

Since, as we have shown, quite high reflex activity is often observed beginning a few hours after combined transection and asphyxiation of the cord, there can hardly be any doubt that asphyxia can curtail spinal shock. This return of reflex activity of the isolated and asphyxiated caudal part of the cord as described above is a strong support for the conception of spinal shock as a dominance of an inhibiting structure in the spinal cord itself.

It must be assumed that the reflex activity of the normal animal depends on a continuous depressing influence of the higher centers on the inhibitory mechanism in the spinal cord. The spinal shock following transection of the cord must be considered as a release of that spinal inhibitory mechanism from this depressing higher control, resulting in a diminution and eventual abolition of reflex excitability.

Acknowledgment is gratefully made for assistance from the Neurological Fund of the California Institute of Technology.

<sup>1</sup> van Harreveld, A., and G. Marmont, *Jour. Neurophysiol.*, **2**, 101-111 (1939).

<sup>2</sup> Hinsey, J. C., and J. E. Markee, *Jour. Comp. Neurol.*, **69**, 471-485 (1939).

<sup>3</sup> Fulton, J. F., and C. S. Sherrington, *Jour. Physiol.*, **75**, 17-22 (1932).

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## PHYSIOLOGY OF DEVELOPMENT OF THE FEATHER. IV. THE DIURNAL CURVE OF GROWTH IN BROWN LEGHORN FOWL

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### I. INTRODUCTION

Evidences of daily periodicity of functions in fowl are abundant; in this paper we add to them a series of measurements demonstrating that the rate of growth of regenerating feathers is not constant during a 24-hour period, but exhibits considerable fluctuations characterized especially by a very low rate during part of the night. The physiological causes and the morphological consequences of this phenomenon will be discussed after presentation of the data.

Rates of growth during the entire period of regeneration of feathers have been determined several times (cf. Juhn and Gustavson, '30; Juhn, Faulkner and Gustavson, '31; and Lillie, '40). In all these cases the measurements were not less than 24 hours apart; but an analysis of the diurnal distribution of 24-hour increments has not hitherto been attempted.

Owing to limitations of the methods of measuring, it was decided that intervals of less than six hours would be impractical. Accordingly, a first

series of measurements of the growth in six-hour intervals in a continuous 24-hour period was made from the base of twelve o'clock. This series was then repeated at a later date. These measurements showed a very marked decline in growth-rate in the period from midnight to six A. M. The measurements did not, however, necessarily determine very closely the time of lowest or highest rates. Accordingly, two other sets of six-hour increments were prepared using nine o'clock as base. Comparison of the results from the twelve o'clock base and the nine o'clock base enables a closer estimation of the time of minimum growth in a 24-hour period.

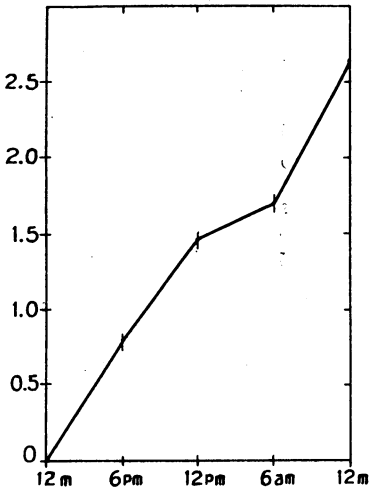


FIGURE 1

Breast feathers. From data of table 1. The grand average of six-hour increments of the three birds plotted. Based on 12:00 o'clock. Ordinates = millimeters of growth; abscissae = time of day.

each period; the grand average of these increments is plotted in figure 1.

These measurements were then repeated on the same feathers on the 28th day of regeneration (table 2), and similarly averaged. The first and second sets of measurements did not differ significantly.

Determinations of six-hour increments in the growth of saddle feathers (posterior region) were made on the same birds in an exactly similar manner on the 25th day of regeneration (April 18-19, 1939) and again on the 28th day of regeneration (tables 3 and 4). As in the case of the breast, ten feathers identified by number, with individual records for each feather, were used in each bird. Both sets of determinations agreed very closely.

## II. THE DATA

1. *Six-Hour Increments Based on Twelve O'Clock.*—Ten actively regenerating feathers of the same age in a small area of the breast of each of three Brown Leghorn capons were isolated by removing adjacent feathers; each feather was identified by number and individual records were kept. On the 25th day of regeneration (March 18-19, 1939) measurements were made of the length of each feather at six-hour intervals beginning at noon and terminating at noon of the next day. The increment in length of each feather during each six-hour period was determined from these measurements (table 1). The increments of the individual feathers, 12:00 noon to 6:00 P. M., 6:00 P. M. to 12:00 midnight, 12:00 midnight to 6:00 A. M., 6:00 A. M. to 12:00 noon, were then averaged for

