

PHYLUM ARTHROPODA

Class Crustacea

Lower Crustacea and Cirripedia

Keys are available only for some of the numerous and varied crustacean groups. Branchiopods in general are found in fresh water, and may be worked out with the aid of Ward and Whipple or of Pennak's guide to fresh water life. Copepods and ostracods, because of the number of species and their small size, do not lend themselves to keying at the level of this guide. Cirripedes, amphipods, and isopods will prove difficult. The decapods, on the other hand, are well known and large forms, and, with some exceptions, can be identified with a fair degree of certainty. A key to the subclasses and major orders of crustaceans is not presented; the reader is referred to a basic reference text on invertebrate zoology.

In matters of classification and nomenclature, these keys follow the system outlined by Waterman and Chace in Chapter I, Vol. I, of "The Physiology of Crustacea", edited by T. H. Waterman. The excellent systematic indices of the two volumes are very helpful in respect to the synonymy of experimentally used crustaceans.

Subclass Cephalocarida (no key) Hutchinsoniella macracantha Sanders, 1955 is found in soft sediments at 10-30 meters depth. Not rare but very small (2-3.5 mm). See figure in Sanders, H. L., 1963. Cephalocarida. Functional morphology, larval development, comparative external anatomy. Mem. Conn. Acad. Arts & Sci., 15: 1-80.

Subclass Branchiopoda

Order Anostraca (no local marine representatives)

Order Notostraca (no local marine representatives)

Order Conchostraca (no local marine representatives)

Order Cladocera (no key): The genera Evadne and Podon occur in the marine plankton.

Subclass Ostracoda (no key): Numerous marine representatives.

Subclass Mystacocarida (no key): Derocheilocaris typicus Pennak and Zinn (Smithsonian Misc. Coll., 103(9): 1943) is the type of this subclass. It is minute (0.4-0.5 mm) and lives in the spaces between sand grains on Nobska and Falmouth beaches.

Subclass Copepoda (no key): Extremely numerous in sea, both free living and parasitic. See Wilson, C. B., 1932. The copepods of the Woods Hole Region, Massachusetts. U. S. Nat. Mus. Bull. 158: I-XIX, 1-635.

Subclass Branchiura (no key): "Fish lice"; the genus Argulus occurs on fish in both fresh and salt water. Formerly considered an order (Arguloida) of the Copepoda, but now separated on the basis of their compound eyes and other features. For local species see Wilson (1932; cited above) pp. 11-18.

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Order Thoracica
(Figure references are to Plate 11)

Classification and identification of thoracic barnacles is based primarily on three sets of criteria: 1) mode of attachment to the substrate, 2) number, morphology and arrangement of the calcareous plates forming the shell wall (compartmental plates) and closing the orifice (opercular valves), and 3) morphology of the mouth parts (trophi) and appendages (cirri). The Thoracica of this region are easily divided into two suborders on the basis of the mode of attachment. Members of the Suborder Lepadomorpha are distinguished by the presence of a conspicuous, fleshy attachment stalk (peduncle) below the distal, expanded end (capitulum) which is more or less completely sheathed by calcareous plates. The shell in members of the Suborder Balanomorpha, on the other hand, is attached directly to the substrate, and it is to this group that most of the common barnacles of the Cape Cod Region belong.

The lepadomorphs included in the key are all of the genus Lepas. Specific determination is based 1) on the form and ornamentation of the plates (scutum, tergum, and carina) sheathing the capitulum (fig. 11), and 2) on the number of filamentary appendages present at the base of Cirrus I and on the prosoma. This latter feature can only be observed by removing one side of the capitular sheath to expose the body of the barnacle (fig. 7).

The balanomorphs commonly found in this region (Chthamalus and Balanus) have a shell wall composed of six compartmental plates and the orifice filled by four opercular valves (2 scuta and 2 terga) (figs. 12-13). Both end plates of the shell wall (rostrum and carina) are overlapped by the adjacent compartmental plates in the genus Chthamalus (fig. 12), but in the genus Balanus, one of the end plates (rostral plate) overlaps the adjacent plates (fig. 13).

Specific identification of balanomorph species requires a more detailed examination of the opercular valves and shell. In some species, the basal plate sealing the barnacle to the substrate is membranous, but in others a calcareous plate is laid down and often remains attached to the substrate upon removal of the barnacle. The shell wall in many species of Balanus is formed of vertical inner and outer laminae separated by longitudinal septa. These septa are usually reflected on the inner shell wall as regularly spaced, longitudinal ribs, which are especially evident near the base of the shell wall. In some instances the number of ribs exceeds the number of septa, and this character is used to differentiate certain species (fig. 8). The development of the articulation between adjacent compartmental plates is also a useful character in the identification of some taxa. In B. improvisus, for example, the overlapping section of the plate (radius, plural radii) is narrow and does not cover the overlapped section (ala, plural alae) or extend to the central part of the adjacent plate (paries, plural parieties) (fig. 9).

