NOTES ON AVIAN COCCIDIOSIS[1]

BY DONALD C. BOUGHTON

Plate 31

INTRODUCTION

To suggest to the ornithologist that his birds are hosts to a variety of interesting animal forms which have elaborated marvelously adapted modes of life within the avian body, is perhaps, to press the point too far. The hint, however, that some of these animals, as parasites, are the causes of severe diseases in birds should arouse his concern. The Coccidia comprise one group of these parasites. Coccidia are one-celled animals which grow and multiply in the epithelial cells of various higher animals, often in the lining of the intestine, causing destruction of host tissues. An end-product of the multiplication cycle within the host is the microscopic spore (oocyst) which passes from the host body in the fecal discharge. In most cases the coccidian spore requires a developmental period (sporulation) in a moist place outside the host, in order to produce within itself the minute forms (sporozoites) which are capable of beginning again the parasitic multiplication within a new host. Should a susceptible bird ingest a few 'ripe' spores of an appropriate avian coccidian, the latter would become established in the bird; the bird would then become 'infected.' The resulting disease is called coccidiosis.

Since coccidiosis is a serious and widespread disease of birds, it may prove of interest to ornithologists to present briefly a few facts regarding: (1) the two types of avian Coccidia; (2) coccidiosis in small birds; (3) examination and sources of bird hosts; and (4) the distribution of Coccidia among bird groups.

TWO TYPES OF AVIAN COCCIDIA

The Coccidia of birds are divided into two genera, *Isospora* and *Eimeria*, which are as distinguishable to the protozoologist as are *Turdus* and *Zonotrichia* to the ornithologist. Morphological differences are most apparent in the mature spores. When first discharged from the bird, the spores contain rounded masses of protoplasm and those of *Isospora* and *Eimeria* look very much alike (Pl. 31, figs. 1, 3). However, in the course of several hours or a few days, depending upon the coccidian species involved, the cystic content undergoes characteristic changes. To facilitate this development, fecal material containing spores may be cultured in 2 per cent potassium-bichromate solution. The spore (oocyst) of *Isospora* forms two secondary cysts (sporocysts) shown in Figure 2 (Plate 31). Each secondary

[1] From the Department of Animal and Plant Pathology, Rockefeller Institute for Medical Research, Princeton, New Jersey.

cyst actually contains four minute, infective forms (sporozoites), but these are not readily made out in detail. The spore of *Eimeria* forms four secondary cysts as shown in Figure 4. Each of these contains only two infective forms (not readily made out in detail). For detailed drawings of various coccidian spores the reader is referred to Becker (1934). The microphotographs presented here faithfully reproduce the appearance of the spores as seen under the microscope.

Various species of *Eimeria* are responsible for the coccidiosis in quail, pigeons, and chickens. For a review of coccidiosis in these birds the reader is referred to Becker (1934) and for a detailed study of poultry coccidiosis to Tyzzer (1929) and Tyzzer *et al.* (1932). No authentic case of coccidiosis in poultry due to *Isospora* has been reported. Likewise, with a possible exception to be noted later, *Eimeria* is not found in perching birds. In 1910, Hadley condemned the House Sparrow and other small birds as carriers of the poultry disease. Actually there is no evidence to support this accusation, as has been shown by several workers (Smith and Smillie; Johnson; Boughton, 1929). To a limited extent, sparrows may carry Eimerian spores mechanically, but they certainly are not natural reservoirs for poultry coccidiosis.

