COLD RESISTANCE IN THE YOUNG RING-NECKED PHEASANT

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COLD resistance in many homoiothermic animals is not fully developed at birth, even though life after birth often entails resistance to low environmental temperatures. Because of less frequent utilization of sheltered burrows and dens for nesting, this problem would appear to be more acute in birds than in mammals. Some birds are further developed at hatching than others, and thereafter use no shelter beyond that afforded by the brooding hen. In northern United States the Ring-necked Pheasant is one of the most successful of these precocial species. In addition it is one of our most valuable game birds, and each year considerable resources are devoted to its propagation and management. Therefore a characterization of the development of cold resistance in this precocial species may well be of practical value in shedding light upon a possible mortality factor of early life.

MATERIALS AND METHODS

The young Ring-necked Pheasants were obtained from the Wisconsin Conservation Department through the agency of Mr. Fred Greeley of the Department of Zoology and were part of a larger group under study by the two departments. Though the principal ancestral stocks of these birds were *Phasianus colchicus torquatus* and *Phasianus c. colchicus, Phasianus c. mongolicus* and *Phasianus c. formosanus* also have been introduced into the game farm breeding stock. In all, 27 chicks from one hatch in 1949 and 38 chicks from five different aged hatches in 1950 were used. They were housed at brooder temperatures of 38 to 40° C., although slightly cooler thermal environments were available towards the periphery of the brooder. They were supplied with a continual source of drinking water and with game farm mash.

Body temperatures were measured with a Cambridge thread recorder utilizing thermocouples of copper-constantan inserted cloacally to a depth of 3.5 cm. Two measurements were made: one immediately after removal from the brooder and another following a timed exposure in a chamber immersed in a regulated cold bath. This exposure chamber afforded the chick just sufficient room to avoid contact with its walls. All measurements were made during the daytime when the chicks were normally active.

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BODY TEMPERATURES IN THE BROODER

Results.—Though the young pheasants lived in a hot thermal environment (38–40° C.), their body temperature was lower than that of adults. In figure 1 the average body temperature of young in the brooder is shown as a function of age. The body temperature of the 1949 hatch rose from about 39° on the 2nd day of life to 42° C. on the 13th day. During this time its standard deviation ranged from 0.49° to 1.14°, averaging 0.66° (figure 2). Again in the 5 hatches from 1950, the average body temperature rose with age to a level over 42°. During this time, its standard deviation ranged from 0.13° to 0.93°, averaging 0.57° (figure 1). The 1950 curve lies above that of 1949, and its individual averages do not describe nearly as regular a rise as those of the 1949 data, although a smooth curve can be easily drawn through the initial points of its 5 different hatches.

Discussion.—The body temperature level in adult pheasants lies between 42° and 43° C. Bennett (cited by Gerstell and Long, 1939) found an average body temperature of 43.0° in 70 pheasants in December, and an average of 42.5° in 60 birds in February. Fronda (1921) lists an average temperature of 42.5° for pheasants. Löer (1910) studying a number of species of pheasants, including the Ring-necked, gave an average of 42.44° (σ = 0.55°) for 22 birds of less than 1 year in age and 42.61° (σ = 0.59°) for 23 birds of from 2 to 4 years of age.

While in the brooder, the young pheasant is not under cold stress, for the temperature is only 2 to 5° lower than the adult body temperature. The brooder temperature would appear to lie within the range of thermic neutrality, for thermic neutrality in the 4 to 14 day old chicken, another gallinaceous species, has been shown to be around 35° (Barott and Pringle, 1946). While living in the brooder, the temperature of the pheasant chicks is only slightly more variable than that of the adults: σ = 0.66° and 0.57° compared to 0.55° and 0.59°. Hence the slow rise in body temperature is not a matter of developing a capacity for regulation, but rather a gradual rise in the regulated temperature level.

