"Some Observations on Birds, chiefly relating to their Temperature, with Supplementary additions on their Bones." By John Davy, M.D., F.R.S., &c. Received May 26, 1865 *.

Received May 26, 1865 *.

The observations which I have now the honour to submit to the Royal Society, have been made with the hope of contributing something to the elucidation of the high temperature for which birds as a class are remarkable.

I. *Of the Temperature of the Common Fowl* (Gallus domesticus).

Mr. Hunter, in his paper entitled "Of the Heat, &c. of Animals and Vegetables," published in the Philosophical Transactions for 1778, states that he found the temperature of the common fowl, both male and female, in the intestinum rectum between 103° and 104° of Fahr. From such observations as I have made, both in Ceylon and in England, it would appear that the temperature of this bird is considerably higher. In the former I found it as high *in recto* as 110° and 111°, and this in December, when the average temperature of the atmosphere, in that part of the island where the trials were made, is about 77°, which was the temperature of the air at the very time. In the latter I have found it to vary from 107° to 109° *. That the temperature of the common fowl should be a little lower in England than in Ceylon, is no more than might be expected, from the analogy of the difference of temperature of man in the two climates; and, in accordance, in the fowl I have found that even in England there is a slight difference in favour of the warmest months, comparing the results then obtained with those in the coldest.

Of the want of agreement between Mr. Hunter's results and mine I can offer no satisfactory explanation. I have thought it right to advert to them, he being so deservedly a high authority in physiology. Were his results to be depended on, then, were the common fowl to be considered as a fair example of the temperature of birds generally, they could hardly be considered as a class peculiar for highness of temperature, some of the mammalia having a temperature differing but little from that which he assigns to the common fowl †. Or, if not a fair example, then an exception, and the

* Read June 15, 1865. See Abstract, page 337.

† The trials from which the last-mentioned results were obtained have been made during the last two or three years, using a delicate thermometer of Negretti and Zambra made for the purpose, which had been compared with a standard instrument. The fowls tried were all barn-door fowls, living at large, and having the run of a field. The number of females examined was 37, of males 25. The mean temperature of the former *in recto* was 107°·64; the highest 109°, the lowest 107°; of the latter the mean temperature was 108°·25, the highest 109°, the lowest 107°.

‡ In Ceylon I found the temperature of the blood of the wild hog, as it flowed from the divided great cervical vessels, 106°, and that of the pig in England, in two instances, of the same degree; both were in excellent condition, and were killed in December; of one the temperature of the blood was tried; of the other, the cavity of the abdomen. The temperature of the sheep I have found to vary from 103° to 105° *in recto*; the latter in Ceylon.

common fowl would have to be placed amongst those birds, few in number, chiefly palmipedes, ocean-birds, peculiar for lowness of temperature*. Now, as neither of these conclusions is admissible, it seems unavoidable that Mr. Hunter's results must be received as inaccurate.

II. *Of the expired Air, and of the Air in the Air-receptacles and Bones of Birds.*

1. *Of the expired air.*—That which I have examined has been obtained from birds in the act of drowning. It is worthy of remark, I may premise, and I am not aware that the fact has been noticed by any previous inquirer, that different birds vary as to their power of retention of life under water. The goose expires I have found in about ten minutes; the duck in about the same time; the common barn-door fowl in about four or four and a half minutes; the turkey in about three minutes; the jay in about a minute and a half; the pigeon, the carrion-crow, rook, jackdaw, in about a minute; the robin, the hedge-warbler in about the same time; the blackbird in about three-quarters of a minute; the tawny owl, the bullfinch, the house-sparrow, in about half-a-minute. Those birds which are capable of retaining the air longest emit little air commonly when first submerged; but later, shortly before the extinction of life, they expel it in large quantities; those, on the contrary, especially the smaller birds, which soonest die, expel no air in the act of drowning.

I have examined the air from the goose in one instance only; it was a portion of the last emitted. Tested by milk of lime and phosphorus, it was found to consist of 7·5 carbonic acid gas, 92·5 azote.

The air from a duck, a small portion collected after four minutes' submersion, was composed of 2·38 carbonic acid, 9·52 oxygen, 88·10 azote. From another duck two portions of air were tried, one after five minutes' submersion, the other after between eight and ten. The first consisted of 7·5 carbonic acid, 7·5 oxygen, 85 azote; the second of 15·7 carbonic acid, 4·1 oxygen, 80·2 azote.

From the common fowl the air was examined in two instances; in both it was that which was emitted near death. Of one, the composition was 6·18 carbonic acid, 5·08 oxygen, 82·84 azote; of the other, 3·3 carbonic acid, 7·79 oxygen, 88·89 azote.

From a pigeon, the air emitted (it was pretty considerable in quantity) consisted of 11·1 oxygen, 89·7 azote.

From these results, and from a few others which I have obtained, it would appear that in the air expired by birds in the act of drowning there

* The temperature of the *Procellaria æquinoctialis* in one instance I found 103°·5 *in recto*, in another 105°. Dr. Brown-Séquard has made similar observations. See his 'Journal de la Physiologie' for January 1858. M. Ch. Martins has found the temperature of some sea-birds even lower, that of *Procellaria glacialis* 102°, of *Larus ridibundus* 104°. See his very interesting memoir on the Temperature of Northern Birds in the same Journal, and in the Number before quoted.

is a certain loss of carbonic acid, a loss equivalent to the proportion of oxygen less than exists in the atmospheric air inspired ; and it may be inferred that the deficient carbonic acid was absorbed and retained in the blood; and that it was so, was indicated by the very dark colour of the blood obtained by the division of the great cervical vessels immediately after the extinction of life, and further by the large quantity of air that was disengaged from the blood when subjected to the air-pump *.