Coccidia of the genus *Isospora* are found in many birds, especially passerines. A recent survey (Boughton, 1938) has shown that 173 species and subspecies of birds have been reported as hosts of *Isospora*. One hundred and forty-seven of these belong to the order Passeriformes, while the remaining twenty-six are scattered through eight other orders. When a sufficient number of individuals is examined, the incidence of infection is found to be relatively high in most of these bird species. For the English Sparrow it is practically 100 per cent (Boughton, 1937). In the summer of 1933 the writer obtained the following records for *Isospora* from birds banded at the Baldwin Bird Research Laboratory: Catbird (*Dumetella carolinensis*), 8 out of 11; Eastern House Wren (*Troglodytes aedon aedon*), 26 out of 45; Eastern Song Sparrow (*Melospiza melodia melodia*), 82 out of 91; Eastern Field Sparrow (*Spizella pusilla pusilla*), 10 out of 11; Eastern Chipping Sparrow (*Spizella passerina passerina*), 13 out of 16. The incidence is high also in troupials and other cagebirds. Captive Birds of Paradise are commonly infected with an *Isospora* which has recently been described as a new species (Boughton, 1937).

COCCIDIOSIS IN SMALL BIRDS

Typical coccidiosis in small birds caused by coccidia belonging to the genus *Isospora* has been reported by various European workers (Condorelli and Fiore, Labbé, Laveran, Sjöbring, Wasielewski). The disease is similar in many respects to coccidiosis in poultry. An infection may eventually

lead to destruction of the intestinal epithelium with subsequent loss of appetite, emaciation, droopiness, diarrhea, and finally death due to acute enteritis. Sjöbring reports finding adult birds in nature heavily infected. When approached, such birds could make only feeble attempts to fly away, and when captured and caged, remained quiet, squatting on the abdomen, and would neither eat nor drink. Death usually followed shortly. Nestlings were found with severe infections; sometimes they would be pushed from the nests and left to die. Wasielewski reports an epidemic which caused severe losses in his stock of experimental canaries.

Observations of the present writer on the disease in House Sparrows may be summarized as follows. Nestlings and juveniles in Nature are heavily infected with Coccidia. Although the daily discharge of enormous numbers of spores must certainly destroy large numbers of intestinal cells, many young birds survive their initial infections without apparent discomfort. Perhaps some do succumb to coccidiosis. Unless brought to our attention in epidemic form coccidiosis might go unnoticed as a "natural" cause of death for birds in Nature. There is certainly sufficient evidence, however, indicating that it can be a fatal disease under certain conditions. For example, in juvenile and adult sparrows which normally maintain chronic infections, apparently indefinitely, fatal infections can readily be induced by feeding heavy suspensions of infective spores. On the fifth or sixth day after inoculation, the bird exhibits characteristic symptoms. The feathers are fluffed out; the head is kept under the wing much of the time. There is weakness of the legs resulting in a squatting position, loss of appetite, and a drop in body temperature. When caged with others, an inoculated bird is irritable and pecks viciously at its fellows when disturbed. Death usually occurs about the seventh day after inoculation. An English Sparrow six days after inoculation is shown in Figure 5 (Plate 31). This bird died two days later. Under ordinary conditions in Nature, birds are not likely to ingest at one time such large numbers of infective spores as are given in these fatal, experimental inoculations. However, further investigation is required to determine to what extent natural conditions may permit the development of fatal infections. Passerine coccidiosis differs from poultry coccidiosis (and avian malaria also) in that relatively little resistance to subsequent infection is built up during the first infection of the young bird.

Figure 6 (Plate 31) shows a typical section of the upper intestine of a naturally infected sparrow killed late in the summer of its first year. The Coccidia are visible as dark, rounded bodies within the epithelial cells; there is no evidence of tissue response. Most of the parasites shown in Figure 6 are macrogametocytes ('female forms') at the characteristic stage for 3 p. m., at which time the host was killed. Had their normal growth

and development been permitted to continue, these forms would have been discharged in the fecal material about 6 p. m. as spores like those shown in Figure 1.

