THE HEART RATE OF SMALL BIRDS[1]

EVER since Buchanan[2] in 1910 recorded the heart beat of the canary as 1,000 per minute it has been known that the heart rate of small birds is very rapid. However, the quoting of these fast rates in text-books and elsewhere has created a misleading impression regarding the rapidity of bird's hearts, especially when attempts have been made to compare these early recordings with basal rates of man and laboratory animals. The heart rate of the canary as well as other small species may reach 1,000 beats per minute or even greater, but only for short intervals under conditions of excitement or vigorous exercise; basal rates are far below this figure.

In making a special study of the heart rate of small birds and mammals by means of the cardio-vibrometer, I have been particularly interested in using the heart rate as an index to the physiological response of the intact animal to environmental changes.[3,4,5,6] Because the heart rate is variable and such a sensitive "physiology-of-the-whole" indicator, it is necessary (1) to determine a basal rate or some sort of standard rate to serve as a basis for comparisons and (2) to obtain quantitative data, that is, a large number of readings over sufficient time period to obtain a true measure of heart activity. To obtain a basal rate, muscular activity, food intake, temperature and cerebral activity (fear, excitement, etc.) must be controlled since, generally speaking, these have the most marked effects on the heart rate. Removal of the unpredictable effects of the conscious centers has been one of the chief difficulties in dealing with the heart rate in the past, but with the cardio-vibrometer this factor can be satisfactorily controlled even in wild species since the heart beat together with breathing and other movements is picked up indirectly, amplified and recorded by a piezo-electric system. There are no electrodes attached to the bird, it perches normally of its own volition, and need not be disturbed in any way during the experimental period. The use of a crystal driven pen recorder facilitates obtaining a large number of accurate readings over long periods, although there is still much to be desired from the quantitative aspect.

Disregarding for the moment age, sex and seasonal variations, the average basal heart rates in round numbers of several species of common wild birds and the canary are listed in Table 1, together with the maximum rates which I have recorded immediately after flying, vigorous exercise or excitement. The basal rates represent the average rates of the birds when at rest, in a post-absorbtive but not starved condition (3–7 hours after last feeding for passerines, longer for larger birds or those with crops), in darkness, away from human presence, and at an air temperature at or slightly below thermal neutrality (about 30–32° C. for small birds). The same standardized procedure[4,5] was followed in all cases, and most of the records were made in the early evening, during the normal roosting time.

TABLE 1

AVERAGE BASAL HEART RATE (TIMES PER MINUTE) IN ROUND NUMBERS AND THE MAXIMUM HEART RATE SO FAR RECORDED FOR SMALL WILD SPECIES AND THE CANARY (PRELIMINARY DATA)

	Number of individuals	Approx. wt. (gms)	Basal rate	Maximum rate
Mourning Dove (*Zenaidura macroura*)	5	130	135	570
Towhee (*Pipilo erythrophthalmus*)	4	40	445	810
Cardinal (*Richmondena cardinalis*)	3	40	375	800
English Sparrow (*Passer domesticus*)	7	28	350	902
Song Sparrow (*Melospiza melodia*)	5	20	450	1,020
Canary (*Serinus canarius*)	10	16	514	1,000+?
Black-capped Chickadee (*Penthestes atricapillus*)	14	12	480	1,000
Chipping Sparrow (*Spizella passerina*)	2	12	440	1,060
House Wren (*Troglodytes aedon*)	4	11	450	950
Ruby-throated Hummingbird (*Archilochus colubris*)	2	4	615	?

Determination of the limits of normal heart function is, of course, only the beginning of an understanding of the heart rate. Some of the general features of the heart rate in small birds, as brought out in the studies so far, may be summarized as follows:

(1) As is to be expected, the smaller the species the more rapid the rate, but the correlation is not necessarily absolute (as can be seen from Table 1), since factors other than body size may influence a species basic heart rate. Thus, the canary appears to have a higher basal rate than wild finches of comparable size; this may be due partially to the fact that the canary has a smaller heart and lower concentration of hemoglobin in its blood than its wild relatives.[7] Likewise, the heart rate of the mourning

[1] Studies with the cardio-vibrometer aided by grants from the American Association for the Advancement of Science and the University Center in Georgia.

[2] Florence Buchanan, *Ann. Rept. Smithsonian Inst.*, 1910: 487–505.

[3] E. P. Odum and S. C. Kendeigh, *Ecology*, 21: 105–106, 1940.

[4] E. P. Odum, *Ecol. Mong.*, 11: 299–326, 1941.

[5] E. P. Odum, *Wilson Bulletin*, 55: 178–191, 1943.