2. *Of the air from the air-sacs.*—On the air from these receptacles I have made the following experiments :—

From a turkey killed by drowning, a portion of air was collected by a puncture made under water into the air-vesicles under the sternum. It was found to consist of 15·5 carbonic acid, 84·5 azote.

From a duck deprived of life in the same manner, a portion of air was obtained from the abdominal air-receptacles. It was composed of 10·52 carbonic acid, 5·26 oxygen, 88·32 azote.

These results would seem to warrant the inference that the very delicate membrane of which the air-receptacles are formed, is like that of the air-cells of the lungs pervious to air; and the further inference, that the deficient carbonic acid in the air examined was owing to its absorption by the blood.

3. *Of the air contained in the bones.*—The experiments I have made on this air have been confined chiefly to that of the humerus. I may premise that in every instance in which I have examined the lining membrane of the hollow bones of birds (the air-containing bones), I have found it distinctly vascular; in this respect differing from the membrane of the air-receptacles communicating with the lungs situated in its thoracic and abdominal cavities. Not unfrequently, both in the humeri and femora, the vessels have had the appearance of being varicose, and this when the examination was made a few minutes after death.

From the humerus of a common fowl, killed by drowning, a portion of air obtained was found to be composed of 4·7 oxygen, 95·3 azote. The bone was dissected out under water, and its head there removed to allow free exit to the included air.

From the humerus of another fowl killed by the division of the great cervical vessels, the air procured consisted of 8·3 carbonic acid, 8·3 oxygen, 83·4 azote. In this instance the bone was dissected out under water, whilst the fowl was still warm. No air escaped until the delicate bony tissue (the reticulated structure) was broken through, and indeed then but little, until the head of the bone had been removed.

* Two trials of the blood were made, one in which the blood was received in water previously purged of air, the other in which it was received in weak solution of potassa, also exhausted of air by the pump: the difference was remarkable, so much air being disengaged from the first, so little from the second.

It may be deserving of mention that in the instance in which the blood diluted with water was allowed to coagulate, no air was disengaged by the action of the pump until the resisting clot was broken up, when the disengagement on exhaustion was copious.

From a third fowl, a cock weighing ten pounds and three-quarters, killed in the same manner as the last, the air from the humerus, measuring one-tenth of a cubic inch, consisted of 15 oxygen and 85 azote.

From the humerus of a rook, a few minutes after the bird had been shot, the air obtained, measuring ·22 cubic inch, was composed of 11 carbonic acid, 89 azote.

From the humerus of a tawny owl, three days after the death of the bird by drowning, the air collected consisted of 5·5 carbonic acid, 5·5 oxygen, 89 azote.

Though these results are not so uniform as might be expected, they seem to prove that the air in the bones undergoes the same change as in the air-sacs, and that there is an absorption, more or less, of the carbonic acid formed by the blood contained in the vessels of the lining membrane, the quantity varying according to circumstances. It may be conjectured that the difference in the results may partly be owing to the air-passage, the foramen or foramina, in the head of the bone, being more free in some instances than in others

III. *On Pulmonary and Cutaneous Aqueous Exhalation.*

The loss of water by exhalation from the lungs in the air expired, and from the cutaneous covering of the body by evaporation, must be considered material elements in the problem of the animal heat of birds. And inasmuch as birds drink but little, inasmuch as their skin generally is very thin, dry, and little vascular; further, as the air in expiration has to pass over a considerable length of surface of comparatively low temperature before it enters the open air, their loss of heat owing to these conditions must be small, and more especially so, taking into account the admirable covering of feathers, such bad conductors of heat, with which they are provided.

The only experiments I have to describe bearing in part on what has just been stated, chiefly the last-mentioned, are the following on the rate of cooling.

Two fowls, hens of the same brood, were selected for trial. The weight of each after loss of blood, having been killed by the division of the great cervical vessels, was five pounds. The temperature of one (No. 1), ascertained just before, was 107°·25 *in recto*; of the other (No. 2), 108°. The latter was rapidly deprived of its feathers, with the exception of the wings, whilst on the other they were left on. Both were suspended by the legs,

* I have occasionally found a delicate transparent membrane connecting some of the cancelli. Invariably the opening into the humerus is obstructed by the muscle attached to the cavity in which the foramen or foramina above mentioned are situated. Mr. Hunter found when the trachea of a cock was tied, and "the wing cut through the os humeri," the passage of air to the lungs was so difficult as to render it impossible for the animal to live longer than to prove that it breathed through the cut bone.—Observations on certain parts of the Animal Economy, p. 82.

the wings of the plucked fowl kept apart from the body, the wings of the other in close contact with the body. The room in which they were suspended was 53° at the time. From the great delicacy of the thermometer used, about a minute and a half sufficed *in recto* to give a good result; as the same instrument was used, the trial was made alternately as to time; in the first trial of the temperature beginning with No. 1, in the second with No. 2, and so on.

	h m		°		°		°
March 29th.—	10 2	A.M., air	53	No. 1,	107·25	No. 2,	108
,,	10 40	,,	52	,,	104	,,	103
,,	11 54	,,	52	,,	97	,,	87
,,	1	P.M., air	52	,,	90	,,	72
,,	2 4	,,	52	,,	87	,,	66
,,	3 7	,,	52	,,	85	,,	62
,,	4 2	,,	52	,,	83	,,	61
,,	5 3	,,	53	,,	80	,,	59·5
,,	6 35	,,	50	,,	75·5	,,	55·5
,,	9 50	,,	50	,,	68	,,	52
March 30th.—	12 15	A.M., air	48	,,	65	,,	50·5
,,	8 30	,,	49	,,	55·5	,,	48·5
,,	10 20	,,	51	,,	55	,,	49
,,	12 15	P.M., air	53	,,	54	,,	50

From the last of these observations it is seen how little was the cooling effects from evaporation, the temperature of the plucked fowl rising a degree, and differing one degree only from the air of the room.

