The distinctive $^3He/^4He$ characteristics of LPS ($\sim 18.1 R_A$) and BBS ($\sim 8.4 R_A$) lavas have a clear bearing on the nature of magma sources supplying Heard Island. First, the high $^3He/^4He$ ratios of the LPS lavas provide unambiguous evidence for involvement of a mantle-plume component in their genesis. This is somewhat surprising given the postulated location of the Kerguelen plume beneath prominent seamounts on the northwest margin of the Kerguelen Plateau ~550 km from Heard[24]. Either the LPS lavas represent a fossil remnant of the plume embedded in the thickened lithosphere of the Kerguelen Plateau and reactivated by the voluminous activity of Big Ben volcano[17], or (more speculatively) there are two plumes in this part of the Indian Ocean. Second, there is no helium isotope evidence that the LPS lavas are related to the BBS volcanics by a binary mixing relationship[16,17]. Indeed, the constancy of the BBS $^3He/^4He$ ratios even at relatively radiogenic Sr (or unradiogenic Nd) isotopic compositions (Fig. 1) does not support the suggestion of an ancient 'recycled' crustal component in their genesis, as such a component would be expected to be characterized by radiogenic helium as well as radiogenic strontium. If the source of radiogenic helium in some samples is the Kerguelen lithosphere, as argued above, then a greater role for magma contamination may be necessary to account for various geochemical features of Heard Island lavas.

The realization that shallow-level radiogenic helium can contaminate mantle-derived phenocrysts at Heard Island raises the possibility that other ocean-island $^3He/^4He$ ratios (<MORB value) have been similarly affected. In Fig. 2 we plot all low-^3He hotspots defined by ol and cpx phenocryst $^3He/^4He$ ratios. Note that: (1) there are relatively few analyses available from each island; (2) three of the eight islands have been classified by cpx analyses alone; and (3) most phenocrysts have low [He]. We argue that without extensive sampling of different lavas flows to check for constancy of $^3He/^4He$ over a range of [He] (as is the present study), then the assumption that the $^3He/^4He$ ratios of these samples have not been affected by shallow-level interaction is clearly questionable. For example, if the arbitrary value of $\sim 40 \times 10^{-9}$ cm^3 STP ^4He g^{-1} for BBS phenocrysts (Fig. 1*a*) is generally applicable, then most samples in Fig. 2 are immediately suspect—particularly the cpxs which seem more susceptible to record the influence of shallow-level crustal helium. Without further sampling, the above points cast considerable doubt on the assumed integrity of the low-^3He phenocrysts, and we suggest that their $^3He/^4He$ ratios represent minimum values. We suspect that the source $^3He/^4He$ ratio of all these islands is higher and probably close to the MORB value (Fig. 2). In this case, the consequences for the use of helium with other petrogenetic isotopes is profound. The Sr–Nd–Pb isotope systematics of ocean islands lie within a tetrahedron delineated by four mantle endmembers (a depleted MORB mantle component, DMM; and three enriched components—HIMU (high U/Pb) and 'enriched mantle' components EM1 and EM2)[25,26]. MORB-like $^3He/^4He$ ratios at Heard Island (EM1–EM2 characteristics) and possibly at other low-^3He hotspots (such as St Helena, HIMU) at the opposite apices to the DMM apex of the tetrahedron show that helium can be completely decoupled from Sr–Nd–Pb isotopes. Therefore, helium cannot be used to infer the provenance of 'enriched materials' in mantle plumes. Alternatively, as the (upper) lithosphere can be the source of the radiogenic helium in mantle-derived materials, $^3He/^4He$ ratios <MORB may instead identify those samples whose 'enriched' character arises, in part, from lithosphere or crustal interactions. □

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Carnivorous sponges

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EXTREMELY food-poor environments, such as the deep sea, place extraordinary demands on organisms with respect to feeding, resulting in modifications of the feeding strategies found in shallow waters. A general rule is that macrophagy becomes a better strategy than microphagous suspension-feeding[1–3]. The characteristics by which phyla are defined, nonetheless, remain unchanged in these adaptations. We present here an apparently unique example of a fundamentally different body plan, derived from a pre-existing phylum, occurring in deep-sea sponges. We demonstrate that the Cladorhizidae have evolved carnivory and capture small crustaceans by means of filaments provided with raised hook-shaped spicules. This adaptation to a food-poor deep-sea environment has resulted in the loss of the diagnostic characteristics of the phylum Porifera: an aquiferous system and choanocytes.