Chronic infections are common in domestic canaries, and as such are potential sources of trouble. In small pet shops in several cities of the United States and in several research laboratories, the writer has found from 15 to 50 per cent infection among canaries. In 1930, through the cooperation of the R. T. French Company, the writer was able to examine fecal samples of a few privately owned canaries. Ten per cent showed oocysts of *Isospora*. The birds were individual pets and had received routine care in the home for a year or more prior to the examination. Unfortunately, the phenomenon of daily periodicity in the appearance of oocysts was not known when this survey was made, and hence the samples were not taken at the most appropriate time of day. However, it is evident that canaries can maintain chronic infections for considerable periods under average care in private homes. The most likely explanation of this condition is that birds reinfect themselves from time to time with small numbers of infective spores, in spite of the daily cleaning of cage floor and perches. The spores of *Isospora* from birds are probably infective ten to twelve hours after being discharged from the host body. One should consider also the ability of the Coccidia to maintain themselves by continuous multiplication within the host tissues. In chronic, low-grade infections it appears that a balance is maintained between host and parasite, such that the host can go through life without apparent discomfort. Under routine caging conditions, captive birds may never have access to sufficient numbers of infective spores to cause trouble. It is always possible, however, that the balance may be upset by some extraneous factor. Certainly the chronic cases are carriers and constitute a reservoir for the propagation of the parasites.

There is no treatment known for coccidiosis in small birds. Preventive measures against infection involve cleanliness in the care of birds and the removal of obviously infected individuals, the point being to reduce repeated ingestion of infective spores. Spores are usually passed in large numbers between 3 p. m. and 9 p. m. (Boughton, 1933). They can readily develop, on the cage floor or in the water dish, so as to be infective, presumably, the next morning. It may sometimes be necessary to adjust the cleaning schedule in order to eliminate each daily batch of spores. Periodic microscopic examinations are helpful for estimating the degree of infection in a group of birds and for singling out offensive carriers.

EXAMINATION AND SOURCES OF BIRD HOSTS

The presence of Coccidia in birds can usually be determined by microscopic examination of the feces of living specimens and of the intestinal

contents or mucosal scrapings of killed specimens. Ordinary smear preparations are satisfactory for demonstrating the spores unless the infection is very light, in which case it may be necessary to resort to concentration by centrifugation. Often, however, one can take advantage of the daily periodicity exhibited by coccidial spores, which results in a natural concentration for certain hours of the day. As suggested above, the spores of *Isospora* in many passerine infections are to be found only in fecal material passed during the afternoon and early evening, with a peak at approximately 6 p. m. that is characteristic. In pigeons, which are parasitized by *Eimeria*, 80 per cent of the daily output of spores is to be found in the fecal material passed between 9 a. m. and 3 p. m. (Boughton, 1934). Examination of living birds has the following advantages: the birds need not be sacrificed; the spores will sporulate naturally when cultured, whereas they are often injured by an abnormal stay within a dead host; often the observer can make sure, by controlling the feeding of the bird, that the spores seen are derived from the host itself and not from material recently ingested. Killed specimens permit macroscopic examination of organs for gross lesions; microscopic examination of mucosal scrapings for the tissue stages of the parasite; and, if the bird is freshly killed, fixation of tissues for histological studies. In all examinations one should guard against the possibility of confusing multiplication stages of different parasites and the misinterpretation of the presence of a few extraneous spores. This last point is emphasized because mistakes have been made by some investigators who have reported the presence of Coccidia in certain hosts which in reality had only accidentally ingested spores belonging to another host.

Museums and zoological gardens are invaluable sources of bird parasites. Unfortunately, as far as Coccidia are concerned, these sources have been almost entirely neglected in the past. Expeditions sent out to collect birds actually destroy large numbers of associated Protozoa. It is to be hoped that the parasitologist will find it possible in the future to work in cooperation with public and private institutions in the study of Coccidia of birds. The present writer has been most fortunate in securing the aid of many ornithologists and institutions in his various studies. It is a pleasure here to acknowledge the cooperation of the following: Mr. Charles Stahnke of the Milwaukee Zoological Garden; Mr. S. Prentiss Baldwin and his staff of the Baldwin Bird Research Laboratory, Gates Mills, Ohio; Dr. Dora P. Henry of the University of Washington; the R. T. French Company, Rochester, N. Y.; Mr. Lee Crandall of the New York Zoological Gardens; Louis Ruhe, Inc., New York City; and the proprietors of various pet shops in several different cities.