TABLE 1<sup>1</sup>

TWELVE O'CLOCK BASIS. MARCH 18-19, 1939. BREAST FEATHERS BROWN LEGHORN CAPONS. TWENTY-FIFTH DAY OF REGENERATION

		1 12 NOON	2 6 P. M.	INC.	3 12 P. M.	INC.	4 6 A. M.	INC.	5 12 NOON	INC.
<b>Capon</b>	1	37.9	38.2	0.3	39.7	1.5	39.7	0.0	40.0	0.3
148	2	37.8	37.9	0.1	38.9	1.0	39.2	0.3	39.6*	0.4
	3	36.5	37.1	0.6	37.1	0.0	37.8	0.7	39.2	1.4
	4	34.7	36.0	1.3	36.1	0.1	36.1	0.0	36.9	0.8
	5	35.1	35.6	0.5	36.5	0.9	37.6	1.1	37.7	0.1
	6	35.0	35.6	0.6	36.5	0.9	36.8	0.3	37.6	0.8
	7	36.7	37.2	0.5	38.6	1.4	39.2	0.6	39.8	0.6
	8	36.6	36.5	-0.1*	37.0	0.5	37.5	0.5	38.8	1.3
	9	35.6	36.1	0.5	36.9	0.8	37.3	0.4	38.4	1.1
	10	35.5	36.1	0.6	37.0	0.9	37.1	0.1	38.4	1.3
	<b>Average</b>	36.14	36.63	0.49	37.43	0.8	37.83	0.40	38.64	0.81
	<b>Total increase in 24 hours:</b>	2.50								
<b>Capon</b>	1	27.7	29.1	1.4	29.2	0.1	29.7	0.5	31.1	1.4
171	2	29.2	29.5	0.3	30.5	1.0	31.2	0.7	33.0	1.8
	3	25.3	26.3	1.0	26.6	0.3	26.6	0.0	28.3	1.7
	4	26.5	27.0	0.5	27.6	0.6	27.9	0.3	29.6	1.7
	5	33.7	34.3	0.6	34.6	0.3	34.6	0.0	36.4	1.8
	6	30.1	31.2	1.1	31.9	0.7	32.0	0.1	32.5	0.5
	7	30.5	31.8	1.3	32.5	0.7	32.6	0.1	33.4	0.8
	8	30.1	30.6	0.5	31.5	0.9	31.5	0.0	32.6	1.1
	9	29.6	30.2	0.6	31.0	0.8	31.4	0.4	32.2	0.8
	10	29.6	30.8	1.2	31.3	0.5	31.5	0.2	32.2	0.7
	<b>Average</b>	29.23	30.08	0.85	30.67	0.59	30.9	0.23	32.13	1.23
	<b>Total increase in 24 hours:</b>	2.90								
<b>Capon</b>	1	34.6	36.6	2.0	37.1	0.5	37.1	0.0	36.9	-0.2*
139	2	33.6	34.8	1.2	36.2	1.4	36.2	0.0	36.9	0.7
	3	29.2	29.3	0.1	29.9	0.6	29.9	0.0	31.5	1.6
	4	34.1	34.9	0.8	35.5	0.6	35.5	0.0	36.9	1.4
	5	32.4	34.4	2.0	34.6	0.2	34.7	0.1	35.4	0.7
	6	33.2	34.8	1.6	35.0	0.2	35.1	0.1	36.3	1.2
	7	31.5	32.3	0.8	32.3	0.0	32.5	0.2	33.2	0.7
	8	33.6	35.0	1.4	35.3	0.3	35.6	0.3	36.5	0.9
	9	29.6	29.6	0.0	31.4	1.8	31.4	0.0	31.5	0.1
	10	26.5	27.2	0.7	27.6	0.4	27.9	0.3	28.6	0.7
	<b>Average</b>	31.83	32.89	1.06	34.49	0.60	33.59	0.10	34.37	0.78
	<b>Total increase in 24 hours:</b>	2.54								
<b>GRAND</b>	<b>AVERAGE</b>	32.40	33.20	0.80	33.86	0.66	34.10	0.24	35.04	0.94
	<b>AVERAGE TOTAL INCREASE IN 24 HOURS:</b>	2.64								

\* Probably due to error.

<sup>1</sup> Tables 1 to 8 give all the original measurements for determination of six-hour increments throughout one day, on which the paper is based, together with the averages for

each bird and the averages of all three together. Columns 1, 2, 3, 4, 5 give the actual measurements in millimeters for the individual feathers. The intervening columns give the increments (Inc.) for the six-hour periods ended in the preceding column. The last horizontal line (grand average) gives the averages of all feathers for each column; the increments in this line are the ones used in the graphs.

TABLE 2

TWELVE O'CLOCK BASIS. SECOND SERIES OF MEASUREMENTS OF THE SAME FEATHERS AS IN TABLE 1. TWENTY-EIGHTH DAY OF REGENERATION

