Chapter 4
Biodiversity of Marine Animals: Introduction to Marine Animals with a Focus on Taxonomy

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4.1 Introduction

If we examine the underside of just one stone on the seashore or observe a drop of water from a plankton net under a microscope, we will find a surprising diversity of animal life belonging to many phyla. Life was born in the sea four billion years ago, and it evolved to comprise an amazing variety of groups, some of which, such as various phyla including Arthropoda, Mollusca, Nematoda, Nematomorpha, Annelida, Platyhelminths, and Chordata, have advanced onto land. The remaining groups remain in the sea or have already become extinct. Most specialists consider the animal kingdom to contain about 35 phyla, of which approximately 12 are exclusively found in marine environments. Most of these phyla are represented on the seashore of the Noto Peninsula and its neighboring sea. The body plans of animals that inhabit the marine environment differ from those that inhabit the terrestrial environment owing to different environmental factors. For instance, the respiratory system of marine animals is different from that of terrestrial animals. Marine animals absorb oxygen dissolved in the seawater through the epidermis, gills, or respiratory tree, whereas terrestrial animals take up oxygen from the air using respiratory organs, including the lungs, book lungs, and trachea. Moreover, there is a wide variety of sessile animals such as sponges, sea anemones, corals, moss animals, barnacles, and ascidians in the marine environment. They appear similar to algae and lack the body structure such as fin and feet to chase prey and escape from predators because seawater contains a large amount of food.

In this chapter, we introduce two important concepts associated with biodiversity and show the characteristics and members of each animal phyla. The current Chapter aims to help students to learn the diversity of marine animals. Primarily, we hope

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that students use it as a textbook to study before the field activity on the seashore of the Noto Peninsula. Therefore, we mainly describe the various phyla of the marine invertebrates and represent a significant species inhabiting the inshore or offshore of the Noto Peninsula.

4.1.1 Taxonomic Rank

The Swedish naturalist Carolus Linnaeus (1707–1778) invented the binominal classification system to classify organisms. In order to increase inclusiveness, this system includes the following categories (taxonomic rank or taxonomic hierarchy): species, genus, family, order, class, division (plants) or phylum (animals), and kingdom (with domain recently added as a higher rank). Additionally, many supplementary classes are now used, such as suborder, infraorder, and superfamily.

The classification system is based on taxonomy and "taxon" is a taxonomic unit: a name given, a particular ranking. The word taxon (plural [pl]: taxa) is from the Greek "taxis," meaning arrangement, and "nomos," meaning law (Fig. 4.1). Taxonomy is a field of study involving grouping organisms based on many fields of biological science, including morphology, ecology, and genetics. It has shown rapid progression, and the classification systems have changed rapidly. This Chapter is primarily based on the study of Brusca et al. (2016) and partly on several other literatures. If students are willing to study the recent progress of taxonomy, we recommend the article by Laumer et al. (2019). Furthermore, we refer to the following articles to study deeper the chapter or different taxonomic theories: Barnes (1963), Russel-Hunter (1979), Hillis et al. (2012), Margulis and Schwartz (1997), and Zimmer and Emlen (2013).

4.1.2 Basic Body Plans of Animals

The body plan of multicellular animals is categorized into nonbilateral, radially symmetrical, and bilateral. The bilaterally symmetric body plan has an anterior end and a posterior end, i.e., a distinction exists between the head and tail, as well as a distinction between the dorsal and ventral. Taxonomically, the two groups are not formally ranked. A few groups have developed a secondary nonbilateral body plan, for example, snails and many groups of the phylum Echinodermata that have obtained secondary radial symmetry. Animals with a bilateral body plan are composed of three well-developed germ layers, the endoderm, mesoderm, and ectoderm, i.e., they are triploblastic, whereas nonbilaterian animals are diblastic or non-blastic. Generally speaking, the respective germ layers of Bilateria form the following organs: The endoderm forms mainly digestive organs including the stomach, the liver, the pancreas, and the bladder. The ectoderm forms the neuron and epidermis, including the lens of the eye. The mesoderm forms the body cavity, skeletal system, muscle, circulatory system, and so on.

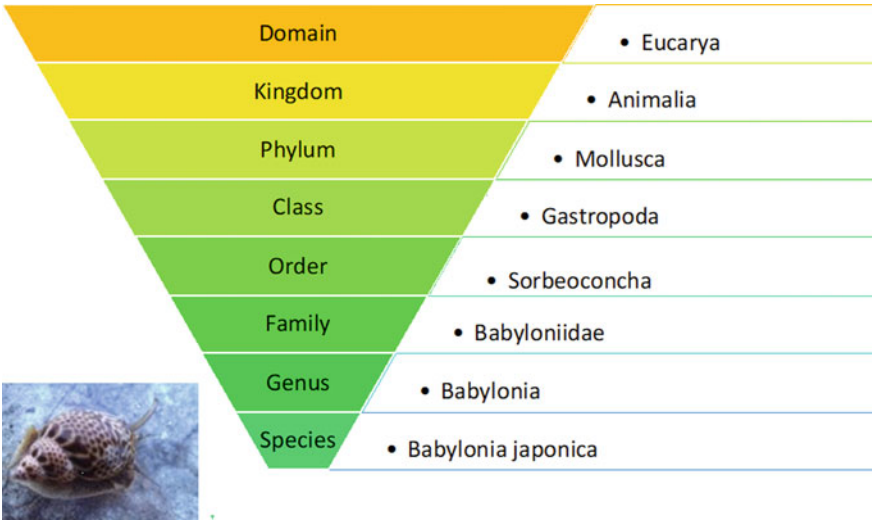

Fig. 4.1 Taxonomic rank (example of sea snail: *Babylonia japonica*)

For a long time, multicellular animals had been summed up into three groups: acoelomates, pseudocoelomates, and eucoelomates. Acoelomates are animals without a body cavity in non-blastic animals (such as Porifera), diblastic animals (such as Cnidaria), and primitive triblastic animals (such as Platyhelminthes). Pseudocoelomates have a pseudocoelom, i.e., a body cavity derived from the blastocoel and not from the mesoderm. Rotifera and some phyla, including a part of Nematoda, have been classified as pseudocoelomates. Eucoelomates have a deuterocoel and comprise phyla including Annelida, Mollusca, Arthropoda, Echinodermata, and Chordata.

4.1.3 Protostomes and Deuterostomes

Animals in which the blastopore (i.e., the first opening of the embryonic gut) develops into the mouth are called protostomes, whereas animals in which the blastopore develops into the anus are called deuterostomes. The differences between these two groups are shown in Table 4.1; however, they are both contained within the rank of infrakingdom.

Protostomes consist of the Lophotrochozoa, Ecdysozoa, and the phylum Chaetognatha. Lophotrochozoa comprises the following phyla: Platyhelminthes, Gnathostomulida, Micrognathozoa, Rotifera, Nemertea, Acanthocephala, Gastrotricha, Cycliophora, Entoprocta, Ectoprocta, Brachiopoda, Phoronida, Mollusca, and Annelida (including Echiura and Sipuncula). Dicyemida and Orthonectida are also considered to be included in this group. Ecdysozoa comprises the following phyla: Kinorhyncha,

Table 4.1 Differences between protostomes and deuterostomes

	Protostomes	Deuterostomes
The first opening of the embryonic gut	Mouth	Anus
Cleavage during cell division	Spiral cleavage	Radial cleavage
Development	Schizocoelous	Enterocoelic
Main digestive tube	Dorsal	Ventral
Representative phyla	Mollusca, Arthropoda, and Annelida	Echinodermata and Chordata

There are exceptions in many cases(1)

(1)The phyla Brachiopoda and Bryozoa belong protostomes, but their mouth does not originate from the first opening of the embryonic gut, and they exhibit a radial type cleavage during cell division. The phylum Chaetognatha has many features similar to other protostome phyla, except that the mouth and anus are formed secondarily after the closure of the blastopore

Priapulida, Loricifera, Nematoda, Nematomorpha, Tardigrada, and Arthropoda. Deuterostomes consist of the Echinodermata, Hemichordata, and Chordata. We do not discuss the phyla Placozoa, Orthonectida, Rhombozoa, Gnathostomulida, Cycliophora, Micrognathozoa, Phoronida, Nematomorpha, Kinorhyncha, Loricifera, Priapulida, Tardigrada, and Onychophora because they do not occur in the sea of Noto and its neighboring waters, they are very small, or they are deep-sea dwellers.

