collected samples were considerably lower than the proposed average departure weight of 20 g (Nisbet et al. 1963). The weights are suspect, however, because drying the specimens may have caused water weight loss. Most (84%) of the birds had fat classes of 3 or 4. A random sample of Blackpoll Warbler weights for fat classes 3 and 4 from the autumn migrations at Manomet Bird Observatory shows that live birds with fat classes of 3 and 4 (class 3 mean = 16.5 g, SD = 2.2, n = 50; class 4 mean = 19.6 g, SD = 2.4, n = 50) weigh close to 20 g. Thus, the fat levels of the dead birds suggest that most of the birds had sufficient fat reserves to complete a trans-Atlantic crossing.

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ARTERIOVENOUS ANASTOMOSES IN THE INCUBATION PATCH OF HERRING GULLS

UFFE MIDTGÅRD

Arteriovenous anastomoses (AVAs) are large vessels through which the blood may be shunted directly from arterioles to venules without passing the capillaries. Thus, the AVAs allow a high level of local blood flow without overburdening the capillary net. The AVAs are particularly abundant in the skin of homeothermic animals. In birds, they are numerous in the feet (Schumacher 1916, Midtgård 1980) and in the naked skin areas of the head (Wodzicki 1929, Baumel et al. 1970, Midtgård 1984b). Histologically, the AVAs are characterized by irregular lumina (3–8 times larger than those of capillaries), muscular walls, and by being more or less tortuous. In contrast to capillaries, which serve tissue nutrition, AVAs are believed to have a thermoregulatory role in most skin areas. For example, the AVAs in the feet provide the structural basis for a high level of peripheral blood flow, which is important for dissipating heat at high ambient temperatures (Wolfenson 1983).

Since the incubation patch is highly vascular and important for transferring heat from the incubating bird to the eggs (Drent 1975), it might be assumed that AVAs also are present in this skin area. A survey of the literature dealing with the histology of the incubation patch showed that AVAs have not been reported from this area of the skin. It is likely that the AVAs have been overlooked, especially since many investigators are unfamiliar with their histological appearance. This contention is supported by the fact that AVAs have been identified in the thoracic skin of the domestic fowl (*Gallus gallus* var. *domesticus*; Midtgård 1984a). In order to establish whether AVAs are present in the incubation patch, I examined the Herring Gull (*Larus argentatus*). This species was chosen because

