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Pancucci-Papadopoulou M.A., Murina G.V.V. & Zenetos A.

The Phylum Sipuncula in the Mediterranean Sea

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ΔΙΕΥΘΥΝΤΗΣ ΕΚΔΟΣΗΣ

Καθηγητής Δρ. Δ. Ι. Παπανικολάου, Πρόεδρος Δ.Σ. και Διευθυντής ΕΚΘΕ

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ΓΡΑΦΕΙΟ ΕΚΔΟΣΕΩΝΆγιος Κοσμάς, ΕλληνικόPUBLICATION OFFICEAghios Kosmas, Helliniko

166 04, Αθήνα 166 04, Athens

Tηλ./Tel.: +301-98 30 405 Fax: +301-98 33 095

e-mail: publ@ncmr.gr Web Site: http://www.ncmr.gr

TABLE OF CONTENTS

	Page
SCOPE OF THIS WORK	7
ABSTRACT	9
INTRODUCTION	11
HISTORY OF THE PHYLUM	11
THE SIPUNCULAN ECOLOGY	
Behaviour	13
Ecological Significance Zoogeographical distribution	
TAXONOMY AND CHARACTERS OF THE PHYLUM	15
SYSTEMATICS OF THE PHYLUM	15
THE SIPUNCULAN MORPHOLOGY	15
THE MEDITERRANEAN SIPUNCULA	20
LAYOUT OF THE MONOGRAPHTAXONOMIC OBSERVATIONS ON THE MEDITERRANEAN SIPUNCULA	22
LITERATURE EXPLOITED FOR THE GEOGRAPHIC DISTRIBUTIONKEY TO THE MEDITERRANEAN SIPUNCULA SPECIES	

REVIEW OF THE SPECIES	27
Family: Sipunculidae	28
Genus Sipunculus	
Family: Golfingiidae	
Genus Golfingia	32
Genus Nephasoma	38
Genus Thysanocardia	
Family: Phascolionidae	
Genus Phascolion	
Genus Onchnesoma	
Family: Phascolosomatidae	
Genus Phascolosoma	
Genus Apionsoma	
Family: Aspidosiphonidae	
Genus Aspidosiphon	84
EPILOGUE	95
DIVERSITY AND DISTRIBUTION OF THE MEDITERRANEAN SIPUNCULA	95
ACKNOWLEDGMENTS	100
REFERENCES	101
INDEX	107

SCOPE OF THIS WORK

Sipunculan detailed taxonomy has often been neglected in ecological studies although some of the species may play an important role in: (a) the destruction of limestone and coral reefs (b) the agricultural economy (edible species and/or used as bait). In fact, the larger representatives, belonging to the genera *Sipunculus, Siphonosoma, Phascolosoma*, are eaten by inhabitants of China, Japan and the islands of the Indo-Malay Archipelago. The reason for overlooking the species' composition so often, must be attributed to the general lack of taxonomists worldwide. In the case of Sipuncula, which according to recent revisions comprise about 162 to 163 species and subspecies (CUTLER, 1994; HYLLEBERG, 1994), there are less than 10 specialists all over the world.

This is an attempt to compile existing information on the Mediterranean species recorded so far, presenting for each species: full synonymy of at least the names used in the Mediterranean records, full description and distinguishing features with accompanying figures, and illustrations where possible, details on its biotope and its geographic distribution in the Mediterranean and worldwide.

ABSTRACT

Keywords: Sipuncula, Mediterranean, Taxonomy, Diversity, Ecology.

The sipunculan diversity in the Mediterranean has been up to now scarce and inaccurate. This monograph is an effort to compile existing information on the Mediterranean species recorded so far, reviewing the nomenclature used. Full synonymy, description with emphasis on distinguishing features, distribution in the Mediterranean and worldwide and ecology are given for each species. A dichotomic key is included along with illustrations for each species pinpointing the distinctive characteristics in order to facilitate the student/researcher in identifying a species.

The produced check list of Mediterranean Sipuncula is presented in taxonomic order according to the classification scheme of GIBBS and CUTLER (1987). This work showed that the phylum is represented in the Mediterranean by 33 species, belonging to five families and nine genera whereas only 22 species were reported to occur in the prexisting literature. Higher species diversity (29 species: 88%) is recorded in the Western basin, whereas in the eastern basin diversity is reduced to 21 species (64%). Worth noticing is the absence of endemic Sipuncula in the Mediterranean.

The present work extends the known bathymetric distribution of the species in 9 cases. This result shows the richness of the Sipuncula in the Mediterranean refering to the world scale: 33 species out of a total of 162 world species, that is 20% are presented in the Mediterranean.

The majority of them (39%) has a wide geographic distribution, occurring from tropical to temperate and boreal zones, while the subtropical component is limited to 15%.

INTRODUCTION

HISTORY OF THE PHYLUM

Phylum: Annelids, Echinoderms or Molluscs?

The phylum is usually considered to be most closely related to the annelids and molluscs, but there is no clear consensus as to its true sister group. Its resemblance to marine worms has placed it in various controversial positions in the phylogenetic tree for over four centuries.

The first descriptions of sipunculans, published by Rondelet (1555), were those of two animals: the so-called *microrhynchoterous* and *macrorhynchoterous* worms respectively. Two centuries later Linnaeus (1766) created the name *Sipunculus* and called Rondelet's two species *Sipunculus* nudus and *S. saccatus*, respectively, placing them in the **Vermes Intestina**. Lamarck (1816) considered sipunculans to be closely related to holothurians, and hence, placed them among the **Radiaires echinoderms**, while Delle Chiaje (1823), who thought they were **annelids**, proposed the group name Sifunculacei. The Sipuncula cannot, however, be placed in the phylum of Annelida because of their total lack of segmentation, both during development and in adult form.

QUATREFAGES (1847) conceived the name of Gephyrea as an intermediate between echinoderms and annelids and regarded sipunculans as degenerated echiuroids. Sipunculans were firstly raised to phylum rank by Sedwick (1898) who called them Sipunculoidea. Nevertheless, since the concept "Gephyrea" offered an easy way of disposing of three groups of very uncertain affinities, it won wide acceptance between the 1850s and 1950s. However, as later studies demonstrated that there was no close relationship between them, the name Gephyrea was abandoned following HYMAN (1959) who firmly stated that "the name and concept Gephyrea must be obliterated from zoology". Scheltema (1993), based on similarities in early development, postulated that sipunculans and molluscs are sister groups. Sipunculans are currently treated as a distinct phylum called Sipuncula. The currently accepted spelling of the phylum was proposed by Stephen (1964).

Although the evidence is not totally conclusive, there is a consensus that there was an ancestral form common to the sipunculans, annelids and molluscs in existence by the earliest Paleozoic Period. From this point there are three possibilities, each supported by some part of the data:

- the annelids separated from an ancestor that later gave rise to the sipunculans and molluscs
- the molluscan stock diverged first, followed by the sipunculan-annelid separation
- the sipunculans diverged from a stock that subsequently became the common ancestor to the

molluscs and annelids.

The first model, supported by the paleontological, biochemical and embryological data appears to be the most probable one (CUTLER, 1994).

Evolution: Evidence of Fossil Records

We have no definitive fossil sipunculan or any fossil that is an acceptable ancestor (Morris, 1985). However, the similarity of **fossil burrows and borings** to those made by modern sipunculans suggests that sipunculans were present from the mid-Paleozoic Period.

The sipunculan origin of ancient **burrows** is supported by recent evidence that Quaternary deep sea burrows along the northwest African and Norwegian continental slopes were made by sipunculans belonging to the genus *Nephasoma*. The fossil burrows were most common in claystones but also present in sandstone formations. There are a few thin deep-water members of the genus *Nephasoma* that could have constructed burrows with these dimensions. Other possible sipunculan burrows include holes in Miocene deposits at depths of 1000-3000m off New Zealand (HAYWARD, 1976).

Coral assemblages containing sipunculans **borings** are known from Upper Jurassic, Miocene, Pliocene, and Pleistocene times (HYMAN, 1959; PISERA, 1987). ROGER (1952) mentioned the finding of fossil madreporarian corals from the Miocene and Plio-Pleistocene of the Indo-Malay region and of tabulate corals from the middle Devonian of Europe that have basal deformities similar to those produced at present by *Aspidosiphon* and plausibly ascribable to sipunculans. Many fossils of the Devonian tabulate coral *Pleurodictyum* contain overgrown gastropod shells, most of which were occupied by a secondary resident, possibly a sipunculan like the modern *Aspidosiphon* (BRETT & COTTRELL, 1982). Solitary corals with sipunculan symbionts are known from the Upper Cretaceous and the Miocene times. The sipunculan is clearly an *Aspidosiphon*, probably *A. muelleri*.

In conclusion, despite the lack of direct evidence, existing data support the following points:

- 1) Sipunculans were living in soft-bottom burrows at least by the mid-Paleozoic Period (Devonian) and probably earlier (Cambrian) and
- 2) Some sipunculans have lived in association with corals since mid-Paleozoic times and throughout the Mesozoic and Cenozoic times.

The Sipuncula thus seem to be an ancient taxon with an unknown history of divergence and retrenchment. It is a group that underwent early but conservative cladogenesis, and its members occupied diverse niches early in its history (hard/soft, shallow/deep, warm/cold) and persist in these niches at the present time.

THE SIPUNCULAN ECOLOGY

Habitat

Sipunculans are exclusively marine benthonic animals. They appear very adaptable to a range of temperatures and depths, living from the intertidal zone to considerable depths (extending into ultra-abyssal waters to a depth of 7000m: Murina, 1973). Very few species are restricted to cold water deeper than 3000m, some live only in warm water less than 10m deep, and a few are found between 10 and 4000m over a wide range of temperatures (Cutler & Cutler, 1987b). With regard to salinity, they are absent from brackish waters. They lead a sedentary existence, in burrows in sandy, muddy, silty, gravelly, or shelly bottoms, in clefts and interstices of rocks and in porous lava. They occur in the holdfast tangles of kelp, under beds of eelgrass and other vegetation, among coralline algae, under rocks, among corals, especially in cavities in rotting coral rocks or under slabs of decaying coral, in sponges, in empty shells and tubes of other animals, and in almost any protected situation (Plate I).

Some species live in clean, coarse sand (e.g. *Siphonosoma cumanense*) while others live only a few meters away in finer sand with more silt or clay (E. CUTLER, 1965). According to HYMAN (1959), in general sipunculans avoid pure sand, no doubt because of its paucity of nutritional material.

Behaviour

Several species bore into coral. Many of the boring species have an anterior shield -like operculum- that plugs the opening of the hole and protects against predation and desiccation. Those that burrow in sand or mud secrete mucus to line the hole, but they produce no permanent tube-making material. The burrows do retain their integrity fairly well as seen in 50-cm burrows recovered in box cores from depths of 1200-2000m in Norwegian waters (ROMERO & WETZEL, 1987).

Most species have a limited ability to move outside the substratum, but they can move into or through the sediment quite quickly by extruding the introvert, expanding and anchoring its tip, and contracting the longitudinal muscles (not the retractors) if the substratum is suitable. When mechanically disturbed, a sipunculan quickly withdraws the introvert and contracts the body. The stronger and more continuous the stimulation, the stronger and longer the contraction of the body.

Ecological Significance

In both recent and fossil coral reefs, sipunculans were determined to be the most important bioeroders (KLEIN *et al.*, 1991).

Although sipunculans have not been used as specific indicator species of environmental deterioration, they have been often included in impact studies. For example in assessing effects of pollution in Belfast Harbour (Parker, 1980), or pollution caused by tin mining in Thailand (Hylleberg & Natewathana, 1983). The disappearance of sipunculan species from heavily polluted areas has been documented for a few species such as the case of *Phascolion strombus* from Narragansett Bay, Rhode Island (E. Cutler, 1973), probably due to human activities. However, sipunculans may also appear as opportunistic species, occurring in high abundance at disturbed to polluted areas (Lewbell, 1985).

In conclusion, the phylum's sensitivity to environmental changes must be investigated in future. Faunal shifts do occur naturally, and it is not always easy to assign the proper cause when faunal changes are observed over time.

Zoogeographical distribution

Sipunculans inhabit all seas except extremely brackish areas and are found at all latitudes. Because of their tolerance to a range of temperatures and depths they have a wide geographic distribution. Moreover, as they are capable of dispersing their planktonic larvae over hundreds or thousands of kilometers fairly quickly, it is possible for sipunculans to be distributed over large areas. This makes the zoogeographical boundaries of a species range difficult to define and delimit (SCHELTEMA & RICE, 1990).

The group undoubtedly centres in warmer waters where the great majority of species are found. Despite the preference of sipunculans for warm waters, arctic and boreal zones support many members of the group, with the usual southward spread along the continental coasts. The most notable representative in terms of geographic distribution is *Sipunculus nudus*, which is practically cosmopolitan but is lacking in polar waters. According to a review work by Murina (1970) it is inferred that the highest species diversity is found in the Indo-West Pacific and particularly in the water of the Indo-Malay Archipelago. Thus, these regions are regarded as the main centre of origin and development of Sipuncula.

TAXONOMY AND CHARACTERS OF THE PHYLUM

SYSTEMATICS OF THE PHYLUM

As a result of its confused classification, until the 70's intermediate taxa (orders and classes) had not been developed for Sipuncula. Stephen & Edmonds (1972) were the first to erect four families that are widely used to date. Since the 80's, efforts have been made to more adequately describe certain genera, establish new families and design key to the sipunculan genera. Cutler & Gibbs (1985) applied some evolutionary, phenetic, phylogenetic methodologies in a cladistic analysis which resulted in grouping 17 genera into six families, four orders and two classes. This classification, which was subsequently better documented and adopted by Gibbs & Cutler (1987), came to replace the earlier one of Stephen & Edmonds (1972).

The diagnostic characters of the families are reviewed in GIBBS & CUTLER (1987). According to their work two classes namely Phascolosomatidea and Sipunculidea are proposed. It is this classification which was further completed (CUTLER, 1994) that is followed in our work.

THE SIPUNCULAN MORPHOLOGY

General characteristics

The Sipuncula are unsegmented wormlike animals comprising two sections namely the **trunk** (main body) and an **introvert**, an extending and contracting neck-like "feeler" which is rapidly run in and out and can be completely invaginated into the trunk by means of strong retractor muscles (Fig.1, Plate II).

The posterior part (trunk) is fatter than the anterior (introvert) whose mouth is generally encircled by tentacular outgrowths (**tentacles**). A ciliated chemoreceptor organ (nuchal organ) is located on the dorsal margin of the oral disk of most species.

The relative lengths of introvert and trunk vary greatly in different genera and species. The adult trunk ranges in length from 1-3mm (Nephasoma diaphanes diaphanes, Onchnesoma steenstrupii steenstrupii) to more than 500-600mm (Sipunculus nudus, Golfingia margaritacea) but commonly 15-30mm. The trunk may be flask shaped, cylindrical, fusiform, threadlike, oviform, sacklike and so on. Its posterior part is oval or fusiform in numerous species of Golfingia (Fig.1).

The introvert may be much shorter than the trunk as in the genus *Sipunculus*, about the length of the trunk as in most species, or even exceed the trunk length as in some species of the genera *Phascolion*, *Aspidosiphon* and *Onchnesoma*.

When the introvert is fully extended the mouth is seen in the center of the anterior tip,

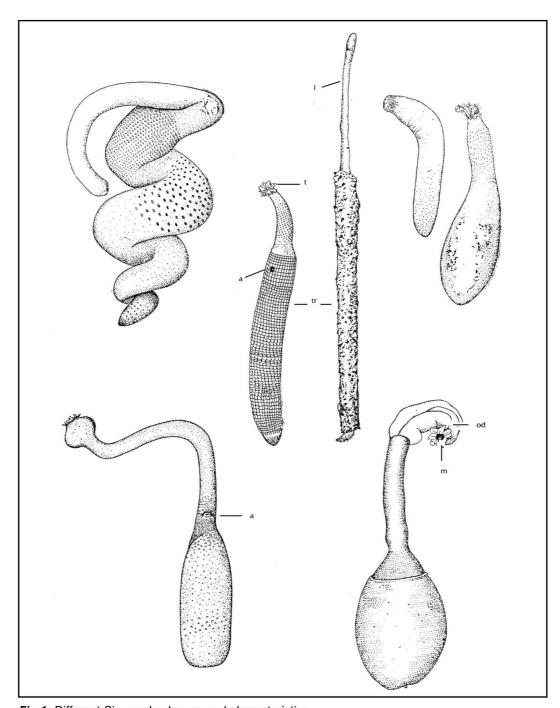


Fig.1: Different Sipuncula shapes and characteristics. *a:* anus, *t:* tentacles, *tr:* trunk, *i:* introvert, *m:* mouth, *od:* oral disk.

which may be termed **oral disk**. The **mouth** leads into an esophagus, followed by a long recurved intestine, which hangs in the coelom. A conspicuous **anus** is situated in the middorsal line anteriorly, on the trunk or the introvert.

The shape of some animals may be molded by the microhabitat in which they live for example burrows, crevices and especially empty shells of Gastropoda and Scaphopoda, tests of Foraminifera, polychaete tubes and so on.

<u>Colour</u>: The body colour, rather dull, depends on the type of substratum that the animals inhabit, as well as on the intestinal content (filled with soil) or on the mass of reproductive products, which are reflected through the transparent body skin and wall of the gut. It varies from white, yellow, greyish and red-brown to black. The tentacles are more colourful, having yellow, white, pink, violet or green colour.

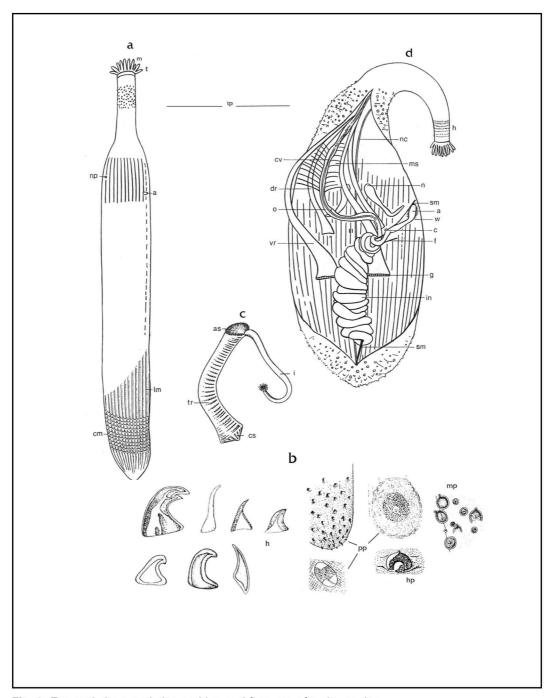


Fig. 2: External characteristics and internal features of a sipunculan.

- **a)** *cm*: circular muscle, *lm*: longitudinal muscle, *a*: anus, *np*: nephridiopores, *tp*: triangular papillae, *t*: tentacles, *m*: mouth.
- b) h: hooks from various genera, pp: papillae, hp: holdfast papillae, mp: mammiform papillae.
- c) as: anal shield, i: introvert, tr: trunk, cs: caudal shield.
- **d)** h: hooks, *nc*: nerve cord, *cv*: contractile vessel, *ms*: mesentery, *n*: nephridium, *dr*: dorsal retractor, *o*: oesophagus, *sm*: spindle muscle, *a*: anus, *w*: wing muscle, *c*: caecum, *f*: fastening muscle, *vr*: ventral retractor, *g*: gonad, *in*: intestine.

External features: The entire surface is usually covered by skin formations called **papillae**, **spines**, **hooks**, **holdfast papillae** or just **skin bodies** (Fig. 2a,b). These may be scattered or arranged regionally. In the genera of *Aspidosiphon* the anterior end of the trunk is armed with a **shield** (Fig. 2c). The presence of shields in sipunculans seems to be associated with life in dead coral rock. In the genus *Phascolion*, which habitually dwells in the empty shells

of gastropods and scaphopods, areas of the trunk are covered with special hard thickenings often called **holdfasts**.

<u>Internal structure</u>: The nervous system consists of a dorsal brain, pair of circumenteric connectives and a ventral nerve cord.

- The circulatory system comprises a pair of metanephridia or only one single nephridium. The nephridiopores are located ventrally on the anterior part of the trunk.
- There are three main muscle systems: (1) the body wall **musculature**, (2) the introvert **retractor muscles**, and (3) **intestinal fasteners** that anchor the digestive tract.
- 1) The muscles in the body wall consist of smooth catch muscles in two layers: an outer layer of circular fibers and an inner layer of longitudinal fibers. The thickness of the layers is generally correlated with the size of the animal, from very thin and film-like in small *Nephasoma* to quite thick in large Sipunculidae (Fig. 2a).
- 2) The retractor muscles in the body cavity extend from their origins on the body wall to their insertions just behind the cerebral ganglia. The common condition is one dorsal pair and one ventral pair, but several genera have a single pair (Fig. 2d).
- 3) The intestinal fasteners hold the gut coils in place. The principal component of this system is the long, thin **spindle muscle**, which is present in most sipunculan species. This muscle is fixed anteriorly to the body wall near the anus or the distal portion of the rectum, sometimes with one or two branches to the body wall. The spindle muscle extends along the rectum and into the centre of the gut coil, ending within the coil in some genera and continuing on to the posterior end of the trunk in others. Along the way, small branches attach to individual intestinal coils (Fig. 2d).

Diagnostic morphological features

The lengths (actual and relative) of trunk and introvert

- Trunk length to width ratio: Most species have cylindrical trunks with length exceeding the diameter by 5-10 times.
- · Introvert length in relation to trunk: A difficult feature to evaluate as a) it changes with age being larger in younger animals b) the measurement is flexible due to the extreme elasticity of the introvert.

<u>Longitudinal muscle bands.</u> The body wall is composed of discrete, usually continuous muscle layers. In some genera the longitudinal muscle layer has separated into bands or bundles.

The presence or absence of pigmented bands/stripes on the introvert. Usually the dorsal side is darker than the ventral.

The body ornamentation (shape, size, arrangement of skin formations)

- papillae (distribution/size/shape): Soft glandular structures of doubtful taxonomic use. In some cases it is quite difficult to distinguish clearly between two types of skin's formations (papillae and skin bodies). According to one of the authors (Murina G.V.V.) the height of papillae is bigger than their diameter, whereas the skin bodies have height nearly equal to the diameter. The papillae of the different parts of the trunk and introvert usually have different shapes. These shapes can vary considerably: conical, finger like, sphaerical, pear-shaped, pin-shaped, nipple-shaped, flakelike; the last one being characteristic of the introvert of *Sipunculus* and *Onchnesoma*.
- · holdfast or attachment papillae: Some papillae in the mid region of the trunk (sometimes posterior) may excrete chitinoid material to form hardened structures which are referred to as *holdfast* or *attachment papillae*. It has been documented that these scrape the bacteria from the inside of the empty shells used for shelter. They are observed in the genus *Phascolion*. Their number, form and distribution is difficult to describe with confidence.
- · shields (shape/structure/colour): A confused term meaning a) a hardened epidermal structure or b) an aggregation of close-packed papillae around the ends of the trunk.

According to Cutler (1994) the anal shield can be described as a hardened, cap-like structure located at different parts of the body depending on the family. The <u>caudal shield</u> is circular or conical, often grooved, found at the posterior end of the trunk in some Aspidosiphon.

<u>Introvert hooks.</u> The morphology of hooks on the introvert and their arrangement has been used a lot as a taxonomic character. According to the shape three main types of hooks can be distinguished:

- Type I: called "claws" or "spines", have narrow bases and pointed non-recurved tips. The spines are more perpendicular to the surface of the skin than the claws.
- Type II: are broad-based, heavy with a recurved pointed tip. Under microscope they show an internal light triangle
- Type III: are smaller in size than the other two (20-70 mm), are also brad-based and recurved but have a round tip.

<u>Tentacles number/complexity/arrangement.</u> As the number of tentacles continues to increase with age, it is difficult to determine the upper limit in a given species. The standard pattern is a series of digitate circumoral tentacles whose number and complexity increases with age. In several genera nuchal tentacles surround the nuchal organ dorsal to the mouth.

Anus/nephridiopores relationship. In most genera the anus is located very near the anterior end of the trunk on the mid-dorsal line. In some species however, it is located on the distal third of the introvert. In genera where the nephridiopores open at the same level as the anus, there might occur an insignificant shift to the anterior (occasionally) or posterior (rarely). In such cases the relationship is not considered a valuable diagnostic feature.

Nephridia number, length and attachment. The nephridia are a pair of tubular organs extending towards the posterior end of the trunk. They may be short (25-45% of the trunk length), quite long (95-100% of the trunk) but usually are 40-65% of the trunk length. The ratio of nephridia length to trunk length decreases with increasing body size. Most sipunculans are bilaterally symmetrical and have two nephridia. Only a single nephridium is present in *Phascolion* and *Onchnesoma* species. The degree of attachment of the nephridium to the body wall has had significance for earlier systematists. The attachment may consist of a series of fine, fragile, thread-like **mesenteries** extending between the nephridium and the adjacent body wall.

<u>Location of retractor muscle origins.</u> The retractor muscles originate from the body wall. The level of the retractor origin is usually expressed as a percentage of the distance between the nephridiopores and the posterior end of the trunk.

<u>Position of the attachment of spindle muscle.</u> In most Sipuncula genera the spindle muscle ends within the gut coil itself, but in a few species it is poorly developed or missing.

<u>Presence or absence of rectal caecum.</u> The terminal rectum usually carries a rectal caecum, frequently connected at its tip with the wing muscle. However, in some species it is absent.

<u>Contractile vessel villi.</u> These villi are thin walled, elastic elongate or digitiform tubes forming part of the hydrostatic system involved in the protrusion of the tentacles. Their number and size can be related to the complexity of the tentacular crown.

THE MEDITERRANEAN SIPUNCULA

LAYOUT OF THE MONOGRAPH

This monograph is essentially literature-based. Because of the controversy in the phylum's nomenclature and continuous recent changes, as mentioned above, the nomenclature and systematic here used is mostly that of GIBBS & CUTLER (1987) although with deviations in certain cases which are therefore open to criticism - see taxonomic observations. The list of the Mediterranean Sipuncula has been prepared after revising the literature - see literature exploited. According to it, the phylum is represented in the Mediterranean by 33 species, belonging to five families and nine genera. The following check-list (Table 1) of Mediterranean Sipuncula is presented in taxonomic order according to the classification scheme of GIBBS & CUTLER (1987). The included key to Mediterranean species is a dichotomic one.