4.2 Classification of Animals

4.2.1 Phylum Porifera

Colorful sponges, belonging to the Porifera, can often be seen covering rocks or stones. Sponges lack digestive, circulatory, and nervous systems as well as other distinct organs. They only have a unique water-based circulatory system that maintains a constant flow of water through their bodies to obtain food and oxygen from the water (Fig. 4.2). Sponges have large and small pores; they obtain food and fresh seawater through small pores known as ostia (pl. of ostium) using flagellated choanocytes and discharge water through large pores known as oscula (pl. of osculum).

Hitherto, more than 5,000 species of sponges have been recorded. Taxonomically, sponges are classified into four classes: Calcarea (calcareous sponge), Hexactinellida (glass sponges), Demosponges, and Sclerospongiae. Demosponges include Halichondrida that are found on the rocky shore. Most of the members of the Sclerospongiae have been known only as fossils.

Fig. 4.2. Porifera, *Halichondria* sp. (*Photo* by Nunomura)

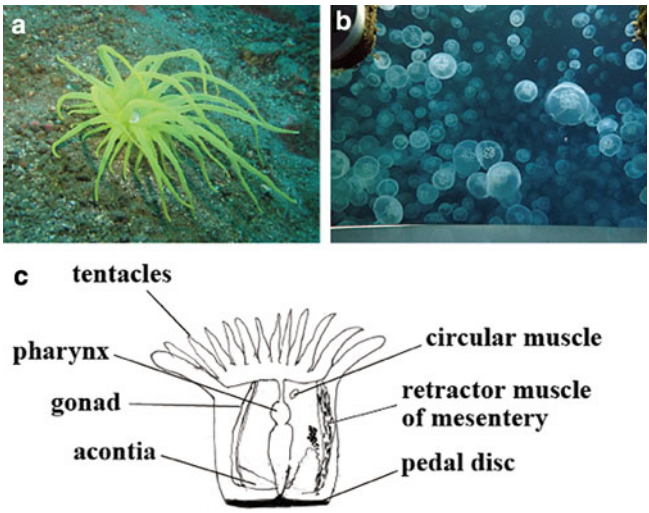

Fig. 4.3 Cnidaria. **a** *Dofleinia armata* (Photo by Ogiso), **b** *Aurelia aurita* (Photo by Ogiso), **c** Body of a sea anemone. The right half shows the part of the mesentery; the left half shows the part of the gonad (Original drawing by Nunomura)

4.2.2 Phylum Cnidaria

The phylum Cnidaria includes sea anemones (Fig. 4.3a), jellyfish (Fig. 4.3b), and corals. More than 11,000 Cnidaria species exist, and these are predominantly found in marine environments. They can be separated into three subphyla: Medusozoa (including Hydrozoa, Cubozoa, and Scyphozoa), Anthozoa, and the parasitic Myxozoa. The distinguishing feature of the Cnidaria is their cnidocytes, specialized cells that are used mainly to capture prey. Although Cnidaria were formerly placed in the phylum Coelenterate together with the Ctenophores, they were subsequently separated into two phyla.

The body of Cnidaria (Fig. 4.3c) has radial symmetry with a mouth located in the center of their body and surrounded by tentacles bearing cnidocytes. It contains

mesoglea, a nonliving jelly-like substance that is sandwiched between two layers of epithelium. Their alignment canals have a single opening, and their body cavities (a gastrovascular system) are used for digestion and respiration.

Generally, heterogony is observed in cnidarians. The majority of the Cnidaria exhibit alternation of two basic forms: swimming sexually reproductive medusae and sessile asexually reproductive polyps. Fertilized eggs hatch into planulae larvae, which are bilaterally symmetrical, ciliated, and free-swimming. The planulae larvae metamorphose into polyps followed by medusa. Many cnidarian species produce colonies that comprise medusa-like and/or polyp-like zooids.

Several free-swimming species of Cubozoa and Scyphozoa possess balance-sensing statocysts, and some groups have simple eyes. Some of the anthozoans form coral reefs, which form ecosystems that nurture a diversity of animal life in tropical and subtropical seas. Some corals are considered valuable as jewels and some parts of jellyfish are edible. Some of the most common species of the Cnidaria in the Noto Peninsula are *Carybdea brevipedalia*, *Aurelia aurita*, and *Anthopleura* spp.

4.2.3 Phylum Ctenophora

The phylum Ctenophora includes the comb jellies, which look like jellyfish due to their soft and gelatinous bodies. Most species of ctenophores have sticky colloblasts that adhere to prey, are composed of jelly-like mesoglea between two layers of epithelia, and lack eyes and apical organs. The mouth of a ctenophore is situated at its rear end, whereas the anus is at the anterior end. They discharge unwanted small particles from their anal pores, but many unwanted pieces are cast out using the mouth. The outer surface of the ctenophoran species usually bears eight rows of combs known as swimming plates, which are used for swimming. Many ctenophoran species found in shallow water are colorless and almost transparent; however, some deeper-living species are strongly pigmented and luminescent. Ctenophora comprises of approximately 100 species. In general, the Ctenophora, along with the Porifera and Cnidaria, are considered prebilateral, whereas the other phyla discussed in the following section are likely to be bilateral, except for some that have a secondary nonbilateral body plan.

4.2.4 Phylum Platyhelminthes

We can commonly find wide but dorsoventrally flat animals (Fig. 4.4a) creeping on the underside of stones or among the holdfast of algae on the seashore. They are members of the phylum Platyhelminthes.

The Platyhelminthes comprises more than 25,000 species, including flatworms (Turbellaria) and infamous parasites such as tapeworms (Cestoda), monogeneans, and flukes (Trematoda); however, some unidentified species may still exist.

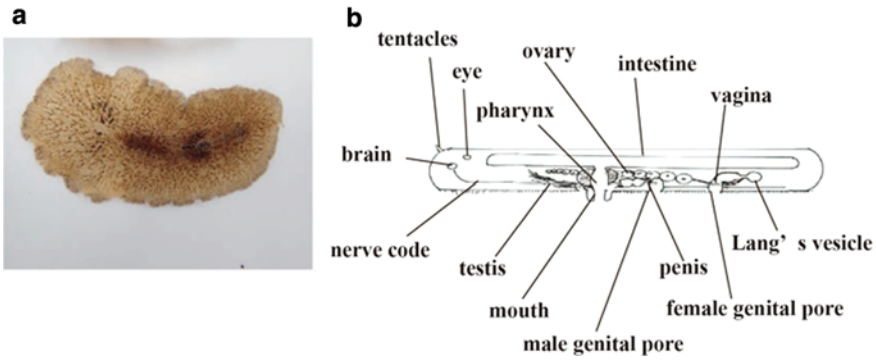

Fig. 4.4 Platyhelminthes. **a** *Planocera multitentaculata* (Photo by Ogiso), **b** Body of a Turbellaria (Original drawing by Nunomura)

Herein, we describe the characteristics of Platyhelminthes using Turbellaria as an example (Fig. 4.4b). In Turbellaria, many species are free-living, whereas some are parasitic. Because of the absence of circulatory and respiratory systems, these species obtain oxygen by direct permeation through the epidermis. Accordingly, relatively large-sized groups of Platyhelminthes have flat-shaped bodies to effectively absorb oxygen. Turbellarians can move using the many cilia found on their ventral surface, and they occasionally swim by winding cilia on the ventral surface. As a sensory system, some species have eye spots or tentacles on their anterior part, whereas species that inhabit the soft sea bottom have statocysts instead of eyes. Most Turbellarians, except for a few species, have a mouth but lack an anus. As far as Polycladida, the most conspicuous order of Turbellarians, is concerned, the mouth is usually located near the center of the ventral side of the body, and the intestine has a complex branching pattern. The excretory system is the most primitive, with protonephridium-bearing flame cells. Polyclad Turbellarians are carnivorous and primarily prey on bivalves. The majority of Turbellarians are hermaphrodites; they have big testes and ovaries that occupy most of their body space. Among Turbellarians, small-sized groups are found in the interstitial environment of sandy beaches.

Cestoda and Trematoda lack sensory organs because of the adaptation to parasites. Moreover, Cestoda lacks digestive organs.

The most common species are *Notoplana humilis* and *Planocera multitentaculata* in the Noto Peninsula (Fig. 4.4a).

