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FAO FISH FINDER

COMMERCIALLY IMPORTANT SEA CUCUMBERS OF THE WORLD

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PREPARATION OF THIS DOCUMENT

Sea cucumbers of commercial importance are distributed globally, with most species harvested in multiple locations. Biological information is available for many species but limited for others, making resource assessments and trade data potentially misrepresented. Species within some taxonomic groups can look similar, both in the field and once processed into a dried product, so identification guides should allow scientists, traders and trade officials to understand the features of each species that easily distinguish them from other ones.

A number of identification guides and taxonomic accounts of sea cucumbers exist, but none has provided global coverage of all commonly exploited species with photographs of live and dried animals. In addition, some use technical language and characters not easily understood by people with limited taxonomic training.

International fora dealing with the conservation of sea cucumbers (i.e. FAO Workshop on Advances in Sea Cucumber Aquaculture and Management – Lovatelli *et al.*, 2004; CITES[1] Technical Workshop on the Conservation of Sea Cucumbers in the Families Holothuriidae and Stichopodidae – Bruckner, 2006; CITES Animals Committee and Fourteenth Conference of the Parties – Toral-Granda, 2007; IUCN Red List Workshop for Sea Cucumbers, Colombia 2010) have underscored a current limitation in available tools for identifying processed animals traded internationally. For example, although *Isostichopus fuscus* was included in CITES Appendix III by Ecuador in October 2003, conservation of this species has lagged, in part, because custom and border control agents have had little information by which to distinguish the dried animals from other similar species.

Consequently, the Food and Agriculture Organization of the United Nations (FAO) coordinated a project to prepare this global identification guidebook. A scientific steering committee for the project, with the help of numerous field experts, compiled a list of commercially exploited sea cucumber species (see Purcell, 2010). Information on biology, diagnostic features, exploitation and distribution of these species were then solicited from taxonomic experts and field biologists globally. Some species were excluded from this guidebook because they are seldomly exploited, or are exploited in minor quantities, or were poorly known to science, or photographs were completely lacking. Three other species exploited for the aquarium trade were also intentionally omitted because the focus of this guidebook is on species exploited for human consumption. Finally, recent genetic work funded by FAO (Uthicke, Byrne and Conand, 2010) enabled the deletion of two synonymic species: *Bohadschia bivittata* and *B. similis*.

In addition to various technical papers, several taxonomic guides were especially relied upon for technical descriptions of the live animals and their calcareous ossicles, and accounts of their distributions: Clark and Rowe (1971), Féral and Cherbonnier (1986), Massin (1999), Samyn (2003), Samyn, VandenSpiegel and Massin (2006), Solis-Marín *et al.* (2009).

Claude Massin and Gustav Paulay also provided valuable comments on the species distributions. The distribution maps in this book are based upon published accounts and personal communications and are certain to be incomplete for some regions (e.g. Southeast Asia) due to a lack of available and reliable accounts.

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[1] CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora

ABSTRACT

Sea cucumbers are harvested and traded in more than 70 countries worldwide. They are exploited in industrialized, semi-industrialized, and artisanal (small-scale) fisheries in polar regions, temperate zones and throughout the tropics. In some fisheries, more than 20 species can be exploited by fishers and should be distinguished from each other by fishery officers and scientists. The processed (cooked and dried) animals, often called bêche-de-mer or trepang, are exported mostly to Asian markets and need to be distinguished to species level by customs and trade officers. This book is intended as an identification tool for fishery managers, scientists, trade officers and industry workers to distinguish various species exploited and traded worldwide.

This book provides identification information on 58 species of sea cucumbers that are commonly exploited around the world. There are many other species that are exploited either in a small number of localities or in relatively small quantities, which are not presented. Species in some regions with active fisheries are also not represented due to limited information available (e.g. Mediterranean species). The accounts are based on more than 170 reports and research articles and by comments and reviews by taxonomists and field workers.