[6] E. P. Odum, *Amer. Jour. Physiol.*, 136: 618–622, 1942.

[7] For canary heart size, see Buchanan, *Ann. Rept. Smithsonian Inst.*, 1910: 487–505; for hemoglobin data,

dove is apparently lower than that of the domestic fowl,[8] a much larger bird.

(2) Not enough data have yet accumulated to justify a general statement regarding the effect of sex on the heart rate in birds. In some species, such as the domestic fowl,[8] there appears to be a distinct difference between the sexes; in many other species little or no difference is evident from data so far accumulated.

(3) In wild birds, a seasonal difference in basal heart rate has been demonstrated for at least one species, the black-capped chickadee, the basal rate being 89 ± 25.1 per minute higher in summer than in winter.[5]

(4) The relation of age to basal heart rate is complicated; much depends on the air temperature being considered and the status of the temperature regulatory mechanism. In altricial species which are hatched completely cold-blooded, the heart rate at hatching varies directly with air temperature as in a frog, then gradually becomes inversely related to the temperature as temperature regulation becomes established. Interestingly enough, at a thermal neutral temperature the heart rate of nestlings of all ages, juveniles and adults of the house wren is about the same, 450/min. At 21° C. (70° F.), however, the heart rate rises from 150/min. at hatching to 600/min. at 9 days of age (when heat loss control is poor) and drops to about 490/min. in the adult[4]—reflecting in a dramatic way the ontogenetic recapitulation of poikilothermism to homeothermism.

(5) There are two types of inherent variations in the heart rate of birds as follows: (a) The rate usually decreases slightly at the peak of lung and air sac inflation and increases between breathing cycles. In mammals this relation of breathing to heart rate is apparently the reverse.[9] (b) Slower, more or less rhythmic but not regular cycles of slow and fast rate which I have called "oscillatory variations" can usually be detected. These cycles occur about 2 to 15 times per minute and the degree of oscillation varies considerably with the individual sometimes amounting to 10 per cent. of average rate for a minute period. Similar variations, presumedly related to vagal periodicity, are known in man.

(6) Any factor which abnormally lowers the heart rate below basal level tends to produce sinus arrhythmia, which also occurs in some individuals at basal level. When the heart speeds up in these individuals, arrhythmia disappears.

(7) Heart rate-air temperature curves are very similar to CO_2 production-air temperature curves,[4] indicating that heart rate is a rough index to the rate of metabolism at least as far as temperature effects are concerned.

(8) At lower temperatures breathing rate is usually directly correlated with heart rate, but at high temperatures the relation may become inverse as a result of reflexive acceleration of breathing rate coming before a rise in body temperature accelerates the heart, since increased ventilation is a principal means of heat loss in birds.

(9) The ratio of breathing rate to heart rate appears to be significantly different in small birds and mammals, being greater than 1 to 6 in birds and less in mammals. In general, small birds breathe less rapidly but have a somewhat higher heart rate than small mammals of the same size, although comparable data are as yet few.

(10) By placing the pick-up crystal under the nest it has been possible to record the heart beat of an entirely wild bird during normal incubation in the field. During a 24-hour recording period the heart rate in the house wren ranged from 950 when the bird had just returned to the nest after a period of active flying and feeding, to 550 after the bird had remained quiet on the nest. A rate as low as the 450/min. basal recorded under controlled conditions was not recorded in the field. Also, strangely enough, the heart rate was actually higher at night than when the bird was resting quietly in daytime. This was apparently to be explained by the fact that the temperature was 20° lower at night. To get a rate as low as 450/min. under natural conditions apparently the night temperatures would have to approach thermal neutrality; during the day activity, feeding, etc., would keep heart rate above basal regardless of temperature.

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APPLYING COLCHICINE TO PLANTS BY THE AEROSOL METHOD

Both the published work[1] and experience of the authors indicate that a fairly sharp distinction exists between the response to colchicine application by mature meristems such as occur in trees, shrubs or herbaceous plants and the response of juvenile meristems such as the plumule. While the results with germinating seeds or very young seedlings on the whole have been satisfactory, results with more mature plants have been meager. For example, complete immersion of very young seedlings of certain species

see Young, *Jour. Parasit.*, 23: 424–484, 1937, and Nice, Nice and Kraft, *Wilson Bulletin*, 47: 120–124, 1935.

[8] E. P. Boas and Walter Landauer, *Amer. Jour. Med. Sci.*, 185: 654–664, 1933.

[9] G. V. Anrep, W. Pascual and R. Rössler, *Proc. Royal Soc. London*, 119(B): 191–230, 1936.

[1] H. Dermen, *Bot. Rev.*, 6: 599–639, No. 11, 1940.