Sponges are considered to represent one of the first steps in multicellular organization during early metazoan evolution because of their organizational simplicity and the resemblance of their diagnostic pumping cells, the choanocytes, to protozoan choanoflagellates[4–6]. Sponges are filter-feeders *par excellence*. Their entire body is organized for filtering water, which is moved inside an aquiferous system by choanocytes. It has long been suspected that the simple filtering system, highly efficient in the retention of particles and colloids in shallow-water environments[7,8], becomes modified in deep-sea conditions. Little is known about possible adaptations to low particle concentrations and still-water conditions because it is so difficult to access these remote environments. The discovery of deep-sea sponges in a shallow Mediterranean marine cave, in which conditions closely resemble those of the deep sea[9,10], has made it possible to observe for the first time how sponges feed in such extreme environments. We found a new cladorhizid sponge in the cave at a depth of between 17 and 23 m. This species belongs to the

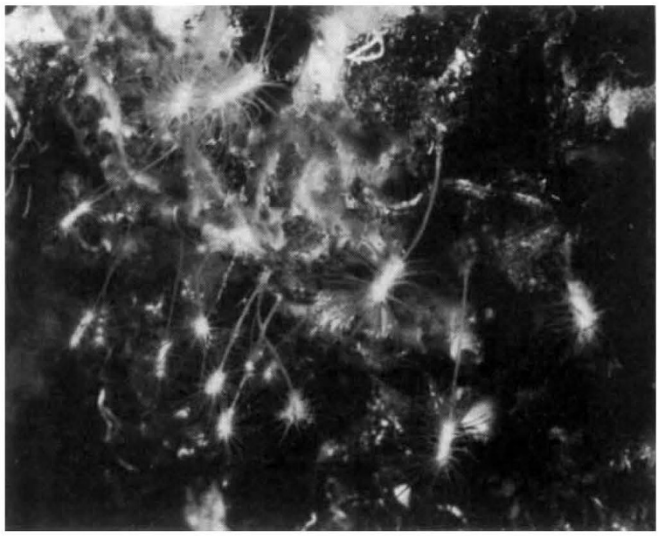

FIG. 1 Clustered specimens, no more than 15 mm high, of an undescribed species of *Asbestopluma*, the otherwise deepest known genus of Porifera, in a Mediterranean cave at a depth of 18 m. The sponge body is anchored by a spicule peduncle and bears long, thin filaments. Unlike other poriferans, this sponge has neither aperture nor canal system, but feeds mainly on swimming prey captured passively by the filaments.

genus *Asbestopluma*, which holds the depth record for all sponge genera (down to 8,840 m[11]). The Cladorhizidae are an exclusively deep-sea family of demosponges, most of whose species are localized in the abyssal zone. Some even live in the hadal trenches. Although these sponges are easily classifiable in the order Poecilosclerida on the basis of spicule features, their hydroid-like shape is unusual for sponges.

The anatomy and biology of the new species could be observed both on living and well preserved specimens. It is devoid both of choanocytes and an aquiferous system. Specimens observed *in situ* (Fig. 1) have long, thin filaments. After *in situ* fixation, which induces only slight contraction, no oscula or inhalant ostia are visible (Fig. 2*a*). The stalked body and the filaments, displaying no canal system or choanocyte chambers, are composed of a loose tissue containing highly ramified stellate cells. Intercellular thread-like bacteria are dispersed in the tissue, and ovoid bacteria are abundant within bacteriocytes. The surface of the filaments is thickly covered by minute spicules (anisochelae) disposed at right angles to the axis and embedded by the small end in collagen fibrils (Fig. 2*b*, *c*). Each anisochela is enclosed in its secreting cell. The spicule cover, absent both from stalk and body surface, gives the filaments a 'Velcro'-like adhesiveness.

How can such a sponge feed in the absence of a filtering system? The dramatic increase in external exchange surface due to the filaments and their dense cover of raised cells supported by the spicules suggests that the animal feeds by surface phagocytosis or osmotrophy. Uptake of dissolved organic matter at least partially fulfils the energy requirements of numerous deep-sea animals, including the gutless Pogonophora[1], and would be possible for the sponge because of its small size, low-density tissue and the increase in surface exchange. The abundance and diversity of symbiotic bacteria might also be an adaptation to an osmotrophic mode of life[12]. Another more bizarre hypothesis, first proposed in ref. 13 but later discounted[14,15], is that the spicules on the surface of the appendages function as 'claws' to capture minute animals and particles.