Of the other trials made, one was on a drake, one on a tawny owl.

The drake, well covered with feathers, weighed seven pounds. It was killed by drowning; the blood was retained. Like the fowls, it was suspended by the legs; its wings were apart. Previously its temperature *in recto* was 107°·5. The thermometer was left *in recto.*

	h m		°		°
April 5th.—	10 51	A.M., air	55	Drake	107·5
,,	11 25	,,	55	,, ...	104.
,,	12 40	,,	55	,, ...	94.
,,	2 8	,,	55	,, ...	89·5.
,,	3 15	,,	55	,, ...	85.
,,	4 35	,,	55	,, ...	81.
,,	5 5	,,	55	,, ...	65.
,,	11 45	,,	53	,, ...	65.
April 6th.—	8 30	A.M., air	51	,, ...	57.

The owl was killed also by drowning. It had been fed the preceding evening. On the 2nd of December, when alive, at 10.30 A.M., its temperature *in recto* was 106°·5. Tho observations on its cooling were made on it placed on a table, the bird resting on its abdomen, the wings close to its sides; the thermometer was left *in recto.*

	h m		air °		°
December 2nd.—	10 45	A.M., air	58	Owl	100
,,	11 45	,,	58	,, ...	93·25
,,	12 45	P.M., air	58	,, ...	86·25
,,	1 45	,,	58	,, ...	80·50
,,	2 45	,,	58	,, ...	75·75
,,	3 45	,,	58	,, ...	72
,,	4 45	,,	57	,, ...	69·25
,,	7 15	,,	57	,, ...	64·50
,,	9 30	,,	56	,, ...	61·25
,,	11 30	,,	55	,, ...	59·25
December 3rd.—	9	A.M., air	55	,, ...	54·5*
,,	12	M., air	58	,, ...	56·25
,,	2	P.M., ,,	60	,, ...	57
,,	4	,,	60	,, ...	58·5
,,	12	,,	57	,, ...	57
December 4th.—	9	A.M., air	58	,, ...	55·5†
,,	4	P.M., air	60	,, ...	58·5
,,	12	,,	57	,, ...	57

These results seem sufficient to show that birds owe much of their high temperature, especially its preservation, to their clothing of feathers. Further, it may be remarked in proof of the little activity of their cuticular structure (except, indeed, in the growth of feathers), that birds are never observed to eat, or have their feathers wet from condensation on them of perspired moisture; nor am I aware that their breath becomes visible, to use a popular expression, in the coldest weather. And in accordance it would appear, comparing birds with animals of other classes, that the proportion of their aqueous element is somewhat less, which also harmonizes with an inconsiderable cooling effect from cutaneous evaporation—a fact which some of the results given seem to prove, and as is shown by the following, so far as trials on the dead are applicable, inferentially to the living animal.

Of four sparrows just shot, one (No. 1) weighing 414·5 grs. was suspended with its feathers entire; a second (No. 2) clipped, *i. e.* its feathers cut short, weighing 405·6 grs. (it had lost 23 grs. by the clipping), was suspended by its side, as were also the other two; No. 3, deprived of its feathers, its skin unbroken, weighing 414 grs.; No. 4, deprived of its skin as well as its feathers, weighing 384·5 grs. During twenty-four hours' exposure to the air of room varying from 48° to 50°, No. 1 lost 1·5 per cent.; No. 2, 2·3; No. 3, 7·9; No. 4, 17·4.

* In the room there was no fire from 5 P.M. on the 2nd to 8 A.M. on the 3rd; during the night the thermometer in air must have been below 54°·5; in a small cup of water close to the bird at 9 A.M. it was 53°.

† Water in cup *covered* 55°.

IV.—*Of the Kidneys and their Excretion.*

Another element in the problem of the temperature of birds is the kidneys, with their excretion. As is well known, these organs in birds are proportionally large and active; their secretion, not inconsiderable in quantity, and formed chiefly of urate of ammonia, is voided in a state far removed from the liquid, hardly semifluid from the little water it contains. Hence in the performance of the function there is but little loss of heat. Moreover, as it would appear from ultimate analysis that the urate contains less oxygen than urea, there must be a less expenditure of oxygen in its formation, leaving more for a more profitable conversion into carbonic acid.

What are the general conclusions which are admissible from the preceding results?

Do they not warrant the inference that the high temperature of birds is owing to a combination of circumstances, some positive, some negative; the one, the positive, acting through the air inspired and the conversion of oxygen into carbonic acid gas, productive of heat; the other, the negative conditions, such as those mentioned, influential mainly by economizing the heat when produced, or checking its escape?

Besides these negative conditions, it may be open to question, considering the proportional smallness of the lungs of birds, and the smallness of the nerves with which they are supplied, whether there are not other circumstances concerned of an ancillary kind—such, to enumerate some of the most probable, as a powerful heart, especially a powerful left ventricle; the quality of their blood, that but little viscid, as indicated by the little, if any tendency of the red corpuscles to collect in piles*; the large proportion of these corpuscles, and their nucleated structure, a structure with which may be connected an electrical influence.

If the chief use of the peculiar pneumatic system of birds be to secure a high temperature, it is probable, and is in part already admitted, that it may subserve other uses inferior only in degree of importance in relation to the habits and well-being of the class: for instance, as generally admitted, it may conduce to great power of flight in some, to running power in others, to vocal power in a third; and, in all, may not the thorough aëration of the blood, as denoted by its more florid hue even in the veins, be essential to the energy, to that intensity of action and endurance for which the muscles of those birds in which the structure under consideration is most developed, are so remarkable?

