Severe undernutrition in growing and adult animals

16*. The ultimate results of rehabilitation: poultry

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1. Rhode Island Red and Light Sussex poultry attained their full size in about 6 months. 2. When they were held back by undernutrition so that they weighed only about 170 g at 6 months of age and were then given unlimited food, they grew—like the normal birds—for about 6 months, i.e. till they were 1 year old, but still they did not attain the same stature as normal birds. 3. The pullets more nearly attained the size of their controls than did the cockerels. 4. On rehabilitation after the period of undernutrition poultry frequently suffered leg weakness which in its extreme form could be diagnosed as perosis. 5. Rehabilitated pullets began to lay large eggs after a comparatively short period of growth and when they were still a small size.

Earlier papers in this series (McCance, 1960; Pratt & McCance, 1961) have dealt with the effects of undernutrition on the physical and anatomical development of cockerels and the extent to which restoration to full feeding can bring about recovery. The present study has extended the earlier findings to cover the growth of both sexes during rehabilitation and the sexual performance of pullets.

EXPERIMENTAL

Most of the birds used have been of the Rhode Island Red breed, but in the more recent work Light Sussex birds have been studied. The birds which were being undernourished received constant illumination from infrared heaters, but the rehabilitating and control birds were reared under conditions of natural light. The experimental poultry were undernourished (see McCance, 1960) until they were 6 months old, and generally weighed, at that time, 140–170 g. The normal animals used for controls were either brood mates or, for some purposes, day-old chicks of the same breed obtained from the same hatchery 6 months later. After the 6 months of undernutrition the birds were allowed free access to food, and they were kept until the body-weight had remained approximately the same for some time. Some birds died when they were being undernourished, others were killed for investigation as undernourished birds and occasional deaths occurred during the period of rehabilitation. Only the birds which survived the entire experiments are included in the results. In the experimental groups described as lots (*a*), (*b*) and (*c*), a total of sixteen undernourished and seventeen control birds were involved. Lots (*a*) and (*b*) were Rhode Island Reds and lot (*c*) Light Sussex birds, each lot comprising a rehabilitated and a

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control group. The control and rehabilitated group in lot (*a*) were hatched in July and February respectively and began to lay in December and November. Both groups in lot (*b*) were hatched in January. The control birds started to lay in June, and the rehabilitated pullets began to lay in the following October. The two groups making up lot (*c*) were hatched in August; the well-nourished birds came into lay in January, and the rehabilitated ones in the following June. At slaughter the femurs were removed from all the birds and measurements were taken of their overall length and of their thickness in an antero-posterior direction at the nutrient foramen. All the measurements were made with a vernier gauge reading to 0·1 mm. Records were kept of the weights of the pullets when their first eggs were laid and the weight and number of eggs laid in the first 8 weeks of the laying period.

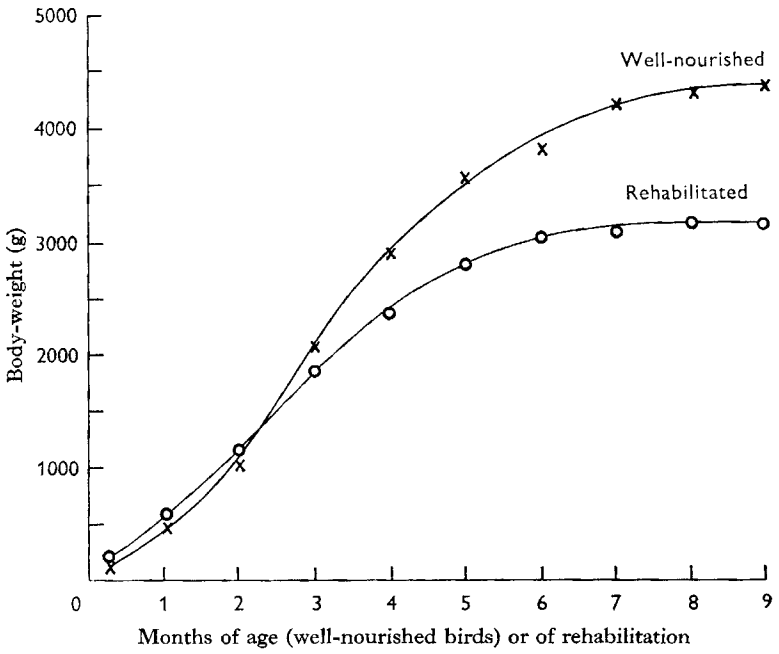

Fig. 1. Increase in body-weight of normal Light Sussex cockerels (×—×) and of birds of the same breed being rehabilitated after 6 months undernutrition (○—○).

