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A PRELIMINARY STUDY OF THE AVIAN ADRENAL

BY FRANK A. HARTMAN AND ROBERT H. ALBERTIN

EXPERIMENTS have demonstrated that the adrenal is as important in birds as it is in mammals. Parkins (1931) reported an average survival of 80 hours following a two-stage adrenalectomy in the fowl. The symptoms resembled those of the cat and dog after a similar operation. Miller and Riddle (1942) were able to maintain young adrenalectomized pigeons an average of nine days by the addition of a salt mixture to their diet. Herrick and Torstveit (1938) destroyed the adrenals in male fowls in which the testes were large. They were given adrenal extract for a few days and then salt solution. Within a few weeks they had the appearance of typical capons, and the testes were reduced to a fraction of their original size, indicating that the adrenals were essential for their normal functioning. Beyond these observations little study has been made of the functions of the adrenal in the bird, but it is presumed that they are similar to those of the mammalian gland. However, more work is needed to demonstrate this.

The adrenal gland is an organ which is called upon in various stresses to increase its activities many-fold (Hartman and Brownell, 1949: 121, 258). No class of vertebrates shows greater range of variety or intensity of stresses to which it is exposed than that of the birds. Therefore, a study of the structure and function of the adrenal in this group should be very profitable.

Riddle (1923) noted the effects of ovulation and disease on adrenal weight in the dove and pigeon. Others have observed the changes in the fowl with age (Hartman and Brownell, 1949: 37). The study of the structure of the avian adrenal has also been limited largely to domestic forms (Hartman and Brownell, 1949: 24 and 56). Aside

from adrenal weights by Crile and Quiring (1940) and Hartman (1946) the adrenal of wild birds has been largely neglected.

A few years ago we began a survey of the adrenal of wild birds as preparation for a more intensive study of selected forms. We have now collected and prepared the adrenals of more than 400 species of birds, half of which were from the tropics, the rest being from the eastern part of the United States. Some of the information which has been obtained will interest ornithologists.

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Location.—The adrenals lie under the gonads and against the anterior tips of the kidneys (Fig. 1). They are usually of distinctive color and may be partially or completely covered by the gonads, depending upon the size of the latter. In the female, even the quiescent ovary may cover the left adrenal, being closely adherent to the connective tissue which encompasses the latter. In the male, the immature testes are too small to cover the glands, but the enlarged active testes of the adult do so. A cushion of connective tissue containing fat adheres closely to the dorsal surface of the adrenals.

Separation.—In most species the adrenals occur as two distinct organs, but vary in degree of separation from a wide gap to nothing but a line of demarcation. Upon superficial examination these glands, in the latter case, appear to be united, but dissection shows them not to be. Rarely, the adrenal tissue is combined into one organ as in: the Stork, *Euxenura manguari;* Rhea, *Rhea americana;* Gannet, *Sula variegata* (Holmberg and Soler, 1942); and Bald Eagle, *Haliaeëtus leucocephalus* (Hartman and Brownell, 1949: 28). Different individuals of the same species may show considerable variation in this respect. Of two Common Loons, *Gavia i. immer,* examined, these glands were fused in one and completely separated in the other. Of nine specimens of the Hairy Woodpecker, *Dendrocopos v. septentrionalis,* they were completely fused in one, appeared to be but were not in four, and were patently separated in the others. They may also be fused or separated in the Herring Gull, *Larus argentatus smithsonianus.*

Shape.—The shape of the adrenals varies so much in different species that it is difficult to make generalizations. They may be ovoid,