DISTRIBUTION OF COCCIDIA AMONG BIRDS

The wholesale parasitism of a specialized group of vertebrates (Aves) by highly adapted Protozoa (Coccidia) presents an opportunity for studying a variety of problems of broad biological significance.

For example, there is the problem of parallelism in evolution of host and parasite. Sometime in their past histories the two genera *Eimeria* and *Isospora* have parted company. The accompanying list shows that Coccidia have been reported from several orders of birds. In most cases only one genus is found in any one order, and, in general, *Eimeria* is the dominant form in the lower orders, and *Isospora* in the higher. (The positive orders of birds are listed in accordance with Wetmore's classification.) Observations are lacking for several groups and only meager negative records are available for others. Perhaps ornithologists having special opportunities to examine certain bird groups can add to our knowledge of the distribution of Coccidia in birds. In the writer's opinion certain observations require verification, as is suggested in relevant notes in the following list.

Orders for which Coccidia have been reported

PELECANIFORMES — *Eimeria*

E. roscoviense (Labbé, 1893) in *Phalacrocorax aristotelis* (= *P. cristatus* = *P. graculus*), cormorant, by Labbé (1896 and 1899). *E. urnula* Hoare, 1933, in *P. carbo lugubris*, cormorant.

ANSERIFORMES — *Eimeria*

E. truncata (Railliet and Lucet, 1891) in kidney and *E. anseris* Kotlan, 1932, and possibly other species in intestine of *Anser anser*, goose. *Vide* Becker (1934).

FALCONIFORMES — *Isospora*

I. buteonis Henry, 1932, in five species of hawks and *I.* sp., Hegner and Chu, 1930, in kite and falconet. *Vide* Boughton (1938). Author's note: *Eumonospora tremula* Allen, 1933, amended to *Caryospora tremula* (Allen, 1933) Hoare, 1934, reported from *Cathartes aura septentrionalis*, Turkey Vulture, may very probably be a reptilian parasite.

GALLIFORMES — *Eimeria; Isospora* (?)

Several species of *Eimeria* in chickens, quail, turkey, ptarmigan, pheasant, peacock. *Vide* Becker (1934). *I. lyruri* Galli-Valerio, 1931, in *Lyrurus tetrix tetrix* (L.), Black Grouse, and *Tetrao urogallus urogallus* L., Capercaillie. *Vide* Galli-Valerio (1931, 1932). Author's note: Because of the preponderance of records of *Eimeria* for this order and the meager details reported by Galli-Valerio, confirmation of the occurrence of *Isospora* in the two hosts listed is greatly to be desired.

GRUIFORMES — *Eimeria*

E. paludosa (Leger and Hesse, 1922) in *Fulica atra atra* L., Gray-black Coot, and *Gallinula chloropus chloropus* (L.), Moor-hen. Author's note: This coccidian was originally placed in a new genus, *Jarrina*, but it properly belongs in *Eimeria*, as Hoare (1933) has shown.

CHARADRIIFORMES *Eimeria; Isospora*

E. roscoviense (Labbé, 1893) in nine species belonging to the families Charadriidae, plovers, etc., and Scolopacidae, sandpipers, etc. *Vide* Labbé (1896, 1899). *Isospora* in two species of Charadriidae. *Vide* Boughton (1938). Seven species of family Laridae, gulls and terns, reported negative by Labbé (1893a). Author's note: Further observations on birds of this order would be of considerable interest because both *Eimeria* and *Isospora* have been reported.

COLUMBIFORMES *Eimeria*

E. labbeana Pinto, 1928, and *E. columbarum* Nieschulz, 1935, in the domesticated pigeon. *Vide* Becker (1934) and Nieschulz (1935).

CUCULIFORMES *Isospora*

Isospora reported from one species in each of two families. *Vide* Boughton (1938).

