode of life, as a result of which the most progressive forms among them (holothurians and irregular sea urchins) again begin to lose the radial symmetry. /467

Adult echinoderms lead a benthic mode of life and occur at various depths ranging from the water line to a depth of several thousand meters. One exception is the holothurian Pelagothuria, which swims in the depths. Echinoderms are carnivorous organisms and, on the basis of their diet, they can be divided into those that feed on plankton and those that feed on

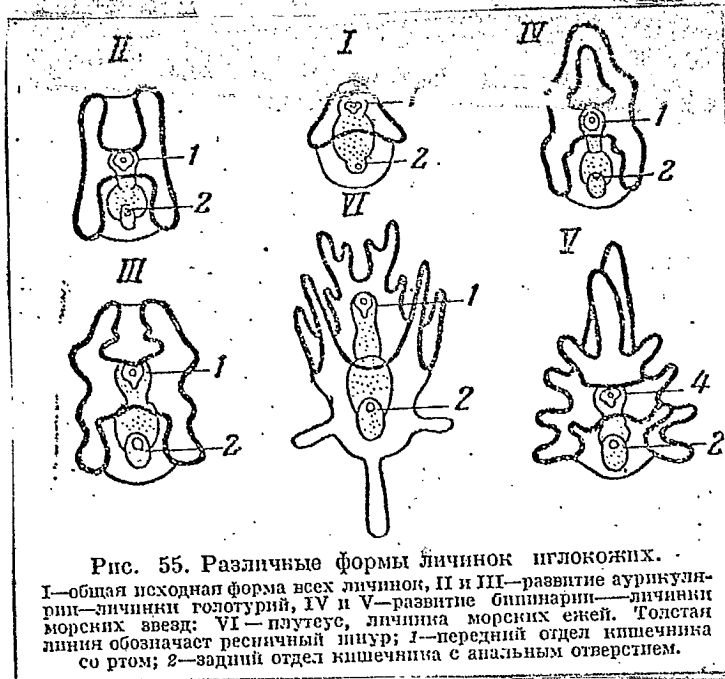


Fig. 55. Different larval forms of echinoderms.

I—initial form common to all larvae; II and III—development of auricularia in holothurians; IV and V—development of bipinnaria in starfishes; VI—pluteus in sea urchins. The bold line signifies the ciliated band. 1—anterior section of intestine with mouth; 2—posterior section of intestine with anal opening.

benthos. Some holothurians and the sea lily feed on plankton. The overwhelming majority of echinoderms feed on benthic organisms such as mollusks, worms, crustaceans, coelenterates and even fish. Among these echinoderms there is a peculiar group known as "soileaters" which pass mud or sand through their intestine and absorb the organisms and organic matter adhering to this material. To this group belong several holothurians, sea urchins and starfishes.

Most predatory among the echinoderms are the starfishes. They are capable of feeding on organisms larger than themselves. They do this by everting their stomach and wrapping it around their prey. The starfishes eat even fishes and their fry. Large echinoderms are serious competitors

of fish, for in many cases they compete for the same food items. The small echinoderms, especially holothurians and ophiurids, serve as food items for some fish such as haddock, catfish, flounders, gobies. Holothurians and urchins are edible and are therefore fished commercially, particularly in the Far East, the United States and Italy.

All echinoderms live exclusively in a marine environment and they are very sensitive to fresh water. That is why they do not occur either in the Caspian or in the Baltic seas. In the Black Sea they are represented by a limited number of species (one ophiurid species and several holothurian species). But in our northern waters the echinoderms play a very important role. In the Barents, White and Kara seas, particularly in their abyssal parts, the echinoderms frequently predominate by weight over other groups of the benthic population. There are about 80 known species of echinoderms in our northern waters. Seventy-four species are known to live in the Barents Sea and adjacent fiords, 22 species in the White Sea, and about 40 species in the Kara Sea.

Of the echinoderms occurring in the Barents Sea, 12 species prefer a muddy sea floor, 19 species prefer mud with stones, 11 species prefer sand with mud, 4 species prefer stones and 6 species prefer sand with stones. Thus the majority of echinoderms in the Barents Sea prefer a muddy sea floor. On other types of sea floors they occur much less frequently. Species belonging to different classes behave differently toward the different sea floors. Thus most starfishes seem to prefer a floor of clean mud, whereas holothurians prefer mud with sand, and the brittle stars definitely prefer a muddy floor with stones (8 out of 11 species). Some of the echinoderms living in shallow water (Asterias rubens, Chiridota laevis, Ophiura nodosa and Cucumaria calcigera) prefer hard sea floors.

As to temperature conditions, all echinoderms living in northern waters are considered to be cold-water organisms. The average temperatures under which echinoderms live in the Barents Sea range from -1° to $+4^{\circ}$, but most of the species prefer average temperatures above 0° . Only 11 out of 54 species live under average below 0° temperatures, the remainder live at average temperature conditions above 0° . Best adapted to the cold are the High-arctic species Ophiopleura borealis, Elpidia glacialis, Pourtalesia jeffreysi and Cucumaria calcigera and glacilias. The first three of these five species occur at water temperatures not higher than $+1^{\circ}$. Most thermophilic are the boreal species Poraniomorpha hispida, Plutonaster parelii, Hippasteria phrygiana, Pentagonaster granularis, Brisaster friagilis. None of these species occurs in water temperatures below 0° . The high-arctic and boreal species are also very stenothermal forms restricted to a narrow range of water temperatures. In contrast, the widely distributed arctic -boreal species are usually eurythermal. Least restricted to a certain temperature range are the common species Ophiocantha bidentata and Ophiopholis aculeata.

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Echinoderms are even more sensitive to fluctuations in salinity. Thus by far the greatest majority of them are found in areas where the salinity factor is not below 33‰, only a few can survive a lower salinity. In the Barents Sea, Ophiocantha bidentata, Ophiura nodosa, Amphiura sundevalli and Asterias groenlandica can withstand the lowest salinity (up to 18—19‰). Strongylocentrotus droebachiensis, Cucumaria glaciales and Henricia sanguinolenta can adjust to salinities as low as 27—29‰. All the species occurring in the White Sea are also thought to be capable of coping with fairly low salinity. In general, the largest number of species occurring in waters with low salinity belong to the group of arctic species. Boreal species, however, with the exception of the shallow-water species

Asterias rubens, are restricted to waters with the highest salinity conditions (usually not below 34%).

By their depth distribution echinoderms are divided into two groups. The overwhelming majority inhabit the continental slope, with rare occurrences in the abyssal part (more than 2000—3000 m). This large group is contrasted by a small group of abyssal species (Pourtalesia jeffreysi and Elpidia glacialis, listed in the Guide), which occur on the continental shelf, at depths less than 800—600 m, only in exceptional cases. The species that never inhabit depths greater than 200 m are Ophiura nodosa, Cucumaria calcigera, C. glacialis and Asterias rubens.

Zoogeographically, all echinoderms of northern waters are distributed as follows: A large proportion (38 out of 80 known species) are arctic forms. Of these, 14 are high-arctic forms distributed mainly in the northern and eastern parts of the Barents Sea, off Novaya Zemlya, Spitsbergen and in the Kara Sea. Then come the arctic-boreal species (24 species). The members of this group are widely distributed in northern waters. The third group is comprised of boreal species (17 species) which appear to have arrived from the west and are distributed mainly in the western parts of the Barents Sea, an area that is strongly affected by warm Atlantic currents. Some of the more thermophilic arctic-boreal species (Ophiura sarsi and to a lesser degree Henricia sanguinolenta) are also restricted to the warm currents and thus are good biological indicators.

Of the three western arctic seas washing the shores of the USSR, the arctic element is more strongly felt in the Kara Sea than in the Barents and White seas. By contrast, the boreal element is most strongly represented in the Barents Sea and is totally absent in the Kara Sea. The most common species (Ophiocantha bidentata, Ophiopholis aculeata, Strongylocentrotus droebachiensis) belong to the arctic-boreal species.

The following Table shows the percentage of species belonging to the various zoogeographic groups and occurring within the three seas referred to above. The percentages for the Kara Sea are approximate.

As to the distribution boundaries of the individual species, they can change significantly, depending on the conditions of the sea. Thus before 1924, the boreal species Echinus esculentus occurred along the Soviet shores of the Murman coast only in isolated numbers west of the Kola Gulf. In subsequent years, when the warm Atlantic currents significantly increased, which warmed the Barents Sea generally, this species began to occur in large numbers even around the entrance to the Kola Gulf. And the boreal species Brisaster fragilis at this time became a common occurrence in the Kola Gulf, whereas before the warm currents arrived only a few dead shells could be found there. Also, the boreal species Poraniomorpha hispida did not occur in the Kola Gulf before the warm-up, but as the warm currents arrived it occurred in rather large numbers.

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The following determination keys and descriptions are compiled on the basis of the work of D'yakonov.

	a	b	c	d
	Бореальные виды	Арктическо-бореальные виды	Арктические виды	В том числе высокоарктические
Barents S. Баренцево море (с фиордами)	33	30	37	8
White S. Белое море	5	63	32	5
Kara S. Карское море	0	40	60	18

a—Boreal species; b—Arctic-boreal species; c—Arctic species; d—High-arctic species.

The keys do not include rare or little-known forms, nor do they include forms that do not occur in Russian northern waters. And the distribution of echinoderms is pertinent only to these waters. The temperature and salinity conditions are pertinent only to the Barents Sea, which is better researched than some of the other seas.

Key for determining classes of Echinodermata of the northern waters of the USSR

- 1 (2) Rays feather-like, without spines; free-living or attached to substrate (some attached only when young). Sea lilies Crinoidea, p.469
- 2 (1) Rays never feather-like; frequent presence of spines 3
- 3 (6) Body star-shaped 4
- 4 (5) Rays not well segmented from disk (disk imperceptibly merges into rays). Tube feet well defined and arranged in 2—4 rows in groove on lower side of ray Starfishes, Asteroidea, p.470
- 5 (4) Rays well defined. Tube feet not clearly defined and situated on the lower side of ray without groove Brittle stars, Ophiuroidea, p.481
- 6 (3) Body shape varies (not radial) 7
- 7 (8) Body spherical or egg-shaped. Many have mouth equipped with masticatory apparatus Sea urchins, Echinoidea, p.487
- 8 (7) Body cylindrical, elongated. Mouth rimmed by feelers Holothuroidea, p.489

Class Crinoidea—Sea Lilies

Sea lilies, by their structure and external appearance, are quite distinct from the other echinoderms. They resemble a feathery flower

consisting of a calyx, branched rays and a stalk. The latter wastes away in the adults of many present varieties of sea lilies. This occurs particularly in the most common northern sea lilies whose adults develop a large number of cirrate processes, resembling roots, on the central cone on the lower part of the body. These processes enable the sea lily to move about. In contrast to all other echinoderms, the mouth in sea lilies is located on the dorsal side of the body, and the anal opening is located on the same side. Also original is the structure of the sex organs, for they are localized not in the body itself but in the side branches (pinnules) of the rays.

