Discussion

Reports of microsporidian infections of nematodes are rare but their occurrence in nature is undoubtedly more widespread than realized. Previous natural occurrences include *Thelohania reniformis* in the gut epithelial cells of the house mouse parasite, *Protospirura muhis* (Kudo & Hetherington, 1922) and *Microsporidium rhabdophilium* from the microtrophic nematode, *Rhabditis myriophila* (Poinar & Hess, 1986). Other possible natural infections are cited by Poinar & Hess (1988). Veremtchuk & Issi (1970) were able to experimentally infect *Neoaplectana carpocapsae* with the microsporidians *Nosema mesnili* and *Plistophora schubergi* respectively after passing the nematodes through insects which contained these infections. The authors did not mention whether the infection could be continued indefinitely in the nematodes when the latter were transferred to healthy hosts. This raises the question of whether in the present case with *N. glaseri*, the infection was initially obtained from an infected insect. Since microsporidian infections are normally obtained *per os* and the feeding stages of neoaplectanids occur in the hemocoel of dying and dead insects, it is highly probable that the infection was originally obtained from an infected insect. However it is clear that the parasite was highly virulent for the nematode and that it is now being carried within the nematode population. It is unlikely that the microsporidian could complete its development in the insect host since with the relatively short period between being released in the host and death of the insect, its development could not be completed.

Aside from seriously reducing a particular nematode population in nature, the microsporidian could have serious consequences if it was inadvertently introduced into a mass culture facility. Thus, care should be excercised before introducing nematodes from nature into an *in vitro* development system.

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A NEW RECORD OF A NEMATODE PARASITE (MERMITHIDAE) OF A SCORPION

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Scorpions represent one of the oldest groups of extant terrestrial arthropods and are among the most primitive of all land arachnids. The now extinct Paleozoic scorpions (suborder Branchioscorpionina K.-W., 1985) lived in water together with representatives of their supposed ancestors, the eurypterids. The oldest known Neoscorpionina Thorell and Lindstrom, 1885 (pulmonate scorpions) are *Paleopisthacanthus* and *Compsoscorpus* from the Carboniferous (Kjellesvig-Waering, 1986).

In contrast to relatively numerous reports of mermithid nematodes from spiders (Poinar, 1985) few nematode parasites have ever been reported from representatives of the order Scorpionida. Millot and Vachon (1949) reported finding two juvenile nematodes in the body cavity and alimentary tract of a male *Parabuthus granimanus* from East Africa. Vachon (1952) also observed juvenile nematodes inside East African scorpions but further details on the above associations are lacking and neither of the reports provides any taxonomic information on the supposed parasites. Thus it was of great interest when a specimen of *Paruroctonus utahensis*