Two-page identification sheets provide sufficient information to allow readers to distinguish each species from other similar species, both in the live and processed (dried) forms. Where available, the following information for each species has been included: nomenclature together with FAO names and known common names used in different countries and regions; scientific illustrations of the body and ossicles; descriptions of ossicles present in different body parts; a colour photograph of live and dried specimens; basic information on size, habitat, biology, fisheries, human consumption, market value and trade; geographic distribution maps. The volume is fully indexed and contains an introduction, a glossary, and a dedicated bibliography. Readers are encouraged to base their identifications on a combination of morphological features, samples of ossicles from different body parts and information on what habitat and locality the species was found.

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A special thank you and recognition goes to Veronica Toral-Granda for the preliminary work that enabled the gathering of the initial set of information and data used in the production of this guidebook. Recent retail and wholesale prices of bêche-de-mer in Hong Kong and Guangzhou were obtained by S. Purcell through PARDI project 2010/004, funded by the Australian Centre for International Agricultural Research.

This book also benefited from the collaboration of sea cucumber scientists worldwide who provided the information included in the species fact sheets, without their information and support this book would not have been possible: Mohammed I. Ahmed, Jun Akamine, Irma Alfonso, Khalfan M. Alrashdi, Juan José Alvarado, Luis Amaro-Rojas, Riaz Aumeeruddy, Mark Baine, José Enrique Barraza, Milena Benavides-Serrato, Maria Byrne, Chen Jianxin, Peter Collin, Poh Sze Choo, Niki Davey, Hampus Eriksson, Vanessa Francisco, Ruth Gamboa, Beni Giraspy, Elena Gudimova, Chita Guisado, Héctor Guzmán, Jean-Francois Hamel, Carlos Roberto Hasbun, Alex Hearn, Philip Heath, María Dinorah Herrero-Pérezrul, Ivy G. Walsalam, Daniel Baskar James, Alex Kerr, Jeff Kinch, Ambithimaru Laxminarayana, Annie Mercier, Bo Meredith, Maria Del Mar Otero-Villanueva, Gustav Paulay, Philip Polon, Erika Paola Ortiz, Mary A. Sewell, Timothy Skewes, Francisco A. Solís-Marín, Veronica Toral-Granda, Akram Tehranifard, Sven Uthicke, Didier VandenSpiegel and Erin Wylie.

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INTRODUCTION

The use of sea cucumbers as a food item and a commodity began in China about 1 000 years ago, which encouraged the development of capture fisheries in the region. However, the rising demand of the markets in Asia led to the depletion of local sea cucumber populations and prompted Asian traders to solicit sea cucumbers from locations further afield (Conand, 2004, 2005b; Bruckner, 2006; Toral-Granda, Lovatelli and Vasconcellos, 2008; Purcell, 2010). Currently, sea cucumber fishing occurs all over the world with some populations reportedly over-harvested (Lovatelli *et al.*, 2004; Bruckner, 2005b; Uthicke and Conand, 2005; Conand and Muthiga, 2007; Toral-Granda, Lovatelli and Vasconcellos, 2008).

Most tropical fisheries are multispecific and at an artisanal scale or for subsistence use. In some cases, fishing evolved to target many low-value species after stocks of the more valuable species were depleted. In temperate regions, fishing commonly focuses on one species harvested with industrial fishing methods (Hamel and Mercier, 2008). The vast majority of species are harvested for the 'bêche-de-mer' or 'trepang' market (e.g. *Actinopyga mauritiana*, *Holothuria scabra*, *Thelenota ananas*), although some species are also consumed cooked, pickled or raw (e.g. *Apostichopus japonicus*, *Cucumaria frondosa*, *Parastichopus californicus*). Some domestic markets also demand the pickled intestines and gonads, while some commercial products have sea cucumber by-products (e.g. "gamat" oil from *Stichopus horrens*) and others are included in the aquarium trade. Generally, sea cucumber harvesting is for export, with little domestic use, and the market is largely driven by oriental entrepreneurs who set the price for the sale (Conand, 2008; Kinch *et al.*, 2008; Toral-Granda, 2008).

