Chemical composition of growth in nestling blackbirds and thrushes

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1. The bodies of twenty-three nestling blackbirds and twenty-one nestling thrushes were analysed at different ages for water, fat, nitrogen, calcium, phosphorus, sodium, potassium and magnesium. These birds grow from a weight of 5 g at hatching to 70 and 50 g respectively when they leave the nest 12–13 d later.

2. The concentration of N in the bodies doubled, while Ca increased seven to eight times during this period, so that the total amount of Ca in the body increased by about 100 times.

3. The femurs of the newly hatched birds were very immature and contained little Ca or collagen but in the fledgelings the femurs were as well calcified as those of 17-d-old chicks.

4. The gastro-intestinal tracts of the birds contained large amounts of Ca. Their food consists of caterpillars, adult insects and earthworms, none of which have much Ca in their tissues but their gut contents may contain much Ca. It is suggested that it is the gut contents of these invertebrates that provide nestling birds with Ca.

Our knowledge about the chemical growth of young birds is derived almost entirely from studies on chicks. Chicks are generally reared in a highly artificial way and, moreover, they are well developed at the time of hatching, and are able to walk and peck from the 1st day. Many wild nestlings, on the other hand, are helpless for the first 2 weeks after hatching, and during this time they depend entirely upon the food their parents bring them. They are known to grow very rapidly; the blackbird, for example, increases in weight from 5 g at hatching to more than 70 g 2 weeks later. At this early age the weight of the fledgeling almost reaches that of the adult bird (Cawkell, 1950; Gurr, 1954; Snow, 1958). The food that sustains this rapid rate of growth consists mostly of earthworms, caterpillars and adult insects. The study reported here was designed to measure the increase in the amounts of nitrogen, fat and minerals in the bodies of nestling birds during growth and to find out how they obtain from these unpromising foods sufficient calcium for their needs.

The blackbird (*Turdus merula*) and the song-thrush (*Turdus philomelos*) were chosen because there are large numbers of them in the vicinity of Cambridge, and because their size makes them suitable for dissection and analysis.

MATERIALS AND METHODS

Source of nestlings

Nests were located in woodland and hedgerows in the Madingley area, and when the hen birds were seen to be sitting on eggs the nests were visited at intervals of 2 or 3 d until the birds had hatched. Often, however, the nest already contained newly hatched

young when first found, so the exact age was not known. In these instances the ages were estimated from the mean weights of nestlings of known ages.

Only one young bird was removed from the nest if the brood was very young, and a sibling was taken from the same nest at a later date. When the nestlings were older, and there were four in a nest, two were taken.

The collection of material covered two seasons. In the first, thirteen blackbirds and seventeen thrushes were taken, in the second, ten blackbirds and four thrushes, making a total of twenty-three blackbirds and twenty-one thrushes.

Preparation of materials for analysis

The young birds were killed with ether and weighed. The gut was removed, the stomach and small intestine were emptied and the contents weighed separately and stored. The gut was returned to the body, and the 'empty' bird reweighed. During the first season both femurs and one tibia were removed, and the remainder of the bodies was stored at $-20°$. Later, the bodies were cooled in liquid N and ground to a powder by hand with a pestle and mortar. The whole of the powdered body was dried in an oven at 105° to constant weight, the fat was extracted with ether and portions of the dry fat-free material were taken for the determination of N and inorganic constituents.

During the second season the 'empty' bodies were covered with HCl (conc. acid:water, 1:1, v/v) and heated gently on a sand-bath. The brown suspension was made up to a known volume and portions were ashed for the determination of Ca.

The femurs from the first series of birds were scraped clean, weighed and measured with vernier calipers to determine the greatest length and smallest width (near the middle of the shaft). The whole bones were dried at 105°, weighed, fat-extracted with ether in a Soxhlet apparatus, re-weighed, and finely ground with a pestle and mortar. Portions were taken for the determination of Ca, collagen and N. The tibias were used for histological study and the results are presented elsewhere (Bilby, 1969).

The contents of the stomachs and small intestines of the first series of birds were dried and ashed and the ash extract was analysed for Ca.