The name of each species is followed by the most common synonyms it has been called over time as well as all names under which it is found in Mediterranean records.

The description following each species summarises the main external and internal morphological characteristics. For many species this description remains unchanged since the species was designated (original description) found in books such as those of Murina (1977), Stephens & Edmonds (1972) and Cutler (1994). However, for those species belonging to genera which have been repeatedly revised, the description is in accordance with the latest revision of the genus i.e. *Nephasoma* (Gibbs, 1982; Cutler & Cutler, 1986), *Golfingia* (Cutler & Cutler, 1987a), *Thysanocardia* (Gibbs *et al.*, 1983) *Onchnesoma* (Cutler & Cutler, 1985), *Phascolion* (Cutler & Cutler, 1985; Gibbs, 1985), *Aspidosiphon* (Cutler & Cutler, 1989).

The figures accompanying the species, which illustrate the diagnostic features, are not original. Most of them are from Murina (1977), less have been redrawn from Stephen & Edmonds (1972); Gibbs (1977) & Cutler (1994).

In giving the distribution of each species the references are cited only for those species that present a limited geographical distribution. For the common species such as in the cases of: Sipunculus nudus, Aspidosiphon muelleri, Phascolosoma granulatum, Phascolion strombus, only the major geographical areas/countries or seas, are given.

With regard to the biotope, the bathymetric range of occurrence is constantly extended with new records in unexplored areas and/or zones. Still, little is known for some rather rare species. The ecological preferences of the species: type of substratum, range of salinity and/or temperature are cited along with literature, when available.

Table 1 Checklist of the Mediterranean Sipuncula.

Class Sipunculidea

Order Sipunculiformes

Family Sipunculidae

Genus Sipunculus

Sipunculus norvegicus

Sipunculus nudus

Order Golfingiiformes

Family Golfingiidae

Genus Golfingia

Golfingia (Golfingia) elongata Golfingia (Golfingia) margaritacea Golfingia (Golfingia) vulgaris

Genus Nephasoma

Nephasoma abyssorum abyssorum

Nephasoma capilleforme Nephasoma confusum Nephasoma constricticervix Nephasoma constrictum Nephasoma diaphanes corrugatum

Nephasoma diaphanes diaphanes

Nephasoma lilljeborgi Nephasoma rimicola

Genus Thysanocardia

Thysanocardia catharinae Thysanocardia procera

Family Phascolionidae

Genus Phascolion

Phascolion (Isomya) convestitum Phascolion (Isomya) tuberculosum Phascolion (Phascolion) strombus

Genus Onchnesoma

Onchnesoma squamatum squamatum Onchnesoma steenstrupii steenstrupii

Class Phascolosomatidea

Order Phascolosomatiformes

Family Phascolosomatidae

Genus Phascolosoma

Phascolosoma agassizii agassizii Phascolosoma granulatum Phascolosoma perlucens Phascolosoma scolops Phascolosoma stephensoni

Genus Apionsoma

Apionsoma murinae bilobatae Apionsoma trichocephalus

Order Aspidosiphoniformes

Family Aspidosiphonidae

Genus Aspidosiphon

Aspidosiphon (Akrikos) mexicanus Aspidosiphon (Aspidosiphon) elegans Aspidosiphon (Aspidosiphon) misakiensis Aspidosiphon (Aspidosiphon) muelleri kovalevskii Aspidosiphon (Aspidosiphon) muelleri muelleri

TAXONOMIC OBSERVATIONS ON THE MEDITERRANEAN SIPUNCULA

In revising the Mediterranean faunal lists in accordance with the valid names, the discrepancy of opinions in contemporary literature quite often led us to take arbitrary decisions. Here are some of the examples where the arguments towards one or other taxonomic system seemed inconsistent and thus were followed or ignored according to the case.

- In their revision of the genus *Thysanocardia* GIBBS *et al.* (1983) proposed that only three morphologically similar species: *T. catharinae*, *T. nigra* and *T. procera*, should remain as valid and considered the possibility of integrating them into a single cosmopolitan species (*T. catharinae*). Popkov (1993) provided evidence for the validity of the three species and also described a fourth one. In this work we treat them as separate species.
- Special attention must be devoted to *Nephasoma lilljeborgi* whose synonymy to *N. glacialis* has been cleared out by Dr. Gibbs who examined specimens of the so called both species and found them to be the same (GIBBS, 1982). Therefore, the name *N. lilljeborgi* remains as the senior one and *N. glacialis* as a synonym.
- The name *Nephasoma minutum*, under which VAMVAKAS (1970, 1971) and KISSELEVA (1963, 1983) had recorded several specimens in Hellenic waters, at depths 89-1000 m, had to be revised. According to GIBBS (1975) *N. minutum*, met in shallow waters, is the only hermaphroditic sipunculan, while deep water specimens, which seem to be single sex, are referable to *Nephasoma diaphanes diaphanes*.
- According to Saiz-Salinas & Villafranca-Urchegui (1990), the anatomical differences between *Aspidosiphon muelleri* and *A. kovalevskii* are not consistent in the literature. Since these structures are inconsistent between populations, they suggest considering all of them as co-specific. Strong reservations about the validity of *A. kovalevskii* as a separate species were also raised by Cutler & Cutler, 1989. However, the anatomical differences we noticed between *A. muelleri* and *A. kovalevskii*, are too obvious and thus we insist on keeping them separately.
- There is a divergence of opinions whether dealing with one species (*Apionsoma murinae*) or two subspecies (*Apionsoma murinae murinae* and *Apionsoma murinae bilobatae*). Although Cutler (1969) recognized two subspecies and his division was adopted by many authors, Saiz-Salinas & Villafranca-Urchegui (1990) argued against it and kept the name of *Apionsoma murinae* for their Alboran species. We accept the division of Cutler and assume all published Mediterranean records of *Apionsoma murinae* to be *Apionsoma murinae bilobatae*, with the reservation of having one more subspecies (*Apionsoma murinae murinae*) in the western Mediterranean.

LITERATURE EXPLOITED FOR THE GEOGRAPHIC DISTRIBUTION

Regarding the geographic distribution of the phylum in the Mediterranean, besides the studies of one of the authors (Murina, 1964; 1976; 1980; 1982; 1984), there are some review papers treating extensively the systematics and distribution of the phylum in major geographic areas such as the Alboran Sea (Saiz-Salinas & Villafranca-Urchegui, 1990), Spain (Saiz Salinas, 1993a), the Adriatic (Murina & Zavodnik, 1986). Recently the eastern Mediterranean sipunculans, with emphasis in those of Hellenic waters, were revised in an extensive paper by Murina et al. (1999). Compiled data on the sipunculans of the Italian waters can be found in Castelli et. al. (1995) though with no details on their distribution nor references to document them.

On reviewing the Mediterranean Sipuncula, all available sources were engaged. While a lot of information was discovered in papers dealing with the benthic ecology of certain areas (faunal lists) a good part was provided through personal contacts with benthologists spread along the Mediterranean countries. Thus unpublished data or yellow literature (technical reports) come to fill some gaps in the distribution and complete the picture as much

as possible. Besides the above, the sources consulted in compiling the data and constructing the distribution maps per country are:

Spanish coasts and offshore: Desbruyeres *et al.*, 1973; Camp & Ros, 1980; Salz & Murina, 1982.

French coasts and offshore: Sluiter, 1912; Fischer, 1922; Murina, 1964; Reyss, 1971; Bourcier, 1969, 1976; Guille, 1970; De Gaillande, 1968; Masse', 1971a,b, 1972a,b; Bourcier et al., 1979; Nodot et al., 1984; Monteiro-Marques, 1981; Bhaud & Duchene, 1979; Diaz-Castaneda et al., 1991.

Italy: Tyrrhenian (Murina, 1964; Chimenz, 1989; Bianchi et al., 1993a, b,c; Cocito et al., 1990), Ligurian (Morri et al., 1990): Genova (Drago & Albertelli, 1978; Albertelli, pers. commun.), Apulia (Bianchi, pers. commun., South Tyrrhenian and Sicily Channel: Berdar et al., 1980; Cutler, 1994 - Palermo (Diesing, 1851), Li Greci, 1980; Messina Strait, Lipari isl. (Spano', pers. commun.) Lampedusa: (Murina, unpublished data).

Greece: Murina et al., 1999.

Tunisia: Murina, 1964. Libya: Murina, 1964.

Malta: (Murina, unpublished data); Schembri & Jaccarini, 1978.

Adriatic Sea: Vatova, 1949; Orepic *et al.*, 1997; Zavodnik, 1971, 1975, 1979; Zavodnik *et al.*, 1981, 1985; Zavodnik & Murina, 1975, 1976; Murina & Zavodnik, 1979; Cukrov, 1973; Del Piero *et al.*, 1983; Zavodnik & Vidakovic, 1987.

Turkish waters: Aegean: Colombo, 1885; Kocatas, 1978; Ergen & Cinar, 1994; Ergen et al., 1994 - Sea of Marmara (Demir, 1952; Caspers, 1968).

Israel: Wesenberg-Lund, 1957; Stephen, 1958; Por, 1975.

Egypt: Murina, 1964; Murina et al., 1999.

Cyprus: Murina, 1964; Galil & Zibrowius, 1998.

KEY TO THE MEDITERRANEAN SIPUNCULA SPECIES

Tentacles in arc encircling dorsal nuchal organ; peripheral tentacles absent; hooks (when present) complex, arranged in distinct rings
2. Anal shield present
3. Longitudinal muscles of body wall in uniform continuous layer. Tentacles not carried on disk outgrowths
4. A single nephridium present Phascolionidae, 6 - Two nephridia present Golfingiidae, 10
5. There are 20-24 longitudinal muscle bands; brain without distinct processes
6. Anus usually situated on anterior trunk; epidermal holdfast or attachement papillae of trunk often present; retractor muscles usually with two or four origins; hooks of introvert often present

- Ventral retractor much thinner than dorsal (less than one-half); usually with distinct proteinized border on holdfast papillae; anterior papillae with single tips
8. Introvert with 6-8 small tentacles; trunk covered with large papillae
9. Large holdfast papillae without chitinized borders; hooks 70-220µm, broad and recurved; 10-30 tentacles
Contractile vessel with numerous villi
 11. Nuchal organ consists of two oval lobes; small (trunk <15mm)
12. Four introvert retractor muscles
13. Introvert hooks in rings
14. Hooks present, central part of the trunk smooth and white, showing different texture and colour, both trunk ends dark brown or black, heavily papillated
15. Introvert one to two times the trunk length; scattered small hooks (< 30µm tall) having ordinary shape, one pointed
16. Introvert length <45% of trunk length; distal hooks >200μm
17. Hooks scattered
18. Scattered small hooks (20-30 μm tall); body transparent to translucent, usually <10mm long
19. Introvert with a few short tentacular lobes, body skin glace and transparent
20. Large hooks (> 50μm tall) having a characteristic shape, arranged spirally
21. Scattered, robust and blunt hooks

 22. Hooks arranged in rings on the dorsal part of the introvert Aspidosiphon (Aspidosiphon), 23 Scattered introvert hooks present, anal shield ill-defined and diffuse, trunk usually 5mm
23. Hooks of the introvert single pointed: anal shield cone-shaped with many knots carrying sharp spines
24. Compressed hooks arranged in rings, followed by scattered dark conical hooks
25. Introvert much longer than trunk: hooks (if present) with basal spinelets; nephridia usually bilobed
26. Papillae, hooks and tentacles absent
27. More than 50 complete and incomplete rings of hooks
28. Hooks with basal warts, posterior crescent, many >75µm; preanal papillae like smooth cones; pigment bands on introvert
29. Angle of hook tip 90o or less, large, rounded hump on concave side of hook; preanal papillae smooth, posteriorly directed, cone shaped
30. Hooks with distinct triangle; narrow band of red cone-shaped preanal papillae

REVIEW OF THE SPECIES

Family: Sipunculidae

Genus Sipunculus

Family: Golfingiidae

Genus Golfingia

Genus Nephasoma

Genus Thysanocardia

Family: Phascolionidae

Genus Phascolion

Genus Onchnesoma

Family: Phascolosomatidae

Genus Phascolosoma

Genus Apionsoma

Family: Aspidosiphonidae

Genus Aspidosiphon

Sipunculus norvegicus Danielssen, 1869

<u>SYNONYMS</u>: *Sipunculus priapuloides* Danielssen, 1875; Cutler, 1994. *Sipunculus aequabilis* Murina, 1964.

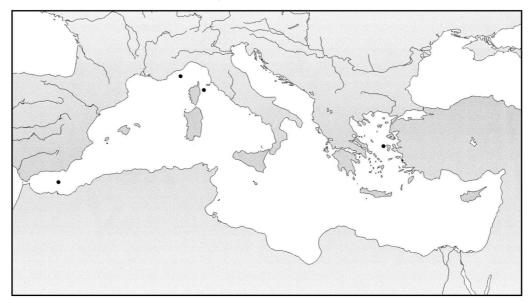
<u>DESCRIPTION</u>: Cylindrical trunk 7-140 mm long. The body skin is thin, translucent and strongly marked by longitudinal furrows (Fig. 3a). The longitudinal muscles split into 20-24 bands, commonly 22-24 (Fig. 3b). The glans region is marked off from the trunk by a ridge, which may commonly be interrupted ventrally by a furrow. Introvert short, about one fourth of the body length, without hooks. The tentacular membrane is divided into 8-12 lobes (Fig. 3c). The brain processes are not developed. Colour varies from grey to light brown.

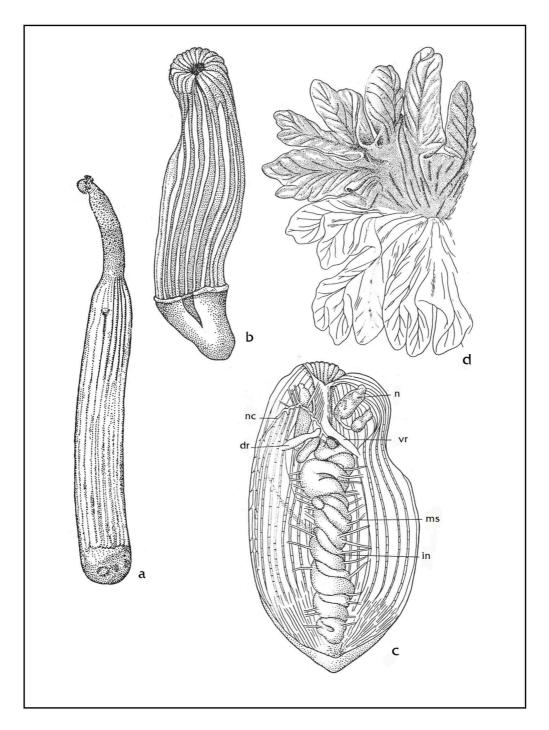
Internally (Fig. 3d), two pairs of retractors arise ventrally from the 3rd and 4th band. Dorsal retractors arise from the 8th and 9th band. Intestinal coils are fastened along their length by many mesenteries. A spindle muscle arises near the anus, transverses the intestinal coils and is fixed near the caecum. Two contractile vessels on the oesophagus. There are two thin nephridia. Their nephridiopores are located at the anus level.

<u>DISTRIBUTION</u>: Species with wide geographical distribution, it is more common in the North Atlantic (East Greenland, Iceland, Norway, North Sea, Ireland, Biscay Gulf, near Azores). Many records along the Atlantic coast of USA. There are scattered records from tropical waters of the West and East Africa, Indonesia, Loyalty Islands, Hawaii, West Australia, New Zealand, while it seems to be absent from the Pacific coast of North and South America, Antarctic waters as well as from the Indian Ocean (Cutler & Cutler, 1996).

In the Mediterranean, SLUITER (1912) firstly reported it at 950 m in front of Monaco. Following the records of Murina (1964) in the Tyrrhenian Sea (Corsica) as *S. aequabilis* and of Saiz Salinas & Villafranca Urchegui (1990) in the Alboran Sea, it has recently been reported in Hellenic waters from the Aegean Sea (west of Chios Island) (Murina *et al.*, 1999).

BIOTOPE: This species has been recorded in sublittoral to bathyal waters 0-5160m (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990). CARPINE (1970) records it as characteristic of the bathyal zone. Scarce information on the ecological requirements of the species is available. It seems to be eurythermic inhabiting sand, muddy sand with detritus and muddy substrata (SAIZ SALINAS, 1993a). In Hellenic waters it was found in muddy substratum at 113 m. Maximum depth in the Mediterranean: 1405m (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990).





- Fig. 3: Sipunculus norvegicus a): External view of entire specimen.
- b): Longitudinal muscle layers of body wall.
- c): Internal view of dissected specimen. nc: nerve code, dr: dorsal retractor, n: nephridium, vr: ventral retractor, ms: mesentery, in: intestine.
- d): Detailed view of tentacular membrane lobes.

Sipunculus nudus Linnaeus, 1766

SYNONYMS: Sipunculus nudus nudus Murina, 1977; Murina & Zavodnik, 1986; Cutler, 1994.

<u>DESCRIPTION</u>: Trunk up to 32 cm long and 2 cm wide. 24-34 (usually 28-32) longitudinal muscle bands, are the main diagnostic features of the species (Fig. 4a). Introvert one fourth to one eighth of the trunk length. No hooks. The scale-like triangular papillae beset the one sixth of the introvert. The oral disk carries tentacles with intertentacular membrane arranged around the mouth (Fig. 4b). The colour of trunk is white, grey, pink, bright yellow to brown.

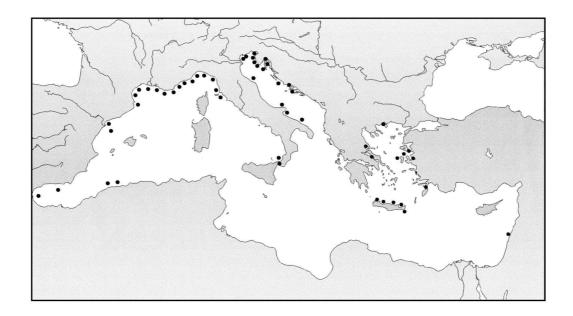
Internally, four retractor muscles are attached to the proximal 16th-20th part of the trunk. Two contractile vessels without villi. The long nephridia are attached to 1/4 -1/5 of their length to the inner layer of the trunk. Gut with postoesophageal loop, spiral intestine with an additional coil in large specimens. There is a rectal caecum with one pair tufted glandular organs on either side of long rectum. The spindle muscle is not attached to body wall posteriorly. Digitate processes are present on the brain (Fig. 4c)

<u>DISTRIBUTION</u>: The most common of all oceanic tropical-temperate species, it is the only member of its genus with a worldwide distribution (MURINA, 1977; CUTLER, 1994).

Well known in the western Mediterranean (Alboran, Algerian coasts, Spain, France, Ligurian Sea, Messina Strait) and the Adriatic. In the eastern Mediterranean there are several records of the species, mostly in Hellenic waters (Murina et al., 1999).

BIOTOPE: A species with wide ecological requirements, present all over the world in warm and warm-temperate habitats (Cutler, 1994), mostly in sandy bottoms. According to Saiz Salinas (1993a) it is a eurytherm (9.4° up to 26°C) species met at salinities between 34% and 38%. It has been considered as characteristic of the fine well sorted sands biocoenoses (Bourcier, 1976). It has usually been sampled in the littoral zone (to 30 m) but a few records are from the bathyal to 2275 m (Southern, 1913). In the Adriatic Sea (Murina & Zavodnik, 1986) it was found mostly on sandy bottoms but also in detritic coastal sand and coastal terrigenous mud, as well as in the seawater pipes of the Rovinj Aquarium. Moreover, it has been recorded on hard substrata from 5 to 6 m (Ergen et al., 1994) as well as on sand with Lithothamnion (95-115 m, Kisseleva, 1983). In Hellenic waters, it was found in silty sand. Maximum depth in the Mediterranean: 160m (Murina et al., 1999).

IMPORTANCE TO HUMAN: Noteworth is its exploitation as bait as well as gastronomic "delicacy" in China and Japan.



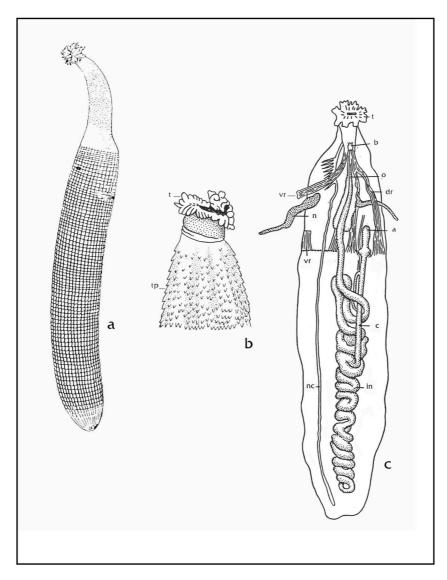


Fig. 4: Sipunculus nudus.

- a) External view of entire specimen.
- **b)** View of the anterior region of the trunk showing triangular papillae and oral disk. *t*: tentacles, *tp*: triangular papillae.
- **c)** Internal view with diagnostic features. *t:* tentacles, *b:* brain, *o:* oesophagus, *dr:* dorsal retractor, *a:* anus, *c:* caecum, *in:* intestine, *vr:* ventral retractor, *n:* nephridium, *nc:* nerve cord.

Genus Golfingia

Golfingia (Golfingia) elongata (Keferstein, 1863)

<u>SYNONYMS</u>: *Phascolosoma elongatum* Keferstein, 1863; Kocatas, 1978. *Golfingia (Golfingia) elongata* Murina, 1977. *Golfingia elongata* Cutler, 1994.

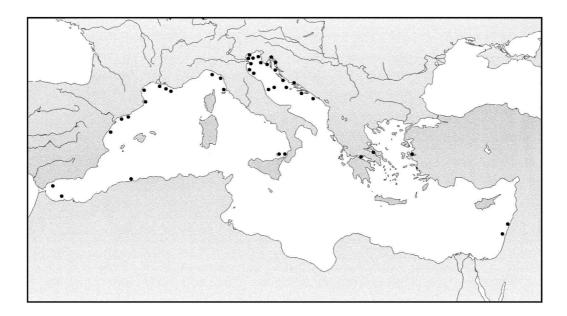
<u>DESCRIPTION</u>: The trunk is cylindrical, its length ranging from 1 to 15 mm. Trunk length is more than 4-20 times its width (Fig. 5a). Introvert short or half the trunk length. Introvert hooks in 5-20 characteristic rings (Fig. 5b). There are large straight and slender hooks up to 0.1 mm in height. The skin of the trunk is smooth and lustrous. There are 15-20 or more tentacles (Fig. 5c). High papillae of skin absent. Colour whitish, often with tints of pink or gray.

Internally, two pairs of retractors are usually present. The dorsal one is attached at the anus level and the ventral one at the one seventh to the middle part of the trunk. However, loss or fusion of one or two muscles has been observed in aberrant individuals (GIBBS, 1977). The rectum has two thin fixing muscles and a rectal caecum. The digestive tract has 30 and more coils. The nephridia open outside at the anus level or anterior to it (Fig. 5d).

<u>DISTRIBUTION</u>: Tropical-boreal species known from the Arctic, the northwest and northeast Atlantic In the Pacific, from the East and South China Seas, while it seems to be very rare in the Indian Ocean.

In the Mediterranean there are many records in the Alboran, Algerian, Spanish, French and Ligurian coasts, the N. Adriatic, Messina Strait, Lipari isls, Ionian, Aegean and Levantine Seas.

BIOTOPE: Common in the sublittoral and upper bathyal zones, it inhabits muddy sand/gravel substrata from the lower shore to about 590 m (Cutler, 1994) or 720 m (Saiz Salinas & Villafranca Urchegui, 1990). In British waters, juveniles are occasionally found in rock crevices together with Nephasoma rimicola and Nephasoma minutum. Its burrows are occasionally inhabited by the polychaete Harmothoe lunulata and the molluscs Epilepton clarkiae and Mysella bidentata (Gibbs, 1977). In Hellenic waters, the sea bottom where it was found ranged from silty sand to coarse sand in the Evvoikos Gulf, while in the Korinthiakos Gulf it occurred in finer sediments (mud, sandy mud and muddy sand). Maximum depth in the Mediterranean: 720m (Saiz Salinas & Villafranca Urchegui, 1990).



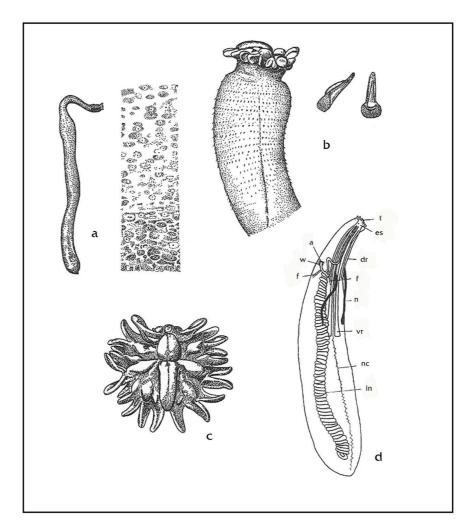


Fig. 5: Golfingia (Golfingia) elongata.

- a) Entire animal and particulars of body wall.
- b) Dorso-lateral view of anterior introvert and details of hooks.
- c) Oral disk with ring of tentacles.
- **d)** Dissected specimen. *t*: tentacles, es: eye spots, *a*: anus, *w*: wing muscle, *t*: fastening muscle, *dr*: dorsal retractor, *n*: nephridium, *vr*: ventral retractor, *nc*: nerve cord, *in*: intestine.

Golfingia margaritacea (Sars, 1851)

<u>SYNONYMS:</u> Sipunculus margaritaceus Sars, 1851. Phascolosoma margaritaceum Danielssen & Koren, 1877; Fischer, 1914; Wesenberg-Lund, 1928. Golfingia nordenskjoldi Wesenberg-Lund, 1955. Golfingia margaritacea Fischer, 1952; Murina, 1971; Cutler, 1973; Gibbs, 1974; Saiz Salinas, 1984.