Since the 1980s, sea cucumber harvesting has boomed but many stocks have collapsed. Concomitantly, fishers in more and more countries are exploiting more species in an attempt to meet the strong demand in Asian markets. Towards the end of the "boom" part of a "boom-and-bust" fishing cycle, populations of some species had been reduced to such low levels that there was little capacity for natural recovery and replenishment, leading to their economic and ecological extinction.

Sea cucumbers belong to the class Holothuroidea and so are also referred to as holothurians. The majority of species harvested commercially belong to the order Aspidochirotida, specifically to the families Holothuriidae and Stichopodidae, and are mostly tropical. A few species belonging to the order Dendrochirotida, family Cucumariidae, are also fished commercially. Species in the orders Apodida, Dactylochirotida, Elasipodida and Molpadida are mostly not fished commercially and are not presented in this field guidebook. Conand (2006) recognized about 40 species of sea cucumber under commercial harvest, while Toral-Granda, Lovatelli and Vasconcellos (2008) listed at least 47 species. Later, Purcell (2010) lists 66 species that are currently exploited commonly in various regions of the world. The chronological increase in the number of reported exploited species echoes the pervasive problem of serial depletion of high-value species, leading to exploitation of new species.

The taxonomy of some groups of sea cucumbers is complex, even for taxonomic experts, and has stimulated much research in recent years. Uthicke, Byrne and Conand (2010) genetically analysed the relationships among many commercial species, shedding new light on a few of them. However, once processed, some sea cucumbers can be difficult to identify to species level, creating a problem for trade officials. This has been identified as a bottleneck when attempting to implement conservation tools in the international trade (e.g. a CITES listing) and has led to the development of illegal, unreported and unregulated (IUU) trade.

This book presents a summary guide to identifying 58 sea cucumber species exploited for human consumption through photographs of the live and processed animals, morphological descriptions, biological and ecological information, and illustrations of the calcareous ossicles ('spicules') found in various body tissues. The shape of ossicles differs among species and may be used to distinguish species in trade (e.g. *Isostichopus fuscus* [Toral-Granda, 2005]). This book also summarizes information on current fisheries and management measures of each species, although the regulatory measures currently in place may be insufficient and in need of improvement (Purcell, 2010).

GENERAL REMARKS

External morphology of sea cucumbers

Sea cucumbers have an orally-aborally (longitudinally) elongated body (Figure 1). The pentamerous symmetry is sometimes recognizable by the presence of 5 meridional **ambulacra** bearing **podia**. Sea cucumbers live on the substrate of the sea floor with their ventral surface (or **trivium**). This creeping sole bears the locomotory podia, while on the dorsal surface (or **bivium**), the podia are often represented by papillae. Consequently, a secondary bilateral symmetry is evident.