STRIGIFORMES *Isospora*

I. buteonis Henry, 1932, in two species and *I. henryi* Yakimoff and Matikaschwili, 1932, in a third. *Vide* Boughton (1938).

CORACIIFORMES *Isospora*

Isospora reported from four species representing three families. *Vide* Boughton (1938).

PICIFORMES *Isospora*

Isospora reported from six species representing two families. *Vide* Boughton (1938).

PASSERIFORMES *Isospora*

Isospora reported from 147 species and subspecies representing 27 families. *Vide* Boughton (1938). Author's note: Labbé (1893a) reports *Eimeria roscoviense* from the White Wagtail (*Motacilla alba*); this observation has not beeen verified by other workers although Labbé (1893) and also Laveran (1898) report *Isospora* in this host.

ORDERS FOR WHICH COCCIDIA HAVE NOT BEEN REPORTED

Struthioniformes (1); Rheiformes; Casuariiformes (2); Apterygiformes; Tinamiformes; Sphenisciformes; Gaviiformes; Colymbiformes (3); Ciconiiformes; Psittaciformes (4); Caprimulgiformes; Micropodiformes (5); Coliiformes; and Trogoniformes.

Author's note: Limited negative records are available for the five orders designated by numbers. These are: (1) two Ostriches negative (author's observation); (2) one Cassowary, one Emu negative (author's observation); (3) negative record for *Podiceps cristatus cristatus* (L.) (= *Vanellus cristatus* Meyer and Wolff), Great Crested Grebe, by Labbé (1893a); (4) several parakeets, parrots and macaws negative (author's observation); and (5) one hummingbird negative (author's observation). There are no observations on the remaining orders.

There is also the problem of host-parasite specificity. Barnyard chickens are continually exposed to spores of *Isospora* dropped by sparrows and yet they do not become infected with species of that genus. Similar opportuni-

ties for quail to become infected with spores from passerine birds must exist in Nature. Specificity is marked for the genera of avian Coccidia. Perhaps it will prove to be so for species also. Species determination in Coccidia is more difficult, in the writer's opinion, than some describers of species have chosen to make it. Does each bird species have its own coccidian species or can one of the latter infect a variety of birds? These questions have more than academic interest. Answers to them would shed light on the problems dealing with the invasion of new territories by introduced bird species and the ability of several host species to occupy the same geographical range. A wealth of information regarding the evolution and distribution of the hosts is already available in the archives of the ornithologist. When the Coccidia of birds have been more thoroughly described and the results of cross-infection experiments are available for analysis, the parasitologist may be able to offer suggestions on relationships of avian species based on a knowledge of their parasites.

The widespread distribution of Coccidia among bird groups suggests the use of these parasites and hosts for studies on several other problems, which may be mentioned here briefly. Because Coccidia of wild birds represent natural parasites living in association with hosts which have not been subjected to such artificial alterations of physiology or environment as are often imposed upon domesticated animals, studies on coccidiosis in wild birds may disclose features of the disease not readily revealed, for example, in poultry work. Of interest to students of human and animal diseases are the problems of host resistance and immunity to sporozoan diseases, including malaria as well as coccidiosis. Experimental work on the genus *Isospora* in relation to its many avian hosts may prove of significance. Also, as pointed out above, there is sufficient evidence to condemn the genus *Isospora*, at least in certain cases, as a pathogenic parasite of small birds; as such it should be studied with an aim toward treatment and control.

REFERENCES CITED

BECKER, E. R.

1934. Coccidia and coccidiosis of domesticated, game and laboratory animals and of man. Ames, Iowa, 147 pp.

BOUGHTON, DONALD C.

