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Coccidian Parasites (Apicomplexa: Eimeriidae) from Insectivores. VIII. Four New Species from the Star-Nosed Mole, *Condylura cristata*

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COCCIDIAN PARASITES (APICOMPLEXA: EIMERIIDAE) FROM INSECTIVORES. VIII. FOUR NEW SPECIES FROM THE STAR-NOSED MOLE, CONDYLURA CRISTATA

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ABSTRACT: Twenty-four star-nosed moles, Condylyra cristata, collected from the northeastern United States (Maine, Massachusetts, Ohio, Vermont) were examined for coccidian oocysts. All of the moles were infected with from 1 to 4 species of coccidia representing 2 eimerian and 3 isosporan spp., but oocysts of only 4 of these species were present in sufficient numbers for detailed study; these are described as new. Sporulated oocysts of Eimeria condylurae n. sp. were subspheroid, 17.7 x 15.7 (17–23 x 14–21) µm, with sporocysts ellipsoid, 11.7 x 5.6 (11–14 x 5–6) µm; E. condylurae was found in 3 of 24 (12.5%) moles. Sporulated oocysts of Isospora condylurae n. sp. were ellipsoid, 19.4 x 9.3 (17–21 x 8–11) µm, with sporocysts ovoid, 11.7 x 5.8 (11–13 x 5–7) µm; I. condylurae was found in 12 of 24 (50%) moles. Sporulated oocysts of Isospora cristatae n. sp. were ellipsoid, 15.7 x 10.1 (13–18 x 9–13) µm, with sporocysts ovoid, 11.0 x 5.7 (10–12 x 5–7) µm; I. cristatae was found in 19 of 24 (79%) moles. Sporulated oocysts of Isospora lamoiillensis n. sp. were ellipsoid, tapering at both ends, 21.6 x 13.0 (19–23 x 11–14) µm, with sporocysts spindle-shaped, 14.9 x 7.7 (14–16 x 7–8) µm; I. lamoiillensis was found in 2 of 24 (8%) moles. Although the second eimerian seen was in 7 of the 24 (29%) moles from Massachusetts, Ohio, and Vermont, there were not enough sporulated oocysts to study in detail to warrant a new species description. Including the 4 new species described here, there are now 48 valid eimerian species and 23 valid isosporan species described from insectivore hosts worldwide.

Of all extant mole species, none is more curious and bizarre than Condylyra cristata (Linnaeus, 1758), the star-nosed mole, that gets its name from a ring of 22 fleshy appendages on the end of its nose (Yates, 1983). This species occurs throughout much of the northeastern United States and eastern Canada, and, unlike all other moles, it is semiaquatic. During our work on the coccidia of other North American moles (Ford and Duszynski, 1988, 1989), I had the opportunity to examine 24 star-nosed moles, all of which were infected with coccidians and were discharging large numbers of oocysts. Study of these oocysts led to the identity of 4 species, an eimerian and 3 isosporans, that are described here as new.

MATERIALS AND METHODS
Moles were live-trapped and fecal samples were collected from them and stored in 2.5% (w/v) aqueous potassium dichromate (K2Cr2O7). All methods for processing and storing fecal samples upon return to the laboratory, and for concentrating, measuring, and photographing oocysts have been described before (Duszynski et al., 1982; Stout and Duszynski, 1983). Measurements are in µm with size ranges in parentheses following the means. All oocysts were measured and photographed when they were between 49 and 68 days old (Isospora spp.) or when they were 627 days old (Eimeria spp.).

RESULTS
All 24 moles were collected from 4 localities: Ashtabula Co., Ohio (6), Franklin Co., Massachusetts (4), Lamoille Co., Vermont (12), and Pendoscoot Co., Maine (2). Each host had numerous oocysts in its feces; 15 of 24 hosts (62.5%) had multiple infections with from 2 to 4 coccidian species. More than 95% of all oocysts seen were isosporans and these represented 3 distinct species described below. Small numbers of eimerian oocysts were also seen; these could be distinguished as 2 species, but sporulated oocysts were present in sufficient numbers to allow careful study and description of only 1 of these.