Lamoreux and Hutt (1939), Scholes and Hutt (1942), and Randall (1943) have described this same gradual rise in the body temperature of the chicken, another precocial species. Scholes and Hutt brooded their chickens at 30.5°, 32°, 34°, 35°, 38° and 40° C. and discovered that the body temperatures at the higher brooder temperatures lay slightly above those at the lower brooder temperatures. But the differences in body temperatures were only 0.5 to 1.3° as compared

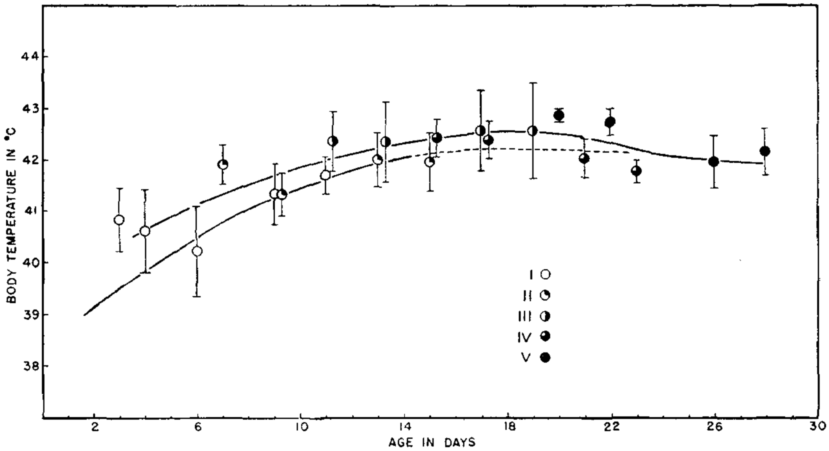

FIGURE 1. The relation between body temperature in the brooder and age. Circles show average values and bars show standard deviations for 6 to 10 individual measurements on 5 hatches of different ages in 1950. Top, average curve for 1950; bottom, average curve for 1949.

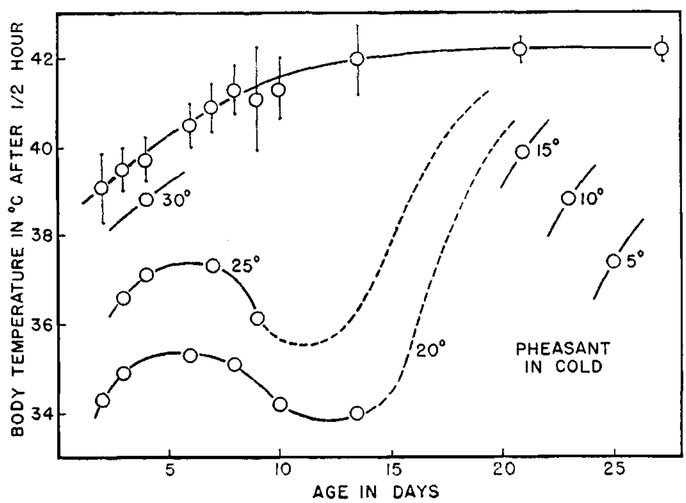

FIGURE 2. The body temperature after exposure to cold for 30 minutes as a function of age; 1949 results. Each circle shows the average value for 10 individual measurements. Ambient temperature is printed beside each curve. Top curve represents the body temperature of the chicks in the brooder. (Dotted lines are extrapolations.)

to a 9.5° difference between the highest and lowest brooder temperatures. At brooder temperatures of 38 to 40°, they noted an increase in body temperature of 1.5° (39.8 to 41.3°) between the ages of 2 and 9 days. This compares with an average increase of 1.6° (39.9 to 41.5°) observed in the pheasant (figure 1).

It would be expected that similar or even greater increases would be observed in altricial species, but only limited data are available on a single species, the House Wren (*Troglodytes aëdon*). In this form Kendeigh and Baldwin (1928) found that during the nestling period the body temperature of the young wren rose higher and higher above that of the incubator (*ca.* 38°). The body temperature of the 12 to 15 day wren was still 1.2 to 3.4° below that of the adult at ambient temperatures of 38 to 41° (Kendeigh, 1939).