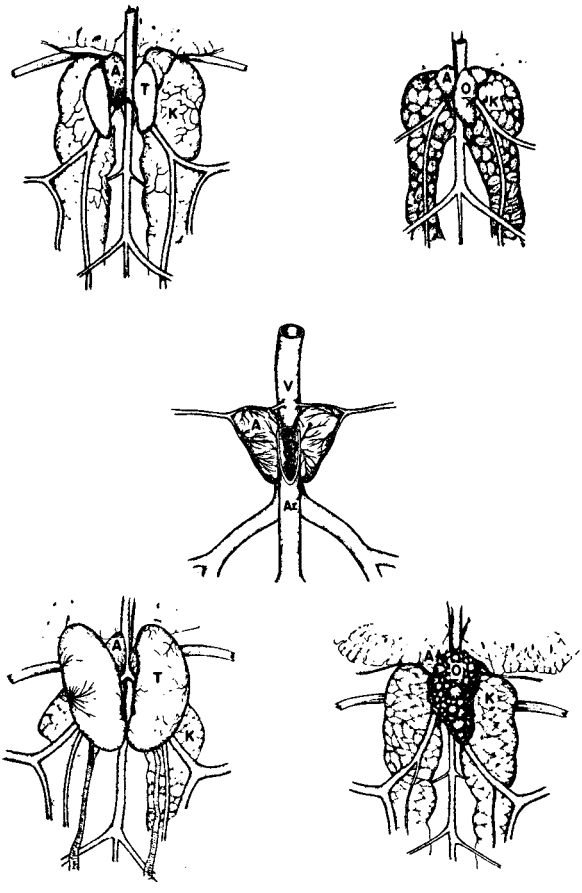

FIGURE 1.—Adrenal of domestic fowl in relation to gonads.—(*Top, left*) male two months old; (*Right*) female one month old; (*Middle*) dorsal aspect showing arterial openings to adrenals. (*Bottom, left*) male; (*Right*) female, both three months old. A—adrenal; T—testis; O—ovary; K—kidney; Ar—aorta; V—vein.

ellipsoid and regular, or they may be flattened, irregular bodies of variable thickness. They may be pointed at one end and the corners or edges may be attenuated. Moreover the two glands are often unlike in form (Fig. 2).

Color.—Usually the color is cream, yellow, or orange. It is rarely red, as is the kidney. Occasionally it is pink, gray, or dark reddish-brown. The color may be determined by the lipid present in the gland. This makes Nighthawk, *Chordeiles minor*, and Parauque, *Nyctidromus albicollis*, adrenals white, and in some water birds it

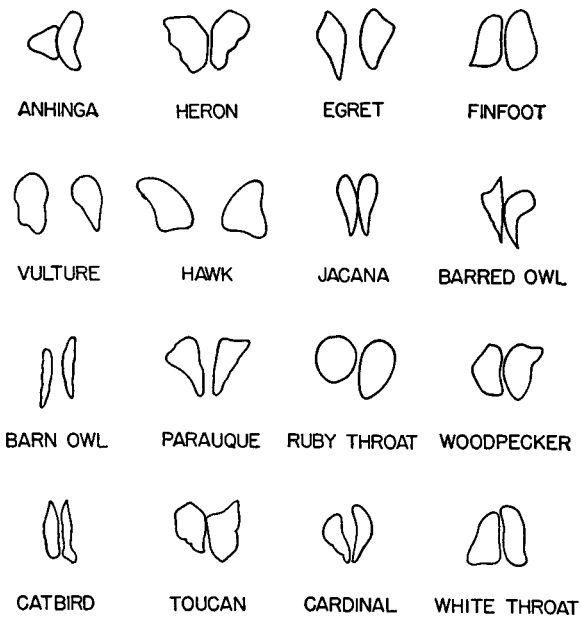

FIGURE 2.—Shapes and relative positions of adrenals: Anhinga, *Anhinga anhinga;* Agami Heron, *Agamia agami;* American Egret, *Casmerodius a. egretta;* Finfoot, *Heliornis fulica;* Black Vulture, *Coragyps atratus;* Marsh Hawk, *Circus cyaneus;* Jacana, *Jacana hypomelaena;* Barred Owl, *Strix varia;* Barn Owl, *Tyto a. pratincola;* Parauque, *Nyctidromus albicollis;* Ruby-throated Hummingbird, *Archilochus colubris;* Pileated Woodpecker, *Dryocopus pileatus;* Catbird, *Dumetella carolinensis;* Swainson's Toucan, *Ramphastos swainsoni;* Cardinal, *Richmondena cardinalis;* White-throated Sparrow, *Zonotrichia albicollis.*

makes them a brilliant orange. In the White Ibis, *Guara alba,* the body fat, as well as the adrenals, is a brilliant orange. This may be determined in some instances by the food, since the adrenal lipochrome pigment in the fowl varies in color with the food (Findlay, 1920).

Adrenal color may vary in different individuals of the same species. The following are examples of those which depart from the more common yellow to orange color. In two Bald Eagles, the adrenals were yellow in one and yellowish-pink in the other. In three Hairy Woodpeckers, they were brown in two and yellowish-white in the third. They were brown in a Red-cockaded Woodpecker, *Dendrocopos borealis;* brownish-yellow in a Phoebe, *Sayornis phoebe;* white in a Florida Blue Jay, *Cyanocitta c. cristata;* grayish brown in a Florida Jay, *Aphelocoma c. coerulescens;* brown in a Florida Crow, *Corvus brachyrhynchos pascuus;* brownish in two Black-capped Chickadees,

Parus a. atricapillus; yellowish-white in a White-breasted Nuthatch, *Sitta c. carolinensis;* and grayish in a Yellow-throated Warbler, *Dendroica d. dominica.*

Microscopic structure.—Thin sections of the adrenal fixed in Zenker-formol solution show two kinds of tissue: one, yellowish to brown in color, which is the chromaffin tissue; and the other, unstained, which is the interrenal tissue. The chromaffin tissue produces epinephrine, while the interrenal tissue, which corresponds to the cortex of the mammalian adrenal, produces hormones essential to life.