Chemical methods

N was determined in the bodies by the method of Chibnall, Rees & Williams (1943), and collagen in the bones by the method of Neuman & Logan (1950) as modified by Baker, Lampitt & Brown (1953). The materials on which minerals were to be determined were ashed in a muffle furnace at 450° and the ash was extracted with HCl as described by McCance, Widdowson & Shackleton (1936). Ca was determined in the ash extract by precipitation as oxalate and titration with permanganate (McCance & Shipp, 1933), P by the method described by King (1932), sodium and potassium in an EEL (Evans Electroselenium Ltd, Halstead, Essex) flame photometer, and magnesium with an SP 90 atomic absorption spectrophotometer (Pye Unicam Ltd, Cambridge).

Growth in weight of nestling blackbirds and thrushes

Fig. 1 shows the mean weights of nestling blackbirds at known ages, based on the measurements of Cawkell (1950) and Gurr (1954). Both authors weighed three birds on each day and their values agreed closely. No published values for the growth of nestling thrushes have been found, but Dr Walter Davies has kindly allowed us to use his unpublished findings for forty-six birds in twelve nests, weighed over successive days. The mean weights of these thrushes are also shown in Fig. 1, and it is clear that, although the hatching weight of the two species is about the same, blackbirds put on more weight than thrushes during the next 10 d. This is confirmed by our own findings that no nestling thrushes weighing more than 54 g were found,

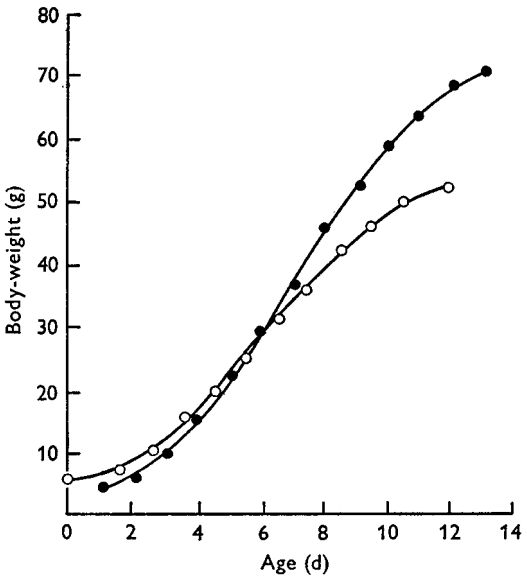

Fig. 1

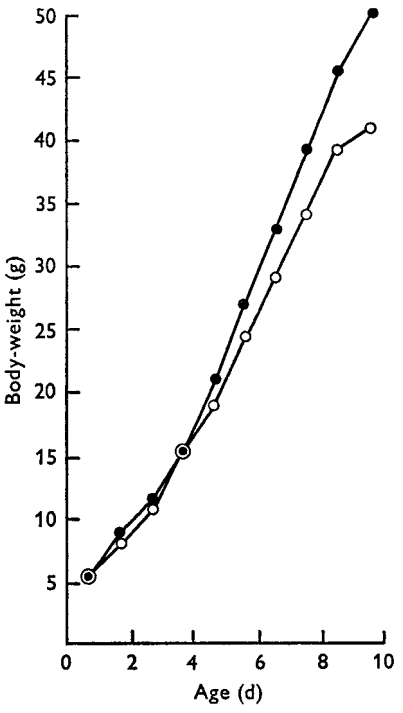

Fig. 2

Fig. 1. Growth in weight of nestling blackbirds (based on values of Cawkell (1950) & Gurr (1954)) and thrushes (unpublished values of Dr Walter Davies). ●—●, blackbirds; ○—○, thrushes.

Fig. 2. Growth in weight of nestling thrushes in broods of three and five. ●—●, three in brood; ○—○, five in brood.

whereas the heaviest blackbird was 75 g. Dr Davies's results show further that a bird in a brood of three grows faster than one in a brood of five; broods of four are intermediate. His mean results for broods of three and five are shown in Fig. 2. The parents clearly bring more food when they have five young to feed than when they have three, for the total gain in weight of the brood was greater, but they do not bring sufficient to enable each individual bird to grow as fast as when there were only three competing for the supply.

