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A STUDY OF THE BODY TEMPERATURE OF BIRDS

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INTRODUCTION

The subject of the body temperatures of the many and varied species that compose the great vertebrate class of birds is one that in the past has been rather slightly treated by those interested in avian physiology. Statements to the effect that the bodily temperatures of birds are higher than in others in the group of classes composing the Vertebrata, are current in many zoologies and text books, but on the whole, literature gives few definite statements of fact on the subject, and observations have been restricted to a comparatively small number of species. In the course of other work many hundreds of birds have been handled in the flesh by the present writer, and after some thought methods were devised for the taking and recording of body temperatures in as accurate a manner as possible. This was a little known field of endeavor and at first no guides as to method were available, so that mistakes were made, and early records had to be abandoned. Continued experimentation led to definite methods that promised accuracy, and it is upon these that the following account is based. The results of studies covering the period from January, 1912, to October, 1919, are included herewith, giving a total of 1,558 records covering observations on 327 species of birds distributed among 50 families. If the number of observations seems small compared to the length of time involved it must be considered that the taking of temperatures was not always feasible as the difficulties attending the task were manifold and varied.

The results of this work are embodied in a series of tables which form the foundation upon which this report is based. In addition to the 327 species of birds on which observations regarding body temperature have been made by the writer personally, a supplementary compilation has been given (in table 5) embodying published records on this subject for other species, in order to render this account of the body temperatures of birds as complete as practicable. In this final table records are given for 89 forms, so that in the following pages may be found definite statements regarding the temperatures of 416 species of birds. It is hoped that the work of securing such records may be continued until a much greater amount of information covering many more species is available.

It was the original intention to incorporate in this paper a table giving in detail the individual records upon which the work has been based. Such a course was desirable as it would have furnished a mass of data far greater than any hitherto available for those who may be interested in using such information in lines of research other than that in which it has been utilized here. In addition it would have given opportunity to check up more carefully the deductions that I have made. Cost of printing of tabular matter has proved so high at the time of publication that it has been necessary to omit such a detailed statement and to supply the records only in a condensed form. The table itself is, however, deposited in the files of the Smithsonian Institution and may be consulted by those interested in using it.

From his studies in the subject of avian body temperatures the writer has ventured to come to certain conclusions and deductions, some in accordance and some at variance with modern ideas as previously accepted. If these seem sufficiently substantiated to meet the approval of others, then may the time and labor required in the compilation of these data be deemed justified. The following pages are respectfully submitted for attention, with the hope that part if not all of this labor may gain the stamp of approval from those who may be interested in such lines of research.

In carrying on these investigations the writer has been indebted to the Smithsonian Institution for a grant of seventy-five dollars from the Hodgkins Fund, for the purchase of specially constructed thermometers required, and for certain other minor expenses incurred.

METHOD OF SECURING AVIAN BODY TEMPERATURES

In recording the body temperatures of birds it was necessary to work with thermometers that permitted a considerable range in registration as it was found that the degree of bodily heat was high or low according to the species in hand. All records were made in the Fahrenheit scale by means of clinical thermometers similar in form to those used by physicians. For the present investigation it was necessary to have these instruments specially made to give accurate registration ranging from 95°+ to 115°+. Ordinary clinical thermometers do not register above 110°+ so that they could not be utilized, for certain passeriform species frequently have temperatures ranging above that figure.

While engaged in field work these special thermometers were carried constantly in suitable carrying cases. When a bird was shot a temperature reading was taken when the specimen could be reached immediately. If there was delay in retrieving for any reason, an accurate temperature record could not be made, so that it was possible to secure records in less than one-half of the birds that were collected. In taking temperatures of specimens of small or medium size the thermometer was placed in the opened mouth of the bird, and worked down until the lower end was entirely within the cavity of the thorax, usually until it reached the proventriculus. With birds of larger size the reading was taken through the anus, with the thermometer thrust in through the cloaca well into the canal of the large intestine. In either case it was necessary to penetrate the body cavity to secure a correct reading. The peripheral circulation of birds is poor, so that often there may be a difference of two to five degrees between the temperature of the upper part of the oesophagus and that of the body cavity proper. A similar variation was noted between the temperature of the cloaca and the large intestine above it.

The thermometers used were self-registering, and were so constructed that they reacted immediately to any increase in heat. The highest point of a reading was reached in a very few seconds, but to insure accuracy the instrument was held in position for a period ranging from half a minute to a minute. After each reading the thermometer was shaken down to be ready for instant use when needed again.

Temperatures were read to tenths of a degree, and were transcribed at once in a note book opposite the name of the bird, together with the date and other needed information. In each case the time of day was noted to the nearest quarter hour. Thus a temperature taken at five minutes past ten in the morning was recorded as 10.00 a. m. and one at ten minutes past ten as 10.15 a. m. Further refinement in recording the time of day was considered useless, as save on certain meridians there is always slight variation between the actual time as shown by the height of the sun, and the time adopted for universal local use as a matter of convenience. The time of observations recorded during the continuance of the so-called "daylight saving" regulations of 1918 and 1919 has been corrected in each instance to normal.

In order to be prepared at all times to secure temperature records of birds it was necessary to have thermometers constantly at hand while in the field. The physical labor involved in field work at times is arduous, so that though carrying cases of an improved type were used many instruments were destroyed in spite of every precaution. Some were broken through accident, others were crushed by birds while records were being secured, and a few were lost. In all a considerable number were used in securing the records given.

The records of temperatures of birds secured have been taken throughout the year, but the localities where this work has been carried on have all been in the limits of the United States in temperate regions where extreme cold in winter has not been encountered. As a matter of fact very few of the observations have been made at a time when the temperature of the air was below +25° Fahr. For this reason it has not been necessary to adopt means for warming the thermometers, or for keeping them warm, immediately previous to their use. During the early course of the observations recorded herein experiments were made in heating thermometers by holding them in the mouth of the observer when it seemed probably that they were to be used in a short time. In this way the temperature of the bulb and the glass for a short distance above was warmed to +98°, more or less (depending upon the condition of the mouth). It was soon found however that the results gained with warm and cold thermometers were so nearly identical that it was impossible to distinguish between them. Where observations on the body temperatures of birds are to be made at times when the air is at zero Fahrenheit, or even lower, it would seem probable that it would be necessary to take some steps to use thermometers that had been previously heated at least to a slight degree. This fact may be readily determined by observation. It is probable that save in the most extreme cold weather error from using unwarmed instruments would not amount to more than a few tenths of a degree.

The observations recorded in the tables at the close of this paper are to be regarded at best as approximations to the actual temperature of the birds handled. In treating data of this nature taken by force from the lower animals we can only assume that we are correct in our observations. Through experience we may establish what we consider as the normal limit of variation, but in many cases it is difficult to be assured that we are absolutely correct. Through long experience the writer believes that the records presented are a portrayal of the conditions as nearly correct as may be with the instruments used.

DIURNAL RHYTHM IN TEMPERATURE

The question of the diurnal rise and fall of temperature in a few species of birds and animals has been carefully investigated by Simpson and Galbraith.[1] These authors, on two different occasions, secured records of the body temperature of living gulls, starlings, sparrow-hawks, a kestrel, thrushes, several owls, and domestic fowls, ducks and pigeons, at three-hour intervals for period of a week. The results obtained when tabulated gave curves that agree essentially with similar curves taken for man and other mammals. (Variation in the time

TABLE I.—*Time of maximum and minimum temperatures in birds*
(Taken from Simpson and Galbraith)

Species	Time of average maximum temp.	Time of average minimum temp.	Species	Time of average maximum temp.	Time of average minimum temp.
Domestic fowl ♂	3.00 p.m.	3.00 a.m.	"Hawk"	4.00 p.m.	1.00 a.m.
Domestic fowl ♀	3.00 p.m.	3.00 a.m.	"Hawk"	4.00 p.m.	1.00 a.m.
Bantam fowl ♂	6.00 p.m.	12.00 a.m.	Thrush	12.00 p.m.	12.00 a.m.
Bantam fowl ♀	6.00 p.m.	3.00 a.m.	Thrush	1.00 p.m.	1.00 a.m.
Domestic duck ♂	9.00 a.m.	3.00 a.m.	Starling	3.00 p.m.	12.00 a.m.
Domestic duck ♀	12.00 p.m.	3.00 a.m.	Starling	6.00 p.m.	3 00 a.m.
Domestic pigeon ♂	6.00 p.m.	12.00 a.m.	Starling	3.00 p.m.	3.00 a.m.
Domestic pigeon ♀	12.00 p.m.	12.00 a.m.	Owl	3.00 a.m.	9.00 a.m.
"Seagull"	3.00 p.m.	12.00 a.m.	Owl	4.00 a.m.	10.00 a.m.
"Seagull"	12.00 p.m.	3.00 a.m.	Owl	4.00 a.m.	7.00 p.m.
Jackdaw ♂	1.00 p.m.	1.00 a.m.	Owl	4.00 a.m.	1.00 p.m.
Jackdaw ♀	1.00 p.m.	1.00 a.m.			

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[1] Journ. of Phys., Vol. XXXIII, 1905, pp. 225-238.

of high and low temperature in individuals belonging to the same species, as shown in the table on page 5, are probably to be explained on the grounds of individual temperament in the birds under experiment. Thus a bird that soon became accustomed to handling would give a slightly different series of readings from one that remained wild and that struggled violently whenever approached.)

In the case of those species normally active during the hours of daylight a constant diurnal rhythm was indicated, with a gradual rise until late in the afternoon and then a corresponding decrease until early in the morning. In owls, species of nocturnal habit, the temperature curves were reversed, the highest point being observed late at night and the lowest during the day. It was found on the whole that the temperature curves of daylight-loving species were similar to those of diurnal mammals save that the point of highest temperature in the birds came earlier in the afternoon and that of low temperature earlier in the morning.

Hildén and Stenbäck[1] record a series of experiments in which birds were confined in a dark room and their activities regulated by means of artificial light. Light was turned on from 6 p. m. to 6 a. m., with a more brilliant illumination from 9 p. m. to 3 a. m. to correspond to the brighter portion of the middle of the normal day. After the second day the diurnal birds studied in general adapted themselves to this change in condition in such a way that the temperature rhythm was reversed, the highest point in the record for each twenty-four hours coming after midnight instead of afternoon. When the experiments were terminated and the birds again led a normal life in relation to daylight the temperature curves at once adjusted to the normal rhythm.

In studies made by the present writer the range of diurnal temperature is well shown by records for certain of the owls. Thus a male barn owl (*Aluco pratincola*) killed at 3.00 p. m., as it flew from a perch in a cottonwood tree had a temperature of 101.9°. The day was bright and clear and the bird had in all probability been at rest since early morning. Another male, shot at 8.30 p. m., while quartering back and forth across a level flat near the Gila River in Arizona, showed a body heat of 105.0°. This bird was seen coursing about for several minutes and had evidently been hunting for food for some time. The variation in the screech owls (*Otus asio*) also is instructive in connection with the same points. A male and a female taken by hand at 3.30 p. m., from a low pine at the edge of a swamp in

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[1] Skandinavisches Arch. für Phys. Bd. 34, 1916, pp. 382-413.

western Florida, gave temperatures of 101.8° and 102.7° respectively. A second male shot an hour later registered 100.7°. These birds had been resting quietly for the entire day. In direct contrast is the condition found in a male killed by moonlight at 8.15 p. m. in the Chiricahua Mountains in southeastern Arizona. On this evening screech owls had been actively calling for over an hour before this one was secured. The bird taken had a temperature of 105.4°. A female secured in the Dragoon Mountains, Arizona, at 8.45 a. m., not long after it had retired for the day, registered a body heat of 105.3°. In the case of those species active during the hours of daylight the difference is less marked, due in large part to the fact that the majority of birds examined had been killed during the period of their normal activity when little or no temperature range was evident that could be correlated directly with time. However, it is possible to cite a few cases showing this regular variation.

The series of mourning doves (*Zenaidura macroura*) obtained may be discussed as pertinent in the matter of diurnal variation in birds of diurnal habit. In four males secured between 5.00 a. m. and 5.45 a. m., the range in temperature is from 108.0° to 109.8°, the four records giving a mean of 108.9°. Five other birds shot between 5.00 p. m. and 6.00 p. m. under similar conditions give a variation of from 109.3° to 110.4° with a mean of 109.6°. An average difference of .7° is thus shown. All of these birds were feeding but in the first set killed early in morning the body heat was still comparatively low.

As stated above, most of the records were secured at hours when the temperature was naturally high so that little time variation is shown. However, the following may be quoted in addition to the above. An ash-throated flycatcher (*Myiarchus cinerascens*) taken at 7.30 a. m. had a temperature of 108.6°. Another taken at 10.00 a. m. registered 110.0° and a third shot at 11.00 a. m. showed a body temperature of 111.8°. All of these birds were males. A male Canadian warbler (*Wilsonia canadensis*) shot at 7.30 a. m. registered 106.7° and another taken at 9.45 a. m. gave a temperature of 107.6°. Females of the same species taken at 7.30 and 9.00 on the same morning had a bodily heat of 107.7° and 107.0° while a third bird of the latter sex killed at 12.00 p. m. showed 108.3°.

The daily increase in bodily temperature in our smaller birds may be exemplified also by the following: On September 12, 1919, at Plummers Island, Maryland, the writer spent the day in observing small birds, many of which were in their southward migration. There had been a heavy rain the previous evening, and later high wind had come up with a considerable fall in temperature. The early morning was damp and cold so that insectivorous birds were more or less inactive until the sun was well up in the sky. As the air became warmer the birds, correspondingly, became more sprightly. A female magnolia warbler (*Dendroica magnolia*) secured at 8.30 a. m., had a bodily temperature of 107.0°. At this time birds of similar habit were just commencing to move about and feed. A male of the same species shot at 9.30 a. m. had a temperature of 108.2° and a second male taken at 10.15 a. m. had a temperature of 108.3°. Other warblers taken between 9.00 a. m. and 10.30 a. m. gave records similar to the last. Thus a female bay-breasted warbler (*Dendroica castanea*) shot at 9.15 a. m. registered 108.8° and a male killed at 10.00 a. m. registered 108.7°. A male black and white warbler (*Mniotilta varia*) secured at 9.15 registered 108.5°. In the observations of this forenoon it was noted that the red-eyed vireo (*Vireosylva olivacea*) was astir much earlier in the day than the warblers. This activity apparently was reflected in the body temperature as a female taken at 9.15 gave a record of 109.7°, a reading distinctly higher than that of the warblers taken at the same time, although average temperatures for the two groups on the whole are about the same.

In perusal of the data used in preparing this paper many cases are found of range in temperature not correlated with time. These, however, cannot be taken as destroying the value of those instances where early and late readings were available that show a distinct rhythm or increase from early to late. As stated above, the bulk of the records are made during the period of high activity when the bodily temperature approaches a maximum. Range in temperature then is to be attributed to other causes. Had records made early in the morning been available in all of these cases there can be no question but that an increase in body heat correlated with time would have been shown.

