5. In addition to the hand-raised juvenile mentioned above, another Nighthawk was reared in captivity for one year and seven months by Mr. and Mrs. Harvey E. Thompson who kept it as a pet. The bird lived successfully under constant care and became accustomed to handling, but its wing and tail feathers were shed after several months and were never fully replaced. Replacement feathers were also shed, a few at a time, before they were completely developed. Nighthawks seem to drop feathers readily.

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WEIGHT CHANGES IN BIRDS

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Weights of birds have been quite often recorded. Usually these have been raw weights, that is, weights at the moment of weighing with little attempt to determine the condition of the bird. A few authors, notably Stewart (1937), have recorded something of the history of the individual for a short period before weighing, whether it had fed in the trap or been held without food before weighing. I have had the opportunity in Lincoln and Lexington, Mass. to make a few, more detailed observations.

The Slate-colored Juncos and Eastern Tree Sparrows were removed from traps after dark and released the next morning about sunrise. The Eastern Purple Finches were held on an experimental basis by Mr. and Mrs. Parker C. Reed. Since the object of the weighings was to determine weight losses the birds were not supplied with food and water and were kept in the dark.

It is clear that there is at first a rapid but declining rate of weight loss if the bird has been feeding up to nearly the time of first weighing. In one Purple Finch (55-02653) the initial rate of loss was 1.8 g/hr for a half hour but the rate fell to 0.6 g/hr for the next half hour. In general, after two hours or so the rate has fallen to about twice the average rate for the next 10 to 15 hours. Changes have not yet been followed later in the period of fasting.

It will be immediately apparent from Table I that the minimum rate of loss, although varying from one individual to another, is of the same general size throughout. Some of the variation may be caused by differences in the relative time of the evening weighings. Junco 22-98651 would probably have shown a lower rate if it had been weighed again about 7:30 pm. The average minimum rate for Junco

TABLE I WEIGHTS AT STATED HOURS

— joins weights in captivity, / indicates a free period.

Band	Dates		Hours and weights				Lowest rate of loss g/hr.
			Slate-colored Junco				
22-98324	28-29 Mar.	'54	7:00 p.m.	20.6—	7:00 a.m.	19.2	0.11
637	7- 9 Jan.	'55	6:30 p.m.	21.0—	6:45 a.m.	19.8	0.098
651	6- 7 Nov.	'54	5:00 p.m.	22.1—	6:30 a.m.	19.6	0.18
653	7- 8 Nov.	'54	5:40 p.m.	20.1—	8:45 p.m.	19.4—	
			6:40 a.m.	18.3			0.11
660	10-11 Jan.	'55	7:30 p.m.	21.5—	6:50 a.m.	20.3	0.11
714	10-11 Jan.	'55	7:30 p.m.	21.3—	6:50 a.m.	20.2	0.097
736	7- 8 Jan.	'55	6:30 p.m.	22.4—	6:45 a.m.	21.1	0.11
736	10-11 Jan.	'55	7:30 p.m.	22.0—	6:50 a.m.	21.0	0.089
			Eastern Tree Sparrow				
22-98677	21-22 Nov.	'54	7:30 p.m.	18.3—	6:30 a.m.	17.2	0.098
678	21-22 Nov.	'54	7:25 p.m.	17.7—	6:30 a.m.	16.8	0.099
679	21-22 Nov.	'54	7:20 p.m.	20.0—	6:30 a.m.	18.7	0.12
689	2- 3 Dec.	'54	5:00 p.m.	19.1—	6:40 a.m.	17.5	0.12
			Eastern Purple Finch				
55-02471	5- 6 Sept.	'54	4:10 p.m.	24.2—	4:40 p.m.	23.6—	
			5:15 p.m.	23.4—	5:45 p.m.	23.1—	
			8:30 a.m.	20.8 /	1:05 p.m.	21.8 /	
			2:35 p.m.	22.5 /	5:35 p.m.	23.3	0.16
549	5- 6 Sept.	'54	3:40 p.m.	26.3—	4:10 p.m.	26.1—	
			4:40 p.m.	25.8—	5:15 p.m.	25.7—	
			5:45 p.m.	25.4—	8:50 a.m.	22.8 /	
			9:30 a.m.	24.7			0.17
653	5- 6 Sept.	'54	3:10 p.m.	26.7—	3:40 p.m.	25.8—	
			4:10 p.m.	25.5—	4:40 p.m.	25.4—	
			5:10 p.m.	25.3—	5:45 p.m.	25.2—	
			8:30 a.m.	23.6			0.11
939	9 Jan.	'55	11:45 a.m.	25.7—	2:05 p.m.	24.7 /	
			3:30 p.m.	26.0			0.57
940	9 Jan.	'55	11:50 a.m.	26.3—	2:05 p.m.	25.5 /	
			3:50 p.m.	26.2			0.36
941	9 Jan.	'55	11:50 a.m.	27.3—	2:05 p.m.	26.5	0.36