RESULTS

Composition of the bodies at hatching

Table 1 shows the mean composition of the whole bodies of five blackbirds and five thrushes less than 2 d old, and the composition of day-old chicks is also shown. There was very little fat in the bodies of the nestlings—just over 1 %. The chicks, on the other hand, contained nearly 4 % fat, excluding the yolk sac which had been removed before analysis.

Table 1. *Composition of the bodies of newly hatched blackbirds and thrushes and of fledgelings, and of the newly hatched domestic chicken*

(Mean values per 100 g and ranges)

	Blackbird		Thrush		Chicken*
	Newly hatched	Fledgeling	Newly hatched	Fledgeling	Newly hatched
Fat (g)	1·2 (0·6–1·7)	1·9 (1·4–2·2)	1·1 (0·8–1·5)	2·0 (1·8–2·2)	3·7
Fat-free body:					
Water (g)	90·0 (89·2–90·8)	78·7 (78·5–79·8)	89·7 (89·5–90·0)	78·9 (77·1–80·9)	80·5
Total N (g)	1·04 (0·84–1·28)	2·30 (2·04–2·49)	1·38 (1·28–1·53)	2·49 (2·22–2·69)	2·32
Ca (mg)	70 (60–80)	510 (320–630)	60 (50–80)	450 (320–520)	390
P (mg)	179 (146–200)	390 (368–429)	166 (142–208)	360 (290–426)	—
Mg (mg)	12·9 (11·2–14·4)	27·6 (25·3–29·6)	11·5 (10·6–12·7)	29·5 (25·3–30·5)	—
Na (mg)	271 (256–294)	150 (127–158)	222 (184–253)	163 (156–175)	—
K (mg)	126 (112–155)	212 (186–230)	177 (157–196)	211 (196–221)	—

* Widdowson, E. M. & McCance, R.A., unpublished observations.

The blackbirds and thrushes contained about 10 % dry matter in their fat-free bodies, whereas the chicks had almost 20 %. The percentage of total N was also lower in the newly hatched nestling birds than in the day-old chicks, and the difference in Ca was even greater, less than 100 mg/100 g fat-free body-weight in the blackbird and thrush compared with 400 mg/100 g in the chick. The chick is therefore much more highly developed at hatching, chemically as well as physiologically.

Changes in composition during the nestling period

Table 1 also gives the mean composition of the bodies of four blackbirds and five thrushes shortly before leaving the nest. The percentage of N in the bodies had approximately doubled during the first 11 or 12 d after hatching, and that of Ca had increased by seven or eight times. The concentrations of P, Mg and K had also increased and that of Na had decreased. All these changes are characteristic also of mammalian development.

Table 2. *Total amounts of substances in the bodies of newly hatched blackbirds and thrushes and of fledgelings*

(Mean values)

	Blackbird		Thrush	
	Newly hatched	Fledgeling	Newly hatched	Fledgeling
Body-weight (g)	5	71	5	52
Fat (g)	0·06	1·4	0·06	1·0
Water (g)	4·5	55·0	4·5	40·0
Total N (g)	0·05	1·62	0·07	1·27
Ca (mg)	3·5	356	3·0	230
P (mg)	9·0	272	8·3	184
Mg (mg)	0·65	19·4	0·58	15·0
Na (mg)	13·5	105	11·1	83
K (mg)	6·3	148	8·9	108

