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The fine structure of cysts of *Sarcocystis moulei* from goats

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Sarcocysts are often found in muscles of naturally infected goats. The original name *Sarcocystis moulei*, given by Neveu-Lemaire in 1912, did not differentiate between macroscopically and microscopically visible cysts. Transmission experiments have shown that at least two species with microscopic cysts exist in addition to those with macroscopic ones. Fischer (1979), Heydorn and Haralambidis (1982), and Heydorn and Unterholzner (1983) have described the life cycles of *S. capracanis* and *S. hircicanis*, both of which species use the dog as final hosts. Apart from biological differences, these two species have significantly different cyst walls; this has been proven by electron microscopy (Aryeetey et al. 1980; Mehlhorn et al. 1985), although it can be seen even by light microscopy. *S. capracanis* forms upright, palisade-like protrusions in its primary cyst wall, whereas *S. hircicanis* is provided with flat, hair-like protrusions.

The present study deals with the ovoid, macroscopically visible cysts of *S. moulei*. Such cysts were obtained from natural infections in Egypt, Saudi Arabia, and Afghanistan (provided by Dr. P. Kirmse) and from goats that were experimentally infected by cat-excreted sporocysts (after being fed with macrocysts; Heydorn and Kirmse 1989). For the fine structural analysis the cysts were taken from the goat's muscles, fixed, and processed for electron microscopy according to our usual techniques, described elsewhere (Mehlhorn et al. 1976).

The cysts studied were ovoid, with a length of about 3–12 mm, and appeared whitish before embedding due to their secondary cyst wall. On electron micrographs, the intracellular cysts were bound by a typical primary cyst wall containing numerous unthickened places (Figs. 1, 2). The primary cyst wall was folded, thus giving rise to many cauliflower-like protrusions with a height of up to 4.4 μm (Fig. 1). The host cell showed signs of degeneration (i.e., vacuolization) but was still recognizable by its filaments; in all cases it was covered by a laminar, secondary cyst wall about 3–4 μm thick (Fig. 1). The dense ground substance within the cauliflower-like protrusions contained numerous solid filaments (Fig. 2). Just below the primary cyst wall the ground substance was very broad (3–4 μm), containing numerous 0.1-μm spherical, electron-dense particles and closely surrounding the 8.5 μm × 3.5 μm metrocytes, which were found singly or in clusters. In serial sections these developmental stages, dividing by endodyogeny, were seen to contain a conoid at the polar ring of their typical pellicle (Fig. 1). Toward the interior of the cysts, the ground substance formed large chamber-like hollows that were filled by the typical cyst merozoites (bradyzoites) as well as some stages intermediate between metrocytes and cyst merozoites. The cyst merozoites measured about 13–15 μm in length and had a diameter of about 2.5 μm. They were provided with the typical organelles (conoid, rhoptries, pellicle, Golgi apparatus, dense bodies, tubular mitochondrion) and showed a significantly close arrangement of their micronemes (Figs. 3, 5). In the center of the cysts the chamber-like hollows were empty apart from membranous whirls, which might be remnants of degenerated cyst merozoites.

The fine structure of these macroscopic cysts was identical in material obtained from natural and experimental infections and did not depend on the absolute size of the cysts. Comparing these actual findings with the results in *S. capracanis* and *S. hircicanis* cited above, it is evident that the large cysts are significantly different with respect to their cyst wall. The primary cyst wall is very similar to that of *S. ovifelis* [apart from some modi-