EXPOSURE TO COLD

Development of cold resistance.—Figure 2 traces the effect of repeated exposure to cold upon the development of cold resistance in chicks of the 1949 hatch. It can be seen that exposure of only 30 minutes to mild ambient temperatures of 20 to 25° C. resulted in considerable losses of body temperature in the young chicks. The severity of the loss was related to the severity of the exposure, for the body temperature curve during exposure at 20° lies slightly below that at 25°. During 30-minute exposures to a temperature of 20°, the 2- to 4-day-old chick dropped 3 to 5°, the 6- to 7-day-old chick dropped almost as much, and the 8- to 13-day-old chick dropped 7 to 8°. These chicks were rested for eight days and then tested again, and their regulatory success was much better. But even on the twenty-fifth day, exposure at 5° resulted in a drop of more than 4° in body temperature. Therefore repeated 30-minute exposures to ambient temperatures of 20 to 25°, even though spaced at least one day apart, not only retarded the development of cold resistance, but actually set it back.

By employing five different hatches in 1950 it was possible to expose simultaneously chicks of 3, 7, 11, 15, and 20 days of initial age, in order to study the effect of repeated cold exposure upon different age classes. Figure 3 traces the effect of repeated cold exposure upon the five hatches from 1950 and shows the 1949 results for comparison.

The 3-day-old chicks from Hatch 1 were divided into two groups, so that both a light and a heavy exposure schedule could be employed. The results from the chicks on the heavier exposure schedule paralleled those obtained on the 1949 chicks. With each repeated exposure

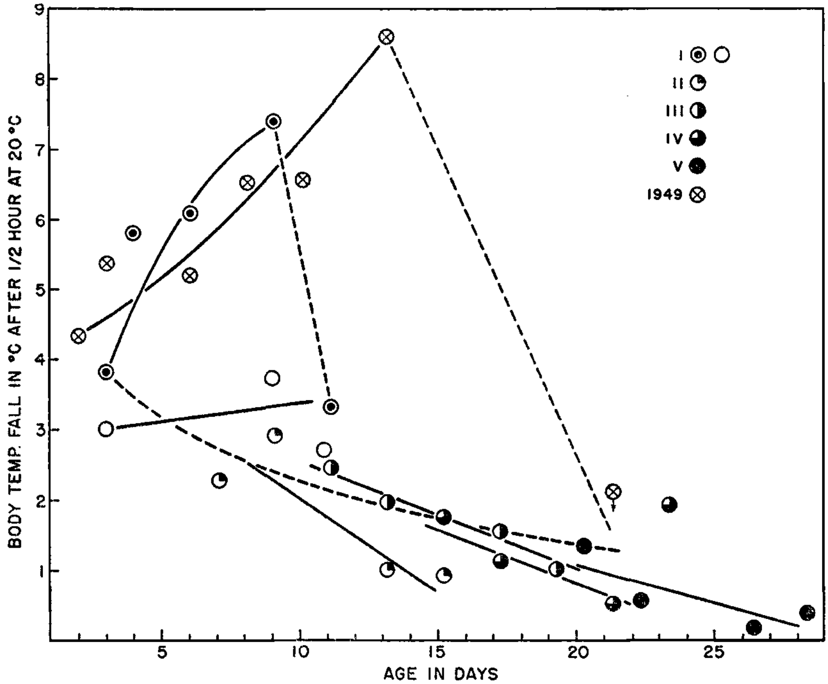

FIGURE 3. The loss in body temperature after 30 minutes at 20° as a function of age. Crossed circles, 1949 hatch; other circles, 1950 hatches. Each circle represents an average of 6 to 10 measurements (except for Hatch 1 in 1950, see table 2). Solid curves show trends within each hatch. The heavy broken curve represents the initial measurements made on each group; i.e., values uncomplicated by previous experimental treatment.

to cold, their cold resistance became progressively poorer, and only one of four chicks lived beyond nine days of age. The chicks on the lighter exposure schedule were not as drastically affected. Although cold resistance had only slightly improved by the eleventh day of age, they did not undergo the same progressive weakening in cold resistance as did both the first group and the 1949 chicks, and four of five chicks lived beyond the ninth day of life.

If the chicks were at least seven days old when initially exposed, no deleterious effects were evident. Indeed, in these older chicks previous cold exposure actually improved their resistance. This is illustrated in figure 3 in which the lines for individual hatches have much steeper slopes, showing faster improvement than the overall curve for all groups without previous cold exposure.