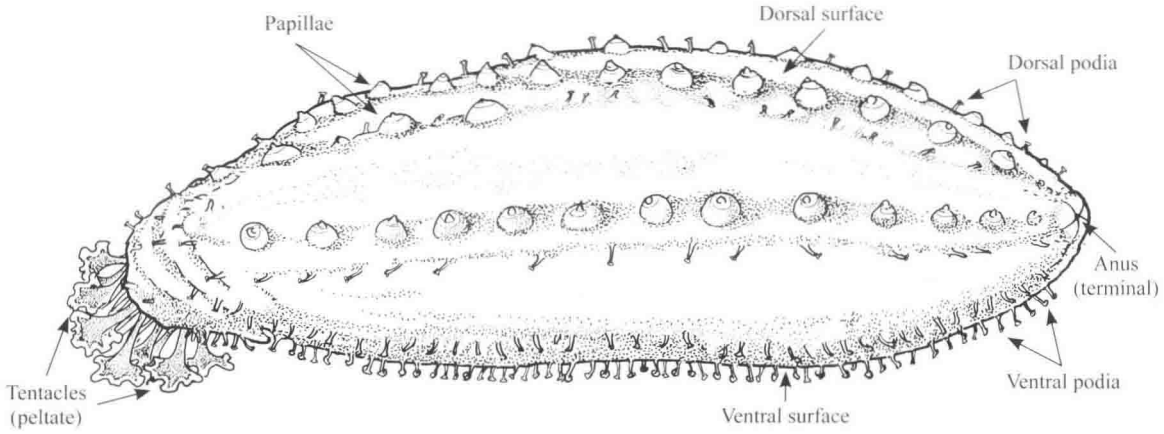


Figure 1 Main external anatomical features of a sea cucumber

The mouth, at the anterior end, has **tentacles** (Figure 1), which the animal extends to acquire food (mainly particulate organic matter). The **anus** is at the posterior end of the animal. Tentacles are buccal podia containing extensions from the water vascular system. Their number varies between 10 and 30, generally being a multiple of 5. In the **Aspidochirotida** all tentacles are of the same size, but in the **Dendrochirotida** tentacles can be of differing size. The shape of the tentacles differs among the various taxonomic orders and is used as a key character (Figure 2). In the Dendrochirotida, they are **dendritic** (branching in an arborescent manner) and can reach a large size when extended. The Aspidochirotida have **peltate** tentacles, each with a central stalk and a little branching disc. Sea cucumber tentacles are very retractile, particularly in the Dendrochirotida, which have an **introvert** where the tentacles insert. The tentacles and the introvert can be contracted into the inside of the animal by 5 retractor muscles.

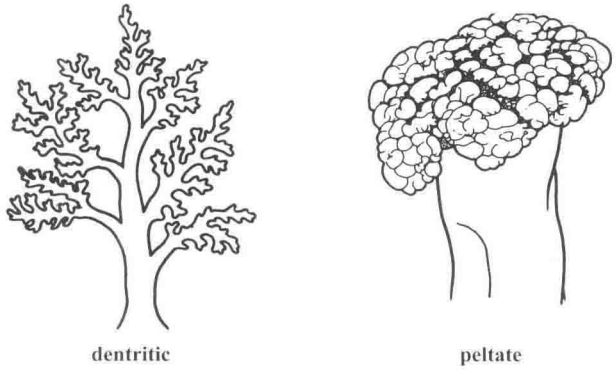


Figure 2 Basic types of tentacles

The body surface is thick, slimy in many species and bears wart-like, conical or fleshy **papillae** (Figure 1). **Podia** appear on the body wall and typically have the form of locomotory tube feet (Figure 1): hollow tubular projections terminating in a flat disc, which allows the podium to adhere to the substratum during locomotion. Epidermal cells produce adhesive secretions. Internally, the disc is supported by a large skeletal ossicle. Podia can also have the shape of papillae. The tube feet are rarely arranged in 5 regular rows, but generally they lose the discs on the dorsal surface and spread into the interradial areas. The **anus** may be encircled by small papillae or heavily calcified papillae called **anal teeth**. The coloration varies between species and sometimes also between individuals of the same species. The ventral surface is often lighter in colour than the dorsal surface.

Body wall

The body wall is thin in Apodida and Molpadida, but thicker in the other orders, particularly in the Aspidochirotida. It constitutes the part of the body that is processed for human consumption and, therefore, commercial species are characterized by a thick body wall. Its structure consists of a thin cuticle over the epidermis and a thick dermis underneath. The dermis is composed of connective tissue, enclosing the endoskeletal ossicles or 'spicules' (see next section). Below the dermis, a layer of circular muscles forms a cylinder, generally interrupted by 5 longitudinal muscle bands situated in the radial positions.

Ossicles

Also called spicules, or deposits, ossicles (Figure 3) are characteristic of sea cucumbers and of primary importance for identification. They are mostly of microscopic size. There is a wide variety of simple to complex shapes. **Rods** can be simple or branching, smooth, warty, or spiny, or can bear knobs only at their ends. They can also have a characteristic C- or S-shape. Fenestrated **plates** also come in various shapes. **Buttons** are oval ossicles, perforated with a varying number of holes arranged in 2 or more rows. **Tables** are more complicated; they appear as a perforated disc, bearing an erect **spire** (or tower) composed of pillars that can unite to form cross-beams or bridges and that terminate in a crown and show many variations according to the arrangement of its constituents. **Rosettes** are short rods subdivided into short branches. **Anchors** are peculiar of the family Synaptidae (order Apodida). They are oriented in the body wall, so that they support the attachment to the substrate during crawling, in the absence of podia. They are attached to an accompanying perforated plate, the

anchor plate. Miliary bodies (**grains**) are very tiny ossicles found in some Stichopodidae. Apart from the body wall, ossicles are found in the tentacles, the podia, and often also in the internal organs. Their developmental stages can differ from the definitive shapes in the adults and thus can make species identification difficult.