The daily variation in temperature is much more in birds of small size than in those of greater bulk. Thus Simpson and Galbraith[1] found the daily range in the "thrush" (*Turdus merula?*) to be from 6.8° to 7.5°, in starlings (*Sturnus vulgaris*) from 5.2° to 7.2°, while in the domestic fowl it amounted to 1.9° and in the domesticated duck from 1.6° to 1.8°. The marked difference in these cases is noticeable.

The diurnal variation in temperature that has been noted may be attributed directly to the metabolism of the individual as reflected by its activities. With movement and the digestion of food heat is generated. Although a part of this is dissipated through the usual

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[1] Journ. of Phys., Vol. XXXIII, 1905, p. 237.

channels there is a gradual accumulation that warms the tissues and thus is held. This accumulation reaches its height near the close of the day's activities. At night the body is inactive so that at once the production of heat is lessened. The stored up heat energy of the day therefore is slowly dissipated and is replaced only in part, so that there is a steady lessening of the body temperature until the beginning of a new period of activity. With this there is a sudden jump again in the production of heat and a corresponding increase in body temperature. In the case of our small birds that migrate by night the increased activity induced must of necessity make a decided break in the daily temperature rhythm. No data on this point is available, but it must be supposed that the prolonged flights that are made tend to bring the temperature above the normal for individuals at rest. A part of the accumulated heat secured during the day may be attributed to the continual ingestion and digestion of food, as the nutriment thus secured would be provocative of renewed energy. As digestion is rapid the stomach is soon empty when no food is being taken in so that the temperature of night-flying migrants may be held down to some extent by a decrease without constant renewal in the stored nutriment in the tissues.

Although in birds there seems at present no indication of a marked seasonal variation in degree of temperature yet we may suppose that the total amount of heat produced by the body may be slightly more in summer than in winter. As the period of daily activity is one of high temperature (considered on the basis of diurnal species) it will be readily seen that that period of activity is much longer, in species living north or south of the tropics, during a day in June than during a corresponding period in December. There is therefore a contrast in many birds in the total amount of heat produced in the seasons of summer and winter even though no birds are known to hibernate. Although it may be supposed that the increased activity in summer among our small birds may be offset in part by brief siestas taken in the heat of the day, still it would not seem that the difference between the two seasons would be anywhere near compensated. The quantity of body heat produced during the summer period may therefore be considered greater than for the winter.

VARIATION IN TEMPERATURE IN RELATION TO SEX

Variation in body temperature correlated with sex has been well established in mammals, where the temperature of the female is stated to average slightly higher than in the male. Thus Roger[1] records a

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[1] Richet's Dict. de Phys., Vol. III, 1898, p. 96.

slightly higher temperature in girls than in boys, although the subjects of experiment were too young to exhibit striking sexual differences. Martins[1] notes a higher temperature in females than in males of the domestic duck, and Simpson and Galbraith[2] make similar observations with regard to other birds in those cases in which the sex of the individuals in hand was known at the time of experiment or was determined later by dissection. A few observations made by Hildén and Stenbäck[3] do not bear this out, as they cite higher temperatures in males than in females. Apparently these authors misunderstood Simpson and Galbraith as they state that these observers also record higher temperatures in males than in females although the reverse is true.

In my own observations there is found in some species a convincing agreement with the findings of Simpson and Galbraith, Martins and Roger in this matter, as where a sufficient amount of data is available the average temperature of the female is usually slightly higher than that in the male. Certain exceptions to this rule will be noted later. The difference in favor of the female where present is rather slight, being usually only a part of a degree. Thus in the green-winged teal (*Nettion carolinense*) the temperature of the male (19 records) averaged 106.1°, of the female (8 records) 106.6°, a difference of .5° in favor of the female. In Traill's flycatcher (*Empidonax trailli*) males (6 records) averaged 108.0° and females (4 records) 108.6° a difference of .6°. Numerous other instances will be noted in table 3 but need not be cited here as the two given will serve to exemplify the statement made above.

The present work, however, has emphasized the fact that in certain groups the temperature of the male on the average is distinctly higher than in the female. Apparently this is true in the herons (*Ardeidae*) as in three species in that group we have the following averages: Great blue heron (*Ardea herodias*) male (2) 104.8°, female (2) 103.7°; snowy heron (*Egretta candidissima*) male (5) 104.8°, female (8) 104.0°; and black-crowned night heron (*Nycticorax naevius*) male (3) 103.5° and female (2) 102.6°. A similar difference is best shown perhaps in certain of the shore-birds, as the phalaropes, where it is indeed striking. In the northern phalarope (*Lobipes lobatus*) males (9 records) averaged 107.6° and females (17) only 106.6°. Males (10) of the Wilson's phalarope (*Steganopus tricolor*) gave 106.3°, and females (18) only 105.7°. The same

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[1] Journ. de Phys., 1858, p. 19.

[2] Journ. of Phys., 1905, p. 237.

[3] Skandinavisches Arch. für Phys., Bd. 34, 1916, pp. 382-413.

holds true of the avocet (*Recurvirostra americana*) where 14 males averaged 106.6° and 12 females only 104.9°. A good series of readings for the black-necked stilt (*Himantopus mexicanus*) showed the same average (105.8°) for both males and females. Through the family Scolopacidae the general average on the whole showed a balance in favor of the males save in a few instances. Among the Charadriidae two species, the black-bellied plover (*Squatarola squatarola*) and the killdeer (*Oxyechus vociferus*) show a balance in favor of the female, while in the snowy plover (*AEgialitis nivosa*) and the mountain plover (*Podasocys montanus*) the reverse is true. In some passerines the two sexes average about the same in degree of bodily heat. Thus in the yellow-headed blackbird (*Xanthocephalus xanthocephalus*) males (29 records) averaged 108.3° and females (18 records) 108.2°. Similarly in the house finch (*Corpodacus mexicanus*) males (20 records) averaged 108.9° and females (7 records) 108.8°. In these species we have, therefore practically an agreement in both sexes as the difference noted, amounting to only one-tenth of one degree may well result from accident in securing the records.

It appears therefore that in many species of birds temperatures of females are higher than those of males. In a considerable number, however, the two sexes average about the same, though with more information it may be found that there is a slight difference in favor of the females. In a few cases there is found a higher temperature in males than in females. This last is true in the Ardeidae, the Phalaropodidae, the Scolopacidae and in part in the Charadriidae.

In the average run of species of homoiothermal animals the difference in temperature between male and female may be ascribed to the needs of sexual activity and reproduction. At least this higher temperature seems correlated with certain phases of reproduction. In many birds the care of the young devolves upon the female and she has the higher body temperature. In the Phalaropodidae, on the contrary, it has long been known that the duties of incubation and the rearing of the young fall to the lot of the male, so that in connection with this it would appear that he has developed a higher body temperature than the female. In the case of the Scolopacidae the writer is prepared to state from his own observations that incubation and brooding of the young may fall largely upon the male in the willet (*Catoptrophorus inornatus*) and it is suspected (though not yet proven) that this may be true of the majority of the species in this family. Males of this group examined in breeding season often exhibit areas upon the lower surface of the body bare of feathers where the skin is thickened and vascular as in birds that have been incubating. This is true also in the Recurvirostridae. In the case of the herons definite knowledge is lacking so that I venture no statement in regard to their sexual aberration in body temperature.

Admitting that the incubation of eggs and the brooding of young necessitate a higher temperature in the parent, it appears that in those species where this duty falls upon the female she has a higher average temperature than the male. Where the male performs these duties the reverse is true. As in many cases, in particular among the passerines, these cares are shared about equally by both parents, we may expect in such species a close approximation in body temperature in the two sexes, a supposition that is well borne out by the data given in table 3. On the basis of this reasoning it may be permissible to theorize further with regard to the shore birds. In many species here the cares of the family are undoubtedly shared by both parents though as has been said, in a good many forms this duty falls on the males alone. However, in those that have been investigated, the greater part show a higher temperature in males than in females. In this group then, where the male is the home drudge taking over all the family cares and leaving the female in freedom after the deposition of the eggs the condition may be assumed to be a primitive one. Males of other species have become emancipated in part from this domestic yoke so that the task of rearing offspring is shared in part by their spouses, though this has occurred so recently that adjustment is not complete and the body of the male still develops a higher average temperature. Such statements however must be taken with reserve and cannot be considered as applying to other groups of birds.

EXTERNAL TEMPERATURE IN RELATION TO BODILY HEAT

In the cold-blooded vertebrates heat generation within the body is slow, while the processes that act in controlling radiation are imperfectly active. In consequence the animal chills or is warmed in close harmony with fluctuations in heat of its surrounding element. Such creatures of necessity are sluggish when they encounter low temperatures and become more active when well warmed. When cooled below a certain point they become torpid and dormant. It would seem that animals of such habit have the means utilized in equalizing or resisting high temperatures better developed than those that might assist them in overcoming cold. Otherwise turtles, frogs, or lizards would be killed when basking in the intense heat of a midsummer sun. This equalization of heat must be accomplished largely by the lungs in Reptilia, as skin glands that might serve this purpose are absent. The amphibians, with their poorly developed lungs, gain the same end by evaporation and radiation through their moist glandular skins. There is a definite limit, however, to the degree of heat that these cold-blooded animals may endure. In Arizona I have seen a Gila monster (*Heloderma suspectum*) fresh from the desert perish when the sack in which it was confined was inadvertently left exposed in the noonday sun for a period of fifteen or twenty minutes.

Although in these cold-blooded animals there is a direct reaction to external cold, with birds the case is entirely different. Some investigators in making studies of avian body temperatures have been careful to record the temperature of the atmosphere and to cite this data in connection with their other records. After due consideration I have not done this as I do not consider that there is any constant relation between the normal temperature of the surrounding medium and that of the body cavity in birds. After making careful records of avian body temperatures at all seasons of the year, I am, in light of the records available at present, unable to recognize any constant difference between body temperatures made in the same species at seasons of marked heat or marked cold. Where the individual is in normal health and is sufficiently supplied with food, the agencies of temperature control will tend to maintain an even body heat. Any variation that may occur, other than that incident to the daily rhythmic rise and fall of body heat, may be attributed to some other condition that under normal conditions would disappear within a comparatively short period through a readjustment of the bodily functions. Any bird may, through inclement exposure, become thoroughly chilled and so have a greatly reduced temperature but such a condition cannot be considered normal. Thus an immature white-faced glossy ibis (*Plegadis guarauna*) exposed for half an hour to a severe rain and hail storm became so chilled that it could scarcely stand and shook violently with cold. When warmed with hot towels and dried out once more it was restored to its normal condition and soon was running about on the floor of the laboratory so far recovered that it mischievously began to torment other smaller birds confined with it.

Birds, however, may be divided roughly into two classes with regard to their ability to adjust to external temperature. The first category includes those able to withstand any reasonable degree of cold, while in the second are included those species that migrate to regions where cold in any degree is not encountered at the approach of inclement weather. Broadly speaking, the question of difference between these two groups is not so much one of change in external temperature as it is of food supply. Thus species that feed on flying or crawling insects, or on fresh fruits, must leave before a supply of this food fails. Others that search out insects in hibernation, dried berries, or live on seeds, pay little attention to the approach of chilling weather. The question seems on the whole one of adequate food supply, that the organism may receive its life-giving elements constantly. However, forms that habitually experience cold weather during a part of the year must have a greater development of reaction for temperature regulation than do those of the other groups. Some species from the category of those accustomed only to a hot climate may experience severe cold without harm if supplied with proper food. Others succumb under these unusual conditions. Thus, Mr. N. Hollister, Superintendent of the National Zoological Park, informs me that red, blue and yellow macaws (*Ara macao*) confined in large flight cages, remain outdoors at Washington, D. C., during the winter in perfect health. An allied species however, the blue and yellow macaw (*Ara ararauna*), was unable to withstand the cold and perished, though it throve during warmer weather. From information available it seems that both of these macaws in their normal range inhabit the tropical zone, and are subjected to the same general conditions of life.

There is a marked decrease in body temperature where food is not obtained in suitable amount while the bird is subjected to cold. This may be seen readily among our smaller insectivorous birds where they are caught by a sudden return of cold weather during their northward migration in spring. Decrease in bodily temperature from this cause may be illustrated by the following:

During the latter part of May, 1916, I was stationed at a small field laboratory in Utah near the point where Bear River enters Great Salt Lake. For several days preceding the evening of May 23 the weather had been mild, and small migrant birds that nested in the mountains had left the middle of the valley for the uplands. On the night in question a cold wind with a driving rain came on and continued until ten the following morning, and there was little rise in temperature of the air until late afternoon. A few Audubon's, pileolated and yellow warblers and an occasional small flycatcher appeared in the willows, and until noon there was a steady flight of swallows down the river toward some haven on the flats below. To escape the driving wind, the latter flew low over the river or beat along behind shelter of the willows that fringed the stream. Hundreds passed, travelling in little flocks so that for a time there seemed to be no end of the constant procession of passing birds. These small birds were not obtaining food as no insects were to be had and in consequence many were suffering from a lowered vitality. This was reflected in the body temperatures of individuals that I collected. Thus, two male violet-green swallows (*Tachycineta thalassina lepida*) registered 103.8° and 106.8°, respectively, a female black-throated gray warbler (*Dendroica nigrescens*) 105.4°, a female Audubon's warbler (*Dendroica auduboni*) 105.6° and two purple martins (*Progne subis*) 104.8° and 105.0°. Such abnormal records, due manifestly to lack of sufficient food, were not included in the register giving the normal average and range of temperature. That they were abnormal may be ascertained by referring to other records given for these species.

Birds that remain in regions where they are exposed to cold, become more heavily feathered before the winter season so that there is less radiation of heat externally. Correspondingly, in summer the feathered covering is thinner, and the feathers themselves often become more worn so they are less burdensome. With increased cold there is apparently some readjustment to maintain the bodily heat at its normal point. Were this not so the individual would become affected so unfavorably that with prolonged exposure it would perish. We must suppose a more rapid metabolism and a conservation of the resultant energy in order to overcome this. Such a condition is not difficult to imagine in hawks, crows, and other birds of large size, but is wonderful when such feathered mites as the kinglets, creepers and chickadees are considered.