In situ tests for the more conventional alternatives, phagotrophy and osmotrophy, were negative. The sponge absorbed neither particles nor large molecules, contrary to the heavy uptake of particles by other sponges, including another deep-sea species living in the same cave, the hexactinellid *Oopsacas minuta*. By contrast, small crustaceans were caught on the non-motile filaments (Fig. 2*a*, *b*), which proved to be very efficient in the passive capture of swimming crustaceans, trapping their

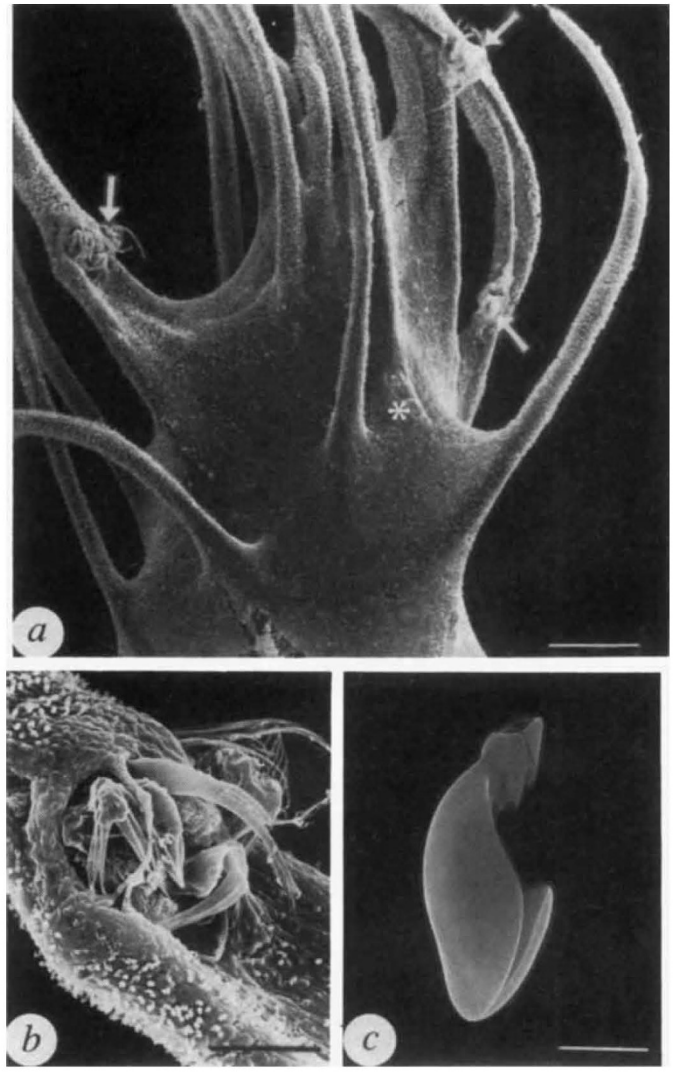

FIG. 2 *a*, Scanning electron microscope (SEM) view of a specimen of *Asbestopluma* sp. fed with live nauplii of brine shrimp (arrows) 40 h earlier. The body, devoid of aperture, displays a smooth surface, whereas the filaments are covered by raised, hooked spicules (anisochelae). A nauplius is almost completely engulfed within the body (*). Scale bar, 285 μm. *b*, Enlarged view of a nauplius trapped by a filament, which sends extensions over the prey (arrow head). Scale bar, 100 μm. *c*, SEM view of a microsclere spicule (palmate anisochelae). Scale bar, 3.8 μm.

METHODS. Most feeding experiments were *in situ* because of the extreme fragility of filaments, which entangled when they were exposed to turbulence. About 50 specimens were detached with their rocky support and placed on plastic (PVC) dishes, 10 cm in diameter, wired to grids near the natural population. The sponges were allowed to recover for 3 days. Polyethylene bottles (250 ml) were fitted tightly over the dishes and 25 ml of nutrients or particles were added with a syringe through rubber plugs. For 1 h, sponges were given: fluorescent latex microspheres (Polysciences, 0.1 and 1.1 μm diameter, 10^6 and 10^7 particles per ml); FITC-labelled dextrans (Sigma, 1×10^3 and 2×10^6 daltons at a concentration of 2 mg l^{-1}); cultures of unicellular algae (*Tetraselmis striata*, 15 μm; *Agmenellum* sp., 1–2 μm); and 24-h-old nauplii of the brine shrimp *Artemia salina*. Specimens were also laboratory-raised in a dark room at 13 °C and fed with a cavernicolous mysid crustacean (*Hemimysis speluncola*, 2–6 mm long). Sponges were fixed *in situ* in OsO_4, mercury chloride 6:1 for 90 min.

thin appendages in the anisochelae. Once captive, the crustaceans were unable to free themselves. They remained struggling for several hours, which indicates that there was no paralysing or toxic secretion. The filament epithelial cells, however, established close contact with the surface of the live prey as early as 1 h after capture. Intense morphogenetic activity involving extensive cell migration occurred after capture. The implicated filaments became shorter and thicker, frequently becoming entangled. New, thin filaments grew over the prey, which was completely enveloped after one day and digested within a few days. After overfeeding in experimental conditions, a complete reorganization occurred, with a normal appearance being resumed only after several days.