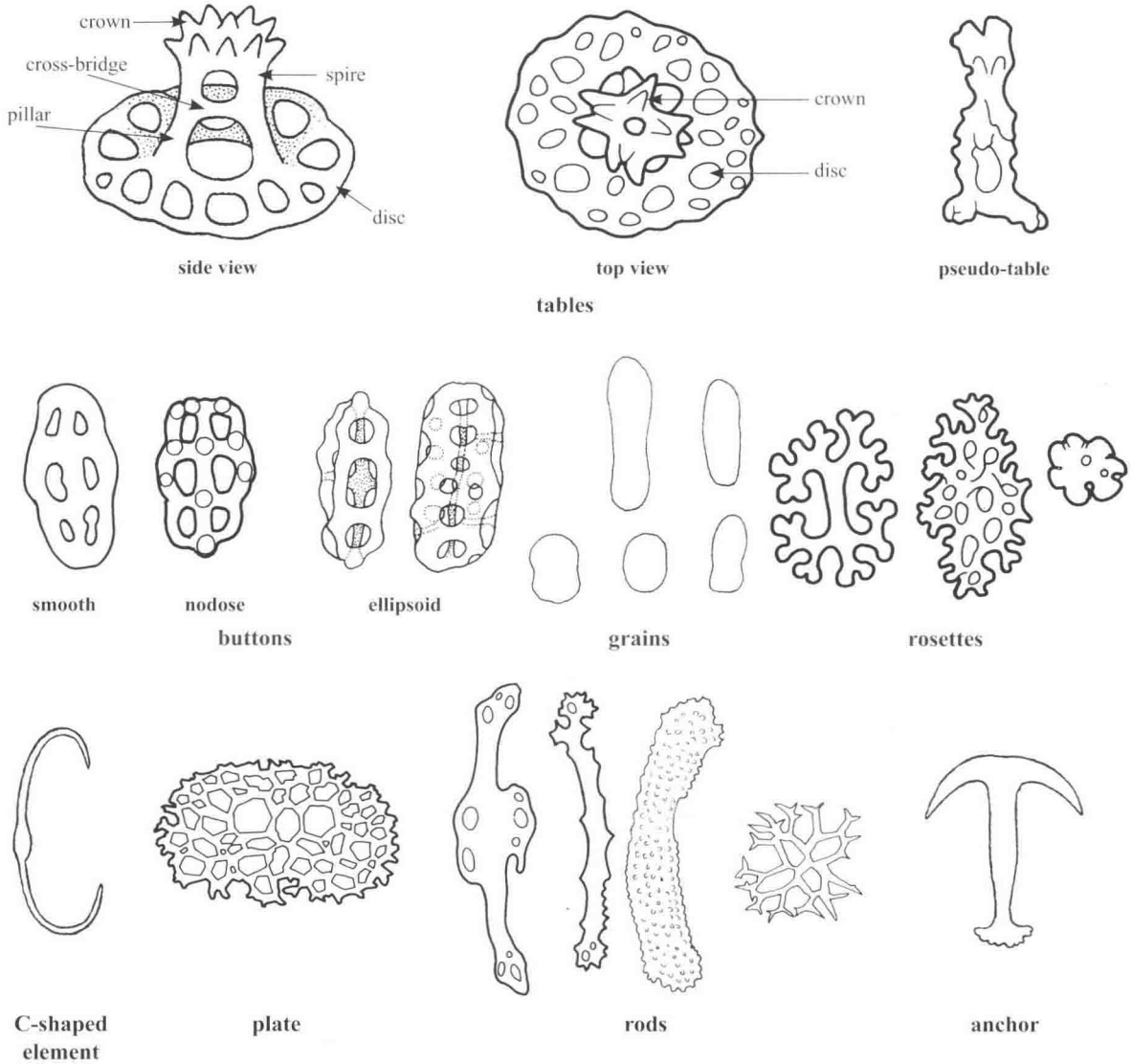
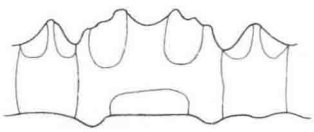