1929. A note on coccidiosis in sparrows and poultry. Poult. Sci., **8**: 184–188.

1933. Diurnal gametic periodicity in avian *Isospora*. Amer. Journ. Hyg., **18**: 161–184.

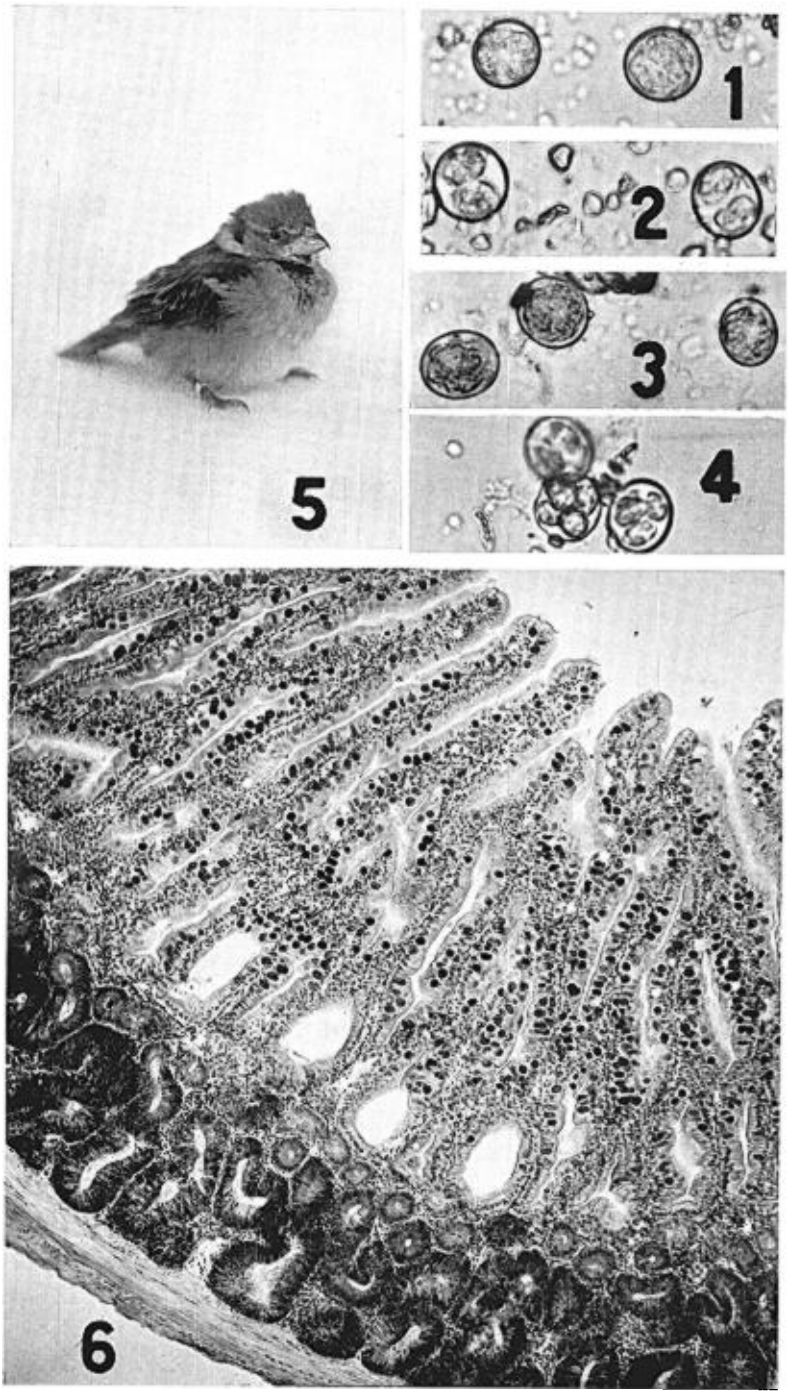
1934. Periodicity in the oocyst-production of the pigeon *Eimeria*. (Abstract.) Journ. Parasitol., **20**: 329.

1937. Studies on oocyst-production in avian coccidiosis. II. Chronic Isosporan infections in the sparrow. Amer. Journ. Hyg., **25**: 203–211.

1937a. *Isospora volki* sp. n., a new avian coccidian. Journ. Parasitol, **23**: 97–98.