and Tree Sparrow is 0.11 g/hr and for Purple Finch (average of first three birds) is 0.15 g/hr. Related to the weight of the birds the rates are, for Junco 0.5%/hr and for the other two species 0.6%/hr.

Some similar figures are available for Song Sparrows *(Melospiza melodia beata)*. Baldwin and Kendeigh (1938) found a loss of 0.95 %/hr based on maximum evening weight but did not follow the decrease in rate. Hoffman's (1930) bird lost 0.6 %/hr over a 24 hour period (water but no food supplied). The loss for the first 12 hours was 0.89 %/hr which would roughly correspond to Baldwin and Kendeigh's figure. Between hours 6 and 18 the loss was 0.5 %/hr or 0.12 g/hr. This is comparable with my fasting rates.

If the fuel consumed is supposed, as is likely, to be entirely fat the energy consumptions work out at 1.0 and 1.3 Cal/hr for my minimum rates of loss. This agrees nicely with Wolfson's (1954) estimate for the similarly sized White-throated Sparrow.

Kendeigh (1934, p. 317) tabulates the over-all average weight losses and rates for House Sparrows held until death, at various temperatures in the dark without food and, presumably, without water. On its face, his table would show that the percentage of weight lost increases up to about 92° F and then declines. The survival time also reaches a maximum at this temperature and there is at the same point a minimum in the rate of weight loss. This would seem to say that the optimum temperature for full-grown House Sparrows is about 92° F. Such a temperature would occur at night but rarely anywhere and in Europe probably only south of the range of *P. d. domesticus.* It must be pointed out also that Kendeigh records the relative humidity for the higher temperatures in his table and that it varied inversely with the temperature, hence at higher temperatures the birds were subjected to increased and, perhaps, excessive water loss. More generally one may question whether there is any optimum temperature for a warm-blooded animal. In the case of human beings temperature, humidity, and air movement all enter the picture when one is concerned with maximum comfort. At the other end of the table we are faced with another dilemma. At about 24° F the survival time was just over 14 hours. In midwinter this puts the northern limit of latitude at 51°, approximately. The minimum survival time of 10½ hours was found at 13½° F. The limit of midwinter nights as short as this may be placed at 11° N.[1] The explanation may be that the tests were made in the warm season and the quite possible occurrence of cold-hardening was ignored. I have discussed this table at some length to emphasize the real difficulty of meaningful experimentation. Further experiment is greatly to be desired but it must be carried out with a watchful eye upon the geographical and ecological implications.

A little consideration will convince one that there are several sources for the variation in weight shown by birds. The first of these is diurnal variation. The usual pattern of feeding leads to a maximum weight during the afternoon and a minimum in the early morning. These changes have two distinct causes. We have already shown that some birds can apparently burn more than a gram of fat during a night. If fat can be consumed so rapidly it is reasonable to suppose that it can be replaced with approximately equal rapidity. The other part of the diurnal variation arises from the uptake of raw food on the one hand and the discharge of feces and urine together with some excess water on the other hand. Undoubtedly we must assign to these latter activities the rapid increase of weight in the morning and the similarly rapid loss at the beginning of a fasting period. It cannot, I think, be argued that any appreciable part of the minimal rate loss during the night is due to loss of water not derived from the consumption of fat. The intake of free water during the winter by most small birds in northern regions (other than carduelines), is evidently small. The seeds composing the diet of Juncos or Tree Sparrows can hardly contain more than 15 per cent of free water, much of which would pass through the bird's system within a short time after ingestion. Such birds must place their major reliance on metabolic water.

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[1] An allowance of two hours of useful twilight is made in both these estimates of latitudes.