The subject in its entireness, it must be allowed, is full of interest. It affords in the variety of structure exhibited by different birds, supplementary to the lungs, ample scope for further research. Why some birds, such as the woodcock, the snipe, the swallow, birds of rapid and long flight, should be destitute of air in their bones; why the small birds, with few exceptions, the tits for instance, some of the smallest, should expe-

* In no instance have I seen the blood-corpuscles of any bird to cohere and form rouleaux or piles, nor have I seen a buffy coat on the blood of birds.

Grouse (*Tetrao scoticus*)	humeri,	scapulæ,	clavicles,	furcula,	femora.
Partridge (*Perdix cinerea*)	do.		—	—	—
Wood-pigeon (*Columba palustris*)	do.		—	—	—
Common pigeon (*C. domestica*)	do.		—		—
Wild duck (*Anas boschus*)	do.		—		—
Common duck (*A. domesticus*)	do.		—		—
Wigeon (*A. Penelope*)	do.	—	—	—	—
Skylark (*Alauda arvensis*)	do.	do.	do.	—	—
Woodlark (*A. arborea*)	do.	do.	do.	—	—
Great tit (*Parus major*)	do.	—	—	—	—
Blue tit (*P. cæruleus*)	do.	—	—	—	—
Marsh tit (*P. palustris*)	do.	—	—	—	—

Section II.

*Titlark (*Anthus pratensis*).
Tufted duck (*Anas fuligula*).
Common guillemot (*Uria Troile*).
Water-hen (*Gallinula chloropus*).
*Corncrake (*G. crex*).
Woodcock (*Scolopax rusticula*).
Snipe (*S. gallinago*).
Bar-tailed godwit (*S. ægocephala*).
Dunlin (*Tringa alpina*).
Little sandpiper (*T. pusilla*).
Missel-thrush (*Turdus viscivorus*).
Blackbird (*T. merula*).
Song-thrush (*T. musicus*).
Redwing (*T. iliacus*).
Fieldfare (*T. pilaris*).
Water-ouzel (*T. cinclus*).
Starling (*Sturnus vulgaris*).
Goldfinch (*Fringilla carduelis*).
Chaffinch (*F. cœlebs*).
Siskin (*F. spinus*).
Lesser-redpole (*F. linaria*).
Common sparrow (*F. domestica*).
Mountain linnet (*F. montana*).
Robin (*Sylvia rubecula*).
*Stonechat (*S. rubicola*).
Wren (*S. troglodytes*).
*Hedge-warbler (*S. modularis*).
*Blackcap (*S. atricapilla*).
*Redstart (*S. phœnicura*).
*Willow warbler (*S. trochilus*).
Bullfinch (*Loxia pyrrhula*).

rience the same exemption; why one bird, the apteryx, a solitary example should be without air not only in every part of its osseous system, but also without air-sacs; and another bird, the grouse, not remarkable for power of flight, should have air in its femora as well as humeri, are questions which at present it may be difficult to answer, but which, it may be hoped, were careful and minute inquiry instituted, might be satisfactorily accounted for on the teleological principle of fitness of structure to use.

If I may be allowed to offer a conjecture, it seems to me probable that in our commonly received generalization relative to the consumption of oxygen in the respiration of birds, the quantity presumed to be used has been overrated, and that in many instances the expenditure of this gas may be found to be less proportionally than in the mammalia.

As supplementary to the preceding observations, I would beg to state some further particulars respecting birds, the results of the inquiry in which I have been engaged.

1st. *Of the birds examined.*—All of them were natives of the Lake District, with two or three exceptions which will be specified, and all were obtained between November and March, excepting those marked with an asterisk, which were shot in April and May. They may be divided into two sections, one including those birds in one or more of the bones of which air was found to exist communicating with the lungs. The other, of those birds in which in the corresponding bones no air could be detected. The birds were all at least one year old, an ample time, I apprehend, for the marrow which exists probably in the bones of every individual of the class at the time of hatching, and for some time after, to be absorbed in those in which it is not permanently present.

It may be right to remark that in every instance the question whether air was present or not was determined by an examination of the contents of the particular bones, and not merely from their appearance, which, as regards colour, is sometimes deceptive.

Of the birds belonging to the first section, the bones, which are named after each, were those only in which air was found, *i. e.* communicating with the lungs.

Section I.

Buzzard (*Falco buteo*)	humeri,	scapulæ,	clavicles,	furcula,	femora.
Tawny owl (*Strix stridula*)	do.	do.	do.	do.	do.
Carrion crow (*Corvus corone*)	do.	do.	do.	do.	—
Rook (*C. frugilegus*)	do.	do.	do.	do.	—
Jackdaw (*C. monedula*)	do.	do.	do.	do.	—
Magpie (*C. pica*)	do.	do.	do.	do.	—
Jay (*C. glandarius*)	do.	do.	do.	do.	—
Cuckoo (*Cuculus canorus*)	do.	—	—	—	—
Common fowl (*Gallus domesticus*)	do.	—	—	—	—
Pheasant (*Phasianus colchicus*)	do.	—	—	—	—

*Greenfinch (*L. chloris*).
Yellowhammer (*Enteriza citrinella*).
Gray wagtail (*Motacilla boarula*).
Yellow wagtail (*M. flava*).
Common creeper (*Certhia familiaris*).
*Pied flycatcher (*Muscicapa atricapilla*).
*Spotted flycatcher (*M. grisola*).
*Swift (*Hirundo apis*).
*Swallow (*H. rustica*).
*Martin (*H. urbica*).
*Sand-martin (*H. riparia*).