Figure 4 shows the same experimental results as figure 3, but in this case the development of cold resistance is correlated with body weight. This correlation appears to be slightly better than the one with age, and a body weight of approximately 30 grams at the time of initial exposure would appear to be critical for repeated cold exposure.

Effect on mortality.—During both 1949 and 1950, there was considerable mortality among the experimental chicks. Table 1 presents

TABLE 1

MORTALITY DURING REPEATED COLD EXPOSURE (30 MINUTES AT 20° C.) IN 5 HATCHES FROM 1950

Hatch	*Initial age in days*	*Number of Chicks*	*Mortality*	
			Number	*Per cent*
1	3	10	5	50
2	7	7	1	14
3	11	6	0	0
4	15	6	0	0
5	20	6	0	0

the mortality data on the five age classes of 1950. Mortality dropped from 50 per cent in the three-day class, to 14 per cent in the seven-day class, and finally to zero in the three older classes.

Table 2 presents a breakdown of the temperature losses and mortality that occurred among the ten chicks of Hatch 1, which were initially exposed when three days old.

During the initial exposure Chick 5 suffered the greatest drop in body temperature and subsequently died.

Chicks 1, 2, 8, and 9 were subjected to the heaviest exposure schedule. During repeated cold exposures they showed considerable losses of body temperature (4.5 to 7.8°), and only 9 lived to be eleven days old. The survival of 9 is of interest in that it showed progressively poorer cold resistance up to 9 days, like 1, 2, and 8, but then suddenly improved.

TABLE 2

BODY TEMPERATURE LOSSES IN HATCH 1, 1950. (AFTER 30 MINUTES AT 20° C.)

Chicks	*3 Days*	*4 Days*	*6 Days*	*7 Days*	*9 Days*	*10 Days*	*11 Days*
5	6.4°	dead					
1	2.7	6.0°	5.9°		7.7°	dead	
2	5.1	5.0	5.9	dead			
8	5.1	7.8	7.8	dead			
9	2.4	4.5	4.7		7.0		3.3°
6	2.6		3.1		2.2		2.7
3	3.1				3.8		2.7
4	2.1				2.8		1.8
7	2.7				4.0		dead
10	4.6				5.7		3.6

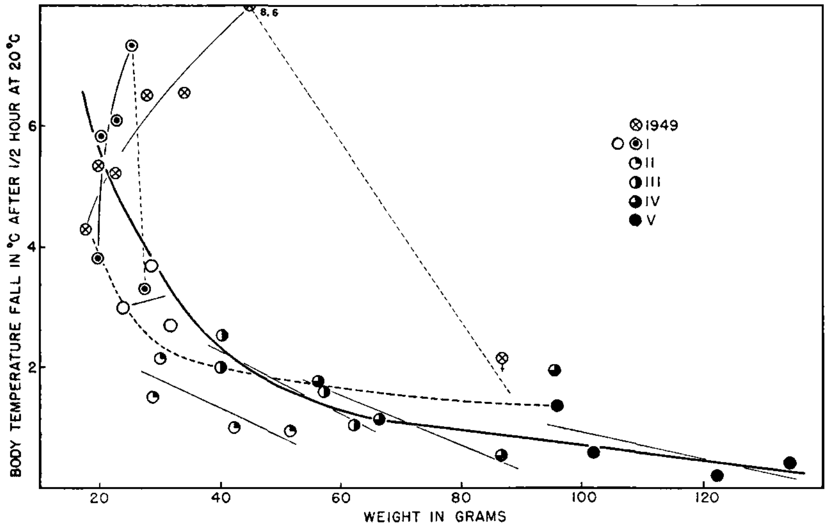

FIGURE 4. The loss in body temperature after 30 minutes at 20° as a function of body weight. Heavy curve shows average trend for all hatches. Crossed circles, 1949 hatch, and other circles, 1950 hatches. Each circle represents an average of 6 to 10 measurements (except for hatch 1 in 1950, see table 2). Solid curves show trends within each hatch. The heavy broken curve represents the initial measurements made on each group; i.e., values uncomplicated by previous experimental treatment.