The part that the feet and tarsi of birds play in equalizing the body temperature is difficult to state. In the majority of birds the space from the lower end of the tibio-tarsus to the tips of the toes is covered with skin in which are developed more or less perfect horny scutes (the whole forming one of the most evident reptilian features visible in the living bird.) The blood supply is of fair quantity clear to the tips of the toes, as blood trickles from slight wounds in the foot. There is no evidence of a forced circulation yet in many cases warm blood must be conveyed constantly to these parts to avoid frostbite. Many ducks, grebes and other aquatic birds remain during winter just south of the line of ice. Swans, phalaropes and loons appear in the Arctic regions with the first breaking up of ice. I have seen auklets, puffins, and murrelets swimming and diving for hours in Bering Sea with no apparent discomfort at a time when the temperature of the water registered +39° Fahrenheit. Mallards and other wild ducks frequently clamber out of the water and stand about on ice for considerable periods without visible hardship. How these birds overcome or avoid the effect of cold upon their feet is a mystery as yet. Although supplied with a certain amount of blood, as has been stated, the feet and tarsi of birds are more often cold or cool to the touch than otherwise in spite of the high body heat. In fact they are seldom warm save in the hottest weather. Frozen feet and toes are not uncommon among domestic fowls but are seldom encountered in wild birds. The skin of the feet and tarsi is smooth and oily, so that in the case of aquatic species water does not adhere when the extremities are exposed to the air, thus preventing danger through the formation of ice. Aquatic birds at rest frequently draw up the feet one at a time beneath the long feathers covering the flanks, and ducks often rest on frozen ground with both feet drawn up in this manner, so that relief is available when needed.

In some groups of birds the tarsi and at times the toes are well protected by a covering of feathers that prevent the radiation of heat. Such a development is found in ptarmigan and certain other grouse, in our owls of northern habitat, and in the sand grouse and rough-legged hawks. A similar covering, though less dense and heavy, is found, however, in other birds that never encounter severe cold. Thus the tarsus is feathered in whole or in part in some trogons, in whippoorwills, in certain species of edible-nest swiftlets (*Collocalia*) and many others. The entire tarsi and upper surfaces of the toes are feathered in the Old World martin (*Delichon urbica*). Although this covering is present in *Delichon,* in the bank swallow (*Riparia riparia*) a species that also breeds regularly far north in Arctic regions, the feathering is restricted to a small tuft on the posterior face of the tarsus near its lower end. Where this covering of the legs and feet is found in species that at present do not seem to require it for protection it may be supposed that it has persisted after an ancient need causing the growth has disappeared, or that it has developed as a correlated structure, perhaps ornamental in nature. Thus in tropical owls the feathering of tarsi and toes is greatly reduced, although in northern species it is very heavy.

On the whole it would appear that radiation of heat through the lower extremities is comparatively slight.

DIVERSE MISCELLANEOUS FACTORS IN THEIR RELATION TO BODY TEMPERATURE

Previous sections have covered various phases of variations in temperature due to sex, daily temperature rhythm and other conditions. It remains to consider a few miscellaneous factors that affect this matter. Some of these are normal and some abnormal.

The ingestion of large masses of food will frequently cause a sudden decrease in body temperature in a bird of small size. The matter swallowed if cold will absorb warmth until it has acquired a degree of heat equivalent to that of the tissues inclosing it. In this way a distinct lowering of internal heat may be occasioned. On Sept. 12, 1919, while watching two yellow-throated viroes (*Lanivireo flavirons*) that were feeding in company I saw one after much effort swallow a very large caterpillar. Both of these birds were collected and were found to be immature females. The bird that had eaten the caterpillar five minutes before it was killed registered a body temperature of 107.2°, while the other gave a reading of 108.1°. This difference of .9° was attributed to heat absorbed by the large mass of recently ingested food. This may be considered a normal variation.

In small birds bathing may also occasion a slight decrease in body temperature where the plumage becomes thoroughly wet. The heat taken up during evaporation incident to drying the feathers may occasion an appreciable drop in body heat. As an example of this, a verdin (*Auriparus flaviceps*) that had just bathed, taken June 16, 1919, near Arlington, Arizona, gave a temperature of only 106.0°, while others of this species ranged from 106.5° to 107.6°. Variation from this cause is slight, however, and would not be appreciable save in species of very small size.

Many persons with whom the writer has discussed the question of the taking and recording of the body temperatures of birds have expressed the belief that the shock produced in the bird when it is shot is sufficient to increase the bodily temperature to a marked degree. Such statements have come in particular from physicians and others of similar training. Experiment and observation have shown, however, that this is not true. On various occasions by accident or intention birds have been killed in such a way that they were instantly riddled by shot, so that all functions of the body, nervous as well as circulatory must have ceased instantly when the bird was struck, and this on occasions when the individual in question had no reason to suspect danger. Temperatures of such specimens show no variation from those of birds taken in a more normal way. As a matter of fact it has transpired that the shock of wound in birds serves rapidly to reduce their body heat after a period of from thirty to sixty seconds. Thus a wing-tipped bird, with an injury that is comparatively slight, will be found usually to have a temperature below normal after a period of two minutes has elapsed from the time that it was injured. With more serious injuries the fall in body heat may be so great that a record made on a living bird four or five minutes after it was shot is so low that it must often be considered as abnormal. As an example of this I may cite the case of a cinnamon teal (*Querquedula cyanoptera*) that was struck in such a way that the sight of both eyes was destroyed though other injury was not present. This bird rested quietly on the water, while I went for a boat in order to retrieve it. On reaching the spot fifteen minutes later the body temperature of the duck was found to register only 102.0°, a reading considerably below normal. Many other examples of a similar sort in the case of birds bearing only slight wounds have come under observation. The rapid reduction in body heat is due perhaps to an abnormal exchange and radiation through the air-sacs.

TEMPERATURE OF YOUNG

During the course of this investigation occasional opportunities were presented for securing temperatures on nestling birds or on young of species that leave the nest as soon as hatched. These have not been used in securing the average temperatures for each species given in table 3 or for the family records in table 4, as they showed some variations from readings for adults. The results obtained are, however, of considerable interest and are presented in tabular form herewith in order that they may be discussed briefly. In this table the few species included are grouped under family headings. In the second column is given the temperature and under remarks is included a statement of the approximate age of the individual and the manner in which the temperature was taken. In certain passerine species, where axillar temperatures were taken, the end of the thermometer was held closely in the hollow between the folded wing and the body. Birds utilized from the same nest or brood are grouped in brackets.

Of the species listed those belonging to the families Colymbidae, Laridae, Anatidae, Rallidae and Recurvirostridae are precocial while those listed under Columbidae, Tyrannidae, Hirundinidae, Mniotiltidae, Mimidae, Paridae, and Turdidae are altricial. A difference in the temperature records in the two groups is readily apparent upon examining the table. In the group of precocial birds there is on the whole less variation and the temperatures given closely approximate those of adults of the same species. The only wide divergence in this group is in the case of the three-day old young of the black-necked stilt (*Himantopus mexicanus*). It so happened, however, that the temperatures of these three birds were taken upon a cold raw day, when the young were very evidently affected by the external cold, perhaps through lack of sufficient food.

In the case of the altricial species considerable variation is present and these birds show a much lower average temperature than adults.

TABLE 2.—*Table of temperatures of young or nestling birds*

Species	Temperature	Remarks
COLYMBIDAE		
Podilymbus podiceps.....	104.5	Newly hatched (interthoracic).
" "	100.4	
" "	101.4	From one brood.
" "	100.3	
LARIDAE		
Sterna forsteri	107.3	Ten days old (rectal).
" "	106.8	" " " "
" "	105.6	Seven " " "
" "	101.5	Two " " "
" "	104.5	Six " " "
Hydrochelidon nigra.....	105.4	Seven " " "
ANATIDAE		
Anas platyrhynchos......	105.8	One-third grown "
Chaulelasmus streperus ..	104.5	One day old "
" " ..	106.1	" " " "
" " ..	107.3	" " " "
" " ..	107.8	" " " "
" " ..	107.8	" " " "
Querquedula cyanoptera..	107.7	" " " "
" " ..	106.5	" " " "
" " ..	105.6	" " " "
" " ..	106.3	" " " "
Spatula clypeata	102.7	One-half grown "
" "	104.0	" " " "
Marila americana........	102.9	Two hours old "
" "	102.7	" " " "
" "	105.6	Five days old "
" "	106.8	" " " "
" "	106.0	" " " "
" "	107.5	" " " "
" "	106.0	" " " "
" "	104.0	Ten " " "
" "	106.0	Two weeks " "
Erismatura jamaicensis..	104.2	Ten days " "
RALLIDAE		
Fulica americana	108.6	One-third grown "
" "	109.0	One-half " "
" "	106.6	" " " "
" "	104.5	" " " "
RECURVIROSTRIDAE		
Recurvirostra americana.	103.9	One week old "
" " .	104.3	" " " "
" " .	104.5	" " " "
" " .	103.6	" " " "
" " .	104.4	Newly hatched.
Himantopus mexicanus ..	95.8	One day old "
" " ..	95.3	" " " "
" " ..	97.8	" " " "
" " ..	105.7	One-half grown "
COLUMBIDAE		
Zenaidura macroura	106.5	Two weeks old "
TYRANNIDAE		
Myiarchus crinitus.......	103.3	Nestling, 12 days old (axillar).
" "	103.8	" " " " "
" "	103.2	" " " " "
" "	103.8	" " " " "
" "	103.7	" " " " (interthoracic)

TABLE 2.—*Continued*

Species	Temperature	Remarks
HIRUNDINIDAE		
Petrochelidon lunifrons . .	103.4	Nestling, 2 weeks old (interthoracic).
" " . .	102.8	" " " " "
MNIOTILTIDAE		
Geothlypis trichas	100.2	Nestling, 7 days old (axillar).
" "	101.8	" " " " "
" "	102.5	" " " " "
" "	102.8	" " " " "
MIMIDAE		
Dumetella carolinensis . . .	105.0	Nestling (axillar). One brood.
" " . .	105.2	
" " . .	105.7	
" " . .	97.7	Nestling, 8 days old (axillar) One brood.
" " . .	98.8	
" " . .	97.9	
PARIDAE		
Penthestes gambeli	101.4	Nestling nearly grown (interthoracic). One brood.
" "	97.0	
TURDIDAE		
Sialia currucoides	97.6	Nestling, week old (interthoracic). One brood.
" "	96.7	

These helpless young are evidently as dependent upon brooding by a parent to maintain their bodily heat as are eggs before hatching. Apparently the body temperature may be considerably reduced, however, without permanent injury so that the body heat may sink as low as 97° without death resulting. Even where nestling birds have developed contour feathers the temperature still remains considerably below the average for the adult. When the bird leaves the nest at once there is agreement between the degree of bodily heat that it develops and that present in the adult.

The single observation recorded for a young mourning dove is apparently anomalous as it averages higher than those given for other altricial birds. This is of interest as the doves have distinct affinities with groups having precocial young but in the Columbidae the immature birds, though covered with down at birth, are confined to the nest until able to fly. Further study of young doves and of other down-covered young that do not leave the nest when first hatched, as young hawks, owls, turacos and others, will be of interest.

From this discussion it may be stated with apparent certainty that in birds with precocial young the mechanism of temperature control is well organized at birth, while in species with altricial offspring this power is so feebly developed that these birds are largely dependent upon the parents for heat. The ability of perfect temperature control is not fully matured until the young leave the nest. The early development of this faculty in precocial young is in line with their advanced stage as regards securing food, general activity, and ability to care for themselves. According to Pembrey,[1] similar statements regarding young birds have been made by Edwards.[2]

METHOD OF TEMPERATURE CONTROL IN BIRDS

Bodily heat in all animals is caused by tissue changes during active work performed by various organs or parts. Mills[3] states that bodily heat, though arising in great part from actual oxidations that take place in the system, is in its entire amount best defined as the outcome of all chemical processes that take place in the organism. In so-called cold-blooded vertebrates the combined energy or rate of these chemical changes is slow, so that heat is given off by the body almost as rapidly as it is generated. In the groups that we class as warm-blooded, Aves and Mammalia, these changes are more rapid and intense so that heat generation may be in excess of heat radiation. In the warm-blooded group there is also a more or less perfect control of heat radiation when the body is normal in health. In homoiothermal animals there is, therefore, an approximation to the maintenance of a fairly uniform internal temperature, and the animal remains independent of the ordinary rise and fall of the degree of heat of its external medium.

Bayliss[4] considers control of heat production (probably in muscles) as the primitive method of temperature control. Among homoiothermal animals, the Monotremes (both *Echidna* and *Ornithorhynchus*) have the lowest body temperatures, as the average for these species is only 85.6° Fahr. In the case of *Echidna* all regulation of temperature appears to be through change in heat production as this animal possesses no sudoriferous glands and shows no apparent change in respiration at high temperatures. In cold weather it hibernates and maintains a temperature only slightly above that of the air. The duck-bill (*Ornithorhynchus*) has the power of regulating both heat loss and heat production so that its temperature is maintained at a more even level. The marsupials are intermediate in this respect between monotremes and higher mammals.

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[1] Schäfer, E. A., Text-book of Phys., London, Vol. I, 1898, p. 804.

[2] "De l'influence des agens physiques sur la vie, Paris, 1824. (Not seen by the present writer.)

[3] Animal Physiology, p. 461.

[4] Principles of General Physiology, 1915, pp. 458-459.

It has been estimated by Helmholtz[1] that in the human body heat lost through transpired air amounts to 5.2%, through the water of respiration to 14.7% and through the skin to 77.5%. The remaining amount disseminated is given off in egesta or is consumed in warming ingesta. The part played by the skin glands in regulating temperature in the mammal is readily seen. The distribution of skin glands varies in different groups, though such glands are known in all save Cetaceans, elephants, Echidna, and some others. It is claimed, for example, that in the dog skin glands are present only in the legs or feet but in this case the open mouth and protruding tongue act as organs for reducing excess body heat. The presence of skin glands in the horse is readily observed in an animal that is hard driven in warm weather.

Amphibians agree with mammals in the presence of many integumentary glands, though in this group the use of these structures is in some ways different in purpose. In reptiles and in birds, the two classes joined in the supergroup Sauropsida, skin-glands are practically wanting and no case is known in which glands similar to those in mammals are found. In birds the development of feathers with their filamentous barbs and barbules, as a body covering, would not have been possible had sudoriferous glands been present in the skin. Excretion of fluid through such glands inevitably would have soiled such delicate structures as feathers and ultimately have destroyed them. The diffusion of heat through the skin in birds is confined to the amount, notably small in quantity, that is, given off by direct radiation. It is a fact easy of verification that the skin in birds is deficient in blood supply when compared with mammals. Only a comparatively small amount of blood, therefore, can be cooled to any extensive degree through the agency of the skin.

As a matter of fact the feathers that form a loose covering over the bodies of birds are not adapted to the radiation of heat but on the contrary tend to conserve it and hold it within. Though the contour feathers lie smoothly one upon the other yet they are permeated and separated by innumerable air-spaces varying in size from the tiny interstices between barbs, barbules, and barbicels in individual feathers, to the broader areas separating one feather from another. These all go to make up series of more or less closed air cells that act efficiently as non-conductors and serve to retain the bodily heat within. The use of so-called "dead" air-spaces between walls as a protection against conduction of heat and cold is too well known to make further explanation of this factor necessary.

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[1] Smith, R. M., Physiology of Domestic Animals, 1889, p. 696.