4.2.5 Phylum Nemertea (Nemertini)

Many members of the phylum Nemertea or ribbon worm (Fig. 4.5a) inhabit the underside of stones or holdfast of algae on the seashore or on the sandy bottom. It comprises more than 1,000 species. Like the platyhelminths, the Nemertea lack a

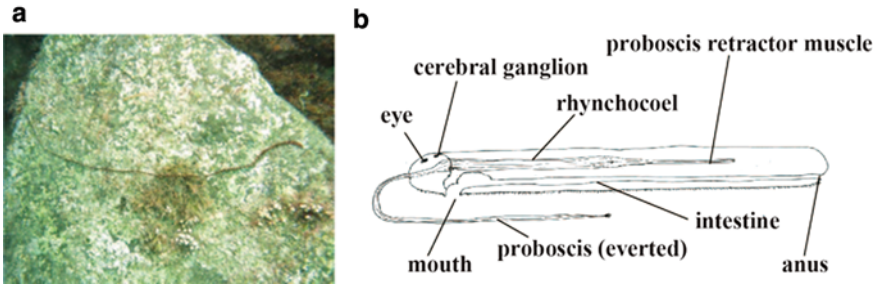

Fig. 4.5 Nemertea. *Notospermus geniculatus* (Photo by Ogiso), B. Body of Nemertea (Original drawing by Nunomura)

coelom and have pronephridium-type excretory organs. However, they have a thick and elongate body (Fig. 4.5b) because they possess a circulatory system, which transports oxygen and nutrients via vessels. Typical nemerteans are carnivores that hunt for prey using a unique eversible proboscis, which is stretched by a muscle lying in the large cavity of the rhynchocoel during the inactive state. The mouth opening of nemerteans is at the anterior margin, whereas the anus is at the rear end. Nemerteans move slowly, using their external cilia to glide on the surface. Although they have a long-unsegmented body, the muscle is alternatively thick and thin. Thus, larger species can move using muscular waves. *Notospermus geniculatus* and *Lineus fuscoviridis* may be relatively commonly seen in the Noto Peninsula.

4.2.6 Phylum Annelida

The phylum Annelida includes ragworms, earthworms, leeches, and various other groups. There are more than 17,000 valid species. Traditionally, annelids bearing many chaetae and parapodia (pl. of parapodium) were summarized as "Polychaeta." However, the classification of the Annelida has changed markedly over time, and the "Polychaeta" is now considered to be a paraphyletic group: the "Polychaeta" has been proved to include groups that are distantly related to each other. In addition, tube worms (Vestimentifera), peanut worms (Sipuncula), and spoon worms (Echiura) were previously considered to be separate phyla, but they have all recently been incorporated into the phylum Annelida. The typical marine annelids are Polychaeta-shaped, (Fig. 4.6a) which are long segmented worms found among the holdfast of algae or under stones on the seashore. Their bodies (Fig. 4.6b) consist of many annular segments, except for some unsegmented annelids belonging to Archiannelida, Echiura, and Sipuncula. The first segment bears eyes on other sensory organs, while the second segment bears a mouth opening. The anus opens on the last segment, i.e., the pygidium. Each segment bears a pair of fleshy protrusions, the parapodia, and many chaetae (chitinous bristle). The body of Annelida is composed of three germ layers, and they have a closed circularity system in the coelom in the mesoderm.

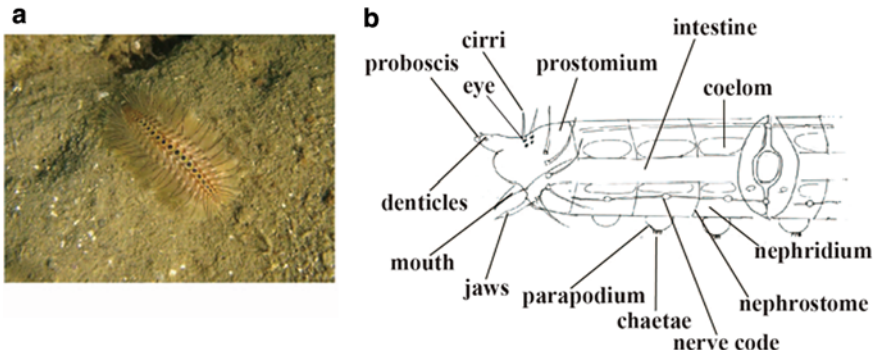

Fig. 4.6 Annelida. **a** *Chloeia flava* (Photo by Ogiso), **b** Body of Polychaetous Annelida (Original drawing by Nunomura)

Many species are sexually gonochoristic, whereas some species are hermaphroditic. During their development, they carry spiral cleavage postfertilization and larvae are typically trochophores; subsequently, they become only a few-segmented larvae, and finally they reach the adult stage. The body surface and parapodia of Annelida function as respiratory organs. The metanephridium has developed as an excretory organ. The nervous system is ladder-like and runs along the ventral side.

Several species are used as fishing bait and, rarely, some are used for food. The most common "polychaetous" annelids in the Noto Peninsula are *Nereis multignatha*, *Platynereis bicanaliculata*, *Perinereis cultrifera*, and *Chloeia flava* (Fig. 4.6b).

4.2.7 Phylum Mollusca

The phylum Mollusca, including Gastropoda, Bivalvia, Cephalopoda, Scaphopoda, Polyplacophora, and some other classes, is arguably one of the most popular marine animal groups. The body of many groups consists of the head, viscera, muscular foot, and mantle (Fig. 4.7). Essentially, they have a bilaterally symmetrical body. However, many snails have a secondary asymmetrical form due to coiling. The body of Mollusca has three germ layers, but their coelom is small due to their strongly developed muscles. Their main body cavity is an open circular system, i.e., haemocoel, except for in Cephalopoda. Their excretory system comprises large metanephridia (pl. of metanephridium), i.e., the kidneys. Some members of the group possess a buccal region with a grater-like radula. Many members also bear a hard calcareous shell. They do not have inner skeletons and lack segmentation, whereas most groups have mantle-containing shell glands that secrete the calcareous epidermis shell. Many species are gonochoristic, but others are hermaphroditic. They possess many types of sensory organs, e.g., eyes, osphradia (pl. of osphradium), and statocysts. During development, they show spiral cleavage after fertilization, and

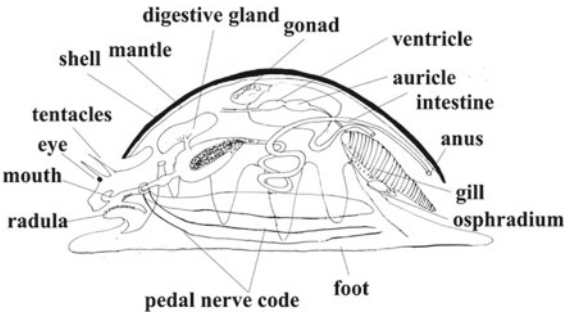

Fig. 4.7 Schematic pattern of a hypothetical ancestral form of Mollusca (Modified after Barnes 1963)

typical larvae become trochophores and then veligers (except for those of Polyplacophora). Many Mollusca groups move rather slowly, but some can swim fast using jet injection. Mollusca comprise the second largest phylum, containing 112,000 species. The other Mollusca groups, except for those mentioned below, are omitted from the discussion because they may not exist in the Noto Peninsula or its neighboring area, they are very small, or they are deep-sea dwellers.

4.2.7.1 Class Gastropoda

The Gastropoda comprises various groups such as the keyhole limpets, top shells, sundials, tower shells, horn shells, and conches; some groups have their original gills, some have secondary gills instead of their lost original ones, and others have lungs instead of gills. Many species of snails occur on the rocky shore. Gastropods have essentially a bilateral body, but many groups show coiling. However, in limpets and some other gastropods, coiling is lost. The Gastropoda have well-developed heads with tentacles and eyes. The buccal part has a grater-like radula.

The Gastropoda were formerly classified into three subclasses depending on the position of the gills and heart: Prosobranchia (gills situated in front of the heart), Opisthobranchia (gills behind the heart), and Pulmonata (possessing lungs but not gills). Recently a new classification system to divide the Gastropoda into five subclasses has been proposed. We will show the diversity of the Gastropoda according to the new classification system (Ponder and Lindberg 1997).

The subclass Patellogastropoda, comprising the true limpets having a flat shell, are found on rocks and wave-out blocks. Many species of the Patellogastropoda leave "scars" on the rock to which they return between tides. Only a few species from the families Patellidae and Acmaeidae occur in the Noto Peninsula.

The subclass Vetigastropoda (Fig. 4.8a) comprises many groups of representative sea snails, including abalones and some limpets such as keyhole limpets. Many species of Vetigastropoda have a single pair of cephalic tentacles as well as a distinct snout containing the mouth. The lateral sides of the body typically have sensory epipodial tentacles. Many species of the families Tegulidae and Turbinidae are commonly found in the Noto Peninsula.