		1 12 NOON	2 6 P. M.	INC.	3 12 P. M.	INC.	4 6 A. M.	INC.	5 12 NOON	INC.
Capon 148	1	47.6	48.0	0.4	49.0	1.0	49.0	0.0	50.7	1.7
	2	47.8	48.5	0.7	48.9	0.4	49.1	0.2	50.4	1.3
	3	46.0	46.6	0.6	47.6	1.0	48.3	0.7	49.0	0.7
	4	45.2	45.6	0.4	46.8	1.2	47.2	0.4	48.2	1.0
	5	44.4	45.2	0.8	46.0	0.8	46.4	0.4	47.4	1.0
	6	44.4	45.2	0.8	46.2	1.0	46.4	0.2	47.3	0.9
	7	46.9	48.0	1.1	48.7	0.7	49.1	0.4	49.5	0.4
	8	45.9	46.8	0.9	47.0	0.2	47.5	0.5	48.4	0.9
	9	45.5	46.4	0.9	46.7	0.3	46.7	0.0	47.8	1.1
	10	45.9	46.7	0.8	47.0	0.3	47.4	0.4	48.6	1.2
		Average	45.96	46.70	0.74	47.39	0.69	47.71	0.32	48.73
	Total increase in 24 hours:			2.77						
Capon 171	1	37.9	38.7	0.8	39.4	0.7	39.4	0.0	40.2	0.8
	2	39.4	40.1	0.7	40.9	0.8	40.9	0.0	42.0	1.1
	3	35.1	36.2	1.1	36.6	0.4	37.0	0.4	38.1	1.1
	4	35.9	36.9	1.0	37.1	0.2	37.1	0.0	38.5	1.4
	5	43.5	44.5	1.0	45.1	0.6	45.6	0.5	46.1	0.5
	6	39.0	39.4	0.4	39.9	0.5	40.1	0.2	40.8	0.7
	7	39.3	39.6	0.3	40.4	0.8	40.4	0.0	41.2	0.8
	8	37.6	38.7	1.1	38.9	0.2	38.9	0.0	39.5	0.6
	9	37.0	37.7	0.7	38.2	0.5	38.2	0.0	38.6	0.4
	10	38.6	38.7	0.1	40.0	1.3	40.2	0.2	40.4	0.2
		Average	38.33	39.05	0.72	39.65	0.60	39.78	0.13	40.54
	Total increase in 24 hours:			2.21						
Capon 139	1	44.8	45.4	0.6	46.9	1.5	46.9	0.0	47.7	0.8
	2	44.4	45.4	1.0	45.9	0.5	45.9	0.0	46.6	0.7
	3	38.2	39.2	1.0	40.1	0.9	40.5	0.4	41.6	1.1
	4	44.6	45.3	0.7	46.0	0.7	46.0	0.0	47.0	1.0
	5	43.0	43.6	0.6	44.3	0.7	44.5	0.2	45.0	0.5
	6	43.4	44.3	0.9	45.0	0.7	45.5	0.5	46.2	0.7
	7	41.3	42.0	0.7	42.4	0.4	42.8	0.4	43.3	0.5
	8	43.8	44.3	0.5	45.0	0.7	45.2	0.2	46.1	0.9
	9	38.0	39.4	1.4	40.0	0.6	40.2	0.2	40.6	0.4
	10	34.8	36.0	1.2	37.0	1.0	37.0	0.0	37.4	0.4
		Average	41.63	42.49	0.86	43.26	0.77	43.45	0.19	44.15
	Total increase in 24 hours:			2.52						
<b>GRAND</b>										
	AVERAGE	41.97	42.74	0.77	43.43	0.69	43.64	0.21	44.47	0.83
	AVERAGE TOTAL INCREASE IN 24 HOURS:			2.50						

The grand average of the increments in the first set of measurements is plotted in figure 2.

TABLE 3  
 TWELVE O'CLOCK BASIS. APRIL 18-19, 1939. SADDLE FEATHERS BROWN LEGHORN  
 CAPONS. TWENTY-FIFTH DAY OF REGENERATION

		1 12 NOON	2 6 P. M.	INC.	3 12 P. M.	INC.	4 6 A. M.	INC.	5 12 NOON	INC.
Capon 148	1	27.4	27.9	0.5	28.8	0.9	28.9	0.1	29.9	1.0
	2	26.0	26.8	0.8	27.6	0.8	27.7	0.1	28.1	0.4
	3	26.4	26.7	0.3	27.6	0.9	27.6	0.0	28.5	0.9
	4	27.4	28.2	0.8	28.3	0.1	28.4	0.1	30.0	1.6
	5	24.1	24.3	0.2	24.7	0.4	24.7	0.0	26.2	1.5
	6	25.2	25.7	0.5	26.5	0.8	27.0	0.5	27.3	0.3
	7	25.3	25.7	0.4	26.5	0.8	26.6	0.1	27.5	0.9
	8	26.5	27.0	0.5	27.2	0.2	27.2	0.0	27.8	0.6
	9	25.5	25.9	0.4	26.7	0.8	27.0	0.3	27.7	0.7
	10	30.2	30.9	0.7	31.6	0.7	31.7	0.1	32.6	0.9
		Average	26.40	26.91	0.51	27.55	0.64	27.68	0.13	28.56
	Total increase in 24 hours:	2.16								
Capon 171	1	27.9	28.2	0.3	29.2	1.0	30.0	0.8	30.5	0.5
	2	32.7	33.7	1.0	33.9	0.2	34.0	0.1	35.4	1.4
	3	28.0	28.9	0.9	29.3	0.4	29.4	0.1	30.2	0.8
	4	26.8	26.9	0.1	27.3	0.4	27.6	0.3	28.0	0.4
	5	25.5	26.2	0.7	27.0	0.8	27.0	0.0	27.4	0.4
	6	28.2	28.5	0.3	29.1	0.6	29.1	0.0	29.7	0.6
	7	28.1	28.6	0.5	29.1	0.5	29.2	0.1	29.9	0.7
	8	27.0	28.1	1.1	28.7	0.6	28.9	0.2	29.3	0.4
	9	30.4	30.6	0.2	31.0	0.4	31.2	0.2	32.1	0.9
	10	28.4	29.0	0.6	29.8	0.8	29.8	0.0	30.3	0.5
		Average	28.30	28.87	0.57	29.44	0.57	29.62	0.18	30.28
	Total increase in 24 hours:	1.98								
Capon 139	1	27.7	28.5	0.8	28.7	0.2	28.7	0.0	29.4	0.7
	2	27.0	27.4	0.4	28.5	1.1	28.5	0.0	28.6	0.1
	3	29.1	29.3	0.2	30.0	0.7	30.0	0.0	30.9	0.9
	4	28.2	29.0	0.8	29.2	0.2	29.4	0.2	29.9	0.5
	5	27.6	27.8	0.2	29.2	1.4	29.3	0.1	29.9	0.6
	6	27.2	27.9	0.7	28.8	0.9	28.8	0.0	29.9	1.1
	7	24.7	25.8	1.1	26.3	0.5	26.5	0.2	27.4	0.9
	8	27.5	28.5	1.0	29.0	0.5	29.0	0.0	29.6	0.6
	9	28.0	28.6	0.6	29.4	0.8	29.4	0.0	30.2	0.8
	10	26.7	27.1	0.4	27.8	0.7	27.8	0.0	29.1	1.3
		Average	27.37	27.99	0.62	28.69	0.70	28.74	0.05	29.49
	Total increase in 24 hours:	2.12								
<b>GRAND</b>										
	AVERAGE	27.36	27.92	0.56	28.56	0.64	28.68	0.12	29.44	0.76
	AVERAGE TOTAL INCREASE IN 24 HOURS:	2.08								