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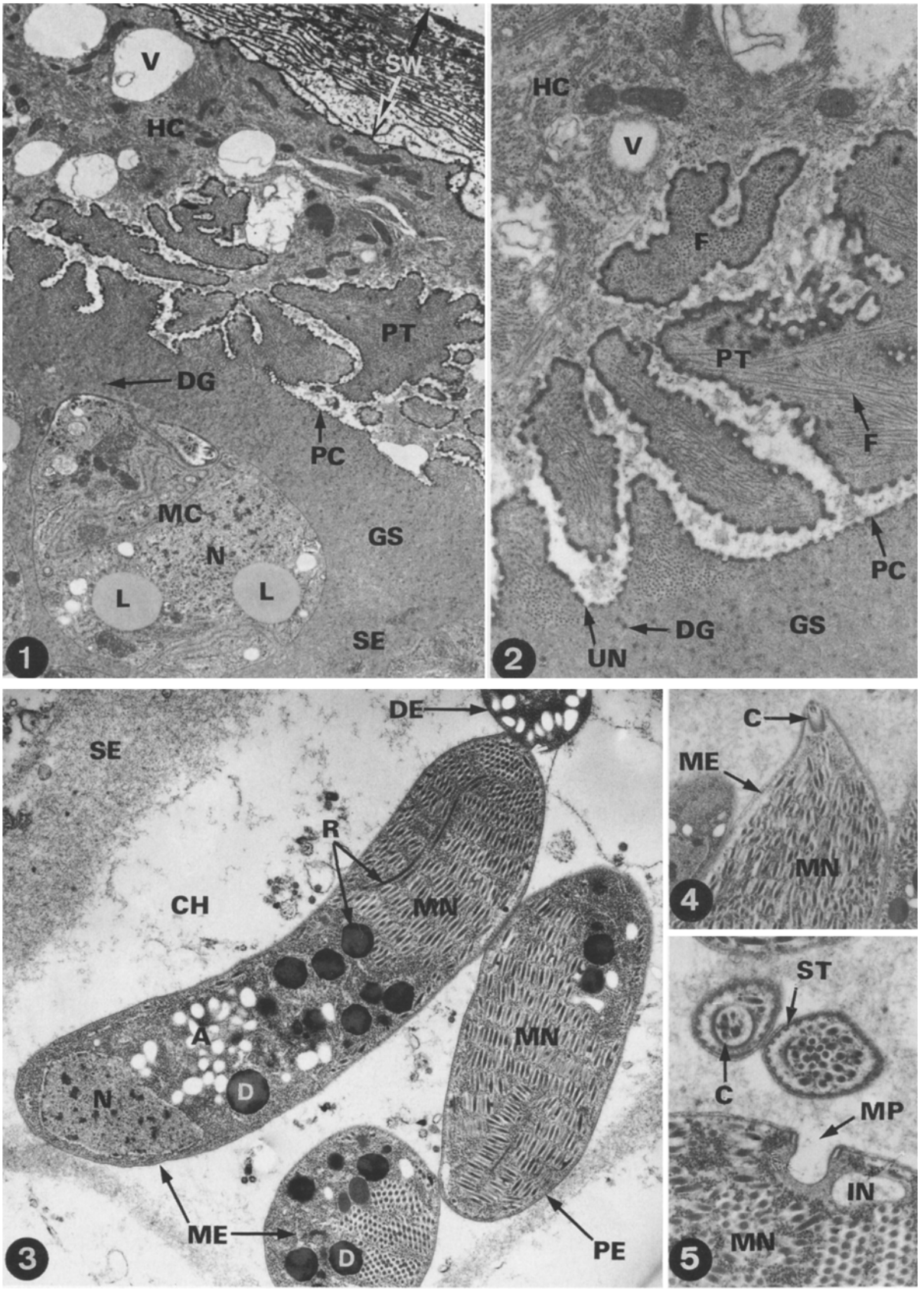
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Figs. 1–5

fications in size, as has been shown by electron microscopy (Mehlhorn and Scholtyseck 1973; Mehlhorn and Heydorn 1978)]. The secondary cyst wall observed in the large cysts of *S. moulei* and in *S. ovifelis* was not found in the *Sarcocystis* species of goats with microscopic muscle cysts. These results prove that the goat is the host of at least three *Sarcocystis* species that are hidden under the first description (*S. moulei*). Thus, the large cyst species of the present study should retain the old (first) name *S. moulei*, and we emphasize our previous proposal (Frenkel et al. 1979; Mehlhorn et al. 1985) to name *S. hircicanis* and *S. capracanis* separately, using a combination of the names of their hosts to define them clearly as species.

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Figs. 1–5. Transmission electron micrographs of *Sarcocystis moulei* tissue cysts. **Figs. 1, 2.** Sections through the periphery of the cyst. **Fig. 1**, ×7100; **Fig. 2**, ×14275. **Figs. 3–5.** Longitudinal (**Fig. 3, 4**) and cross sections through cyst merozoites situated in the central region of the cyst. **Figs. 3, 4**, ×11400; **Fig. 5**, ×28500

Abbreviations: *A*, amylopectin granule; *C*, conoid; *CH*, chamber-like hollow; *D*, dense bodies; *DE*, degenerating stage; *DG*, dense granules of ground substance; *F*, filaments; *GS*, ground substance; *HC*, host cell (degenerating); *IN*, invagination of micropore; *L*, lipid; *ME*, cyst merozoites (bradyzoites); *MN*, micronemes; *MP*, micropore; *N*, nucleus; *PC* primary cyst wall; *PE*, pellicle; *PT*, cauliflower-like protrusions of PC; *R*, rhoptries; *SE*, septum of ground substance; *ST*, subpellicular microtubules; *SW*, secondary cyst wall; *UN*, unthickened places of PC; *V*, vacuolization