<u>DESCRIPTION</u>: Total trunk length more than 3 times its width, ranging between 1.5 and 300 mm. The introvert is shorter or about as long as the trunk (Fig. 6a). No chitinous hooks are present on the introvert. The skin of the trunk is slightly wrinkled by transverse and longitudinal creases. It has numerous cuticular bodies that are raised to minute papillae; the latter are most distinct at the posterior end of the trunk. The slender, flattened tentacles are arranged in a single circle around the mouth (Fig. 6b). The maximum number of tentacles is less than 24 but most specimens appear to have only 8 to 16. Tentacle crowns may be developed to the extent that the tentacles become very numerous and are arranged in longitudinal rows. The nuchal organ has two main lobes separated by a longitudinal groove and each lobe is subdivided by a shallow furrow to give a four-lobed structure. The body wall is quite thin and its musculature weak: the longitudinal muscle layer is continuous, not divided into bundles. Body colour varying from light to medium brown.

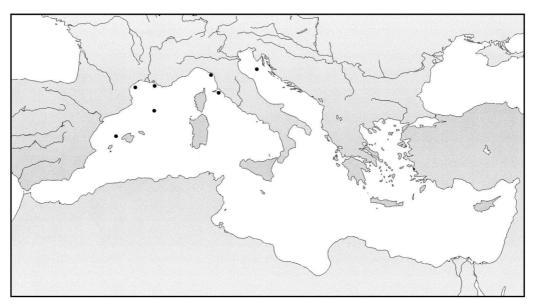
Internally, there are four retractor muscles. The dorsal retractors are attached to the body wall at a level just posterior to the anus and the ventral retractors in the middle third of the trunk. The descending and ascending portions of the gut are each coiled 8-15 times around a spindle muscle, which is not attached to the posterior body wall. A rectal diverticulum is present and wing muscles attach the return to the adjacent body wall. The gut-fixing muscles are variable in their development: usually one, occasionally two, attach the oesophagus to the left side of the body and a further one or two fasten the anterior coils of the gut on the left and/or right side. Thin mesenteries attach the oesophagus to the ventral retractor muscles. The two nephridia hang freely in the coelom. The nephridiopores are situated to the anterior of the anus at about halfway along the length of the body. The cerebral mass lacks pigmented spots (Fig. 6c).

<u>REMARKS</u>: Species with a wide morphological variability, which results in numerous synonyms and difficulties in the exact identification. Larger specimens, presumably old, show the greatest morphological variation, particularly in the structure and appearance of the skin.

<u>DISTRIBUTION</u>: Cosmopolitan species with a distribution mainly in temperate and boreal regions. It has been reported from the Atlantic, Arctic and Antarctic Seas, North Pacific and sporadically from the Indian Ocean.

In the Mediterranean reported from the French coasts, offshore NW Mediterranean, Gulf of Lions, Balearic isles, Ligurian Sea and Adriatic Sea (Cukrov, 1973 as *G. nordenskjoldi*).

BIOTOPE: Known as eurybathic species, it occurs from the littoral zone to abyssal depths (5470, Murina 1977). In mud and sand/gravel bottoms (Gibbs, 1977). The species is apparently uncommon but where found is usually in crevices co-habited by *Nephasoma minutum* and *G. rimicola*. Sometimes it has been referred from hard substrata (volcanic stones, holystone, corals). Maximum depth in the Mediterranean: 41m (Cukrov, 1973).



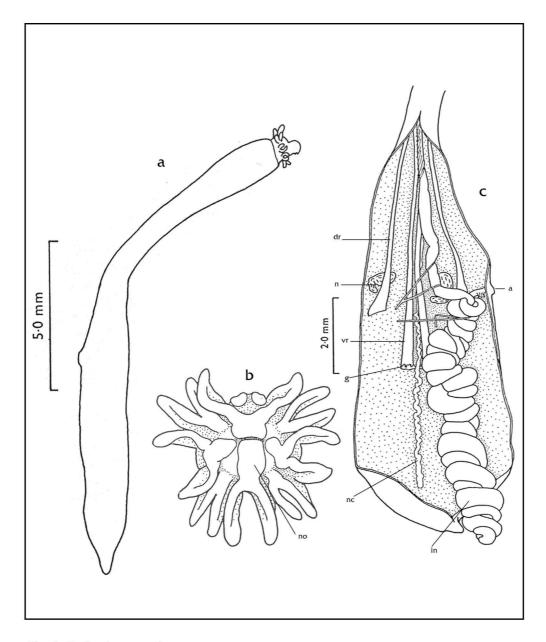


Fig. 6: Golfingia margaritacea.
a) Entire animal.

- b) Tentacle crown of oral disk. no: nuchal organ.
 c) Internal view of dissected animal. dr: dorsal retractor, n: nephridium, a: anus, vr: ventral retractor, g: gonad, nc: nerve cord, in: intestine.

Golfingia (Golfingia) vulgaris (De Blainville, 1827)

<u>SYNONYMS</u>: Sipunculus vulgaris De Blainville, 1827. Phascolosoma vulgare Keferstein, 1862; Ergen et al., 1994. Golfingia (Dushana) adriatica Murina 1975; Murina & Zavodnik, 1986. Golfingia vulgaris Murina, 1971. Golfingia (Golfingia) vulgaris vulgaris Cutler & Cutler, 1987. Golfingia solitaria Saiz & Murina, 1982; Stephen & Edmonds, 1972; Murina, 1977; Cutler, 1994.

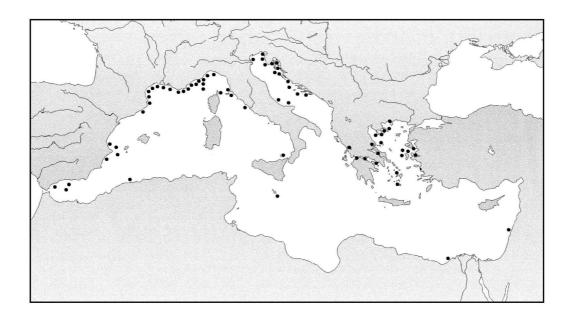
<u>DESCRIPTION</u>: Trunk is 4-198 mm long, usually 10-50 mm. The trunk length is more than 7-12 times its width. The introvert is shorter than the trunk and carries numerous tentacles (Fig. 7a,b,c). Their number varies, depending on the age of the animal, from 8 to 80 (Fig. 7d). The scattered hooks are more than 60-70 µm long and spinelike. There are two pigmented eyespots. Both ends of the trunk are dark brown or black and heavily papillated (Fig. 7e). The mid-trunk is smooth and white or grey or grey-yellow.

Internally, the ventral pair of retractors is attached to the middle one third of the trunk. The dorsal pair has more anterior origins. The intestinal spiral forms 6-60 coils and is attached to the short rectum. The spindle muscle is well developed and originates under the wing muscle just posterior to the anus. There are 1-3 fixing muscles of intestine. The rectal caecum is hidden under of intestine coils. Pear-shaped nephridia open anterior to the anus. Mature animals have white or yellow eggs of 0.08-0.15 mm diameter (Fig. 7f).

<u>DISTRIBUTION</u>: Very widely distributed, it is known from Greenland to the Red Sea, Pacific Ocean and North Sea. Rare or even absent in the West Atlantic and East Pacific.

Common in the Mediterranean (Alboran, Balearic, Algerian, Spanish, French, Ligurian coasts, Corsica, Adriatic Sea, Tyrrhenian, Lipari isls, Aegean and Levantine).

BIOTOPE: Usually in the same substrata as *G. elongata*. It inhabits muddy sand/gravel bottoms from lower shore to about 5000 m (0-5540 m in agreement with SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990). Its burrows are often inhabited by the bivalve *Mysella bidentata* (GIBBS, 1977). In the Turkish waters it was found on hard substrata at 5-6 m (ERGEN *et al.*, 1994). In Hellenic waters at depth 95 m, in sandy substrata associated with *Lithothamnion* (KISSELEVA, 1963). Also on hard bottoms, associated with the algae *Halimeda* sp., *Padina* sp. and *Cystoseira* sp. in Sporades Islands (SIMBOURA *et al.*, 1995) and associated with *Verongia aerophoba* and *Geodia cydonium* in Chalkidiki peninsula (KOUKOURAS *et al.*, 1985). According to SAIZ SALINAS (1993a) it is a species typically eurythermic (temperature ranges between -0.2 to 30°C) and euryhaline (salinity from 8 to 38‰). Maximum depth in the Mediterranean: 1900m (SLUITER, 1912).



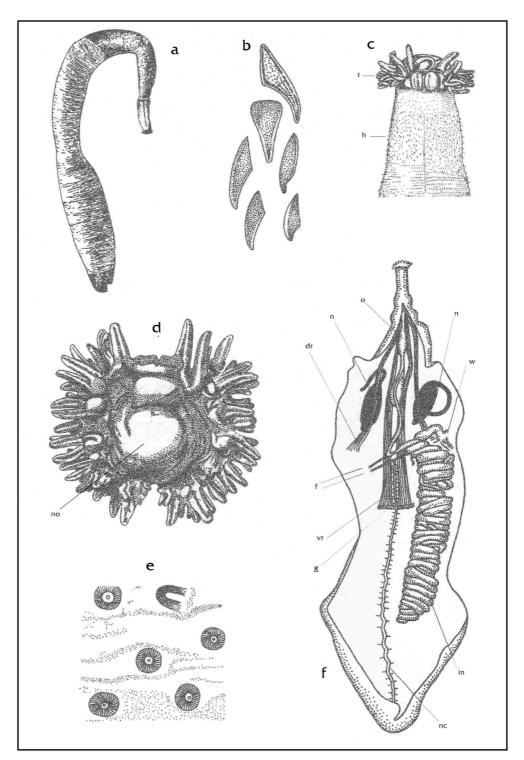


Fig. 7: Golfingia (Golfingia) vulgaris.

- a) Entire specimen.
- b) Hooks of the introvert.
- c) Introvert with tentacular crown. t: tentacles, h: hooks.
- d) Ring of tentacles. no: nucal organ.
- e) Papillae of the trunk.
- **f)** Entire dissected animal. *o:* oesophagus, *n:* nephridium, *dr*: dorsal retractor, *w:* wing muscle, *f:* fastening muscle, *vr:* ventral retractor, *g:* gonad, *in:* intestine, *nc:* nerve cord.

Genus Nephasoma

Nephasoma abyssorum abyssorum (Koren & Danielssen, 1875)

<u>SYNONYMS</u>: Phascolosoma abyssorum Koren & Danielssen, 1875. Golfingia (Phascoloides) abyssorum abyssorum Stephen & Edmonds, 1972. Golfingia abyssorum Fisher, 1952; Murina, 1964. Golfingia (Nephasoma) abyssorum Murina, 1977. Nephasoma abyssorum abyssorum Cutler, 1994.

<u>DESCRIPTION</u>: The trunk length, commonly 10-30 mm (2 to 59 according to SAIZ SALINAS, 1993a) is more than 8-10 times the width (Fig. 8a). The introvert has 8-24 digitiform tentacles (Fig. 8b). Distal tip of introvert shows very characteristic medium-sized hooks, typically arranged in spiral (Fig. 8c). There are elliptical shaped skin bodies (5-6 μ m in diameter) in the middle part of the trunk (Fig. 8d) and dome-shaped papillae (5-7 μ m in length) on the posterior part of trunk. Eyespots absent. In appearance, they are smooth, white, grey or yellow animals.

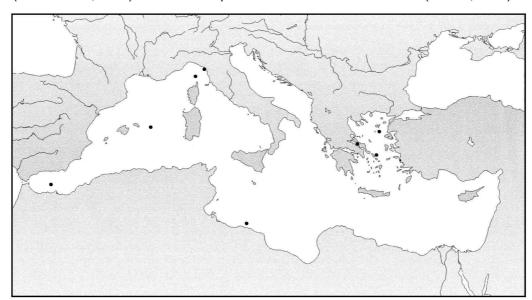
Internally, one pair of retractors originates commonly in the middle part of the trunk. One fixing muscle, a weakly developed spindle muscle and wing muscles are present. Two small yellow pear-shaped nephridia open outside almost at the anus level (Fig. 8e).

REMARKS: According to ISERN ARUS (1975) there is a subspecies in the Mediterranean Sea (*N. abyssorum mediterraneum*) which differs from *N. abyssorum abyssorum* mainly in the shape of the hooks as well as in the presence of small papillae at the posterior part of the trunk. However, it does not appear in the revision of the genus (CUTLER & CUTLER, 1986), neither is reported in later studies (CUTLER, 1994; SAIZ SALINAS, 1993a) Thus, the presence or absence of the subspecies remains doubtful until a comparative study on the individuals is realised. Lacking any personal view, *mediterraneum* form is not included in the present list of Mediterranean species.

<u>DISTRIBUTION</u>: Common in the northeastern Atlantic and north seas of Russia and Arctic. Also reported from northwest Atlantic (Cuba, South Portugal). Rarer in the Pacific, Red Sea, Japan and SW Africa.

Scattered records in the Mediterranean Sea (Alboran, Libyan coasts, off Corsica, Ligurian Sea and Aegean Sea).

BIOTOPE: The species presents wide bathymetric distribution (35-5318 m). It has been reported from sand, muddy sand, mud and is often associated with corals or *Cerianthus* (STEPHEN & EDMONDS, 1972). Sometimes it has been reported from hard substrata, inside burrows of *Cliona abyssorum* and in the valves of *Lima excavata*. In the Aegean Sea it was associated with *Lithothamnion* and sandy mud (MURINA, 1964). It was also found at 72-76 m on coarse sand associated with metalliferous wastes (MURINA *et al.*, 1999). Maximum depth in the Mediterranean: 1085m (MURINA, 1964).



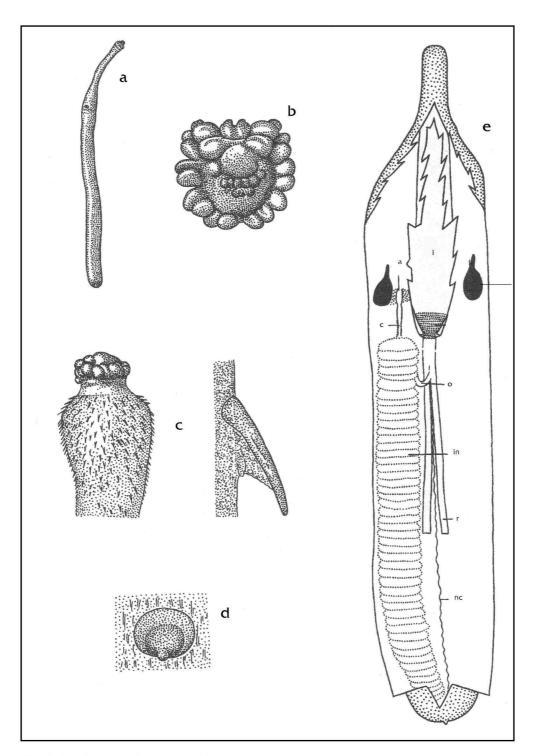


Fig. 8: Nephasoma abyssorum abyssorum.

- a) Entire animal.
- b) Tentacular crown.
- c) Anterior view of introvert and isolated hook.
- d) Skin body of trunk.
- **e)** Dissected animal. *a:* anus, *n:* nephridium, *c:* caecum, *i:* introvert, *in:* intestine, *r:* retractor muscle, *nc:* nerve cord, *o:* oesophagus.

Nephasoma capilleforme (Murina, 1973)

<u>SYNONYMS</u>: Golfingia capilleformis Murina, 1973. Golfingia glacialis Murina, 1964. Nephasoma capilleforme Cutler & Cutler, 1986; Cutler, 1994.

<u>DESCRIPTION</u>: A threadlike white body with length 12-40 times more than its width (Fig. 9a). Its maximum length is 19 mm. The long introvert is one or two times more than it. It bears small one-pointed hooks (20-25 μ m) (Fig. 9b). Eyespots absent. The trunk is often irregularly contracted, giving the worm a beaded appearence. The anterior part of the body is often bulbous. On its smooth skin, small skin bodies are observed, sometimes reaching the size of thin papillae (up to 25 μ m in height) (SAIZ SALINAS, 1993).

Only two very short retractors originate in anterior or middle one third of the trunk. Two sack-like nephridia open outside near the anus. The intestinal spiral consists of 40-50 coils and is not attached to the spindle muscle at the posterior part of the trunk. Fixing muscles and rectal caecum are absent. Weakly developed wing muscle is present (Fig. 9c).

<u>DISTRIBUTION</u>: Widespread species, known in the Atlantic, Indian and Pacific oceans (Cutler & Cutler, 1987b). It has recently been reported in the Antarctic (Weddell Sea, Saiz Salinas, 1995).

Some records in Mediterranean Sea near Balearic Islands (SAIZ SALINAS, 1993a), offshore French coasts, Corsica and Adriatic. In the eastern Mediterranean very restricted distribution. Besides the old record of Murina (1964) in the N. Aegean erroneously reported as *Golfingia glacialis* there is a recent record in Evvoikos Gulf (Murina et al., 1999).

BIOTOPE: Species considered as characteristic of deep sea cold waters (1.6-14° C). Its bathymetrical distribution ranges from 82 to 5840 m (CUTLER & CUTLER, 1987b). Recent findings in the North Aegean Sea at 65-75 m extend its vertical distribution to even shallower areas. Lives on muddy sand (MURINA, 1964) and on coarse sand associated with metalliferous wastes (MURINA *et al.*, 1999). Maximum depth in the Mediterranean: 1400m (MURINA, 1982).



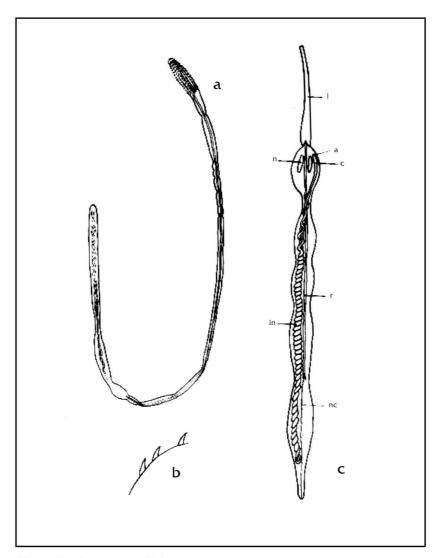


Fig. 9: Nephasoma capilleforme.

- a) External view of entire animal.
- b) Hooks of introvert.
- c) Internal structures of trunk. i: introvert, a: anus, n: nephridium,
- c: caecum, r: retractor, in: intestine, nc: nerve cord.

Nephasoma confusum (Sluiter, 1902)

<u>SYNONYMS</u>: *Phascolosoma confusum* Sluiter, 1902. *Golfingia confusa* Murina, 1957, 1978; Stephen & Edmonds, 1972; E. Cutler & Cutler, 1980; Ditadi & Migotto, 1981; E. Cutler *et al.*, 1984. *Golfingia confusa zarenkovi* Murina, 1974. *Nephasoma confusum* N. Cutler & Cutler, 1986; Saiz Salinas, 1993.

<u>DESCRIPTION</u>: Trunk length from 1.3 to 33 mm, about 3 times its width (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990; SAIZ SALINAS, 1993a). The introvert is slightly longer or about as long as the trunk (Fig. 10a). Papillae or "skin bodies" resembling papillae are present over the entire surface of the trunk less so in the middle region. Those on the anterior and posterior region are digitate in shape, 10-20 μm in diameter and 10-30 μm in height. In the middle of the trunk the papillae are smaller and less obvious. (Fig. 10b,c,d) Medium sized hooks (70-90 μm) are scattered irregularly. They are thick, bent in shape and have a reinforcement on their edges and a clear streak in the inner part (Fig. 10e). Skin varies from smooth and translucent to coarse and dark. It may be darker at the two ends. Two retractors are attached to the trunk wall in the middle or posterior one-third of the trunk. Nephridiopores behind the anus (Fig. 10f).

REMARKS: The presence or absence of papillae has caused much confusion in the literature. DITADI and MIGOTTO (1981) in their revision of the species, stated that papillae were absent, but they wrote later: "the thin skin is covered all over by skin bodies, low in the middle region of the trunk, similar to tiny finger at the anterior end of the proboscis". Later, CUTLER & CUTLER (1986) confirmed that the skin lacks papillae but does have "round skin bodies". SAIZ SALINAS & VILLAFRANCA URCHEGUI (1990) however, observed prominent papillae over the trunk. Thus, two basic "morphs" seem to exist within the genus: low, inconspicuous "skin bodies" vs. well developed, obvious, mammiform papillae. SLUITER (1902) differentiated these two structures on the basis of whether the platelets are lacking in the skin bodies or are present in the papillae. The shape of the hooks must be considered as the distinctive characteristic of the species. Doubt still remains whether the presence/absence of conspicuous papillae constitutes a significant difference, although in the opinion of CUTLER & CUTLER (1986) this feature carries very little taxonomic weight.

<u>DISTRIBUTION</u>: More common in the Southern Hemisphere around Antarctica, southern Australia, and Indonesia, but also reported in the north-western Pacific Ocean and off Brazil. Recent records from around Gibraltar in the northeastern Atlantic may be *N. constrictum*, as evidenced by the animals' larger papillae, much smaller hooks, and cryptobiotic lifestyle in that area (see Saiz Salinas & VILLAFRANCA URCHEGUI, 1990).

In the Mediterranean Sea its occurrence is restricted to the Iberian abyssal plain (Murina, 1982): Alboran Sea and Spanish coasts.

BIOTOPE: Eurybathic species, it is known from coastal to deep locations. Considered as opportunistic (DITADI & MIGOTTO, 1981), it has been met in various habitats. In bathyal samples it is common in muddy sediments with detritus. In the coastal zone it inhabits mainly hard substrata (inside corals and sponges, on the base of bryozoans and ascidians). Many specimens inhabit discarded gastropod and pteropod shells and also foraminiferan tests. Maximum depth in the Mediterranean: 1376m (MURINA, 1982).



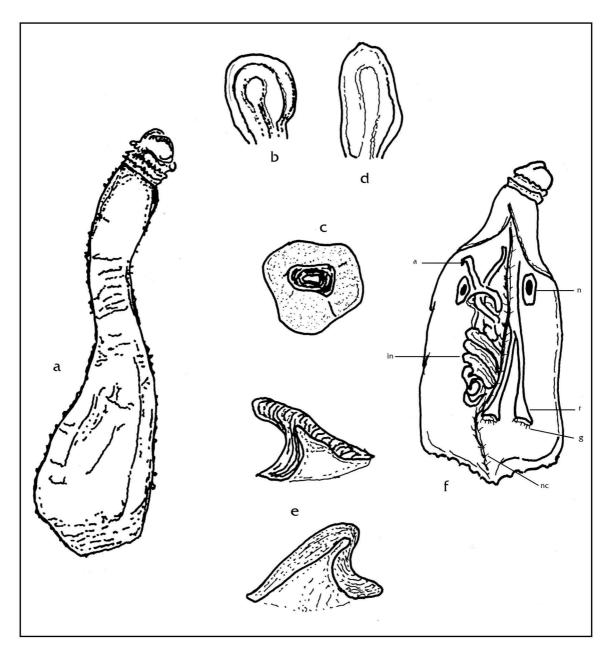


Fig. 10: Nephasoma confusum.

- a) External view.
- b, c, d) Papillae from the anterior (b), central (c) and posterior (d) part of the trunk.
- e) Hooks of the introvert.
- f) Internal view.a: anus, n: nephridium, in: intestine, r: retractor muscle, g: gonad, nc: nerve cord.

Nephasoma constricticervix (E. Cutler, 1969)

SYNONYMS: Golfingia constricticervix E. Cutler, 1969; E. Cutler & Cutler, 1980. Nephasoma constricticervix N. Cutler & Cutler, 1986; Saiz Salinas & Villafranca Urchegui, 1990; Saiz Salinas, 1993a.

<u>DESCRIPTION</u>: Trunk threadlike, 5-20 mm long and 0.3-1.1 mm wide, that is less than one-tenth of its length (Fig. 11a). Introvert 3-5 times shorter than the trunk length. The bulbous region at the anterior end of the trunk tapers quickly into the constricted neck. Skin smooth and translucent. Skin bodies, 10-20 μm in diameter, present over its trunk (Fig. 11b,c,d). Distal hooks, 70 μm in height, are scattered (Fig. 11e). This is one of the two *Nephasoma* species that have some hooks exceeding 200 μm. The hooks on a single worm may range in size from 40 to 250 μm; only the more distal hooks exceed 200 μm.

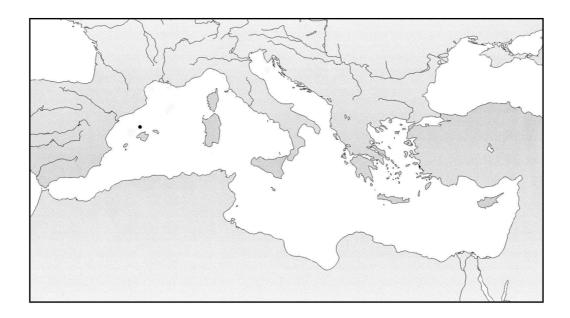
Two retractors attach to the middle one-third of the trunk. Nephridiopores are slightly behind the anus.

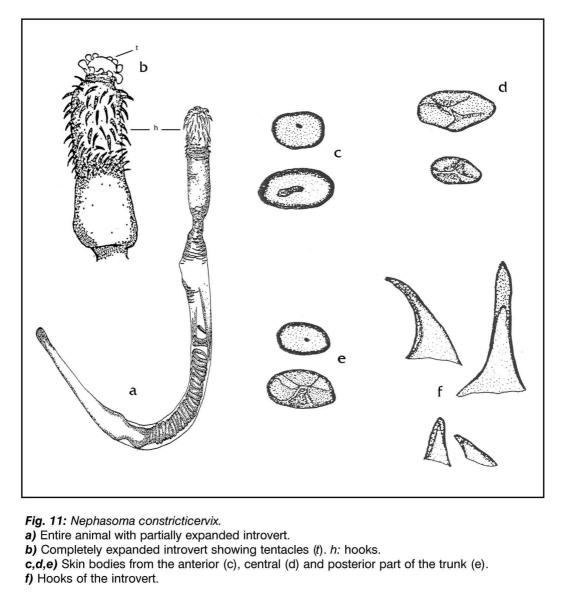
<u>REMARKS</u>: The thread-like appearance of the trunk, the presence of skin bodies and elongated distal hooks are useful taxonomic characteristics. However, if the short introvert (20-45% of the trunk length) is withdrawn or incomplete, it can be difficult to identify. Moreover, if only the smaller proximal hooks are seen, it is possible to mistake this for some other species (e.g., *N. cutleri*).

