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TEM and SEM Investigations of Lymph Hearts in Birds*

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Summary

The fine structure of lymph hearts in birds is described. These organs could be made visible by application of marker medium and indirect and direct injection of contrast medium. As two special morphologic features we note strange modified skeletal muscle cells in the wall of the lymph hearts and efferent collectors to the epidural spinal lymphovenous sinus. The lymph hearts possess valves that regulate the passage of lymph from the lymphatic copulatory organ and the thoracic duct into the venous blood system.

Introduction

Lymph hearts occur in different number in amphibia (4). Generally, reptiles (5) and birds just possess only one pair of caudal lymph hearts. Our investigations deal with lymph hearts of juvenile and adult aves (ducks, swans, emus, rheas).

Results

Avian lymph hearts (ALH) are located upon the transversal processuses of the synsacrum. Nearly all efferent and afferent collectors of the lymph hearts are passing the foramina intertransversaria.

Avian lymph hearts are either totally or partly covered by the caudal levator muscle. The lumen of the ALH is sporadically septated and crossed by trabeculae (Fig. 1, above). The wall of the ALH is composed of an endothelial interna, a muscular media, and an externa that consists of plurivacuolar white fat cells.

The media has – like the wall of the collector – an inner layer of smooth muscle cells (Fig.1 below) and an outer layer of so-called striated lymph heart muscle cells (Fig. 1, insert). The outer layer is relatively thick in struthioniform thinner in swans, and even thinner in ducks. The lymph heart muscle cells crisscross and insert at the synsacrum and the first three caud vertebrae. They also pass through the trabeculae and septa and show similarities with the mammalian skeletal and heart muscle cells. Th multi-nuclear muscle cells are relatively short and sporadically ramified, and have short bundles of filaments. The broad-flattened endings of cells get in contact by end-to-end nexus. Besides these lymph heart muscle cells, there are lightly coloured, filament-poor cells, that show striking similarity with the bundle of His. The musculature of the lymph hearts is innervated by non-medullated synsacral nerves and possesses numerous satallite cells.

The adventitia of the ALH is predominantly formed by white, plurivacuolar fat cells (Fig. 2, above) that serve as pressure pads (3).

The investigation of afferent and efferent lymph heart collectors was performed by injecting India-ink, Berlin-blue, Latex, and contrast medium like Lipiodol® and Iotasul® (Schering AG, Berlin/Bergkamen).

Caudal afferent collectors transport the lymph fluid from the lymphatic copulatory organ to the lymph hearts (Fig. 2, below). According to previous investigations the copulatory organ is erected by lymph that transudes into the so-called lymphobulbus (2). It is passed on into the lymph sinuses of the phallus, thus

*This article is dedicated to the late *Otto Frederic Kampmeier*

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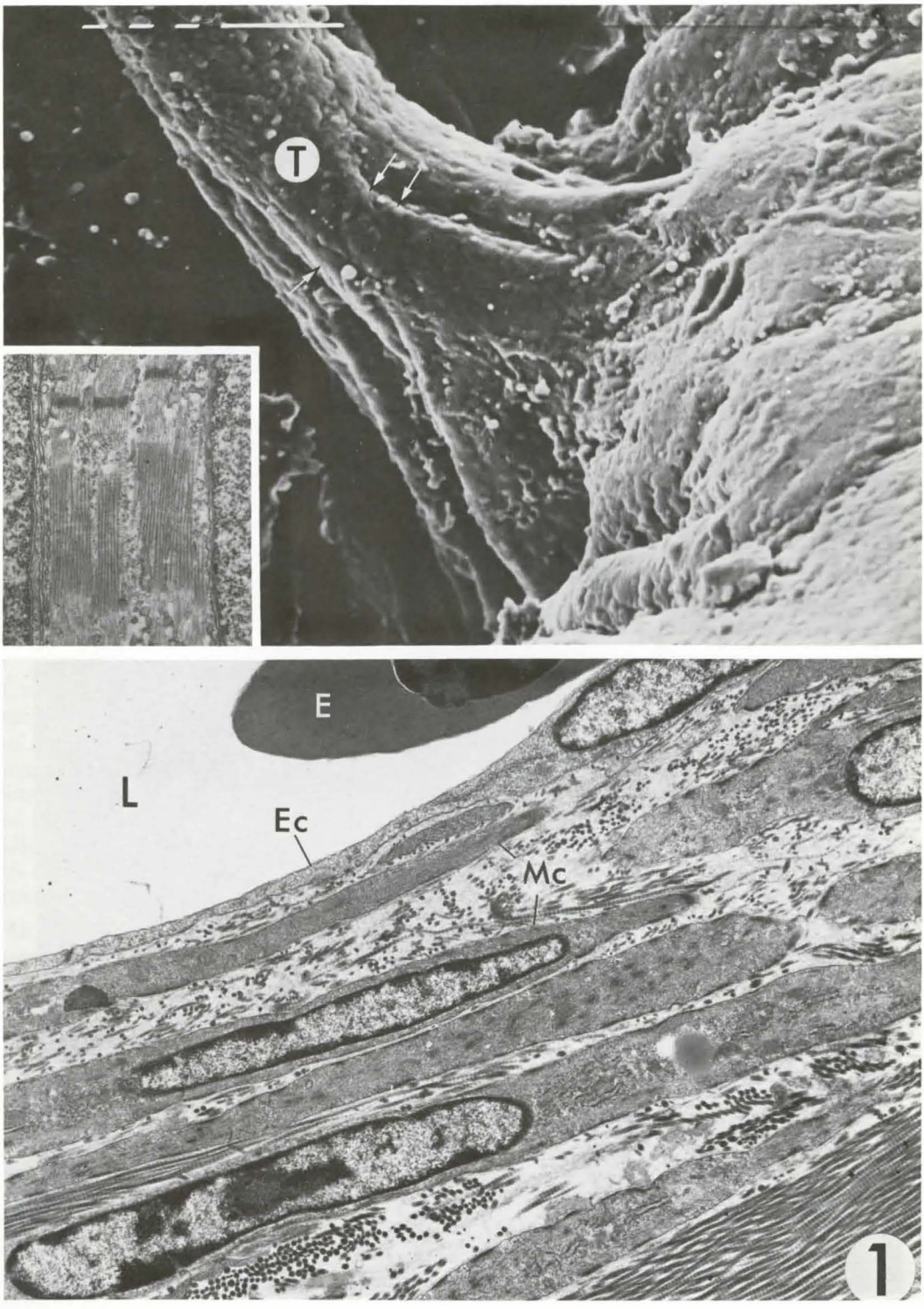

