170. STUDIES OF CALCIUM AND PHOSPHORUS METABOLISM IN RELATION TO THE CHEMICAL STRUCTURE OF BONE

2. EXPERIMENTS WITH MOULTING BIRDS

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In a previous paper, Tyler [1940] has shown that there is a reciprocal relationship between changes in the Ca of the $\text{Ca}_3(\text{PO}_4)_2$ of bone (designated Ca_P) and changes in the residual Ca of bone (designated Ca_R) for laying birds, and also that it is the Ca_R which is chiefly concerned with the fluctuations of bone Ca during laying. In the experiments from which these results were obtained two other birds moulted and it is now proposed to discuss the bone changes for these two birds. The experiments were described in the preceding paper and it is only necessary to add that the bird C1 received calcium carbonate as the calcium supplement and that the bird G1 received calcium gluconate.

Results

Table 1 gives the relevant data regarding the two birds. The balance data for the 4 days when G1 was laying are not truly representative, for no figures were available for one day out of the 4 and therefore they will not be considered

Table 1.

Length of period days	Bird	No. of eggs laid	% Ca in food	% P in food	Ca : P of food	Ca balance over period	P balance over period	Ca : P of balance
10	C1	4	1.68	0.40	4.20	-1.09	0.37	—
25	C1	Moult	1.68	0.40	4.20	-8.99	-0.37	24.29
4	G1	2	1.65	0.32	5.16	-0.88	0.45	—
31	G1	Moult	1.65	0.32	5.16	6.19	-0.51	—

in that form; however, the daily figures have some value and these will be considered. As in the case of the laying birds, the Ca : P ratios of the total Ca and P balances do not approach 2.2 : 1, which is the value for normal bone, and in fact in the case of C1 in lay and of G1 in moult a positive value of one corresponds to a negative value of the other. This being the case, the chemical composition of the bone must be changing and calculations of Ca_P and Ca_R were therefore made to find out whether these values give any clue as to bone changes. The methods of calculation and a justification of such a calculation are given in the previous paper. It was there pointed out that such a calculation was not valid if the bird was losing or gaining considerably in weight, for this reason it has only been possible to calculate values for the very short laying periods for each bird and for the moulting period of bird G1. The bird C1 lost too much weight during the moult (355 g.) for the calculation to be of value.

Table 2. *Bird C1, 10 days in lay; Ca_P and Ca_R lost or gained by bone, the retention of Ca (Ca_A) and egg shell Ca (Ca_S) (g.)*

Day	Laying days				Non-laying days		
	Ca_P	Ca_R	Ca_A	Ca_S	Ca_P	Ca_R	Ca_A
1	—	—	—	—	+0.00	+0.20	+0.20
2	—	—	—	—	+0.46	+0.07	+0.53
3	—	—	—	—	+0.23	+0.53	+0.76
4	+0.42	-1.51	+0.46	1.52	—	—	—
5	—	—	—	—	-0.35	+1.04	+0.69
6	+0.37	-1.19	+0.82	1.59	—	—	—
7	—	—	—	—	-0.58	+1.02	+0.44
8	+0.41	-1.17	+0.98	1.89	—	—	—
9	—	—	—	—	-0.46	+0.52	+0.06
10	+0.19	-1.29	+0.71	1.76	—	—	—
Sum	+1.39	-5.16	+2.97	6.56	-0.70	+3.38	+2.68
Mean	+0.35	-1.29	+0.74	1.64	-0.12	+0.56	+0.45

Table 3. *Bird G1, 4 days in lay; Ca_P and Ca_R lost or gained by bone, the retention of Ca (Ca_A) and egg shell Ca (Ca_S) (g.)*

Days	Laying days				Non-laying days		
	Ca_P	Ca_R	Ca_A	Ca_S	Ca_P	Ca_R	Ca_A
1	+0.33	-1.25	+1.02	1.89	—	—	—
2	—	—	—	—	+0.54	+0.34	+0.88
3	—	—	—	—	Omitted because of incomplete data		
4	-0.02	-0.82	+1.05	1.84			
Sum	+0.31	-2.07	+2.07	3.73	—	—	—
Mean	+0.16	-1.04	+1.04	1.87	—	—	—

Table 4. *Bird G1, 31 days in moult; Ca_P and Ca_R lost or gained by bone, and the retention of Ca (Ca_A) (g.)*