RESULTS

Growth and stature

Fig. 1 shows the weight curve of six normal Light Sussex cockerels, and also, superimposed upon it, the weight curve of five brood mates being rehabilitated after 6 months undernutrition. The curve for the Rhode Island Red cockerels has been published previously (McCance, 1963). The day-old Light Sussex averaged 50 g in weight and the birds which had been undernourished averaged 146 g in weight at 6 months of age. The normal cockerels grew most rapidly during the first 3 months. The rehabilitating birds sometimes increased in weight even more rapidly than the

normal birds had done after this period. The normal birds completed their growth in about 6 months, i.e. in the time for which the experimental birds had been undernourished. On rehabilitation the latter proceeded to grow for a little less than 6 months, by which time they were almost 1 year old. After a prolonged period of undernutrition in early life, therefore, cockerels were able to grow for almost the length of time normal birds required to attain their full genetic size—although they were twice as old. They did not, however, attain their full genetic stature, measured by length of femur (Table 1) or body-weight. These results confirm those of Pratt & McCance (1961).

Table 1. *Body-weights and femur lengths and thicknesses of rehabilitated and control Rhode Island Red poultry. Mean values for six rehabilitated and six control cockerels and for nine rehabilitated and five control pullets*

	Males		Females	
	Control	Rehabilitated	Control	Rehabilitated
Body-weight (kg)	3·67	2·89**	2·64	2·42*
Femur: length (cm)	11·18	9·95**	9·30	8·92^{ns}
thickness (cm)	0·95	0·91^{ns}	0·95	0·91^{ns}

ns, not significant.
* $P < 0{\cdot}05$. ** $P < 0{\cdot}01$.

The upper portions of Fig. 2*a*, *b* and *c* show the increase in body-weight of well-nourished and rehabilitated Rhode Island Red and Light Sussex pullets. The pullets' growth curves were similar in shape and duration to the cockerels', but the rehabilitated pullets almost attained the mature weight of their controls. Table 1 deals with this statistically and shows that the full stature of the rehabilitated birds as measured by femur length, was not significantly different from that of the control group. This behaviour of the two sexes on rehabilitation confirms in another species the results obtained by Lister (1965) with guinea-pigs.

It was mentioned by McCance (1960) that rehabilitating birds succumbed to varying degrees of leg weakness, suggestive of perosis or slipped tendon. Of all the rehabilitated birds, 25% suffered from this lesion, and sometimes half of those being rehabilitated in any one experiment went down with it. True perosis, however, has been confirmed only in one bird and the animals could not be protected by manganese and choline supplements. The lesion is probably due to a failure of the muscles to recover their tone in time to support the rapidly increasing weight of the birds. This is not uncommon in rapidly growing birds (L. G. Chubb, personal communication).

Sexual maturity and egg production

Fig. 2*a* and *b* and Table 2 give some information on the egg-laying performances of rehabilitated and normal Rhode Island Red pullets. The attainment of sexual maturity is usually taken as the time when 50% lay is achieved (Giesbrecht & Nordskog, 1963). Although the experimental groups were small there was little variation within them and they have been considered in the same way in demonstrating the effects of age, body-weight and season of the year on this index of sexual maturity in Fig. 2.

The normal Rhode Island Reds became sexually mature from the 24th to the 28th week of age and Light Sussex (Fig. 2*c*) about the 24th week. All three groups of rehabilitated birds were sexually mature by the 45th or 46th week of their lives, but during 26 weeks of this time the pullets were being undernourished.