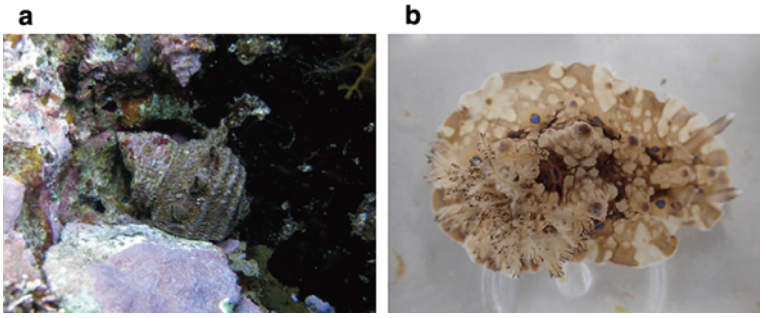

Fig. 4.8 Mollusca, Gastropoda. **a** *Turbo sazae* (Photo by Ogiso), **b** *Homoiodoris japonica* (*Photo* by Nunomura)

The subclass Neritaemorphi has wide shell entrances and slight torsion; therefore, they are similar to both limpets and typical snails. Internally, only the left ctenidium is present. The Neritidae is a relatively common family of snails found in the Noto Peninsula. This group includes some terrestrial and freshwater species.

The subclass Caenogastropoda includes many snails belonging to two groups: Architaenioglossa (river snails and terrestrial Cyclopohoridae) and Sorbeoconcha (many snails including creepers, turret shells, periwinkles, cowries, triton shells, whelk volutes, and rock shells). Many species are relatively abundant in the Noto Peninsula.

The subclass Heterobranchia comprises various groups including snails such as those belonging to Pyramidellidae. Their shell whorls change when they develop from a larva into an adult. The whorls of adult and larval shells are coiled in the opposite directions. Heterobranchia also contains the formally independent subclasses "Opisthobranchia" (Fig. 4.8b), including sea hares and sea slugs, and "Pulmonata," including terrestrial snails and slugs. Many species of the Opisthobranchs have secondary gills located after the heart. However, the concept of "Opisthobranchia" has become invalid. It includes many groups that are rich in variation. Not a few groups have well-developed shell; however, sea hares, some of which are rather large species, have a residual shell on the dorsal side of their body, and many sea slugs lost their shell perfectly. When *Aplysia* species of sea hares and related genera are attacked or disturbed, they can release ink from their ink glands, which creates a smoke-like toxic screen that is whitish, purple, or red in color. Not a few sea slugs have brilliant coloration and some are poisonous. Their coloration is regarded as a warning. Members of the order Pulmonata have lungs instead of gills. Sea Pulmonata, i.e., false limpets, occur on rocks and have lungs instead of gills.

4.2.7.2 Class Bivalvia

The Bivalvia, comprising clams, mussels, oysters, and many other shellfish groups, bears two connected valves that can be closed tightly using two calcareous valves

by a ligament and adductor muscle. Many bivalves are not often visible on the rocky shore, but they are abundant on the soft bottom, e.g., the sandy bottom or sandy-muddy bottom. A limited number of groups inhabit rocky surfaces, e.g., mussels can attach to a surface using a soft byssus. Some oysters inhabit the hard sea bottom; the valves of the oyster are highly calcified but rather irregular in shape. They are filter feeders and take food and oxygen using an incurrent and excurrent siphon. Many bivalves, the pelecypods, have a well-developed muscular foot. There are many classification systems of bivalves. Here, we will deal with four subclasses: Protobranchia, Pteriomorphia, Palaeoheterodonta, and Heterodonta. Subclass Pteriomorphia (Pteriomorpha) is a group comprising Ostreoida, Pectinoida, Pterioida, and Mytiloida. This group possesses a byssus in the adult stage or in younger periods. For example, *Mytilus galloprovincialis* and other species of Mytilidae attach to rock or wharf pilings using a thread-like byssus. Oysters attach to the hard bottom and only possess byssi in their younger stage. Oysters such as *Crassostrea nippona* are very important fishery products in the Noto Peninsula. Subclass Palaeoheterodonta occurs mainly in freshwater and brackish water; they have two shells of equal size and hinge teeth in a single row. Subclass Heterodonta bears two types of hinge teeth: cardinal teeth and lateral teeth. They also possess two adductor muscles. This subclass comprises many kinds of representative clams such as those from the families Veneridae and Mactridae. Many species are edible and important products for fisheries. Protobranchia dwells in the deep sea.

4.2.7.3 Class Cephalopoda

The Cephalopoda includes squids, cuttlefishes, octopuses, and nautiluses. The Cephalopoda body consists of an anterior head-foot and posterior visceral mass, and members have eight, ten, or more tentacles as well as a mouth with a strong beak. The ancestors of squids, cuttlefish, and octopus are nautilus-like or ammonite-like. Many existent cephalopods have reduced shells, i.e., cuttlefish have a thick shell, squids often have a thin shell, and octopuses lack a shell. The female *Argonauta* forms a shell for an egg case, which is secreted by two specially modified arms. Generally, Cephalopoda has strong locomotion ability and high intelligence. Cephalopods exchange gas by forcing seawater through their gills; they have a branchial heart at the basal part of the gills. They also have a visual cortex and camera-type eyes with high functionality, similar to those of vertebrates. Cephalopods, except for Nautiloidea, have an ink sac from which they can release ink when alarmed. The Noto Peninsula is famous for the fishery of squids such as *Todarodes pacificus.*

4.2.7.4 Class Scaphopoda

The Scaphopoda, i.e., the tusk shells or tooth shells, is relatively unfamiliar because they inhabit the subtidal zone or relatively deeper waters. Their foot extends from the

larger end of the shell and bears a thread-like captacula (pl. of captaculum), which may be used to burrow into the substrate.

4.2.7.5 Class Polyplacophora

The Polyplacophora, i.e., chitons, has a series of eight separate shell plates on their dorsal part surrounded by spicules, bristles, hairy tufts, or snake-like scales (Fig. 4.9). Their nervous system is ladder-like and similar to that of Annelida. Some species exhibit homing behavior. The most common chitons in the Noto Peninsula are *Ischnochiton comptus*, *Ischnochiton boninensis*, *Acanthopleura japonica*, *Acanthochitona achates*, and *Lepidozona coreanica* (Fig. 4.9).

4.2.8 Phylum Entoprocta

The members of Entoprocta or "Kamptozoa" are mostly sessile aquatic animals of up to 7 mm in size that form colonies. They occur on the stems of sea algae or on the surface of dead shells. Their body consists of a flower-like calyx bearing tentacles and a stem; thus, they resemble Hydrozoa. Their anus opens within the crown of tentacles.

4.2.9 Phylum Rotifera

The Rotifera are small and often occur as plankton. They possess a goblet-type body covered with a lorica and corona or "wheel organ" bearing ciliated field. Their most

Fig. 4.9 Mollusca, Polyplacophora, *Lepidozona coreanica* (*Photo* by Ogiso)

unique feature may be a large pharynx known as a "trophy" or "mastax." Many individuals of the Rotifera are usually female; males appear for a limited time only in a season. Hitherto, about 2,000 species have been reported. Many are used as natural bait for aquaculture.

4.2.10 Phylum Bryozoa (Ectoprocta) and Related Phyla

The Bryozoa or "moss animals" (Fig. 4.10a) can be found attached to rocks, stones, or the surface of other organisms on the intertidal rocky shore at ebb tide. Bryozoa mostly make colonies consisting of many small zooids (Fig. 4.10b). They have a crown of ciliated tentacles on their upper surface and a mouth in the center, followed by a U-shaped gut and an anus that opens outside of the crown. Members do not possess circulatory or excretory organs, but possess a network of "funiculus," which functions like a circulatory system. Besides normal autozooids, heterzooids exist: avicularia (pl. of avicularium), which resemble a birds' head, serve to protect the colonies, and a vibracula (pl. of vibraculum) with a flagellum-like modified operculum serves to clean the surface of the colony.

The Bryozoa has been treated as Tentaculata or Lophophorata together with the Phoronida and Brachiopoda because not only they have a lophophore, i.e., a crown of tentacles used for filter feeding, but also a body composed of three parts (prosoma, mesosoma, and metasoma).