In the bird and reptile, interrenal and chromaffin tissues are intermingled, but in the former these tissues are usually more thoroughly interspersed. The darker chromaffin tissue stands out, forming a pattern (Fig. 3). When there is a relatively small amount of chromaffin tissue, it is scattered through the interrenal tissue in the form of small bodies or islands of various sizes. As the amount increases the islands become larger, often elongated, and sometimes connected with one another by thin bridges. With a large proportion of chromaffin tissue much of it reaches the surface of the gland. In some species the chromaffin tissue seems to surround the blood sinuses (Fig. 3, *Rhinoptynx* and *Sitta*).

There is similarity in pattern of the different individuals of the same species, at least in some instances, but there may be little similarity between species in the same genus (Hartman, Knouff, *et al.* 1947). Species of different genera of the same family may show considerable contrast (*Rhinoptynx* and *Ciccaba*, Fig. 3).

Of the birds studied thus far, some of those belonging to the Suborder Pelecani possess adrenals whose cells are largest and so arranged that they present a clearer picture than that found in many other groups. Adrenals of the Cormorant, *Phalacrocorax auritus*, and Brown Pelican, *Pelecanus occidentalis*, are among the best examples. Indeed they may serve as a standard for a study of other avian adrenals.

The adrenal capsule is relatively thin and if removed reveals a characteristic structure beneath, especially after fixation with hardening agents (Fig. 4, A). Sections under the microscope may show a rather orderly arrangement of interrenal cells which appear as double rows with the nuclei toward the inner contiguous ends far removed from the blood vessels which bathe the outer ends. Actually these are solid cords with the nuclei in the centers, the longitudinal sectioning making them appear as a double row (Fig. 4, B). When a cross-section is made of a cord the cells are shown to be arranged radially, the inner portions containing the nuclei being wedge-shaped. The

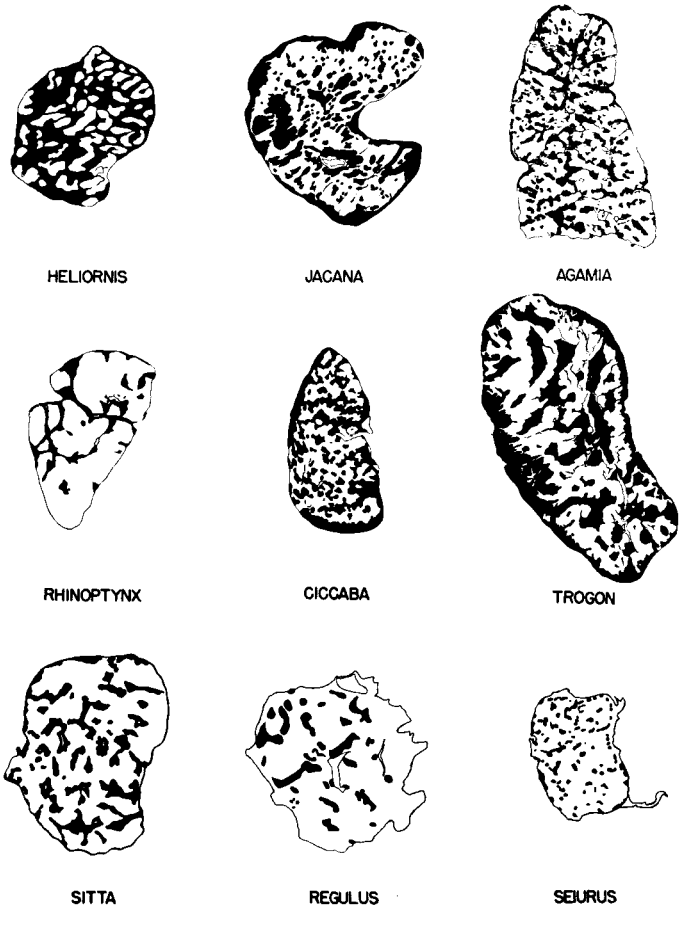

FIGURE 3.—Patterns of chromaffin tissue (black) in different species: *H. fulica, J. hypomelaena, A. agami, R. clamator, C. nigrolineata, T. curucui tenellus, Sitta carolinensis, R. satrapa, Seiurus noveboracensis.*

cords extend inward from the periphery and may follow a tortuous course as they approach the interior of the gland.

The islets of chromaffin tissue are few in number and small in this group of birds. The cells are more irregular than those of the interrenal tissue (Fig. 4, C). In preparation for paraffin sectioning the lipid is replaced by vacuoles. These often constitute a considerable portion of the cytoplasm of the interrenal cell. Interspersed among them are elliptical or rod-shaped mitochondria. When there is much lipid material there are fewer mitochondria and vice versa (Fig. 4, D and E). Although these bear some relation to hormone production, their function is not well understood.