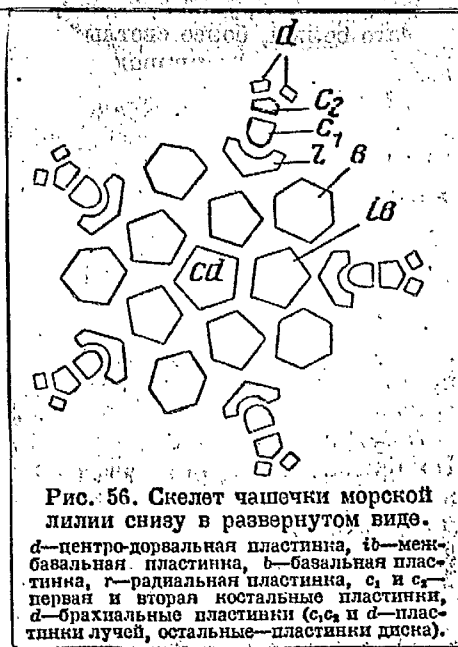


Fig. 56. View of opened calyx frame of sea lily as seen from the bottom.

d—middle-dorsal plate; *ib*—inter-basal plate; *b*—basal plate; *r*—radial plate; *c₁* and *c₂*—first and second costal plates; *d*—brachial plates; (*c₁*, *c₂* and *d*—ray plates; remainder—disk plates).

The designations that are required for identification are shown in Fig. 56 and Plate CXX, 1--2. In order to establish the form of the central cone, part of the cirri must be removed.

The sea lilies listed in the key belong to the family Antedonidae, whose adults are distinct in that they do not have a stalk. It is present only in the form of its first segment, which forms the central cone covering the frame portion of the calyx.

Key for determining the genera of sea lilies of the northern waters of the USSR

- 1 (2) Lower part of body (central cone) shaped somewhat like an elongated cone. Cirri arranged in vertical rows (Plate CXX, 2). The pinnule closest to the calyx is three times longer than its neighboring one Peliometra, p.470
- 2 (1) Central conus hemispheric or slightly conical. Cirri arranged at random or in irregular oblique rows (Plate CXX, 1a, 1b). The pinnule closest to the calyx is almost the same length as the adjacent one Heliometra, p.470

Family Antedonidea

Peliometra A. H. Clark

Peliometra prolixa Sladen (Plate CXX, 2)

This species is relatively small, has thin, well-proportioned rays and thin cirri. Color dark, yellowish-brown or yellowish-red. Central cone elongated, tapered. Cirri arranged in regular vertical rows. Pinnule situated closest to the calyx consists of approximately 26 segments and is significantly longer than the adjacent pinnule.

High-arctic species; occurs along northern coast of Norway, northern part of the Barents Sea, along the Spitsbergen coast and in the

Kara Sea. Depths: 18—2,000 m at temperatures of -2° to $+3^{\circ}$. Frequently occurs at depths of 400—1000 m at below 0° temperatures. Prefers muddy sea floor with rocks. Rare species.

Heliometra A. H. Clark

Heliometra glaciales Learch (Antedon eschrichttii O. F. Müll.) (Table CXX, 1b)

A larger species than the preceding one; coarser structure. Color yellowish-white, lighter than that of P. proluxa. Central cone hemispheric, cirri arranged irregularly; first pinnules considerably widened and flattened; pinnule closest to the calyx is almost the same length as the adjacent pinnule.

A widely distributed arctic species; Barents Sea, Kola Gulf, Kara Sea, along the Siberian coast and northern Pacific. Depths: 10--1,359 m, at temperatures of -2° to $+5^{\circ}$. Occurs on all sea floors but prefers muddy floors with rocks. Salinity higher than 33‰.

Class Asteroidea

The body of starfishes is dorsoventrally flattened, with the radii usually elongated in the form of rays but not clearly differentiated from body, giving the latter a star-like shape. In some, the arms are elongated so little that the body assumes the shape of a pentahedron. Usually five rays but some species have more. Solaster papposus has up to 16 rays and some tropical species have up to 40 rays. The ventral side of the rays contains an open ambulacral groove containing several rows of tube feet. The stomach has processes that merge into the rays. The mouth is located in the middle of the ventral side of the starfish, the anal opening is situated on the dorsal side. Some species do not have an anal opening. Some starfishes have pedicellariae.

The size of starfishes is determined by two measurements: length of ray (R) (distance from center of body to end of ray) and disk radius (r) (distance from center of body to edge of disk between rays). The ratio of these two dimensions (R:r) may be quite important systematically.

The indicators that must be known when determining the dimensions of starfishes are shown in Fig. 57.

It is also necessary to become acquainted with the structure of a cross section of a ray of a starfish and with the plates that make up the ray (see Fig. 57) and with all the terms that are used to describe a starfish:

1) Marginal plates. Two on each side: the upper, lying close to the dorsal side, and the lower, which is lying closer to the ventral side (Fig. 57). Sometimes the marginal plates contain spinous appendages, as shown in Plate CXX, 3.

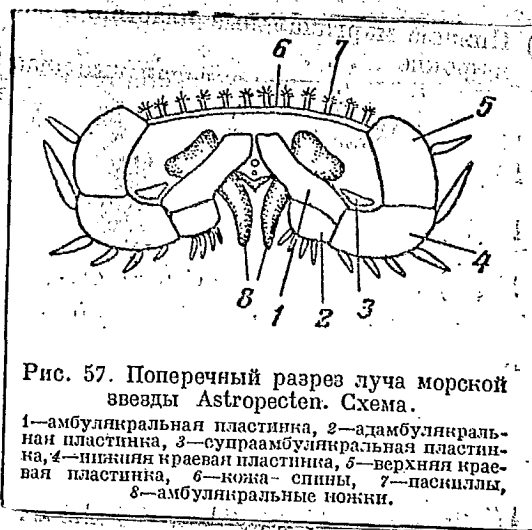


Рис. 57. Поперечный разрез луча морской звезды *Astropecten*. Схема.

1—амбулякральная пластинка, 2—адамбулякральная пластинка, 3—супраамбулякральная пластинка, 4—нижняя краевая пластинка, 5—верхняя краевая пластинка, 6—кожа спины, 7—пациллы, 8—амбулякральные ножки.

Fig. 57. Cross section of a ray of an *Astropecten* starfish.

1—ambulacral plate; 2—adambulacral plate; 3—supra-ambulacral plate; 4—lower marginal plate; 5—upper marginal plate; 6—dorsal skin; 7—paxillae; 8—tube feet.

2) Membrane. In some starfishes the dorsal skin is covered by another thin membrane which serves as a cover for embryos that develop under it; in other forms this membrane is considerably more compact and has a cortical consistency. In the latter case the dorsal area of the starfish has a bulging look about it.

3) Ambulacral spines localized along the edge of the ambulacral groove. Sometimes they are connected by a membrane somewhat like a fin. The spines of the marginal (lower) plates can form similar fins. Fins formed in this manner have different shapes. In some, the fin widens from the base of the ray toward the center, then narrows again toward the end; in others, the fin is uniformly tapered from the base toward the end, giving it the general outline shown in Plate CXXI, 5.

4) Paxillae. Slightly raised pillars sprouting tufts of spines (Plate CXXI, 1b, 2a, 3a). The bundles of spines are localized on the dorsal side of the starfish either close together or far apart.

The starfishes occurring in the northern waters of the USSR belong to three orders: Phanerozonia, Spinulosa, and Forcipulata. The first of these orders is distinct from the others in that its marginal plates are well-defined and clearly visible, forming a definite edge both of the disk and of the rays. The members of Spinulosa are distinct from those of Forcipulata by their small number of pedicellariae and by their total lack of crossed pedicellariae. The tube feet are arranged in two rows inside the ambulacral grooves (with the exception of one genus). Dorsal spines usually arranged in groups.

In contrast, the pedicellariae in Forcipulata are always crossed and the tube feet are usually arranged in four rows (rarely in two). Dorsal spines usually solitary.

The northern starfishes of the Phanerozonia order belong to five families (Porcellanasteridae, Astropectinidae, Benthoplectinidae, Goniasteridae and Poraniidae); those of the Spinulasa order belong to three families (Pterasteridae, Solasteridae and Echinasteridae); those of the Forcipulata order belong to two families (Pedicellasteridae and Asteridae).

Key for determining the genera of starfishes of the northern waters of the USSR

- 1 (16) Marginal plates well-defined and form a definite boundary between dorsal and ventral sides. Tube feet arranged in two rows 2
- 2 (3) Each marginal plate contains a comb-like process (Plate CXX, 3).
The central portion has the form of a more or less prominent tapered papilla. Rays short, blunt Ctenodiscus, p.473
- 3 (2) Comb-like processes lacking 4
- 4 (11) Rays relatively long, longer than diameter of disk, with the shortest of them being the same length as disk diameter 5
- 5 (8) Marginal plates spiny 6
- 6 (7) Upper and lower marginal plates bear long spines. Rays very long, thin and sharply tapered toward the end Pontaster, p.474
- 7 (6) Only the lower marginal plates bear short, solitary spines. Rays short, wide at the base and tapering toward the end . Psilaster, p.473
- 8 (5) Marginal plates lack spines and bear only granules 9
- 9 (10) Lower marginal plates significantly larger than upper plates.
Rays short, wide Leptychaster, p.474
- 10 (9) Lower and upper marginal plates large, almost identical in size, not covered by skin. Dorsal side covered with granules. Body more or less flattened. Rays long (ray can be three times longer than disk diameter). Marginal plates completely covered with granules Pseudarchaster, p.474

- 11 (4) Rays short, always shorter than disk diameter 12
- 12 (15) Dorsal side not covered with membrane. Marginal plates very large. Body more or less strongly flattened 13
- 13 (14) Rays short. Body strongly flattened, pentagonal, with slightly protruding rays (Plate CXX, 5) Ceramster, p.474
- 14 (13) Dorsal side bulged. Rays longer than in preceding species, which gives the body a star-shaped rather than a pentagonal form (Plate CXX, 7a, 7b) Hippasteria, p.475
- 15 (12) Dorsal side covered with soft membrane (Plate CXX, 4a, b) Poraniomorpha, p.475
- 16 (1) Marginal plates not well-defined and do not form a sharp boundary between dorsal and ventral sides. Tube feet arranged in two or four rows 17
- 17 (20) Dorsal side covered with membrane. Interradii under the membrane contain special cavities for breeding the young. Linked to the cavity is a wide opening in the center of the disk 18
- 18 (19) Tube feet not arranged in comb-like fashion and not webbed like fins. Integument transparent (Plate CXXI, 6a—b),, Hymenaster, p.476
- 19 (18) Ambulacral spines arranged comb-like and webbed like a fin (Plate CXXI, 5). Ambulacral grooves relatively narrow; tube feet arranged in two rows Pteraster, p.476
- 20 (17) Dorsal side lacks skin membrane 21
- 21 (24) Spines on dorsal side form paxillae 22
- 22 (23) Five rays. Two rows of well-defined paxillae lying on the marginal plates. Disk skeleton consists of star-shaped plates adjacent to each other Lophaster, p.477