Days	Ca_P	Ca_R	Ca_A	Days	Ca_P	Ca_R	Ca_A
1	+0.25	+0.30	+0.55	16	-0.19	+0.60	+0.41
2	+0.48	-0.23	+0.25	17	+0.12	+0.37	+0.49
3	-0.10	+0.54	+0.44	18	+0.19	-0.27	-0.08
4	-0.27	+0.47	+0.20	19	+0.14	+0.24	+0.38
5	+0.08	+0.33	+0.41	20	-0.02	+0.51	+0.49
6	-0.35	+0.34	-0.01	21	+0.02	+0.47	+0.49
7	-0.23	+0.46	+0.23	22	+0.06	+0.24	+0.30
8	-0.37	+0.16	-0.21	23	-0.17	+0.37	+0.20
9	-0.37	+0.18	-0.19	24	0.00	+0.26	+0.26
10	-0.12	+0.05	-0.07	25	+0.15	+0.31	+0.46
11	-0.08	+0.22	+0.14	26	-0.04	-0.38	-0.42
12	-0.14	+0.36	+0.22	27	+0.02	-0.06	-0.04
13	-0.29	+0.35	+0.06	28	+0.29	-0.09	+0.20
14	-0.19	+0.21	+0.02	29	0.00	+0.55	+0.55
15	-0.14	+0.21	+0.07	30	+0.04	+0.06	+0.10
				31	+0.29	0.00	+0.29
				Sum	-0.94	+7.13	+6.19
				Mean	-0.03	+0.23	+0.20

The first day of the moult corresponds to the 5th day of full period.

Tables 2 and 3 give the values obtained during lay and Table 4 those obtained during the moult.

Considering first the few laying days of the birds it will be seen that the changes in Ca_P were small compared with those for Ca_R . The limitation of the total loss of Ca from the bone to a maximum value of about 1 g. is clearly seen

on all 4 days in the case of bird C1 and on the one day it was necessary in the case of G1; in each instance a large loss of Ca_R was partly counteracted by a gain of Ca_P . With regard to non-laying days C1 shows fairly small changes of Ca_P , some negative and some positive, but the large gains of Ca_R are only noticeable on 2 days of the period. The bird G1 had only one non-laying day but on that day there was not the usual relatively large gain of Ca_R . However, the findings for birds laying immediately before a moult are in general agreement with the findings for normal laying birds already described in the previous paper, namely, relatively large gains of Ca_R on non-laying days and relatively large losses on laying days with relatively small fluctuations of Ca_P , some being negative and some positive.

Turning to the moulting period for the bird G1 (Table 4) the same daily fluctuations in Ca_P are to be noted as for laying birds, with a loss as the final result; there were, on the other hand, almost consistent gains of Ca_R over the whole period of the moult which resulted in the bird storing 7.13 g. Ca as Ca_R

Fig. 1. Regression line of Ca_R on Ca_P for the moulting bird G1. AB represents the calcium equilibrium line. To the N.E. is a total calcium gain; to the S.W. is a total calcium loss.

over the 31 days. On calculating the correlation coefficient for Ca_P and Ca_R changes during the moult a value of $r = -0.4309$ for 31 pairs of readings was found; this negative value is highly significant. The regression line representing the regression of Ca_R on Ca_P within the limits of the experimental values of Ca_R is shown in Fig. 1.

Discussion

From the results obtained it appears that the changes in Ca_P and Ca_R which take place in a laying bird just before moulting tend to be of a similar nature to the changes taking place in a bird in full lay but the correlation coefficient for Ca_P and Ca_R is not significant. The paucity of readings must however not be overlooked. In the case of the moulting bird G1 the changes in Ca_P and Ca_R were similar, but not as great in magnitude as those taking place in laying birds on non-laying days. A reciprocal relationship did hold between Ca_P and Ca_R for this moulting bird and a study of the regression line shows it to be similar to the ones obtained for laying birds on non-laying days [Tyler, 1940], except that it crosses the "balance" line within the region studied and not at some theoretical point beyond the range of experimental values.

Thus the Ca_P and Ca_R relationships already noted for four laying birds hold good for one moulting bird also. These relationships are such that a bird can show concomitant gains or losses of Ca_P and Ca_R or gains of one with losses of the other, and this makes it possible for the bones of a bird under differing conditions to show gains or losses of both total Ca and total P or gains of total Ca with a loss of total P or *vice versa*. By such means a bird is more able to accommodate itself to the calls made upon its bones than if concomitant gains or losses of Ca and P were alone possible.

SUMMARY

The changes in the Ca of the $\text{Ca}_3(\text{PO}_4)_2$ of bone and the residual Ca of bone of two birds laying just prior to moulting and of one of the birds in moult are discussed. It is shown that these changes are substantially similar to the changes taking place in birds in full lay.

The reciprocal relationship between the changes of Ca_P and Ca_R which was shown to exist for four laying birds in a previous paper is found for one moulting bird.

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REFERENCE

Tyler (1940). *Biochem. J.* **34**, 202.