Fig. 1 Legend see page 189

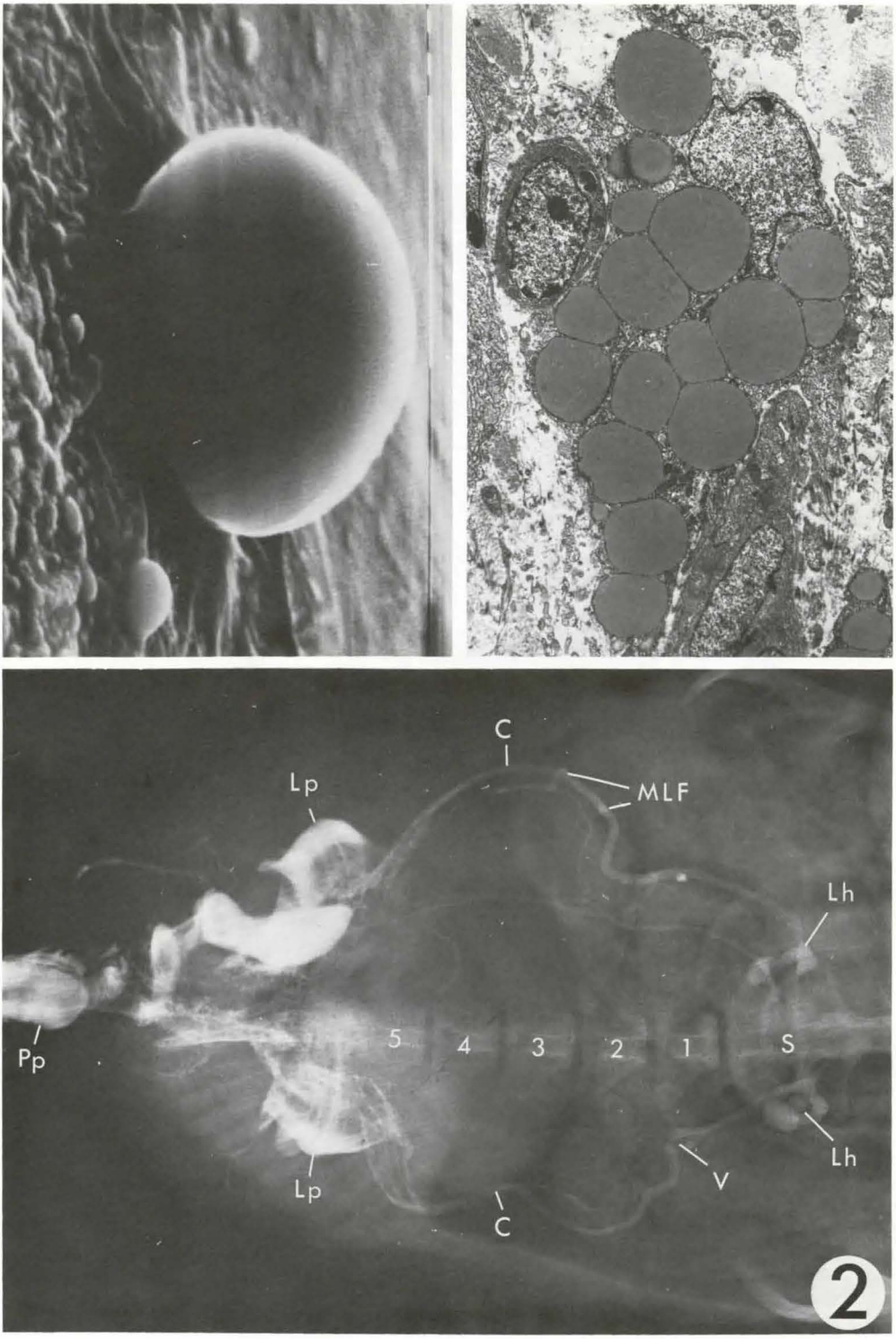

Fig. 2 Legend see page 189

Legends for Figs. 1 and 2:

Fig. 1 above: Trabecula (T) in the lumen of the lymph heart in swan (12 months old): The arrows outline striated lymph heart muscle cells. SEM-picture, Magn. 2150 x
Insertion: Striated lymph heart muscle cells in emu-embryo (d 36). TEM-picture, Magn. 16800 x
below: Wall of the lymph heart in adult duck: E erythrocyte, Ec endothelial cell, L lumen of lymph heart, Mc smooth muscle cells. TEM-picture, Magn. 16800 x

Fig. 2 above left: Plurivacuolar white fat cell in the media of the lymph heart in juvenile swan. SEM-picture, Magn. 4600 x; above right: Plurivacuolar white fat cell in the media of the lymph heart im emu-embryo (d 56). TEM-picture, Magn. 2925 x; below: Lympnography of the Phallus protrudens (Pp), Lp lymphobulbus phalli and lymph hearts (LH) in the drake after a direct application of Urografin® into the phallus. C afferent caudal lymph heart collector, 1–5 free vertebrae caudales, MLF mural lymphoreticular formations, V valve, S synsacrum. Magn. 1:0.5

provoking the erection. Is one of the marker medium injected into the phallus of ostrich or drake, it moves via caudal afferent collectors into the lymph hearts. These thick collectors of large calibre contain many valves (Fig. 2, V) with smooth muscle cells. The valves regulate the lymph flow between the lymphatic copulatory organ and the lymph hearts. Direct lymphographies, performed by injecting contrast medium into the phallus, show that the two lymph hearts of the male duck are connected with each other (Fig. 2, below).

Cranial *afferent collectors* of the lymph hearts can be made visible by marker medium injected into the pulvinus metatarsalis. This technique leads to very good results in bird embryos. The marker medium can also be injected directly into the Vas 1. tibiale caud., thus filling the collectors of the pelvic limb up to its entry area into the paired thoracic duct (truncus thoracoabdominalis) (6).

Within this duct, the marker medium takes a retrograde-caudal course and fills the lymph hearts via afferent collectors. The lymph hearts can also be demonstrated by an indirect lymphotography with Iotasul® injected into the pulvinus metatarsalis. Iotasul® can be determined in the collectors of the pelvic limb in one of the lumbal lymph nodes, in the thoracic duct, a and in the lymph hearts.