<u>DISTRIBUTION</u>: Common in the northern Altantic (both sides) and south to 22° S on the eastern side, Ibero-Moroccan Bay, Eastern coasts of Africa, Biscay Gulf, Canarian Islands.

In the Mediterranean Sea one single record northern of Balearic Islands (SAIZ SALINAS, 1993a).

<u>BIOTOPE</u>: Very little is known about its ecological requirements. The species is common in deep waters at 1200-5500 m. Reported from fine sediments (clay, mud with foraminiferans and pteropod tests). SAIZ SALINAS (1993a) cites its restrict temperature requirements (2.5-3.5°C) typical of a coldwater boreal species. Maximum depth in the Mediterranean: 2360m (SAIZ SALINAS, 1993a).





Nephasoma constrictum (Southern, 1913)

<u>SYNONYMS</u>: *Phascolosoma constrictum* Southern, 1913. *Golfingia constricta* Stephen & Edmonds, 1972. *Nephasoma constrictum* Gibbs, 1986; N. Cutler & Cutler, 1986; E. Cutler and Cutler, 1987; Saiz Salinas & Villafranca Urchegui, 1990; Saiz Salinas, 1993.

<u>DESCRIPTION</u>: Flask-shaped trunk 1.5-32 mm long and 0.4-7 mm wide (Fig. 12a). Introvert slightly longer or shorter than trunk (1-16 mm in length and 0.2-2.5 mm in width). Skin rough, but in some specimens it is smooth and translucent. Stubby tentacles or lobes, as well as a narrow constriction on the introvert-trunk junction are present in most specimens. Finger-shaped tentacles have also been observed in some specimens with extended introverts. Dark papillae (1-50 μm in height and 25-80 μm in diameter) cover the entire surface of the trunk, being larger at its ends (Fig. 12b,c,d). Pale hooks (16-35 μm tall) scattered when observed (Fig. 12e). When hooks are absent, the papillae in the bulbous region behind the tentacles are more apparent. A nipplelike posterior is evident in many worms. Colour varies from pale gray to creamy.

Internally, two retractor muscles originate from the posterior one-third of the trunk, or even in the middle. Nephridiopores sligthly in front of the anus or at the same level (behind the anus in some big specimens). A spindle muscle is present in most animals, but it is weakly developed and does not extend anteriorly out of the gut coil along the rectum (Fig. 12f).

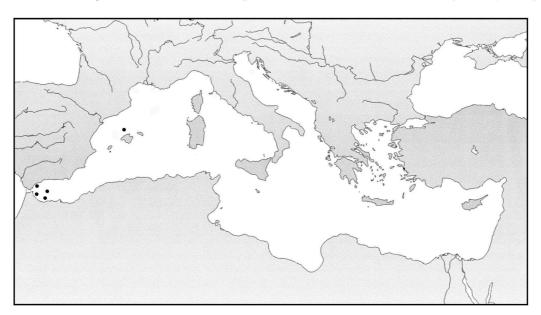
<u>REMARKS</u>: The presence of numerous, variously formed papillae over most of the trunk is especially diagnostic for this species. Some of its external features are subject to great variations, specimens appearing with no trace of hooks, with various degrees in the development of papillae, or even small specimens looking very much like *N. diaphanes*.

<u>DISTRIBUTION</u>: Common in the east north Atlantic Ocean. Unpublished records (Cutler, 1994) from the French *Safari* collections extend this range, distinctly, into the central Indian Ocean (2-8° S, 79-87° E).

It has been reported from the western Mediterranean (Alboran Sea, Northern Balearic islands: Saiz Salinas & Villafranca Urchegui, 1990; Saiz Salinas, 1993a).

<u>BIOTOPE</u>: Species met at a wide bathymetric range varying from 205 m (W. Mediterranean) to 4300 m (Indian Ocean). Commonly known from bathyal and abyssal bottoms of the eastern North Atlantic. The only published temperature data range between 7,9 and 8,2°C.

It lives a *Phascolion*-type lifestyle in empty gastropod and scaphopod shells or within the sclerosepts of dead solitary corals or under the basis of the tunicate *Ascidia tritonis* or makes clay-mud tubes in soft muddy bottoms. Maximum depth in the Mediterranean: 2800 m (Cutler, 1994).



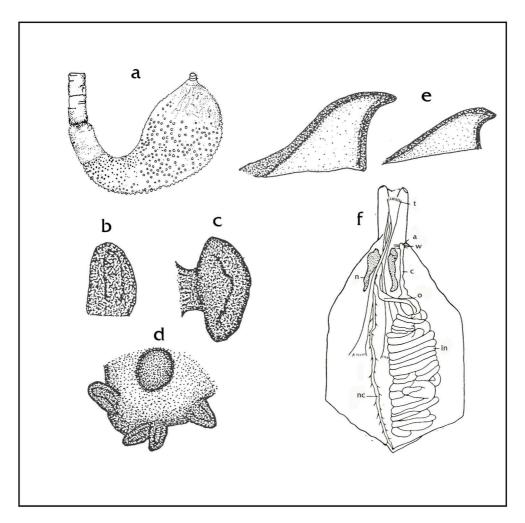


Fig. 12: Nephasoma constrictum.
a) External view.

- **b**,**c**,**d**) papillae from the anterior (b), central (c) and posterior (d) part of trunk.
- e) Hooks.
- f) Internal view. t: tentacles, a: anus, w: wing muscle, c: caecum, n: nephridium, o: oesophagus, in: intestine, nc: nerve cord.

Nephasoma diaphanes corrugatum Cutler & Cutler, 1986

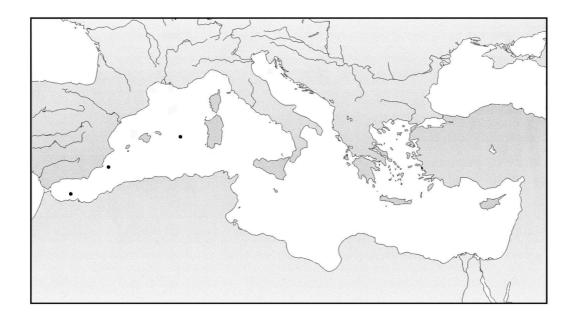
<u>SYNONYMS</u>: *Phascolosoma schuttei* Augener, 1903. *Golfingia schuettei* Murina, 1964,1977; E. Cutler & Cutler, 1980; Saiz-Salinas & Murina, 1982.

<u>DESCRIPTION</u>: Pear shaped to cylindrical trunk usually 5-10 mm long (occasionally 20-30 mm). There are irregular, wavy, zigzag longitudinal epidermal ridges on the introvert base and the anterior part of the trunk (Fig. 13a). The papillae on the posterior end of the trunk are often darker that the surrounding skin (Fig. 13b). The introvert is usually about as long as the trunk (ranging from 50 to 150%) and bears small (20-30 μ m), scattered, pale, triangular hooks (Fig. 13c). The tentacular crown consists of six to eight short lobes plus two longer dorsal tentacles. The colour is tan to grayish brown, translucent to opaque.

Internally, a ventral pair of retractor muscles is attached to the 1/3 of the posterior end in small animals (<4 mm) but in the middle one-third in larger ones. The weakly developed spindle muscle ends within the coil and does not extend onto the rectum (Fig. 13d).

<u>DISTRIBUTION:</u> Broad latitudinal range from the Atlantic and Pacific Oceans, to the Red Sea. In the Mediterranean (Alboran, Balearic and western basin: SAIZ-SALINAS & MURINA, 1982).

<u>BIOTOPE</u>: Collected at depths ranging from 80 to 5900 m (CUTLER, 1994) or 7000m (MURINA, 1982), mostly at about 1000 m. The sea bottom where it was found was red clay with agglomerations and light- grey sandy silt. Maximum depth in the Mediterranean: 3540m (MURINA, 1982).



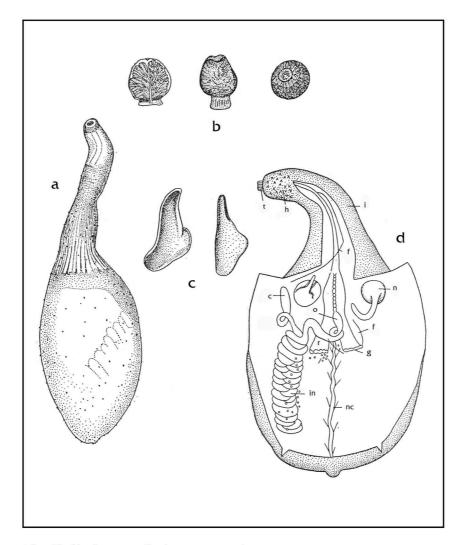


Fig. 13: Nephasoma diaphanes corrugatum.

- a) External view showing longitudinal epidermal ridges.
- b) Papillae of the trunk.
- c) Hooks of the introvert.
- **d)** Internal view. *t:* tentacles, *h:* hooks, *i:* introvert, *f:* fastening muscle, *c:* caecum, *n:* nephridium, *o:* oesophagus, *r:* retractor muscle, *g:* gonad, *in:* intestine, *nc:* nerve cord.

Nephasoma diaphanes diaphanes (Gerould, 1913)

SYNONYMS: Phascolosoma diaphanes Gerould, 1913. Golfingia diaphanes E. Cutler & Cutler, 1980; E.Cutler et al., 1984; Saiz Salinas & Villafranca Urchegui, 1990; Saiz Salinas, 1993. Phascolosoma minutum Theel, 1911; Wesenberg-Lund, 1937. Golfingia minuta Wesenberg-Lund, 1955; Murina, 1957, 1978; Stephen & Edmonds, 1972; E.Cutler, 1973; E.Cutler & Cutler, 1979; Saiz Salinas, 1984; Murina & Zavodnik, 1986. Nephasoma diaphanes diaphanes N.Cutler & Cutler, 1986.

<u>DESCRIPTION</u>: Trunk length commonly around 5 mm, although specimens up to 55 mm have been reported. They have a transparent or translucent body wall (Fig. 14a). The introvert is shorter than the trunk with a few short tentacular lobes (Fig. 14b) and scattered spinelike hooks, 20-30 μ m in height (Fig. 14c).

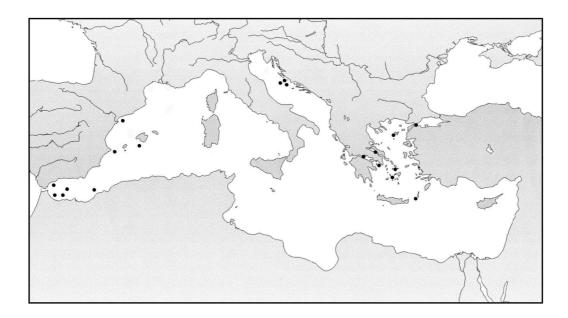
Two retractor muscles are attached to the middle third of the trunk. Nephridiopores open at the anus level (Fig. 14d).

<u>REMARKS</u>: Animals of this taxon are similar to *N. minutum* and *N. lilljeborgi* but generally smaller. In contrast to *N. minutum*, *N. d. diaphanes* is a dioecious species living in deeper water. Thus, immature members of other species are easily mistaken for this species.

<u>DISTRIBUTION</u>: Cosmopolitan species, it is recorded from the equatorial to the Antarctic and the Arctic waters. There are many records in the Pacific and Atlantic Oceans.

In the Mediterranean a few records (Alboran Spanish and French coasts, Adriatic and Aegean Seas). In the Sea of Marmara reported by CASPERS (1968).

BIOTOPE: It presents a wide range of bathymetric distribution, from the littoral zone to 6710 m (Murina, 1977). It often lives in arenaceous foraminiferan tests, small polychaete tubes, or scaphopod and gastropod shells; larger shelter dwellers may have enlarged and darker posterior papillae. It also occurs in various types of substrata: sandy, silty, muddy, red clay with agglomerations. It has been frequently found in eutrophic waters rich in organic matter (Adriatic Sea: Murina & Zavodnik, 1986). This species is considered as exclusive of the bathyal muds biocoenosis (Vamvakas, 1970; Carpine, 1970). Nephasoma diaphanes is often the most common sipunculan in deep-sea communities (E. Cutler & Cutler, 1987b). In Hellenic waters it has been reported in coarse sand associated with metalliferous wastes in the Aegean (Murina et al, 1999), as well as in sandy mud and mud in the Ionian Sea (Korinthiakos Gulf). Maximum depth in the Mediterranean: 1234m (Saiz Salinas & Villafranca Urchegui, 1990).



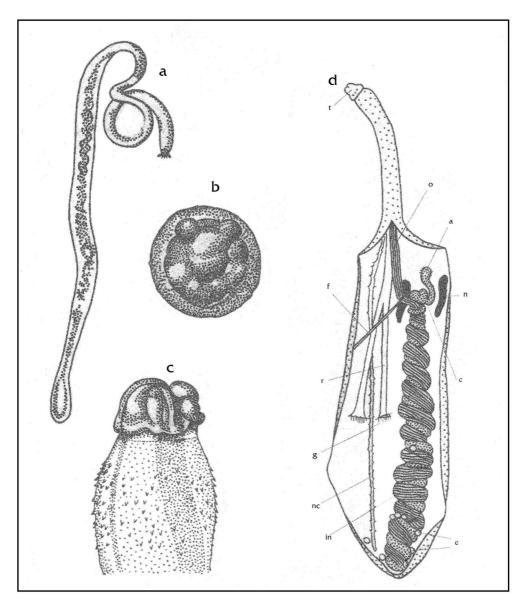


Fig. 14: Nephasoma diaphanes diaphanes.

- a) Entire animal.
- b) Frontal view of tentacular crown.
- c) Anterior part of introvert showing scattered hooks.
 d) Entire dissected specimen. t: tentacle, o: oesophagus, a: anus, f: fastening muscle, n: nephridium, r: retractor muscle, c: caecum, g: gonad, nc: nerve cord, in: intestine, e: eggs.

Nephasoma lilljeborgi (Danielssen & Koren, 1880)

<u>SYNONYMS</u>: Onchnesoma glaciale Danielssen & Koren, 1880. Golfingia (Nephasoma) lilljeborgi Murina & Zavodnik, 1986. Nephasoma lilljeborgi Cutler, 1994.

<u>DESCRIPTION</u>: Small thread - like worms up to 60 mm long, but usually less than 10-15 mm (Fig. 15a). The skin of the trunk is smooth, thin and transparent, bearing low skin bodies (Fig. 15b). The oral disk is small, carrying two short tentacles and a few rounded lobes around the mouth. The introvert is about equal to the trunk in length. Small triangular hooks (45-64 μm in height) (Fig. 15c) are arranged irregularly over the anterior introvert. Colour white to pale gray.

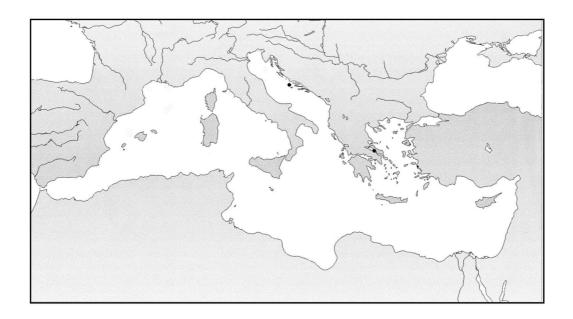
Internally, one pair of retractor muscles is fused for most of their length (Fig. 15d). There are two nephridia, their nephridiopores opening at the level of the anus. The intestine is loosely coiled in double spiral; a spindle muscle is either lacking or weakly developed (Fig. 15e). Rectal caecum absent. The eggs are 0.2-0.25 mm in diameter.

<u>REMARKS</u>: Very similar to *N. d. diaphanes*, especially in absence of gametes. This species is more opaque than *N. diaphanes* and does not live in foraminiferan tests. Also this species, especially when found at abyssal depths, may be misidentified with *N. capilleforme* (CUTLER, 1994).

<u>DISTRIBUTION</u>: Widely distributed in the North Hemisphere, it has been reported many times from the Atlantic (Norway, Bay of Biscay, Ibero-Moroccan Bay), the Baffin Bay and the Russian Arctic Seas.

In the Mediterranean its distribution is restricted to the Adriatic (Murina & Zavodnik, 1986) and the N. Aegean Sea (Murina *et al.*, 1999).

BIOTOPE: Eurybathic species. Its known bathymetric distribution ranges between 65 and 5350m, being more frequent in bathyal bottoms. On soft bottoms (mud, clay, sandy mud) as well as on detritic bottoms, gravel and shells. In the North Aegean Sea it was found at 65-75 m on coarse sand associated with metalliferous wastes. Maximum depth in the Mediterranean: 370m (MURINA, 1982).



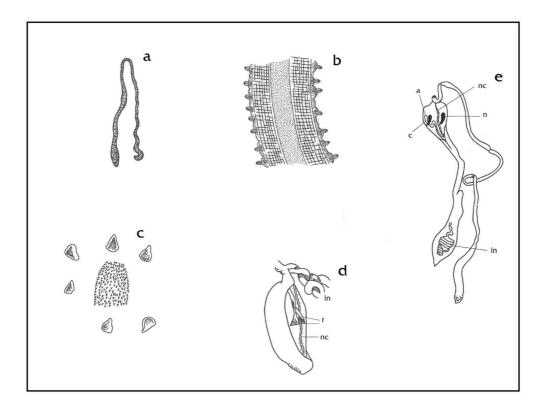


Fig. 15: Nephasoma lilljeborgi.

- a) Entire animal.
- b) Body wall bearing skin bodies.
- c) Hooks of introvert.
- d) Roots of retractors of introvert. in: intestine, r: retractor muscle, nc: nerve cord.
- e) Internal structures. a: anus, nc: nerve cord, n: nephridium, c: caecum, in: intestine.

Nephasoma rimicola (Gibbs, 1973)

SYNONYMS: Golfingia rimicola Gibbs, 1973; Saiz Salinas, 1986. Nephasoma rimicola N. Cutler & Cutler, 1986; Saiz Salinas & Villafranca Urchegui, 1990; Saiz Salinas, 1993.

<u>DESCRIPTION</u>: Trunk up to 50-60 mm, slender and cylindrical (Fig. 16a). Introvert shorter than the trunk (3.2-15mm in length and 0.4-2 mm in width). In the posterior region of the trunk there are conspicuous skin bodies 30 μ m in diameter (Fig. 16b). Hooks 57-100 μ m in height, arranged in rings (usually 6-10) (Fig. 16c). Skin smooth and a little translucent with brownish or reddish colouration, lacking papillae. Oral disk with a lobed nuchal organ and 12-20 flattened tentacles surrounding the mouth (Fig. 16d).

Internally, two retractor muscles originate in the anterior one-third of the trunk. The nephridiopores are ventrolateral, anterior to the anus which is situated on the anterior end of the trunk. Contractile vessel without villi. Intestine with 25-40 coils (Fig. 16e). Rectal caecum present.

<u>REMARKS</u>: The general appearance of the trunk and especially the arrangement of hooks are noteworthy for the species. The hooks, arranged in distinct rings, differentiate this species from the very similar *N. minutum*. It is the only species in the genus with such a hook arrangement (as is *Golfingia elongata* in its genus). Moreover, the anus is positioned posteriorly to the nephridiopores, in reverse to *N. minutum*.

GIBBS (1973) first described *Nephasoma rimicola* from southwestern England. Later it was found intertidally in northern Spain (SAIZ SALINAS, 1986). This finding extends both the latitudinal and vertical known range of this species, the latter to bathyal depths.

DISTRIBUTION: Atlantic (coasts of Devon, Cornwall, Gulf of Biscay, Northern Spain).

In the Mediterranean recent records in the Tyrrhenian: north of Rome (Chimenz, 1989) and off southern Spain: Alboran Sea (Saiz Salinas & Villafranca Urchegui, 1990; Saiz Salinas, 1993a).

<u>BIOTOPE:</u> From intertidal waters to the bathyal zone (0-720m). Inhabits mud and sand filling rock crevices on the lower shore. Its burrow is occasionally inhabited by the bivalve *Epilepton clarkiae*. Maximum depth in the Mediterranean: 395m (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990).



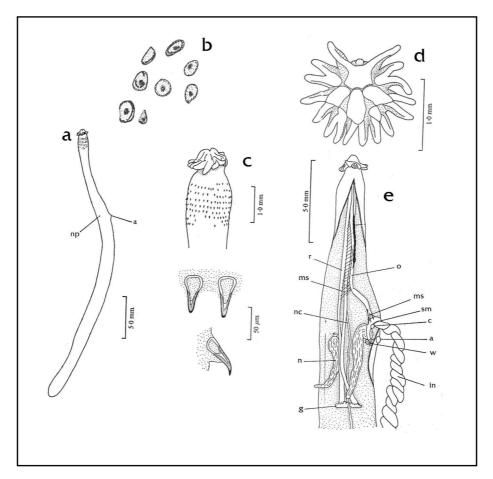


Fig. 16: Nephasoma rimicola.

- a) Entire animal. np: nephridiopores, a: anus.
- b) Skin bodies from the posterior part of trunk.
- c) Hooks of introvert.
- d) Oral disk showing tentacles and nucal organ.
- e) Internal anatomy. r: retractor muscle, ms: mesentery, nc: nerve cord,
- o: oesophagus, sm: spindle muscle, c: caecum, a: anus, n: nephridium,
- w: wing muscle, in: intestine, g: gonad.

Genus Thysanocardia

Thysanocardia catharinae (Grube, 1868)

<u>SYNONYMS</u>: *Phascolosoma catharinae* Grube, 1868. *Golfingia (Thysanocardia) catharinae* Fisher, 1952; Murina, 1977; Murina & Zavodnik, 1986; Cutler, 1994.

<u>DESCRIPTION</u>: The trunk is 4-70 mm long, 4-5 times as long as thick. The body is cylindrical or bottle-like with zigzag wrinkles in the skin (Fig. 17a). At the end of the introvert -which can be up to twice the trunk length- there are numerous finger or thread-like tentacles (Fig. 17b). The hooks of the introvert are absent. The surface of the skin is covered with yellow or brightly-brown short finger or ball-like papillae, which are highest (90 μ m) at the basis of the introvert. The colour of freshly fixed in alcohol specimens is whitish-gray.

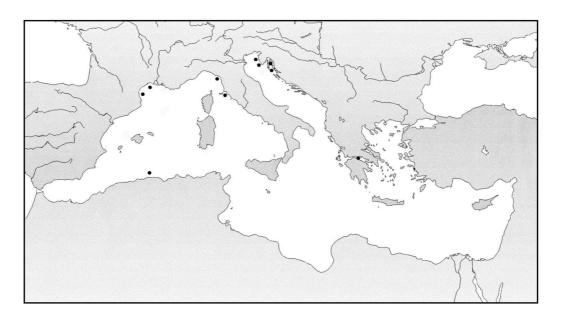
Two strong broad retractor muscles are attached to the posterior part of the trunk. The intestine spiral with 10-40 coils is attached only to the anterior part of the body with one spindle muscle. The rectal caecum is present. Contractile vessel is fluffy, beset with many short yellow or orange coloured tubules. Two nephridia are free and short. The nephridiopores are situated in front of the anus. Ripe eggs are spherical and 0.1-0.14 mm in diameter.

<u>REMARKS</u>: According to one of the authors (G.V.V.M) in small specimens, with introvert withdrawn, it is impossible to separate *T. catharinae* from its congeneric *T. procera*.

<u>DISTRIBUTION</u>: Tropical-temperate species reported from the Pacific, Atlantic and Indian Oceans to the Red Sea.

A few records from the western Mediterranean Sea (Algerian coasts, Gulf of Lions (SAIZ & MURINA, 1982), Tyrrhenian coasts (BIANCHI et al., 1993b, c), Ligurian Sea (MORRI et al., 1990) and from the Adriatic (MURINA & ZAVODNIK, 1986). HERUBEL (1925) recorded *T. catharinae* (probably referable to *T. procera*) from the Morocco coast. In the eastern Mediterranean it has been referred only in the Ionian Sea: Korinthiakos Gulf (MURINA et al., 1999).

<u>BIOTOPE</u>: Eurybathic species mostly found in the littoral zone. In the Adriatic it has been referred from coastal detritic bottoms, to muddy sediments characterized by the *Nephrops norvegicus-Thenea muricata* community. This species seems to belong to the group living in muddy bottoms and tolerating other fractions. In the Ionian Sea, mostly in mud but also in muddy sand. Maximum depth in the Mediterranean: 540 m (Murina *et al.*, 1999).



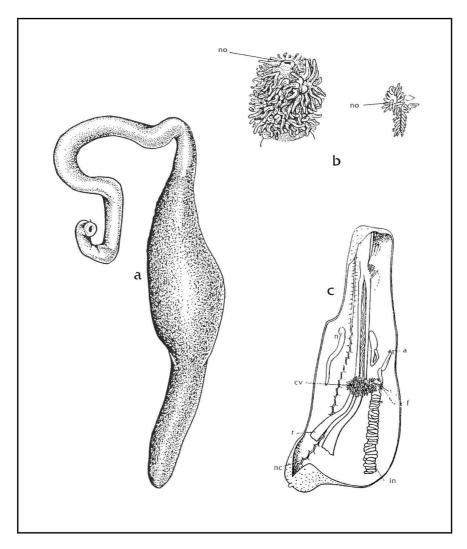


Fig. 17: Thysanocardia catharinae.
a) Entire animal.

- b) Thread-like tentacles showing uni-lobed nucal organ (no).
 c) Internal anatomy. cv: contractile vessel, n: nephridium, a: anus, f: fastening muscle, r: retractor muscle, in: intestine, nc: nerve cord.