- 23 (22) More than five rays. One row of well-defined marginal paxillae.
Skeletal plates not star-shaped (Plate CXXI, 1—3) . Solaster, p.477
- 24 (21) Dorsal paxillae lacking. Spines solitary or grouped in simple
tufts 25
- 25 (28) Tube feet arranged in two rows 26
- 26 (27) Skeleton of dorsal side forms irregular grid. Ambulacral groove
very narrow Henricia, p.478
- 27 (26) Skeleton of dorsal side forms grid whose meshes on the rays
are arranged in regular longitudinal and transverse rows.
Ambulacral groove a little wider Pedicellaster, p.478
- 28 (25) Tube feet, at least at the base of the rays, arranged in four
rows 29
- 29 (30) Most ambulacral plates bear three spines arranged in the form
of a transverse comb. Only a number of the ambulacral plates,
especially those situated toward the end of the ray, bear two
spines. Rays relatively short and thick, varying in number
(from 5 to 11), some usually in a stage of regeneration
. Stephanasterias, p.478
- 30 (29) Adambulacral plates bear one or two spines; Always five rays
(only one species, not listed in the key, has six rays) 31
- 31 (34) All adambulacral plates bear two spines each. Rays very long,
thin, tapered at the end. Dorsal spines solitary, rare. Crossed
pedicellariae very large with narrow, elongated valves 32
- 32 (33) Lower marginal plates bear one spine and a dense pad of long,
crossed pedicellariae. Dorsal spines on rays sparse but more or
less evenly distributed. Scattered among the dorsal spines are
a large number of straight pedicellariae Urasterias, p.479

- 33 (32) Lower marginal plates bear two spines and lack crossed pedicellariae. On dorsal side of ray only middle row of spines well-defined; additional spines solitary or lacking altogether. Numerous crossed pedicellariae scattered among dorsal spines Icasterias, p.479
- 34 (31) Most, or at least some, of the adambulacral plates bear one spine. Frequently plates with one and two spines alternate. If all or almost all of the adambulacral plates bear two spines, the dorsal side of the ray bears numerous small spinules localized in groups or in transverse rows. Crossed pedicellariae small with short valves. Rays relatively short and thick 35
- 35 (36) Upper marginal plates usually bear three (rarely 2 or 4) spines arranged in a triangle. Dorsal spines solitary, arranged sparsely. Among them are numerous straight and sometimes crossed pedicellariae. The straight pedicellariae lanceolate with tapered valves at the end (Plate CXX, 6b) Asterias, p.479
- 36 (35) Upper marginal plates usually bear one or two spines. Pedicellariae among spines on dorsal side either lacking altogether (the crossed pedicellariae are attached to the base of the spines), or there are a few straight ones, which are blunted at the end, widened, or contain protuberances Leptasterias, p.479

Order Phanerozonia

Family Porcellanasteridae

Ctenodiscus Müller et Trosch

Ctenodiscus crispatus Retzius (Plate CXX, 3)

Disk wide, flattened; rays relatively short, blunted. Dorsal side covered with papillae; tapered papilla present in center of disk.

Comb-like organ present between all marginal plates. Marginal, interradii and adambulacral plates covered with a soft membrane. Color yellowish. One of the most widely distributed northern species of starfishes.

Arctic-boreal species. Barents and Kara seas (also Northern Pacific and Sea of Japan). Depth of occurrence: In the Arctic: 10—1,100 m; in the boreal zone: to 2,000 m. Occurs on all sea floors, prefers muddy floors. Temperatures: from -2° to $+5^{\circ}$.

Family Astropectinidae

Psilaster Sladen

Psilaster andromeda Müller et Troschel

Disk small, flattened, with a papilla in the middle. Rays rather long, gradually tapered with pointed end. Lateral surface of rays very high owing to the extended marginal plates. Paxillae small and densely arranged. Color light-red.

Boreal species. Southwestern part of Barents Sea. Depth: 70—1,850 m. In the Barents Sea this rare species occurs at a depth of 229 m at a temperature of $+4.25^{\circ}$.

Leptychaster Smith

Leptychaster arcticus M. Sars

Disk relatively wide; rays short, wide at the base, tapered at the end $R : r=2-3$. Upper marginal plates considerably smaller than lower ones. Both are uniformly covered with a layer of fine spinules or elevated granules and lack well-defined individual spines. Rose- or orange-colored.

Boreal-arctic species; that is to say, confined mainly to the transitional zone between the boreal and arctic regions. By its distribution and ecology in the Barents Sea it approximates the boreal species

(temperature from 1° to 6°). Southwestern part of Barents Sea (also Bering Sea). Depths: 50—432 m but prefers depths of more than 300 m. All sea floors.

Family Benthopectinidae

Pontaster Sladen

Pontaster tenuspinus Dübén et Koren

Body strongly flattened. Rays very long, thin, tapered. Upper marginal plates bear one long spine in addition to numerous spinules. Lower marginal plates bear one long spine in the upper portion and shorter, gradually diminishing spinules in the lower. Pedicellariae simple, in the shape of two elongated valves on the adambulacral plates. Color bright-red.

Arctic-boreal species. Occurs in the entire Barents Sea, except in its most easterly areas, in the Kara Sea and along the Siberian coast. Occurs at depths of 16—1,960 m but prefers depths of over 300 m. All sea floors, but prefers mud. Temperatures: from -2° to +5°. One of the most widely distributed starfish species in the Barents Sea.

Family Goniasteridae

Pseudarchaster Sladen

Pseudarchaster parelii Dübén et Koren (Plutonaster parelii)

Body strongly flattened; disk wide; rays very long and narrow. R : r=3 (approximately). Dorsal side covered with granules arranged in groups similar to paxillae. These granules occur to the very end of the ray, dividing both rows of the upper marginal plates. The marginal plates are covered with low granules. The lower marginal plates also bear several small scaly spines. Color red.

Boreal species. Southwestern part of Barents Sea. Depths: 15—2,500 m (in Barents Sea from 232 to 432 m). Occurs on all except rocky sea floors. Prefers a muddy sea floor. Temperatures: from 1° to +5°.

Ceramster Verril

Ceramster granularis Retzius (Pentagonaster granularis) (Plate CXX, 5)

Body strongly flattened. The rays are short to the point where the starfish resembles a pentagon with protruding corners. The dorsal side is covered with flat granules organized in groups similar to paxillae and with a regular hexagonal outline. These groups of granules adjoin each other very closely.

Boreal species. Southwestern part of Barents Sea. Depths: 20—1,435 m (in the Barents Sea at depths of 50—432 m). Prefers rocky and sandy sea floors. Temperatures: from 1° to 6°.

Hippasteria Gray

Hippasteria phrygiana Parelius (Plate CXX, 7a, b)

Dorsal side of body bulging. Disk very wide; rays short, wide, but still longer than in the preceding species, giving the body a general form of a star rather than that of a pentagon. $R : r=2$. Attains very large dimensions. Dorsal plates vary in size. The larger ones bear in the center a short blunt spine or a bivalved pedicellaria surrounded by granules. The smaller plates are covered only with granules or bear a small pedicellaria.

Boreal species. Southwestern part of Barents Sea and area of Medvezh'e island. Depths: 70—861 m. Prefers rocky and sandy sea floors. Temperatures: from 1° to 4°.

Family PoraniidaePoraniomorpha Daniel et KorenPoraniomorpha hispida M. Sars

We are presenting separate descriptions of the two geographic subspecies of this widely distributed, variable, arctic-boreal species because some investigators still consider them to be separate species. Recognition of the existence of transitional specimens and of a transitional zone appears to be convincing evidence that these forms are not separate species.

Key for determining the subspecies of Poraniomorpha hispida of the northern waters of the USSR

- 1 (2) Upper marginal plates, although covered with a membrane, are well defined, forming together with the lower marginal plates a high edge of the disk and of the rays. Rays short, wide, blunted . . .
 Poraniomorpha hispida hispida
- 2 (1) Upper marginal plates completely covered with a membrane, and disk and ray margin is formed only by the lower marginal plates. Body bulging; rays longer and more tapered (Plate CXX, 4a, b) . .
 Poraniomorpha hispida tumida

Poraniomorpha hispida hispida M. Sars

Body massive, dorsal side more or less bulging. Disk very wide; rays wide and very short, giving some specimens the appearance of a pentahedron. $R : r$ of typical specimens = 1.20—1.43, and in the var. rosea Dan. et Kor. it is 1.9—2.0. Upper marginal plates, although covered with a cortical, are fairly well defined externally, and together with the lower plates they form an almost vertical margin of the disk and of the rays.

Both upper and lower marginal plates are covered with granules. The lower plates, in addition, contain on their lower margin a group of small spinules.

Boreal form. Southwestern part of Barents Sea where, together with the following subspecies, it constitutes transitional forms. In warmer periods it occurs in the Kola Gulf. Depths: 90—1,171 m (in the Barents Sea 150—385 m). Prefers sandy sea floors. Temperatures: from 2° to 4°.

Poraniomorpha hispida subsp. tumida Stuxberg (Plate CXX, 4a, b)

Dorsal disk strongly bulging. Rays thinner and longer than in the preceding subspecies: $R : r = 1.6 - 2.6$. P. h. tumida, in turn, comprises two forms: a lower arctic form with shorter rays, and a high-arctic form with longer rays.

Upper marginal plates completely covered with a cortical, so that the margin of the disk and of the rays is formed only by the lower marginal plates. These lower plates do not usually have spines. However, in this regard there is a whole series of transitions between P. h. tumida and P. h. hispida. Color red and yellowish-red.

Arctic form. Barents, White and Kara seas and along Siberian coast. Depths: 10—1,200 m. Prefers mostly muddy sea floors. Temperatures: from -2° to 4°.

Order Spinulosa

Family Pterasteridae

Pteraster Müller et Trochel

Key for determining Pteraster species of the northern waters of the USSR

- 1 (2) Presence of ventral fin formed by marginal spines and that widens from base of ray toward center from which point it rapidly tapers toward the end. Usually six rays Pteraster obscurus
- 2 (1) Presence of ventral fin formed by marginal spines and gradually and evenly tapered from base of rays toward end. Five rays 3
- 3 (4) Rays long; up to four spinules on paxillae localized dorsally; spinules thin, not widened at the end. Dorsal side smooth. Rather large forms Pteraster militaris
- 4 (3) Rays shorter; 5—10 spinules on dorsal paxillae; spinules widened toward the end. Dorsal side rough; Form small (Plate CXXI, 4) Pteraster pulvillus

Pteraster obscurus Perrier

Six rays. Body on dorsal side bulging and very rough. Rays wide and short. $R : r=1.4-1.6$. Ventrolateral membrane (fin) wide in middle of ray, with slight tapering toward base and sharp tapering toward end of ray. Dorsal membrane thick; no calcareous spicules and reticular muscles. Ambulacral groove bears two rows of tube feet. Color brown.