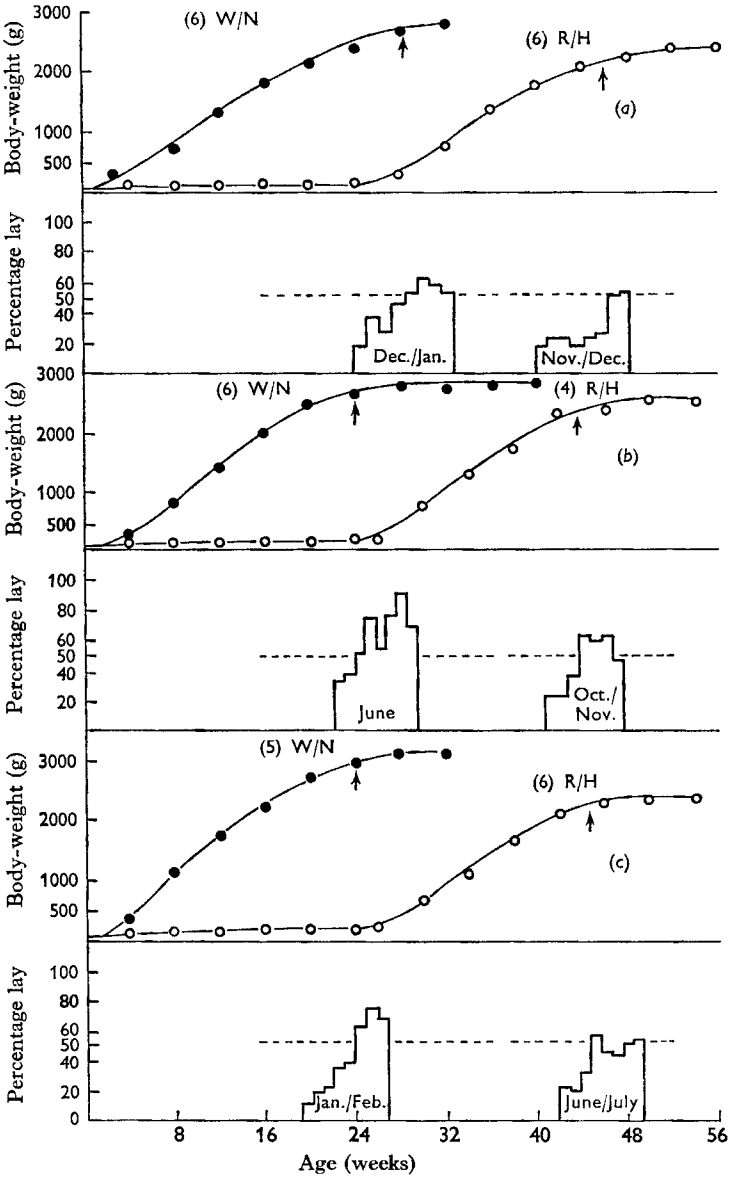

Fig. 2. Growth curves and egg-laying performances of normal (●—●) and rehabilitated (○—○) pullets. The numbers of birds in each group are given in parentheses. (*a*), Rhode Island Red birds: experimental (R/H) group hatched in February, control (W/N) group hatched in July; (*b*) Rhode Island Red birds: experimental (R/H) and control (W/N) groups hatched in January; (*c*), Light Sussex birds: experimental (R/H) and control (W/N) groups hatched in August. ↑ Indicates age and body-weight at which sexual maturity (50% lay, shown by dotted lines) was attained.

The normal Rhode Island Reds weighed 2600–2700 g at 50% lay, but those being rehabilitated weighed only 2250–2300 g at the same stage. Normal Light Sussex pullets weighed 2900 g at 50% lay, whereas the rehabilitated birds were sexually mature at about 2200 g body-weight. With the numbers available and as these experiments were carried out, it is not possible to say anything quantitative about the extent to which the season of the year and the length of the day (Morris & Fox, 1960) may have modified the results attributable to nutrition. The season, however, may have affected the total number of eggs produced in the first 60 days of lay. These results are shown in Table 2 and also that the eggs of the rehabilitated pullets always weighed more than those of the well-nourished ones in spite of the fact that their body-weights were considerably less.

Table 2. *Egg production during the first 60 days of the laying period of well-nourished and rehabilitated pullets*

(Results for the same birds as in Fig. 2)

		Mean egg weight (g)		Total no. eggs/bird in 60 days	
Lot	Period of lay (days)	Well-nourished	Rehabilitated	Well-nourished	Rehabilitated
a	0–10	46·0	55·3	—	—
	11–20	49·3	57·4	—	—
	21–30	52·4	56·0	26·8	19·0
	31–40	54·2	52·0	—	—
	41–50	53·5	56·1	—	—
	51–60	53·5	58·3	—	—
b	0–10	45·2	55·0	—	—
	11–20	48·5	56·9	—	—
	21–30	49·6	56·8	35·7	25·0
	31–40	51·7	58·4	—	—
	41–50	52·0	59·7	—	—
	51–60	54·4	57·8	—	—
c	0–10	42·7	52·0	—	—
	11–20	44·6	54·7	—	—
	21–30	48·4	54·0	25·2	25·2
	31–40	49·3	52·8	—	—
	41–50	50·6	51·8	—	—
	51–60	52·1	53·1	—	—

In other words, sexual maturity was delayed in terms of chronological age by undernutrition yet it was precocious in terms of bodily size on rehabilitation, which confirms the results Dickerson, Gresham & McCance (1964) obtained after undernutrition in pigs and Widdowson, Mavor & McCance (1964) in rats. Something of the same sort, but in a quite different setting, has been recorded before in poultry (Deaton & Quisenberry, 1963).