The removal and examination of opercular valves is necessary for proper identification of most species. The presence or absence on the scutum of an adductor ridge, or external radial striae (figs. 16, 18), and the degree of development of the tergal spur (figs. 15, 17) are characters which are used in the key. However, there are many other features of these valves which are equally significant in specific determination.

KEY TO COMMON BARNACLES OF THE WOODS HOLE REGION

1. Animal enclosed in shell composed of varying numbers of plates 2
1. Animal without shell, found in burrow with comma shaped aperture in the shells of gastropods occupied by hermit crabs . . Trypetesa lampas
2. Shell attached directly to substrate Suborder BALANOMORPHA 3
2. Shell attached to substrate by fleshy stalk or peduncle Suborder LEPADOMORPHA 9

3. Both end plates of shell wall (rostrum and carina) overlapped by adjacent plates (fig. 12); shell dull brown or grey; basis membranous Chthamalus fragilis
3. Only one end plate (carina) overlapped by adjacent compartmental plates, the opposing rostral plate overlapping adjacent plates (fig. 13) Balanus 4
4. Basis membranous Balanus balanoides
4. Basis calcareous 5
5. Exterior of scutum distinctly striate longitudinally (fig. 16) 6
5. Exterior of scutum lacking distinct longitudinal striae 7
6. Ribs at base of interior of parieties more numerous than parietal septa (fig. 8); basis solid; basal margin of tergum entire Balanus balanus
6. Ribs at base of interior of parieties a continuation of parietal septa; basis porose; carinal side of basal margin of tergum deeply excavated (fig. 17) Balanus eburneus
7. Adductor ridge of scutum absent Balanus crenatus
7. Adductor ridge of scutum well developed (fig. 18) 8
8. Radii not extending to parieties of adjacent compartmental plates, with oblique summits (fig. 9); tergal spur narrow, less than $\frac{1}{4}$ width of basal margin (fig. 15); parieties white Balanus improvisus
8. Radii extending to parieties of adjacent compartmental plates, with slightly sloping summits (fig. 10); tergal spur at least $\frac{1}{4}$ width of basal margin; exterior of parieties with regularly arranged gray, purple, or red-purple longitudinal striae (fig. 14) Balanus amphitrite niveus
9. Carina terminating below in an expanded disk, with umbo projecting angularly; valves thin, papery Lepas fascicularis
9. Carina terminating below in a fork; umbo basal; valves well calcified 10
10. Valves radially furrowed or strongly striate (fig. 11) 11
10. Valves smooth or minutely striate 12
11. Occludent margin of scutum arched, protuberant, forming wide shelf between margin and umbonal-apical ridge; 5-6 filamentary appendages on either side of body Lepas anserifera
11. Occludent margin of scutum not arched, nearly parallel with umbonal-apical ridge, leaving comparatively narrow area between margin and ridge; 0-2 filamentary appendages on either side of body at base of Cirrus I Lepas pectinata
12. One or 2 filamentary appendages (fig. 7) on either side of body Lepas anatifera
12. Three filamentary appendages on either side of body Lepas hilli

ANNOTATED LIST OF COMMON BARNACLES

Order Thoracica

Suborder Lepadomorpha

- Lepas anatifera Linnaeus, 1758. Common during July and August on floating wood and Sargassum.
- Lepas anserifera Linnaeus, 1767. Occasionally associated with L. pectinata on drift-wood.
- Lepas fascicularis Ellis and Solander, 1786. Found attached to floating Sargassum during the summer months.
- Lepas hilli Leach, 1818. Some of the records of this species from the Cape Cod Region may be based on misidentifications of L. anatifera.
- Lepas pectinata Spengler, 1793. This species is often associated with L. anatifera on floating wood in Buzzards Bay and Vineyard Sound during the summer months.

Suborder Balanomorpha

- Balanus (Balanus) amphitrite niveus Darwin, 1854. (= B. venustus niveus). The most common barnacle in the subtidal waters of Buzzards Bay and Vineyard Sound. Found on stones and shells, especially those of gastropods occupied by hermit crabs. Not known north of Cape Cod nor in Cape Cod Bay.
- Balanus (Balanus) balanus (Linnaeus 1758). (= B. porcatus). A large, strongly ribbed barnacle in the lower intertidal zone north of and throughout the Cape Cod Canal. Occasional specimens are found subtidally in Vineyard Sound.
- Balanus (Balanus) crenatus Bruguière, 1789. Occasionally associated with B. amphitrite niveus in the subtidal waters of Vineyard Sound, but more common in Cape Cod Bay.
- Balanus (Balanus) eburneus Gould, 1841. Common in the lower intertidal of protected inlets and bays, and especially in waters of lower salinity with B. improvisus.
- Balanus (Balanus) improvisus Darwin, 1854. Common in waters of low salinity on the southern coast of Cape Cod, and often associated with B. eburneus.
- Balanus (Semibalanus) balanoides (Linnaeus, 1767). The most abundant and ubiquitous barnacle in the intertidal zone of the Cape Cod Region, but drops out in brackish waters.
- Balanus (Chirona) hameri (Ascanius, 1761). Not in key. Common on the large commercial scallop, Placopecten magellanicus, abundant in deeper water, as on fishing banks. Potentially important to physiologists because it is by far the largest barnacle in this region, over 5 cm in basal diameter.
- Chthamalus fragilis Darwin, 1854. Abundant in the upper intertidal zone of Buzzards Bay and Vineyard Sound. Also present in limited numbers along the southern shore of Cape Cod Bay, but not known to occur north of this area.