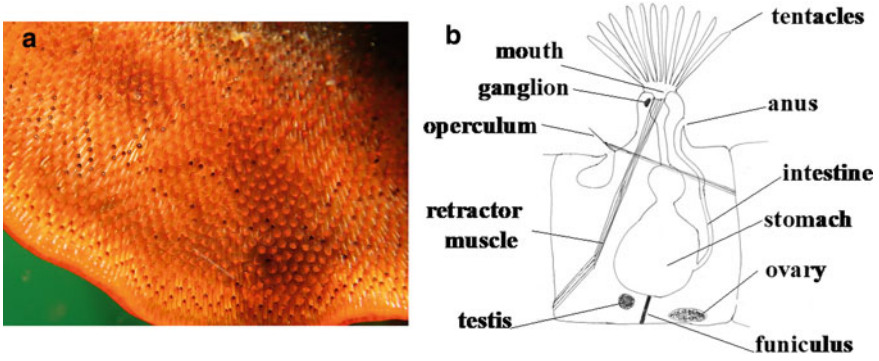

Fig. 4.10 Bryozoa. **a** *Watersipora suboboidea* (Photo by Ogiso), **b** Body of Bryozoa (Original drawing by Nunomura)

4.2.11 Phylum Chaetognatha

The Chaetognatha, also known as arrow worms, have a slender body, and moves like an arrow. To date, 120 species have been recorded. Although approximately 80% of Chaetognatha species are planktonic and approximately 20% are benthic, planktonic species have much larger populations. The latter species has muscles for locomotion and is found in the low tidal zone. Chaetognaths have translucent dart-shaped bodies covered by a cuticle. Their bodies are bilateral with one or two paired lateral fins and a caudal fin; therefore, by their outline, chaetognaths resemble fish. They have both ovaries and testes (testes and ovaries are found in the posterior half and anterior part, respectively), but they lack circulatory, respiratory, and excretory systems. Seminal receptacles are situated near the caudal end, and the female gonophores are located near the middle part of the lateral margin. From the mouth, a straight intestine travels to the anus, located in the posterior part of the body. Chaetognaths are carnivorous and capture their prey using a characteristic grasping spine.

4.2.12 Phylum Nematoda

The Nematoda or round worms are mostly small, free-living, thread-like animals; however, the parasitic species are large and harmful to plants and animals including humans. Large numbers of free-living species can, for example, be found in the interstitial environment of the sandy beach. Their bodies are unsegmented and bilaterally vermiform. Some groups have cephalic sense organs known as amphids, whereas others have caudal sense organs known as phasmids. Excretal organs of some species are unique one or two renette cells. Because they are thin, the Nematoda possess special circulatory organs and lack respiratory organs. To date more than 80,000 species have been recorded, but more may be still undescribed because they are almost all a similar shape and interpreting the taxonomy of the Nematoda is difficult. Most nematodes are gonochoristic and their cleavage is holoblastic. The phylum Nematomorpha, which includes mostly terrestrial members, is closely related to the Nematoda.

4.2.13 Phylum Arthropoda

The Arthropoda comprises more than 1,134,000 species. Their bodies are covered by cuticular exoskeletons; therefore, they must replace their exoskeletons by undergoing ecdysis. They shed the old exoskeleton after growing a new one that is not yet hardened. Arthropod bodies are segmented, and the nervous, muscular, circulatory, and excretory systems also have repeating components. Many species also have well-developed articulated legs. Therefore, most arthropods can move quickly; they are

"athletic," although large-sized species are relatively rare. This phylum is divided into four subphyla: Chelicerata, Myriapoda, Crustacea, and Hexapoda. The subphylum Chelicerata includes horseshoe crabs, spiders, mites, and scorpions; they are characterized by their chelicerae, i.e., appendages situated near the mouth, and four pairs of walking legs. The subphylum Myriapoda includes the millipedes, centipedes, and some other groups; they have many body segments and each segment bears one or two pairs of legs and/or a pair of antennae. The subphylum Crustacea includes shrimps, lobsters, crabs, barnacles, crayfish, and many groups; they are primarily aquatic and are characterized by their biramous appendages and two pairs of antennae. The subphylum Hexapoda comprises of the insects and insect-like animals, which possess six thoracic legs and a pair of antennae. Descriptions of the subphyla Myriapoda and Hexapoda are not included below because they are essentially terrestrial groups. In addition, a few subphyla, such as Artiopoda, include extinct animals, such as Trilobita. Here, they are also omitted.

4.2.13.1 Subphylum Chelicerata

The bodies of chelicerates are composed of two parts: the prosoma and opisthosoma. The first pair of appendages is chelicerae, the second pair is pedipalps, and the third to sixth pairs are walking legs; this group lacks antennae. All classes except Pycnogonida are omitted below because they are essentially terrestrial groups. The Class Pycnogonida is a group comprising of the sea spiders. Their bodies are composed of a head and trunk (segmented thorax) with conspicuously long legs and a reduced abdomen. A proboscis with four ocelli (pl. of ocellus) tubercles on a tubercle is observed in the cephalosoma. The first pair of legs are known as chelifores, the second pair of legs are known as palps (these serve as sensory organs and food-grasping appendages), and the third pair of legs are known as ovigers (these are used by males to carry eggs). Another group of the subphylum is the Arachnida, including the mites, spiders, and scorpions, which are not included here because of their terrestrial nature.

4.2.13.2 Subphylum Crustacea

The bodies of crustaceans are composed of a head (cephalon), thorax (pereon), abdomen (roughly pleon), and a tail (telson). The head comprises six segments that bear simple ocelli and/or compound eyes. Each segment, except the first, possesses a pair of appendages, i.e., the first antenna, second antenna, mandibles, first maxilla, and second maxilla. The mouth opens at the anterior part. Each appendage consists of the protopod and rami; each ramus is biramous, but one is often reduced to become uniramous. Some of the anterior thoracic appendages have become maxillipeds, i.e., appendages of the mouth part. Crustaceans comprise the following classes: Remipedia, Cephalocarida, Branchiopoda, Copepoda, Ostracoda, Thecostraca, Malacostraca, Branchiura, Mystacocarida, Tantulocarida, and Pentatomida. In this book, we

only focus on the group that is most conspicuous and larger than average in size. Several groups that do not inhabit the shore of the Noto Peninsula or are small in size are excluded.

Class Copepoda

If a water drop from a plankton net is examined with a microscope, a large number of copepods will usually be found. Many copepods are planktonic and are important natural food for fish. Some copepods are benthic and a few groups are also serious parasites of fish and other animals; the latter are often largely deformed in shape. Primarily, the body of copepods is composed of a head with five segments, six pereonal and five abdominal segments and a telson, and an abdomen composed of three segments without appendages and an anal segment. Demarcation of the segments has often partly disappeared in many groups.

Subclass Thecostraca

On the surface of the rocky shore or wharf piling, barnacles (Fig. 4.11a) may be found. Barnacles are representative of the Cirripedia, which are members of the Thecostraca. Adult barnacles (Fig. 4.11b) are sessile; they are attached to substrata through cement glands. Six pairs of recurved vines form their cirri (pl. of cirrus), each of which is divided into two branches. Their body is essentially composed of a five-segmented cephalon, seven-segmented thorax, three-segmented abdomen, and an anal segment, but they have four swimming larval stages. After hatching, they become a one-eyed nauplius, after which they progress into a cyprid stage, and finally become a sessile adult. Barnacles adapt to sessile life, even though the reproduction of this group involves copulation. To increase the chances of meeting both sexes, they are adapted as hermaphrodites with a long penis and dwarf males sometimes appear. Besides, the same species dwell close together. In parasitic groups, there is a tendency toward reduction of segmentation of the body. Around 1,000 barnacle species are currently known. Another subclass Mystacocarida is omitted below. In the Noto Peninsula, *Chthamalus challengeri*, *Megabalanus rosa*, *Balanus trigonus*, and *Capitulum mitella* (Fig. 4.11a) are commonly seen.

Class Malacostraca

The Malacostraca includes many shrimps, crabs, hermit crabs, mantis shrimps, woodlice, mysids, and many other groups. The Malacostraca body essentially originally consists of 19 or 20 segments: the cephalon is composed of 6 segments with mouthparts and 2 pairs of antennae, 1 of which is sometimes branched. They often have compound eyes with stalks. The thorax is essentially eight-segmented, but mostly the anterior one–three segments are fused to their head, and their legs are

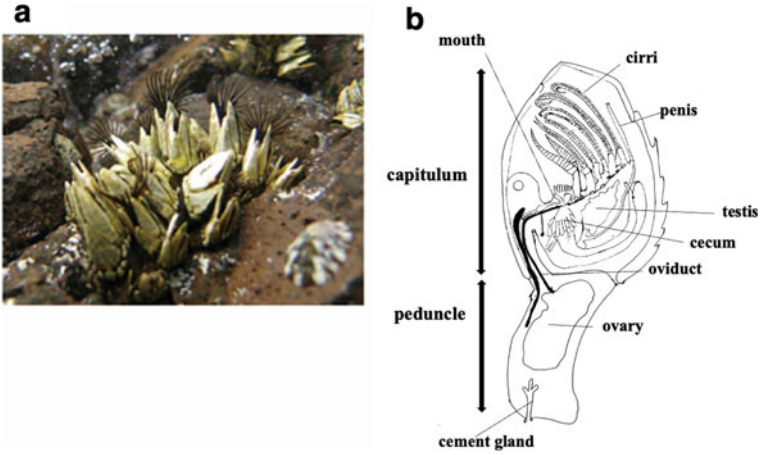

Fig. 4.11 Arthropoda, Thecostraca, Cirripedia. **a** *Capitulum mitella* (Photo by Ogiso), **b** Body of Cirripedia (Modified after McLaughlin 1980)

converted into maxillipeds as a part of mouthparts and often covered with a carapace along with a head. The abdomen (here, it means pleon) consists of six segments (seven in Phyllocarida) and a telson, but the last pleonal segment is fused to the telson.