Thysanocardia procera (Moebius, 1875)

<u>SYNONYMS</u>: Phascolosoma procerum Moebius, 1875. Golfingia procera Fisher, 1952. Golfingia (Thysanocardia) procera Stephen & Edmonds, 1972; Gibbs, 1977. Thysanocardia procera Cutler, 1994.

<u>DESCRIPTION</u>: They are the smallest animals in the genus. The trunk is 1,5-15mm long and 0.5-2.5 mm wide. 10 mm specimens can be sexually mature, and specimens longer that 15 mm are rare. The introvert is two to four times the trunk length (Fig. 18a). Skin smooth, bearing minute papillae (Fig. 18b), smaller at the posterior end of the trunk. The tentacle crown (when observed) is relatively simple, commonly with only eight short festoons, each with 6-10 tentacles (Fig. 18c), plus 6-10 small tentacles surrounding the bilobed nuchal organ (Fig. 18d). Its two oval lobes are separated by a longitudinal groove. In preserved material the tentacles are generally colourless, but in a few specimens a faint rust brown line is present on the oral surface of the tentacle.

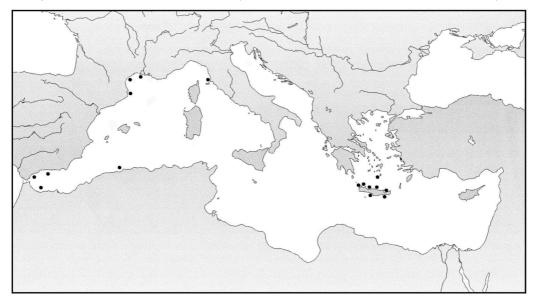
The two retractor muscles are fused for most of their length and originate in the posterior onethird of the trunk. Contractile vessel with villi. Nephridiopores at the same level to the anus or slightly in front of it. (Fig. 18e).

<u>REMARKS</u>: The small size of specimens and the bilobed nuchal organ are diagnostic for the species. Gibbs *et al.* (1983) reviewed this genus and reduced the taxonomic validity of 17 species to only three (*T. procera, T. catharinae* and *T. nigra*) with different distribution areas and morphological characteristics sufficiently distinct to warrant specific status.

<u>DISTRIBUTION</u>: The species is mainly known from the eastern North Atlantic, the Skagerrak, the North and Celtic Seas.

In the Mediterranean from the Gulf of Lions, the Algerian coasts (SAIZ SALINAS 1993a), the Alboran (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990), the French coasts (GUILLES, 1970; BOURCIER, 1976), the Tyrrhenian (BIANCHI *et al.*, 1993a) and South Aegean Sea (Santorini: VAMVAKAS, 1970; Kriti: KARAKASSIS, 1991).

BIOTOPE: It has been characterised as an exclusive dweller of muddy bottoms (PICARD, 1965; VAMVAKAS, 1970; BOURCIER, 1976) but it seems to inhabit a great variety of substrata (detritic, mud with shells, calcareous algae, sand, sand with *Zostera*). According to Thorson (1957) there exists a parasitic behaviour of *T. procera* on the polychaete *Aphrodite aculeata*. According to GIBBS (1977) it inhabits muddy sand at depths 2-200 m, while Stephen & Edmonds (1972) report it from shallow water and up to depths of 484 m. In Hellenic waters it is known from 40-370 m in muddy bottoms. Maximum depth in the Mediterranean: 555m (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990).



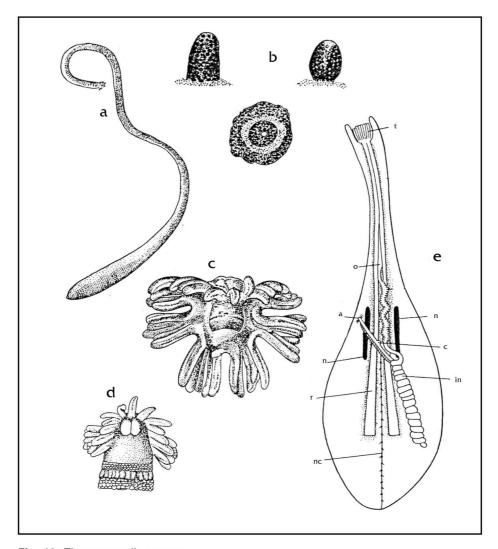


Fig. 18: Thysanocardia procera.
a) Entire animal.
b) Papillae.

- c) Tentacular crown.
- d) Tentacles with details of nuchal organ.
 e) Internal anatomy. t: tentacles, o: oesophagus, a: anus, n: nephridium, c: caecum, r: retractor muscle, in: intestine, nc: nerve cord.

Family Phascolionidae Genus Phascolion

Phascolion (Isomya) convestitum (Sluiter, 1902)

SYNONYMS: Phascolion convestitus Sluiter, 1902. Phascolion convestitum Stephen & Edmonds, 1972. Phascolion mediterraneum W. Fischer, 1922; Stephen & Edmonds, 1972; Saiz Salinas, 1986. Phascolion beklemischevi Murina, 1964; Stephen & Edmonds, 1972. Phascolion (Isomya) convestitum Cutler & Cutler, 1985.

<u>DESCRIPTION</u>: Trunk, occasionally curved, up to 12 mm in length and 4 mm in thickness (Fig. 19a). The introvert somewhat longer than the body with numerous irregularly situated broad based recurved pointed hooks (Fig. 19b). The holdfast papillae are unusually variable, from large and bulbous to small and compact; some have granular material around the border as disjunct units, others are without hardened material, and still others have a smooth, slightly darker border (Fig. 19c). About 20-25 normal tentacles are present.

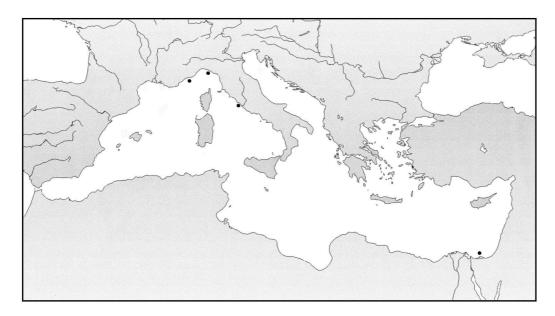
The dorsal retractor muscle is sometimes slightly larger than the ventral muscle. The dorsal muscle has a single origin, while the ventral has two, which straddle the ventral nerve cord near its posterior end. In this species the esophagus seems to be connected to the dorsal, not the ventral, retractor muscle as in *P. tuberculosum*. The gut is in loops with a few loose coils. There is a short, strong fixing muscle (but no spindle muscle) at the posterior end of the coil attaching it to the body wall between the roots of the ventral retractor (Fig19d).

<u>REMARKS</u>: According to Cutler (1994), the similarities of *Phascolion convestitum* to *P. tuberculo-sum* are striking and this taxon may not deserve specific rank.

DISTRIBUTION: Pacific, Indonesia, Gulf of Aden and Red Sea.

In the Mediterranean: French coasts (SLUITER, 1902), Tyrrhenian Sea: North of Rome (CHIMENZ, 1989), Ligurian Sea (MURINA, 1977), Egypt: off Suez Channel (MURINA, 1964).

BIOTOPE: At depths 25-275 m, on fine sand with admixture of silt. Maximum depth in the Mediterranean: 260m (MURINA, 1976).



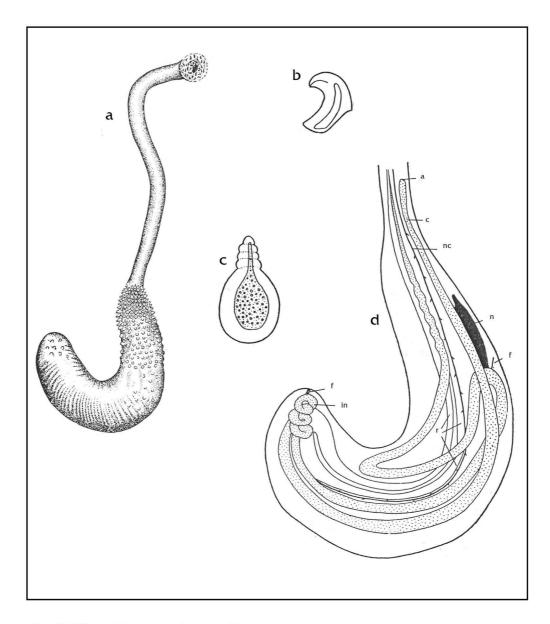


Fig. 19: Phascolion (Isomya) convestitum.
a) Entire animal.

- **b)** Hooks of introvert.
- c) Papillae of the anterior part of trunk.d) Internal view. a: anus, c: caecum, nc: nerve cord, n: nephridium, f: fastening muscle, in: intestine, r: retractor muscle.

Phascolion (Isomya) tuberculosum Theel, 1875

<u>SYNONYMS</u>: *Phascolion tuberculosum* Theel, 1875; Stephen & Edmonds, 1972; Cutler & Cutler, 1980. *Tylosoma lytkenii* Koren & Danielssen, 1875. *Phascolion pallidum* Koren & Danielssen, 1877; Stephen & Edmonds, 1972. *Phascolion hirondellei* Sluiter, 1900; Stephen & Edmonds, 1972. *Phascolion temporariae* Edmonds, 1976. *Phascolion (Isomya) tuberculosum* Cutler & Cutler, 1985; Saiz Salinas & Villafranca Urchequi, 1990; Saiz Salinas, 1993.

<u>DESCRIPTION</u>: Trunk up to 50 mm long. The introvert is equal to, or slightly shorter than trunk (Fig. 20a). This largest *Phascolion* has characteristic large (70-220 μ m), broad, recurved hooks (Fig. 20b). In a 1mm specimen the hooks are pale and only 35 μ m tall, but they still have the same shape. The large holdfast papillae (80-300 μ m) are spherical and lack chitinous borders (Fig. 20c). Occasionally some granular material is visible along the anterior margin. The large mammiform papillae around the anterior end of the trunk usually have one protruding tip, some have two and some others have up to four tips (Fig. 20d). Colour yellow, with greyish or brownish tones.

The two retractor muscles, of equal width, originate near the posterior end of the trunk at nearly the same level. The ventral occasionally originates 1-2 mm anterior to the dorsal. These muscles occasionally differ from one another in diameter by 25%. Nephridiopore a little behind the anus (Fig. 20e).

<u>REMARKS</u>: The shape and size of hooks and the lack of dark cuticularized border to the holdfast papillae are diagnostic for the species.

<u>DISTRIBUTION</u>: Common in the eastern north Atlantic (including the Azores, Mid-Atlantic Ridge, Bay of Biscay) and Scandinavian waters. The few specimens from Japan and New Zealand suggest a low-density population in the Pacific while single records come from the Indian Ocean.

In the Mediterranean a few records from the Alboran Sea and Spanish waters (SAIZ SALINAS & VILLAFRANCA URCHEGUI, 1990) and the Adriatic (CUKROV, 1973).

BIOTOPE: Phascolion tuberculosum is known from inshore to circalittoral zone and bathyal depths (25-2700 m). Although originally described from shallow waters (30-50m) this species appears to be predominantly found along the continental slope (Gibbs, 1985). It usually inhabits empty gastropod and scaphopod shells (more common in scaphopod than gastropod shells) and also, together with N. constrictum, lives within the sclerosepts of dead solitary corals or free in the sediment. Found in sand, muddy sand, mud or even in Globigerina mud mixed with sand, gravel, foraminiferans and pteropod tests. Species typical of cold waters, its temperature requirements varying between -0.2 and 13°C. Endoprocts, hydrozoans and bryozoans have been observed to be fixed on its skin. Commensal epizoans are common around the anterior end of the trunk. Maximum depth in the Mediterranean: 875m (Cukrov, 1973).



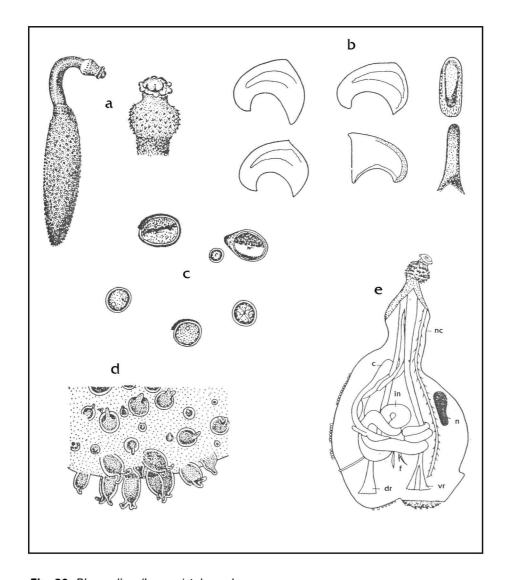


Fig. 20: Phascolion (Isomya) tuberculosum.

- a) Entire animal and details of the anterior part of introvert.
- b) Hooks of the introvert.
- c) Spherical holdfast papillae.
- d) Mammiform papillae.
- **e)** Dissected specimen. *nc:* nerve cord, *c:* caecum, *in:* intestine, *n:* nephridium, *f:* fastening muscle, *dr:* dorsal retractor, *vr:* ventral retractor.

Phascolion (Phascolion) strombus (Montagu, 1804)

SYNONYMS: Sipunculus strombus Montagu, 1804. Phascolion alberti Sluiter, 1900; Murina, 1964. Phascolion brotzajae Murina, 1964; Murina & Zavodnik, 1986. Phascolion strombi Theel, 1975; Murina, 1977; Gibbs, 1977. Phascolion (Phascolion) strombus Cutler & Cutler, 1985.

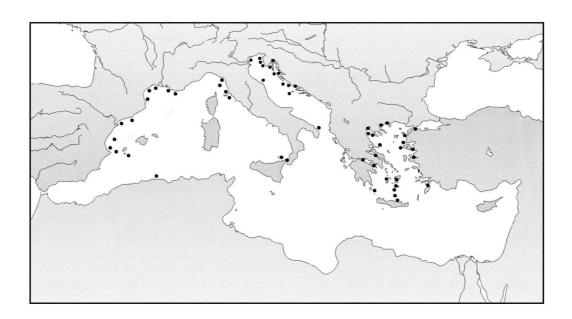
<u>DESCRIPTION</u>: The trunk length, commonly 5-15 mm, may reach 30-40 mm. The introvert is twice as long as the trunk (Fig. 21a). The mouth is surrounded by 10-30 well-developed tentacles (Fig. 21b). There are sharp, clawlike pointed hooks 60-70 μ m tall (Fig. 21c). The holdfast papillae (100-250 μ m tall), having commonly triangular-shaped aggregates in the belt, are displaced in the posterior third of the trunk (Fig. 21d).

There are two retractors of unequal size: the ventral retractor is one-fourth to one-half the diameter of the dorsal one. They are attached to the posterior end of trunk with origins at the same level. The intestine is in loose loops or a short friable spiral with many fixing muscles. Nephridiopores located at the anus level (Fig. 21e).

<u>DISTRIBUTION</u>: Cosmopolitan species with numerous records from the north Atlantic, Arctic (circumarctic-boreal), from north and Far-Eastern Russian Seas (Murina, 1977; Murina & Cholodov, 1985). There are scattered records from the Caribbean Sea, Red Sea, Gulf of Aden, Madagascar, South Africa, Argentina, Chile, New Zealand and Antarctic, Comoran and Kerguelen Islands (Cutler, 1994).

In the Mediterranean there are many records along the: Algerian, Spanish coasts, near Baleares Islands, French coasts (Gulf of Lions), Italian coasts (Ligurian Sea, Messina Strait, Lipari isls, Apulia) as well as in the Adriatic Sea and Aegean Sea. Very common in Hellenic waters (MURINA *et al.*, 1999) it has also been recorded from the Sea of Marmara (DEMIR, 1952).

BIOTOPE: Species eurythermic (-1.9 to 28°C), euryhaline (23 to 38.2‰) and eurybathic (1-4031 m) extending its distribution at depths exceeding 5000 m (GIBBS, 1985). Most commonly met between 50 and 200 m (CUTLER & CUTLER, 1996). It lives free on various bottoms, from detritic to sandy, silty and clay. Usually inhabits mollusc shells (*Dentalium, Turritella, Natica, Trochus* etc.) and polychaete tubes (*Pectinaria*). The shelter is often inhabited by a variety of other animals, such as *Syllis cornuta, Menestho diaphana, Mysella cuneata* and *Tellimya phascolionis*. In the eastern Mediterranean, it has been found on hard substrata from 5 to 6 m (Ergen et al., 1994). In the Sporades (North Aegean) it was found on hard bottoms associated with *Cystoseira* sp. (SIMBOURA et al., 1995). Maximum depth in the Mediterranean: 1000m (MURINA et al., 1999).



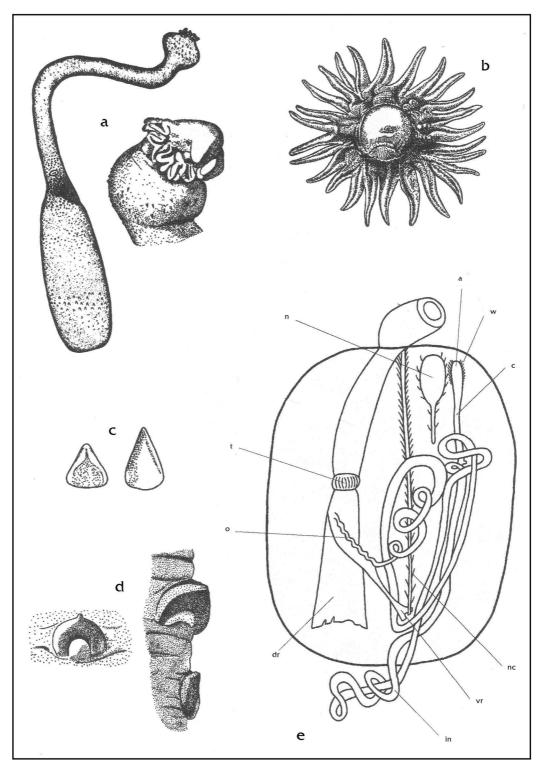


Fig. 21: Phascolion (Phascolion) strombus.

- a) Entire animal and details of the mouth.
- b) Tentacular crown.
- c) Hooks of the introvert.
- d) Holdfast papillae.
- **e)** Internal structure. *a:* anus, *n:* nephridium, *w:* wing muscle, *c:* caecum, *t:* tentacles, *o:* oesophagus, *nc:* nerve cord, *dr:* dorsal retractor, *vr:* ventral retractor, *in:* intestine.

Genus Onchnesoma

Onchnesoma squamatum squamatum (Koren & Danielssen, 1875)

<u>SYNONYMS</u>: *Phascolosoma squamatum* Koren & Danielssen, 1875. *Onchnesoma squamatum* Stephen & Edmonds, 1972; Gibbs, 1977; Cutler & Cutler, 1996. *Onchnesoma squamatum cutler* & Cutler, 1985; Saiz Salinas & Villafranca Urchegui, 1990.

<u>DESCRIPTION</u>: Typically these worms resemble a ball on a string. The trunk, 4-5mm long and 2-3 mm wide, is nearly spherical, and the thin introvert is up to five times the trunk length (Fig. 22a). The skin is coarse and densely covered with large gray papillae. 6-8 small tentacles are present (Fig. 22b). The anus is located on the introvert, 65-75% from its base.

A single retractor with two roots originates from the end of the trunk and is fastened to the introvert near the tentacular crown. The single (right) nephridium is one-third to two-thirds the trunk length and is attached for most of its length to the body wall. The gut coil is a regular golfingiid spiral consisting of several loops and a spiral of 10-12 double coils. It is attached posteriorly by one of the fixing muscles (Fig. 22c).

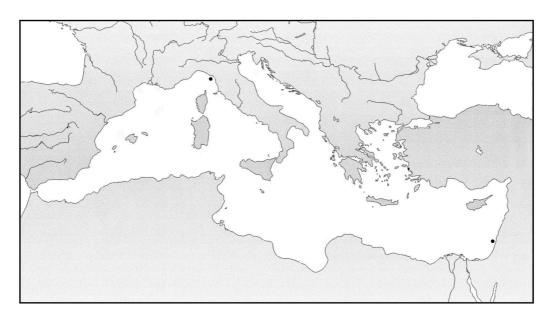
<u>REMARKS</u>: The external appearance of the trunk covered by large papillae and the lack of "keels" at the posterior end of the trunk clearly separate this species from its congeneric and well known in the Mediterranean *O. steenstrupii* steenstrupii.

<u>DISTRIBUTION</u>: Initially known from the North Atlantic (from Canary Islands to Iceland, from Florida to N. Carolina) it was recently reported from the Indian Ocean (Cutler & Cutler, 1996).

In the Mediterranean Sea reported from the Ligurian Sea (Morri *et al.*, 1990, Bianchi *et al.*, 1993c) and the Israel coasts (Stephen, 1958).

<u>BIOTOPE</u>: Inhabits muddy and sandy bottoms, as well as detritic bottoms. In the Atlantic its depth distribution ranges between 150 and 1440 m, with few records down to 2300 m. In the Indian Ocean the species was found at 325 m, while Mediterranean records seem to be limited to the circalittoral zone (10-57 m).

Known temperatures range between 4 and 10°C. Maximum depth in the Mediterranean: 57m (STEPHEN, 1958).



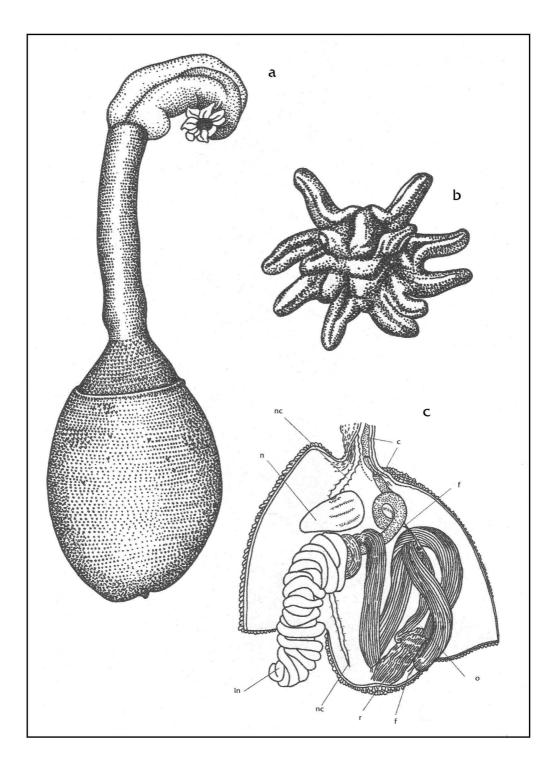


Fig. 22: Onchesoma squamatum squamatum.
a) Entire animal.

- b) Tentacular crown.
- **c)** Internal structure. *c:* caecum, *nc:* nerve cord, *f:* fastening muscle, *n:* nephridium, *in:* intestine, *r:* retractor muscle, *o:* oesophagus.

Onchnesoma steenstrupii steenstrupii Koren & Danielssen, 1875

<u>SYNONYMS</u>: Onchnesoma steenstrupii Koren & Danielssen, 1875; Stephen & Edmonds, 1972; Murina, 1977; Saiz-Salinas, 1993. *Phascolion dogieli* Murina, 1964; Stephen & Edmonds, 1972. *Onchnesoma steenstrupii steenstrupii* E. Cutler & Cutler, 1985.

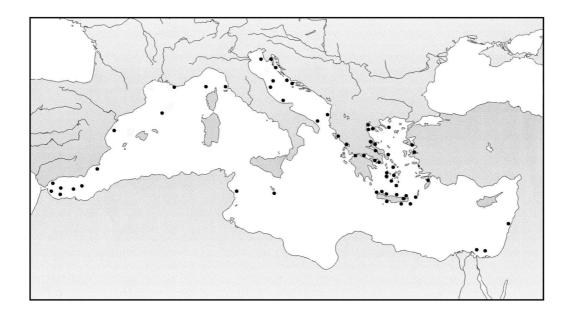
<u>DESCRIPTION</u>: Spherical, pear-shaped or barrel-shaped trunk 0.5-5 mm long and 0.3-2 mm wide (Fig. 23a). Introvert thin and long 5-10 times the trunk (Fig. 23b), at the end of which there is an oral disk, without tentacles (Fig. 23c). Eyespots present. The anus is located near the mouth. At the posterior part of the trunk there are 11-30 radiating keels. They consist of many small rectangle or oval flat chitin plates 10-30 μ m in size. Between them there are rather sparse cutaneous glands in the form of shiny light bluish circles 10-50 μ m in diameter (Fig. 23d). The color varies: grey, yellow, orange, rusty red.

Only one retractor originates from the posterior end. Contractile vessel absent. The gut consists of a few loops plus a spiral with a long rectum. There are 1-2 fixing muscles of intestine. Nephridium single and elongate. The mature specimens have oval white eggs 130-150 mm in diameter (Fig. 23e).

<u>DISTRIBUTION</u>: Common in the Atlantic Ocean (including Arctic). Scattered records in the Red Sea, Indian and Pacific Ocean (MURINA, 1977; CUTLER, 1994).

In the Mediterranean from east to west: (Alboran, Spanish, French, Italian (Tyrrhenian, Ligurian, Apulian) coasts, Adriatic Sea, Aegean, Levantine Sea.

BIOTOPE: Eurybathic species, considered as inhabiting waters at bathyal depths on continental slopes (100-1500 m, rarely 40-3000 m) (CUTLER & CUTLER, 1996). In mud and sand between 25 and 900 m (GIBBS, 1977). There are a few records at depths more than 2000 m. Although PICARD (1965), VAMVAKAS (1970) and CARPINE (1970) considered it as exclusive of the biocoenoses of deep muddy bottoms, it has been collected at various depths and bottoms, from sandy to silty. In Hellenic waters, it has been collected in large numbers, mainly in coarse sediments (MURINA *et al.*, 1999). There appears to be a pattern of distribution in which its abundance is related to sediment type, that is dense populations reaching 340 ind m² in coarse sediments (up to 100% coarse sand associated with metalliferous wastes) and down to 2 ind m², in finer sediments (about 1% coarse). SAIZ SALINAS (1993a) refers densities up to 420 ind.m². Maximum depth in the Mediterranean: 1376m (MURINA, 1982).