This lack of heat regulation by means of the skin would throw the vital work of temperature control directly upon the respiratory system. In this fact then we have a ready explanation for the presence of the great series of pulmonary air-sacs that are developed throughout the avian class as a whole. Birds in order to maintain a high rate of metabolism, necessary to continued activity without reference to shifts and changes in the temperature of their surrounding media, have been forced to develop an auxiliary to the small amount of heat that may be thrown off through the lungs. This has led to the evolution of the air-sacs that, while connected by ostia directly with the lungs, radiate throughout the coelom and penetrate the bones to serve as an agency of temperature control. In other words, safety to the organism demanded that if activity be great and continued, there be some safe release for the excess heat developed during rapid muscular movement.

The proper function of the air-sacs has been a moot point for many years and has given rise to considerable discussion. Some have considered that these sacs acted as reservoirs to replenish air in the lungs, as containers that, balloon like, raised the weight of the bird in flight, or that the presence of these open spaces reduced the relative specific gravity of the body. While the idea of the true use of the air-sacs in birds as organs of temperature control was arrived at independently by the present writer, subsequently an admirable exposition of the same fact has been found in an account by J.-M. Soum.[1] This author in turn believed that the discovery of this fact originated in an hypothesis first advanced by De Vescovi.[2] W. P. Pycraft[3] also has adopted this view as he states that "the air stored in these reservoirs serves not only for respiratory purposes, but also as regulators of temperature, thereby compensating for the lack of sweat glands." With this comment, however, he goes no further, as he gives no details to support this statement.[4] M. Soum, however, made an admirable exposition of his hypothesis. He pointed out that all birds possess air-sacs, have a covering of feathers, and lack skin glands, and all have a high temperature. To correlate these facts he believed it necessary to consider the air-sacs as a means of temperature control. The additional facts that I am able to bring forth leave no doubt as to the correctness of this belief.

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[1] Soc. Linn. de Lyon, Vol. XLII, 1895, pp. 153-157.

[2] Res Zoologicae, Ann. 1, No. 1, Rome. (This publication I have not seen.)

[3] History of Birds, London, 1910, p. 17.

[4] With regard to statements by other authors consult also Headley, Structure and Life of Birds, pp. 100-103.

To continue, as the statement given in the preceding paragraphs becomes more clear, it seems evident that the bird owes its high development, when compared with the reptile, to the growth of these air-sacs as well as to a complete double circulation of the blood. The truth of this statement is apparent when it is considered that the Crocodilia among reptiles possess a double circulation so nearly perfect that only a comparatively small amount of venous blood finds its way into the purified stream of the trunk arteries. Yet these creatures are "cold-blooded" and become dormant when subjected to cold. In other words, their body processes function so slowly that when they encounter an outside temperature below a certain point heat is given off by the body more rapidly than it can be produced. It follows then that the bodily activities ebb lower and lower until finally they are practically at a standstill.

With animals as active as are birds means of relief from overheating must be well organized; the extension of the air-sacs through the body cavity is excellent for this purpose. The walls of the sacs are very poorly supplied with blood so that heat is not radiated directly by means of special circulatory vessels. The thin walls of the sacs, however, are brought into intimate contact with the trunks bearing the blood stream and their principal branches while in addition the sacs closely invest the glands and organs that generate heat. It is claimed that the liver produces more heat than any other organ so that the blood from the hepatic drainage is warmer than any other in the body. The liver itself is partly enclosed by air-sacs, while the venous trunks coming from it adjoin sacs that give excellent opportunity for the casting off of excess heat. Ramifications of air-sacs in the bones of the body are not uniform in distribution and appear to follow no set plan. Some species have the osseous system highly pneumatic throughout while in others this pneumaticity is greatly reduced. When air-sacs are present in bones invested by considerable muscle masses they may be considered as developments that tend to further the proper radiation of excess heat. Thus air cells in the keel of the sternum and the coracoids would aid in controlling heat generated in the pectoral muscles and supplement the work of those divisions of the sacs that underlie the body of the sternum and penetrate from the thorax into the cervical region.

Evolution of the air-sacs beyond their normal development of five main pairs that fill the body cavity and the cervical region apparently has been partly beyond control. The presence of numerous cells between the skin and muscles in brown pelicans may be supposed to break the impact of the water as the birds dive for food. The presence of these same air-pads in the white pelican and, possibly, in the man-o'-war bird may be explained by considering that they were developed as a protection while diving from a height and that they have persisted now that these birds have altered their mode of securing food. Similar air-pads in the screamers, however, cannot be explained by the same argument. Similarly there seems no adequate explanation on the basis of use for pneumaticity in the pedal phalanges of the Bucerotidae or in the pygostyle of the Picidae.

Many physiologists have supposed that air-sacs have been developed by birds to impart lightness to the body, especially to the bones. Anatomists, however, have pointed out that while the main air-sacs are more or less uniform in growth, in many cases the bones are highly pneumatic in species not especially noted for strong or prolonged flight. The hornbills, already cited as having the osseous system more extensively permeated with ramifications of air cells than any other group, are not known to be especially active on the wing.

In the most recently published extensive account of avian air-sacs Bruno Müller[1] considers that air-sacs serve no special physiological function but that they give bulk to the bird body without adding to its weight. This author continues with the statement that the connection of the air-sacs with the lungs comes from their manner of development, and that this connection serves merely to "assist in renewing the air in the trachea." Reflection and study of the facts of avian anatomy show, however, that this line of reasoning is untenable. Bats among mammals fly with the utmost ease and yet possess no such system of air cells as permeates the body in birds. Some of our most ancient birds from the standpoint of phylogeny are flightless, have been in this condition for millions of years, and yet have as perfect a system of air-sacs as are found in forms noted for their powers of flight. Fossil remains of an ostrich have been found in the Pliocene deposits in the Siwalik Hills in India, an indication of the ancient ancestry of our present-day struthious birds. To those who would adhere to the theory of Müller as propounded above the highly emphysematous condition prevailing in the screamers (*Anhima* and *Chauna*) and others may seem of importance but the condition, as has been said, may be ascribed more to an exaggerated development, unchecked because it had no particular significance to the organism as a whole. Otherwise we must expect a similar condition in other species, as the Old World vultures and American buzzards

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[1] Air-sacs of the Pigeon, Smithsonian Misc. Coll. (Quart. Iss.) Vol. 50, pt. 3, Jan. 16, 1908, pp. 403-404.

(*Cathartidae*) that like the screamers spend hours in soaring high in air.

The action of the air-sacs in controlling the body temperature may be demonstrated clearly by the following. A house sparrow (*Passer domesticus*) was caught across the neck in a spring mouse trap of the "Out o' Sight" type. The bird struggled and fluttered violently for approximately 60 seconds while at the same time ingress or egress of air to or from the lungs was prevented by compression of the trachea against the edge of the trap platform by the spring of the trap. I reached this bird as it became quiet and found that the body temperature (interthoracic) registered 114° Fahr. The violent, sustained muscular exertion had produced a considerable amount of heat that could not be given off as the accustomed outlet was blocked. The temperature, therefore, rose several degrees above the usual maximum for this species. These same factors operate occasionally when the trachea of a wounded bird is clogged with blood that prevents the passage of air. The air current must be cut off quickly, however, as the temperature falls rapidly in a wounded bird even when it is struggling.

During hot weather it is common to see birds breathing rapidly with the mouth held open. This facilitates the rapid inspiration and expiration of air from the lungs. Cooling of the mucous membranes of the posterior portion of the mouth may also be of slight aid in reducing the excess internal heat. In the case of some young birds, as, for example, young herons, there is in connection with this habit of breathing with open mouth another development to aid in regulating the internal temperature of the body. When overheated these birds open the mouth widely so as to expand the capacious mouth cavity and pharynx while at the same time the skin on the sides of the upper throat is vibrated with great rapidity. The inner walls of the pharynx and upper throat in the birds in question are highly vascular so that the currents of air set in motion aid in cooling the blood exposed in the radiating blood vessels found near the surface in the moist mucous lining. Conversely it may well transpire that the checking of the rapidity of interchange of air between the branches of the bronchi and the air-sacs during extremely cold weather may bring about a storage or an increase in internal heat. In other words the heat of the body cavity may be held at a higher level by the cessation of inhalation of constant supplies of cold air into the air-sacs. We may imagine a delicate adjustment here that will vary expiration of heated air at need. With the air-sacs acting thus as heat reservoirs the ability of some species of birds to withstand bitter cold winter weather may be better understood.

Temperature control among birds is less perfect in juvenile than in adult individuals so that the action described in the case of young herons in the preceding paragraph is of great aid to control of heat through the air-sacs. As temperature is poorly regulated in young individuals parent birds often find it highly necessary to shelter their offspring when these are reared in exposed nests. On hot cloudless days, therefore, one bird of each pair remains constantly at the nest during the warmer part of the day, and intervenes its body and partly spread wings between the young in the nest and the burning rays of the sun. I have seen many young herons and ibises perish when the adults were driven from their nests on hot days, and during field work in rookeries of these birds have made it a point to visit them during the cooler portions of morning or afternoon, or to come on days when the sky was overcast by clouds in order to prevent such mortality. As another evidence of poorer temperature control in young birds I may add that in several cases I have seen immature coots (*Fulica americana*) die, apparently of sunstroke, when unduly excited while exposed to the burning rays of a western sun. Adult birds seem able to react against these circumstances in such a way that they do not succumb but often exhibit evident signs of severe suffering. It is probable that the more perfect development of the feathered covering in adult birds is of as great advantage in this as the increased efficiency of the heat regulatory organization in the body.

On a few occasions I have observed a further development of the function of temperature control by air-sacs in certain forms of birds while in the fledgling state. Those who have had occasion to work in summer in marshes densely grown with rushes will agree that at times the heat encountered is almost overpowering. In a few instances in such situations I have observed young yellow-headed blackbirds recently from the nest, resting quietly with the cervical air-sacs immensely swollen so that the lower part of the neck was greatly enlarged. The whole gave the appearance of some unwholesome tumorous growth and at first I was under the impression that the birds were diseased. On handling them, however, the sacs rapidly subsided and the birds seemed normal in every respect. The same phenomenon has been observed in young savanna sparrows and in young red-winged blackbirds. In these cases I was forced to conclude that the distended air-sacs form an insulation or protection against heat from without. In other words, that the enlarged cavity of the sac acted as a dead air space protecting the blood stream in the larger vessels from becoming overheated. The importance of the enlarged cervical sacs in preventing excessive heating of the carotid artery carrying blood to the head may readily be seen.

SIGNIFICANCE OF TEMPERATURE CONTROL

In common parlance animals are divided in two groups distinguished as those with "warm blood" or "cold blood," according to their condition as regards body heat. Though two classes may be recognized without difficulty, the criterion implied in these two terms is not exact as a "cold-blooded" animal temporarily may have its body temperature raised to a high degree. The distinction between the two, in fact, is not one of actual degree of heat, but rather one of maintenance of a more or less uniform temperature in the group defined as possessing "warm blood," and of fluctuation in bodily temperature in those distinguished as "cold-blooded." To express this idea with exactness, the first group of animals is said to be homoiothermal, and the second poikilothermal, terms proposed by Bergman[1] in 1847.

It will be admitted without question that the possession and maintenance of warm blood is of advantage to any animal. We may suppose, therefore, with what amounts to some certainty that this faculty when once gained, would not be lost. On the basis of this assumption it may be concluded further that the first vertebrates were cold-blooded, an hypothesis in line with facts of evolution as they are understood and accepted at the present time. Whether these types developed in regions of equable temperatures or in areas with moderate seasonable changes is a matter of no moment in the present discussion. In either case these early vertebrates as they extended their ranges, encountered barriers erected by cold during a part of the year. Groups successful in coping with this condition developed an ability to undergo certain periods, longer or shorter in length, in the state of suspended animation that we term hibernation, and then to revive and carry on their activities as before with return of a period of increased warmth. In meeting these conditions of cold it was of advantage to develop increased resistance to the torpor induced. In other words, it was an advantage to the organism to maintain its activity at lower and lower temperatures. In order to accomplish this it was necessary to evolve a mechanism for temperature control in the body, and for regulation of the rate of production of heat from ingested food elements. When once begun, such control would prove

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[1] Göttinger Studien, Vol. I, 1847, p. 593.

of value not only in overcoming cold but in enabling the organism to withstand excessive heat.

It seems probable that in our living fishes there is little actual temperature control. In Amphibia, this regulation is developed to some extent, and it has progressed somewhat farther in modern reptiles. In the bird, however, the regulation of body temperature has reached its highest point, though birds stand second to mammals from an evolutionary standpoint. Proof of this is found in the fact that birds have the highest body temperatures known, and that none of them hibernate (in spite of ancient beliefs to the contrary). Where conditions become too unfavorable, birds, through their power of flight, pass readily to regions where the environment is more clement. They are enabled, therefore, to foster their powers of temperature control and keep them at the highest pitch. Small mammals, on the contrary, are more or less sedentary and in many cases must still undergo hibernation in order to maintain themselves in regions with cold winters. As they must always hibernate in order to survive there is, in their case, less incentive to develop temperature and temperature control beyond a certain point.

Thermogenic centers or areas in the central nervous system developed for temperature control have been studied in mammals and have been fixed tentatively by some in or near the corpus striatum. Others would recognize a cortical heat center. Seemingly this matter has received little attention in birds and it would be unwise in the absence of definite data to decide that this function is vested in the same areas in this group when the wide separation between birds and mammals is considered. It may be assumed as certain that heat production and heat control are under nervous direction and that these two functions are directly concerned in whatever mechanism has developed for temperature control.

The origin of the warm-blooded animal may be attributed to natural selection in which certain individuals showed a slight reaction against temperature conditions producing hibernation in their fellows. In other words, these favored ones were able to remain active in a temperature a few degrees colder than others of their kind. With this tendency as a basis and with strains developing in which this tendency was perpetuated it followed that there were evolved groups of species with a more independent metabolism in regard to the degree or the lack of heat of the surrounding medium. " Warm blood " therefore arose in a struggle against enforced hibernation. During evolution of the vertebrates it may be that among living groups of today, warm blood arose first among the birds.[1] We may suppose, however, that primitive pro-avian creatures (on the borderline between small-brained reptile and large-brained bird) were cold-blooded and that they were subject to hibernation as is any reptile today. However, it seems probable that *Archaeopteryx,* the most primitive of known birds, was warm-blooded, as impressions of feathers are shown distinctly in the slabs of stone containing the remains of these creatures. These marks made by feathers indicate the development of a body covering designed to retain heat, a circumstance unknown in any cold-blooded vertebrate. How far back we may safely trace this supposed warm-blooded ancestral bird creature is problematical but in this connection attention may be called to the supposition that there are grounds for believing that Pterosaurs, among ancient reptiles, possessed warm blood. As warm blood permitted greater mental and physical activity it was natural that the mammal should also develop this faculty, though it seems probable that this function arose independently in the Reptilian-Avian and Mammalian groups.