Order Acrothoracica

- Trypetesa lampas (Hancock, 1849). (= Alcippe lampas). Found only in the floor and side of the interior of the body whorl of gastropod shells such as Lunatia heros and Neverita duplicata occupied by hermit crabs.

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Order Rhizocephala

The Rhizocephala are parasitic cirripeds which infest decapod crustaceans and isopods. The adult rhizocephalan is highly modified in body form and bears no resemblance to other cirripeds. The affinities of this group are exhibited only by the larval stages which include a nauplius with characteristic frontal horns (although lacking an alimentary canal) and a cypris.

The life history of the common European species Sacculina carcini (Thompson) was worked out by G. Smith in 1907. The fertilized eggs mature and develop into cirripedan nauplii within the "mantle cavity" of the parent. The nauplii are released and swim actively for four days during which they pass through four molts. On the fifth day the nauplius undergoes metamorphosis into the cypris stage which is also actively free-swimming and lasts from two to three days. About the third day the cypris attaches itself by the antennules to the base of a seta of the portunid crab Carcinus maenas. The thoracic appendages and musculature are cast off and a new larva, the kentrogen, composed of a mass of mesodermal cells surrounded by an ectodermal chitinous bag is produced under the old cypris shell. A hollow, dart-like ectodermal process pierces the base of the seta to which the kentrogen is attached, and the enclosed mesodermal cells pass through into the haemocoel of the crab and settle near the midgut. The cells rapidly divide and form a tumor about the midgut with numerous divergent roots which eventually extend into the extremities of the crab. The main body mass of Sacculina emerges from the interior after the following molt of the host at a point near the ventral juncture of the thorax and abdomen. Further molting is inhibited by the parasite, whose adult organs (including paired ovaries and testes, and a neural ganglion) now differentiate.

Rhizocephalans have not been reported from the Cape Cod Region, although Sacculina carcini parasitizes the green crab Carcinus maenas, and Peltogaster the hermit crab Pagurus bernhardtus in European waters. The works of Professor Hilbrand Boschma (1925-1963) may be consulted for details on the Rhizocephala. A complete bibliography is given in Zool. Meded. (1964), vol. 39, pp. XLI-XLVI.

Plate 11

PYCNOGONIDA, CIRRIPIEDIA

(1-6) Pycnogonids after Hedgpeth (scale bars = 1 mm);
 (7-18) barnacles after Zullo; all redrawn by Bruce
 Shearer.

1. Anatomy of a generalized pycnogonid: Abdomen (ab)
 Eye tubercle (et)
2. Phoxichilidium femoratum. Chelifore (ch)
 Palp (pa)
3. Callipallene brevirostris. Proboscis (pr)
 Ovigerous leg (ov)
4. Tanystylum orbiculare. Femur (f)
 Tarsus (t)
5. Anoplodactylus lentus. Tibia, first, second (t₁, t₂)
 Propodus (p)
6. Ovigerous leg of male A. lentus.
7. Generalized lepadomorph barnacle with capitular sheath cut away to show cirri and filamentary appendages.
8. Balanus balanus, base of shell wall seen from below, showing internal ribs and septa.
9. Balanus improvisus, shell only, showing radius only partly overlapping ala.
10. Balanus eburneus, shell only, showing extensive overlap of ala by radius. ala (a)
 carina (car)
 carinolateral plate (clp)
 cirri (c)
11. Lepas anserifera, seen from right side. excavation of tergum (e)
 filamentary appendages (f)
 lateral plate (lp)
12. Diagram of plate arrangement in Chthamalus. paries (p)
 radius (r)
 rostral plate (rp)
13. Diagram of plate arrangement in Balanus. (rp = fused ros + rlp)
 rostromedial plate (rlp)
 rostrum (ros)
14. Balanus amphitrite niveus, showing color pattern of longitudinal striae. scutum (s)
 tergal spur (ts)
 tergum (t)
15. Exterior of tergum of Balanus improvisus, showing tergal spur.
16. Exterior of scutum of B. eburneus, showing radial striations.
17. Interior of tergum of B. eburneus, showing excavation on carinal side of basal margin.
18. Interior of scutum of B. amphitrite amphitrite, showing adductor ridge (diagonal line near center).

Plate II