Boreal-arctic or low-arctic (?) species. Barents Sea, usually in vicinity of warm currents, and Kola Gulf. Depths: 33—394 m. Mainly muddy-sandy sea floors. Temperatures: from -2° to 5° .

Pteraster militaris O. F. Müller

Five rays. Body fleshy, on dorsal side soft and smooth. Rays clearly separated and elongated. $R : r=2-2.5$. Ventrolateral membrane (fin) gradually tapered from base to end. Dorsal membrane thick; muscular strands lacking but calcareous corpuscles present. Paxillae low with 3—5 spinules. Rose-colored or yellowish-red. Ambulacral groove bears two rows of tube feet.

Arctic-boreal species. Barents, White and Kara seas and along Siberian coast (also Northern Pacific). Depths: 10—1,100 m. Various sea floors. Temperatures: from -2° to $+5^{\circ}$.

Pteraster pulvillus M. Sars (Plate CXXI, 4)

Five rays. Body compressed; dorsal side bulging, rough. Rays short, thick. $R : r = 1.2—1.5$. Fin narrow, gradually tapered toward end of ray. Dorsal membrane compact, containing only weakly developed muscles. Calcareous corpuscles lacking. Paxillae high with 6—10 spinules widened at the end. Color brown. Small forms.

Arctic-boreal species. Barents, White and Kara seas and Siberian coast (also Bering Sea and Sea of Okhotsk). Depths: 35—320 m. Various sea floors. Temperatures: from -2° to $+5^{\circ}$.

Hymenaster W. Thomson (Plate CXXI, 6a—b)

Body flattened with wide disk and wide flattened rays. Rays tapered to a sharp end. $R : r = 1.5$. All membranes thin, transparent. Ventrolateral membrane very wide, forms a margin of the entire animal. Dorsal membrane thin. Paxillae bear 6—8 spinules which protrude a little above membrane. Rose- or lilac-colored.

Arctic species. Barents and Kara seas and Siberian coast. Depths: 12—2,800 m but mostly at depths greater than 300 m. Mostly muddy sea floors. Temperatures: from -2° to $+4^{\circ}$. Occurs mostly in below 0° temperatures.

Family Solasteridae

Lophaster Verrill

Lophaster furcifer Dübén et Koren

Five rays. Disk narrower than in Solaster species. $R : r=3$ (approximately). Two rows of well-defined marginal paxillae. Dorsal side covered with uniform paxillae, arranged in more or less regular longitudinal rows. Dorsal plates stellate and interconnected with processes. Color brown or red.

Arctic-boreal species. Barents and Kara seas and Siberian coast. Depths: 30—1,360 m. Mostly on muddy sea floors. Temperatures: from -2° to $+3^{\circ}$.

Solaster Forbes

Key for determining Solaster species of the northern waters of the USSR

- 1 (2) Paxillae arranged sparsely. Marginal paxillae particularly large, forming wide brush-shaped rows on the side of the rays (Plate CXXI, 1a, b) Solaster papposus (=Crossaster papposus)
- 2 (1) Paxillae arranged close to each other. Marginal paxillae not distinguished for size. Ray sides more or less smooth 3
- 3 (4) Paxillae arranged close to each other, almost touching each other, bearing a large number (over 20) of spinules. Spinules of each paxilla almost identically long (Plate CXXI, 3a, b). Rays thinner, longer Solaster glacialis (=S. syrtensis Verril)
- 4 (3) Paxillae arranged farther apart from each other. Fewer spinules (not more than 20). Spinules of each paxilla vary in length, central spinules being longer. Rays usually thicker and shorter (Plate CXXI, 2a, b) Solaster endeca

Solaster papposus Linnaeus (Plate CXXI, 1a, b)

Eight to sixteen rays; predominant number of specimens have 10 to 12 rays. Disk flattened, very wide. Paxillae far apart. Lower marginal

paxillae particularly large, forming high brush-shaped rows along margin. Some dorsal paxillae larger, some smaller. Spinules in same paxilla vary in length: longer in center, shorter at margins. Color reddish with a lighter transverse band on rays.

Arctic-boreal, circumpolar species. Barents, White and Kara seas and Siberian coast (also Northern Pacific down to the Sea of Japan). Depths: 0—1,200 m. Various floors. Temperatures: from -2° to $+6^{\circ}$. Salinity: from 33‰ and higher.

Solaster endeca Linnaeus (Plate CXXI, 2a, b)

Rays 7—10. Disk very wide. Rays relatively short, curved at the sides. Paxillae close to each other. Individual paxillae bear fewer than 20 spinules of different lengths, with those in the center being longer and those in the margins shorter, giving the paxillae a bulging outline. Color varies from orange to red to violet.

Arctic-boreal species. Barents and White seas (also Northern Pacific, Sea of Japan). Depths: 0—475 m. Various sea floors. Prefers rocks and sand. Temperatures: from -2° to $+6^{\circ}$.

Solaster glaciales Danielssen et Koren (Plate CXXI, 3a, b)

Resembles S. endeca, but rays thinner and longer. Paxillae very close to each other. Spinules in each paxillae of identical length, giving the paxillae a flat outline. Large number of spinules (frequently more than 20). Color red.

Arctic species. Barents and Kara seas and Siberian coast. Depths: 30—487 m. Occurs on various sea floors but prefers mud. Temperatures: from -2° to $+4^{\circ}$. More of a cold-water species than S. endeca.

Family Echinasteridae

Henricia Gray

Henricia sanguinolenta O. F. Müller

Very widely distributed, variable species. Rays rather long, thin. Dorsal spines small, bunched together in various numbers. Sometimes these tufts occur closely together, sometimes farther apart. Ambulacral groove very narrow. Color varies from yellow to rose-colored to cherry-red. Evident parental care for progeny.

Arctic-boreal species. Barents Sea (mainly southern part), White and Kara seas and Siberian coast (and Northern Pacific down to Japan). Depths: 6—2,450 m. Mostly rocky and sandy floors. Temperatures: from -2° to $+6.5^{\circ}$. Prefers temperatures above $+2^{\circ}$. Salinity from 29‰ and higher.

Order Forcipulata

Family Pedicellasteridae

Pedicellaster M. Sars

Pedicellaster typicus M. Sars

Rays five, narrow, cylindrical. Loops of dorsal skeleton form regular quadrate. Ambulacral grooves rather wide, tapered at the base of the ray. Numerous crossed pedicellariae scattered over the entire dorsal surface and ray sides. Tufts around spinules lacking. Pedicellariae of two kinds: small ones on the dorsal side and larger ones, with elongated serrate valves, on the sides of the rays. Size usually not exceeding 30 mm. Color orange-yellow.

Arctic-boreal species. Barents and Kara seas. Depths: 20—1,134 m. Mostly on rocky floors and on shells.

Family AsteridaeStephanasterias VerrilStephanasterias albula Stimpson

Number of rays can vary, but usually 7. Marked capacity for division, with subsequent regeneration. Specimens with identically developed rays very rare; usually one or several rays in process of regeneration. Starfish sometimes seems to consist of one ray from which other rays seem to develop. Dorsal side densely covered with identical small spinules which are usually arranged in transverse rows. Most adambulacral plates bear three spinules situated transversely like little combs. Numerous crossed pedicellariae located at base of spines.

Arctic species. Barents, Kara and Bering seas. Depths: 12—616 m. Prefers depths of down to 200 m, preferably on muddy floors. Temperatures: from -2° to $+5^{\circ}$. Prefers lower temperatures.

Urasterias W. FisherUrasterias lincki Müller et Troschel

Disk average size. Rays long, more or less tapered at the end. Dorsal side bears isolated spinules which are distributed more or less evenly. Upper and lower marginal plates bear one large spine each. Crossed pedicellariae large with narrow, elongated valves. They form dense tufts around the lower and less dense tufts around the upper marginal spines. Attains large dimensions (R up to 220 mm). Color red with yellowish border along sides of rays.

Arctic species. Barents, White and Kara seas and Siberian coastal area. Depths: 12—340 m. Occurs on various floors but preferably mud. Temperatures: from -2° to $+5^{\circ}$; prefers temperatures of around 0° .

Icasterias W. FisherIcasterias panopla Stuxberg

Disk small; rays long, thin, tapered at the end, strongly constricted at the disk and break off easily. On dorsal side only middle row of spines well developed. Upper marginal plates bear one spine, the lower usually two. Adambulacral plates bear two or three spines without pedicellariae. Crossed pedicellariae of the same type as found as U. lincki but smaller and they do not form tufts around the spines and are scattered in singles among the spines. Color dark-red, lilac.

Arctic species. Barents and Kara seas and Siberian coastal area. Depths: 18—560 m. Occurs on different sea floors but prefers muddy floors. Temperatures: from -2° to $+4^{\circ}$; prefers temperatures of -1° to 0° . It is more of a cold-water species than U. lincki.

Asterias LinnaeusAsterias rubens Linnaeus (Plate CXX, 6a, b)

Disk rather wide; rays relatively short, wide, blunted. Adambulacral plates bear one to two spinules, usually in alternating sequence. In the plates with two spinules the inner spinule lies deeper in the groove than the two solitary spinules of the adjacent plates. Adambulacral spinules usually bear straight pedicellariae. Lower marginal spinules lie on ventral side immediately adjacent to the adambulacral spinules. Usually three lower marginal spinules on a plate (young specimens have two). They lie in transversely oblique rows or show a triangular arrangement. Three upper marginal spinules, usually arranged in a triangle, sometimes only two and less frequently one (young specimens). Very large specimens can have more than three marginal spinules. Can reach a size of more than a half meter in diameter. Color varies from orange to red to violet to almost black.

Boreal species. Southwestern part of Barents Sea and White Sea.
 Depths: 0—400 m. Mostly on rocky and sandy floors. Temperatures: from -2°
 to +7°, mostly above 4°.

Leptasterias Verrill

Key for determining Leptasteris species of the northern
 waters of the USSR

- 1 (6) Dorsal spinules mostly solitary, arranged in longitudinal rows or
 haphazardly. Spines bear clusters of crossed pedicellariae 2
- 2 (3) Dorsal spines on rays arranged in more or less regular longitudinal
 rows, tapered. Adambulacral plates mostly bear one spinule . . .
 Leptasterias milleri
- 3 (2) Dorsal spines on rays arranged haphazardly. Spines cylindrical
 or cephalate with a rounded or flattened apex. Adambulacral plates
 alternately bear one and two spinules 4
- 4 (5) Dorsal spines cylindrical with a rounded apex. Rays relatively
 long, thin. Disk small Leptasterias milleri s. sp. hyperborea
- 5 (4) Dorsal spines thick, strongly cephalate with a flattened apex.
 Rays short, thick. Disk relatively wide Leptasterias arctica
- 6 (1) Dorsal spines arranged in groups forming more or less prominent
 transverse rows. Spines rather thin, tapered and arranged very
 closely together. Some spines, particularly the adambulacral spines,
 may lack the clusters of crossed pedicellariae
 Leptasterias groenlandica

Leptasterias milleri M. Sars

Arctic-boreal species; divides into two geographic subspecies—a
 boreal and an arctic species.