Birds have in addition to the cranial and caudal afferent collectors, also *cranial and caudal efferent collectors* to the venous blood system.

Besides these collectors, there is one *medial efferent vessel,* that has a ventral branch to the internal iliac vein and a dorsal branch to the epidural spinal lymphovenous sinus. This sinus and the dorsal branch can be filled with marker medium injected into the spatium interarcuale sacrococcygeum.

The passage of lymph in all these afferent and efferent collectors in the AHL is regulated by valves.

Discussion

Finally, we wish to accentuate the following special features of the ALH:

1) In the wall of the lymph hearts we note a special muscle tissue that can be considered lymph heart muscle cells. These striated muscle cells represent early, however, retarded, myogenetic stages, so that no continuous syncytium is formed in the subadult and adult birds. The cells, however, exhibit a contractility in ducks and emus, while in some other birds they show already signs of degeneration.

2) As known from mammals, birds possess in addition to the cranial lymphovenous anastomosis near the pre-caval vein, a caudal anastomosis near the lymph heart area. In drakes and struthioniforms, at least 10 ml lymph fluid flows after each erection from the lymphatic copulatory organ into the blood system within 15 minutes. Post-ejaculation, the transport of lymph to the lymph heart is promoted by rhythmic movements of animal's taile. In contrast to the drake, the lymph hearts in the male chicken have degenerated by onset of sexual maturity. In this species, the greater portion of the lymph flows while mating from the lymphatic copulatory organ

through the epithelium of the lymph folds into the cloacal lumen (1). This lymph portion (transparent fluid) constitutes the final fraction of the ejacualte.

3) Anastomoses between the lymph hearts on the one hand and the epidural spinal lymphovenous sinuses on the other hand, represent a drainage system not yet mentioned in literature.

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