This class comprises three subclasses: Phyllocarida, Hoplocarida, and Eumalacostraca.

The subclass Phyllocarida contains the order Leptostraca. The body is composed of a six-segmented head, eight thoracic and six to seven pleonal segments, and a narrow tail. Their carapace covers cephalon, thorax, and anterior part of abdominal somites. *Nebalia japonica* may be found in eutrophic and relatively dirty water in Japan.

The subclass Hoplocarida contains the order Stomatopoda, i.e., the mantis shrimp. Their bodies have a cylindrical abdomen as well as a flat well-developed tail with a wide uropod. The cephalon bears two pairs of antennae with well-developed eyes and a movable rostrum. The carapace covers the head and thoracic segments 1–4. Thoracic segments 1–5 are uniramous with subchelate legs. The unique appendage in the mantis shrimp is the second maxilliped. The first to fifth thoracic legs lack exopods. *Oratosquilla oratoria* is important edible species found in the middle region of Japan.

The subclass Eumalacostraca comprises three superorders: Peracarida, Eucarida, and Syncarida (omitted here). Their bodies have 19 segments in total: five cephalic, eight thoracic, and six abdominal segments. A carapace envelops the thoracic region. They bear movable stalked eyes; the antennae and other appendages are essentially biramous, but a few groups have uniramous versions. Many groups have natatory exopods on the thoracic limbs with a tail fan formed by the lamellar rami of the uropods on either side of the telson.

The superorder Peracarida comprises the orders Mysida, Amphipoda, Cumacea, Isopoda, Tanaidacea, and several little-known orders. Mature females have brood pouches formed by oostegites (extensions from the coxae); they lay their eggs in these brood pouches, and the young exits the pouch after it hatches. Consequently, females lay a relatively small number of eggs in the brood pouch. More than 25,000 species of the Peracarida are known, and there may be many species as yet undescribed or undiscovered. The abundance of peracarids in the sea is similar to that of insects in terrestrial environments. In addition to the abovementioned five orders, some orders, Lophogastrida, Mictacea, Spelaeogriphacea, and Thermosbaenacea, are not described below.

The order Mysida, the opossum shrimps, is relatively small shrimp-like crustaceans. Both of their antennae are bifid. The basal part of first antenna has masculine processus in males. The pereopods of mysids are biramous and without gills. The pleopods are reduced in males, and the endopods of uropods have statocysts. Young individuals are hatched already bearing all pereopods. Many benthic species make daily vertical migrations from the deeper parts to shallower waters.

The order Cumacea or the hooded shrimp/comma shrimp is generally abundant on the sea bottom. Their bodies have a large carapace and a relatively long and slender abdomen. Their second antenna consists of numerous segments in males, but the number of segments is notably reduced in females; the first three pairs of pereopods have become maxillipeds.

The order Amphipoda often occurs in large numbers on algae or under stones, and they usually swim sideways. Their bodies lack a carapace and are generally compressed "side-to-side." Amphipods are 1–340 mm in size and are mostly detritivores or scavengers. Almost 10,000 species have been described so far; these contained suborders Gammaridea, Caprellidea, Hyperiidea, and Ingolfiellidea. The Gammaridea seems to be the typical group, i.e., small, shrimp-like crustaceans, but their anterior legs face the anterior direction, whereas their posterior legs face the posterior direction. Many species are commonly seen in the rocky shore of the Noto Peninsula. The Caprelloidea, known as the skeleton shrimp, have a stick-like body. The first two pairs of pereopods are modified into gnathopods, which are used for feeding, defense, and locomotion. The third and fourth pair of pereopods are reduced with two pairs of gills. The fifth to seventh pair of pereopods is used for clasping objects.

The order Isopoda comprises 10,000 known species worldwide. Isopodan crustaceans lack a carapace and generally have a "top-to-bottom" (dorsoventrally) depressed body. Many species have seven pairs of walking legs (some are prehensile or reduced) followed by five pairs of plate-shaped pleopods. Pill bugs or sow bugs are well-known, and the wharf roach "*Ligia*" can often be observed running on the rocks of the shore; however, these are classed as terrestrial groups. Nevertheless, many diverse groups exist in marine environments, e.g., under the rocks of the intertidal zone: Sphaeromatidae such as *Gnorimosphaeroma ray*i, Cirolanidae such as *Cirolana harfordi,* and Anthuroidea such as *Paranthura japonica* are often found in the Noto Peninsula. Among seaweed colonies, Valvifera such as *Synidotea laevidorsalis* can also be found.

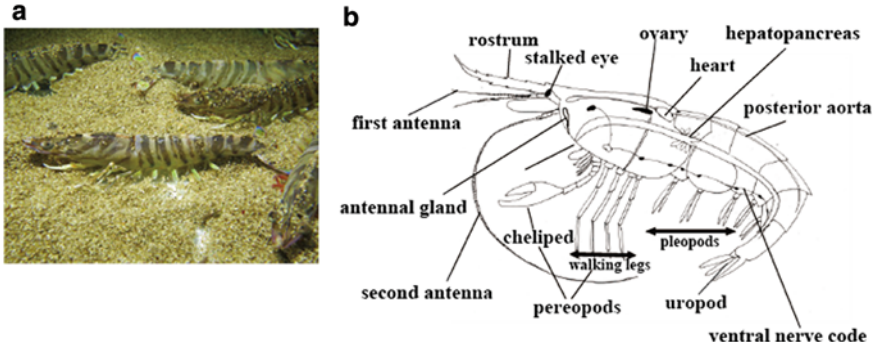

Fig. 4.12 Arthropoda, Decapoda. **a** *Marsupenaeus japonicus* (Photo by Ogiso), **b** Body of a shrimp (Original drawing by Nunomura)

The order Tanaidacea is somewhat similar to Isopoda in terms of external shape, but they have a cephalon fused to first and second thorax somites and covered with a carapace. The first pairs of legs are large gnathopods.

The superorder Eucarida includes two important orders: Decapoda (Fig. 4.12a) and Euphausiacea. The carapace of the Eucarida is fused and covers the head and thorax. Generally, their sensory and nervous systems, as well as their muscles, are well developed; therefore, they have strong locomotion ability. Their breeding patterns involve oviparity: females release eggs into the sea, and after they have hatched, they pass into the nauplius larvae stage.

The order Decapoda includes about 14,400 species such as true shrimps, ghost shrimps, porcelain crabs, hermit crabs, mole crabs, sand crabs, and regular crabs. Specifically, the Decapoda comprises two subclasses: Dendrobranchiata and Pleocyemata. Their carapace covers the cephalon and thorax perfectly, and the sensory, nervous, and muscular systems are highly developed leading to advanced locomotion ability. The exopods of their maxilla are wide, and they play a role in sending water toward the gill chamber. The first three pairs of pereopods have become maxillipeds. The fourth to eighth appendages are well-developed for walking, grasping, and other functions; thus, many groups may have ten walking legs, although one or more pairs may be reduced. Outwardly, the body is distinctly separated into a cephalothorax and abdomen. Thoracic legs are outwardly visible, and the exoskeleton is usually well calcified. Decapoda have well-developed gills and a branchial chamber. The cephalon is also well-developed with stalked compound eyes.

The suborder Dendrobranchiata (Fig. 4.12b) includes more than 400 species and comprises prawns such as *Marsupenaeus*. Adults bear finely branched and feathered gills, except for the genus *Lucifer*. The gonads open at the base of the fifth pair of walking legs in males; the male genitalia, known as the petasma, is located at the inner side of the first pair of pleopods. The gonads open at the base of the third pair of walking legs in females; the female genitalia known as the thelycum is located at the inner sides of the fourth and fifth walking legs. These are important for identification.

The suborder Pleocyemata includes nearly 14,000 species and comprises infraorders Caridea, Achelata, Anomala, Brachyura, and several others. Here, only the important and conspicuous groups are described. In this group, the fertilized eggs are protected by the female. They remain stuck to her swimming leg, and the zoea larvae hatch from this location.