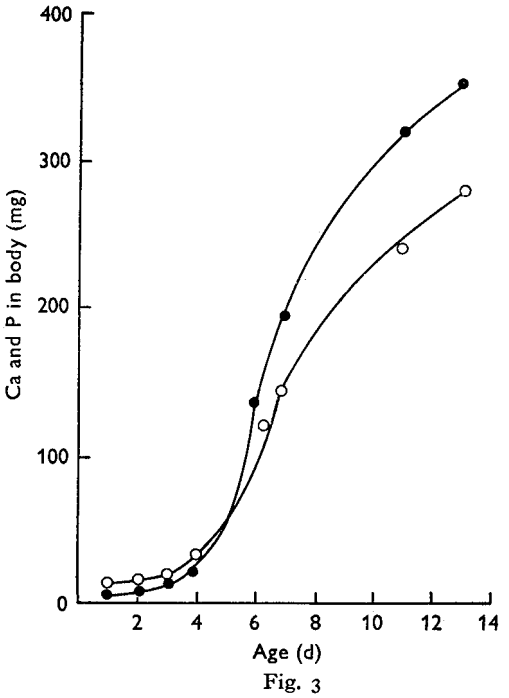

Fig. 3

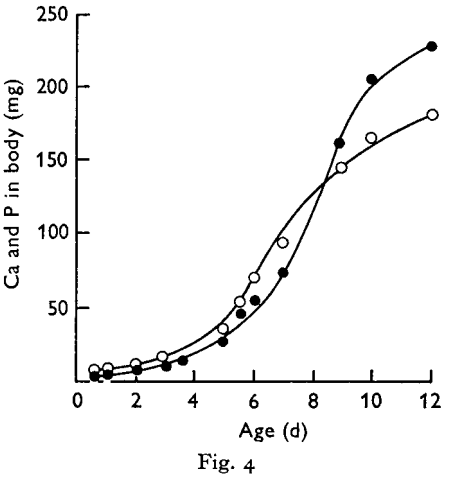

Fig. 4

Fig. 3. Total amounts of calcium and phosphorus in the bodies of nestling blackbirds. ●—●, Ca; ○—○, P.

Fig. 4. Total amounts of calcium and phosphorus in the bodies of nestling thrushes. ●—●, Ca; ○—○, P.

Table 2 shows the amounts of the various substances in the bodies of the birds just after hatching, and again less than 2 weeks later when they are ready to leave the nest. During this time the mean weight of the blackbirds had increased fourteen times, and that of total Ca in the body had increased by about 100 times. The amounts of N, P, Mg and K had increased by about thirty times. The thrushes gained a little less weight so the mineral accretions in their bodies were a little less spectacular. Figs. 3 and 4

show the amounts of Ca and P in the bodies of the blackbirds and thrushes throughout the nestling period. The rate of increase was slow at first, but rose rapidly after 4 or 5 d. For the 1st week or so the weight of P in the body exceeded that of Ca, but with the progressive calcification of the bones the Ca began to increase more rapidly than the P and ultimately the body contained considerably more of the former element. At all ages the blackbird contained more Ca than the thrush, primarily because it is a bigger bird, though in fact its body also had a slightly higher concentration of Ca.

Table 3. *Weight, dimensions and composition of the femur of newly hatched birds and fledgelings*

(Mean values and ranges)

	Blackbird		Thrush	
Measurement	Newly hatched	Fledgeling	Newly hatched	Fledgeling
Weight (mg)	12·5 (12·1–12·8)	210 (175–232)	9·3 (7·5–15·1)	152 (138–159)
		Dimensions		
Length (mm)	9·1 (8·9–9·5)	28·0 (24·4–30·0)	8·7 (8·2–9·7)	26·7 (26·1–27·2)
Width (mm)	0·7 (all 0·7)	2·3 (2·2–2·4)	0·6 (0·5–0·8)	2·0 (1·9–2·1)
		Composition of fresh bone		
Water (g/100 g)	81·4 (80·2–82·6)	65·2 (59·0–69·4)	84·8*	62·5 (59·7–65·3)
Total N (g/100 g)	1·68 (1·60–1·75)	2·35 (2·02–2·82)	1·52*	2·27 (2·20–2·32)
Collagen (g/100 g)	3·05 (2·8–3·3)	7·36 (6·90–7·80)	3·45*	7·70 (7·48–7·84)
Calcium (g/100 g)	1·13 (1·10–1·16)	6·18 (5·48–6·87)	1·08*	6·27 (5·90–6·94)
Ratio, Ca:collagen	0·37	0·84	0·32*	0·82

* Bones from only one bird analysed.