Eimeria condylurae n. sp.
(Figs. 1–3, 13)

Description
Oocyst subspheroid (Figs. 1–3) with thick wall (~1.5) composed of 2 layers: outer layer smooth, yellow, ~½ of total thickness; inner layer pale yellow, smooth; micropyle and polar body absent; oocyst residuum irregularly shaped, highly refractile (transmitted light) body (Fig. 3), ~2 x 3; sporulated oocysts (n = 33) 17.7 x 15.7 (17–23 x 14–21) with L/W ratio 1.1 (1.05–1.25); sporocysts (n = 20) ellipsoid, pointed at both ends, 11.7 x 5.6 (11–14 x 5–6) with L/W ratio 2.1 (1.9–2.6); Stieda and substieda bodies present (Figs. 1, 2), but parastieda body is absent; sporocyst residuum of

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large granules that may be a compact mass or diffuse and occupies ~1/2 of sporocyst body. Sporozoites with a large posterior refractile body.

Taxonomic summary

**Type host:** *Condylura cristata* (Linnaeus, 1758).

**Type locality:** Lamoille County, Vermont, 10.3 km N of Stowe off Highway 100.

**Prevalence:** Found in 3 of 24 (12.5%) *C. cristata* including 2 of 12 (17%) from Vermont and 1 of 6 (17%) from Ohio.

**Site of infection:** Unknown, oocysts collected from feces.

**Material deposited:** Syntypes (=phototypes, see Bandoni and Duszynski, 1988) of sporulated oocysts in the U.S. National Museum (USNM), Beltsville, Maryland, Parasite Collection No. 80626. Host skin, skull, skeleton, and tissues (heart, kidney, liver) in the Division of Mammals, Museum of Southwestern Biology (MSB), The University of New Mexico (UNM), NM 3024 (male), M. Sullivan #479, 13 June 1980, MSB #43334.

**Etymology:** The nomen triviale is derived from the generic name of the host.

**Remarks**

Sporulated oocysts of this eimerian resemble in size and shape those of *Eimeria madagascariensis* Uilenberg, 1967, from the Madagascar “hedgehog,” *Setifer setosus*. They differ, however, by being slightly larger (18 × 16 vs. 16 × 15) and by having sporocysts that have a substieda body and that are pointed at the end opposite the Stieda body, both features that are absent in *E. madagascariensis*.

**Isospora condylurae** n. sp.  
(Figs. 4-6, 14)

**Description**

Oocyst ellipsoid (Figs. 4–6), sometimes slightly asymmetrical; wall ~1.0, with 2 layers of equal thickness, but difficult to distinguish in intact oocyst: outer layer smooth; micropyle and oocyst residuum absent, but small refractile polar body is present; sporulated oocysts (n = 50) 19.4 × 9.3 (17–21 × 8–11) with L/W ratio 2.1 (1.7–2.3); sporocysts (n = 50) elongate-ovoid, 11.7 × 5.8 (11–13 × 5–7) with L/W ratio 2.0 (1.8–2.4); Stieda and substieda bodies present (Figs. 4, 6), with substieda body 2× wider than Stieda body, but parasitied body is absent; sporocyst residuum of 10–12 homogeneous globules, dispersed (Figs. 4, 6) or in a compact mass (Fig. 5); sporozoites with 1 obvious refractile body in posterior half of body.

**Taxonomic summary**

**Type host:** *Condylura cristata* (Linnaeus, 1758).

**Type locality:** Lamoille County, Vermont, 9.7 km N Stowe, ungrazed pasture by Highway 100.

**Prevalence:** Found in 12 of 24 (50%) *C. cristata* including 7 of 12 (58%) from Vermont, 3 of 6 (50%) from Ohio, and 2 of 4 (50%) from Massachusetts.