TABLE 4

TWELVE O'CLOCK BASIS. SECOND SERIES OF MEASUREMENTS OF THE SAME FEATHERS AS IN TABLE 3. TWENTY-EIGHTH DAY OF REGENERATION

		1 12 NOON	2 6 P. M.	INC.	3 12 P. M.	INC.	4 6 A. M.	INC.	5 12 NOON	INC.
Capon	1	33.7	34.1	0.4	35.1	1.0	35.4	0.3	36.8	1.4
148	2	32.8	33.0	0.2	33.5	0.5	33.8	0.3	34.7	0.9
	3	33.0	33.5	0.5	34.1	0.6	34.3	0.2	34.7	0.4
	4	34.5	35.0	0.5	35.3	0.3	35.3	0.0	36.5	1.2
	5	30.6	31.5	0.9	31.9	0.4	32.5	0.6	33.4	0.9
	6	32.5	32.7	0.2	33.3	0.6	33.3	0.0	34.4	1.1
	7	32.2	32.6	0.4	33.3	0.7	33.4	0.1	33.8	0.4
	8	32.8	33.4	0.6	33.8	0.4	34.4	0.6	34.7	0.3
	9	32.0	32.3	0.3	32.8	0.5	32.8	0.0	33.7	0.9
	10	36.6	37.4	0.8	37.7	0.3	37.8	0.1	38.7	0.9
	Average	33.07	33.55	0.48	34.08	0.53	34.30	0.22	35.14	0.84
	Total increase in 24 hours:			2.07						
Capon	1	33.3	34.4	1.1	35.6	1.2	35.6	0.0	35.8	0.2
171	2	39.0	39.2	0.2	39.6	0.4	39.9	0.3	41.1	1.2
	3	34.0	34.5	0.5	35.3	0.8	35.3	0.0	36.0	0.7
	4	31.3	32.2	0.9	32.6	0.4	32.6	0.0	33.4	0.8
	5	31.4	32.2	0.8	32.6	0.4	32.8	0.2	33.4	0.6
	6	33.5	35.2	1.7	35.5	0.3	35.5	0.0	36.0	0.5
	7	34.1	34.9	0.8	35.5	0.6	35.5	0.0	35.9	0.4
	8	33.5	34.8	1.3	34.9	0.1	35.2	0.3	35.9	0.7
	9	35.5	36.4	0.9	36.8	0.4	36.8	0.0	37.9	1.1
	10	34.0	34.7	0.7	35.3	0.6	35.3	0.0	36.0	0.7
	Average	33.96	34.85	0.89	35.37	0.52	35.45	0.08	36.14	0.69
	Total increase in 24 hours:			2.18						
Capon	1	33.5	34.7	1.2	34.9	0.2	35.2	0.3	35.5	0.3
139	2	31.2	32.0	0.8	33.0	1.0	33.0	0.0	33.4	0.4
	3	35.1	35.5	0.4	36.5	1.0	36.9	0.4	37.5	0.6
	4	32.1	32.3	0.2	32.8	0.5	32.9	0.1	33.2	0.3
	5	33.2	33.9	0.7	35.0	1.1	35.0	0.0	35.4	0.4
	6	33.1	33.9	0.8	35.0	1.1	35.1	0.1	35.7	0.6
	7	30.8	31.4	0.6	31.7	0.3	32.0	0.3	32.9	0.9
	8	33.7	34.6	0.9	34.7	0.1	34.7	0.0	35.2	0.5
	9	34.2	34.8	0.6	35.3	0.5	35.3	0.0	35.8	0.5
	10	32.7	33.4	0.7	33.9	0.5	33.9	0.0	34.8	0.9
	Average	32.96	33.65	0.69	34.28	0.63	34.40	0.12	34.94	0.54
	Total increase in 24 hours:			1.98						
<b>GRAND</b>	<b>AVERAGE</b>	<b>33.33</b>	<b>34.02</b>	<b>0.69</b>	<b>34.58</b>	<b>0.56</b>	<b>34.72</b>	<b>0.14</b>	<b>35.41</b>	<b>0.69</b>
	<b>AVERAGE TOTAL INCREASE IN 24 HOURS:</b>			<b>2.08</b>						

Measurements were made to the nearest tenth of a millimeter as follows: A piece of white paper was inserted beneath the feather which was then held flat against it, and an original measurement was made with spring nut outside calipers from the mouth of the follicle on the upper side to the tip of the feather. The space between the points of the spring calipers was then measured with vernier calipers with direct gauge reading to 0.1 mm. (made by Schietrumpf of Jena). The part of the feather within the follicle (about 7 mm. in length) was not taken into account. The principal sources of error by this method are, first, that the position of the points of the spring calipers in the original measurements must be judged by the eye alone, and, second, the assumption is made that the opening of the follicle maintains a fixed position during the 24 hours. These possible sources of error tend to be averaged out. The very large averaged difference between the six-hour period from midnight to 6:00 A. M. and the other six-hour measurements are consistent for the separate measurements with some exceptions (see tables).