Of the birds in each section, the crania, with some exceptions, contained air. The skull of the water-ouzel is one of the exceptions. It is not cellular like that of the majority, but compact and sinks in water. Its greater heaviness may be suitable to the habits of the bird, seeking its prey in the bed of ruuning streams with its head downmost. The same compactness of bone is seen in the crania of the Scolopacidæ. This compactness is remarkably contrasted with the cellular state of cranium of certain other birds, in which it is most strongly marked, where lightness as well as power of resistance is needed, such as that of the owls and tits.

There are certain bones which in the adult stage of the bird appear to be without both marrow and air; the scapular arch is occasionally an example of this, especially its posterior wing*, and also the sternum.

Professor Rudolph Wagner, in his 'Elements of Comparative Anatomy' (English translation), refers to the blackbird and thrush as instances of birds which have air in their femora. I have sought for air in these bones in all the thrushes I have examined, seven different species, but have found only marrow. If verified it would be a curious fact, that in one country air should occur in the bones in question and in another marrow.

Whether the circumstance of the presence or absence of air in the bones is deserving of attention in the classification of birds, may be worthy of the consideration of the naturalist. In all the tits I have examined, and the number has been considerable, especially of the blue tit, I have never found marrow in the humeri, and the same remark applies to these bones in the larks, but not to those of the pipits.

2nd. *Of the proportions of certain parts of birds as determined by weighing.*—In the Table which follows a statement is given of results, comprising the weight of the birds examined, of their feathers, and, with a few exceptions, of their bones, the latter after having been cleaned, deprived of their periostrum, and dried by exposure to the air†. In the first column the

* The posterior wing in the tabular list is designated scapula, the anterior portion, the coracoid process of some authors, is designated clavicle.

† In one instance (the bones of the buzzard) it was found, by weighing them before and after drying, that the difference or loss was 12·5 per cent.

weight in grains of the fresh birds, before the removal of their feathers, is inserted, the heading of the other columns is sufficiently distinctive. The primates of the wings and the quill-feathers of the tail in each instance were weighed apart. The weight of the whole of the plumage was ascertained by two weighings, one before, the other after the feathers had been taken out, the loss, including the whole of the quill-feathers, showing the total amount. When a trial was made of more than one of a species, the results have been inserted, on the idea that possibly they may be of some interest in relation to variations; these no doubt depending on many circumstances, such as sex, condition as to fatness, and others less easy of appreciation.

Species.	Sex.	Weight of bird.	Weight of tail-feathers.	Weight of wing-feathers.	Total weight of feathers.	Weight of bones.
		grs.	grs.	grs.	grs.	grs.
Buzzard	F.	23040	128	454	2276	1163·6
Buzzard	M.	12994	89	330·5	2022	1050·8
Tawny owl	M.	5776	22·6	127·6	696·2	428·5
Carrion crow	M.	7885	48·4	223·6	1074	556·9
Rook	F.	8664	45	207·3	1122·3	537
Rook	M.	6556	45·5	201·6	974	463·7
Jackdaw	M.	3900	28	98	390	272·5
Jay	—	2539	14·9	43·7	250·4	152·2
Cuckoo	M.	2091	23·6	49	197·6	106·9
Common fowl	F.	24851	57·5	214	1846·5	1438·7
Common duck	F.	22547	30	160·4	1755·5	
Woodcock	...	4198	8·1	58·9	306	280
Little sandpiper	...	629·4	1·7	8·8	62·7	36·6
Blackbird	...	1668	8·1	20·2	104·5	81·3
Song-thrush	...	1175	4	12	76·5	
Missel-thrush	...	2127	......	......	156	
Water-ouze	...	873	3	6·5	53·2	46·9
Skylark	F.	744	......	......	56·6	
Skylark	M.	657·7	......	......	53·2	33·2
Skylark	F.	643·7	2·8	12·2	64·7	
Skylark	F.	523	2·6	9·1	47·9	24·2
Woodlark	F.	493	2·3	9·1	47	24·2
Titlark	F.	368	1·5	5·4	14·5	20·2
Black-cap	M.	273·2	1·2	3·3	19·7	12·4
Stone-chat	M.	346·8	1·8	6·2	34·8	21·4
House-sparrow	...	421·7	2	5·7	30·6	25·3
Chaffinch	...	401	......	......	......	19
Bullfinch	M.	374	1·9	5·9	31·9	15·3
Greenfinch	M.	388·6	1·5	6	34·1	22
Swallow	F.	321·8	1·8	8·1	25·8	16
Swift	F.	784·3	9	18	55·3	39·5
Martin	F.	301	1·3	7	21	14·6
Sand-martin	F.	210·5	·9	6·2	14·5	9·4
Great tit	...	320·5	1·5	4	22	
Blue tit	...	180·9	·95	1·15	18·4	
Blue tit	M.	162·1	·83	2·16	16·49	8·71
Blue tit		145	......	......	15·4	
Blue tit		137	......	......	13·5	
Blue tit		167·5	......	......	13·8	

On the results in this Table I have but few remarks to offer. The regularity of feathers as to number, *i. e.* of the primates of the wings and of

the quill tail-feathers, is well known to the naturalist. In all the instances in which I have weighed the primates of each wing, I have found them, if not precisely of the same weight, to differ in the smaller birds not more than by ·1 or ·01 grain, and in the larger the difference has rarely exceeded 1 grain; a degree of equality this which might be expected, as essential to the regularity of flight; and small as it is, I am disposed to think that in the larger birds even it would hardly be appreciable could the quills be extracted with precisely the same proportion of adhering tissue.