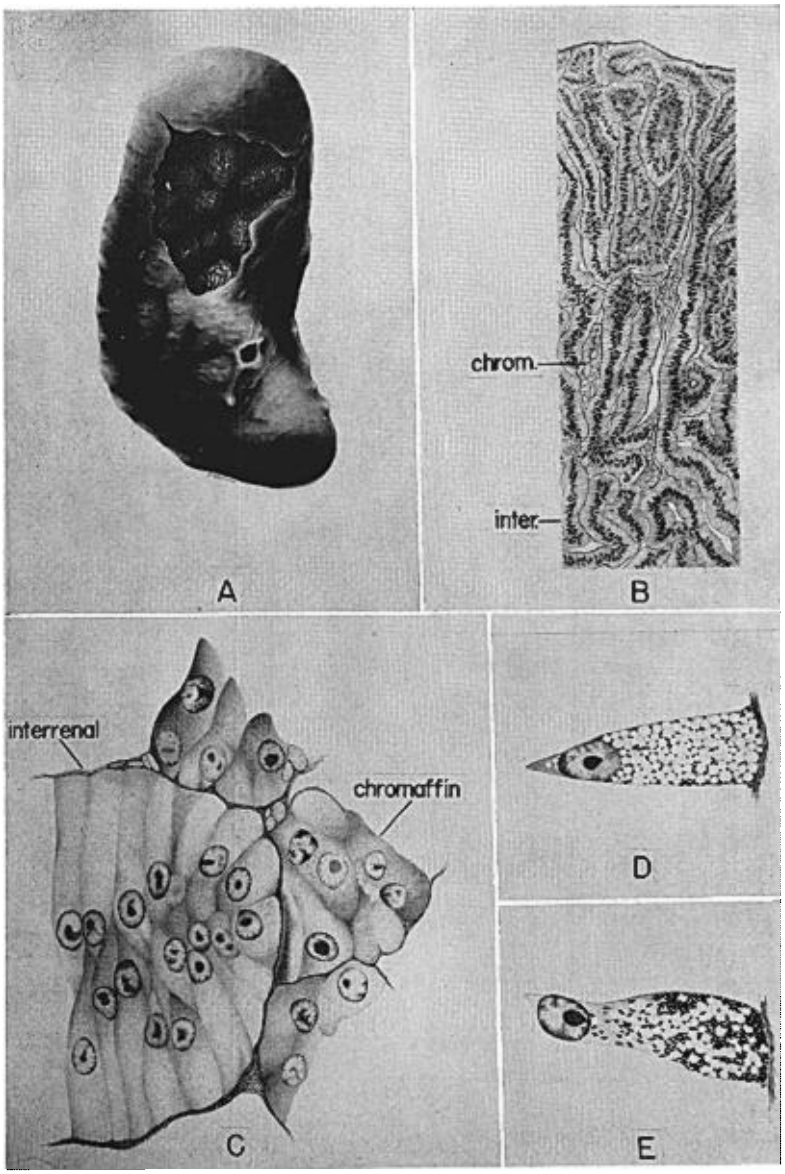

FIGURE 4.—Adrenal of Cormorant, *Phalacrocorax auritus floridanus: A.* Ext. view, capsule partially removed to show glandular structure; *B.* Section showing arrangement of cells; chrom.—chromaffin tissue; inter.—interrenal tissue, Zenker-formol fixation; *C.* Enlarged section of *B. D* and *E*, interrenal cells from the adrenal of the Brown Pelican, *Pelecanus occidentalis:* D, with large amount of lipid (vacuoles) and few mitochondria (black); *E*, with many mitochondria but less lipid material, fixation in Zenker-formol.

The interrenal cell of the Brown Pelican is the largest that we have seen in any vertebrate and offers the best preparation for a study of cellular changes under different conditions of activity.

From this preliminary survey we may conclude that the adrenals of certain avian groups will be very useful in the study of the relation of cellular structure to function.

SUMMARY

A preliminary study has been made of more than 400 species of birds, half of them from the tropics. The adrenals are located on the anterior poles of the kidneys just below the lungs and posterior to the gonads. In most species they are separate, but in a few they are fused into a single organ. The adrenals differ greatly in shape, often being irregular and varying among different individuals in the same species. Their color may be cream, yellow, or orange, but is sometimes pink, gray, or reddish brown. Microscopically the chromaffin tissue forms a pattern varying from scattered islets to an interwoven network, depending upon the amount of tissue present. The interrenal cells of certain members of the Suborder Pelecani are the largest of any vertebrate observed thus far, offering excellent material for a study of cytological changes. Because of the marked arrangement of these cells, the adrenals of this group can be used as a standard for the study of the adrenals of other birds.

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