**Site of infection:** Unknown, oocysts collected from feces.

**Material deposited:** Syntypes (=phototypes) of sporulated oocysts in the USNM Parasite Collection No. 80626. Host skin, skull, skeleton, chromosomes, tissue culture cells, tissues (heart, kidney, liver), and serum in the MSB, Division of Mammals, NM 3038 (male), K. McBee #96, 14 June 1980, MSB #43346.

**Etymology:** The nomen triviale is derived from the generic name of the host.

**Remarks**

Oocysts and sporocysts of this isosporan have the largest L/W ratios of any isosporans described from insectivores; because of this and the presence of other features (e.g., substieda body) these sporulated oocysts do not resemble those from any species previously described from insectivores.

**Isospora cristatae** n. sp.  
(Figs. 7–9, 15)

**Description**

Oocyst ellipsoid (Figs. 8, 9), sometimes asymmetrical (Fig. 7); oocyst wall ~1.0 composed of 2 layers of equal thickness, outer layer smooth; micropyle and oocyst residuum absent, but small polar body is present; sporulated oocysts (n = 50) 15.7 × 10.1 (13–18 × 9–13) with L/W ratio 1.55 (1.35–1.8); sporocysts (n = 50) ovoid, 11.0 × 5.7 (10–12 × 5–7) with L/W ratio 1.9 (1.6–2.1); Stieda and substieda bodies present (Figs. 7, 8), with substieda body ≥ 2× wider than Stieda body, but parasitied body is absent; sporocyst residuum with 2–8 dispersed globules; sporozoites with 1 refractile body in posterior half of body.
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Taxonomic summary

Type host: Condylura cristata (Linnaeus, 1758).
Type locality: Ashtabula County, Ohio, 2302 Morningside Dr., Ashtabula.

Prevalence: Found in 19 of 24 (79%) C. cristata including 9 of 12 (75%) from Vermont, 5 of 6 (83%) from Ohio, 3 of 4 (75%) from Massachusetts, and 2 of 2 from Maine.

Site of infection: Unknown, oocysts collected from feces.

Material deposited: Sytypes (=phototypes) of sporulated oocysts in the USNM Parasite Collection No. 80627. Host skin, skull, skeleton, and tissue culture cells in the MSB, Division of Mammals, NK 3112 (male), R. M. Sullivan #512, 28 June 1980, MSB #43403.

Etymology: The nomen triviale is derived from the specific part of the scientific name of the host.

Remarks

Sporulated oocysts of this isosporan are similar in size and shape to those of Isospora dymecodi Duszynski and Moore, 1986, from Dymecodon pilostris True, 1886, a Japanese shrew mole and to those of Isospora sporopointaea Duszynski and Wattam, 1988, from Talpa europaea, the European mole. They differ from Isospora dymecodi oocysts by having a larger L/W ratio (1.55 vs. 1.25) and by having sporocysts with both Stieda and substieda bodies that those of I. dymecodi lack. They differ from oocysts of I. sporopointea in many ways. They have a smooth outer oocyst wall (vs. mamillated) and a polar body that is absent in I. sporopointea. In addition, their sporocysts are rounded at end opposite Stieda body (vs. pointed) and have substieda bodies that are 2× wider than the Stieda body (vs. equal in width).

Isospora lamillensis n. sp.
(Figs. 10–12, 16)

Description

Oocyst ellipsoid, tapers slightly toward both ends (Figs. 10, 12), with wall ~1.5 composed of 1 obvious layer; microcyst and oocyst residuum absent, but polar body is present; sporulated oocysts (n = 25) 21.6 × 13.0 (19–23 × 11–14) with L/W ratio 1.7 (1.4–1.8); sporocysts (n = 25) spindle-shaped, tapering toward a point at end opposite Stieda body (Figs. 11, 12), 14.9 × 7.7 (14–16 × 7–8) with L/W ratio 1.95 (1.8 × 2.2); wide Stieda body present (Figs. 10–12), but sub- and parasitieda bodies absent; sporocyst residuum of many dispersed granules of various sizes; sporozoites with 1 obvious refractile body in middle of body (Fig. 10).