The average growth in 24 hours of all breast feathers in both sets of determinations was 2.58 mm.; for all saddle feathers, 2.08 mm. If the growth in each six-hour period in the diurnal cycle were uniform, each would record 25% of this amount. The actual percentages,<sup>1</sup> averaging all determinations for each six-hour period for breast and for saddle, were as follows:

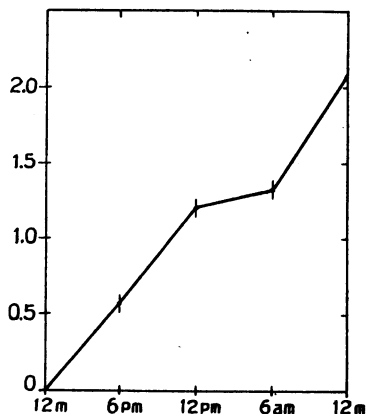


FIGURE 2

Saddle feathers. From data of table 3. The grand average of six-hour increments of the three birds plotted. Based on 12:00 o'clock. Ordinates = millimeters of growth; abscissae = time of day.

	BREAST	SADDLE
12:00 noon to 6:00 P. M.	31%	30%
6:00 P. M. to 12:00 midnight	26%	29%
12:00 midnight to 6:00 A. M.	9%	6%
6:00 A. M. to 12:00 noon	34%	35%

It will be noted that the amount of depression of growth rate from midnight to 6:00 A. M. is greater in the saddle than in the breast. This is perhaps due to a lower threshold of susceptibility similar to that which Juhn and Gustavson ('30) found in saddle as compared with breast feathers

<sup>1</sup> The nearest whole number is used for each percentage.

in the case of reaction to the female hormone, and which they attributed to slower rate of growth.

It is interesting to note that 50 zero increments are recorded between midnight and 6:00 A. M. out of the 120 records made for this period, only one between noon and 6:00 P. M., two between 6:00 P. M. and midnight and none between 6:00 A. M. and noon, similarly out of 120 records for each period. Two of the determinations for six-hour periods are small decrements, 0.1 and 0.2, respectively, obviously due to errors of recording. There are five records between midnight and 6:00 A. M. out of 120 in

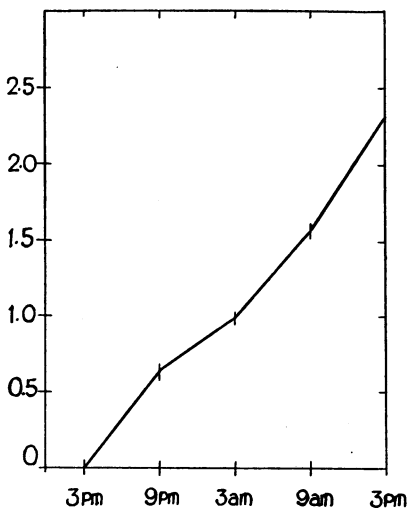


FIGURE 3

Breast feathers. From data of table 5. The grand average of six-hour increments of the three birds plotted. Based on 9:00 o'clock. Ordinates = millimeters of growth; abscissae = time of day.

which the increment of individual feathers exceeds 25% of the total growth for 24 hours. The range of variation of increment within each period is considerable. There are also slight differences to be noted between the three birds used.

Except for the disturbance due to measurement, the birds were on a normal régime with no artificial lighting. No attempt has been made to determine how differences in feeding, lighting or activity would affect the diurnal cycle.

2. *Six-Hour Increments Based on Nine O'Clock.*—The amount of growth was then measured at six-hour periods beginning at nine o'clock instead of twelve o'clock. The regeneration age at the beginning of the measurements was 20 days in the case of the breast feathers and 22 days in the case of the saddle feathers. The same

three capons were used as before, and precisely the same methods were followed. The observations were made June 12–14 for the breast feathers (tables 5 and 6 and Fig. 3), and June 24–26 for the saddle feathers (tables 7 and 8 and Fig. 4). In each case two consecutive 24-hour periods were used. In the case of the measurements beginning at twelve o'clock, the two 24-hour periods were separated by three days in both breast and saddle feathers. The measurements for six-hour periods beginning at twelve o'clock were made in March and April when the temperature of the animal house was much lower than in the case of the periods based on nine o'clock, which were made in June. These differences may have had some effect.