DISCUSSION OF DIFFERENCES IN AVERAGE TEMPERATURES

Attention has been called to the general statement that the body temperatures of birds vary as a rule from low to high as the species change from those considered low in the scale of development to those farther advanced. Agreement with this theory is shown in part in the data summarized in table 4. Thus grebes, the totipalmate groups (Anhingidae, Phalacrocoracidae and Pelecanidae) and herons are in general low in average body temperature, while gulls, shorebirds, pigeons and cuckoos are high. Many apparent discrepancies to this broad statement may be noted. These must be left for the present without attempt at explanation save to note that knowledge of the actual evolution of groups in birds is slight, while new facts constantly demand a revision of the status of many forms. Whether the variations in body temperature here noted may have significance time alone can tell. It is probable that temperature level is of value as a criterion only between the most primitive and the most highly developed groups and that the great mass of intermediate orders and families may in some cases in themselves develop high or low temperature according to their actual needs.

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[1] According to Osborn (Origin and Evolution of Life, 1918, p. 236) primitive mammals arose during the Jurassic period. The earliest known birds are found in deposits of this same age but are so highly specialized that it is evident that they were preceded by a long line of pro-aves of more ancient origin than the early mammals.

When ranged by families the highest temperatures noted are to be found in pigeons, cuckoos, woodpeckers and in the great passerine order beginning (in table 4) with the Tyrannidae and ending with the Turdidae. It must be noted too that the range of body temperature among ducks is in general comparatively high. Gulls and shorebirds show a general agreement, compatible with their close relationship as now commonly accepted. The quails (Odontophoridae) seem to have a temperature high for birds that have been considered comparatively low in development. The observations recorded for the owls probably do not represent a true average as many of the readings upon which the mean is based were taken during the day when temperature in these birds normally is at low ebb. The low average given for the kingfishers is based upon a small number of observations and may be incorrect. Humming-birds, with their tiny bodies seem to have a considerable range in temperature, but as a whole fall low in body warmth. This apparent lack of heat may be due in part to the small bulk of their bodies in comparison with the size of the thermometers used. Part of their heat may have been absorbed and dissipated by the glass of the inserted instrument.

Observations upon the greater part of the species of woodpeckers found in the United States reveal an almost uniform high level of body temperature. The general range and the limits of variation from high to low are similar to those of passerine families. As in other families individuals large in body show a general lower temperature and a smaller limit of variation than do some others of smaller bulk. The records on the whole are so uniform that further comment regarding them is superfluous.

An examination of the species and families of passerine birds reveals much of interest. Of the twenty-two families for which records are given eleven or exactly one-half, have a mean temperature averaging below 108°. It will be noticed that most of these families are those having only a small number of species represented in the records. In several instances observations were available on one species alone and only in the crows, swallows, vireos, wrens and nuthatches is the number of species available comparatively large. The Hirundinidae (seven species) with an average temperature of 106.7° is the only family in the order falling below 107°. Seven families, the Tyrannidae, Alaudidae, Fringillidae, Tangaridae, Bombycillidae, Mimidae and Turdidae, have mean temperatures higher than 108.5°. These seven families include 86 of the 203 species of passeriform birds represented, or approximately 42 per cent. The Alaudidae show a mean temperature of 109.4°, which is higher than for any other group, but is not comparable, as this family is represented by only one species, the horned lark (*Otocoris alpestris*). A number of species included in other families have a higher average temperature than this so that this must be discarded. Among the others the Bombycillidae, Mimidae, and Turdidae each show an average of 108.9° while the three families remaining in the category under discussion vary only two- or three-tenths of a degree below this. From 108.6° to 108.9° would seem therefore to be the maximum for families of perching birds where records are available for a number of species.

A comparative examination of some of the species of perching birds brings out still other facts of interest. It has already been stated that the swallows as a group possess the lowest average body temperature. In the seven species examined in this family only one, the rough-winged swallow (*Stelgidopteryx serripennis*), showed an average body heat above 107.5°. Turning to the higher temperatures it is found that in the Tyrannidae there are five species in which the mean temperature for the male or female is 110° or more. The Fringillidae include three species in this category and the Corvidae, Icteridae, Mniotiltidae and Turdidae each possess one. In other words there are records for twelve species in all in which this is true. The highest average temperature for both sexes is that of the western wood pewee (*Myiochanes richardsoni*) with a mean of 110.2°. The highest single reading believed to be valid was found in this species in an individual killed in the Graham Mountains, Arizona, at two o'clock in the afternoon on June 25, 1919. This bird, shot dead as it rested quietly in the shade of a cottonwood fell to the ground without a struggle. When the temperature was taken the extraordinary reading of 112.7° was secured. From the data at hand it is indicated that the highest average body temperatures for a number of related species may be found in the Tyrannidae. This statement is made only tentatively as further observation may show that other groups are equal in this respect. It is not unusual for individual birds in several other groups of perching birds to register 110° or more as shown by the column of maximum temperatures in table 3, and accident of association of such high records might give a high average. Only by recording many extended observations can error from this cause be reduced to a minimum.

EXPLANATION OF TABLES

The data secured during this investigation into the body temperature of birds are summarized in two tables that are given in the pages that follow. The table giving in detail the individual records, which it was found necessary to omit from this paper owing to the excessive cost of publishing tabular matter, is deposited in the files of the Smithsonian Institution and may be consulted by those who wish to use the data contained in it.

The order of arrangement and the nomenclature, followed is that of the third edition of the American Ornithologist's Union Check-list of Birds, published in 1910.[1] By referring to this check-list physiologists and others interested in these tables, who may not have made detailed studies of birds, will have no difficulty in ascertaining the application of the names that are used, and the relationship of the various forms that are treated. At one time the writer intended, in publishing this information, to use names of birds in accordance with the most modern findings in nomenclature, and to arrange them in a sequence of families that would express his own ideas in classification. The latter idea was commendable as it tended to place the species into what may be considered a somewhat more natural sequence that showed a tendency (not universal, however) for a gradual increase in degree of bodily temperature from forms low in the scale to those conceded to be higher in development. With regard to the names to be employed it was soon seen that changes were so rapid that they tended to bewilder even those more or less adept in such matters, while to workers in other fields, they would be wholly unintelligible without great expenditure of time in looking up and verifying the various authorities. As the present contribution is not one of research into systematic ornithology but rather a treatise designed to throw light upon the physiological and more general aspects of our science, this scheme of using such a classification was abandoned and another plan was adopted.

In table 3 is given a synopsis of the information of all of the records secured with the average, minimum and maximum temperatures summarized for males and females of the species treated so far as this data is available. In this table attempt is made to arrange the matter in order of convenience for reference. The name and sex of the bird are followed by the mean temperature. After this are given the minimum and maximum range, the number of records available, and a symbol that indicates the manner in which they were taken, the abbreviation R. meaning rectal and I. interthoracic. In this table subspecific names are ignored entirely and all information is grouped under

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[1] Check-list of North American Birds, prepared by a Committee of the American Ornithologists' Union, Third Edition (Revised), New York, 1910, pp. 1-430, 2 maps.

specific names. The mean temperature for each sex is given where information for both males and females is available.

In grouping this information a departure has been made from a method that has been utilized by many authors that gives the minimum temperature, then the maximum, and then the mean. In the present connection the mean temperature for each species is considered the most important fact and is therefore placed first, nearest the name of the bird concerned. Records showing the minimum and maximum range follow immediately where they are readily available in case this information is desired.

In table 4 is given another summary in which mean temperatures for each of the families of birds represented is tabulated. The name of the family is followed by the number of species represented in the present studies. Following this are mean, minimum and maximum temperatures with the mean as the most important fact given first. The data in these three columns are taken from the column of mean temperatures in table 3. In other words, this is a summary based upon the mean temperatures alone of the various species.

The laborious work of securing the averages in these various tables was performed with the aid of a computing machine. This not only greatly lessened the labor and expedited the work in hand but also made the results less liable to error than would have been the case had it been necessary to perform so many computations mentally.

In a final table (table 5), is given a compilation of temperature records for species of birds that I have not been able to examine personally in the flesh. This table has been taken from available literature and includes only those records for which it has been possible to assign specific names with certainty. Where a record is listed simply as "gull," "hawk," etc., it has been discarded. No attempt has been made to cite all records available for each species but simply to give enough to indicate the body temperature in relation to other forms. Many published notes have been discarded for lack of certain identification, while in utilizing other records I have simply quoted what I have found with no assumption as to accuracy of statement. Records are given for 89 species of birds in addition to those found in table 3. The table has been made as complete as practicable but no claim is made that it includes all records that have been published.

The system of nomenclature to be used in recording the data in table 5 has given considerable trouble. The records cited cover birds from all parts of the world. This material is listed according to the arrangement found in Sharpe's Handlist [1] and the names used are given in accordance with this list in most cases. In a few instances relating to North American birds, to avoid confusion with the system of names found in the previous tables, the names given are those of the A. O. U. Checklist for 1910 as in tables 3 and 4. Such deviations from the general rule are indicated by reference to a suitable footnote. This has eliminated confusion in generic names that might otherwise arise, as for example in the case of the two closely related scaup ducks, where the lesser scaup is given in table 3 as *Marila affinis,* while following Sharpe in table 5 the greater scaup would appear as *Fuligula marila.* By using the name in the A. O. U. Checklist this is changed to *Marila marila* thus dispelling any uncertainty as to the relationship of the two birds in the minds of those not familiar with the changes that have occurred in the application of generic names to these birds.

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[1] Sharpe, R. B., Handlist of the Genera and Species of Birds, 5 vols., 1899-1909.

TABLE 3.—*Summary of records of body temperature in birds*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
COLYMBIDAE						
Æchmophorus occidentalis	M.	101.3	....	....	1	R.
Colymbus auritus	M.	103.7	....	....	1	“
“ “	F.	104.9	....	....	1	“
Colymbus nigricollis	M.	104.2	103.0	104.6	4	“
“ “	F.	104.9	104.7	105.2	2	“
Podilymbus podiceps	F.	102.7	....	....	1	“
LARIDAE						
Larus californicus	M.	106.7	106.2	107.2	3	R.
“ “	F.	106.3	....	....	1	“
Larus delawarensis	F.	106.3	....	....	1	“
Larus atricilla	M.	105.9	....	....	1	“
Larus franklini	M.	105.1	104.5	106.0	3	“
“ “	F.	105.9	105.0	106.6	4	“
Larus philadelphia	M.	106.5	....	....	1	“
Sterna caspia	M.	105.3	103.7	106.8	2	“
“ “	F.	107.0	....	....	1	“
Sterna maxima	M.	105.6	....	....	1	“
“ “	F.	106.8	....	....	1	“
Sterna sandvichensis	M.	106.9	....	....	1	“
Sterna forsteri	M.	106.3	105.6	107.0	4	“
“ “	F.	106.8	105.7	107.3	4	“
Hydrochelidon nigra	M.	106.9	106.0	107.3	4	“
“ “	F.	107.0	106.5	107.6	6	“
RYNCHOPIDAE						
Rynchops nigra	M.	105.0	104.5	105.9	2	R.
ANHINGIDAE						
Anhinga anhinga	M.	105.7	....	....	1	R.
PHALACROCORACIDAE						
Phalacrocorax auritus	M.	106.1	101.4	107.0	4	R.
“ “	F.	106.3	106.2	106.3	2	“
PELECANIDAE						
Pelecanus erythrorhynchos	M.	103.5	103.0	104.0	2	R.
“ “	F.	103.8	....	....	1	“
Pelecanus occidentalis	M.	104.6	104.2	105.0	2	“
“ “	F.	104.5	103.4	106.3	4	“
ANATIDAE						
Mergus serrator	M.	107.5	....	....	1	R.
“ “	F.	107.5	106.3	108.6	2	“
Anas platyrhynchos	M.	106.4	105.1	108.0	4	“
“ “	F.	106.1	105.4	109.0	7	“
Chaulelasmus streperus	M.	107.5	....	....	1	“
Mareca americana	M.	105.8	....	....	1	“
Nettion carolinense	M.	106.1	104.2	108.0	19	“
“ “	F.	106.6	104.4	109.8	8	“
Querquedula discors	M.	108.6	107.7	109.4	2	“
“ “	F.	107.3	....	....	1	“
Querquedula cyanoptera	M.	106.5	105.0	108.2	7	“
“ “	F.	108.0	105.8	109.1	5	“
Spatula clypeata	M.	105.8	104.6	107.7	3	“
“ “	F.	107.3	106.3	109.0	3	“
Dafila acuta	M.	106.1	104.4	108.0	9	“
“ “	F.	107.5	106.9	108.0	2	“
Marila americana	M.	106.3	104.0	108.1	4	“
“ “	F.	109.9	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
ANATIDAE—*Continued*						
Marila affinis	M.	106.5	105.8	107.0	3	R.
“ “	F.	106.4	104.4	108.0	7	“
Erismatura jamaicensis	M.	106.2	103.9	108.2	2	“
“ “	F.	108.0	105.4	109.7	3	“
Chen hyperboreus	F.	107.7	....	....	1	“
Branta canadensis	M.	106.9	....	....	1	“
“ “	F.	105.8	104.6	107.0	2	“
IBIDIDAE						
Guara alba	F.	108.0	....	....	1	R.
Plegadis guarauna	F.	105.1	104.4	105.6	5	“
ARDEIDAE						
Botaurus lentiginosus	M.	104.0	....	....	1	R.
Ardea herodias	M.	104.8	104.5	105.0	2	“
“ “	F.	103.7	103.4	103.9	2	“
Egretta candidissima	M.	104.8	104.0	105.2	5	“
“ “	F.	104.0	102.2	106.2	8	“
Hydranassa tricolor	F.	105.5	105.5	105.5	2	“
Butorides virescens	F.	105.8	....	....	1	“
Nycticorax nycticorax	M.	103.5	102.4	105.4	3	“
“ “	F.	102.6	101.6	103.7	2	“
ARAMIDAE						
Aramus vociferus	M.	104.5	104.3	104.6	2	R.
RALLIDAE						
Rallus virginianus	M.	105.5	....	....	1	I.
“ “	F.	105.6	....	....	1	“
Fulica americana	?	106.7	105.9	109.0	12	R.
PHALAROPODIDAE						
Lobipes lobatus	M.	107.6	105.6	109.9	9	I.
“ “	F.	106.6	103.2	108.7	17	“
Steganopus tricolor	M.	106.3	104.8	108.6	10	“
“ “	F.	105.7	103.9	107.4	18	“
RECURVIROSTRIDAE						
Recurvirostra americana	M.	106.6	104.7	108.9	14	R.
“ “	F.	104.9	104.1	106.4	12	“
Himantopus mexicanus	M.	105.8	104.6	106.9	10	“
“ “	F.	105.8	103.8	108.4	9	“
SCOLOPACIDAE						
Gallinago delicata	M.	106.3	....	....	1	R.
“ “	F.	105.3	....	....	1	“
Macrorhamphus griseus	M.	106.1	103.4	108.0	9	“
“ “	F.	105.2	102.4	108.4	10	“
Pisobia maculata	F.	107.0	107.0	107.0	2	I.
Pisobia bairdi	M.	107.9	106.5	108.6	4	“
“ “	F.	107.2	....	....	1	“
Pisobia minutilla	M.	106.1	106.1	106.2	2	“
“ “	F.	106.6	105.9	107.8	6	“
Pelidna alpina	F.	106.8	....	....	1	“
Ereunetes mauri	M.	107.4	106.4	108.2	4	“
“ “	F.	107.3	106.0	108.4	21	“
Calidris leucophaea	M.	107.2	....	....	1	“
“ “	F.	107.1	106.3	108.8	7	“
Limosa fedoa	M.	105.9	104.6	106.5	4	R.
“ “	F.	105.1	102.3	107.3	27	“