L. mülleri mülleri M. Sars

Disk small, strongly set apart from rays. Rays usually long, thin, but short rays occur as well. Dorsal spinules on rays arranged more or less in regular longitudinal rows. Spines tapered, solitary, sparse. Upper and lower marginal plates bear one spine. Adambulacral plates bear mostly one or two spines; and adambulacral spines bear clusters of crossed pedicellariae, as do dorsal, lateral and ventral spines. Madreporic plate not surrounded by a special ring of spinules. Color red.

Boreal subspecies. Western Murman [coast]. At the northern distributional boundary the species gradually changes into the next subspecies.

L. mülleri s. sp. hyperborea Danielssen et Koren

Rays coarser than in the typical form, less tapered, more curved at the sides. Dorsal spines also coarser, usually cylindrical with a rounded apex, arranged solitary but closer together. Adambulacral plates alternately bear one and two spines. The young specimens of these subspecies are indistinguishable from each other.

Arctic subspecies. Spitsbergen and area of Medvezh'e Island and sometimes in the Barents and Siberian seas. Depths: down to 200 m. Prefers hard sea floors.

Leptasterias arctica Murdoch

Resembles L. mülleri s. sp. hyperborea but is distinct from it by a number of indicators. Disk wide; rays wide, thick and short. Dorsal spines thick with a flattened tuber at the end. Spines solitary, though very close to each other. Adambulacral plates bear one or two spines, frequently in alternating sequence. Clusters of crossed pedicellariae are

strongly developed, surround all spines and frequently the former are attached to the middle and even to the end of the spines. Adambulacral spines also bear crossed pedicellariae.

Sea of Okhotsk, Bering Sea, Arctic Ocean. Barents Sea near Medvezh'e Island in shallow water.

Leptasterias groenlandica Steenstrup

Variable species consisting of several forms. In typical specimens disk small, somewhat bulging; rays short, thick, bulging at the base and rounded at the sides. Dorsal spines uneven, small, tapered, closely together, frequently arranged in clusters. Lateral spines on rays arranged in transverse rows. Upper marginal plates bear two or three spines; lower marginal plates bear two or one. Ambulacral plates usually bear two spines, occasionally three, without crossed pedicellariae. Madreporic plate surrounded by a ring of small spinules. In typical specimens the crossed pedicellariae are in the form of clusters only on the marginal spines; on the dorsal spines they are solitary or in small groups.

Arctic circumpolar species. Barents and Kara seas and Siberian coast up to the Bering Strait. East of Taymyr the typical form changes to f.[sic] cribraria. Depths: 4—200 m.

Class Ophiuroidea

The ophiurids are distinguished by a flattened round or pentagonal body and strongly elongated rays prominently set apart from the body. The Rays consist of individual segments covered with fine plates. An open ambulacral groove is lacking and the tube feet are arranged in two rows on the ventral side of the rays. They protrude through small pores. The feet themselves lack suction cups and serve as respiratory organs. The mouth

is located ventrally in the center of the disk. The anus is lacking. The stomach does not form processes in the rays.

Externally the disk is covered with plates resembling small scales that overlap one another like roof tiles. Dorsally, near the base of the rays, there are larger paired radial scales. The disk margins between each pair of these scales are frequently notched and bear one or two rows of spinules or papillae (See Plate CXXI, 7c, 8b, 9b). Other designations necessary for a determination are given in Figures 58 and 59.

The class of ophiurids divides into two orders: Euryalae and Ophiurae. The Euryalae that are listed in the key are distinguished from the Ophiurae by their branching rays, which in the latter never branch. The members of this second order listed in the key are divided into five families (Ophiomyxidae, Ophiocanthidae, Ophiactidae, Amphiuridae and Ophiolepidae).

Key for determining the genera of Ophiuroidea of the northern waters of the USSR

- 1 (16) Disk and rays covered with scales. Rays never branch 2
- 2 (9) Disk, on the dorsal side near the rays, has more or less deep notches from which the rays branch off. The notches are usually covered with papillae (small marginal processes). Ray spines relatively short, situated almost parallel with, or at a sharp angle to, the longitudinal ray axis (Plate CXXI, 7) 3
- 3 (4) Disk recesses on dorsal side near base of rays smooth, without papillae. Dorsally, disk covered with small scales. Spinules very short, several times shorter than the length of the segment.
- Large forms Ophiopleura, p.486



Fig. 59. Cross section of an ophiuroid ray.

1—ventral plate; 2—lateral plate; 3—dorsal plate; 4—spines; 5—radial tube of the ambulacral system; 6—radial tube of the nervous system; 7—radial tube of the blood-vascular system; 8—vertebra; 9—tube foot.

-
- 4 (3) Disk recesses on dorsal side covered with papillae. Disk scales well-defined, some of them being in the form of more or less large plates 5
 - 5 (6) Marginal disk recesses near the base of the rays not well-defined, the entire margin being covered with a slightly curved row of tapered papillae. Dorsally, disk bears several large plates; spaces between them are covered with very small scales or granules (Plate CXXI, 9b). Disk margins appear sharp if viewed laterally Ophiecten, p.486
 - 6 (5) Marginal disk recesses triangular and rather deep. Only lateral margins of recesses are covered with papillae which lie in two rows arranged in a semicircle, one on each side (Plate CXXI, 7c). Disk on dorsal side covered entirely with more or less large scales. Disk margins slightly curved 7

- 7 (8) Rays rather short, at the base thick, high. Disk markedly bulged, with large, somewhat bulging plates. Disk recesses bear about ten wide papillae Stegophiura, p.485
- 8 (7) Rays long, thin, width considerably exceeding height. Disk markedly flattened with small, flat plates Ophiura, p.485
- 9 (2) Disk recesses near base of rays lacking; disk overhangs the base of the rays. Spines mostly long and situated perpendicular to the longitudinal axis of the ray 10
- 10 (11) Dorsal side of disk covered with soft skin; spinules lacking. Dorsal plates on rays lacking; ray spinules covered with a skin (Plate CXXII, 2a, b) Ophioscolex, p.483
- 11 (10) Disk on dorsal side covered with scales, granules or spinules. Dorsal plates on rays developed 12
- 12 (13) Only smooth scales present on dorsal and lateral sides of disk. Top of mouth angle bears two papillae lying side by side. Rays well-proportioned, thin, frequently long Amphiura, p.484
- 13 (12) Disk dorsally and laterally bears spinules and granules in addition to scales 14
- 14 (15) Disk dorsally covered with smooth, rounded plates surrounded by fine spinules. Rays wide, strong (Plate CXXII, 1a—c) Ophiopholis, p.484
- 15 (14) Disk dorsally covered with a uniform layer of spinules. Bare plates lacking. Rays narrow, well-proportioned . Ophiocantha, p.484
- 16 (1) Disk and rays covered with soft skin; no scales. Rays branching (Plate CXXII, 3a) Gorgocephalus, p.483

Order Euryale—Branching Ophiurids

Family Gorgonocephalidae

Gorgonocephalus LeachKey for determining the species of Gorgonocephalus of the northern waters of the USSR

- 1 (2) Radial ribs on dorsal side of disk covered with a number of rather large, unevenly distributed spines or granules (Plate CXXII, 3b).
Rays relatively thin with long spaces between branches
. Gorgonocephalus arcticus
- 2 (1) Radial ribs covered by numerous evenly distributed, more or less small, rounded granules (Plate CXXII, 4). Rays with smaller spaces between branches Gorgonocephalus eucnemis

Gorgonocephalus eucnemis Müller et Troschel (Plate CXXII, 4)

Radial ribs of disk covered with many small, uniform, rounded granules. Sometimes these granules lie between the ribs. Rays are relatively coarse with little spaces between the branches. Very large forms. Disk radius can reach a size of over 5 cm. Color: yellowish-orange.

In the process of development, as all species of this genus, this species passes through the "ophiurid" stage with unbranched rays. The young live as parasites on the polyp, subsequently transferring to the back of adult specimens of its own species where it remains some time as a semiparasite.

Arctic species. Barents and Kara seas and Siberian coast. Depths: 15—1,850 m, on various sea floors. Temperatures: from -2° to +5°. Prefers temperatures of around 0°.

Gorgonocephalus arcticus Leach (Plate CXXII, 3b)

Resembles preceding species but differs from it in that its disk ribs bear a number of very irregular, more or less large, frequently coarse

spines, granules, protuberances. Spaces between ribs almost always bare, without granules. Rays better proportioned than in G. eucnemis, with longer spaces between branches.

Arctic species. Barents, White and Kara seas and along Siberian coast. Depths: 72—939 m. Prefers muddy floors. Temperatures: from -2° to $+5^{\circ}$.

Order Ophiuræ—True Ophiurids

Family Ophiomyxidae

Ophioscolex Müller et Troschel

Ophioscolex glacialis Müller et Troschel (Plate CXXII, 2a, b)

Disk and rays covered with thick soft skin. Dorsal side of disk bare, without spines. Dorsal plates rudimentary, not visible. Three and sometimes four thin spines on the rays are covered with skin. Rather large forms. Disk diameter up to 25 mm. Color coral-red. Phosphorescent in darkness.

Arctic-boreal species. Barents and Kara seas. Depths: 37—1,900 m. Prefers depths of around 400 m and muddy floors. Temperatures: from -2° to $+5^{\circ}$.

Family Ophiocanthidae

Ophiocantha Müller et Troschel

Ophiocantha bidentata Retzius

Disk dorsally and ventrally uniformly covered with a dense layer of low spines with several points. Radial ribs not prominent. Rays bear 6—9 long spines; average size. Disk diameter up to 12 mm. Color dark-brown. Phosphorescent in darkness.

Most common echinoderm species in the north. Arctic-boreal species. Barents, White and Kara seas and along Siberian coastline (also Northern Pacific to the shores of Japan). Depths: 5—4,500 m. Various sea floors. Temperatures: from -2° to $+7^{\circ}$. Salinity from 18‰ and higher.

Family Ophiactidae

Ophiopholis Müller et Troschel

Ophiopholis aculeata Linnaeus (Plate CXXII, 1a—c)

Disk on dorsal side bears rounded, bare plates and blunted low spinules. Some spinules can be rather high. Rays relatively wide, short, coarse. Their oval dorsal plates are surrounded by additional small plates (Plate CXXII, 1c)—a feature by which this species is readily distinguishable from others. Average sizes, with disk diameter up to 20 mm. Color extremely variable, ranging from yellowish to rose-colored to different patterns of red.

Very common arctic-boreal species. Barents, White and Kara seas and Siberian Sea (also along Pacific coast down to Japan). Depths: 0—1,880 m; prefers depths of 100—500 m, on various floors. Temperatures: from -2° to $+7^{\circ}$. Salinity from 30‰ and higher.