TABLE 5

NINE O'CLOCK BASIS. JUNE 12-13, 1939. BREAST FEATHERS BROWN LEGHORN  
CAPONS. TWENTIETH DAY OF REGENERATION

	1	2		3		4		5		
	9	3		9		3		9		
	A. M.	P. M.	INC.	P. M.	INC.	A. M.	INC.	A. M.	INC.	
<b>Capon</b>	1	20.3	21.1	0.8	21.7	0.6	22.0	0.3	22.1	0.1
<b>148</b>	2	20.0	20.7	0.7	20.9	0.2	21.5	0.6	22.0	0.5
	3	20.1	21.5	1.4	22.2	0.7	22.2	0.0	22.4	0.2
	4	19.7	20.5	0.8	21.4	0.9	21.4	0.0	22.2	0.8
	5	18.9	19.8	0.9	21.2	1.4	21.3	0.1	22.0	0.7
	6	18.0	18.8	0.8	19.5	0.7	20.2	0.7	20.7	0.5
	7	18.0	18.8	0.8	19.5	0.7	20.5	1.0	21.3	0.8
	8	18.9	19.7	0.8	20.4	0.7	20.8	0.4	21.3	0.5
	9	18.7	19.8	1.1	20.4	0.6	20.8	0.4	21.3	0.5
	10	16.7	17.7	1.0	17.9	0.2	18.3	0.4	19.1	0.8
	<b>Average</b>	<b>18.93</b>	<b>19.84</b>	<b>0.91</b>	<b>20.51</b>	<b>0.67</b>	<b>20.90</b>	<b>0.39</b>	<b>21.44</b>	<b>0.54</b>
	<b>Total increase in 24 hours:</b>			<b>2.51</b>						
<b>Capon</b>	1	16.6	17.4	0.8	18.0	0.6	18.0	0.0	18.7	0.7
<b>171</b>	2	16.6	17.4	0.8	18.0	0.6	18.4	0.4	19.4	1.0
	3	16.0	16.5	0.5	17.0	0.5	17.5	0.5	18.0	0.5
	4	15.0	15.9	0.9	16.3	0.4	16.9	0.6	17.6	0.7
	5	15.5	16.1	0.6	17.2	1.1	17.6	0.4	17.9	0.3
	6	15.2	15.8	0.6	16.7	0.9	17.6	0.9	17.7	0.1
	7	15.0	15.6	0.6	15.9	0.3	16.5	0.6	16.7	0.2
	8	15.8	16.8	1.0	17.4	0.6	17.4	0.0	18.3	0.9
	9	15.6	16.7	1.1	17.6	0.9	17.9	0.3	18.4	0.5
	10	13.7	14.6	0.9	15.3	0.7	15.3	0.0	16.4	1.1
	<b>Average</b>	<b>15.50</b>	<b>16.28</b>	<b>0.78</b>	<b>16.94</b>	<b>0.66</b>	<b>17.31</b>	<b>0.37</b>	<b>17.91</b>	<b>0.60</b>
	<b>Total increase in 24 hours:</b>			<b>2.41</b>						
<b>Capon</b>	1	20.2	20.6	0.4	20.8	0.2	20.9	0.1	21.5	0.6
<b>139</b>	2	20.3	21.1	0.8	21.5	0.4	21.6	0.1	21.9	0.3
	3	17.5	18.1	0.6	18.6	0.5	18.9	0.3	19.3	0.4
	4	21.1	21.7	0.6	22.2	0.5	22.3	0.1	23.1	0.8
	5	19.7	20.6	0.9	21.5	0.9	21.5	0.0	21.9	0.4
	6	21.0	21.5	0.5	22.1	0.6	22.9	0.8	23.3	0.4
	7	19.7	20.4	0.7	20.9	0.5	21.4	0.5	21.8	0.4
	8	20.7	21.2	0.5	21.9	0.7	22.9	1.0	23.3	0.4
	9	19.7	20.0	0.3	20.8	0.8	20.9	0.1	21.7	0.8
	10	18.9	19.4	0.5	19.8	0.4	20.1	0.3	21.2	1.1
	<b>Average</b>	<b>19.88</b>	<b>20.46</b>	<b>0.58</b>	<b>21.01</b>	<b>0.55</b>	<b>21.34</b>	<b>0.33</b>	<b>21.90</b>	<b>0.56</b>
	<b>Total increase in 24 hours:</b>			<b>2.02</b>						
<b>GRAND</b>										
<b>AVERAGE</b>		<b>18.10</b>	<b>18.86</b>	<b>0.76</b>	<b>19.49</b>	<b>0.63</b>	<b>19.85</b>	<b>0.36</b>	<b>20.42</b>	<b>0.57</b>
<b>AVERAGE TOTAL INCREASE IN 24 HOURS:</b>				<b>2.32</b>						