Comparing the quill-feathers of the small with those of the large birds, the proportional weight of the latter, it would appear, is commonly greater than that of the former,—a disproportion, it may be inferred, connected with the larger birds having, as needed, stronger wing- and tail-quill feathers, and, indeed, stronger feathers generally, the few exceptions harmonizing, at least those of the common fowl and duck.

Comparing their bones, those of the larger and more powerful, as might also be anticipated, appear, too, proportionally heaviest.

Comparing individuals of the same species, whether as to the total weight of birds, or of feathers and bones, variations will be found to occur. The skylarks may be mentioned as examples, and also the tits, the former obtained not from the same locality, one having been procured from Lincolnshire, one from Oxford, a third from Yorkshire, a fourth from the immediate neighbourhood of Ambleside, where it is rarely seen, and where it came during a severe frost probably in quest of food, having been found close to a running stream*; the tits were all from the immediate neighbourhood of Ambleside.

3rd. *Of the weight of the principal bones of the skeleton.*—The results obtained are given in the next Table. The birds, the bones of which were the subjects of trial, have already been all mentioned, and may be identified by their weight, as inserted again in the first column. With the cranium, it may be stated, the maxillæ and facial bones were weighed, and with the pelvis the caudal vertebræ: the spine comprised all the other vertebræ excepting those anchylosed with the pelvis; the terminal bones of the extremities are designated by metacarpi, &c. for the upper, and by phalanges for the lower.

* In the gizzard of all the larks I have examined I have found grass, tending to prove that, at least in winter, meadow-grass is their chief food.

Species.	Sex.	Weight of birds.	Weight of cranium	Weight of os linguæ and hyoides.	Weight of spine.	Weight of pelvis.	Weight of sternum.	Weight of ribs.	Weight of furcula.	Weight of scapular arch.	Weight of humeri.	Weight of ulnæ and radii.	Weight of metacarpi.	Weight of femora.	Weight of Tibiæ.	Weight of tarsi.	Weight of phalanges.	Total weight.
		grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.
Buzzard	F.	23040	86	2	51·6	88	36·5	24·8	10·1	44·5	125	223·7	85·6	73·4	141·6	81·6	89	1163·6
Buzzard	M.	12994	85·6	1·4	57·3	84·9	35·9	22·4	10·4	53·8	116	184·8	79·4	54·6	115·5	81	77·6	1050·8
Owl..................	M.	5776	61·5	1·1	25·8	25·4	12·5	10·4	2·4	16	37·5	60·6	28	33·5	47·6	32	34·2	428·5
Cuckoo	M.	2091	10·8	·3	7·5	8·3	6	2·3	1·5	7·4	12·1	18·1	12	5·8	7·6	3·2	4	106·9
Carrion crow	M.	7885	72	1·8	42·5	40·3	25·2	26·2	5·7	27·1	51·9	80·9	42·6	30	52	30·3	29	556·9
Rook	...	6556	56·6	3·6	36·5	30·1	17·7	12·4	5·3	21·5	41·7	74	42·6	26·3	48·8	26·4	20·4	463·7
Rook	...	8664	67·4	3·9	36·3	34·7	21·8	15·6	6	25·9	49·3	83·4	45·3	33·5	58·6	30·4	25	537·1
Jay	F.	2538	30·5	·6	13·3	10·8	5·2	3·9	1	7·5	11·5	18	8·4	9·8	16·7	10	5	152·2
Jackdaw	M.	3900	40·5	1·3	19	20	12·8	8·1	3	14·4	24·1	36·1	24·4	14·8	27·3	14·5	12·2	272·5
Common fowl......	F.	24851	57·4	1	121	195	97	51	11·4	77·6	101·2	100·8	60	156·8	217·6	115·3	74·8	1438·7
Woodcock	M.	4198	30·5	·3	19·4	23	22·5	5·3	4·1	16·2	39·9	32·4	20·5	20·2	25·6	11·1	9	280·1
Blackbird	M.	1668	10·4	·25	6·7	6·7	4·3	1·2	1	5·3	9·7	9	5·3	5·8	8·8	4·3	2·6	81·3
Skylark	M.	657	4·2	·1	2	2·8	2	1	·5	2·1	2·6	5·6	3·1	1·4	2·8	1·8	1·2	33·2
Woodlark	F.	493	3·6	·1	1·9	1·7	1·5	·8	·3	1·2	2·3	3·5	2·2	1	2	1·4	·7	24·2
Titlark	F.	368	2·6	·04	2·3	2·3	·8	·3	·2	1·28	1·86	2·2	1·4	·7	2	1·8	·5	20·2
Water-ouzel	...	873	6·3	·15	4·5	5·1	2·5	1·6	·6	2	4·2	4·2	2·4	2·2	5·1	3·4	1·8	46·9
Little sandpiper ...	...	629	4·2	·09	3	2·3	2·5	·8	·2	1·5	4·4	4·4	2·9	1·6	2·9	1·9	1·5	36·6
Yellow-hammer...	...	365	3·4	·08	1	1·5	1·3	·5	·1	1	2·6	2·4	1·6	1	1·5	·8	·4	19·9
Bullfinch	M.	367	3·8	...	1·3	1·1	·8	·3	·2	1·8	1·8	1·7	1·2	·66	1·2	·75	·24	15·8
Greenfinch	M.	388	6·7	...	1·3	1·5	1·4	·6	·2	1·6	2	2	1·4	·8	1·3	·6	·4	22
Sparrow	M.	421	7·05	·14	2	1·7	1·4	·9	·3	·45	2·4	2·1	1·3	1·2	1·9	·8	·3	25·4
Sparrow	F.	428	5·5	·13	1·6	1·5	1·2	·8	·3	1·4	2	1·7	1·1	1·06	1·8	·9	·3	21·3
Stone-chat	M.	347	3·2	·1	1·5	1·5	1·1	·7	·3	1·4	2·3	2·8	1·6	1·1	2·2	1·2	·4	21·4
Blackcap............	M.	273	2·3	·03	1·1	1·1	·6	·2	·1	·65	1	1·2	·7	·65	1·3	·68	·2	12·48
Blue tit	M.	273	2·3	·03	·7	·7	·4	·2	·04	·4	·6	·85	·5	·45	·7	·46	·2	8·93
Swift	F.	784·3	4·2	·20	3·3	3·7	3·4	1·2	·50	2·4	3·7	4·30	6·8	1·70	2·4	·9	·8	39·5
Swallow	F.	321·8	1·9	·06	1·3	1·3	1	·8	·24	1·2	2·1	2·4	2·2	·5	·7	·3	·1?	16·1
Martin	F.	301	1·9	·04	1·15	1·15	1	·7	·23	1·2	2	2·1	1·8	·48	·6	·3	·05	14·6
Sand-martin	F.	201·5	1·35	·02	·6	·3	·65	·3	·14	·7	1·2	1·5	1·2	·3	·5	·2	·04?	9·48