Family Amphiuridae

Amphiura Forbes

Key for determining the Amphiura species of the northern waters of the USSR

- 1 (2) Disk, dorsally and ventrally, covered with dense scales. Ray spines simple. Large forms up to 20 mm in diameter
 Amphiura sundvalli

2 (1) Entire ventral side covered with scales; dorsal side has bare sections along interradiial margins (Plate CXXI, 11). Small forms up to 5—6 mm in diameter. Rays seven times longer than disk diameter Amphiura borealis

Amphiura sundevalli Müller et Troschel

Extremely variable, widely distributed species. Dorsal side of disk usually covered with small identical scales. Occasionally larger primary plates become more prominent. Small scales also cover the disk at the interradiial bulges on the ventral side. Ambulacral spines normally bear one scale each, but frequently this scale is lost on some ray segments. Sometimes the scales are lacking on most or all of the segments. All lateral spines, whose number varies from 4 to 6, are simple. Color yellowish.

Arctic circumpolar species. Barents and Kara seas (also Bering Sea). Depths: 8—413 m. Occurs on different sea floors, prefers muddy floors. Temperatures: from -2° to $+4^{\circ}$. Salinity from 18‰ and higher.

Amphiura borealis G. Sars (Plate CXXI, 11)

Margins of interradii on dorsal side of disk, and its ventral side, are bare. Remainder of disk is covered with small scales. Ambulacral scales lacking. 3—4 lateral spines. Second spine from top is wide, flattened, widened at end. Color reddish or pale-blue. Small forms.

Boreal species. Western part of Barents Sea. Depths: 150—800 m.

Family Ophiolepidae

Ophiocten Lütken

Ophiocten sericeum Forbes (Plate CXXI, 9a, b)

Disk markedly flattened with sharp margins. Rays thin, break off easily. Dorsally, disk bears several large primary plates. The spaces between them are filled with very small scales. Very slight recesses in the disk margins near the base of the rays. Entire margin of recess covered with a solid row of tapered papillae. Color mostly violet.

Very common arctic-boreal species. Barents and Kara seas and along Siberian coast (also Bering Sea). Depths: 3—4,500 m. Occurs on different sea floors, prefers muddy floors. Temperatures: from -2° to $+5^{\circ}$. Salinity from 31.5‰ and higher.

Stegophiura Matsumoto

Stegophiura nodosa Lütken

Disk bulging, dorsally covered with large, somewhat bulging plates. Rays relatively short, thick at the base and gradually tapering toward the end. 3—6 ambulacral scales which change directly to short lateral spines. Ray spines very short, several times shorter than the lateral plates; 2—4 spines; spine length varies, can be lacking completely on some segments. Color bright-red. Disk up to 20 mm in diameter. Viviparous.

Arctic circumpolar species. Spitsbergen coast and eastern part of Barents Sea, White and Kara seas and Siberian coast (also Bering Sea and Pacific coast down to Korea). Depths: 0—380 m. Prefers depths down to 100 m. Occurs on various sea floors, but prefers sandy floors. Temperatures: from -2° to $+4^{\circ}$. Can endure, temporarily, a water temperature of up to $+16^{\circ}$. Salinity from 18‰ and higher.

Ophiura Lamark

Key for determining Ophiura species of the northern waters of the USSR

- 1 (2) Width of mouth plates exceeds length. Dorsal plates on rays narrow; ventral plates heart-shaped, with the point oriented toward the center (Plate CXXI, 8a, b). Small forms Ophiura robusta
- 2 (1) Length of mouth plates usually exceeds width; these dimensions are hardly ever identical (Plate CXXI, 7) 3
- 3 (4) Each ray segment bears three short spines, being significantly shorter than the lateral plate of the ray (frequently they scarcely reach half the length of the lateral plate). Disk markedly flattened. The first dorsal plate, situated in the disk recess among papillae, is simple, not divided into parts . . Ophiura albida
- 4 (3) Each ray segment bears two longer and one or several shorter spines. These spines are of the same length or longer than the lateral plate of the ray 5
- 5 (6) At least two ambulacral scales present in the basal part of the ray, in larger specimens 4—5 scales. Ventral plates of rays wide. More or less large forms (Plate CXXI, 7a—c) Ophiura sarsi
- 6 (5) Entire length of ray bears only one ambulacral scale. Mouth plates very large, almost twice as long as wide. Forms small, scarcely 7—8 mm in diameter Ophiura affinis

Ophiura robusta Ayres (Plate CXXI, 8a, b)

Dorsal side of disk covered with large uniform scales. Scales on ventral side almost of the same size. Disk recesses not deep. Mouth plates wide, width exceeding length (these measurements very rarely equal). One small ambulacral scale; three short lateral spines, the upper one of which is longer than the other two and almost the same length as the segment. Color mostly brown. Disk diameter up to 10 mm.

Arctic-boreal species. Barents, White and Kara seas. (A related species, O. maculata which may be only a subspecies of O. robusta, occurs

in the Bering and Okhotsk seas). Depths: 3—450 m. Various sea floors. Temperatures: from -2° to $+7^{\circ}$. Salinity from 30‰ and higher.

Ophiura albida Forbes

Dorsal side of disk covered with varisized scales. Primary plates not particularly well-defined. Radial plates can be one-third of the size of the disk radius and are adjacent to each other at their wide points. Three short lateral spines, which are at least twice as short as the lateral plate. Disk diameter up to 15 mm. Color: rose-colored-gray or pale-blue at the top and white from the bottom.

Boreal species. Western Murman coast. Depths: 4—850 m.

Ophiura sarsi Lütken (Plate CXXI, 7a—c)

Dorsal surface covered with varisized scales. Primary plates can be well-defined. Radial plates large, prominent, extending approximately up to the center of the radius of the disk. They may be immediately adjacent to each other. Basal part of ray bears 4—5 but not fewer than two ambulacral scales. Three lateral spines, with the two upper ones being longer than the lower one and, usually, longer than the ray segment. After O. borealis it is the largest of the true ophiurs of the north. Disk diameter up to 40 mm. Color variegated.

Arctic-boreal species. Barents Sea (mostly within the influence of Gulfstream currents), Kara Sea and Siberian coast (also Bering Sea, Sea of Okhotsk and Sea of Japan). Depths: 3—3,000 m. Various sea floors. Temperatures: from -2° to $+7^{\circ}$. Prefers above 0° temperatures. Salinity from 33‰ and higher.

Ophiura affinis Lütken

Dorsal surface covered with small scales, including well-defined primary plates. Radial plates small, not touching each other. Mouth plates large and very long; length almost twice as long as width. One ambulacral scale; three lateral spines, the upper one of which being longer than the others and reaching a length equal to that of a ray segment. Disk up to 8 mm in diameter. Color reddish-brown or gray.

Boreal species. Western Murman coast. Depths: 8—550 m.

Ophiopleura Danielssen et KorenOphiopleura borealis Dan. et Koren

Dorsal surface covered with small scales that are not very noticeable because they are covered with a thick skin. Radial plates well-defined, small, oval shape, with large distances between them. Disk recess at base of rays quite deep, without papillae. Mouth plates triangular with curved corners. Three rudimentary, very short, lateral spines. Largest of the true ophiuroids in the north. Disk diameter up to 45 mm. Color yellowish-red.

High-arctic species. Northern part of Barents Sea and Kara Sea and Siberian coast. Depths: 10—1,400 m. Muddy-rocky sea floors. Temperatures: from -2° to $+1^{\circ}$.

Class Echinoidea—Sea Urchins

Sea urchins are distinguished by their lack of prominent rays (the same as in holothurians) and by the presence of a compact calcareous shell consisting of immovably joined plates. Sea urchins lead a mobile way of life. Its tube feet are arranged in rows going from one pole to the other.

The mouth is on the underside and the anus is on the upper surface. Most sea urchins have a masticatory apparatus (Aristotle's lantern) located deep in their mouth cavity.

True sea urchins have a globular body which is slightly flattened at the bottom; irregular sea urchins have an egg-shaped, heart-shaped or disk-shaped body. The surface of the body is covered with many spines, sometimes very long ones, pedicellariae of various forms which are used for the removal of dirt, catching prey and for defense (gemmiform pedicellariae contain toxic glands) and with sphaeridia which are used as tactile organs.

To determine the number of distribution of ambulacral pores, a piece of skin and spines should be removed with a scalpel. The pedicellariae are examined under a microscope. The details that must be known for a determination are shown in Fig. 60.

The sea urchins that occur in the northern waters of the USSR belong to three orders: True sea urchins (Diadematoidea), flattened sea urchins (Clypeastroidea) and heart urchins (Spatangoidea). The first of these orders is distinguished by a globular body and central location of mouth and anum on opposite sides of the body. The flattened sea urchin, as the name implies, is distinguished by a strongly flattened, frequently disk-shaped body. Its mouth is located centrally but its anus is removed to the shell margin. The distinguishing features of heart urchins are a heart-shaped body and the eccentric locations of mouth and anus.

The true sea urchins listed in the key belong to two families, the Echinidae and the Strongylocentrotidae, which differ from each other by the number of ambulacral pores on the ambulacral plates (3 in Echinidae, 4—7 in Strongylocentrotidae) and by the presence of valves on the gemmiform pedicellariae (Plate CXXIII, 1b, c, 2a, b). The heart urchins occurring in northern waters of the USSR belong to two families, Hemiasteridae and

Pourtalesiidae. The former is distinguished by the frequency of a heart-shaped body, and the latter by an oblong body and a "proboscis" in the posterior part of the body.

Key for determining the genera of sea urchins of the northern waters of the USSR

- 1 (4) Body more or less globular (Plate CXXIII, 1a). Mouth and anal openings located centrally on opposite sides of the body. A masticatory apparatus (Aristotle's lantern) 2
- 2 (3) Ambulacral plates bearing three pairs of pores (Plate CXXIII, 2a). In addition to the unpaired hook on the valve of the gemmiform pedicellariae, there are paired lateral teeth (Plate CXXIII, 2b). Body almost globular Echinus, p.488
- 3 (2) Ambulacral plates (Plate CXXIII, 1b) contain more than three pairs of pores (from 4 to 7). Valves of gemmiform pedicellariae are equipped with one unpaired terminal hook (Plate CXXIII, 1c). Body more or less dorsoventrally flattened . Strongylocentrotus, p.488
- 4 (1) Body egg- or heart-shaped. Mouth located centrally or eccentrically; anal openings always located eccentrically in the shell margin or on the ventral side. Aristotle's lantern lacking in most specimens 5
- 5 (6) Mouth opening central. Body egg-shaped. Anal opening on ventral side. Presence of Aristotle's lantern. Small forms
. Echinocyamus, p.488
- 6 (5) Mouth opening eccentric 7
- 7 (8) Body heart-shaped. Anal opening on shell margin. Apical (dorsal) field near posterior end of body (Plate CXXIII, 3). Aristotle's lantern lacking. More or less large forms Brisaster, p.489

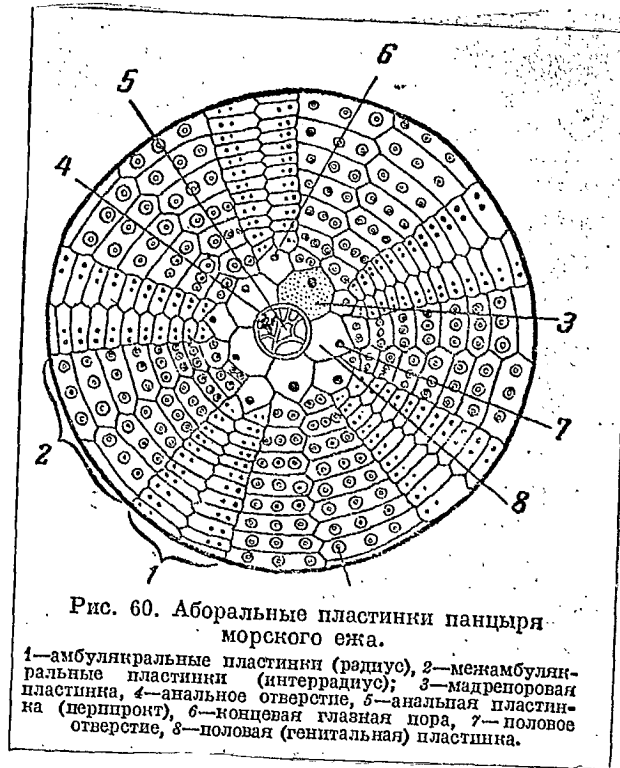


Fig. 60. Aboral plates of a sea urchin.