TABLE 6

NINE O'CLOCK BASIS. SECOND SERIES OF MEASUREMENTS OF THE SAME FEATHERS AS IN TABLE 5. TWENTY-FIRST DAY OF REGENERATION

		1	2		3		4		5	
		A. M.	P. M.	INC.	P. M.	INC.	A. M.	INC.	A. M.	INC.
Capon 148	1	22.1	22.8	0.7	23.3	0.5	23.5	0.2	24.7	1.2
	2	22.0	22.4	0.4	22.8	0.4	23.5	0.7	24.5	1.0
	3	22.4	23.4	1.0	23.9	0.5	24.2	0.3	25.1	0.9
	4	22.2	22.5	0.3	23.3	0.8	23.4	0.1	24.2	0.8
	5	22.0	22.4	0.4	23.2	0.8	23.5	0.3	24.2	0.7
	6	20.7	21.4	0.7	21.9	0.5	22.6	0.7	23.3	0.7
	7	21.3	21.7	0.4	22.7	1.0	23.2	0.5	23.7	0.5
	8	21.3	22.2	0.9	22.7	0.5	23.2	0.5	24.0	0.8
	9	21.3	22.2	0.9	22.7	0.5	23.0	0.3	24.1	1.1
	10	19.1	20.0	0.9	20.2	0.2	21.0	0.8	21.6	0.6
	Average	21.44	22.10	0.66	22.67	0.57	23.11	0.44	23.94	0.83
Total increase in 24 hours:			2.50							
Capon 171	1	18.7	19.8	1.1	20.1	0.3	20.8	0.7	21.5	0.7
	2	19.4	20.5	1.1	20.8	0.3	21.5	0.7	21.6	0.1
	3	18.0	18.6	0.6	19.2	0.6	20.0	0.8	20.5	0.5
	4	17.6	18.5	0.9	18.8	0.3	19.4	0.6	20.0	0.6
	5	17.9	19.0	1.1	19.6	0.6	20.4	0.8	20.8	0.4
	6	17.7	18.5	0.8	19.3	0.8	19.6	0.3	20.0	0.4
	7	16.7	17.6	0.9	18.5	0.9	18.8	0.3	19.5	0.7
	8	18.3	19.0	0.7	19.8	0.8	20.2	0.4	20.9	0.7
	9	18.4	19.5	1.1	20.2	0.7	20.7	0.5	21.5	0.8
	10	16.4	17.2	0.8	17.5	0.3	18.0	0.5	18.6	0.6
	Average	17.91	18.82	0.91	19.38	0.56	19.94	0.56	20.49	0.55
Total increase in 24 hours:			2.58							
Capon 139	1	21.5	22.5	1.0	23.1	0.6	23.7	0.6	24.3	0.6
	2	21.9	22.8	0.9	23.5	0.7	23.7	0.2	24.3	0.6
	3*	18.9	19.6	0.7	20.0	0.4	20.4	0.4	21.6	1.2
	4	23.1	23.7	0.6	24.4	0.7	24.8	0.4	25.4	0.6
	5	21.9	22.3	0.4	22.9	0.6	23.4	0.5	23.8	0.4
	6	23.3	24.1	0.8	24.7	0.6	25.4	0.7	25.6	0.2
	7	21.8	22.4	0.6	23.2	0.8	23.5	0.3	24.3	0.8
	8	23.3	23.5	0.2	24.3	0.8	24.6	0.3	25.7	1.1
	9	21.7	22.5	0.8	22.8	0.3	23.4	0.6	24.5	1.1
	10	21.2	21.5	0.3	22.0	0.5	22.4	0.4	23.5	1.1
	Average	21.86	22.49	0.63	23.09	0.60	23.53	0.44	24.30	0.77
Total increase in 24 hours:			2.44							
<b>GRAND</b>										
AVERAGE	20.40	21.13	0.73	21.71	0.58	22.19	0.48	22.91	0.72	
AVERAGE TOTAL INCREASE IN 24 HOURS:			2.51							

\* A newly selected feather to replace the one used in the first series of measurements (table 5) which was lost.

TABLE 7

NINE O'CLOCK BASIS. JUNE 24-25, 1939. SADDLE FEATHERS BROWN LEGHORN  
CAPONS. TWENTY-SECOND DAY OF REGENERATION

		1 9	2 3		3 9		4 3		5 9	
		A. M.	P. M.	INC.	P. M.	INC.	A. M.	INC.	A. M.	INC.
Capon 148	1	27.7	28.2	0.5	28.7	0.5	28.8	0.1	29.3	0.5
	2	17.4	17.9	0.5	18.2	0.3	18.7	0.5	19.1	0.4
	3	17.8	18.2	0.4	18.7	0.5	18.8	0.1	19.2	0.4
	4	18.9	19.5	0.6	19.7	0.2	19.9	0.2	20.6	0.7
	5	12.3	13.2	0.9	13.6	0.4	14.0	0.4	14.7	0.7
	6	14.3	15.2	0.9	15.9	0.7	15.9	0.0	16.3	0.4
	7	14.1	14.8	0.7	15.1	0.3	15.2	0.1	15.8	0.6
	8	14.1	14.8	0.7	15.1	0.3	15.5	0.4	16.2	0.7
	9	14.9	15.2	0.3	15.8	0.6	16.2	0.4	16.7	0.5
	10	16.1	16.4	0.3	16.7	0.3	16.9	0.2	17.3	0.4
	Average	16.76	17.34	0.58	17.75	0.41	17.99	0.24	18.52	0.53
	Total increase in 24 hours:	1.76								
Capon 171	1	17.8	18.4	0.6	18.9	0.5	19.1	0.2	19.6	0.5
	2	18.4	19.0	0.6	19.5	0.5	19.6	0.1	20.2	0.6
	3	17.5	17.8	0.3	18.5	0.7	18.7	0.2	19.3	0.6
	4	16.5	16.9	0.4	17.4	0.5	17.6	0.2	18.2	0.6
	5	18.4	18.7	0.3	19.3	0.6	19.5	0.2	20.1	0.6
	6	18.7	19.0	0.3	19.5	0.5	19.6	0.1	20.5	0.9
	7	15.5	16.2	0.7	16.8	0.6	17.2	0.4	17.5	0.3
	8	18.6	19.4	0.8	19.8	0.4	20.1	0.3	20.4	0.3
	9	17.5	18.4	0.9	18.6	0.2	18.7	0.1	19.7	1.0
	10	16.8	17.5	0.7	18.0	0.5	18.4	0.4	18.8	0.4
	Average	17.57	18.13	0.56	18.63	0.50	18.85	0.22	19.43	0.58
	Total increase in 24 hours:	1.86								
Capon 139	1	15.7	16.0	0.3	17.0	1.0	17.3	0.3	17.9	0.6
	2	14.7	15.3	0.6	15.9	0.6	16.0	0.1	16.6	0.6
	3	24.5	25.1	0.6	25.4	0.3	25.8	0.4	26.3	0.5
	4	15.5	16.0	0.5	16.7	0.7	17.0	0.3	17.6	0.6
	5	15.5	16.1	0.6	16.5	0.4	16.8	0.3	17.3	0.5
	6	17.1	17.5	0.4	18.3	0.8	18.4	0.1	19.1	0.7
	7	17.8	18.5	0.7	18.8	0.3	19.3	0.5	19.9	0.6
	8	14.6	15.5	0.9	16.0	0.5	16.3	0.3	16.7	0.4
	9	14.8	15.8	1.0	16.1	0.3	16.3	0.2	16.7	0.4
	10	17.2	17.8	0.6	18.1	0.3	18.5	0.4	19.1	0.6
	Average	16.74	17.36	0.62	17.88	0.52	18.17	0.29	18.72	0.55
	Total increase in 24 hours:	1.98								
<b>GRAND</b>										
	AVERAGE	17.02	17.61	0.59	18.09	0.48	18.34	0.25	18.89	0.55
	AVERAGE TOTAL INCREASE IN 24 HOURS:	1.87								