DISCUSSION

There is no doubt that a lifetime of undernutrition or of unsatisfactory nutrition delays the rate of growth in all animals and in some species—rats, guinea-pigs and probably pigs—reduces the size of the adults (Berg, 1960; Widdowson & McCance,

1963; Lister & McCance, 1965). It is known also that periods of undernutrition are more deleterious to the growth of male rats, human beings and guinea-pigs than to females of the same species and that their recovery is less complete (Slonaker & Card, 1923; Greulich, 1951; Tanner, 1962; Lister, 1965). The results presented here show that the same is true for another species.

In undernutrition the normal reproductive cycle is to some extent suppressed. Kennedy & Mitra (1963) showed that chronic underfeeding prevented normal oestrous cycles in rats, but allowed follicular growth, and this led to the development of follicular cysts. In small undernourished female pigs, Dickerson *et al.* (1964) found evidence of follicular growth, but no oestrous cycles were observed (McCance, 1960) and ovulation was apparently prevented by an insufficiency of luteinizing hormone.

Sexual maturity was attained by the rehabilitated pullets at lower body-weights than by normal birds, and the same is true for pigs, although the relative differences in weight were not so large (Dickerson *et al.* 1964; Lister, 1965). Both these findings are in agreement with those of Allen & Lamming (1961) who reported that puberty occurred later in time but at a significantly lower live weight in lambs fed on a moderate plane than in those reared on a high plane of nutrition.

It has been noted (Barnett & Coleman, 1959; Widdowson & McCance, 1960) that when the growth of animals was restricted by cold or a short period of undernutrition during suckling puberty was reached when the body-weight of the restricted animals was similar to that at which puberty occurred in control animals. Kennedy & Mitra (1963), however, pointed out that whilst weight was a much more important determinant of the onset of reproduction in rats than age, the variability of their results indicated that other factors were probably concerned. One or more of these is apparently involved in controlling the attainment of sexual maturity in animals which have been severely undernourished for a longer time than that taken by normal animals to reach puberty. In poultry precocious sexual maturity often results in the production of small eggs (Morris & Fox, 1960), but in the present experiments the period of time between the start of rehabilitation and the attainment of puberty was very much shorter than the time which the control birds took from hatching to laying, yet the eggs of the rehabilitated birds were considerably larger. It would appear, therefore, that with the rehabilitated birds, the size of the eggs was related more to the age of the birds than to their bodily weights or to the time allowed for growth to take place.

REFERENCES

Allen, D. M. & Lamming, G. E. (1961). *J. agric. Sci., Camb.* **57**, 87.
Barnett, S. A. & Coleman, E. M. (1959). *J. Endocr.* **19**, 232.
Berg, B. N. (1960). *J. Nutr.* **71**, 242.
Deaton, J. W. & Quisenberry, J. H. (1963). *Poult. Sci.* **42**, 608.
Dickerson, J. W. T., Gresham, G. A. & McCance, R. A. (1964). *J. Endocr.* **29**, 111.
Giesbrecht, F. G. & Nordskog, A. W. (1963). *Poult. Sci.* **42**, 83.
Greulich, W. W. (1951). *Am. J. Phys. Anthrop.* NS **9**, 55.
Kennedy, G. C. & Mitra, J. (1963). *J. Physiol., Lond.* **166**, 408.
Lister, D. (1965). The effect of nutrition before and after birth on adult size and structure. PhD Thesis, University of Cambridge.
Lister, D. & McCance, R. A. (1965). *Br. J. Nutr.* **19**, 311.
McCance, R. A. (1960). *Br. J. Nutr.* **14**, 59.

McCance, R. A. (1963). *Proc. int. Nutr. Cong.* VI. *Edinburgh*, p. 74.
Morris, T. R. & Fox, S. (1960). *Br. Poult. Sci.* **1**, 25.
Pratt, C. W. M. & McCance, R. A. (1961). *Br. J. Nutr.* **15**, 121.
Slonaker, J. R. & Card, T. A. (1923). *Am. J. Physiol.* **63**, 503.
Tanner, J. M. (1962). *Growth at Adolescence*, 2nd ed. Oxford: Blackwell.
Widdowson, E. M. & McCance, R. A. (1960). *Proc. roy. Soc.* B **152**, 188.
Widdowson, E. M. & McCance, R. A. (1963). *Proc. roy. Soc.* B **158**, 329.
Widdowson, E. M., Mavor, W. O. & McCance, R. A. (1964). *J. Endocr.* **29**, 119.

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