Taxonomic summary

Type host: Condylura cristata (Linneaus, 1758).
Type locality: Lamoille County, Vermont, 6.4 km E, 3.2 km S Morrisville.

Prevalence: Found in 2 of 24 (8%) C. cristata including 1 of 6 (17%) from Ohio and 1 of 12 (8%) from Vermont.

Site of infection: Unknown, oocysts collected from feces.

Material deposited: Sytypes (=phototypes) of sporulated oocysts in the USNM Parasite Collection No. 80628. Host skin, skull, skeleton, chromosomes, tissue culture cells, and tissues (heart, kidney, liver) in the MSB, Division of Mammals, NK 3055 (female), R. M. Sullivan #488, 17 June 1980, MSB #43323.

Etymology: The nomen triviale combines the name of the county in Vermont from which the first infected moles were caught and -ensis (L., belonging to).

Remarks

Sporulated oocysts of this isosporan most closely resemble those of Isospora sporopointea and those of Isospora talpae Agostinucci, 1955, both from the European mole, T. europaea. They differ from those of I. sporopointea by not having a mamillated outer wall, by having a polar body, by having larger oocysts with a larger L/W ratio (1.7 vs. 1.5), and by lacking a substieda body that the sporocysts of I. sporopointea possess. They differ from those of I. talpae by lacking a microcyst, by having a polar body, by the shape of the Stieda body (flat vs. nipplelike), and by having sporocysts that are pointed at the end opposite the Stieda body, whereas those of I. talpae are rounded.

DISCUSSION

Condylura cristata is the fourth of the 7 known North American talpids (moles, shrew moles) that my students and I have examined for coccidia (Duszynski, 1985; Ford and Duszynski, 1988, 1989). Three of these species, C. cristata; Parascalops breweri (Bachman), the hairy-tailed mole; and Scapanus aquaticus (Linnaeus), the Eastern mole, occur in the eastern two-thirds of the United States and have ranges that overlap (Hall, 1981). The other 4 species, Neurotrichus gibbsii Baird, a shrew mole; Scapanus townsendii (Bachman), Townsend's mole; Scapanus orarius True, the coal mole; and Scapanus latimanus (Bachman), the broad-footed mole, are all confined mainly to the western coastal states (Hall, 1981).

Because C. cristata is morphologically unique, it has been placed historically in a subfamily (Condyliniae) separate from the other 6 North American talpids (Scalopinae) (Hall, 1981). In addition, cladistic and other analyses of genic data (Moore, 1986) indicated that Condylura diverged very early from the main talpid lineage (26 million years before present), long before talpids appeared in North America. Thus, it is likely that the Condyliniae first appeared in Eurasia and invaded the New World when a land bridge connected Asia and North America either during the early or late Miocene (Moore, 1986). Although the ancestors of C. cristata became isolated in North America as long ago as 8 million years (see Hutchison, 1984) and their current ranges overlap those of 2 other North American
mole species, it might still be predicted that their coccidia should be structurally more similar to the coccidia from Eurasian moles, given the historical and genic data presented by Moore (1986). In fact, *C. cristata* is the only insectivore we have examined to date that was infected almost exclusively by isosporans. The oocysts of these *Isospora* spp. are indeed more similar morphologically to oocysts of isosporans from Eurasian moles than they are to isosporans found in North American talpids.

Finally, moles have very high infection rates with coccidians and most individual hosts harbor multiple infections (Duszynski and Wattam, 1988a, 1988b; Ford and Duszynski, 1988, 1989). The infection pattern in *C. cristata* is consistent with this observation. To date, we have examined 195 individual moles belonging to 8 species and 6 genera from England, Japan, and the United States; 183 (94%) have been infected with coccidia and 153 (84%) of those infected had oocysts from 2 to 8 coccidian species in their feces when examined.

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**LITERATURE CITED**