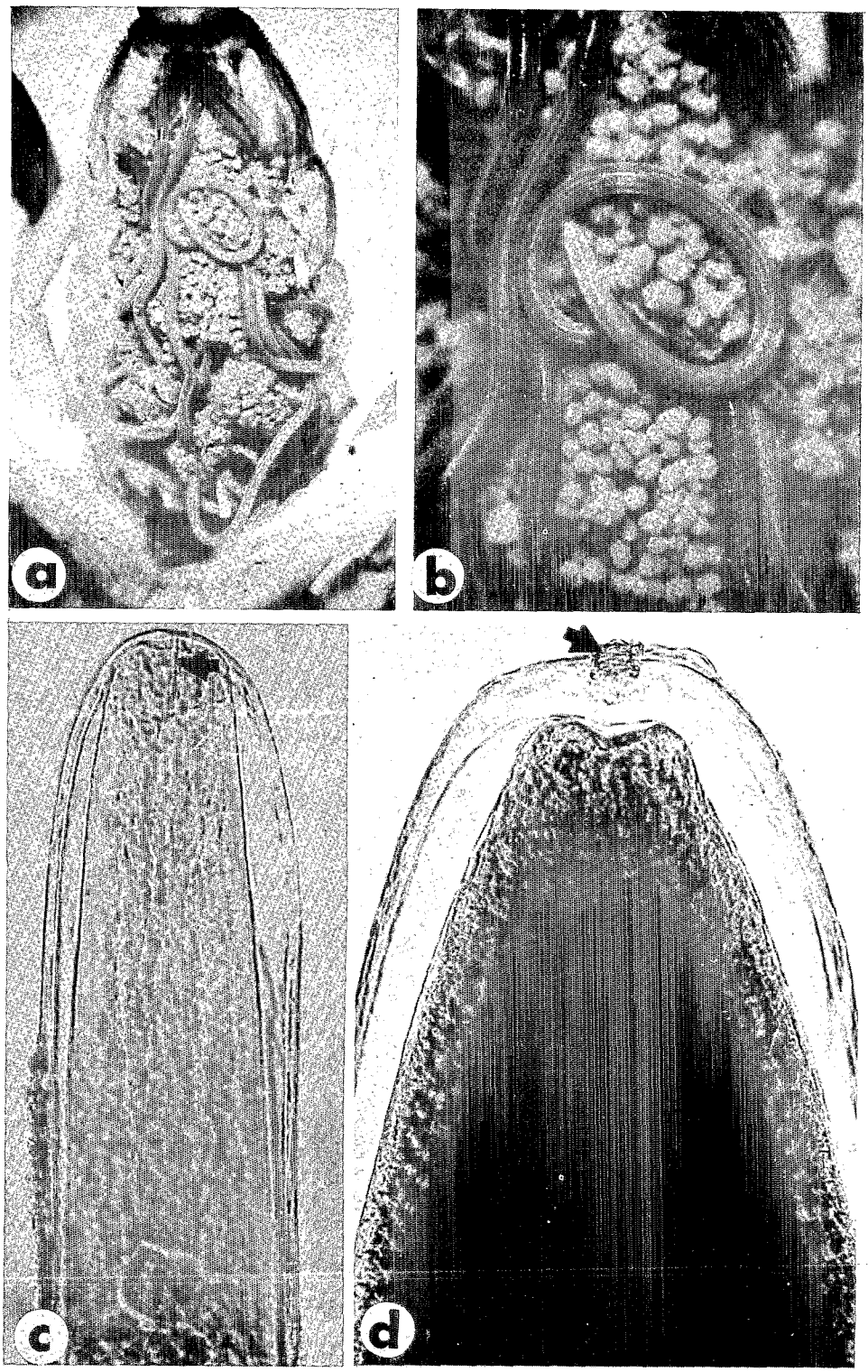

Fig. 1. a : Ventral portion of abdominal cavity of the scorpion, *Paruroctonus utahensis*, opened to expose the nematode; b : Detail showing head of nematode emerging from the digestive gland of the scorpion; c : Anterior portion of nematode showing mouth tube (arrow) and nerve ring (N); d : Posterior end showing bifurcated hypodermal tissue and plug in the tail cuticle (arrow).

(Williams, 1968) was discovered with a fully developed parasitic juvenile mermithid in its body cavity. An account of this event and tentative description of the parasite is presented here.

Materials and methods

A parasitized male of *Paruroctonus utahensis* was collected from Monahan's Sans Hills State Park in Ward County, Texas on June 15, 1984 (S.A. Stockwell). It was preserved in 70 % alcohol and subsequently opened for investigation of the development of the reproductive organs. At that time, a long, brownish worm was seen coiled up in the body cavity (Fig. 1 a). It was intimately associated with the digestive glands (Fig. 1 b). The worm was subsequently removed, processed to glycerin and examined microscopically.

Results

The parasitic worm was identified as a fully developed parasitic juvenile mermithid (Mermithidae) which was just at the point of emergence. This could be surmised from the relative thickness of the tail cuticle which is generally much thinner on developing parasitic juveniles. Unfortunately the reproductive structures and the head papillae had not yet fully formed so it was not possible to assign the species to an existing genus or determine if it represented a new genus, although the structure of the tail appeared unique for mermithid nematodes.

The mermithid was an immature female that possessed six faint head papillae and a pair of small projections on either side of the mouth tube which could be interpreted as lip papillae. The total length was 13.2 cm, the body width at the head was 63 µm and at midbody, 238 µm. The distance from the head to nerve ring was 231 µm, from the head to anterior tip of the trophosome, 349 µm and from the tail to the posterior tip of trophosome, 95 µm. The body cavity of the nematode was filled with spherical lipid droplets ranging from 2-18 µm in diameter.

At the head end could be seen a mouth opening with a cuticularized mouth tube extending back 35 µm and then changing into a non-cuticularized canal that could not be followed to its terminus (Fig. 1 c). The body cuticle ranged from 3-5 µm in thickness and the cuticle surrounding the tail ranged from 19-25 µm in thickness. The tail tip was unique. The hypodermal mass presented a bifurcate aspect which is unusual in mermithids. The tip of the cuticle surrounding the tail contained a plug or scar roughly 16 µm long by 16 µm wide which was composed of modified fibrous material (Fig. 1 d). Such a scar type of terminus as found here is unique for mermithids although similar structures occur on the mermithid grasshopper parasite, *Agamermis decaudata* Cobb, Steiner & Christie (Christie, 1936).

There were patches of roughened cuticle along the body of the parasite. These could be areas of cuticular infection by some microorganism, evidence of a host reaction or indication of a gradual decline in vitality (Fig. 1 c).