1—ambulacral plates (radius); 2—interambulacral plates (interradius);
 3—madreporic plate; 4—anal opening; 5—anal plate (periproct);
 6—terminal eye pore; 7—genital opening; 8—genital plate.

8 (7) Body strongly elongated with a snout-like process in the posterior part (Plate CXXIII, 4) Pourtalesia, p.489

Order Diadematoidea

Family Echinidae

Echinus L

Echinus esculentus L

Largest member of sea urchins (up to 170 mm in diameter) occurring in our northern waters. Body almost globular, with slight flattening at the bottom. Spines relatively short, violet or reddish with violet-colored

ends. Shell red. Each ambulacral plate bears three pairs of pores (Plate CXXVIII, 2a). The gemmiform type pedicellariae bear, in addition to an unpaired terminal hook, one lateral tooth on each side toward the end of the valve.

Boreal species. Western Murman coast. Enters Kola Gulf during warming periods. Depths: from 0—1,200 m (prefers a depth of down to 100 m). Thermophilic.

Family Strongylocentrotidae

Strongylocentrotus Brandt

Strongylocentrotus droebachiensis O. F. Müller

Most common, widely distributed species of northern sea urchins. Smaller than the preceding species (diameter up to 90 mm). Color extremely variable—from white-greenish, to dark-violate, almost black. Length of spines also variable. Body somewhat flattened dorsoventrally. Each ambulacral plate bears 4—7 pairs of pores (Plate CXXVIII, 1b). Valves of gemmiform type pedicellariae bear only one terminal tooth; lateral teeth lacking.

Arctic-boreal, circumpolar species. Barents, White, Kara, and Siberian seas from the west to Taymyr, and east of Wrangel Island (also Northern Pacific down to Korea). Depths: 0—1,200 m (prefers a depth of 200 m). All sea floors. Temperatures: from -2° to $+6^{\circ}$, prefers the low temperature above 0° . Salinity from 27‰ and higher, preferably around 34‰.

Order Clypeastroidea

Family Fibulariidae

Echinocyamus Leske

Echinocyamus pusillus O. F. Müller

Small species (up to 15 mm in length). Body elongated, oval. Anal opening on ventral side near mouth. Lantern present. Color grayish or greenish.

Boreal species. Finmark . During marked warming periods this species can probably enter the western Murman coast, but so far it has not been found there. Depths: to 1,200 m. Sea floors: sand, gravel.

Order Spatangoidea

Family Hemiasteridae

Brisaster Gray

Brisaster fragilis Dübén et Koren (Plate CXXIII, 3)

Average size (length to 90 mm). Body heart-shaped, flattened, toward the posterior end somewhat higher. Posterior end of shell high, steep, with anal opening in its upper part. Color dark-brown. Shell thin, very brittle, hence the name of the species. Apical plate situated toward posterior part of body. Dorsal spines short, anterior spines markedly longer, ventral spines rather long, slightly curved.

Boreal species. Southwestern part of Barents Sea. During warming periods occurs in large quantities in the Kola Gulf. Depths: 65—1,300 m (in Barents Sea, 124—413 m). Occurs on various floors, prefers muddy-sandy floors. Temperatures: 0°—5°.

Family Pourtalesiidae

Pourtalesia Agassiz

Pourtalesia jeffreysi W. Thomson (Plate CXXIII, 4)

Body cylindrical, elongated with a snout-like process at the posterior end. Shell thin, brittle. Color dark-reddish-violet. Average

dimensions, up to 60 mm in length. Apical system located toward the anterior. Carina present dorsally and ventrally. Dorsally carina slightly overhangs anal opening.

High-arctic, abyssal species. Northern parts of Barents and Kara seas. Depths: 220—2,450 m, preferably below 800 m. Temperatures: from -2° to $+1^{\circ}$. On muddy floors.

Class Holothuroidea

Body elongated, worm-shaped or barrel-shaped. Holothurians, as sea urchins, do not have prominent rays. Of the echinoderms, holothurians have the least developed calcareous skeleton, which in the holothurians consists of small individual calcareous bodies of various forms. These bodies are not regularly arranged and sometimes they are lacking altogether. The mouth is in the anterior part of the body, the anal opening in the posterior. The mouth is surrounded by tentacles that are frequently branched. Dorsal and ventral sides of body almost always distinguishable. The ventral side is frequently flattened and sometimes forms a creeping sole. Holothurians, as irregular sea urchins, deviate from radial symmetry and return to bilateral symmetry.

In classifications it is frequently necessary to establish the form and relative positions of the calcareous bodies. This can be accomplished by boiling a piece of skin in an alkali solution (10% KOH). The liberated bodies are then examined under a microscope. The location of the bodies is established by clarifying a piece of skin in clove oil, bergamot oil or in xylene.

The holothurians occurring in the northern waters of the USSR belong to five orders: Elasipoda, Aspidochirota, Dendrochirota, Molpadonia and Apoda. The first three of these orders differ from the last two in

that they have tube feet. Dendrochirota are distinguished from Elasipoda and Aspidochirota in that the former have branching retractile tentacles, whereas the latter have short, shield-shaped tentacles that are not retractile. The Elasipoda differ from Aspidochirota by their small number of large-sized tube feet which are situated along the sides of the body. Molpadonia, which have a spindle-shaped or globular body whose posterior end is tapered into a tail-like structure, are distinguished from Apoda, which have a worm-like body that is uniformly curved at the posterior end.

The Dendrochirota listed in the key belong to two families:

Cucumariidae, which have dorsal as well as ventral tube feet but do not have a well-defined sole and tile-like scales; and Psolidae, which have tube feet only on the ventral side which has the appearance of a sole. The remainder of their body surfaces is covered with tile-like scales. The Molpadonia also belong to two families: Eupyrgidae, which have simple tentacles without lateral processes, and Molpadiidae, whose tentacles are equipped with short lateral processes.

Key for determining the genera of holothurians in the northern waters of the USSR

- | | | |
|--------|--|--------------------------|
| 1 (10) | Tube feet present | 2 |
| 2 (7) | Antennae long, dendritically branched, retractile | 3 |
| 3 (4) | Tube feet present only on ventral side which is flattened like a sole. Body surfaces, except ventral, covered with tile-like calcareous scales | <u>Psolus</u> , p.493 |
| 4 (3) | Tube feet on ventral as well as dorsal side; no tile-like scales . | 5 |
| 5 (6) | 10 antennae; tube feet present only on radii, at least on ventral side (Plate CXXVIII, 5) | <u>Cucumaria</u> , p.491 |

- 6 (5) 15 and more antennae, not uniformly developed; tube feet usually distributed more or less uniformly over all body surfaces Thyonidium, p.492
- 7 (2) Antennae short, neither branched nor retractile 8
- 8 (9) Feet large, few in number (four feet on each side), located along the flanks of a flattened ventral side. On dorsal side two rows (4 feet in each) of ambulacral appendages (Plate CXXIII, 6) Elpidia, p.491
- 9 (8) Feet small and rather numerous (more than 10 on each side) on ventral side located in three longitudinal rows. Color, dorsally, reddish, at the bottom light with black dots . . . Stichopus, p.491
- 10 (1) No tube feet; antennae feather-like or finger-like 11
- 11 (18) Body elongated, worm-like, at posterior end uniformly curved . . 12
- 12 (13) Calcareous bodies shaped like anchors and round perforate plates elongated into a process on one side (Plate CXXIII, 9); 11 antennae, each bearing 3 finger-like processes . . Labidoplax, p.494
- 13 (12) Calcareous bodies shaped like wheels 14
- 14 (15) Wheel-shaped bodies grouped in small skin warts. Each wheel contains only six spokes; rim without sharpened teeth. Color milk-white Chiridota, p.495
- 15 (14) Wheel-shaped bodies scattered more or less uniformly over entire body. Each wheel has at least 8 spokes; rim bears large, sharp teeth 16
- 16 (17) Rim contains numerous triangular teeth, with sharp points orientated toward the center of the wheel (Plate CXXIII, 10). Wheels lie singly , with large distances between them. 12 antennae Myriotrochus, p.495

- 17 (16) Wheel rim contains scattered lugs pointing in all directions
(Plate CXXVIII, 11). Wheels lie close to each other. 10 antennae.
Very small forms Trochoderma, p.495
- 18 (11) Body either worm-like or round, tapered to a tail at posterior
end 19
- 19 (20) Antennae simple, without lateral processes. Body short,
barrel-shaped, with a short tail at posterior end. Calcareous
bodies resemble wide perforate plates with lug-like pyramids
rising in the center. Small forms Eupyrgus, p.494
- 20 (19) 3—7 antennae with lateral processes. Rather large forms.
Embedded in the skin in addition to calcareous plates may be
little anchor-like bodies situated on a rosette consisting of
several (3—8) elongated and perforate plates . . Trochostoma, p.494

Order Elasipoda

Family Elpidiidae

Elpidia Theel

Elpidia glacialis Theel (Plate CXXVIII, 6)

Body oval. Dimensions small (length up to 200 mm). 16 Large tube feet arranged in four rows (two lateral and two dorsal), with four feet in each row. Sole flat without feet. Mouth situated somewhat ventrally and surrounded by ten antennae. Calcareous bodies resemble rods tapered at both ends and bearing two rows of transverse processes pointing in all directions. Also present are small wheels with lugs in their rims.

High-arctic, abyssal species. Northern part of Barents Sea, Kara Sea, Shokal'sky Gulf. Depths: 70--3,000 m (prefers depths below 800 m). Muddy floors. Temperatures: from -2° to +1°.

Order AspidochirotaFamily StichopidaeStichopus BrandtStichopus tremulus Gunnerus

Body up to 50 mm in length, more or less quadrangular and ventrally somewhat flattened. Color on dorsal side red, ventrally lighter with small black dots. Tube feet in the middle row on ventral side small and sparse, in the flanking rows larger and more numerous. 20 antennae. The ring of antennae is surrounded by a fold formed by anterior papillae connected by a membrane.