Table 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Mini-mum	Maxi-mum		
Scolopacidae—*Continued*						
Totanus melanoleucus	M.	107.0	106.5	107.6	4	R.
“ “	F.	106.4	105.4	108.0	6	“
Totanus flavipes	M.	106.2	105.8	106.6	2	“
“ “	F.	106.9	105.4	108.2	4	“
Helodromas solitarius	M.	109.1	....	....	1	“
Catoptrophorus semipalmatus	M.	106.7	105.3	108.9	7	“
“ “	F.	106.6	104.6	108.3	10	“
Actitis macularia	M.	108.4	....	....	1	I.
Numenius americanus	M.	105.6	104.3	106.4	4	R.
Charadriidae						
Squatarola squatarola	M.	106.1	105.3	107.9	4	R.
“ “	F.	106.3	....	....	1	“
Oxyechus vociferus	M.	107.0	106.3	108.3	5	I.
“ “	F.	107.1	106.1	108.9	5	“
AEgialitis semipalmata	F.	109.0	....	....	1	“
AEgialitis nivosa	M.	106.8	106.4	107.3	2	“
“ “	F.	105.1	104.2	106.6	3	“
Ochthodromus wilsonius	F.	108.0	....	....	1	“
Podasocys montanus	M.	105.1	104.3	105.8	2	“
“ “	F.	106.7	106.6	106.8	2	“
Odontophoridae						
Colinus virginianus	M.	106.8	....	....	1	R.
“ “	F.	107.4	....	....	1	“
Oreortyx picta	M.	107.4	106.8	108.2	3	“
“ “	F.	107.8	....	....	1	“
Lophortyx californica	M.	108.0	107.4	108.7	4	“
“ “	F.	107.9	107.0	108.7	3	“
Columbidae						
Columba fasciata	M	108.0	....	....	1	R.
Zenaidura macroura	M.	109.0	107.3	111.8	11	“
“ “	F.	107.7	107.4	109.7	2	“
Melopelia asiatica	M.	108.5	107.3	111.8	7	“
“ “	F.	108.9	107.4	109.7	8	“
Chaemepelia passerina	M.	107.2	106.6	107.8	2	I.
Cathartidae						
Cathartes aura	M.	103.8	....	....	1	R.
Buteonidae						
Circus hudsonius	F.	105.5	....	....	1	R.
Accipiter velox	F.	109.0	108.0	110.0	2	“
Buteo borealis	M.	105.0	104.2	105.8	2	R.
Buteo swainsoni	M.	105.1	104.9	105.3	2	“
“ “	F.	105.5	....	....	1	“
Falconidae						
Falco peregrinus	F.	105.2	104.2	107.3	4	R.
Falco sparverius	M.	106.8	....	....	1	“
Aluconidae						
Aluco pratincola	M.	103.5	101.9	105.0	2	R.
Strigidae						
Asio wilsonianus	M.	104.2	....	....	1	R.
Asio flammeus	M.	102.2	....	....	1	“
Otus asio	M.	102.6	100.7	105.4	3	I.
“ “	F.	104.0	102.7	105.3	2	“
Otus flammeolus	M.	102.5	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
Strigidae—*Continued*						
Bubo virginianus	F.	103.8	102.0	105.8	3	R.
Speotyto cunicularia	F.	106.6	....	....	1	“
Cuculidae						
Coccyzus americanus	F.	108.1	106.9	109.3	3	I.
Coccyzus erythropthalmus	M.	109.6	....	....	1	“
“ “	F.	108.3	108.2	108.5	2	“
Alcedinidae						
Ceryle alcyon	M.	104.0	102.6	105.3	2	R.
Picidae						
Dryobates villosus	M.	108.2	108.0	108.4	2	I.
“ “	F.	108.7	108.3	109.0	2	“
Dryobates pubescens	M.	107.2	106.2	108.2	7	“
“ “	F.	108.3	107.9	108.7	2	“
Dryobates borealis	M.	108.2	....	....	1	“
“ “	F.	108.5	108.2	108.8	2	“
Dryobates scalaris	M.	107.3	106.8	107.9	4	“
“ “	F.	109.8	....	....	1	“
Dryobates nuttalli	M.	108.0	108.0	108.0	3	“
“ “	F.	108.4	108.1	108.7	2	“
Dryobates arizonae	M.	108.2	108.0	108.4	2	“
Picoides arcticus	M.	108.1	....	....	1	“
Picoides americanus	M.	107.0	106.5	107.4	2	“
“ “	F.	107.4	....	....	1	“
Sphyrapicus varius	M.	109.4	....	....	1	“
“ “	F.	107.8	106.8	109.0	3	“
Sphyrapicus ruber	M.	107.0	....	....	1	“
“ “	F.	108.5	....	....	1	“
Sphyrapicus thyroideus	M.	107.1	....	....	1	“
“ “	F.	106.3	105.2	107.3	2	“
Phloeotomus pileatus	M.	107.0	106.9	107.2	3	R.
Melanerpes erythrocephalus	M.	108.0	....	....	1	I.
“ “	F.	108.6	....	....	1	“
Melanerpes formicivorus	M.	108.6	108.0	109.2	3	“
“ “	F.	108.2	107.5	108.8	2	“
Asyndesmus lewisi	M.	108.6	....	....	1	“
“ “	F.	107.3	....	....	1	“
Centurus carolinus	M.	109.4	109.4	109.4	3	“
Centurus uropygialis	M.	108.7	....	....	1	“
“ “	F.	107.0	....	....	1	“
Colaptes auratus	M.	109.1	108.3	110.0	2	“
Colaptes cafer	M.	107.2	....	....	1	“
“ “	F.	108.9	....	....	1	“
Colaptes chrysoides	M.	105.8	....	....	1	“
“ “	F.	108.6	....	....	1	“
Caprimulgidae						
Antrostomus vociferus	M.	108.4	....	....	1	I.
Phalaenoptilus nuttalli	M.	107.2	....	....	1	“
Chordeiles virginianus	M.	106.2	....	....	1	“
“ “	F.	105.7	105.0	106.4	2	“
Chordeiles acutipennis	M.	107.8	107.7	107.9	2	“
“ “	F.	107.4	....	....	1	“
Micropodidae						
Chaetura pelagica	F.	107.2	....	....	1	I.
Aëronautes melanoleucus	M.	106.0	105.7	106.3	4	“
“ “	F.	105.3	105.2	105.3	2	“