Figure 3 Basic types of ossicles

Calcareous ring

A ring of usually 10 calcified plates encircles the pharynx. It is composed of alternating larger radial plates, opposite to the ambulacra and smaller interradial plates. The plates may be simple or composed of smaller pieces. Longitudinal muscles attach to the radial plates.



calcareous ring

Digestive system and connected organs

The gut is composed of a pharynx, an esophagus, a stomach, all of which are short structures, and a very long intestine (Figure 4). The intestine consists of 3 portions, a descending, an ascending and finally a descending loop that connects to both the rectum and the **cloaca** opening outwards through the anus. Where present, **respiratory trees** are connected to the cloaca. The oxygenated water enters the body by these water lungs, which are found in all orders except the Apodida. **Cuvierian tubules**, present in several species of Aspidochirotida, are generally considered defensive structures. They are sticky tubules attached to the base of the respiratory trees and can be expelled in some *Holothuria* and *Bohadschia* species through the cloaca towards the source of irritation.

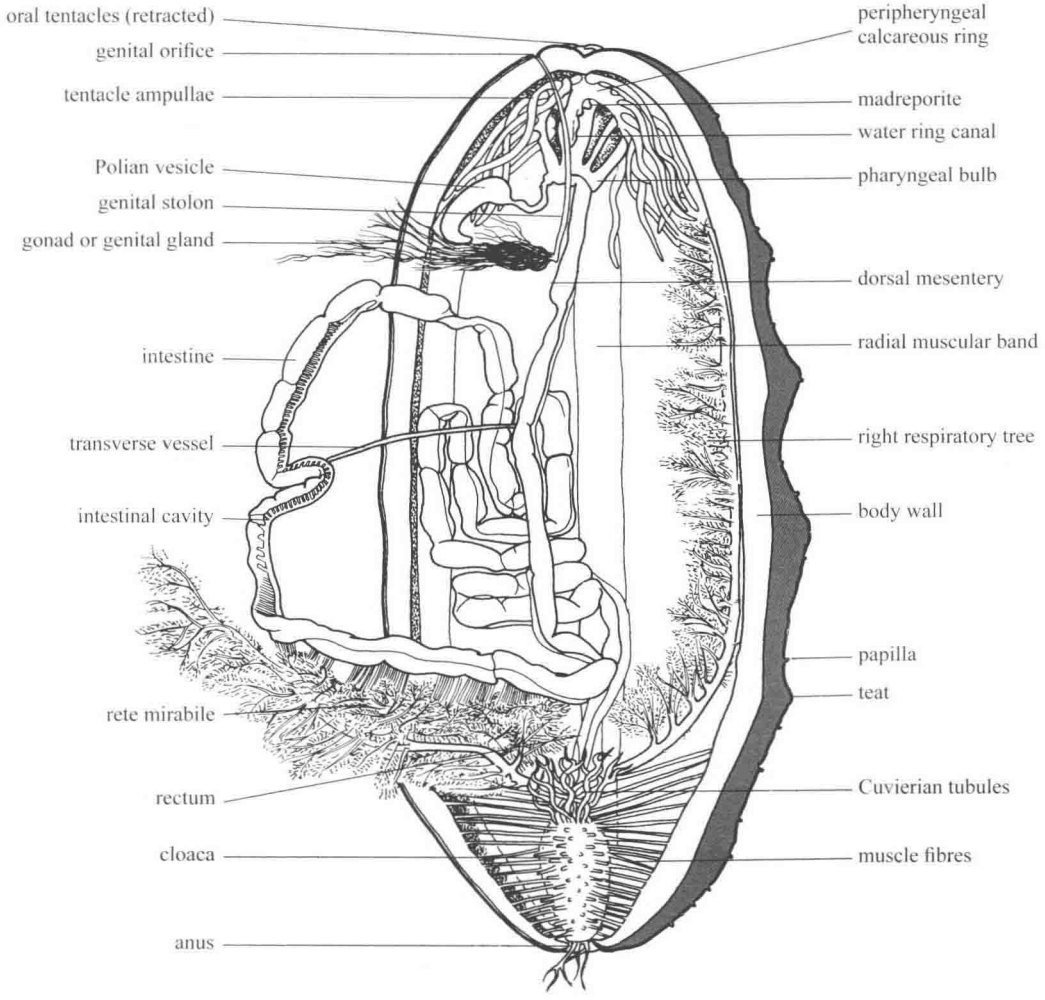


Figure 4 Anatomy of the aspidochirotid sea cucumber *Holothuria whitmaei* Bell, 1887 (after Conand, 1989)

Reproductive system

In contrast to other echinoderms, the reproductive system of holothurians consists of a single **gonad** or genital gland (Figure 4). The gonad is situated dorsally and in the Aspidochirotida composed of either 2 tufts of tubules (Stichopodidae), or only 1 tuft (Holothuriidae). The sexes are generally separated and show little dimorphism unless in the period of maturing. The gonad is attached to the dorsal mesentery through which the **gonoduct** or genital stolon opening passes, leading to the outside by the **gonopore** (genital orifice) or a genital papilla. In most species, the mature gametes are freely released into the seawater. The spawning behaviour, observed in many Aspidochirotida species, involves an upright posture of males and females followed by a swaying back and forth, while the gametes are being released.