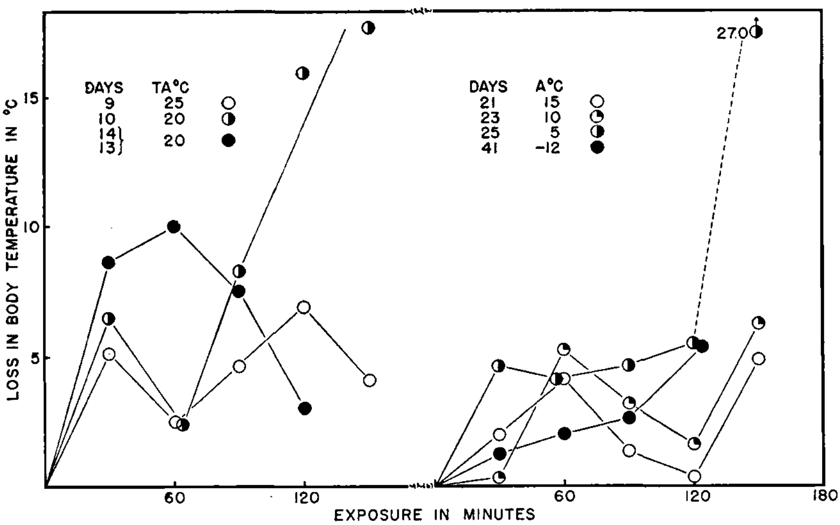

FIGURE 5. The relation between loss in body temperature and length of cold exposure in individual chicks. Various ages and ambient temperatures as indicated.

Chicks 6, 3, 4, 7, and 10 were subjected to a lighter exposure schedule, and only 7 died. Chick 10 survived although it experienced considerable temperature losses (4.6 to 5.7°). Even though this group suffered fewer fatalities, the early exposure certainly had a deleterious effect, for at eleven days of age, one chick (6) had poorer and 3 chicks (3, 4 and 10) only slightly better cold resistance than at three days.

Effect on length of exposure.—Figure 5 presents the results on the older chicks (9 to 41 days) which were exposed both for longer durations and to lower ambient temperatures than the younger chicks. There was no simple relationship between length of exposure and drop in body temperature. Even when a prolonged exposure resulted in a large drop, as in the case of the ten-day-old chick at 20° C. and the 25-day-old chick at 5°, the body temperature either fluctuated or leveled off for some time before it made a final precipitous drop. These fluctuations in body temperature were probably associated with changes in muscular activity of the chick within the exposure chamber.

Effect of growth.—Body weight was the only measurement of growth followed in the developing chicks. In 1950 the chicks were weighed before each exposure. Figure 6 shows the average weight per bird for each of the five different hatches during the progress of the study. Although the initial weights for each hatch lie slightly above the average curve, no striking effect of repeated exposure on body weight can be seen among the five hatches.

Discussion.—The impairment of cold resistance and the mortality experienced by the younger age classes when repeatedly exposed to cold was quite surprising, for both the severity and duration of exposure were moderate. However, both the reproducibility of the responses (1949 and 1950 results) and the differential responses of the younger and older age classes affirm it. Furthermore, 25° has previously been found to be the critical environmental temperature in the chicken, a related precocial form, for at temperatures lower than this 1 to 3 week old chicks huddled together when not feeding (Kleiber and Winchester, 1933). Cold resistance was studied in the pheasant by Long (1948), however this work is not comparable for his chicks were only exposed once, and high temperatures, fasting, and long exposures were employed. He concluded that temperature regulation in young pheasants was not fully developed at 15 days of age, irrespective of the plane of nutrition.

Apparently interspecific differences in cold resistance occur among precocial young. During the first week of life, pheasant chicks may show substantial drops in body temperature when exposed to 20° C.,