Table 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
Trochilidae						
Archilochus colubris	M.	106.0	....	....	1	I.
“ “	F.	101.4	100.8	102.0	2	“
Archilochus alexandri	M.	103.0	102.7	103.6	3	“
“ “	F.	102.7	101.4	104.3	3	“
Selasphorus platycercus	F.	101.5	....	....	1	“
Selasphorus rufus	M.	102.2	101.8	102.6	2	“
Cynanthus latirostris	M.	105.9	105.1	106.5	3	“
Tyrannidae						
Tyrannus tyrannus	F.	107.8	....	....	1	I.
Tyrannus verticalis	M.	108.5	108.3	108.6	2	“
Tyrannus vociferans	M.	107.0	....	....	1	“
“ “	F.	108.2	....	....	1	“
Myiarchus cinerascens	M.	109.8	108.6	111.8	4	“
“ “	F.	110.1	109.2	111.0	2	“
Myiarchus lawrencei	M.	109.5	109.2	109.8	2	“
“ “	F.	110.2	....	....	1	“
Sayornis phoebe	M.	109.9	....	....	1	“
Sayornis nigricans	M.	109.1	108.6	109.7	3	“
“ “	F.	110.0	....	....	1	“
Nuttallornis borealis	M.	109.0	108.0	110.0	2	“
“ “	F.	108.4	....	....	1	“
Myiochanes pertinax	F.	110.3	108.7	111.6	5	“
Myiochanes virens	M.	108.9	....	....	1	“
Myiochanes richardsoni	M.	110.0	108.6	112.7	4	“
“ “	F.	110.4	....	....	1	“
Empidonax flaviventris	M.	108.0	107.4	109.0	6	“
“ “	F.	108.2	107.6	108.7	4	“
Empidonax difficilis	M.	108.2	107.0	109.8	3	“
Empidonax virescens	M.	108.8	108.4	109.2	2	“
“ “	F.	108.6	....	....	1	“
Empidonax trailli	M.	108.0	107.5	108.7	6	“
“ “	F.	108.6	107.2	109.6	4	“
Empidonax minimus	M.	107.5	....	....	1	“
“ “	F.	108.3	107.6	109.0	2	“
Empidonax hammondi	M.	106.2	....	....	1	“
“ “	F.	107.9	107.3	108.7	3	“
Empidonax wrighti	M.	108.3	107.7	108.7	3	“
Pyrocephalus rubinus	M.	108.6	108.2	109.0	2	“
Alaudidae						
Otocoris alpestris	M.	109.4	108.6	110.4	3	I.
“ “	F.	109.4	108.6	110.3	6	“
Corvidae						
Pica pica	M.	107.3	106.4	108.6	9	I.
“ “	F.	107.1	106.2	108.8	9	“
Pica nuttalli	M.	108.1	....	....	1	“
“ “	F.	107.7	107.6	107.8	2	“
Cyanocitta cristata	M.	108.4	108.0	108.8	2	“
“ “	F.	109.3	....	....	1	“
Cyanocitta stelleri	M.	107.4	....	....	1	“
“ “	F.	107.8	107.3	108.3	2	“
Aphelocoma cyanea	M.	108.2	107.7	108.5	5	“
“ “	F.	107.9	107.1	108.6	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Mini-mum	Maxi-mum		
CORVIDAE—*Continued*						
Aphelocoma woodhousei	M.	108.6	108.4	108.7	2	I.
“ “	F.	110.3	....	....	1	“
Aphelocoma californica	M.	107.5	107.3	107.6	2	“
“ “	F.	108.7	....	....	1	“
Aphelocoma sieberi	M.	108.5	108.2	108.7	2	“
“ “	F.	108.4	108.2	108.6	2	“
Perisoreus obscurus	M.	108.2	107.8	108.6	2	“
“ “	F.	107.3	....	....	1	“
Corvus corax	M.	107.4	....	....	1	R.
“ “	F.	108.6	107.6	109.6	2	“
Corvus cryptoleucus	M.	107.6	107.6	107.7	2	“
“ “	F.	106.8	....	....	1	“
Corvus brachyrhynchos	M.	107.9	107.6	108.4	4	“
Nucifraga columbiana	M.	106.6	....	....	1	“
“ “	F.	107.1	106.8	107.4	2	“
Cyanocephalus cyanocephalus	M.	106.6	....	....	1	I.
“ “	F.	108.3	....	....	1	“
ICTERIDAE						
Dolichonyx oryzivorus	M.	107.0	....	....	1	I.
Molothrus ater	M.	108.1	107.3	108.5	4	“
“ “	F.	108.2	108.0	108.3	2	“
Xanthocephalus xanthocephalus	M.	108.3	107.0	110.0	29	“
“ “	F.	108.2	106.6	110.3	18	“
Agelaius phoeniceus	M.	108.3	106.5	110.3	10	“
“ “	F.	108.1	106.7	108.7	6	“
Agelaius tricolor	M.	108.5	....	....	1	“
“ “	F.	108.6	108.0	109.0	4	“
Sturnella neglecta	M.	107.6	....	....	1	“
“ “	F.	108.4	107.8	109.0	2	“
Icterus parisorum	M.	107.9	107.2	108.4	4	I.
“ “	F.	108.1	107.8	108.3	2	“
Icterus cucullatus	M.	109.3	108.3	110.4	2	“
“ “	F.	107.6	....	....	1	“
Icterus spurius	M.	108.1	....	....	1	“
Icterus galbula	M.	109.1	109.1	109.2	2	“
Icterus bullocki	F.	108.0	107.8	108.2	3	“
Euphagus carolinus	M.	110.3	110.0	110.6	2	“
“ “	F.	109.7	109.6	110.0	3	“
Euphagus cyanocephalus	M.	108.7	108.6	108.8	2	“
“ “	F.	107.1	106.1	108.1	2	“
Quiscalus quiscula	F.	109.6	....	....	1	“
Megaquiscalus major	M.	109.4	109.3	109.6	2	“
“ “	F.	108.6	....	....	1	R.
FRINGILLIDAE						
Hesperiphona vespertina	M.	109.5	....	....	1	I.
“ “	F.	108.0	....	....	1	“
Carpodacus purpureus	M.	108.3	106.7	109.5	6	“
“ “	F.	108.3	....	....	1	“
Carpodacus mexicanus	M.	108.9	108.0	110.0	20	“
“ “	F.	108.8	108.6	109.2	7	“
Loxia curvirostra	M.	108.2	107.9	108.6	3	“
Loxia leucoptera	F.	109.4	108.9	109.9	2	“
Passer domesticus	M.	107.6	106.8	108.6	7	“
“ “	F.	107.9	107.0	108.8	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
FRINGILLIDAE—*Continued*						
Astragalinus tristis	M.	107.7	106.0	109.9	4	I.
“ “	F.	108.1	106.6	109.7	2	“
Spinus pinus	M.	108.3	107.4	108.8	3	“
“ “	F.	107.3	106.7	107.6	3	“
Calcarius lapponicus	F.	107.0	....	....	1	“
Passerculus sandwichensis	M.	108.3	106.6	110.0	5	“
“ “	F.	109.2	108.4	110.0	3	“
Ammodramus savannarum	M.	108.6	....	....	1	“
Passerherbulus henslowi	M.	106.2	....	....	1	“
Chondestes grammacus	F.	109.2	108.3	110.2	2	“
Zonotrichia querula	M.	108.2	107.5	109.6	3	“
“ “	F.	108.8	....	....	1	“
Zonotrichia leucophrys	M.	109.0	106.8	110.2	4	“
“ “	F.	108.9	108.8	109.1	2	“
Zonotrichia coronata	M.	108.5	....	....	1	“
“ “	F.	109.5	109.4	109.6	2	“
Zonotrichia albicollis	M.	110.2	109.4	110.8	5	“
Spizella monticola	M.	108.0	....	....	1	“
“ “	F.	108.6	107.3	109.5	8	“
Spizella passerina	M.	109.6	....	....	1	“
“ “	F.	106.9	....	....	1	“
Spizella pallida	M.	108.0	107.5	108.4	3	“
Spizella breweri	M.	108.1	107.7	108.5	2	I.
“ “	F.	108.7	108.0	109.4	2	“
Spizella pusilla	M.	107.4	106.2	108.7	5	“
“ “	F.	108.2	....	....	1	“
Junco hyemalis	M.	108.6	106.8	110.0	8	“
“ “	F.	108.8	107.1	110.3	3	“
Junco oreganus	M.	109.2	108.5	110.6	7	I.
“ “	F.	108.5	108.6	109.0	2	“
Junco phaeonotus	M.	108.3	108.0	108.9	4	“
“ “	F.	108.8	107.9	109.7	6	“
Amphispiza bilineata	M.	108.0	107.9	108.0	3	“
“ “	F.	110.0	....	....	1	“
Amphispiza nevadensis	F.	109.4	108.6	110.0	3	“
Peucaea aestivalis	M.	107.8	....	....	1	“
Aimophila ruficeps	M.	109.8	109.4	110.2	2	“
Melospiza melodia	M.	109.1	108.0	109.8	11	“
“ “	F.	109.1	108.3	110.2	4	“
Melospiza lincolni	M.	107.8	107.2	108.5	2	“
Melospiza georgiana	M.	108.8	107.9	109.8	3	“
“ “	F.	109.0	....	....	1	“
Passerella iliaca	M.	109.3	108.5	110.0	3	“
“ “	F.	109.3	108.6	109.9	2	“
Pipilo erythrophthalmus	M.	110.0	109.6	110.3	3	“
Pipilo maculatus	F.	109.1	108.4	110.3	3	“
Pipilo fuscus	M.	107.9	107.6	108.0	3	“
Pipilo crissalis	M.	108.5	108.0	109.6	3	“
“ “	F.	107.8	....	....	1	“
Pipilo aberti	M.	109.4	....	....	1	“
“ “	F.	110.4	....	....	1	“
Cardinalis cardinalis	M.	109.3	107.6	110.8	7	“
“ “	F.	109.3	108.6	110.0	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
FRINGILLIDAE—*Continued*						
Zamelodia ludoviciana	M.	107.8	107.3	108.2	2	I.
“ “	F.	108.8	....	....	1	“
Zamelodia melanocephala	M.	108.5	108.2	109.0	5	“
“ “	F.	108.5	108.0	109.5	4	“
Guiraca caerulea	M.	108.0	107.0	108.6	3	“
Passerina cyanea	M.	107.6	107.5	107.6	2	“
“ “	F.	109.8	....	....	1	“
Passerina amoena	M.	108.9	....	....	1	“
“ “	F.	108.2	....	....	1	“
Spiza americana	M.	108.3	107.9	108.9	7	“
Calamospiza melanocorys	M.	108.3	108.2	108.4	2	“
TANGARIDAE						
Piranga ludoviciana	M.	108.4	108.1	108.7	4	I.
“ “	F.	107.3	....	....	1	“
Piranga erythromelas	M.	107.8	106.8	109.5	4	“
“ “	F.	107.3	....	....	1	“
Piranga hepatica	M.	108.6	107.2	109.4	5	“
“ “	F.	110.2	110.0	110.4	2	“
Piranga rubra	M.	109.9	....	....	1	“
“ “	F.	109.3	109.1	109.5	3	“
HIRUNDINIDAE						
Progne subis	M.	107.4	107.0	107.7	4	“
“ “	F.	106.8	....	....	1	“
Petrochelidon lunifrons	M.	106.3	105.0	107.3	4	“
Hirundo erythrogastra	M.	106.5	....	....	1	“
Iridiprocne bicolor	M.	106.8	106.8	106.8	2	“
“ “	F.	107.0	106.0	107.9	2	“
Tachycineta thalassina	M.	105.7	104.6	106.8	2	“
“ “	F.	105.5	....	....	1	“
Riparia riparia	M.	105.7	105.4	106.2	4	“
Stelgidopteryx serripennis	M.	108.8	108.7	109.0	2	“
BOMBYCILLIDAE						
Bombycilla cedrorum	M.	108.2	107.2	109.2	3	I.
“ “	F.	109.7	109.0	110.7	3	“
PTILOGONATIDAE						
Phainopepla nitens	F.	107.4	107.4	107.4	2	I.
LANIIDAE						
Lanius ludovicianus	M.	107.5	....	....	1	I.
“ “	F.	108.0	107.3	109.3	3	“
VIREONIDAE						
Vireosylva olivacea	M.	108.5	107.9	109.2	2	I.
“ “	F.	109.7	....	....	1	“
Vireosylva philadelphica	M.	107.3	106.8	107.8	2	“
Vireosylva gilva	M.	107.5	107.0	107.9	3	“
“ “	F.	107.6	107.6	107.7	2	“
Lanivireo flavifrons	M.	108.0	....	....	1	“
“ “	F.	107.7	107.2	108.1	2	“
Lanivireo solitarius	M.	108.0	107.8	108.3	2	“
“ “	F.	107.3	107.3	107.4	2	“
Vireo griseus	F.	107.4	....	....	1	“
Vireo huttoni	F.	107.9	....	....	1	“
Vireo belli	M.	107.5	106.5	108.3	3	“
“ “	F.	106.3	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
MNIOTILTIDAE						
Mniotilta varia	M.	108.0	107.0	109.0	5	I.
“ “	F.	108.0	....	....	1	“
Helmitherus vermivorus	M.	107.4	107.2	107.5	2	“
“ “	F.	108.8	....	....	1	“
Vermivora pinus	M.	106.9	....	....	1	“
Vermivora chrysoptera	M.	109.4	....	....	1	“
“ “	F.	108.2	....	....	1	“
Vermivora luciae	M.	108.7	108.6	108.9	2	“
“ “	F.	108.8	108.0	109.5	2	“
Vermivora virginiae	M.	108.0	107.8	108.3	2	“
“ “	F.	108.2	108.0	108.5	2	“
Vermivora celata	M.	107.7	106.3	109.1	2	“
“ “	F.	107.3	107.2	107.4	2	“
Vermivora peregrina	M.	107.9	107.5	108.0	4	“
“ “	F.	108.3	....	....	1	“
Compsothlypis americana	M.	107.2	106.7	107.8	3	“
“ “	F.	108.4	....	....	1	“
Peucedramus olivaceus	M.	107.5	....	....	1	I.
Dendroica tigrina	M.	108.8	107.6	109.9	2	“
Dendroica aestiva	M.	108.6	107.9	109.8	3	“
Dendroica caerulescens	M.	108.0	107.5	108.5	6	“
“ “	F.	108.6	106.8	108.4	2	“
Dendroica coronata	F.	108.5	107.6	109.0	4	“
Dendroica auduboni	M.	107.7	106.9	108.4	3	“
“ “	F.	108.0	....	....	1	“
Dendroica magnolia	M.	108.0	106.6	109.3	5	“
“ “	F.	107.7	107.0	108.2	4	“
Dendroica cerulea	M.	109.0	....	....	1	“
Dendroica pennsylvanica	M.	108.6	107.2	109.4	6	“
“ “	F.	108.4	108.0	108.7	2	“
Dendroica castanea	M.	107.9	107.2	108.7	7	“
“ “	F.	108.8	108.7	108.9	3	“
Dendroica striata	M.	107.8	107.2	108.5	3	“
“ “	F.	107.4	107.0	107.8	2	“
Dendroica fusca	M.	107.8	107.8	107.8	3	“
“ “	F.	108.2	107.8	108.6	2	“
Dendroica dominica	M.	108.3	108.0	108.6	2	“
Dendroica graciae	M.	108.0	107.2	109.5	4	“
Dendroica nigrescens	F.	108.2	....	....	1	“
Dendroica virens	M.	108.0	107.6	108.5	9	I.
Dendroica vigorsi	M.	108.3	108.0	108.6	2	“
“ “	F.	109.2	....	....	1	“
Dendroica palmarum	M.	108.9	108.0	109.5	3	“
“ “	F.	108.3	107.8	109.2	4	“
Dendroica discolor	M.	108.0	107.6	108.4	2	“
Seiurus aurocapillus	M.	107.4	107.1	108.0	3	“
Seiurus noveboracensis	M.	108.5	106.2	109.7	4	“
“ “	F.	109.0	....	....	1	“
Seiurus motacilla	M.	109.4	....	....	1	“
Oporornis formosus	M.	107.8	....	....	1	“
Oporornis philadelphia	M.	107.7	107.3	108.0	3	“
Oporornis tolmiei	M.	108.2	107.0	109.4	2	“
“ “	F.	107.0	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
Mniotiltidae—*Continued*						
Geothlypis trichas	M.	108.0	....	....	1	I.
“ “	F.	108.1	106.6	109.0	3	“
Icteria virens	M.	109.2	108.0	110.4	2	“
“ “	F.	107.9	....	....	1	“
Wilsonia citrina	M.	109.6	....	....	1	“
Wilsonia pusilla	M.	107.7	106.8	108.6	6	“
“ “	F.	106.6	....	....	1	“
Wilsonia canadensis	M.	107.2	106.7	107.6	2	“
“ “	F.	107.6	107.0	108.3	3	“
Setophaga ruticilla	M.	106.8	....	....	1	“
“ “	F.	109.0	....	....	1	“
Setophaga picta	M.	108.5	108.0	109.0	3	“
“ “	F.	111.0	....	....	1	“
Motacillidae						
Anthus rubescens	M.	107.9	107.6	108.1	2	I.
“ “	F.	109.1	108.4	109.8	2	“
Anthus spraguei	M.	108.6	108.6	108.6	2	“
Cinclidae						
Cinclus mexicanus	M.	107.3	....	....	1	I.
Mimidae						
Oreoscoptes montanus	M.	109.0	....	....	1	I.
“ “	F.	109.2	....	....	1	“
Mimus polyglottos	M.	109.2	108.1	110.4	4	“
“ “	F.	109.0	108.4	109.6	2	“
Dumetella carolinensis	M.	108.6	....	....	1	“
“ “	F.	108.7	108.6	108.8	2	“
Toxostoma curvirostre	M.	108.0	....	....	1	“
“ “	F.	109.7	....	....	1	“
Toxostoma crissale	M.	108.5	....	....	1	“
“ “	F.	109.5	....	....	1	“
Troglodytidae						
Heleodytes brunneicapillus	F.	108.5	....	....	1	I.
Catherpes mexicanus	F.	107.9	....	....	1	“
Thryothorus ludovicianus	M.	108.9	108.4	109.7	3	“
“ “	F.	108.4	108.2	108.7	4	“
Thryomanes bewicki	M.	107.9	107.4	108.2	3	“
“ “	F.	107.5	107.5	107.6	2	“
Troglodytes aëdon	M.	106.2	....	....	1	“
Nannus hiemalis	M.	107.3	106.6	107.9	5	“
Telmatodytes palustris	M.	107.4	106.2	109.2	7	“
“ “	F.	105.7	105.2	106.6	3	“
Certhiidae						
Certhia familiaris	M.	107.7	107.1	108.5	4	I.
“ “	F.	107.4	....	....	1	“
Sittidae						
Sitta carolinensis	M.	107.7	106.8	108.3	3	I.
“ “	F.	107.7	106.0	108.8	3	“
Sitta canadensis	M.	107.9	107.5	108.2	5	“
“ “	F.	107.9	107.8	107.9	3	“
Sitta pusilla	M.	106.2	....	....	1	“
Sitta pygmaea	F.	107.8	107.8	107.9	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
PARIDAE						
Baeolophus bicolor	M.	108.8	108.6	109.0	3	I.
“ “	F.	109.4	109.2	109.6	2	“
Baeolophus inornatus	M.	108.7	107.7	110.0	4	“
“ “	F.	108.6	....	....	1	“
Baeolophus wollweberi	M.	107.6	....	....	1	“
“ “	F.	108.5	108.3	108.7	2	“
Penthestes atricapillus	M.	107.9	....	....	1	“
“ “	F.	108.7	108.2	109.6	3	“
Penthestes carolinensis	M.	108.0	106.6	109.4	4	“
“ “	F.	108.3	107.5	109.3	8	“
Penthestes sclateri	M.	107.3	106.3	108.4	2	“
“ “	F.	107.8	....	....	1	“
Penthestes gambeli	M.	109.0	....	....	1	“
“ “	F.	108.3	107.9	108.6	2	“
Psaltriparus minimus	M.	106.0	106.0	106.0	2	“
“ “	F.	105.3	....	....	1	“
Psaltriparus plumbeus	M.	108.2	....	....	1	“
“ “	F.	107.4	....	....	1	“
Auriparus flaviceps	M.	106.2	106.0	106.5	2	“
“ “	F.	107.5	107.5	107.6	2	“
CHAMAEIDAE						
Chamaea fasciata	M.	106.8	....	....	1	I.
“ “	F.	108.0	108.0	108.1	2	“
SYLVIIDAE						
Regulus satrapa	M.	106.9	106.3	107.3	4	I.
“ “	F.	107.7	....	....	1	“
Regulus calendula	M.	106.0	106.0	106.1	2	“
“ “	F.	107.7	107.3	108.3	3	“
Polioptila caerulea	M.	107.7	106.0	108.7	5	“
“ “	F.	107.6	....	....	1	“
Polioptila plumbea	M.	107.8	107.5	108.0	2	“
TURDIDAE						
Myadestes townsendi	F.	109.3	108.6	110.0	2	I.
Hylocichla mustelina	M.	109.0	....	....	1	“
Hylocichla fuscescens	M.	109.0	108.6	109.4	2	“
Hylocichla aliciae	M.	109.6	....	....	1	“
“ “	F.	108.3	108.0	108.6	2	“
Hylocichla ustulata	M.	108.3	107.2	109.5	2	“
“ “	F.	110.4	110.1	110.8	2	“
Hylocichla guttata	M.	109.3	108.4	109.8	6	“
“ “	F.	107.6	....	....	1	“
Planesticus migratorius	M.	109.8	107.6	111.6	8	“
“ “	F.	109.7	....	....	1	“
Sialia sialis	M.	108.1	108.0	108.2	2	“
“ “	F.	108.0	....	....	1	“
Sialia mexicana	M.	109.6	....	....	1	“
Sialia currucoides	M.	108.0	....	....	1	“