Water vascular system, perivisceral coelom, and hemal system

The **water vascular system** (Figure 4) is a coelomic space bordered by a mesothelium. It consists of the lumen of the buccal tentacles and the podia, a **water ring** around the esophagus, the **radial canals**, the **madreporic canal** and the **Polian vesicles**. The perivisceral coelom is a large cavity containing watery proteinaceous coelomic fluid and different forms of cells (coelomocytes).

The haemal system is well developed and composed of large haemal vessels along the gut, sinus and lacunae. The haemal vessels associated with the gut can form a complex meshwork with the left respiratory tree, the **rete mirabile**, suggesting different functions of nutrient and gas transfers.

Habitat and biology

Holothurians are found throughout all oceans and seas, at all latitudes, from the shore down to abyssal plains. The adult stages are benthic (living on the sea bottom); some species live on hard substrates, rocks, coral reefs, or as epizoites on plants or invertebrates. Most of the species inhabit soft bottoms, on the sediment surface or buried in the sediment. Among the commercial coastal holothurians, the Aspidochirotida are predominant in the tropics, while the Dendrochirotida are more common in temperate regions. Sea cucumbers within the order Aspidochirotida have **planktotrophic** larvae, i.e. that feed on microalgae in the water column during the dispersive larval phase. Within the order Dendrochirotida, the larvae of sea cucumbers described in this book are **lecithotrophic**, i.e. the dispersive larvae feed on a lipid yolk rather than on microalgae in the water column.

Fisheries

Holothurians have been harvested commercially for at least a thousand years, occasionally for the raw body wall or viscera, but mostly in order to be processed into a dry product called **bêche-de-mer**, **trepang**, or hai-san, which is considered a delicacy and a medicinal food by Chinese and other Asian peoples. Harvesting in the tropics is usually done by hand, while wading in shallow waters, or gleaning, at low tide or by free-diving from small boats, although SCUBA and hookah have increasingly been used.