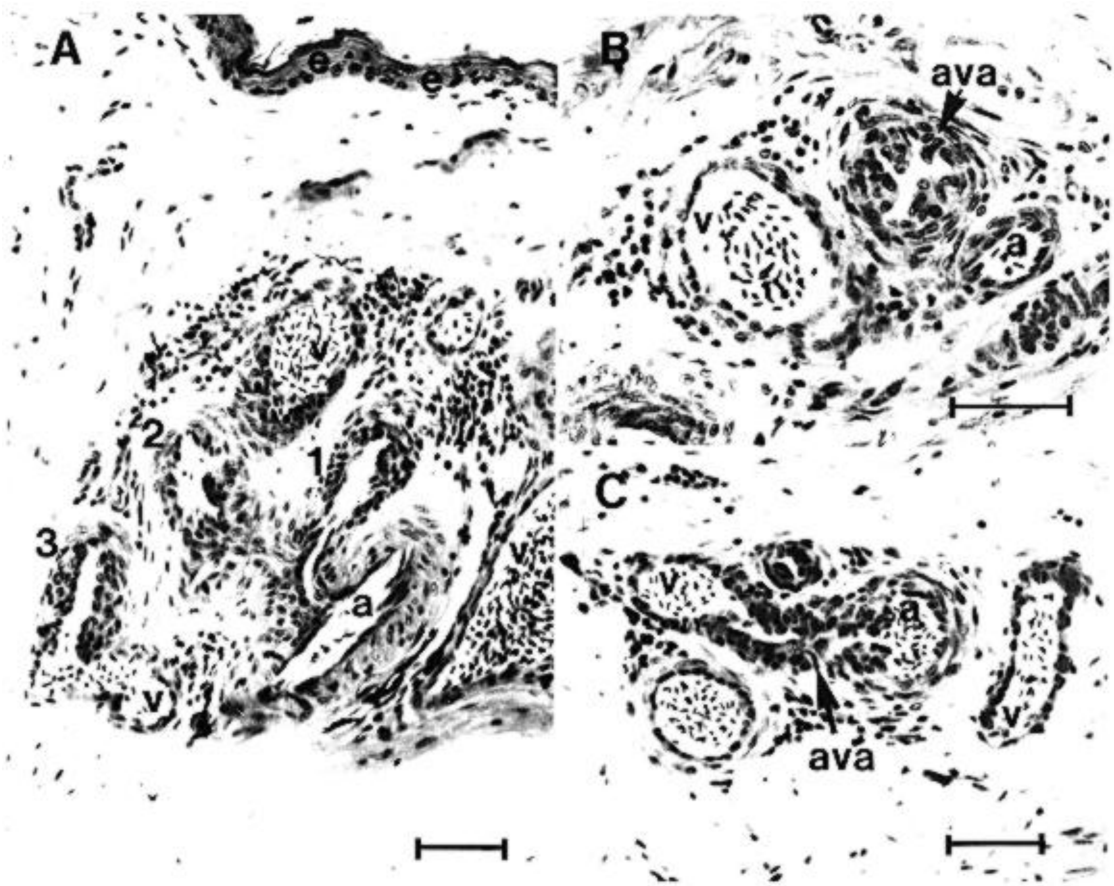

FIGURE 1. Histological sections of blood vessels in the incubation patch of the Herring Gull. A: section through a glomus-like structure in which an arteriovenous anastomosis has been cut at three different levels; (1) at its origin from the parent artery, (2) through its middle segment, and (3) at the inlet to a vein. B: cross section of an anastomosis showing the typical stellate lumen and thick, muscular wall. C: longitudinal section of a straight arteriovenous anastomosis. Abbreviations: a, artery; ava, arteriovenous anastomosis; e, epidermis; v, vein. Scale bars equal 0.05 mm.

it is not protected in Denmark and is easily obtained during the incubation period.

MATERIAL AND METHODS

Seven Herring Gulls were live-trapped on the nests in a gullery near Copenhagen in early May. Since both sexes of the Herring Gull incubate, the collection included both male and female gulls. The birds were killed with ether, and the incubation patches and interscapular skin were excised and fixed in a mixture of alcohol-formol-acetic acid. In each individual, small skin samples (ca. 1 × 1 cm) for histological analysis were cut out from the central part of one of the thoracic incubation patches, which include parts of the thoracic apterium and feather tract, and from the dorsal feather tract. The skin samples were embedded in paraffin and serially sectioned at 10–15 μm. The sections were stained with haematoxylin and eosin. The number of serial sections used for calculating the density of AVAs ranged from about 100 to 180 per skin sample.

RESULTS AND DISCUSSION

Histological observations. Birds of both sexes showed that the blood vessels were larger and more numerous in the dermal and subdermal tissues of the incubation patch than in the interscapular skin. The dermis of the incubation patch contained many complicated, glomus-like structures in the basal layer (Fig. 1 A). The glomi were seen both in the thoracic feather tract and thoracic apterium of the incubation patch, but not in the interscapular skin. They consisted of AVAs (often two or three), veins, and arteries, all packed in dense, connective tissue that was infiltrated with lymphocytes.

In cross sections, the thick walls of the AVAs were seen to consist of circular and longitudinally arranged, smooth muscle fibers. The opening was usually narrow and had a stellate outline, owing to ridges of smooth muscle cells that protruded into the lumen (Fig. 1 B). Although the AVAs generally were tortuous and located in groups, simple, straight anastomoses were occasionally found (Fig. 1 C). The density of AVAs in the central part of the thoracic incubation patch of the seven Herring Gulls was 440 ± 120 per cm^2 (mean ± SD), and there was no obvious difference between males and females.

It is surprising that AVAs have not previously been reported as present in the incubation patch of birds, especially since numerous histological observations have been made in connection with studies of the hormonal control of the development of the incubation patch (for review, see Drent 1975). Most investigators have apparently restricted their observations to the density and size of blood vessels, whereas few have been concerned with the vascular anatomy. Detailed morphological studies are available, however, for the White-crowned Sparrow (*Zonotrichia leucophrys gambelii*) and Canary (*Serinus canaria*; Kern 1979, Kern and Coruzzi 1979), and Lange (1928) provided information about the blood supply and general histology of the incubation patch in about 20 species, including the Herring Gull. In his detailed study of incubation in the Herring Gull, Drent (1970) also made histological observations on the incubation patch. None of these investigators, however, mentioned AVAs, although Lange (1928), Kern (1979), and Kern and Coruzzi (1979) described glomi or clusters of blood vessels in the incubation patch. Perhaps some of the birds that have been studied really lack AVAs in their incubation patch, but this must be confirmed by new investigations. Alternatively, the AVAs may simply have escaped attention because they were mistaken for arteries, which they resemble closely, owing to their thick walls.

Functional aspects. There is increasing evidence that incubating birds respond physiologically to egg temperatures that deviate from the normal. By using water-circulated eggs, it has been shown that egg cooling initiates shivering (Franks 1967, Drent et al. 1970, Tøien et al. 1984) and increases the metabolic rate considerably (Biebach 1979, Vleck 1981, Tøien et al. 1982). Presumably, the heat derived from the increased metabolism is distributed preferentially to the incubation patch by way of the circulating blood. In support of this view, we have recently found that egg cooling increases the blood flow significantly in the incubation patch of the domestic fowl (Midtgård et al. 1985). The role of the AVAs in this cold-induced vasodilatation has not yet been determined. Since the AVAs have a considerably larger diameter than capillaries, however, they constitute low-resistance channels by means of which the high capacity venous bed can be rapidly perfused. Therefore, if the AVAs are open, a large amount of warm blood from the core of the body will perfuse the incubation patch and increase the skin temperature and rate of heat transfer to the eggs. This would be particularly important when a bird returns to cooled eggs after feeding excursions. Conversely, if heat loss from the incubation patch must be reduced, e.g., when the parent bird is off the nest, the AVAs are probably closed and blood flow to the incubation patch is minimal.

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