The second sort of variation is seasonal. This may have more than one cause and at least two are quite probable. Seasonal differences in the nature or availability of food may determine whether a bird can store and maintain large fat deposits or converts its food largely to current energy requirements. Other causes of seasonal variation are more strictly physiological. The molt is one of the events related to change of weight. There is evidence, for example, that juvenal Purple Finches gain weight up to the inception of post-juvenal molt, lose some weight and gradually regain it in the course of the molt. More importantly it has been shown (Wolfson 1945, Odum and Perkinson 1951) that some species accumulate large amounts of fat just prior to migration. Further, Williamson (1951a) has presented some data on weight gain by migrants "off passage." Since his paper is rather inaccessible I tabulate his data in Table II with rounded figures. While some of the weight changes certainly are in part diurnal variation, they are far too great to be ascribed wholly to the latter cause.

Table II Williamson's data on weight gain of "off passage" birds

Hedge Sparrow *(Prunella modularis)*						
	3 Oct.	16.8 /	16 Oct.	21.9 /	19 Oct.	24.5
Robin *(Erithacus rubecula)*						
	13 Oct.	13.5 /	17 Oct.	15.4		
	15 Oct.	13.7 /	18 Oct.	15.5 /	22 Oct.	16.5
Chaffinch *(Fringilla coelebs)*						
♀	7 Oct.	17.8 /	24 Oct.	26.0		
♂	13 Oct.	19.9 /	23 Oct.	23.7		
♂	13 Oct.	19.4 /	23 Oct.	23.0 /	24 Oct.	26.0

A third source of variation is individual. Not only may a bird's weight be partly dependent on its age and sex but individuals of the same age and sex may differ in weight just as they differ in other dimensions.

The fourth sort of variation may be termed random. It is owing to causes that may fairly be called unpredictable, accidental, and generally transitory. Some of these causes may be identified after the event. As an example, bad weather may prevent feeding for a day or so. Again Williamson (1951b) gives two very striking instances apparently stemming from a December storm at Fair Isle. The birds are both female Blackbirds *(Turdus merula)*:

First winter	7 Nov.	97.6/	1 Dec.	105.0/	3 Dec.	99.5
Adult	29 Nov.	90.2/	1 Dec.	93.8/	3 Dec.	83.4/
	14 Dec.	79.5/	4 Jan.	92.9/	16 Jan.	102.4/
	1 Feb.	111.6				

Further, when a large number of birds are being handled there may be considerable delay in weighing some of them.

Finally, we may refer to geographical variation in weight. From Williamson's (1951c) data on the Wren *(Troglodytes troglodytes)* we conclude that the species weighs about 9.3 g in England as against about 16.5 g in Iceland. That we are here comparing two subspecies does not rule out the possibility of weight clines. Indeed, Williamson points out that some Scottish birds (from Ross-shire) average about 10 per cent heavier than English birds.

Questions remain as to how to handle an uncontrolled collection of weights and what should be considered the true weight. Whatever is done with a collection of weights should be clearly stated.

Any scheme of rejection of a few readings in a series may introduce unintended bias unless the scheme is completely definable and preferably in rather simple terms referable to the statistical distribution of the readings themselves. This boils down in practice to the reasonable demonstration of error in the recorded reading. Both Stewart (1937) and Baldwin and Kendeigh (1938, p. 418-421) come to the following conclusion of which the latter authors give a simple but adequate practical demonstration. Averaging all the readings for a group of birds does not unduly increase the standard deviation over that for a series from a single individual. This implies that any bias as to time, date, or other factor is distributed in the same general way among the components of a group as among the readings on an individual. This holds whether the bias is introduced by the operations of the bander, the birds or by both. It does not imply absence of bias nor any specific relation between the average weight so found and the weight under any specially defined conditions.

On the other hand, there may be good grounds for selecting out a certain part of a series of readings. Obviously age or sex forms such a basis, as does season or time of day. Whether the differences between these selected series are significant is another matter. If the difference between two selected months, for example, is statistically significant it can mean either that there was a real change in weight or that different populations were sampled. Evidently a population difference could also conceal a real change in weight. The ideal solution would be to use the correlation between the weights of the same individuals at different times. In practice the application of this method is often severely limited by smallness of the obtainable samples.