Common processing techniques

The Asian markets are now accepting new product forms of sea cucumbers, such as semi-dried vacuum packed, frozen whole or as separate body parts. Processing methods to achieve the dried form (bêche-de-mer) vary depending on the species, the final product to be achieved and the market to which the product will be sold. The Secretariat of the Pacific Community (SPC, formerly the South Pacific Commission) and the National Fisheries Authority (NFA) of Papua New Guinea have summarized the most common methods for tropical species, as reproduced below:

Method 1

Boil sea cucumber for a short time (2–5 minutes) until it swells; remove gut and body content by gently squeezing the body or by making, if necessary, a very small cut in the mouth. Put back in boiling water until rubbery and hard. Bury in a sandpit for 12–18 hours; upon retrieval, rub the outer part of the body to remove decomposed parts. Boil a third time in clean water. Drain and dry in hot air. Do not smoke. Leave to dry in the sun (from four days to two weeks depending on moisture content).

Method 2

Boil sea cucumber for a short time (2–5 minutes) until it swells; remove gut and body content by gently squeezing the body or by making, if necessary, a very small cut in the mouth. Put back in boiling water until rubbery and hard. Wash in seawater. Boil a third time in clean water. Drain and dry in hot air or with smoke. Leave to dry in the sun (from four days to two weeks depending on moisture content).

Method 3

For animals with very thick body wall, boil until it swells (may take up to 10 minutes). Slit upper dorsal side about 3 cm from each end, and remove body contents. Do not remove the five longitudinal string muscles. Wash in seawater. Boil again in clean water until hard and rubbery. Remove any remaining guts and other body contents. Place a stick across the slit to keep it open, and hot air or smoke for 12–48 hours. Sun dry for one to two days with the slit downwards. Remove sticks and tie with string or vines. Leave to dry in the sun (from four days to two weeks depending on moisture content). Remove string/vines before packing.

Method 4

For animals with very thick body wall, boil until it swells (may take up to 10 minutes). Slit ventral side about 3 cm from each end, and remove body contents. Do not remove the five longitudinal string muscles. Wash in seawater. Boil again in clean water until hard and rubbery. Remove any remaining guts. Place a stick across the slit to keep it open, and hot air or smoke for 12–48 hours. Sun dry for 1–2 days with the slit downwards. Remove sticks and tie with string or vines. Leave to dry in the sun (from 4 days to two weeks depending on moisture content). Remove string/vines before packing.

Method 5

Temperate species (*Cucumaria frondosa*, *C. japonica*, *Parastichopus californicus* and *P. parvimensis*) are also consumed raw, quick frozen or canned. The processing technique varies among countries and regions and the final product, which may be muscle strips, aquapharyngeal bulbs (called 'flowers'), gut, gonads and respiratory trees. For detailed information on individual species, refer to Hamel and Mercier (2008). These species are normally harvested and processed industrially.

Preparation of ossicles

As in other echinoderms, species identification of sea cucumbers is aided by the examination of the skeletal elements (ossicles) found in various parts of the body. The calcareous ossicles, which are hidden in the body wall (mainly in the dermis tissue), papillae, podia and tentacles are, in the species within this book, mostly just one-twentieth to one-tenth of a mm in length. They are embedded in soft tissues, but can be dissected out of the live, dried or preserved animals and isolated by the following method:

1. Small pieces (e.g. a few square mm) of tissue are removed with a scalpel from dorsal body wall and ventral body wall, as well as the tentacles and podia, and each placed into separate small vials.

2. A small volume (e.g. 0.5 ml) of sodium hypochlorite (concentrated household bleach), or sodium hydroxide, is then added to each vial in order to dissolve the organic tissue away from the calcareous ossicles. The soft tissue will be dissolved/digested in 20–30 minutes, leaving the hard ossicles to fall to the bottom of the vial.

3. After decanting, or pipetting, out the bleach, the ossicles are washed 5 times in distilled water. This step can be achieved by sucking the liquid out of the vial with a pipette, taking much care to rinse the pipette in fresh water each time so as not to contaminate a sample with the ossicles from another.

4. The ossicles can then be rinsed in alcohol and placed onto a microscope slide with a drop of a mountant (Euparal medium). They can also be put on a scanning electron microscope (SEM) stub.

5. After processing, the ossicles can be observed either on permanent slides with a light microscope, or prepared for a scanning electron microscope.