Discussion

With this report representing the first documented case of a mermithid parasite of scorpions, it is obvious that this phenomenon is of rare occurrence. It is not known whether the mermithid is an opportunistic parasite that chanced to come into contact with the host or a specific scorpion parasite. Dissections of additional specimens of *P. utahensis* revealed no further incidence of parasitism and tend to support the former conclusion. Given the rather unique morphological characters of the nematode, however, it is also possible to consider the parasite as a highly specialized form that has become adapted to scorpions but occurs very infrequently. It could have a very long developmental period inside the scorpion, only emerging during brief periods of rain. Contact with new hosts might occur when the scorpions burrow into loose sand to escape the heat. It is even more likely, however, that the infection was acquired when the scorpion ingested prey that already contained infective stages of the parasite. Such a cycle (indirect) has been shown to occur in mermithid parasites of spiders, however, in such cases the spiders always return to water when the parasite emerges and an aquatic habitat appears to be necessary for further nematode development and the location of paratenic hosts (Poinar & Benton, 1986). In the present case, the infected scorpion was collected in shifting sand dunes and probably never came into contact with permanent or temporary surface water. This might imply that the nematode was adapted to another medium of survival in the free-living stages after leaving the body of the scorpion, or that the nematode chanced to infect a scorpion that never had an opportunity to return to a water source for liberation of the parasite. The roughened areas on the cuticle of the nematode might be signs of a reduction in parasite vitality, which supports the hypothesis that the scorpion was a developmental dead-end for the parasite.

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A TECHNIQUE FOR STAINING THE ENDOSPORES OF *PASTEURIA PENETRANS*

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The following simple staining technique increases the ease of detection and counting of endospores of *Pasteuria penetrans* (Sayre & Starr, 1985) adhering to the second stage larvae (L_2) of species of *Meloidogyne*.

Adhering endospores were stained to varying degrees by a range of histochemical stains. The most satisfactory of these was Brilliant Blue G (BBG), obtained from Sigma (Catalogue No. B-1131). This stain has a molecular weight of 854.04 and should not be confused with the closely related Brilliant Blue R (BBR) (Sigma B-0630)

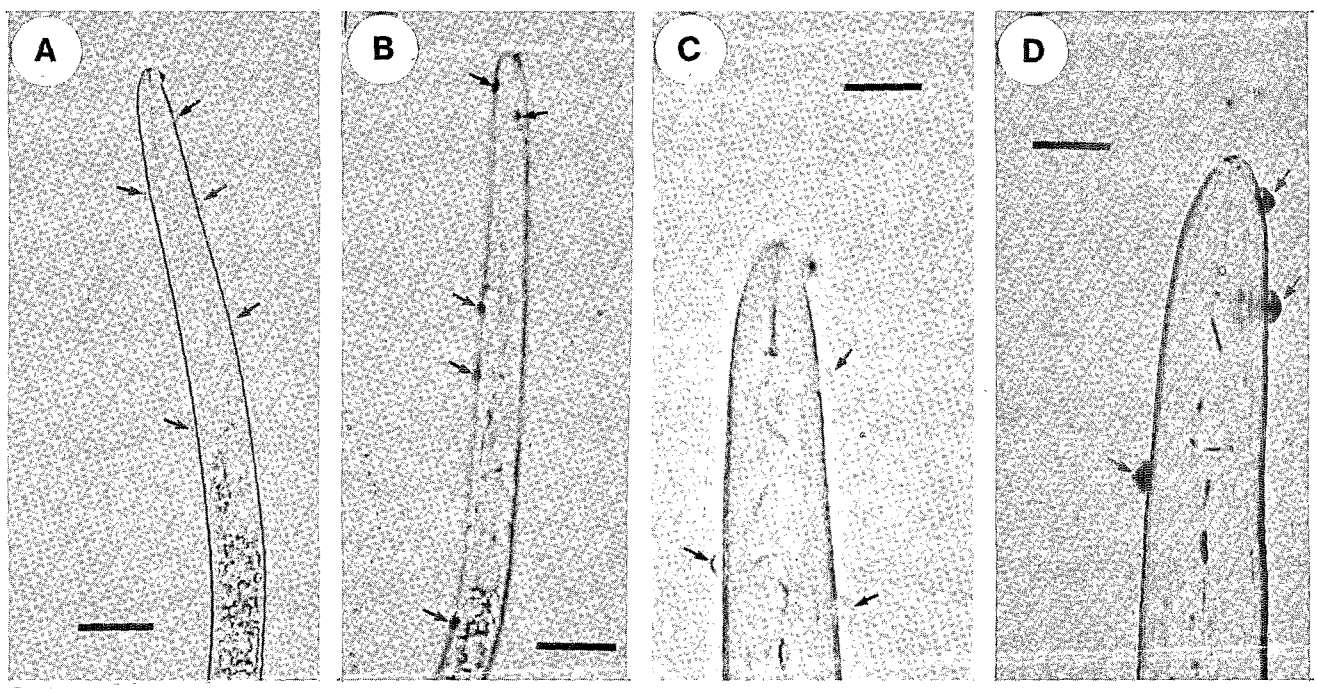

Fig. 1. A : Part of a living unstained infective second stage larva (L_2) of *Meloidogyne hapla* with attached spores of *Pasteuria penetrans* (see arrows) viewed under normal (bright field) illumination; B : Similar to A but the spores on this specimen were stained with Brilliant Blue G (BBG) and show up much more clearly (see arrows) than those in A; C : Anterior part of A at higher magnification under oil immersion showing unstained spores (arrows); D : Anterior part of B at higher magnification under oil immersion showing spores stained with BBG (arrows) (Bars represent, A, B : 25 µm; C, D : 10 µm).