1938. Avian hosts of the genus *Isospora* (Coccidia). Ohio Journ. Sci. (in press).

CONDORELLI, M., AND FIORE, C. DE
1892. Un caso di sporospermosi intestinale nel *Coccothraustes vulgaris*. Boll. Soc. Rom. Studi Zoolog., **1**: 68.
GALLI-VALERIO, B.
1931. Notes de parasitologie. Centralbl. f. Bakt., etc. I. Orig., **120**: 98–106.
1932. Notes de parasitologie et de technique parasitologique. *Ibid.*, **125**: 129–142.
HADLEY, P. B.
1910. Studies in avian coccidiosis. III. Coccidiosis in the English Sparrow and other wild birds. *Ibid.*, **56**: 522–523.
JOHNSON, W. T.
1923. Avian coccidiosis. Poult. Sci., **2**: 146–163.
LABBÉ, A.
1893. Sur les coccidies des oiseaux. Comptes Rend. Acad. Sci., Paris, **116**: 1300–1303.
1893a. Sur les coccidies des oiseaux. *Ibid.*, **117**: 407–409.
1896. Recherches zoologiques, cytologiques et biologiques sur les coccidies. Arch. Zool. Exper., ser. 3, **4**: 517–654.
1899. "Sporozoa," in Das Tierreich, **5**: 71–72. Berlin.
LAVERAN, A.
1898. Sur les modes de reproduction d'*Isospora lacazei*. Comptes Rend. Soc. Biol., Paris, **5** (10): 1139–1142.
LEGER, L., AND HESSE, E.
1922. Coccidies d'oiseaux palustres. Le genre *Jarrina*n.g. Comptes Rend. Acad. Sci., Paris, **174**: 74.
NIESCHULZ, O.
1935. Ueber Kokzidien der Haustauben. Centralbl. f. Bakt., etc. I. Orig., **134**: 390–393.
HEGNER, R. W., AND CHU, H. J.
1930. A survey of protozoan parasites in plants and animals of the Philippine Islands. Philippine Journ. Sci., **43**: 451–480.
SJÖBRING, N.
1897. Beiträge zur Kenntnis einiger Protozoen. *Ibid.* **22**: 675–680.
SMITH, T., AND SMILLIE, E. W.
1917. Note on coccidia in sparrows and their assumed relation to blackhead in turkeys. Journ. Exp. Med., **25**: 415–420.
TYZZER, E. E.
1929. Coccidiosis in gallinaceous birds. Amer. Journ. Hyg., **10**: 269–383.
TYZZER, E. E., THEILER, HANS, AND JONES, E. E.
1932. Coccidiosis in gallinaceous birds, II. A comparative study of species of *Eimeria* of the chicken. *Ibid.*, **15**: 319–393.
WASIELEWSKI, T. VON
1904. Studien und Mikrophotogramme zur Kenntnis der pathogenen Protozoen. 1 Heft. III. Ueber den Erreger einer Coccidienseuche bei Vögeln (*Diplospora lacazei*), 69–88. Leipzig.
WETMORE, ALEXANDER
1934. A systematic classification for the birds of the world, revised and amended. Smithsonian Misc. Coll., **89** (no. 13): 1–11.



AVIAN COCCIDIOSIS

EXPLANATION OF PLATE 31

Fig. 1.—Unsporulated spores (oocysts) of *Isospora* from the domestic canary. × 475.

Fig. 2.—Sporulated spores (oocysts) of *Isospora* from the domestic canary. × 475.

Fig. 3.—Unsporulated spores (oocysts) of *Eimeria* from the domestic pigeon. × 475.

Fig. 4.—Sporulated spores (oocysts) of *Eimeria* from the domestic pigeon. × 475.

Fig. 5.—English Sparrow with coccidiosis. Six days after inoculation with infective spores of *Isospora*.

Fig. 6.—Section of intestine of English Sparrow parasitized by Coccidia of genus *Isospora*. × 80.

[Photographs by J. A. Carlile.]

Department of Zoology,
University of Georgia
Athens, Georgia