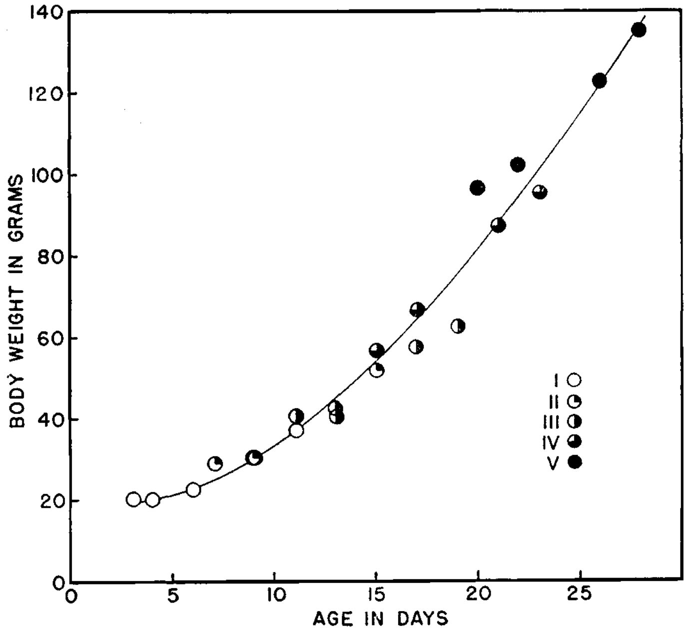

FIGURE 6. The relation beween body weight and age; 1950 results. Each circle shows the average of 6 to 10 chicks.

and at four weeks may still experience losses at 5°. Likewise in the chicken, another gallinaceous species, the young experience a rapid drop in body temperature at ambient temperatures of 20° during the first week, and protection against ambient temperatures lower than 20° is not complete until the down feathers are completely replaced by the adult plumage (Randall, 1943). In contrast Bartholomew and Dawson (1952) found that newly hatched Western Gulls (*Larus occidentalis wymani*) were successful in maintaining their body temperatures at ambient temperatures of 20° and above in the field, but that only the older nestlings could maintain their temperatures at 14 to 18°. However, the newly hatched gulls' success at 20° may have been due in part to behavioral thermo-regulation—the utilization of sunlight, wind shelter, and huddling to gain and conserve heat. Barth (1951) also has studied young gulls and found that complete homoiothermy, comparable to that of the adults, is not attained until the young can fly.

It was clear that a single chilling of a two- to three-day-old chick usually was not in itself fatal. Mortality and impairment of cold resistance were associated with repeated chillings. These detrimental effects appeared to be related to stress repetition and recovery time.

In nature, young pheasants could alternate peaks of muscular activity and broodings by the hen and would not necessarily experience repeated chillings of the same degree of severity as experienced by the chicks in this study.

Brooding during early life must be of the utmost importance for the survival of pheasant chicks, for environmental temperatures of 20° and lower are common in the field. No quantitative data were found in the literature concerning the brooding of chicks by adult pheasants, but its frequency and duration must be related to the environmental temperatures. Lehmann (1941) has field observations on the brooding of another gallinaceous species, the Attwater's Prairie Chicken (*Tympanuchus cupido attwateri*). Hens with young chicks were mainly concerned with watchfulness and brooding, and chicks less than seven days old were probably brooded about 50 per cent of the daylight period. During a timed brooding ten chicks (approximately two days old) spent 42 minutes out of 90 under the hen.

Field data on altricial species are available since observations can be much more readily made on young restricted to nests than on wandering forms. The studies of Brown and Davies (1949) on the Reed-warbler (*Acrocephalus scirpaceus*) revealed that the young of this altricial form are brooded frequently even during the daylight hours. The periods of brooding averaged between 60 and 70 per cent of the daytime during the first five days after hatching and dropped to zero by the ninth day. The extent of brooding was influenced by environmental temperatures. These altricial young certainly experience repeated drops in body temperature during the periods of inattentiveness. Baldwin and Kendeigh (1932) have measured the body temperatures of young House Wrens at the end of both the period of attentiveness and that of inattentiveness. In newly hatched wrens the body temperature dropped as much as 7.8° during inattentiveness, and for two nests of young the average drop was 4.3 to 0.8° during the first five days of life. Unlike the young pheasants these young wrens evidently experienced no detrimental effects from repeated exposure, and their cold resistance steadily improved.

The fact that there is a difference in capacity to resist cold between altricial and precocial birds was realized by Edwards (1824 and 1836–1839), who employed controlled exposures of young birds to study this problem. He found that a sparrow several days old lost 12° when exposed at 22° for 67 minutes. Three-weeks-old magpies lost 2° when exposed at 22° for 180 minutes, and 4° when exposed at 19° for 145 minutes. Three young Sparrow Hawks (*Accipiter nisus*) lost between 14 and 15° when exposed at 17° for 110 minutes.