The infraorder Caridea includes many types of shrimp. The second pleonal segment of this group is wide and overlaps the first and third segments. They have one pair of stalked eyes, which is sometimes covered by the carapace. Their gills are within a thin plate, and the muscle of the abdomen is well-developed to enable rapid locomotion. They have five pairs of walking legs; the first two pairs form chelipeds in many groups. Sometimes, one of the chelipeds is huge in males.

The infraorder Achelata is rather large in size and important for fisheries. Their body, walking legs, and second antennae all bear a hard well-developed exoskeleton. The second antennae are long with a few flagellar segments. The bodies of younger individuals are as broad as phyllosoma. The members of this group are exclusively warm-water dwellers.

The infraorder Anomala (Anomura) comprises various groups, including the porcelain crabs, hermit crabs, mole crabs, and sand crabs. Among these, the hermit crabs are possibly the most familiar group. Their abdomen and tail are not well-developed, and they are collapsed toward the ventral side of the cephalothorax or they insert themselves into the shells of dead sea snails; however, some species attack snails to obtain a suitable shell. However, hermit crabs can use many kinds of shells, including the shells of scaphopods, and even artificial materials. The first pairs of walking legs are cheliped and the fifth (sometimes also the fourth) pairs are short; therefore, they appear to have only three pairs of walking legs. Almost all species of hermit crabs have soft spirally curved abdomens, into which the whole body can retract; thus, their body can be protected from predators when using an empty shell. In some groups, the claw on one side is often much bigger than that on the other side. Porcelain crabs also belong to Anomura. Their exterior shape is similar to that of a regular crab. The carapace is rounded and the anterior rostrum is not well developed. The first walking legs are well-developed chelipeds, but the right and left sides are often asymmetrical, while the fifth leg is reduced and located within the gill chamber.

The infraorder Brachyura or the regular crabs (Fig. 4.13) include more than 6,500 species. They have a rigid, chitinous, cephalothorax that occupies most of their body, but their abdomen is thin and narrow, especially in males. They have a pair of stalked compound eyes and two pairs of short antennae in the anterior margin. They also possess a pair of mandibles, maxillulae, maxillae, and three pairs of maxillipeds; the third maxilliped covers the mouth parts on the ventral surface. The thorax has five pairs of pereopods; the first walking legs are chelipeds used to grasp prey or frighten enemies. In the genus *Uca*, the male has an extremely large cheliped, which is used during courtship. In many crabs, side-stepping locomotion is common; however, Mictyridae walks forward, Raninidae walks backward, and Inachidae can walk in any direction. Members of Portunidae have an oar-shaped last pair of legs that are used for swimming.

Fig. 4.13 Arthropoda, Decapoda, *Leptodius exaratus* (*Photo* by Nunomura)

The order Euphausiacea or krill resembles true shrimp or opossum shrimp. The cephalon and thorax are wholly covered by a carapace, and the abdomen is composed of six segments and a telson. The thorax is composed of eight segments, each with a pair of appendages, but they are not modified to maxillipeds. The second and third pairs are modified as chelipeds in some groups, and the posterior 1–2 pairs are reduced in some groups. Branched gills have developed at the base of the thoracic appendages, but they are not covered by the carapace. Euphausiacea have statocysts in their uropods. They are gonochoric and their spermatophores are sticky.

Class Ostracoda

The Ostracoda is small-sized with a body enclosed by two valves, which are closed by an adductor muscle and hinged dorsally. Body segmentation is much reduced, with only six to eight pairs of appendages. Ostracods are found on seaweeds and the sandy bottom of the shore.

4.2.14 Phylum Echinodermata

The Echinodermata, which belongs to Deuterostomia, comprises five major unique groups: the sea urchins (class Echionoidea), sea stars, (class Asteroidea), brittle stars (class Ophiuroidea), sea cucumbers (class Holothuria), and sea lilies (class Crinoidea). Although adult Echinodermata are recognizable by their (usually five-point) radial symmetry, the larvae show bilateral symmetry. They possess a unique water vascular system; this comprises a network of fluid-filled canals derived from the body cavity (Fig. 4.14). It functions not only in gas exchange and feeding but also in sensory perception and locomotion. Adult echinoderms are found on the sea bed, but the larvae are planktonic; thus, the morphology of adults and larvae clearly differs. The Echinodermata is relatively large in size and the phylum contains about 7,000 living species, none of which are freshwater or terrestrial species.

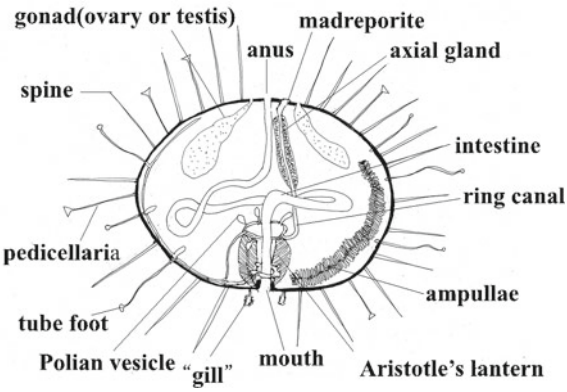

Fig. 4.14 Body of Echinonoidea from Echinodermata (Original drawing by Nunomura)

4.2.14.1 Class Echioidea

Typical echinoids are spherical and chestnut-burr-shaped, but elliptical and flat species also exist. They have a hard epidermis and three types of protuberances from the epidermis: spines, tube feet, and pedicellariae (pl. of pedicellaria) (Fig. 4.14). The length of spines varies according to species. For example, *Diadema* has long poisonous spines. The pedicellariae are used for protection and may also contain poison; for instance, the flower urchin, *Toxopneustes pileolus*, can administer a dangerous, painful, and medically significant poison when touched, which is rarely lethal. The tube feet of echinoids are soft, flexible, and their tips adhere to the substrata; they are organs used largely for locomotion as well as grasping food. Echinoids possess a typical water vascular system, the opening of which is a hydropore with a sieve-like madreporite near the central part of the upper side, i.e., close to the anus in a "typical" sea urchin (Fig. 4.14). The hydropore is connected to a thin duct (a stone canal) and extends to a ring canal, after which it branches off to short lateral canals, each one ending in an ampulla and tube foot (Fig. 4.14). The area of the surface with tube feet is known as the ambulacral zone, whereas the surface without tube feet is called the interambulacral zone. The part with ampulla can protrude through a pore (or a pair of pores), to the exterior of which is a tube foot. The water vascular system serves to distribute nutrients throughout the body; it is most obviously expressed in the tube feet, which can move by extension or contraction caused by the redistribution of fluid between the foot and the internal sac, which functions in gas exchange, feeding, sensory perception, and locomotion. The mouth of regular echinoids is located near the central part of the lower surface, and the pharynx is surrounded by a strong jaw termed Aristotle's lantern. The anus is located near the central area of the upper surface. The gonopore also opens near the anus at the upper part of a regular sea urchin. The most common species found in the Noto Peninsula are *Heliocidaris crassispina* and *Hemicentrotus pulcherrimus* (Fig. 4.15a).

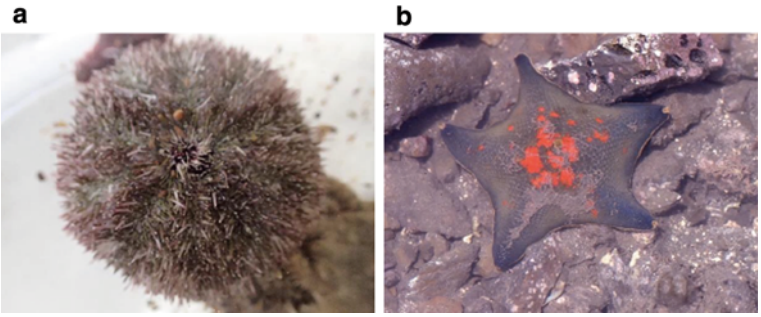

Fig. 4.15 Echinodermata. **a** Echioidea, *Hemicentrotus pulcherrimus* (Photo by Nunomura), **b** Asteroidea, *Patiria pectinifera* (Photo by Nunomura)

4.2.14.2 Class Asteroidea

The body of Asteroidea has five (or more) arms. Thus, they are star-shaped, and they bear ambulacral grooves on the ventral side of the arms, which possess many tube feet. Adults are recognizable by their radial symmetry. In the Asteroidea water vascular system, radial canals extend along the arms from a circular canal. Sea stars are carnivorous and attack bivalves and other prey: they expel their stomach from their mouth and use it to consume prey outside of their body. Larvae of asteroids are initially bipinnaria, similar to those of Auricularia of Holothuroidea; subsequently, they transform into brachiolaria and finally into adult forms. The most common species in the Noto Peninsula are *Patiria pectinifera* (Fig. 4.15b), *Aquilonastra bather*, and *Certonardoa semiregularis.*

4.2.14.3 Class Ophiuroidea

The body of Ophiuroidea, the brittle stars, consists of an obvious central disk and five or more whip-like or snake-tail-like arms with spines: these are sometimes branched and used to crawl along the sea bed. Some ophiuroids, such as basket stars, have complicatedly branched arms. Their mouth is rimmed with five jaws. Ophiuroids are abundant not only onshore but also on the deep-sea bottom where they may feed on the skeletons of fish and hard parts of animals; thus, they are of great advantage to clean the sea bottom. Ophiuroidea larvae, Ophiopluteus, are similar to those of Echionoidea. The most common species in Noto is perhaps *Ophioplocus japonicus* (Fig. 4.16a).

