10 days following the bite of an infected mosquito. During and since the last war in particular, birds have been used as laboratory animals for the screening of antimalarial drugs.

Lastly, incubated chicks form an excellent method for the manufacture of various vaccines. In 1938 Cox's yolk sac method was adopted for preparing the typhus vaccine. Up to then it took 300 lice to make a single typhus shot, and it involved injecting the typhus rickettsia into the rectum of the lice and rearing them on humans, tedious and dangerous procedure. Since then incubated chicks have proved invaluable in the manufacture of vaccines for many kinds of pathogenic organism.

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RESPIRATION RATES

By CHARLES H. BLAKE

Some years ago I attempted to determine the respiration rates of a number of species of birds as they were available in the course of banding. The results were by no means entirely satisfactory, but they serve to show some of the difficulties to be overcome and also the general level and variability of the rates for small- and medium-sized birds.

The method I used was to determine with a stopwatch the time required for a counted (usually 10-40) number of movements of the belly wall. The figures obtained were then converted to respiratory movements per minute. The birds were confined in three ways: (1) held belly up in the hand, (2) placed in a carrying compartment with a transparent end, and (3) placed head first in a conical weighing tube. Methods 2 and 3 were not feasible with all species, and method 3 was finally abandoned when it was certain that it almost always yielded higher rates than the other methods.

One point should be noted. The usual pattern of respiration is several shallow movements followed by a deeper one, much as in man. The shallow movements can be overlooked, especially when watching a caged bird whose position or attitude may be somewhat unfavorable.

TABLE 1

Respiration rates. For further explanation see text.

No. birds		Approx. wt. gms.		Hand		Cage		Tube
1	Mourning Dove	130	(3)	69-80 (75)	(2)	68, 76 (72)		
2	Downy Woodpecker	27	(6)	127-143 (132)	(6)	111-177 (142)	(3)	167-177 (172)
1	Phoebe	20	(1)	137		—	(1)	161
1	Tree Swallow	19	(3)	93-98 (95)	(3)	100-107 (104)	(3)	87-93 (89)
2	Blue Jay	80	(9)	87-136 (105)	(3)	97-115 (104)		—
2	Black-capped Chickadee	11	(2)	140, 160 (150)	(2)	162, 172 (167)	(4)	182-240 (206)
1	House Wren	11	(3)	263-334 (294)	(3)	200-286 (242)		—
1	Catbird	37	(3)	83-86 (85)		—	(3)	107-117 (112)
2	Brown Thrasher	70	(2)	82, 116 (99)	(2)	86-90 (88)		—
2	Robin	72	(2)	91, 107 (99)		—		—
1	Wood Thrush	48	(3)	71-74 (72)		—		—
1	Veery	30	(3)	96-100 (98)		—		—
2	E. Bluebird	28	(4)	107-122 (113)		—	(2)	122, 123 (122)
2	Starling	70	(4)	60-73 (66)	(2)	60, 75 (67)		—
1	Black and White Warbler	12	(3)	188-200 (194)		—	(3)	182-193 (189)
1	Myrtle Warbler	13	(3)	177-193 (186)		—	(3)	214-231 (225)
1	Ovenbird	20	(3)	120-136 (127)		—	(3)	131-136 (133)
1	Yellow-breasted Chat	26	(3)	105-109 (108)		—	(3)	120-123 (121)
2	Baltimore Oriole	38	(3)	103-111 (108)	(1)	150	(3)	158-167 (164)
3	Cowbird	40	(2)	139, 153 (146)	(2)	137, 144 (140)	(2)	147, 160 (153)
1	House Sparrow	30	(2)	109, 113 (111)		—	(2)	120, 122 (121)
1	Rose-breasted Grosbeak	42	(5)	88-110 (97)	(2)	65, 76 (70)	(3)	98-125 (109)
3	Eastern Purple Finch	25	(8)	73-131 (93)	(5)	98-130 (113)	(8)	81-154 (108)
1	Eastern Goldfinch	13	(1)	127		—	(1)	127
4	Red-eyed Towhee	42	(11)	106-139 (131)		—	(2)	144, 153 (148)
1	Slate-colored Junco	21	(1)	159		—	(1)	163
1	Eastern Chipping Sparrow	11	(3)	143-158 (149)	(3)	140-150 (144)	(3)	150-154 (153)
2	White-throated Sparrow	30	(6)	154-172 (164)	(3)	172-193 (186)	(6)	193-207 (202)
1	Swamp Sparrow	19	(3)	147-154 (150)		—	(3)	167-177 (172)
2	E. Song Sparrow	24	(4)	170-198 (184)	(3)	137-172 (149)	(3)	195-230 (213)

Table I gives the results obtained. Under each method the number of observations is placed first in parentheses, then the range and in a second parenthesis the mean rate. Over all, the rates in hand and in a cage are nearly the same. The average difference of the means is 0.2 higher in the hand. On the other hand, in a tube the mean rate averages 20.4 greater than in a cage.

Inspection of the table shows that there is no simple relation or set of relations between respiration rate and weight. Only in a very general way does the rate decline with increasing weight. Even within a family the decline is not very regular. Some of the causes of variation are easily made out.

First, let us define the normal respiration rate as that shown by a bird at rest, awake, and not alarmed or otherwise under some nervous tension. Further, the bird must not have taken exercise for some few minutes before the observation is made. It is unlikely that the rate can be observed under these qualifications except in a tame captive. The protocols of the observations do show that a bird held belly up in the hand tends to show a fall in rate to a fairly stable level within two or three minutes. But species differ in their tendency to become quiet when so held.

No cage data are available for certain species because the individuals studied would not stay quiet in a cage long enough for counts to be made. It will be noted that this was especially the case with thrushes and warblers.

The effect of confinement in a weighing tube is particularly noticeable in the case of larger birds. The tube constricts the body causing the breathing movements to be shallower and faster.

One is tempted at this point to launch into a discussion of the possible relation between body weight, lung weight, and respiration weight. In theory, with certain simplifying assumptions, it is possible to deduce one of these entities if the other two are known. The simplifying assumptions as to the architecture of the lungs and the oxygen requirements may not really be true. Since the lung weights are eventually measurable it is better to resist temptation and wait for the actual facts.

I will note, however, that the essential point is the relation between the vital capacity (for practical purposes the tidal air volume) and the demand for gas interchange. A low vital capacity and a high respiration rate may be as effective as a higher capacity and correspondingly lower rate. This assumes an optimal relation between the vital capacity and the respiratory surface within the lungs, both as to area and architecture.

In any event the data do suggest that there are characteristic differences between species which are not directly related to weight differences. They may be rather related to the type of activity normal to the species and the power output which it requires. Birds capable of a wide range of power output might have relatively low resting respiratory rates. The low rate for the starling is striking but without evident explanation.

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