TABLE 4.—*Average temperatures of families of birds, summarized from Table 3*

Family	No. of species	Temperature			No. of records
		Mean	Minimum	Maximum	
Colymbidae	4	103.6	101.3	104.9	10
Laridae	10	106.3	105.1	107.0	38
Rynchopidae	1	105.0	.....	.....	2
Anhingidae	1	105.7	.....	.....	1
Phalacrocoracidae	1	106.2	106.1	106.3	7
Pelecanidae	2	103.6	103.5	103.8	9
Anatidae	14	107.0	105.8	109.9	98
Ibididae	2	106.5	105.1	108.0	6
Ardeidae	6	104.3	102.6	105.8	26
Aramidae	1	104.5	.....	.....	2
Rallidae	2	105.9	105.5	106.7	14
Phalaropodidae	2	106.6	105.7	107.6	54
Recurvirostridae	2	105.7	104.9	106.6	45
Scolopacidae	15	106.7	105.1	109.1	140
Charadriidae	6	106.7	105.1	109.0	26
Odontophoridae	3	107.6	106.8	108.0	13
Columbidae	4	108.2	107.2	109.0	39
Cathartidae	1	103.8	.....	.....	1
Buteonidae	4	106.0	105.0	109.0	8
Falconidae	2	106.0	105.2	106.8	5
Aluconidae	1	103.5	.....	.....	2
Strigidae	6	103.7	102.2	106.6	12
Cuculidae	2	108.7	108.1	109.6	6
Alcedinidae	1	104.0	.....	.....	2
Picidae	20	108.0	105.8	109.8	64
Caprimulgidae	4	107.1	105.7	108.4	8
Micropodidae	2	106.2	105.3	107.2	7
Trochilidae	5	103.2	101.4	106.0	15
Tyrannidae	19	108.7	106.2	110.4	71
Alaudidae	1	109.4	.....	.....	9
Corvidae	14	107.9	106.6	110.3	62
Icteridae	15	108.4	107.0	110.3	106
Fringillidae	46	108.6	106.2	110.4	236
Tangaridae	4	108.6	107.3	110.2	21
Hirundinidae	7	106.7	105.5	108.8	23
Bombycillidae	1	108.9	108.2	109.7	6
Ptilogonatidae	1	107.4	.....	.....	2
Laniidae	1	107.8	107.5	108.0	4
Vireonidae	8	107.7	106.3	109.7	23
Mniotiltidae	41	108.2	106.6	111.0	163
Motacillidae	2	108.5	107.9	109.1	6
Cinclidae	1	107.3	.....	.....	1
Mimidae	5	108.9	108.0	109.7	15
Troglodytidae	7	107.6	105.7	108.9	30
Certhiidae	1	107.5	107.4	107.7	5
Sittidae	4	107.5	106.2	107.9	17
Paridae	10	107.9	105.3	109.4	44
Chamaeidae	1	108.0	108.0	108.1	3
Sylviidae	4	107.3	106.0	107.8	18
Turdidae	10	108.9	107.6	110.4	33

TABLE 5.—*Temperatures of species of birds not included in Table 3, taken from available literature*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
STRUTHIONIDAE						
Struthio camelus	M.	104.0	.....	.....	1	Bergtold, 1917, p. 52.
“ “	F.	101.0	100.0	102.0	2	Bergtold, 1917, p. 52.
DROMAEIDAE						
Dromaeus novaehollandiae.	?	102.2	.....	.....	?	Sutherland, 1899, p. 789.
CASUARIIDAE						
Casuarius intensus ...	?	101.8	.....	.....	?	Sutherland, 1899, p. 789.
Casuarius beccarii ...	?	102.5	.....	.....	?	Sutherland, 1899, p. 789.
APTERYGIDAE						
Apteryx mantelli	M.	100.0	99.3	100.7	2	Sutherland, 1899, p. 789.
Apteryx haasti	M.	100.5	.....	.....	1	Sutherland, 1899, p. 789.
TINAMIDAE						
Rhynchotus rufescens.	?	105.4	.....	.....	?	Sutherland, 1899, p. 789.
Nothura maculosa ...	?	104.9	102.5	108.3	3	Sutherland, 1899, p. 789.
CRACIDAE						
Crax globicera	M.	106.4	.....	.....	3	Bergtold, 1917, p. 53.
“ “	F.	106.4	.....	.....	4	Bergtold, 1917, p. 53.
PHASIANIDAE						
Francolinus natalensis.	?	107.9	.....	.....	?	Bergtold, 1917, p. 53.
Phasianus torquatus..	M.	107.5	.....	.....	2	Bergtold, 1917, p. 53.
“ “ ..	F.	106.0	.....	.....	1	Bergtold, 1917, p. 53.
Gallus gallus	M.	106.5	105.6	107.5	52	Simpson and Galbraith, 1905, p. 237.
“ “	F.	106.7	105.5	107.4	52	Simpson and Galbraith, 1905, p. 237.
“ “ (Bantam).	M.	106.4	105.2	107.3	52	Simpson and Galbraith, 1905, p. 237.
“ “ “ .	F.	106.9	105.6	107.8	52	Simpson and Galbraith, 1905, p. 237.
Pavo cristatus	?	107.1	104.9	109.4	2	Milne-Edwards, H., 1863, p. 17.
Numida meleagris ...	?	110.0	.....	.....	?	Pembery, 1898, p. 791.
Meleagris gallopavo..	?	109.0	.....	.....	?	Pembery, 1898, p. 791.
COLUMBIDAE						
Columba livia (domestic).	M.	105.6	103.9	105.6	51	Simpson and Galbraith, 1905, p. 237.
Columba livia (domestic).	F.	106.4	105.1	107.5	52	Simpson and Galbraith, 1905, p. 237.
Columba phaeonota...	?	110.0	.....	.....	1	Bergtold, 1917, p. 55.
Geotrygon montana...	?	110.0	.....	.....	1	Bergtold, 1917, p. 55.
RALLIDAE						
Rallus crepitans[1].....	?	104.2	.....	.....	...	Weber, 1918, p. 31.
Fulica atra	?	104.9	.....	.....	1	Milne-Edwards, H., 1863, p. 18.
SPHENISCIDAE						
Eudyptula minor	?	102.1	100.0	104.2	?	White, 1916, p. 56.
PROCELLARIIDAE						
Procellaria pelagica...	?	103.6	.....	.....	1	Simpson, 1912a, p. 31.
PUFFINIDAE						
Puffinus tenuirostris[1].	?	101.6	100.0	103.2	?	White, 1916, p. 46.
“ “ .	yg.	100.2	99.4	101.0	?	White, 1916, p. 46.
Fulmarus glacialis....	?	101.8	100.5	103.3	5	Martins, 1858, p. 32.
Daption capensis	?	103.6	102.8	104.3	4	Brown-Sequard, 1858, p. 44.

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[1] A. O. U. Checklist, 1910.

TABLE 5.—*Continued*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
DIOMEDEIDAE						
Diomedea exulans ...	?	105.2	103.2	107.4	7	Brown-Sequard, 1858, p. 43.
Thalassogeron chlororhynchus	?	105.8	105.2	106.3	2	Brown-Sequard, 1858, p. 43.
ALCIDAE						
Alca torda	M.	103.8	.....	.....	1	Simpson, 1912a, p. 32.
" "	F.	105.9	.....	.....	1	Simpson, 1912a, p. 32.
Uria troille	M.	104.3	102.3	106.1	2	Simpson, 1912a, pp. 27-32.
" "	F.	104 5	103.6	105.4	3	Simpson, 1912a, pp. 27-32.
Uria lomvia	?	104.9	103.5	106.7	8	Martins, 1858, p. 32.
Cepphus grylle	M.	105.1	104.1	105.8	6	Simpson, 1912a, pp. 27-32.
" "	F.	105.6	104.3	106.7	7	Simpson, 1912a, pp. 27-32.
Fratercula arctica	?	105.3	105.2	105.5	2	Martins, 1858, p. 32.
LARIDAE						
Larus ridibundus	?	1 6.5	.....	.....	1	Martins, 1858, p. 32.
Larus argentatus	?	108.2	106.9	109.4	10	Martins, 1858, p. 32.
Larus fuscus	?	107.0	106 3	107.7	3	Simpson, 1912a, p. 31.
Larus canus	?	107.1	105.9	107.7	8	Simpson, 1912a, p. 31.
Larus glaucus	?	105.3	103.6	107.0	12	Martins, 1858, p. 33.
Pagophila eburnea ...	?	104.8	103.9	106.2	3	Martins, 1858, pp. 32-33.
Rissa tridactyla	?	106.6	103.8	108.3	16	Simpson, 1912a, p. 31.
Megalestris catarrhactes.	?	104.2	103.2	105.4	6	Brown-Sequard, 1858, p. 44.
STERCORARIIDAE						
Stercorarius parasiticus.	?	106.2	.....	.....	1	White, 1916, p. 46.
CHIONIDIDAE						
Chionis minor	?	104.0	.....	.....	?	Eydoux and Souleyet, 1838, p. 458.
EURYPYGIDAE						
Eurypyga helias	?	102.4	.....	.....	1	Bergtold, 1917, p. 54.
ANATIDAE						
Cygnus olor	M.	105.9	105.7	106.3	3	Martins, 1858, p. 33.
" "	F.	105.9	105.6	106.3	4	Martins, 1858, p. 33.
Cairina moschata	?	107.7	105.5	108.2	16	Martins, 1858, p. 37.
Aix sponsa[1]	?	107.6	.....	.....	1	Simpson, 1912a, p. 31.
Anser (domestic goose).	?	106.4	104.4	107.6	96	Martins, 1858, pp. 34-36.
Anser albifrons	?	109.1	.....	.....	1	Martins, 1858, p. 36.
Cygnopsis cygnoides..	?	109.1	108.3	109.9	4	Martins, 1858, p. 33.
Branta bernicla	?	108.9	.....	.....	1	Martins, 1858, p. 36.
Tadorna tadorna	?	108.8	108.3	109.2	3	Martins, 1858, p. 36.
Anas platyrhynchos[1] (domestic).	M.	106.4	105.6	107.2	42	Simpson and Galbraith, 1905, p. 237.
Anas platyrhynchos[1] (domestic).	F.	107.0	105.9	107.7	41	Simpson and Galbraith, 1905, p. 237.
Anas rubripes[1]	?	105.8	105.2	106.7	3	Simpson, 1912a, p. 31.
Mareca penelope	?	108.5	106.6	109.5	18	Martins, 1858, p. 40.
Marila marila[1]	?	108.8	107.9	109.9	7	Martins, 1858, p. 36.
Clangula clangula ...	?	104.7	.....	.....	1	Simpson, 1912a, p. 31.
Oidemia nigra	?	106.3	105.6	107.0	2	Simpson, 1912a, p. 31.
Somateria mollissima.	?	108.4	104.1	109.8	9	Martins, 1858, p. 36.

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[1] A. O. U. Checklist, 1910.

TABLE 5.—*Continued*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
PHALACROCORACIDAE						
Phalacrocorax carbo.	?	103.6	102.0	104.5	12	Simpson, 1912a, p. 31.
Phalacrocorax graculus.	M.	104.7	102.9	105.6	7	Simpson, 1912a, pp. 27-32.
Phalacrocorax graculus.	F.	104.8	103.2	106.1	12	Simpson, 1912a, pp. 27-32.
SULIDAE						
Sula bassana	?	107.0	104.5	108.1	7	Simpson, 1912a, p. 31.
FALCONIDAE						
Astur palumbarius	?	107.2	106.8	107.4	?	Hildén and Stenbäck, 1916, pp. 382-413.
Gypaëtus barbatus	?	105.8	....	.....	?	Milne-Edwards, H., 1863, p. 17.
Archibuteo lagopus	M.	105.8	....	.....	1	Bergtold, 1917, p. 53.
Falco mexicanus	M.	106.6	....	.....	1	Bergtold, 1917, p. 53.
BUBONIDAE						
Strix varia[1]	?	102.6	102.6	102.6	?	Weber, 1918, p. 31.
MOMOTIDAE						
Momotus paraensis	?	104.1	....	.....	1	Bergtold, 1917, p. 55.
MICROPODIDAE[1]						
Micropus apus	?	111.2	....	.....	?	Pembery, 1898, p. 791.
MUSOPHAGIDAE						
Turacus corythaix	?	104.2	....	.....	1	Bergtold, 1917, p. 55.
CUCULIDAE						
Geococcyx californianus.	M.	107.4	....	.....	1	Bergtold, 1917, p. 55.
MIMIDAE						
Toxostoma rufum	?	109.6	....	.....	1	Weber, 1918, p. 29.
TURDIDAE						
Turdus pilaris	?	110.6	....	.....	?	Pembery, 1898, p. 791.
Hylocichla iliaca	?	109.9	....	.....	?	Pembery, 1898, p. 791.
Hylocichla musica	?	105.6	101.2	108.7	29	Simpson and Galbraith, 1905, p. 237.
“ “	?	106.0	101.5	108.3	21	Simpson and Galbraith, 1905, p. 237.
BOMBYCILLIDAE[1]						
Bombycilla garrula[1]	M.	108.0	....	.....	1	Bergtold, 1917, p. 56.
“ “[1]	F.	107.1	106.2	107.8	3	Bergtold, 1917, p. 56.
PARIDAE						
Parus major	?	111.2	....	.....	?	Pembery, 1898, p. 791.
MNIOTILTIDAE						
Oporornis agilis	?	108.6	....	.....	1	Weber, 1918, p. 29.
FRINGILLIDAE						
Ligurinus chloris	?	106.8	106.1	107.9	?	Hildén and Stenbäck, 1916, pp. 382-413.
Pyrrhula pyrrhula	?	107.9	....	.....	1	Milne-Edwards, H., 1863, p. 17.
Emberiza citrinella	?	109.8	....	.....	?	Pembery, 1898, p. 791.
Plectrophenax nivalis.	?	109.6	109.2	110.1	2	Milne-Edwards, H., 1863, p. 17.
Calcarius ornatus	M.	109.6	....	.....	1	Bergtold, 1917, p. 57.
Passerherbulus caudacutus[1].	?	109.2	....	.....	1	Weber, 1918, p. 30.
Peucaea cassini[1]	M.	108.0	....	.....	1	Bergtold, 1917, p. 57.

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[1] A. O. U. Checklist, 1910.

TABLE 5.—*Continued*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
STURNIDAE						
Sturnus vulgaris	?	106.7	101.9	109.1	17	Simpson and Galbraith, 1905, p. 237.
" "	?	107.8	104.3	110.2	55	Simpson and Galbraith, 1905, p. 237.
" "	?	106.5	103.5	108.7	55	Simpson and Galbraith, 1905, p. 237.
" "	?	106.6	103.3	109.2	56	Simpson and Galbraith, 1905, p. 237.
PARADISEIDAE						
Paradisea apoda	?	106.7	.....	.....	1	Bergtold, 1917, p. 55.
CORVIDAE						
Coloeus monedula ...	M.	107.0	105.2	108.4	56	Simpson and Galbraith, 1905, p. 237.
" " ...	F.	107.7	106.2	108.8	57	Simpson and Galbraith, 1905, p. 237.
Psilorhinus morio ...	?	110.0	.....	.....	1	Bergtold, 1917, p. 57.
Pyrrhocorax alpinus ..	?	107.7	.....	.....	1	Milne-Edwards, H., 1863, p. 17.

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