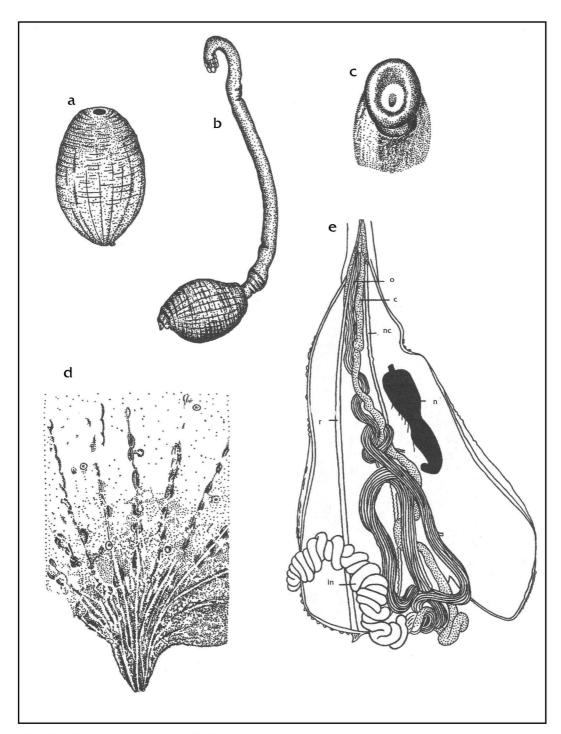


Fig. 23: Onchesoma steenstrupii steenstrupii.

- a) Entire specimen (introvert inside the body).
- b) Entire specimen (introvert extruted).
- c) Oral disk.
- d) Posterior part of the trunk, bearing keels and glands.
- **e)** Internal anatomy. *a:* anus, *c:* caecum, *nc:* nerve cord, *n:* nephridium, *r:* retractor muscle, *in:* intestine.

Class Phascolosomatidea Order Phascolosomatiformes Family Phascolosomatidae Genus *Phascolosoma*

Phascolosoma agassizii agassizii Keferstein, 1866

SYNONYMS: Phascolosoma (Phascolosoma) agassizii Stephen & Edmonds, 1972; Rice, 1980; Frank, 1983; Saiz Salinas, 1986; Phascolosoma (Rueppellisoma) golikovi Murina, 1957; E.Cutler & Cutler, 1983. Phascolosoma (Phascolosoma) agassizzi agassizii Cutler & Cutler, 1990.

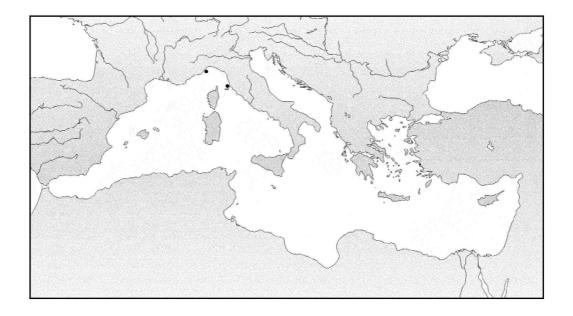
<u>DESCRIPTION</u>: Trunk up to 70 mm in length (usually 30-40) covered with papillae often darker than the skin. Papillae platelets are variable in size (3-9 μ m) and distributed randomly (Fig. 24a). The introvert is as long as the trunk or sligthly longer and has irregular dark pigment bands. Hooks 30-70 μ m tall, arranged in less than 30 rings (Fig. 24b). Each hook has a variable clear streak (not easily seen in worms smaller than 8 mm) and a triangle that is usually indistinct. A secondary tooth is small or absent. There are 18-24 tentacles (Fig. 24c). Body wall from translucent to opaque, skin pinkish-gray, yellowish-gray, pale sepia to reddish-brown.

The longitudinal muscle layer demonstrates 20-25 often merging bands, so that 15-17 remain on the nephridia level. Two pairs of retractors arise at the beginning of the posterior third of the trunk. A single fixing muscle is attached to the rectum and the beginning of the intestinal coils. The spindle muscle arises in front of the anus and is attached to the posterior end of the trunk. Contractile vessel inconspicuous, intestinal caecum present (Fig. 24d).

<u>DISTRIBUTION</u>: Common on both sides of the North Pacific from Mexico to Alaska on the eastern side and in Japanese waters in the west. Scattered records from Indian Ocean waters. In the tropical Atlantic from south and West Africa.

In the Mediterranean Sea two records, in the coasts of France (FISCHER, 1922) and the Tyrrhenian Sea (BIANCHI et al., 1993a).

BIOTOPE: Littoral zone. Less often in the circalittoral to 200 m, on coral reefs. According to FISHER (1952), this species prefers the littoral (intertidal) zone. It is probably most abundant in the lower littoral zone, just below low tide. Beds of mussels *Mytilus californias* are ideal conditions for the Californian population of this species. Specimens of *Ph. agassizii* have been found: under rocks, on fine sand, on muddy bottoms, in crevices of rocks together with *Themiste pyroides*, in roots of the seagrass *Phyllospadix*, as well as in the base of a colony of the hydrocoral *Allopora californica*. Some young specimens have been found among the elytra of *Aphrodite* sp. (Polychaete).



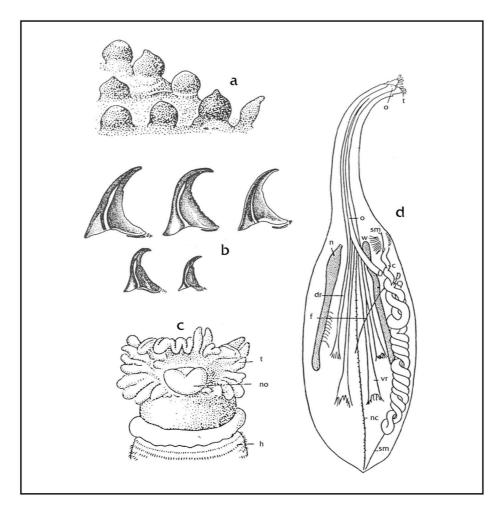


Fig. 24: Phascolosoma agassizii agassizii.

- a) Trunk papillae.b) Variation of hooks' shape.
- c) Tentacular crown. t: tentacles, no: nucal organ, h: hooks.
- d) Internal view of entire specimen. t: tentacles, o: oesophagus, sm: spindle muscle, c: caecum, n: nephridium, dr: dorsal retractor, f: fastening muscle, vr: ventral retractor, nc: nerve cord.

Phascolosoma (Phascolosoma) granulatum Leuckart, 1828

<u>SYNONYMS</u>: Physcosoma granulatum Sluiter, 1900; Vamvakas, 1971. Phascolosoma (Phascolosoma) granulatum Stephen & Edmonds, 1972; Murina, 1977; Cutler, 1994.

<u>DESCRIPTION</u>: The cylindrical trunk is 4.5 -60 mm long and 1.5-8 mm wide. The introvert is about as long as the trunk. The body wall is thick (Fig. 25a). Numerous papillae cover the entire body, especially dense at the anterior and posterior parts. There are irregular dark spots on the dorsal side of the trunk. The adult forms have 25-26 tentacles of dark-blue colour, the young worms only 12-16 ones (Fig. 25b). Two conspicuous eyespots present. Behind the crown of tentacles there is a zone of hooks 50-94 μ m, often 35-70 μ m, in height, arranged in 10-17 rings in young and 60-100 rings in adults. The inner structure of hooks is a diagnostic feature. Their apical end is sharply bent and a narrow clear streak equally wide along their whole length is present. A secondary tooth is ill-defined or lacking (Fig. 25c). The colour is diverse from gray-brown to red-brown.

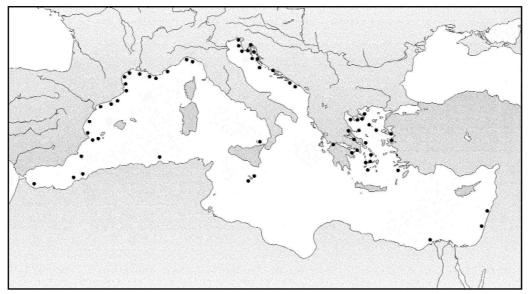
The longitudinal muscle comprises 18-28 bands, commonly 24-25. Four retractors are attached to the middle third of the trunk. The intestine spiral is composed of 6-12 double coils. The contractile vessel is simple without villi. The spindle muscle is attached to both ends of the trunk. There is a pair of well developed wing muscles and the diverticulum. The long nephridia are attached to the body wall along most of their length. The anus and nephridiopores dispose at the same level (Fig. 25d).

<u>REMARKS</u>: This species can be distinguished from the very similar *P. stephensoni* by the granular dome-shaped papillae (which are taller and cone-shaped in *P. stephensoni*) and the lack of dark pigmented bands on the introvert.

<u>DISTRIBUTION</u>: Common in the eastern north Atlantic Ocean from Norway to the Cape Verde Islands. Reexamination of the Brazilian and Indian Ocean records showed that they belong to another species (Cutler & Cutler, 1990).

In the Mediterranean there are many records: Alboran, Algerian, Spanish, French, Italian coasts (Tyrrhenian, Ligurian, Lipari isles), Malta, Adriatic Sea, Aegean Sea, Levantine.

BIOTOPE: According to Gibbs (1977) it inhabits muddy sand/gravel, from lower shore to 90 m depth. There are some deep records (1504-2050 m) from the North Atlantic Ocean (Wesenberg-Lund, 1930). Intertidally it occurs under stones, in crevices and amongst *Lithothamnion*, agglomerates of *Crassostrea* and *Sabellaria*. The bivalve *Epilepton clarkiae* occurs in its burrows (Gibbs, 1977). In the Adriatic Sea, its common habitats are rock crevices, detritic bottoms, clumps of calcareous algae, but also shelters under stones and burrows of endolithic bivalves, such as *Lithophaga lithophaga*, *Petricola lithophaga* and *Rocellaria dubia* (Murina & Zavodnik, 1986). Sometimes it has been reported from muddy sediments (Desbruyeres *et al.*, 1973). Schembri & Jaccarini (1978) reported this species as a member of the constant associated infauna of the echiuran worm *Bonellia viridis* in inshore waters around Malta. In Hellenic waters, it has been reported in hard bottoms with *Halimeda sp.*, calcareous algae and *Cystoseira sp.* (Simboura *et al.*, 1995), as well as associated with sponges (Κουκουras *et al.*, 1985), and inhabiting the shells of *Aporrhais serresianus* (Vamyakas, 1971). Maximum referred density 8000 ind.m² (Chapman, 1955). Maximum depth in the Mediterranean: 230m (Kisseleva, 1983).



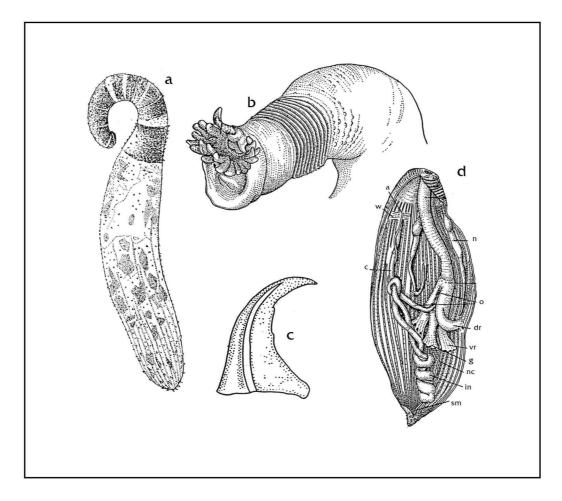


Fig. 25: Phascolosoma (Phascolosoma) granulatum.

- a) External view of entire specimen.
- b) Details of the anterior part of the introvert, showing the tentacular crown and the rings of hooks.
- c) Hooks' shape.
- **d)** Entire dissected specimen. *a:* anus, *w:* wing muscle, *c:* caecum, *o:* oesophagus, *dr:* dorsal retractor, *vr:* ventral retractor, *g:* gonad, *nc:* nerve cord, *in:* intestine, *sm:* spindle muscle.

Phascolosoma perlucens Baird, 1868

<u>SYNONYMS</u>: *Phascolosoma (Phascolosoma) perlucens* Stephen & Edmonds, 1972; Cutler & Cutler, 1990; Haldar, 1991. *Sipunculus (Phascolosomum) vermiculus* De Quatrefages, 1865. *Phascolosoma (Phascolosoma) vermiculus* Saiz Salinas, 1984. *Phascolosoma thomense* Murina, 1967.

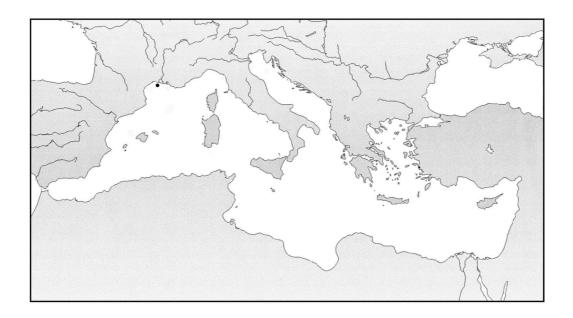
<u>DESCRIPTION</u>: The often thin-walled trunk, through which the longitudinal muscle bands are visible, is commonly up to 35 mm long, rarely 45-50 mm. The introvert is equal to or shorter than the trunk and usually displays patches of dark reddish pigment on the dorsal surface. The reddish, conical, posteriorly directed preanal papillae on the dorsal base of the introvert characterise this species (Fig. 26a). The hooks are in 15-25 rings (8-10 rings in 5-mm animals), 30-60 μm tall, and have a large, rounded secondary tooth. The internal triangle is separate from the clear streak (Fig. 26b). Trunk slim, skin yellow or blue-gray, covered with conical papillae larger on the dorsal side.

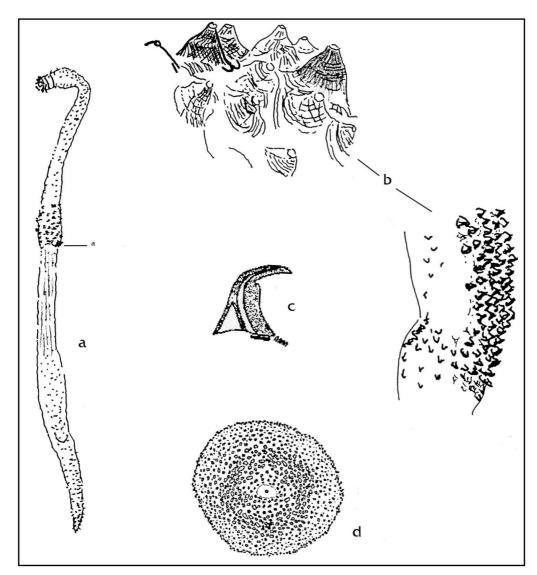
Internally, longitudinal muscles gathered into 22-24 bands visible through the skin. A strong spindle muscle is attached posteriorly and traverses the intestinal coils. There is a simple contractile vessel, the nephridia are short and arise at the anus level.

<u>DISTRIBUTION</u>: Common in the Caribbean (Venezuela to southern Florida) and the western Pacific (Queensland to Vietnam and central Japan); also recorded from many Indian Ocean locations and in the eastern Pacific off Panama and northern Mexico. Two eastern Atlantic records complete this circumtropical but patchy and disjunct distribution.

In the Mediterranean it has been found in the Gulf of Lions (MURINA, 1982).

<u>BIOTOPE</u>: The most common rock boring sipunculan in the Caribbean met at depths 0-2580 m. It occurs inside *Pinna* and *Ostrea* shells, along with alive corals of the genera *Pavonia* and *Pocillopora*. It has also been noted inside dead corals and among the branches of *Seriatopora angulata* (Madagascar). Maximum depth in the Mediterranean: 18 m (MURINA, 1982).





- Fig. 26: Phascolosoma purlucens.
 a) Entire specimen. a: anus.
 b) Preanal conical papillae.
 c) Hook from the introvert.
 d) Papilla (Skin body) from the central part of the trunk.

Phascolosoma scolops (Selenka & de Man, 1883)

<u>SYNONYMS</u>: *Phymosoma scolops* Selenka & de Man, in Selenka et al., 1883. *Physcosoma scolops* Shipley, 1898; Sato, 1930; Leroy, 1942. *Phascolosoma (Phascolosoma) scolops* E.Cutler, 1977; E.Cutler & Cutler, 1979; N.Cutler & Cutler, 1990; Saiz Salinas, 1984. *Phascolosoma riukiuensis* Murina, 1975. *Phascolosoma scolops* Wesenberg-Lund, 1957; Stephen, 1965; Edmonds, 1980.

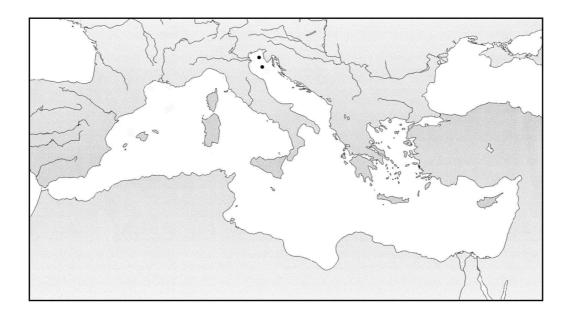
<u>DESCRIPTION</u>: Usually small (10-20mm), pale animals with distinct reddish brown, dome-shaped to mammiform preanal papillae at the base of the introvert. The introvert is commonly shorter than the trunk and exhibits pigmented bands (Fig. 27a). The mid-trunk papillae are small and widely scattered, but their size, color, and density increase at both trunk ends (Fig. 27b). The hooks, 20-60 μ m tall, are arranged in less than 25 rings, and a secondary tooth is small, if present. A clear streak is separate from the distinct triangle in the convex portion of the hook (Fig. 27c). Two dark lines cross the clear area of each hook. Two eyespots present. Colour blue-gray or red-gray, sometimes yellowish or brownish.

The longitudinal muscles are gathered into 20-21 bands which show few anastomoses. Two pairs of retractor muscles originate in the central third of the trunk. There are reports of loss or fusion of dorsal retractors in this species and of nephridia with an anterior lobe (E.Cutler et al., 1984). The intestinal spiral comprises 12-14 coils, the spindle muscle is strong and fastened to the posterior end of the trunk. Two nephridia about half the trunk length. Contractile vessel without villi. A rectal caecum is present in more than half the animals (Fig. 27d).

<u>DISTRIBUTION</u>: Common throughout the Pacific (north to northern Japan, south to northern Australia, and east to Hawaii) to the Indo-Pacific, including the Red Sea.

In the Mediterranean only met in the Adriatic Sea (MURINA & ZAVODNIK, 1986).

BIOTOPE: Usually found at intertidal and shallow depths (<30 m) in soft rocks, it was found by the Galathea research vessel near south Africa at a depth of 5220m. It lives among ascidian colonies and sandstone debris in the sand, between gravel stones in intertidal pools, among shells, in abandoned tubes of the polychaete *Gunnaria capensis* and in the corridors among loose gravels or in the heaps of dead corals (Murina & Zavodnik, 1986). Occasionally found together with *Phascolosoma nigrescens*. Maximum depth in the Mediterranean: 65m (Murina, 1976).



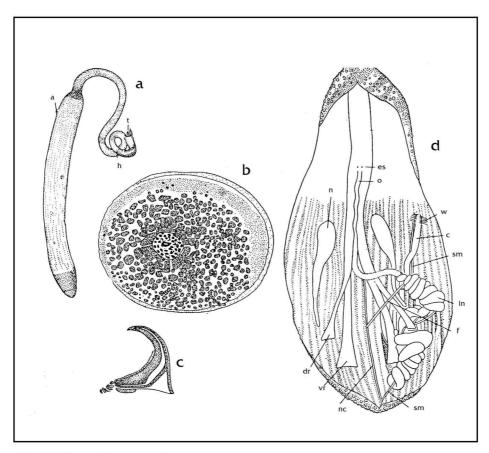


Fig. 27: Phascolosoma scolops.

- a) Entire animal. a: anus, t: tentacles, h: hooks.
- **b)** Papillae from the central part of the trunk.
- c) Hook of the introvert.
- **d)** Dissected specimen. es: eye spots, o: oesophagus, n: nephridium, w: wing muscle, c: caecum, sm: spindle muscle, in: intestine, f: fastening muscle, dr: dorsal retractor, vr: ventral retractor, nc: nerve cord.

Phascolosoma stephensoni (Stephen, 1942)

SYNONYMS: Physcosoma stephensoni Stephen, 1942. Phascolosoma (Phascolosoma) stephensoni Stephen & Edmonds, 1972; Edmonds, 1980; Saiz Salinas, 1986; 1993; N.Cutler & Cutler, 1990; Haldar, 1991. Phascolosoma laeve Keferstein, 1862. Sipunculus (Phymosomum) spinicauda De Quatrefages, 1865. Phascolosoma spinicauda Baird, 1868. Physcosoma lanzarotae Harms, 1921. Phascolosoma heronis Edmonds, 1956. Phascolosoma (Phascolosoma) heronis Stephen & Edmonds, 1972. Phascolosoma granulatum Murina, 1981. Phascolosoma stephensoni Wesenberg-Lund, 1963.

<u>DESCRIPTION</u>: Trunk up to 40 mm, bearing prominent papillae. In the pre-anal and posterior part of the trunk the papillae are numerous, dark red and cone-shaped while in the middle part they are smaller and hemispherical (Fig. 28a). The introvert has irregular pigmented bands and 10-20 complete rings of hooks, 60-110 μ m tall. In addition, dorsal patches of hooks, not arranged in rings, are present. The internal clear streak is smooth, the triangular space is clear, and posterior to the clear streak there is a distinct clear crescent (Fig. 28b). The hooks vary in shape, the proximal ones being more scattered, blunter, smaller (30-45 μ m), and more triangular, and the crescentic clear area is often not present. In most hooks a secondary tooth is present and distinct. The colour of the trunk and introvert is generally dirty-gray, sometimes darker with the dorsal surface red-brown.

The longitudinal muscles are gathered into 22-23 bands which show few anastomoses. Two pairs of retractors, the dorsal slighter than the ventral pair. Intestinal tract with about 10 coils, fastened by the spindle muscle. Contractile vessel without villi, rectal caecum absent, nephridia long with their posterior third free (Fig. 28c).

REMARKS: The species has been confused and thus synonymised, time by time, with other congeneric species. However, most of the uncertainty has been cleared in a recent revision of the genus (Cutler & Cutler, 1990). The distinctive smooth, conelike pre-anal and posterior papillae distinguish *P. stephensoni* from the similar *P. granulatum*, which is sympatric for part of its range. Under the light microscope these papillae show none of the platelets which are typical of this genus. The smaller papillae in the mid-trunk have only very small granules of uniform size, not platelets.

<u>DISTRIBUTION</u>: Eastern Atlantic (Azores, Canary islands, Gulf of Guinea to South Africa), western and northwestern Indian Ocean (Durban, Mozambique, Somalia, southwestern India), and western Pacific (northern Australia, Solomon Islands and Hawaii).

A somewhat disconnected distribution, from the Mediterranean Sea (Sicily: Cutler, 1994; Southern and Northern Spain: SAIZ & MURINA, 1982).

BIOTOPE: Its vertical destribution ranges between 0 and 1445 m. Scarce information on the ecological requirements of the species refer to it as associated with coralligenous bottoms, encrusting algae as *Lithophyllum incrustans*, in crevices and in the interior of the sponge *Verongia aerophoba* (VOULTSIADOU-KOUKOURA *et al.*, 1987). The species appears able to actively burrow in rocks, even though the exact mechanism is unknown.



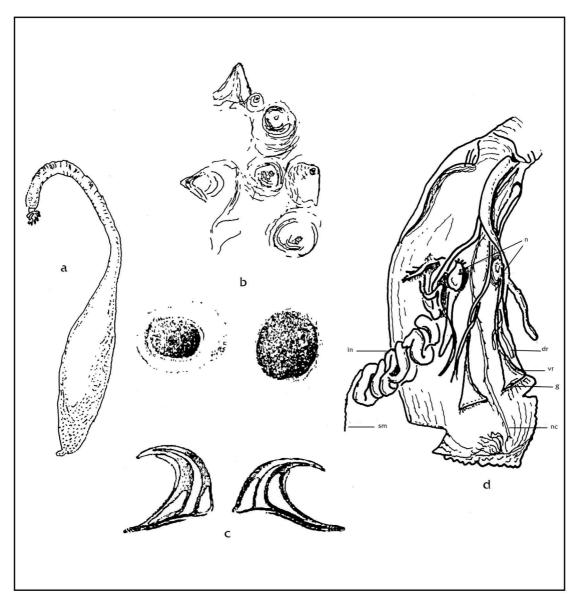


Fig. 28: Phascolosoma stephensoni.

- a) Entire specimen.
- b) Papillae from different body areas.
- c) Hooks of the introvert.
- **d)** Internal features of the species. *n:* nephridium, *dr:* dorsal retractor, *vr:* ventral retractor, *g:* gonad, *nc:* nerve cord, *sm:* spindle muscle, *in:* intestine.

Genus Apionsoma

Apionsoma murinae bilobatae (E. Cutler, 1969)

SYNONYMS: Golfingia (Mitosiphon) murinae bilobatae E.Cutler, 1969. Golfingia (Apionsoma) murinae murina Cutler 1979; Murina & Zavodnik, 1986. Golfingia hespera Murina, 1964. Apionsoma murinae bilobatae E.Cutler & Cutler, 1987.

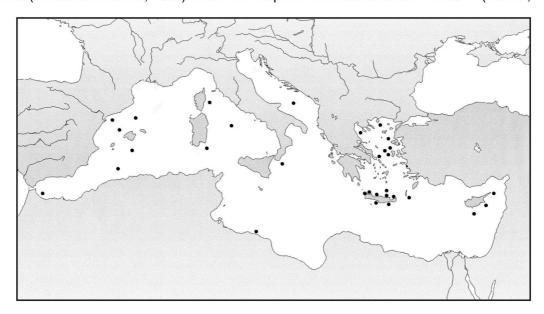
<u>DESCRIPTION</u>: Flasc-like or cylindrical trunk of small size (1-22 mm in length). The introvert is thin and usually 4-6 times longer than the trunk (Fig. 29a). There are 8-10 small finger-like tentacles and 10-15 rings of hooks. At the base of the hook there is an additional comb with 6-8 basal spinelets. The posterior end of large adult specimens bears mammiform or blister-shaped papillae (Fig. 29b). Colour grey, yellow or brown.