Composition of the femur

The femurs of the newly hatched blackbird and thrush were extremely immature (Table 3). They contained only just over 1% Ca compared with 2·9% in the femur of the newly hatched chick (Dickerson, 1962*a*). In fact they were less highly calcified than the femur of a human foetus of 12–14 weeks gestation (Dickerson, 1962*b*). Perhaps even more striking is the fact that only about one-quarter of the total N was in the form of collagen (containing 13·8% N), so that in this respect, too, they resemble the femur of the human foetus of less than 12 weeks gestation. Glycoproteins probably account for much of the remainder of the nitrogenous fraction. By the time the young birds were ready to leave the nest, their femurs had reached a state of development similar to that of the newborn infant, the 21-d-old rat and the 17-d-old chicken (Dickerson, 1962*a*, *b*), and they achieved this in only 12 or 13 d. The phenomenal growth and change in chemical structure of the long bones was accompanied by changes in their morphology that were equally great (Bilby, 1969). In the tibia at

hatching, primary bone had hardly begun to form and the bone was nearly all cartilage. By the time the nestling was about to fly the tibia had increased by about three times in length. The marrow cavity was well developed and surrounded by a thin wall of cortical bone.

The femur of the fledgeling blackbird was heavier, longer and wider than that of the thrush, in keeping with the greater size of the bird, but the degree of calcification of the bone, as judged by the Ca:collagen ratio, was about the same.

Table 4. *Calcium in the gut contents and in the bodies of individual blackbirds and thrushes*

Blackbirds			Thrushes		
Age (d)	Total body Ca (mg)	Ca in gut (mg)	Age (d)	Total body Ca (mg)	Ca in gut (mg)
1·5	3·32	2·20	0·5	2·46	1·72
1·5	3·36	1·28	0·5	2·94	2·24
2	4·28	1·13	1	4·12	1·51
2	4·73	1·15	2	8·85	1·14
2·5	5·98	1·96	3	10·6	2·86
4	19·1	6·84	4	13·3	5·02
6	141	4·43	5	26·4	20·7
6	143	31·5	6	47·5	7·9
6	148	9·48	7	70	11·1
7	186	8·2	8	116	11·8
8	227	10·5	9	141	23·3
13	360	11·7	10	192	21·2
			11	223	12·8
			12	232	8·1
			12	247	19·9

Ca in the gut contents

Table 4 shows the amounts of Ca found in the gut contents of individual nestling blackbirds and thrushes of various ages compared with the total amounts of Ca in their bodies. The contents of the gastro-intestinal tract of the younger birds sometimes contained more than half as much Ca as the body itself, and these young birds were obviously obtaining an ample sufficiency of Ca for bone growth and calcification in spite of their unpromising diet of earthworms, caterpillars and adult insects. It is unlikely that the tissues of these invertebrates contain much Ca, but Ca is one of the main excretory products of insects (Uvarov, 1928), and also of caterpillars and earthworms. Caterpillars eat green leaves, which contain much Ca (McCance *et al.* 1936) and earthworms consume soil which, in a chalky area, fills the gut with Ca-rich material. Earthworms collected near Cambridge were found to have 1·66% Ca in their guts and 0·23% in their body tissue, which may have had traces of soil adhering to the surface. This gives a mean concentration of 0·89% Ca in the worms as a whole. Smaller worms weighed about 0·3 g, larger ones 1·3 g, so the Ca in the gut contents of the young nestling could have been obtained from one very small worm. If a blackbird absorbed and retained all the Ca it ate, it would obtain its Ca requirements during the whole nestling period from 30 large or 130 small worms. The corresponding numbers for a thrush would be 20 and 85. It seems likely that it is the gut contents

of these invertebrates that provide the nestling birds with most of the Ca they need. How the birds fare in an area where the soil is not chalky still remains to be discovered.

We are grateful to Dr P. W. Davies for allowing us to use his values for the weight of the nestling thrush. We also thank Mrs G. Foreman for help with some of the analytical work. L.W.B. acknowledges with thanks the studentship awarded to her by Messrs Joseph Rank Ltd during the course of which this investigation was made.

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