4.2.14.4 Class Holothuroidea

The Holothuroidea, the sea cumbers, has soft bodies that lack a single rigid big skeleton but have small ossicles embedded beneath the skin. Sea cucumbers

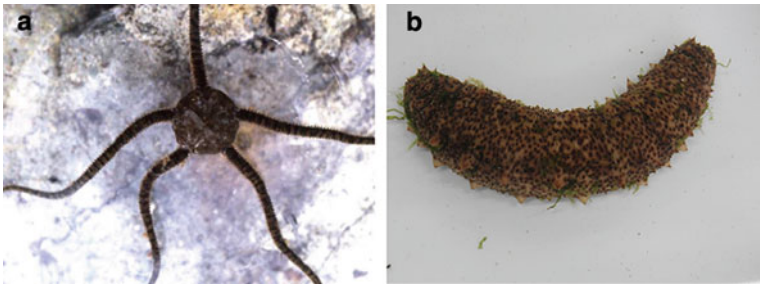

Fig. 4.16 Echinodermata. **a** Ophiuroidea, *Ophioplocus japonicus* (Photo by Nunomura), **b** Holothuroidea, *Apostichopus armata* (*Photo* by Sekiguchi)

are deposit or suspension feeders; their mouths are situated at the anterior end, surrounded by feeding tentacles, whereas the anus is found at the posterior end in the anal area. Characteristic respiratory trees are located in the posterior part of the body; they open in the rectum and gas exchange is completed using seawater taken in through the anus. Sometimes organisms such as pearlfish (Carapidae) or pea crabs (Pinnotheridae) inhabit the cloaca of sea cucumbers. Certain holothurians have characteristic defense methods, one of which is the Cuvierian organ: when they are attacked by enemies, they extrude sticky clusters of fine tubes from the base of the respiratory trees in the cloaca. After these tubules contact seawater, they lengthen, become adhesive, and effectively deter enemies. Another defense mechanism, used by some species when they are severely threatened, involves emitting the viscera; this can be regenerated in time. The larvae of holothurians, the auricularia, are somewhat similar to the bipinnaria of Asteroidea. The most common species in the Noto Peninsula are *Apostichopus armata* (Fig. 4.16b) and *Holothuria decorata.*

4.2.14.5 Class Crinoidea

Members of the Crinoidea have a flower-like body with many feather-like arms. They live on subtidal rocks in the sea. In adult crinoids, the mouth is situated on the upper surface. Primitive groups of Crinoidea in the deep sea are known to have a stem. However, more recently evolved feather stars have lost this stem, although juvenile feather stars do possess a short stem. The first larvae of crinoids are doliolaria, followed by cystidians, pentacrinoids, and finally the adult form.

4.2.15 Phylum Hemichordata

The Hemichordata, including the acorn worms, is rather rare vermiform animals. Their bodies consist of three parts: a proboscis (prosoma), collar (mesosoma), and trunk (metasome). The circulatory system is open with the heart situated on the

dorsal side. The mouth cavity is tubular and bears a narrow stomochord that extends up into the proboscis. A plexus of nerves lies in both the dorsal and ventral nerve cords. Some hemichordates have pelagic larvae known as tornaria, which resemble the bipinnaria or auricularia of Echinodermata. Some species produce an iodoform smell.

4.2.16 Phylum Chordata

The Chordata includes various groups, e.g., the ascidians, lanceolates, and vertebrates; they have a fluid-filled body cavity (coelom) and pharyngeal slits (gill slits) throughout life or during the early developmental stages. The pharynx is part of the throat situated immediately behind the mouth. Many terrestrial groups use their tails for balance and many other roles. The chordates have a notochord, a fairly stiff rod that extends along the anterior–posterior axis of the body; a dorsal neural tube runs along the notochord. The endostyle is a groove in the ventral wall of the pharynx that assists in filter-feeding but has disappeared in the adult of many groups; it is considered to be homologous to the thyroid gland in vertebrates. The Chordata comprises more than 66,000 species and the group is divided into three subdivisions: Cephalochordata, Tunicata (Urochordata), and Craniata (Vertebrata).

4.2.16.1 Subphylum Tunicata (Urochordata)

The subphylum Tunicata contains 3,000 species and comprises the classes Ascidiacea (sea squirts), Thaliacea (salps), and Appendicularia (larvaceans). Adult sea squirts (Fig. 4.17a) are solitary or colonial sessile animals after their larval phases, whereas members of Thaliacea and Appendicularia are planktonic or swim slowly. The larvae of Tunicata are tadpole-shaped and swim; they also have an otolith, a notochord, a dorsal nerve formed from a neural plate, an ocellus, and muscles; however, the larval stage is short. Sea squirts (Fig. 4.17b) have a rounded body, thick body wall tunic, and two siphons: the oral siphon (opening internally) and atrial siphon. Seawater containing small planktonic particles is ingested from the oral siphon and discharged from the atrial siphon (Fig. 4.17b). Though the seawater is passed through many pores of the branchial sac, food particles are first captured by a mucous net secreted from the endostyle in the branchial sac and then transported to the digestive tract, including the esophagus, stomach, and intestine (Fig. 4.17b). After digestion and absorption are completed in the digestive tract, undigested food is discharged from the anus (Fig. 4.17b). Solitary sea squirts reproduce both sexually and asexually. The classes Thaliacea and Appendicularia can be planktonic or may swim. In the Noto Peninsula, *Styela plicata*, (Fig. 4.17a) *Halocynthia roretzi*, and many colonial species are often observed.

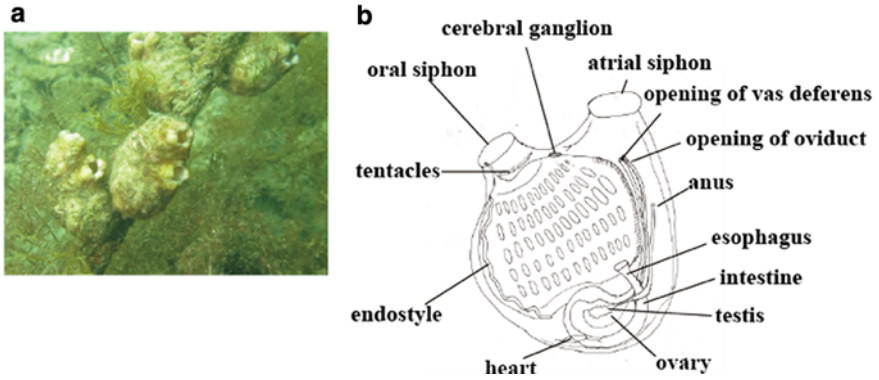

Fig. 4.17 Chordata, Tunicata. **a** *Styela plicata* (Photo by Ogiso), **b** Body of an ascidian (Modified after Brusca, Moore, Shuster, 2016)

4.2.16.2 Subphylum Cephalochordata

The Cephalochordata, the fish-shaped lancelets, has a dorsal nerve tube and notochord running from the head to the tail. The notochord is maintained throughout their life. Their head lacks a brain, although they possess specialized sense organs. The members of the Cephalochordata are essentially burrowing filter feeders that are found on the clean sandy bottom.

4.2.16.3 Subphylum Vertebrata

The Vertebrata, including fishes, amphibians, reptiles, birds, and mammals, is the most well-known subgroup of the chordates. The vertebrates possess a backbone that runs through the length of their body. A dorsal neural tube develops into the spinal cord, which is the main communication trunk of the nervous system, and a large brain is protected by a skull. The mouth is situated at or near the anterior part of the body, whereas the anus opens at the posterior part of the body. The posterior behind the anus is known as the tail. The internal organs of vertebrates are suspended in the abdominal cavity. In particular, the heart and circulatory system are well developed. Fish is one of the most major marine vertebrates and they can be grouped into two groups: Cyclostomata, including hagfish, lampreys, and Gnathostomata, i.e., jawed vertebrates, including Chondrichthyes, and Osteichthyes.

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