The ventral retractors are thicker than the dorsal ones. Both pairs of retractors are fused from the base, forming thus a long white muscle, which is attached by the spindle muscle to the posterior part of the trunk. The intestine spiral consists of 10-30 coils and has 1-3 fixing muscles (Fig. 29c). A long rectum and poorly developed wing muscles are present. In contrast to *Apionsoma murinae murinae* a secondary lobe may be present on the nephridia, with length about 25-33% of the primary one. Variation of nephridia morphology is show on Figure 29d. The mature worms have eggs with 85 µm in diameter.

<u>DISTRIBUTION</u>: A northern Atlantic species, which was recently recorded from the Indian Ocean (CUTLER & CUTLER, 1996). Earlier records in the Indian Ocean are now attributed to *A. murinae murinae* (CUTLER & CUTLER, 1996).

Well known in the Mediterranean Sea (Alboran Sea, Balearic Isl., Sardinia, Corsica, Adriatic, Aegean, Levantine).

BIOTOPE: Its known bathymetric distribution in the northern Atlantic ranges between 300 and 1900 m, while in the Mediterranean it seems to extend between 40 and 1400 m (assuming that all Mediterranean records refer to the subspecies *bilobatae*). According to SAIZ SALINAS & VILLAFRANCA URCHEGUI (1990) the depth distribution of *A. murinae* ranges between 56 to 5260 m. It lives on various substrata, usually in muddy sediments mixed with sand or gravel, as well as on sandy bottoms with *Lithothamnion* or biogenic detritus. In Hellenic waters this subspecies has been reported between 40 and 1215 m in mud (MURINA, *et al.*, 1999). In the Adriatic it was noted on fine silty sediments (MURINA & ZAVODNIK, 1986). Maximum depth in the Mediterranean: 1400 m (MURINA, 1982).



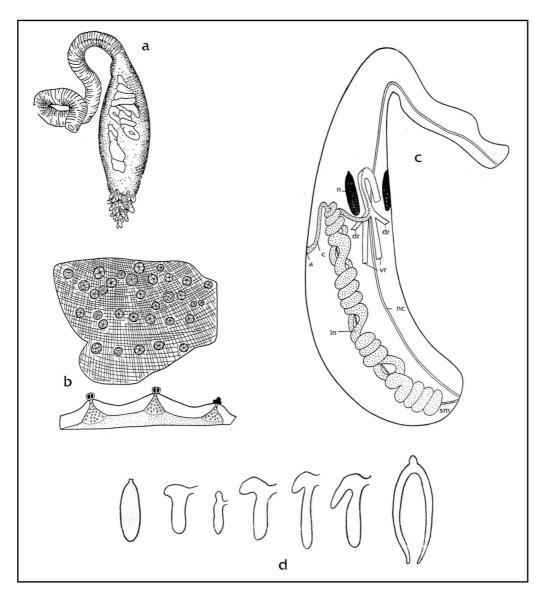


Fig. 29: Apionsoma murinae bilobatae.

- a) Entire specimen.
- b) Details of papillae.
- c) Internal anatomy. n: nephridium, dr: dorsal retractor, c: caecum, a: anus,
- vr: ventral retractor, nc: nerve cord, in: intestine, sm: spindle muscle.
- d) Variation of nephridia morphology.

Apionsoma trichocephalus Sluiter, 1902

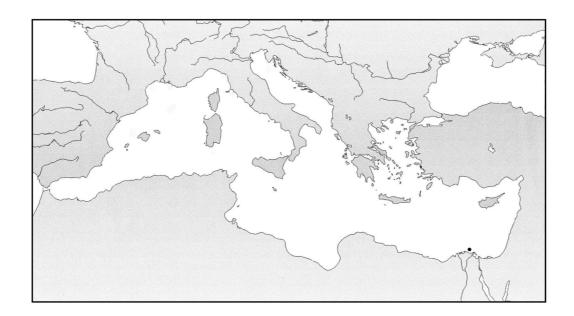
SYNONYMS: Golfingia (Golfingia) trichocephala Stephen & Edmonds, 1972. Golfingia (Mitosiphon) trichocephala E.Cutler & Cutler, 1979; Edmonds, 1980. Golfingia (Apionsoma) trichocephala Murina, 1977; E.Cutler, 1979. Apionsoma trichocephala E. Cutler et al., 1984; Haldar, 1991; N. Cutler et al., 1992. Phascolosoma pusillum Sluiter, 1912. Golfingia (Golfingiella) pusilla Stephen & Edmonds, 1972. E. Cutler & Murina, 1977.

<u>DESCRIPTION</u>: Trunk up to 8 mm long, oval, pointed posteriorly and tapering into the introvert. Very long introvert, 8-14 times the trunk length (Fig. 30a). The posterior end of the trunk is smooth and bears only scattered low, round or elliptical papillae (Fig. 30b). Both hooks and tentacles absent. The anus is shifted toward the middle of the trunk, so the nephridiopores are used to mark the anterior end. Skin colour yellow-gray with musculature weak and transparent, so that the internal organs are visible.

The two pairs of retractor muscles are thin and attach equally close to the ventral nerve cord near the middle of the trunk. Two thin nephridia arise quite near the nerve cord and open in front of the anus. The two long lobes of each nephridium are usually of equal length, althouth occasionally one is shorter, especially in young worms. About 20 intestinal coils posteriorly free. Rectal caecum absent.

<u>DISTRIBUTION</u>: A circumtropical species known from the Atlantic, Indian and Pacific Oceans. In the Mediterranean, it was found during the RV "Akademik Kovalewskii" cruise in August 1966 in front of the Nile Delta (Murina *et al.*, 1999).

<u>BIOTOPE</u>: A sand dwelling species, found mostly at intertidal depths to 100 m (CUTLER & CUTLER, 1996), with maximum depth in the Indian Ocean 4563m (MURINA, 1977). In the Mediterranean in muddy substrata at densities up to 100 ind.0.25m⁻² at depths 24-75 m.



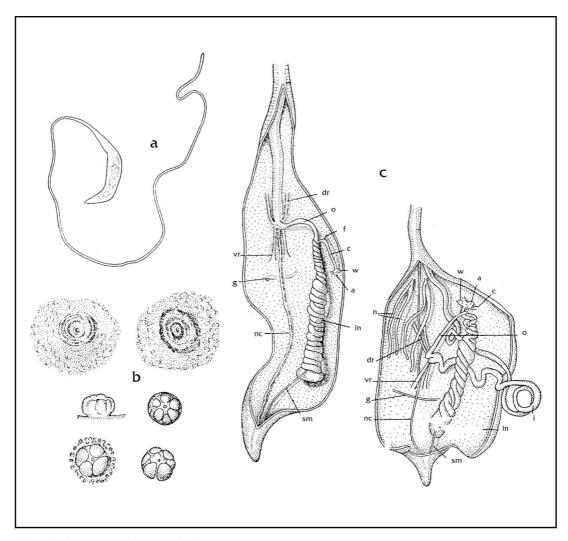


Fig. 30: Apionsoma trichocephalus.

- a) Entire specimen.
- b) Papillae of the posterior end of the trunk.
- **c)** Dissected specimens. *dr:* dorsal retractor, *o:* oesophagus, *t:* tentacles, *c:* caecum, *vr:* ventral retractor, *g:* gonad, *w:* wing muscle, *a:* anus, *nc:* nerve cord, *in:* intestine, *sm:* spindle muscle, *n:* nephridium.

Genus Aspidosiphon

Aspidosiphon (Akrikos) mexicanus (Murina, 1967)

<u>SYNONYMS</u>: Golfingia (Siphonoides) mexicana Murina, 1967; Murina & Zavodnik, 1986. Aspidosiphon mexicana Cutler et al., 1983. Aspidosiphon longirhynchus Cutler & Cutler, 1980. Aspidosiphon (Akrikos) mexicanus Cutler, 1994.

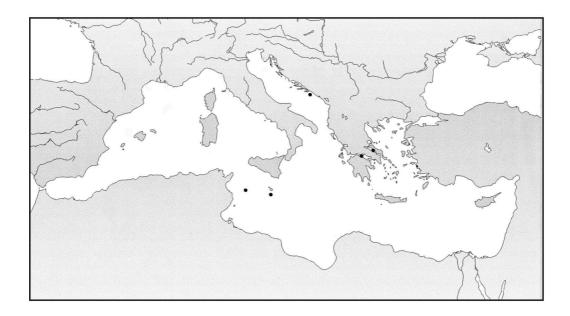
<u>DESCRIPTION</u>: The trunk is spindle-like with a rounded posterior. Trunk length is more than 4.5 times the width (Fig. 31a). The anal shield is very weakly developed with scattered, ill-defined platelets. The caudal shield is not discernible. The introvert length is four-five times the trunk length. It bears scattered small (30-32 μ m) hooks with slightly curved apex. At the base of the introvert there are skin bodies of an elongated oval shape 7-10 μ m in diameter. In the posterior part there are papillae (25-30 μ m high and 3-5 μ m wide). The body wall is white, robust, slightly shining.

The inner longitudinal muscle layer is continuous. Two short retractors begin at the posterior fourth of the trunk and join into a long muscle. The intestine spiral has 15 coils. The anus is clearly above the nephridiopore. Intestine spiral attached to posterior end of trunk with the spindle muscle. Other fixing muscles and caecum were not found. Contractile vessel simple. Eyespots absent. The nephridia are single-lobed and take 34-75% of the trunk length (Fig.31b).

<u>DISTRIBUTION</u>: West Atlantic Ocean (Mexican Gulf, southeastern United States, Azores). Recently it has been reported from the Indian Ocean (SAIZ SALINAS, 1993b).

In the Mediterranean a few records from Malta and Lampedusa Islands (Murina, unpublished data), the Adriatic (Murina & Zavodnik, 1986) and Hellenic Seas (Murina *et al.*, 1999).

BIOTOPE: At depths between 67 and 320 m, mostly on silt and clay. In the Eastern Mediterranean it was found in sand and sandy mud. Maximum depth in the Mediterranean: 160 m (MURINA et al., 1999).



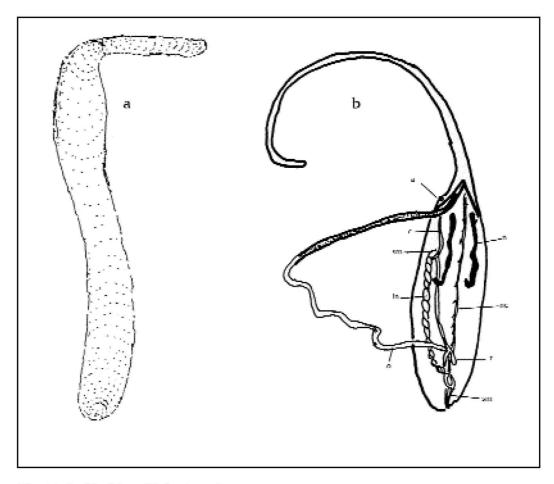


Fig. 31: Aspidosiphon (Akrikos) mexicanus.
a) Entire specimen.

- **b)** Dissected specimen. *a:* anus, *c:* caecum, *n:* nephridium, *sm:* spindle muscle, *in:* intestine, *nc:* nerve cord, *r:* retractor muscle, *o:* oesophagus.

Aspidosiphon (Aspidosiphon) elegans (Chamisso & Eysenhardt, 1821)

<u>SYNONYMS</u>: Sternaspis elegans Chamisso & Eysenhardt, 1821. Aspidosiphon elegans elegans Stephen & Edmonds, 1972. Aspidosiphon brocki Augener, 1903; Murina, 1967. Aspidosiphon elegans Selenka et al., 1883; Cutler & Cutler, 1989; 1994.

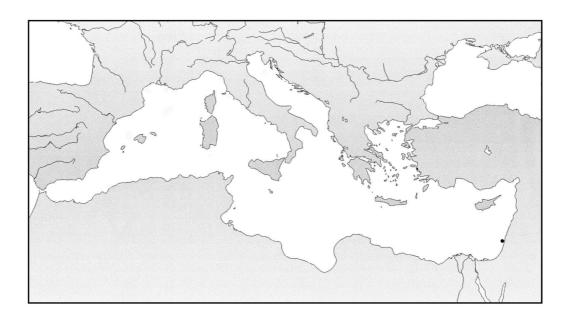
<u>DESCRIPTION</u>: The animals are usually smooth, white, and 4-22 mm long, but specimens up to 80 mm have been recorded (Fig. 32a). 6 to 12 short, stubby nuchal tentacles are present. The species is characterised by an ungrooved anal shield, bidentate compressed hooks in rings, plus characteristic dark, scattered, conical hooks (Fig. 32b). The variation in bidentate hook morphology is considerable (see Cutler & Cutler, 1989). The caudal shield is weakly developed and barely discernible in many animals.

Internally, the longitudinal muscle layer often splits in the area of the anal shield. About one in five animals has a caecum, and about one in twenty has a fixing muscle. The nephridia open at the level of the anus or just posterior to it. About 20 intestinal coils. Two retractors, joined to form a single muscle, originate from about 85-95 % of the distance toward the posterior end (Fig. 32c).

<u>DISTRIBUTION</u>: Widely distributed in tropical areas, from Indian and western Pacific Oceans to the Caribbean. Reported also from the Red Sea.

In the Mediterranean a single record from the Levantine Sea (Wesenberg-Lund, 1957).

<u>BIOTOPE</u>: It lives in dead coral and soft rock in shallow waters, boring into the coral skeleton of *Stylophora sp.* (Por, 1975). Maximum depth in the Mediterranean: 30 m (Wesenberg-Lund, 1957).



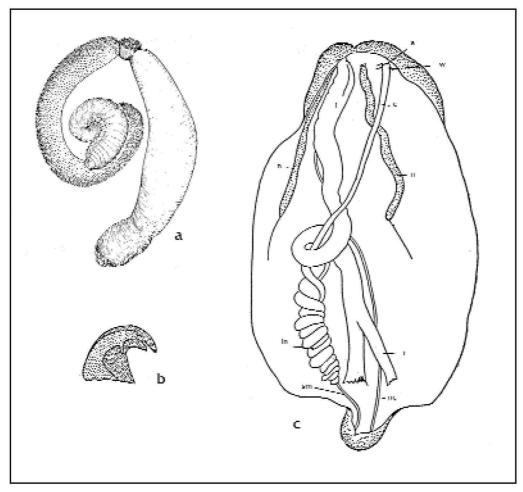


Fig. 32: Aspidosiphon (Aspidosiphon) elegans.
a) Entire specimen.

- b) Hook of the introvert.
- **c)** Dissected animal. *a:* anus, *w:* wing muscle, *c:* caecum, *n:* nephridium, *r:* retractor muscle, *nc:* nerve cord, *i:* introvert, *in:* intestine, *sm:* spindle muscle.

Aspidosiphon (aspidosiphon) misakiensis Ikeda, 1904

<u>SYNONYMS</u>: Aspidosiphon hartmeyeri W. Fischer, 1919; Stephen & Edmonds, 1972. Aspidosiphon gerouldi ten Broeke, 1925; Stephen & Edmonds, 1972; E. Cutler & Cutler, 1979; Migotto & Ditadi, 1988. Aspidosiphon speculator Saiz & Murina 1982; Saiz Salinas, 1986. Aspidosiphon (Aspidosiphon) misakiensis E. Cutler et al., 1984; E. Cutler & Cutler 1989; Saiz Salinas, 1993.

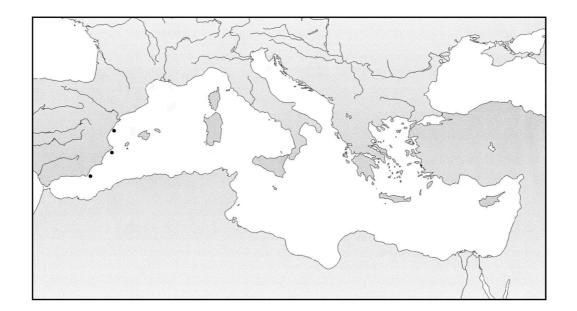
<u>DESCRIPTION</u>: The largest known animal is 25 mm, but commonly are about 10 mm. The introvert is two to three times the trunk length (Fig. 33a). The anal shield is composed of 5-6 irregular units arranged occasionally in indistinct rows. Widely spaced square blocks of shieldlike material form a more gradual transitional zone around the anterior quarter of the trunk. The caudal shield is granular with vague radial grooves. Bidentate hooks, 25-40 μm tall, are present in distal rings, followed by scattered proximal hooks or slighly bent spines (25-60 μm tall) that are unidentate and compressed (Fig. 33b). The secondary tooth has normal dimensions on the distal hooks but is very small in many proximal hooks. Colour light brownish-pink in life, with the introvert base and shields darker.

One pair of retractor muscles, which originates close to the caudal shield. The longitudinal musculature varying greatly among individuals, appears to be continuous with fractures in the anterior part, especially on the dorsal side, and the gut is loosely wound in ill-defined coils. The nephridia occupy 50-100% of the trunk length. Intestine organised in loose loops (Fig. 33c).

<u>DISTRIBUTION</u>: In the western Atlantic, from Brazil, Haiti and Cuba. In the Pacific Ocean (both sides of central Japan, South and Western Australia; and Kermadec Island). In the eastern Atlantic from the Azores, Cape Verde, and the Canary Islands to the Gulf of Guinea.

In the Mediterranean restricted to the Spanish coastal area (SAIZ & MURINA, 1982).

BIOTOPE: Usually at depths 1-75 m (0-150m according to SAIZ SALINAS, 1993a), exceptionally at 795 m (CUTLER, 1977). Generally lives on hard substrata, from corals to calcareous rocks and algae. CUTLER (1977) reports it from muddy sediment, inside a *Dentalium* shell, even though it does not usually occupy empty molluscan shells. Maximum depth in the Mediterranean: 31m (SAIZ SALINAS, 1986).



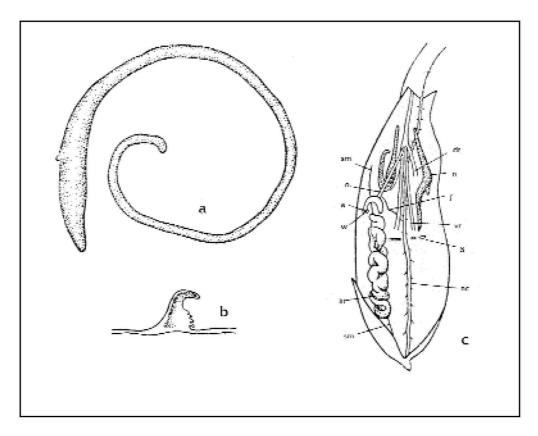


Fig. 33: Aspidosiphon (aspidosiphon) misakiensis.

- a) External view.
- **b)** Hook of the introvert.
- **c)** Dissected specimen. *sm:* spindle muscle, *dr:* dorsal retractor, *o:* oesophagus, *n:* nephridium, *a:* anus, *f:* fastening muscle, *w:* wing muscle, *vr:* ventral muscle, *g:* gonad, *in:* intestine, *nc:* nerve cord.

Aspidosiphon (Aspidosiphon) muelleri kovalevskii Murina, 1964

SYNONYMS: Aspidosiphon kovalevskii Murina, 1964; 1977; Murina & Zavodnik, 1986; Stephen & Edmonds, 1972.

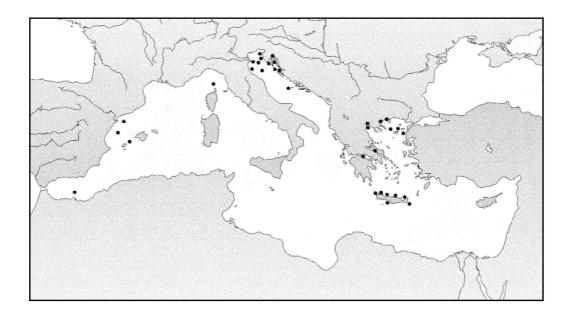
<u>DESCRIPTION</u>: Trunk up to 17 mm long. The ratio of trunk length/ width varies between 4:1 and 20:1 depending on the form of the shelter (gastropod and scaphopod shells). White thin-walled introvert shorter than half the trunk length (Fig. 34a). The distal part of the introvert is armed with small chitinized hooks having slightly curved points (0,02-0,025 mm heigth). The anterior shield is golden-yellow. In animals with completely inverted introvert the shield is composed of two parts: a low cylindrical base and an irregularly contoured cone. The last is furrowed with many plates of raised wartlike units, which bear spines (Fig. 34b). They are longer near introvert. On the ventral side, the plates with spines form a series of rows (12 and more) which encircle the introvert. The posterior conus-like shield is yellow, smaller than the anterior one and with no clearly defined border. The colour of trunk is white to yellow.

The retractor muscle begins at the posterior part of the trunk in two roots. There are 10-18 coils of the intestine spiral and 1-3 fixing muscles. The rectum with a caecum is fixed to the inner wall of body by two wing muscles. Two white, pear-shaped nephridia. The nephridiopores are situated posterior to the anus and are attached to the body wall all along their length (Fig. 34c).

<u>DISTRIBUTION</u>: There are rare records of the species in the Arabian Sea (Aden Gulf) and South China Sea (Tonkin Bay).

Numerous records in the Mediterranean (Alboran, Spain, Ligurian Sea, Aegean, Levantine), especially in the Adriatic Sea.

BIOTOPE: Mostly as for *A. muelleri muelleri*, probably due to their similarity and misidentification in earlier records. Its known bathymetric distribution ranges between 1 and 820 m. The main substratum it occurs is fine sand, sandy silt and clayey silt. The species inhabits the empty shells of gastropods, scaphopods and the hollow tubes of some serpulids (polychaetes). It was the first dominant species in the benthic assemblages of the biocoenoses of *Amphiura chiajei* and *Sthenolepis yhleni* (muddy substrata), reaching a density of 3245 ind. in 40 liters of sediment (Aegean Sea: Papazacharias, 1991). Maximum depth in the Mediterranean: 820 m (Murina *et al.*, 1999).



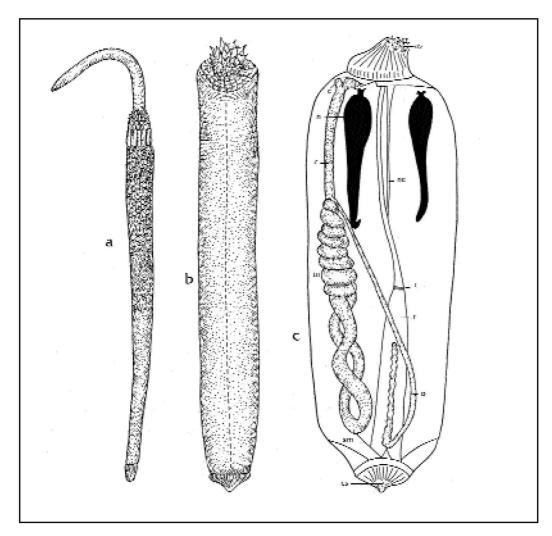


Fig. 34: Aspidosiphon (Aspidosiphon) muelleri kovalevskii.

- a) Entire specimen, showing introvert.
- b) Entire specimen, showing the sharp spines on the anal shield.
- **c)** Internal anatomy. *as:* anal shield, *c:* caecum, *n:* nephridium, *nc:* nerve cord, *t:* tentacles, *r:* retractor muscle, *o:* oesophagus, *sm:* spindle muscle, *cs:* caundal shield, *in:* intestine.

Aspidosiphon (Aspidosiphon) muelleri muelleri Diesing, 1851

<u>SYNONYMS</u>: Sipunculus scutatus Muller, 1884. Aspidosiphon clavatus Diesing, 1851; Demir, 1952; Kisseleva, 1963. Aspidosiphon hispitrophus Li Greci, 1980. Aspidosiphon muelleri Murina, 1977; Murina & Zavodnik, 1986; Saiz Salinas, 1993; Cutler, 1994.

<u>DESCRIPTION</u>: Trunk length usually 2-30 mm, but specimens up to 80 mm have been reported. The trunk may be either coiled or straigth, depending on the form of the habitat: shelter-empty gastropod or scaphopod shell. The introvert is 2-3 times the trunk length (Fig. 35a). The body wall is commonly thin, semitransparent. There are 6-12 small tentacles at the end of the introvert. Hooks arranged in rings and bidentate in the distal part of the introvert, scattered and pyramidal in the proximal one (Fig. 35b). Both shields are brown and grooved. The caudal shield is more brightly coloured, granulated or with radiale grooves (up to 18). The anal one is semielliptical or heart-shaped with some (up to 22) longitudinal grooves (Fig. 35c). Colour grey, light yellow or dark-brown.

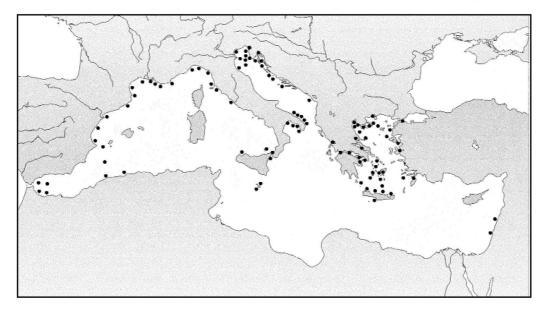
The longitudinal muscle layer is continuous and only at the level of anus it is split into 10-11 bands. The two retractors originate almost immediately from the edge of the caudal shield. The intestinal spiral consists of 28-30 coils. Fixing muscles may be absent. The rectum has the well-developed muscles and the rectal caecum. Nephridiopores on the level anus. The eggs are flattened, discoidal, 112-130 µm in diameter.

<u>REMARKS</u>: The absence of sharp spines on the anal shield easily discriminates this species from the very similar *A. muelleri kovalevskii*. See arguments for sustaining both species in the taxonomic observations chapter.

<u>DISTRIBUTION</u>: This tropical-temperate species is common in the Eastern Atlantic and Red Sea, scarcer in the Indian and Pacific Oceans (KONOPKA, 1979).