Boreal species. Norwegian coastal area to Våranger fjord; has so far not occurred in Soviet waters, but can enter these waters during warming periods.

The species of this genus occurring in Far Eastern waters are edible and are sought commercially. Known by the name trepang.

Order DendrochirotaFamily CucumariidaeCucumaria BlainvilleKey for determining the Cucumaria species of the northern waters of the USSR

- 1 (2) Posterior end tapered to a tail; tube feet thin, arranged in 2—4 rows along radii Cucumaria calcigera
- 2 (1) Posterior end not tapered but uniformly curved; feet more or less thick 3
- 3 (4) Feet arranged in two irregular or in one zig-zag row along radii; feet usually absent from interradii. Skin always bears many calcareous bodies Cucumaria glacialis

4 (3) Feet situated in two or more rows on radii. On dorsal side feet also present on interradii. Skin of adult specimens (more than 20 mm in length) bears no calcareous bodies. Large forms
 Cucumaria frondosa

Cucumaria calcigera Stimpson

Body cylindrical, slightly curved, 60 mm in length, and yellowish-white in color. Posterior end tapered to a tail. Feet small, numerous, arranged in two parallel rows only on radii. The two rows may give way to four rows in the middle of the ray. Skin always bears many calcareous bodies arranged in two layers. Internal layer consists of elongated, perforate plates; external layer is in the form of small pedestals (plates with a rising peg in the center).

High-arctic species. Southeastern part of Barents Sea, White and Kara seas (also Northern Pacific down to the Sea of Japan). Depths: 8—143 m. Sandy floors. Temperatures: from -2° to $+3^{\circ}$. Salinity: from 31‰ to 34.25‰. Most frequent occurrence in salinity of around 31.5‰.

Cucumaria glacialis Ljungman

Body short, cylindrical, with hardly any tapering; up to 80 mm in length; white. Posterior end uniformly curved; feet arranged in one or two irregular rows on radii. Skin always bears many calcareous bodies arranged in two layers. Internal layer consists of plates with many perforations; external layer consists of infrequent cross-shaped bodies. Viviparous.

High-arctic species. Eastern part of Barents Sea, eastern coast of Spitsbergen, Kara Sea, Siberian coastal area (also Bering, Okhotsk and Japan seas). Depths: 15—200 m. All types of sea floors. Temperatures:

from -2° to $+4^{\circ}$. Prefers below 0° temperature. Salinity: from 27‰ to 35‰. Most frequent salinity range: from 29 to 33‰.

Cucumaria frondosa Gunnerus (Plate CXXIII, 5)

Body cylindrical, resembles a cucumber; up to half meter in length; color dark, brown or violet. Feet arranged in two and more rows, not only on radii but also between them, especially on dorsal side; feet can be retractile, in contrast to those of the two preceding species. Calcareous bodies few, in adult specimens absent altogether. In young specimens these calcareous bodies are in the shape of perforate plates with low elevations.

Arctic-boreal species. Barents Sea—only in shallow areas affected by warm currents, i.e. entire Murman coast, Medvezh'e Bank, coastal areas of Spitsbergen, the funnel-shaped part of the White Sea, the Kara Sea near the entrance of Karskie Vorota [Kara Strait]. Depths: 0—300 m. All types of sea floors, but prefers sandy floors. Temperatures: from -2° to $+6^{\circ}$. Prefers above 0° . Occurs in such large quantities in Barents Sea that it actually interferes with trawl fishing.

Thyonidium Dübet Kor

Key for determining the Thyonidium species of the northern waters of the USSR

- 1 (2) Skin thin, transparent; feet large and relatively few; Calcareous bodies scattered over entire body, including those of adults.
Calcareous bodies are in the form of plates with relatively large perforations and low central elevations . . . Thyonidium pellucidum
- 2 (1) Skin thick, opaque; feet small, numerous; calcareous bodies infrequent and in adults may be lacking altogether. The calcareous bodies themselves are in the form of plates with small perforations

and a higher central elevation which is absent in some cases

(Plate CXXIII, 8) Thyonidium commune

Thyonidium pellucidum Fleming

(Phyllophorus pellucidus Trosch) (Plate CXXIII, 7)

Body short, cylindrical, somewhat tapered toward the ends; body rose-colored with violet antennae up to 12 cm in length. Feet present on interradii as well as on radii. Typical forms have 20 antennae, with 15 antennae in the eastern variety (var. Barthi Trosch). Calcareous bodies scattered over entire animal body. In large specimens these calcareous bodies are infrequent and concentrated near body margins.

Arctic-boreal species. Barents, White and Kara seas, and Siberian coast. Depths: 10—380 m on all sea floors. Temperatures: from -2° to $+5^{\circ}$. Prefers low above 0° temperature. Salinity: 29—35‰. Most frequent occurrence at salinity of 32—33‰.

Thyonidium commune Forbes (Plate CXXIII, 8)

(Phyllophorus drummondi Thoms.)

Body longer than that of the preceding species, with thick opaque skin of various colors (from white to dark-brown); up to 20 cm in length. Small, numerous feet present over entire body. Fewer calcareous bodies than in preceding species. In young specimens these bodies are concentrated in the anterior part, in adults they can be absent together. Some researchers regard both of these Thyonidium species as subspecies of one species.

Boreal species. Barents Sea, Spitsbergen coast, Kola Gulf.

Family Psolidae

Psolus Oken

Key for determining Psolus species of the northern waters of the USSR

- 1 (2) Body more or less cylindrical, elongated, slanted upward at both ends. Underside contains three longitudinal rows of feet (one middle row and two lateral). Scales relatively small, not well-defined, containing frequent, small granules Psolus phantapus
- 2 (1) Body shows more dorsoventral flattening, not elongated at either end. Underside contains two longitudinal rows of feet. Scales relatively large and well-defined Psolus fabricii

Psolus phantapus Strussenfelt

Body of adult specimens almost cylindrical, with a marked upward slant at both ends, especially at posterior end; up to 15 cm in length; color varies from yellowish-brown to almost black. Tube feet on underside arranged in three rows. Body of young specimens more flattened with slight upward slanting. These specimens can be distinguished from specimens of the following species only on the basis of their internal structure. Two retractile dorsal muscles are attached to the body wall in the interradii areas, whereas in Psolus fabricii these muscles are attached radially to longitudinal muscle bands.

Arctic-boreal species. Barents and White seas. Depths: 0—380 m. Various sea floors, prefers muddy floors. Temperatures: from -2° to +4°. In the Barents Sea this species occurs most frequently at low temperatures.

Psolus fabricii Dübén et Koren

Body markedly flattened, with wide underside and slightly prominent cones; up to 10 cm in length; color yellowish; middle row of feet always absent but can be faintly outlined in the anterior and posterior parts of the underside.

Arctic species. No reliable proof of its occurrence in the Barents and White seas. Near New Siberian Islands (also Sea of Okhotsk).

Order Molpadonia

Family Eupyrgidae

Eupyrgus Lütken

Eupyrgus scaber Lütken

Body short, barrel-shaped, with a short, tapered tail in the posterior end; color blue-gray; length up to 12 mm. 15 simple tentacles without lateral processes. Calcareous bodies in the form of wide plates containing a large number of perforations and a central elevation shaped like a pyramid and apex of which is covered with spinules.

Arctic, circumpolar species. Barents and Kara seas and Siberian coast. Depths: 7—480 m. Various sea floors but prefers mud. Temperatures: from -2° to $+3^{\circ}$. Occurs most frequently at below 0° temperatures.

Family Molpadiidae

A systematic division of holothurians of this family and occurring in the northern waters of the USSR has still not been resolved. Two Soviet investigators have opposing views in this regard. D'yakonov subdivides these holothurians (following Heding's work) into two genera and six species. He admits that "the question regarding their individual specificity has not yet been fully established..." Shorygin, on the other hand, regards all of them as one species which divides into two geographic subspecies. However, in the northern parts of the Barents and Kara seas one comes across specimens that do not fit Shorygin's scheme. Until the question is resolved, we shall adhere to a simpler classification, all the more, because even if the six species do exist, their determination, which is

based on extremely variable indicators, would be very difficult for beginners to carry out.

Trochostoma Dan. et Koren

Trochostoma obliticum Pourtales

Body elongated with a thin tail at posterior end. Color varies, usually dark, brown, sometimes with a violet tone. Extremely variable. Skin can contain a large number of red corpuscles; but they can also be few in number or may be absent altogether. The calcareous corpuscles may include little anchor-type bodies (protruding from the skin) sessile on a rosette of elongated plates. Other corpuscles may be in the form of little benches with a style. The corpuscles themselves have little processes whose ends either protrude freely or adjoin each other forming a series of closed orifices. The number and form of these corpuscles can vary greatly.

Arctic-boreal form. Barents and Kara seas and Siberian coastline. Depths: 160—1,203 m. Muddy sea floors. Temperatures: from -2° to $+5^{\circ}$.

Order Apoda

Family Synaptidae

Labidoplax Oestergr.

Labidoplax buski M. Intosh (Plate CXXIII, 9)

Body worm-shaped, uniformly curved at the posterior end, with thin, transparent skin; up to 30 mm in length. 11 antennae, each of which has three processes: two short ones on the sides and one longer one at the apex; calcareous corpuscles in the form of anchors and anchor-like plates; the anchors have a motile function.

Boreal species. Western Murman coast to the Kola Gulf. Kola Gulf. Depths: 10—420 m.

Chiridota Esch scholtzChiridota laevis Fabricius

Body long, worm-like, with thick skin; color whitish; up to 200 mm in length. 12 antennae, each bearing 16 lateral processes. Calcareous corpuscles in the form of wheels are arranged in groups in the inter-radii, forming irregular longitudinal rows.

Low-arctic species. Spitsbergen coast, Murman coast, Kola Gulf, White and Kara seas. Depths: usually less than 100 m, although known to occur down to a depth of 400 m. Mostly on sandy floors.

Trochoderma TheelTrochoderma elegans Theel

Small forms up to 15 mm in length, with 10 tentacles, silvery-whitish color. Many calcareous corpuscles arranged in the skin in several layers. The corpuscles are in the form of wheels with 10—16 spokes and a rim which contains spines pointing in various directions (Plate CXXIII, 11).

Arctic species. Barents and Kara seas and Siberian coast. Depths: 9—250 m.

Myriotrochus SteenstrupMyriotrochus rinkii Steenstrup

Body curved at posterior end, semitransparent, reddish, up to 60 mm in length. 12 tentacles. Calcareous corpuscles in the form of infrequent, large wheels with 12—25 spokes and 16—35 teeth pointing toward the center (Plate CXXIII, 10).

Arctic, circumpolar species. Barents and Kara seas and Siberian coast (also Bering Sea). Depths: 2—660 m. All floors, but prefers sandy

floors. Temperatures: from -2° to $+5^{\circ}$. Salinity: from 30‰ and higher.

Prefers regular oceanic salinity.