Thus all available evidence shows that the sponge is an effective carnivore. The high frequency of crustaceans found still alive or in various stages of decay, both on the surface and within the bodies of specimens collected in natural conditions, suggests that crustaceans smaller than 1 mm are the animal's main source of food in the cave.

Are the adaptations and unusual mode of life observed in this sponge living in a specific sublittoral environment shared by other Cladorhizidae in their deep-sea habitats? Their anatomy and histology are poorly known because of the difficulties in collecting and adequately preserving deep-sea animals. Our unpublished observations of several correctly preserved deep-water cladorhizids did confirm the general absence of canals, apertures and choanocyte chambers that intrigued early observers[13–15]. Moreover, lateral expansions provided with hook-shaped spicules are common specialized structures in Cladorhizidae. Small animals are frequently found trapped in specimens collected by trawls. It seems likely, therefore, that the entire family Cladorhizidae has developed non-filter-feeding adaptations. Morphological features indicate that the genera *Asbestopluma* and *Cladorhiza* share the same adaptations for the capture of swimming animals with thin appendages; other adaptations may occur in a third genus, *Chondrocladia*[16].

These sponges may have other nutrient sources as well. As yet unpublished observations on a *Cladorhiza* from a cold seep with methane venting, located 4,900 m deep near Barbados, have shown that it is associated with bacteria displaying the morphological characteristics of methanotrophs. Such an association has so far not been described in Porifera, although it has been shown to sustain some deep-sea molluscs and pogonophorans[17–19].

Our results raise fundamental questions about the validity of characteristics used to distinguish the phyla of lower invertebrates. A sponge is defined as "a sedentary, filter-feeding metazoan which utilizes a single layer of flagellated cells (choanocytes) to pump a unidirectional water current through its body"[20]. Except for being sedentary, the cave *Asbestopluma* and presumably all Cladorhizidae lack these basic sponge attributes. In an extreme environment where active filter-feeding has a low yield, cladorhizids have developed a mode of life roughly similar to that of foraminiferans or cnidarians. Their feeding mechanism relies on passive capture of living prey and on transfer of nutrients into the body through intense cell migrations, the analogue of cytoplasmic streaming in foraminiferan pseudopodia. This may be compared to the emergence of macrophagy in abyssal tunicates, also accompanied by a reduction of the filtering system[2,3] although in Cladorhizidae the result is more extreme, with a main body plan different from Porifera and resembling no other modern anatomical design.

Such a unique body plan would deserve recognition as a distinct phylum, if these animals were not so evidently close relatives of Porifera. Their siliceous spicules show clear similarities to several families of poecilosclerid Demospongiae. The importance of cell mobility and cytological features such as the structure of the external epithelium and the absence of specialized intercellular junctions are also characteristics of Porifera. Given the evidence thus far, we interpret these organisms to be sponges that have deviated from the filtering organization typical of Porifera and developed adaptations that accommodate totally different feeding habits in the still, nutrient-poor deep-sea environments. □

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Protection and repair of the nigrostriatal dopaminergic system by GDNF *in vivo*

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GLIAL-CELL-LINE-DERIVED neurotrophic factor (GDNF), a recently cloned new member of the transforming growth factor-β superfamily, promotes survival of cultured fetal mesencephalic dopamine neurons[1] and is expressed in the developing striatum[2,3]. There have, however, been no reports about effects of GDNF *in situ*. We have used the dopaminergic neurotoxin 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP), which produces parkinsonian symptoms in man, to determine whether GDNF might exert protective or regenerative effects *in vivo* in the adult nigrostriatal dopamine system in C57/Bl mice. GDNF injected over the substantia nigra or in striatum before MPTP potently protects the dopamine system, as shown by numbers of mesencephalic dopamine nerve cell bodies, dopamine nerve terminal densities and dopamine levels. When GDNF is given after MPTP, dopamine levels and fibre densities are significantly restored. In both cases, motor behaviour is increased above normal levels. We conclude that intracerebral GDNF administration exerts both protective and reparative effects on the nigrostriatal dopamine system, which may have implications for the development of new treatment strategies for Parkinson's disease.

The possibility that Parkinson's disease is caused by lack of sufficient 'dopaminotrophic' support and/or the prospect of treating the disease with a neurotrophic factor has led to searches for 'dopaminotrophic' factors. Tissue extracts as well as several known growth factors[4–10], including brain-derived neurotrophic