The results given in the preceding Table may justify the remark,—a conclusion that might be anticipated, that generally the comparative weight of the bones of each species of birds bears a relation to the power exercised by the limbs on parts to which they belong; of this striking examples are afforded in the instances of the upper and lower extremities of the buzzard and common fowl; of the one, the buzzard, a bird of powerful flight, the wing-bones are proportionally the heaviest; whilst of the other, the fowl, which makes so little use of its wings and so much use of its legs, the opposite is the case; and other contrasts not less striking are noticeable.

Also, as might be anticipated, and in accordance with what was before observed of the feathers, the primates of each wing, the weight of the bones of each was found to be nearly the same, the difference being no greater than might be expected from the mode of preparing them.

4th. *Of the Composition of some of the principal bones.*—This was ascertained by calcination, by which merely the proportion of animal or combustible matter was determined and that of the incombustible, chiefly phosphate of lime. I shall first give the results of the trials on humeri and femora: in each instance the shafts of these bones were selected; and previously to a thorough drying over steam, they were deprived of their investing membrane internally as well as externally. Though the quantities employed did not exceed a few grains, and were even less than a grain from some of the smaller birds, yet as the weighing was carefully made to the one hundredth of a grain, the results may be received as tolerably reliable for comparison.

	Humerus.		Femur.	
	Phosphate of lime.	Animal matter.	Phosphate of lime.	Animal matter.
	grs.	grs.	grs.	grs.
Buzzard	69·53	30·47	68·80	31·20
Owl	68·50	31·50	71·20	28·80
Rook	69·20	30·80	70·70	29·30
Jackdaw	70·30	29·70	71·30	28·70
Grouse	67·70	32·30	71·40	28·60
Common fowl (cock two years old	70·22	29·78	71·40	28·60
Pigeon	74·70	25·30	73·40	26·60
Skylark	77·00	23·00	72·00	28·00
Blackbird	71·60	28·40	76·20	23·40
Water-ouzel	71·10	28·80	71·90	28·10
Sparrow	70·70	29·30	72·50	27·50
Woodcock	72·80	27·20	73·23	26·77
Guillemot	70·10	29·90	67·60	32·40

If inferences may be drawn from these results, they seem to favour the conclusion, first, that the proportion of phosphate of lime is somewhat greater in the bones of birds, the cylindrical of the extremities, than in the like bones of the Mammalia; and secondly, that the composition of those containing air and of those containing marrow is much the same, which is not

in accordance with a statement that has been made, that the former have a larger proportion of earthy constituents *.

It may generally be stated, I believe, that the composition and structure of each particular bone has relation to its function,—that where unyielding resistance is required, there, *cæteris paribus,* the proportion of phosphate of lime is largest, as witnessed in the majority of the long bones of the extremities; that where yielding and elasticity are needed, the proportion of animal matter is somewhat more considerable, as seen in the sternum, cranium, ribs, and maxillæ.

Also it may be generally stated, I believe, that in different species of the same family or genus of birds, the composition of corresponding bones varies comparatively little; and that where there is a variation, it too is connected with use, irrespective of size. And the same remark, I am disposed to infer, would be near the truth relative to the proportional weight of the bones in different species. The following results are offered in illustration.

First, of the cranium. The portion subjected to calcination was that covering the cerebrum.

	grs.		grs.	
Buzzard.	60·7	phosphate of lime,	39·3	animal matter.
Carrion crow.	59·5	,,	40·5	,,
Rook.	60·1	,,	39·9	,,
Jackdaw	59·5	,,	40·5	,,
Magpie	60·0	,,	40·0	,,
Owl	57·4	,,	42·6	,,
Common fowl	60·0	,,	40·0	,,
Common duck	60·0	,,	40·0	,,
Woodcock.	58·2	,,	41·8	,,
Skylark.	63·0	,,	47·0	,,
Blue tit.	58·0	,,	42·0	,,
Water-ouzel	57·5	,,	42·5	,,
Godwit, bar-tailed . .	60·0	,,	40·0	,,
Dunlin	67·0	,,	33·0	..

Of the above, some of the crania were cellular, others were compact, sinking in water. The crania of the owl and water-ouzel, as already mentioned, are extreme examples, and yet their proportion of phosphate of lime and animal matter is much the same, both conditions of bone, the very cellular structure of the one, and the compact structure of the other without cells, being suitable to the habits of the individual,—in the owl, great strength with lightness; in the water-ouzel, strength with a comparatively high specific gravity.