The development of good resistance to moderately cool ambient temperatures is slower in altricial than in precocial species. House Wrens attained good resistance to exposure at 22° by nine days of age (Baldwin and Kendeigh, 1932); and resistance to 22° is almost complete in the Red-backed Shrike (*Lanius collurio*) at 11 days, in the Grass Parakeet (*Melopsittacus undulatus*) at 11 days, and in the Wryneck (*Jynx torquilla*) at 13 days after hatching (Böni, 1942). Previously, the pigeon was characterized by Pembrey (1895), who experimentally determined that temperature regulation at moderate ambient temperatures (19°) was well developed by 15 days of age.

Stoner (1928, 1935, 1937, 1939, and 1945) has published a series of interesting field studies on body temperature and growth in various altricial birds, but it is difficult to compare such observations directly with controlled laboratory studies. The complete thermal history of the young birds was not known, although ambient temperatures usually were measured before the body temperatures were taken. During the first days, body temperatures were taken immediately after the young had been brooded. In the species on which the measurements were most complete (House Wren, Barn Swallow [*Hirundo rustica*], Bank Swallow [*Riparia riparia*], Eastern Phoebe [*Sayornis phoebe*], and Northern Cliff Swallow [*Petrochelidon albifrons*]), the average body temperature of the nestlings of from 35 to 38° on the first few days had risen to from 41 to 42° by 14 days of age.

During much of their life in the nest the altricial species are essentially poikilothermous and can survive not only repeated chillings but also extremely severe ones. Kelso (1931) observed a nest of ten- to eleven-day-old Desert Horned Larks (*Eremophila alpestris leucolaema*) during a wet snow storm, and although two nestlings died, the other two survived body temperatures of 14–16°. On the next day the body temperature of one survivor had risen to 41.5° and the other survivor had left the nest. Previously, Leichtentritt (1919) had pointed out that young altricial birds are not harmed by exposure to cold and the resulting drop in body temperature and metabolism. Almost fully fledged young sparrows experienced drops in body temperature to 19.1 to 23.1° without ill effects. Considering the absences of the parents while they forage and the limited insulation afforded by the nest, he concluded that the incomplete heat regulation in young altricial birds is not as in the case of very young mammals a transient unreadiness, but rather a biological expedient which results in decreased food requirements.

There are intermediate forms between the typical altricial and the typical precocial species (Pettingill, 1946). At hatching, birds such as owls and hawks may be covered with down but are helpless and are restricted to the nest. Barth (1949) has studied the development of cold resistance in one of these forms, the Snowy Owl (*Nyctea scandiaca*). He found during the first day of life that their temperature dropped to 25 to 29° during periods of inattentiveness. Although they were repeatedly exposed during the first 12 days of life, their cold resistance steadily improved. None of the ill effects experienced by the pheasants were manifested by the owls.

Wetmore (1921) remarked on the apparent anomaly of his single body temperature measurement on a young Mourning Dove (*Zenaidura macroura*), which was distinctly higher than those measured in other young altricial birds. He concluded that this was of interest in that doves have distinct affinities with groups having precocial young. However, young doves must be repeatedly chilled during periods of inattentiveness, for Gardner (1930) showed that at eight to nine days of age Mourning Doves dropped 1 to 3° in body temperature when exposed even to the high environmental temperature of 36°.

Thus it appears that the pheasant may pay a price for its precocity, in that unlike altricial and intermediate forms, cold resistance may be impaired and fatalities result from repeated moderate chillings.

SUMMARY

The development of cold resistance was studied in young Ring-necked Pheasants. Although living in a hot thermal environment the body temperature of the chick is lower than that of the adult, and the regulated level of body temperature gradually rises during the first few weeks of life in a brooder to the adult level. During this period (2 to 15 days), exposure to moderate cold (20°) results in substantial losses in body temperature (2 to 4°). When two- to three-day-old chicks are repeatedly chilled by 30-minute exposures at 20°, the development of cold resistance is impaired, and they experience a high rate of mortality. Chicks of seven days and older are not adversely affected by repeated exposures at 20°, which instead improve their resistance to cold.

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