In certain circumstances it may be possible to construct another sort of selected series. To introduce this we return to a discussion of the observations in Table I. It was suggested that the rate of weight loss in a fasting bird declines more and more slowly and, under conditions of rest, as when the bird is kept in darkness, may, perhaps, reach a stable value. In any event after two or three hours the digestive tract is probably empty and the bird is existing on stored energy. The ideal base weight of the bird would be the weight at which the digestive tract is just empty and any dispensable water has been voided. This would be an easy solution if we could be sure that there is a stable rate of weight loss identifiable as such. At least four factors disturb the identification of a single stable rate attained once and for all by a quiet bird during each fasting period. First, if the bird has stored carbohydrates, these will be used before it goes over to an exclusive fat katabolism. The rate of weight loss will approach 1.8 times that for fat. Second, the rate of fat consumption will vary somewhat with the ambient temperature if the bird does not maintain a constant difference between this and its internal temperature. The power to follow the ambient temperature must be, at best, quite limited. The third is a small effect stemming from the consumption of subcutaneous fat. The bird's volume decreases more rapidly than the surface as the fat is used. This will slightly increase the heat required to maintain the internal temperature at a given level above the ambient temperature. At the same time there is less weight of bird to maintain at temperature which will partly compensate for the increased surface/volume ratio. These three factors were referred to by Baldwin and Kendeigh. The fourth factor was called to my attention by Prof. Henri Koch (Univ. of Louvain). He has found that small birds show two 'basal' metabolic rates, a resting rate and a sleeping rate. The latter is about 30 per cent lower than the former. This suggests that partial torpidity may be widespread among avian species. Going a step further, it is conceivable that birds may be aided to survive periods of adverse weather by some depression of the metabolic rate.

Survival tests contain still another complication. If we assume the minimum rate of weight loss to occur when the subject has gone over to fat katabolism, then, when the metabolizable fat has been consumed, the fuel remaining is protein and the rate of weight loss should double. Probably none of the transition points we have mentioned is entirely sharp nor is the metabolism ever purely one of carbohydrate, fat, or protein. Baldwin and Kendeigh quote some earlier work on respiratory quotients showing that the latter point is not very significant. There is the question of how far a bird can go in consuming its body protein and still recover.

Two procedures for approximating the base weights of birds are suggested by the foregoing discussion. The first method is to weigh at intervals a sample of birds held in the dark and fasting as was done for the first three Purple Finches in Table I. Their base weights may be considered to be 23.4, 25.8, and 25.5 g respectively.

Second, when many birds are being handled repeatedly over a brief period, say a week end, it sometimes appears that the least weights for an individual are all about the same. These least weights are an approximation to the base weight.

Much more experimental work is needed before we can really say anything convincing about the normal course of changes in a bird's weight as opposed to differences in the amount of ingested food. The collector has an initial advantage over the bander. He can determine fat, at least, independent of other components of weight but cannot follow changes in an individual bird.

Wolfson (1954) has been able to put one bridge across the gap. His fat classes (p. 415) may be usefully recorded for other species in relation to weights. Ultimately such observations of fat classes should yield reliable rank-order statistics with, at least approximate, numerical values attached to them.

In any holding experiments more attention should be paid to temperature than I have yet done.

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[2] I am indebted to Mr. E. Alexander Bergstrom for the loan of Williamson's papers.

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THE TOPOGRAPHY OF A BIRD

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The regions used in the formal descriptions of the plumage of birds have been often illustrated. Much the same illustration will serve as general guide for field characters or for the study of museum specimens which lack much of the underlying structures. The bander is left at a loose end when he wishes to place with precision an abnormally colored feather or to state to which region the short new feathers on a molting bird pertain. For example, new feathers at the anterior edge of the rump may be covered by old feathers of the back. In the hope of assisting banders to record information about the plumage and molt of their birds I present a set of figures and definitions for an average passerine and some comments on birds of other orders.

Three intergrading types of feathers are significant to us. 1) Downs. The rhachis or shaft is imperceptible beyond the calamus, the thickened portion inserted in the skin. The barbules have a particular microscopic structure which is also usual at the bases of feathers of the next two types. Briefly barbs and barbules are slender and flexible, the barbules without hooklets. 2) Contour feathers. The rhachis is evident beyond the calamus. The barbs do not usually lock together to form a firm vane. These are the feathers of the head, body, legs, and bases of the wings. 3) Quill feathers. Similar to contour feathers but much larger and usually with firm vanes. The obvious quills are the primaries and secondaries (remiges) and the tail feathers (rectrices). On the basis of development, structure or behavior we might include here the greater primary coverts, the inverted secondary coverts on the underside of the wing and the upper tail coverts.