In the Mediterranean [Alboran, Spain, Algeria, France, Italy (Ligurian, Tyrrhenian, Sicily), Adriatic, Aegean, Levantine].

BIOTOPE: Common in shallow as well as in deeper bottoms (1-1262 m, Sluiter, 1912; 0-2934 m, Saiz Salinas & Villafranca Urchegui, 1990). The species has been reported in the Adriatic from coastal terrigenous ooze and coastal detritic bottoms, usually inhabiting empty mollusc shells (*Vermetus, Turritella, Dentalium* etc). According to Bourcier (1976) it presents higher abundance in sediments with mud content of about 20%. Often found living symbiotically with the bivalve *Jousseaumiella concharum* (Montacutidae) and the polychaete *Syllis cornuta* (Stephen & Edmonds, 1972). Schembri & Jaccarini (1978) reported this species, together with *Phascolosoma granulatum*, as a member of the constant associated infauna of the echiuran worm *Bonellia* viridis in inshore waters around Malta. In Hellenic waters it has been found in empty shells of *Turritella communis* in muddy biotopes, on sandy and hard bottoms associated with *Padina sp.* and *Cystoseira sp.*, as well as associated with sponges (Koukouras et al., 1985). Active boring of the species has been observed in massive chalk rocks (Por, 1975). Maximum depth in the Mediterranean: 1262m (Sluiter, 1912).



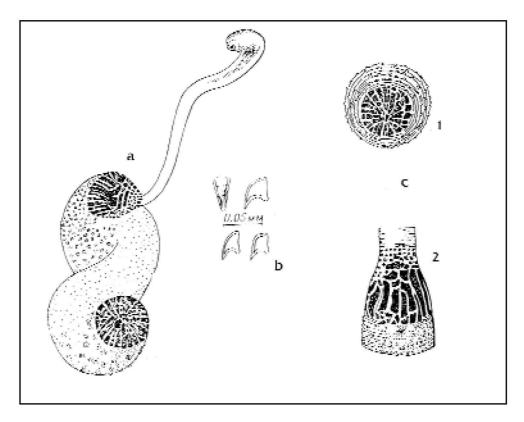


Fig. 35: Aspidosiphon (Aspidosiphon) muelleri muelleri.a) Entire specimen.b) Hooks.c) Caudal (1) and anal (2) shields.

EPILOGUE

DIVERSITY AND DISTRIBUTION OF THE MEDITERRANEAN SIPUNCULA

The phylum Sipuncula in the Mediterranean comprises 33 species distributed among five families as follows: Sipunculidae - 2 species, Golfingiidae -14 species, Phascolionidae -5 species, Phascolosomatidae -7 species and Aspidosiphonidae - 5 species. Their distribution in the Mediterranean appears to be even at the generic level (9 genera from the western to the eastern basin). However, at the species level the picture differs significantly. Figure 36 illustrates the variety in genera and in species at the main Mediterranean provinces. The figure shows the apparent richness in sipunculan diversity at the western basin where 29 species, 88% of the overall Mediterranean variety, are met whereas in the eastern part the diversity is reduced to 21 species (64%). The Adriatic Sea holds even less species (17 species), only 52% of the known in the Mediterranean.

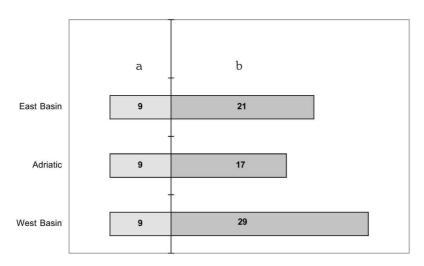


Fig. 36: Distribution of Sipunculan genera (a) and species (b) across the Mediterranean Sea.

Table 2 gives the distribution of all known species in the Mediterranean at the three major biogeographic divisions of the Sea as well as their distribution in the neighbouring Seas that is the Atlantic and Red Sea. It is clear from the Table that only 12 species (36,4%), marked in bold, are widely distributed throughout the Mediterranean. Two species, namely Apionsoma trichocephalus and Aspidosiphon elegans, are restricted in the extreme eastern basin while another nine species (Nephasoma confusum, N. constricticervix, N. constrictum, N. diaphanes corrugatum, N. rimicola, Phascolosoma agassizii agassizii, Ph. perlucens, Ph. stephensoni and Aspidosiphon misakiensis) do not occur further than the Sicilian Strait.

Table 2
Biogeographic and bathymetric distribution of the Mediterranean Sipuncula.
C: cosmopolitan, B: boreal (cold-temperate), TB: tropical-boreal, TT: tropical-temperate, TS: tropical-subtropical.

	Depth range in the Med	Depth range in the world ocean	
a Chara	cteristic raphical		
В	113-1405	0-5160	
,	5-160	0-2275	
В	2-720	2-720 (10-370)	
-TB	41	0-5470	
-TB	0-1900	0-5540	
1	35-1085	35 -5318 (40)	
-B	65-1400	65 -5840 (82)	
;-B T	145-1376	145 -4900 (289)	
1	1980- 2360	1200-5500	
В	205-2800	205 -4300	
ם	200-2000	(1100)	
В	253-3540	80-7000	
:-TB	45-1234	0-6710	
-	65-370	65-5350	
	0-395	0-720	
:-TT	16-540	0-3479	
)	40-555	2-555	
S	140-260	25-275	
)	310-875	25-2700	
-TB	0-1000	0-5000	
В	10-57	10 -2300 (150)	
В	8-1376	8 -3362 (40)	
В	<u>76</u>	<u>0-300</u>	
В	0-230	0-2050	
S	18	0-2580	
T	35-65	0-5220	
Ŝ	Littoral	0-3220	
B S T S B	40-1400	56-5260	
S	24-75	0-4563	
S T	<u>65-160</u>	65- 320 (80)	
<u>S</u> <u>T</u> T	<u>0-30</u>	<u>0-380</u>	
T	0-31	0-795	
_ T	1-820	1-820 (35-500)	
TT	0-1262	0-2934	

kovalevskii

Asp. muelleri muelleri +

Worth noticing is the presence of *Ph. scolops* exclusively in the Adriatic Sea. Its presence may be related to accidental introduction by means of navigation or other unknown reason.

On examining the geographic distribution of the Mediterranean Sipuncula in the neighbouring Seas an effort was made to define their way of introduction in the Mediterranean. As depicted from Table 2, most species (30 out of 33) occur in the Atlantic, which implies that they may have entered through the Gibraltar Strait. This holds true even for species inhabiting tropical-subtropical waters such as *Ph. stephensoni*. On the other hand, 14 species, also present in the Red Sea, may have entered through the Suez Canal. Only one species (*Phascolion convestitum*), and that inhabiting tropical, subtropical waters, absent from the Atlantic, is certain to have entered through the Suez Canal. Questionable is the presence in the Atlantic of *Ph. scolops* and *Asp. muelleri kovalevskii*, due to taxonomic uncertainties. Two species namely *N. diaphanes diaphanes* (recorded as *N. minutum*) and *P. strombus* are distributed NE as far as the Marmara Sea.

Considering the significant percentage of endemism in the Mediterranean (average 28%) which may reach 46% per taxonomic group, worth noticing is the absence of Mediterranean endemics among sipunculans.

Table 2 also summarises the bathymetric distribution of the Mediterranean Sipuncula within the Sea as well as in the World Ocean. The data are taken from review works, referenced in detail in the text. According to the results shown on the Table, the Mediterranean sources seem to extend the known bathymetric distribution of the species to lower depths in nine cases, noted in bold. The previous depths are cited in parentheses. In two cases only, the bathymetric distribution within the Mediterranean extends both the lower and upper limits of the known distribution. We refer to *Golfingia elongata*: previously known to occur at depths between 10 and 370 m, now at 2 to 720 m and *Asp. muelleri kovalevskii*: previously 25-500 m, now 1-820 m.

From Table 2 it can be seen that the great majority of species are eurybathic, occurring from the littoral zone (0 m) to bathyal and abyssal depths (7000 m). Among the Mediterranean species, only one (*N. constricticervix* noted underlined) is exclusively bathyal (1200-5500 m) while four species: *Phascolion convestitum, Phascolosoma agassizii agassizii, Aspidosiphon mexicanus* and *Asp. elegans* (noted double underlined), can be considered as mesobathic (depth range 0 to 300-400 m).

According to the species' geographic distribution in the World Ocean, each species has been assigned to a specific group, describing both the wideness of its distribution and its ecological requirements. Only seven species, having a worldwide distribution can be considered as cosmopolitan (noted with C on the Table), the rest have a more restricted distribution related mostly to temperature ranges. Thus, of the 33 Sipuncula, only *S. nudus* is a true cosmopolitan inhabiting all climatic zones. The rest are characterised as follows:

a TB denoting tropical and boreal (cold to temperate) zones:
a TT denoting tropical and temperate zones:
a TS denoting tropical and subtropical zones:
a B denoting cold to temperate zones:
3 species = 39,4%
7 species = 21,2%
5 species = 15,1%
7 species = 21,2%

In conclusion, the tropical-subtropical component in the Mediterranean, among sipunculans, is limited to 15% while the boreal component is slightly higher (21%). The higher species diversity recorded in the western basin, is partly due to intensive research (Saiz-Salinas, 1993a) but can also be explained by the ecological requirements of the species.

Plate I

Sipuncula species of the genus Aspidosiphon inhabiting molluscan shells.





Living in various gastropod shells.

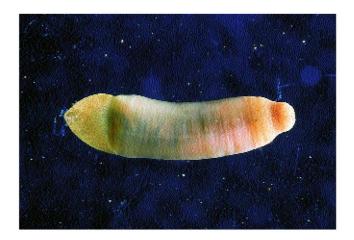


Living in scaphopod shells.

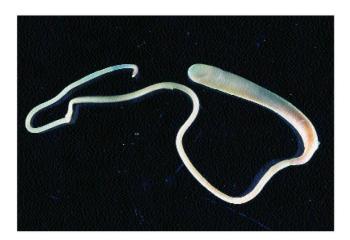


Living in gastropod shell of the genus Turritella, fitting into its shape.

Sipuncula species of the genus Golfingia.



With contracted introvert.



With extended introvert.

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102

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INDEX

Index of Sipuncula Species in alphabetical order Valid generic and species names in the Mediterranean are noted in bold

```
abyssorum, Golfingia 38
abyssorum, Golfingia (Nephasoma) 38
abyssorum abyssorum, Golfingia (Phascoloides) 38
abyssorum abyssorum, Nephasoma 21, 24, 38, 39, 96
abyssorum, Phascolosoma 38
adriatica, Golfingia (Dushana) 36
aequabilis, Sipunculus 28
agassizii agassizii, Phascolosoma 21, 25, 70, 71, 95, 96, 97
Akrikos 21, 84
alberti, Phascolion 64
Apionsoma 21, 25, 27, 80
Aspidosiphon 12, 15, 17, 19, 20, 21, 25, 27, 84
Aspidosiphonidae 21, 23, 27, 84, 95
Aspidosiphoniformes 21, 84
beklemischevi, Phascolion 60
bilobatae, Golfingia (Mitosiphon) murinae 80
brocki, Aspidosiphon 86
brotzajae, Phascolion 64
capilleforme, Nephasoma 21, 24, 40, 41, 52, 96
capilleformis, Golfingia 40
catharinae, Phascolosoma 56
catharinae, Golfingia (Thysanocardia) 56
catharinae, Thysanocardia 21, 22, 24, 56, 57, 58, 96
clavatus, Aspidosiphon 92
confusa zarenkovi, Golfingia 42
confusa, Golfingia 42
confusum, Nephasoma 21, 24, 42, 43, 95, 96
confusum, Phascolosoma 42
constricta, Golfingia 46
constricticervix, Golfingia 44
constricticervix, Nephasoma 21, 24, 44, 45, 95, 96, 97
constrictum, Nephasoma 21, 25, 42, 46, 47, 62, 95, 96
constrictum, Phascolosoma 46
convestitum, Phascolion 60
convestitum, Phascolion (Isomya) 21, 24, 60, 61, 96, 97
convestitus, Phascolion 60
cumanense, Siphonosoma 13
cutleri, Nephasoma 44
diaphanes corrugatum, Nephasoma 21, 24, 48, 49, 95, 96
diaphanes, Golfingia 50
diaphanes diaphanes, Nephasoma 15, 21, 22, 24, 50, 51, 52, 96, 97
```

diaphanes, Nephasoma 24, 46, 50, 52 diaphanes, Phascolosoma 50

dogieli, Phascolion 68

Dushana 36

elegans, Aspidosiphon (Aspidosiphon) 21, 25, 86, 87, 95, 96, 97

elegans, Sternaspis 86

elongata, Golfingia (Golfingia) 21, 24, 32, 33, 36, 54, 96, 97

elongatum, Phascolosoma 32

Gephyrea 11

gerouldi, Aspidosiphon 88

glaciale, Onchnesoma 52

glacialis, Golfingia 40

glacialis, Nephasoma 22

Golfingia 15, 20, 21, 24, 27, 32

Golfingiella 82

Golfingiidae 21, 23, 27, 32, 95

Golfingiiformes 21, 32

golikovi, Phascolosoma (Rueppellisoma) 70

granulatum, Phascolosoma 20, 21, 25, 72, 73, 78, 92, 96

granulatum, Physcosoma 72

hartmeyeri, Aspidosiphon 88

heronis, Phascolosoma 78

hespera, Golfingia 80

hirondellei, Phascolion 62

hispitrophus, Aspidosiphon 92

Isomya (Phascolion) 21, 24, 60, 62

kovalevskii, Aspidosiphon 22, 90

laeve, Phascolosoma 78

lanzarotae. Physcosoma 78

lilljeborgi, Golfingia (Nephasoma) 52

lillieborgi, Nephasoma 21, 22, 24, 50, 52, 53, 96

Iongirhynchus, Aspidosiphon 84

lytkenii, Tylosoma 62

margaritacea, Golfingia 15, 21, 24, 34, 35, 96

margaritaceum, Phascolosoma 34

margaritaceus, Sipunculus 34

mediterraneum, Nephasoma abyssorum 38

mediterraneum, Phascolion 60

mexicana, Aspidosiphon 84

mexicana, Golfingia (Siphonoides) 84

mexicanus, Aspidosiphon (Akrikos) 21, 25, 84, 85, 96, 97

minuta, Golfingia 50

minutum, Nephasoma 22, 32, 34, 50, 54, 97

minutum, Phascolosoma 50

misakiensis, Aspidosiphon (Aspidosiphon) 21, 25, 88, 89, 95, 96

Mitosiphon 80

muelleri, Aspidosiphon 12, 20, 22, 92

muelleri kovalevskii, Aspidosiphon (Aspidosiphon) 21, 25, 90, 91, 92, 96, 97

muelleri muelleri, Aspidosiphon (Aspidosiphon) 21, 25, 90, 92, 93, 96

murina, Golfingia (Apionsoma) murinae 80

murinae, Apionsoma 22

murinae bilobatae, Apionsoma 21, 22, 25, 80, 81, 96

murinae bilobatae, Golfingia (Mitosiphon) 80

murinae murina, Golfingia (Apionsoma) 80

murinae murinae, Apionsoma 22, 80

Nephasoma 12, 18, 20, 21, 24, 27, 38, 44

nigra, Thysanocardia 22, 58

nigrescens, Phascolosoma 76

nordenskjoldi, Golfingia 34

norvegicus, Sipunculus 21,23, 28, 29, 96

nudus, Sipunculus 11, 13, 15, 20, 21, 23, 30, 31, 96, 97

Onchnesoma 15, 18, 19, 20, 21, 23, 27, 66

pallidum, Phascolion 62

perlucens, Phascolosoma 21, 25, 74, 75, 95, 96

Phascolion 15, 17, 18, 19, 20, 21, 23, 27, 46, 60

Phascolionidae 21, 23, 27, 60, 95

Phascoloides 38

Phascolosoma 7, 21, 25, 27, 70

Phascolosomatidae 21, 23, 27, 70, 95

Phascolosomatidea 21, 23, 70

Phascolosomatiformes 21, 70

Phascolosomum 74

Phymosoma 76

Phymosomum 78

Physcosoma 72, 76, 78

priapuloides, Sipunculus 28

procera, Golfingia 58

procera, Thysanocardia 21, 22, 24, 56, 58, 59, 96

procerum. Phascolosoma 58

pusilla, Golfingia (Golfingiella) 82

pusillum, Phascolosoma 82

rimicola, Golfingia 54

rimicola, Nephasoma 21, 24, 32, 34, 54, 55, 95, 96

riukiuensis, Phascolosoma 76

Rueppellisoma 70

saccatus, Sipunculus 11

schuettei, Golfingia 48

schuttei, Phascolosoma 48

scolops, Phascolosoma 21, 25, 76, 77, 96, 97

scolops, Phymosoma 76

scolops, Physcosoma 76

scutatus, Sipunculus 92

Siphonoides 84

Siphonosoma 7

Sipunculidae 21, 23, 27, 28, 95

Sipunculidea 21, 23, 28

Sipunculiformes 21, 28

Sipunculus 7, 11, 15, 18, 21, 27, 28

solitaria, Golfingia 36

speculator, Aspidosiphon 86

spinicauda, Phascolosoma 78

spinicauda, Sipunculus (Phymosomum) 78

squamatum squamatum, Onchnesoma 21, 24, 66, 67, 96

squamatum, Phascolosoma 66

steenstrupii steenstrupii, Onchnesoma 15, 21, 24, 66, 68, 69, 96

stephensoni, Phascolosoma 21, 25, 72, 78, 79, 95, 96, 97

stephensoni, Physcosoma 78

strombi, Phascolion 64

strombus, Phascolion (Phascolion) 13, 20, 21, 24, **64**, **65**, 96, 97

strombus, Sipunculus 64

temporariae, Phascolion 62

Themiste pyroides 70

thomense, Phascolosoma 74

Thysanocardia 20, 21, 22, 24, 27, 56

trichocephala, Apionsoma 82

trichocephala, Golfingia (Apionsoma) 82

trichocephala, Golfingia (Golfingia) 82

trichocephala, Golfingia (Mitosiphon) 82

trichocephalus, Apionsoma 21, 25, 82, 83, 95, 96

tuberculosum, Phascolion 62

tuberculosum, Phascolion (Isomya) 21, 24, 60, 62, 63, 96

vermiculus, Phascolosoma (Phascolosoma) 74

vermiculus, Sipunculus (Phascolosomum) 74

vulgare, Phascolosoma 36

vulgaris, Golfingia (Golfingia) 21, 24, 36, 37, 96

vulgaris, Sipunculus 36

zarenkovi, Golfingia confusa 42

ΜΟΝΟΓΡΑΦΙΕΣ ΘΑΛΑΣΣΙΩΝ ΕΠΙΣΤΗΜΩΝ ΟΔΗΓΙΕΣ ΠΡΟΣ ΤΟΥΣ ΣΥΓΓΡΑΦΕΙΣ

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Τα κείμενα των Μονογραφιών, με έκταση άνω των δύο 16σελιδων, πρέπει να παραδίδονται σε ηλεκτρονική μορφή (δισκέτα Η/Υ) επεξεργασμένα σε πρόγραμμα Word, σε σελίδα Α4. Οι σελίδες θα πρέπει να αριθμούνται.

Η δομή της Μονογραφίας πρέπει να περιλαμβάνει εισαγωγή, κεφάλαια (κυρίως μελέτη), αποτελέσματα, συμπεράσματα, ευχαριστίες, βιβλιογραφία.

Ο τίτλος της Μονογραφίας, το όνομα του συγγραφέα και η διεύθυνση γράφονται σε ανεξάρτητη σελίδα. Μαζί με το πρωτότυπο υποβάλλονται δύο αντίνοσφα

Το κείμενο αρχίζει με εκτεταμένη περίληψη (abstract) που θα αντιστοιχεί περίπου στο 3% της συνολικής μελέτης. Στη συνέχεια δίνονται λέξεις - κλειδιά (το ανώτερο 6).

Οι πίνακες, οι εικόνες και τα σχήματα στην πρωτότυπη μορφή τους παραδίδονται σε ξεχωριστό φάκελο (αριθμημένα κατά κεφάλαια) και υπάρχει σαφής αναφορά για την τοποθέτησή τους στο κείμενο. Οι μεν πίνακες είναι αριθμημένοι με λατινικούς αριθμούς, οι δε εικόνες ή σχήματα με αραβικούς και σε μέγεθος κατάλληλο για να υποστούν σμίκρυνση (κατά προτίμηση όχι μεγαλύτερη από 50%). Οι φωτογραφίες πρέπει να είναι καλής ποιότητας, σε γυαλιστερό χαρτί.

Η βιβλιογραφία θα γράφεται με αλφαβητική σειρά κατά το ακόλουθο παράδειγμα:

Για περιοδικό:

GIRARD, J. P., DEYNOUX, M. & NAHON, D. 1989.- Diagenesis of the upper proterozoic siliclastic sediment of the Taoudeni basin. *J. Sedim. Petrol.*, 59, 2, 233-284

Για βιβλίο:

SKAAR, K. E. 1992.- Tectonomagmatic evolution. Monograph, 3, Kluwer Acad.

Public., Dordrecht, 102 pp.

Τα ονόματα των περιοδικών γράφονται σύμφωνα με το Word List of Scientific Periodicals.

Διευκρινίζεται ότι το πλήρες όνομα των Μονογραφιών είναι:

ΜΟΝΟΓΡΑΦΙΕΣ ΘΑΛΑΣΣΙΩΝ ΕΠΙΣΤΗΜΩΝ

MONOGRAPHS ON MARINE SCIENCES

Με σύντμηση:

ΜΟΝΟΓΡ. ΘΑΛΑΣ. ΕΠΙΣΤ.

MONOGR. MAR. SCI.

Οι προς δημοσίευση εργασίες αποστέλλονται στο Γραφείο Εκδόσεων του Ε.Κ.Θ.Ε., το οποίο τις προωθεί στην εκδοτική επιτροπή και τους κριτές. Μετά την αποδοχή τους για δημοσίευση με ενδεχόμενες διορθώσεις, συμπληρώσεις κ.λ.π. δίδονται για εκτύπωση. Ο συγγραφέας παραλαμβάνει ένα πλήρες δοκίμιο για έλεγχο, πριν από την τελική εκτύπωση. Σε περίπτωση περισσοτέρων συγγραφέων, θα στέλνεται στον πρώτο, εκτός αν οριστεί κάποιος άλλος.

Είκοσι (20) ανάτυπα δίδονται δωρεάν στον συγγραφέα (-φείς).

Οι Μονογραφίες ανταλλάσσονται με άλλα περιοδικά -μέσω της Βιβλιοθήκης του ΕΚΘΕ - και διατίθενται σε τιμή που ορίζεται ξεχωριστά για κάθε τόμο.

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Dr. Maria-Antonietta PANCUCCI-PAPADOPOULOU is a senior scientist of the Institute of Oceanography of the National Centre for Marine Research. Born in Agrigento (Italy) in 1953, she acquired her degree of Biological Sciences from the Palermo University, Italy (1975), her MSc. in Biological Oceanography from the University of Athens (1984) and her Ph.D. (1996) on the life history of *Paracentrotus lividus* (Echinoid) from the Athens University.

Since 1985 she has a permanent post in NCMR after a 4 years participation in a joint research program of NCMR and the Zoology Department of the Athens University.

Her main research interests focus on marine benthic ecology, especially on echinoderms and sipunculids (systematics, ecology, zoogeography), as well as on the biology and

genetics of *Paracentrotus lividus* (mainly based on genomic DNA with the use of PCR-RAPD fingerprinting). The molecular approach to ecological studies, or Molecular Ecology, outlines her present research field, as an attempt to link "classical" ecology and biotechnology and at the same time she is promoting the collaboration between Italian and Greek laboratories. Environmental Education is also one of her fields of interest.

She has offered her taxonomy expertise, participating in about 40 national and international projects, in some of which as principal investigator or task responsible. She has presented her research work in national and international congresses and has published more than 23 papers in international journals and a Monograph on the Echinoderms living in Greek waters.



Dr. Galena-Vantsetti Murina is a leading scientist of the Mariculture Department of the Institute of Biology of the Southern Seas (National Academy of Science) in Sevastopol (Ukraine). Born in Moscow in 1927, she graduated in Invertebrate Zoology at the Biological faculty of Moscow State University (MSU), received her MSc. in Biological Science at the MSU and her Doctor's degree on Biological Science at the Zoological Institute of the USSR Academy of Science in Leningrad. In 1999 she acquired the title of Professor of Hydrobiology.

Zoologist and marine hydrobiologist of the Russian scientific community, she contributed to Invertebrate Zoology for more than 40 years, travelling all around the world exchanging knowledge and experience. Her main research fields include taxonomy, zoogeography and ecology of Sipuncula and Echiura of the World Sea. Distribution, ecology and biology of

Decapoda and Turbellaria of the Black Sea represent another significant part of her scientific work.

Her current research interest includes mariculture (dynamic of mussels pelagic larvae) as well as of the meroplankton living in the Black and Mediterranean Seas and the relationships between these two neighbouring basins. Her rich scientific production has been presented in congresses and workshops and has been published in numerous papers, mostly in Russian. She is author of a Monograph on the USSR Sipuncula.

Dr. Argyro Zenetos is currently a Senior Research Scientist at NCMR.

Born in Athens in 1953, she received her BSc in Natural Sciences from Athens University in 1975, her M.Sc. on Computational Paleoecology from St. Andrews, Scotland in 1980 and her Ph.D. on Marine Biology from Athens University in 1986. She was a research assistant at the Biology Dept., University of Athens between 1980-1984 and has been employed at the NCMR since 1984, serving as head of the benthos group since 1989.

Dr Zenetos has collaborated in many national and international projects, the results of which have been presented in major symposia. She is the author of a monograph for the "Fauna Graeciae" series on "The Marine Bivalvia Mollusca of Greek Waters" and numerous



papers published in international journals. Her current research activities are in: a) mollusca, as co-ordinator of an atlas on exotic molluscs in the Mediterranean to be published by CIESM; b) marine benthic ecology of coastal ecosystems (Environmental Impact Assessments); c) biodiversity: responsible for the biodiversity issue in the Mediterranean and Black Sea (under contract to European Environmental Agency); d) benthos databases. She is married with two children.