The following is the composition of the sternum of a few of the same birds, illustrative of the quality of lightness coupled with a considerable degree of yieldingness, which in the moist bone is very observable. The

* *Op. cit.* p. 69.

perpendicularity of the crest or keel of this bone, I may remark, is very characteristic of the equality of action of the great pectoral muscles attached to it.

	grs.		grs.	
Buzzard..........	55	phosphate of lime,	45	animal matter.
Stork............	54	,,	46	,,
Carrion crow......	54	,,	46	,,
Jackdaw	55	,,	45	,,
Skylark..........	58	,,	42	,,

The composition of the maxillæ of a very few birds is given illustrative of the same quality. The lower jaw has been selected, and it has been divided, its anterior portion deprived of its horny integuments; its posterior, including its head, have been taken for the sake of comparison, the one being more elastic than the other.

		Phosphate of lime. grs.	Animal matter. grs.		Phosphate of lime. grs.	Animal matter. grs.
Buzzard.	Anterior portion	64·8	35·2	Posterior	67·0	43·0
Song-thrush.	,,	56·3	43·7	,,	59·1	40·9
Carrion crow.	,,	52·1	47·9	,,	56·8	43·2
Godwit ...	,,	64·8	35·2	,,	67·0	33·0*

Here I would beg to offer a few remarks more on the subject of the bones of birds. It is stated, and by so high an authority as Professor Wagner, that their hollow bones are whiter than those filled with marrow. Generally this is a fact, and for the reason that, being translucent, the latter owe their colour to the marrow within them. Accordingly their colour varies with the colour of the marrow. Thus in some in which the marrow is of a light hue, almost white, as in the instance of the tawny owl, its ulnæ and radii are so white as to suggest their containing air. In another (the yellow-hammer), in which the marrow is of a bright yellow, as is also the fat, the long bones have the same hue. The same hue is seen in the bones of the cuckoo, and from the same cause, and also, but in a less degree, in those of the greenfinch. Nor are there wanting examples of a dark colour of the bones, from a dark colour of the marrow: those of the little sandpiper may be mentioned as an instance. Generally it may be remarked that the femora are darker than the humeri; and that the lower portion of the tibiæ is very much lighter than their upper, corresponding to the colour of the marrow in each. Another circumstance influencing the colour of the bones of birds is the degree of thickness of their walls. The thicker

* The bone of the under bill of the godwit, like that of the majority of the long-billed birds, is very slender and remarkably elastic, especially its anterior portion, that which is covered with integuments and a hard horny cuticle; the same portion is cellular and very vascular, suitable for renewing the growth of the beak as it is wasted in use, a remark more or less applicable to the beak of birds generally.

they are, the less translucent they are, and consequently the lighter is the colour, being less affected thereby by that of their contents. The long bones of the common guillemot, and also of the corn-crake, the parietes of which, especially of the wing-bones, are more than ordinarily thick, may be mentioned as illustrative examples.

In a preceding part of this paper I have referred to the size of some of the more important organs of birds. In many instances I have ascertained their weights. As examples, those of five different species are selected, and I give them without comment.

1. Tawny owl. Weight 5776 grs. April 7.	grs.
Brains, its membranes detached	139
Eye freed from muscle and fat	91
Lens (·58 inch diameter)	19·6
Skin freed from most of its fat	250
Membranous stomach	115
Liver without gall-bladder	154·7
Spleen	4·6
Pancreas	9·5
Kidneys	57·7
One lung, it contained a little coagulated blood	13·2
Heart freed from fat	39
Testes (no spermatozoa could be detected in them)	2·5
Great pectoral muscles	634
Other muscles of chest, those attached to furcula and scapular arch, exterior of costal	198
Muscles of humeri	188
Muscles of ulnæ and radii	156
Muscles of femora	272
Muscles of tibiæ	346
2. Rook. Weight 6556 grs. April 19.	
Brain freed from its membranes	118·6
Eye formed from muscle and fat*	41
Skin, exclusive of that of tarsi and phalanges, or very little fat adhering	344
Gizzard	208
Liver, gall-bladder detached	167
Spleen	2·8
Pancreas	23·2
Kidneys	72·6

* Of another male rook, shot April 29, and examined whilst still warm, the eye weighed 37·6 grs., the lens 1·2 gr.; it was very soft; evaporated to dryness it lost ·75 gr., or 62·5 per cent. of water. The lens of the rook, of that of which the weight of the organs is given above, was almost as liquid as the vitreous humour.

	grs.
One lung; it contained a very little clot	46
The other; it contained a little more *	49
Heart freed from fat	77
Testis, spermatozoa were abundant in its ducts	67
Glandula uropygii †	10·7
Great pectoral muscles	960
Muscles attached to scapular arch and bones of wings	493
Ditto, of lower extremities	680

3. Common fowl, a hen. Weight 24,851 grs.

Brain	53
Eye	30
One lung	53
The other; it contained a little clot	60
Gizzard	466
Spleen	27
Pancreas	36
Kidneys	181

4. Swallow, female. Weight 321·8 grs. May 5.

Brain	8
Heart	4·6
Liver	17·8
One lung	1·7
Stomach	8
Pancreas	·3
Spleen	·5
Kidneys	6·6
Great pectoral muscles	75

5. Cuckoo. Weight 2091 grs. May 3rd.

Brain	26·3
Eye	29
Lens	2·3
Liver	34·7
Spleen	·7
Pancreas	1·6
Kidneys	18
Stomach	33·2
Testis	1·3

* By steeping in water and expressing the blood the first was reduced to 32·7 grs., the second to 26·2 grs.

† The whitish semifluid expressed from it consisted of very minute oil-globules, and of the casts of the secreting tubes.