TABLE 8

NINE O'CLOCK BASIS. SECOND SERIES OF MEASUREMENTS OF THE SAME FEATHERS AS IN TABLE 7. TWENTY-THIRD DAY OF REGENERATION

	1	2		3		4		5		
	9	3	INC.	9	INC.	3	INC.	9	INC.	
	A. M.	P. M.		P. M.		A. M.		A. M.		
Capon	1	29.3	30.2	0.9	30.6	0.4	31.0	0.4	31.7	0.7
148	2	19.1	19.8	0.7	20.3	0.5	20.3	0.0	21.0	0.7
	3	19.2	19.8	0.6	20.6	0.8	21.0	0.4	21.7	0.7
	4	20.6	21.2	0.6	22.4	1.2	22.4	0.0	23.4	1.0
	5	14.7	15.1	0.4	15.6	0.5	16.2	0.6	16.6	0.4
	6	16.3	17.0	0.7	17.4	0.4	17.9	0.5	18.8	0.9
	7	15.8	16.1	0.3	17.0	0.9	17.7	0.7	18.1	0.4
	8	16.2	16.7	0.5	16.9	0.2	16.9	0.0	17.7	0.8
	9	16.7	17.4	0.7	18.2	0.8	18.5	0.3	18.9	0.4
	10	17.3	17.9	0.6	18.6	0.7	19.0	0.4	19.5	0.5
	Average	18.52	19.12	0.60	19.76	0.64	20.09	0.33	20.74	0.65
	Total increase in 24 hours:			2.22						
Capon	1	19.6	20.2	0.6	20.6	0.4	21.2	0.6	21.6	0.4
171	2	20.2	20.6	0.4	21.2	0.6	21.3	0.1	21.9	0.6
	3	19.3	19.7	0.4	20.0	0.3	20.3	0.3	20.8	0.5
	4	18.2	18.6	0.4	19.4	0.8	19.5	0.1	20.0	0.5
	5	20.1	20.8	0.7	21.5	0.7	21.8	0.3	22.4	0.6
	6	20.5	21.3	0.8	21.8	0.5	21.8	0.0	22.5	0.7
	7	17.5	18.0	0.5	18.7	0.7	19.0	0.3	19.7	0.7
	8	20.4	21.6	1.2	22.1	0.5	22.5	0.4	23.0	0.5
	9	19.7	20.2	0.5	20.8	0.6	21.0	0.2	21.5	0.5
	10	18.8	19.4	0.6	19.8	0.4	20.3	0.5	20.9	0.6
	Average	19.43	20.04	0.61	20.59	0.55	20.87	0.28	21.43	0.56
	Total increase in 24 hours:			2.00						
Capon	1	17.9	18.4	0.5	18.9	0.5	19.2	0.3	20.0	0.8
139	2	16.6	17.1	0.5	17.5	0.4	17.7	0.2	18.5	0.8
	3	26.3	26.7	0.4	27.5	0.8	27.9	0.4	28.1	0.2
	4	17.6	18.4	0.8	18.7	0.3	19.1	0.4	19.8	0.7
	5	17.3	17.7	0.4	18.0	0.3	18.4	0.4	19.1	0.7
	6	19.1	19.9	0.8	20.4	0.5	20.5	0.1	21.1	0.6
	7	19.9	20.2	0.3	20.8	0.6	20.8	0.0	21.7	0.9
	8	16.7	17.4	0.7	18.0	0.6	18.1	0.1	18.9	0.8
	9	16.7	17.4	0.7	18.0	0.6	18.4	0.4	19.0	0.6
	10	19.1	19.9	0.8	20.6	0.7	21.0	0.4	21.4	0.4
	Average	18.72	19.31	0.59	19.84	0.53	20.11	0.27	20.76	0.65
	Total increase in 24 hours:			2.04						
GRAND	AVERAGE	18.89	19.49	0.60	20.06	0.57	20.36	0.30	20.98	0.62
	AVERAGE TOTAL INCREASE IN 24 HOURS:			2.09						

The average growth in 24 hours of all breast feathers in both sets of determinations was 2.15 mm., of all saddle feathers, 1.98 mm., in each case somewhat less than the previous sets. The averages of percentages of daily increments for six-hour periods were as follows:

	BREAST		SADDLE	
	1ST DAY	2ND DAY	1ST DAY	2ND DAY
9:00 A. M. to 3:00 P. M.	32.76	29.08	31.55	28.70
3:00 P. M. to 9:00 P. M.	27.15	23.11	25.67	27.27
9:00 P. M. to 3:00 A. M.	15.52	19.12	13.37	14.36
3:00 A. M. to 9:00 A. M.	24.57	28.69	29.41	29.67

There is a depression of growth rate here from 9:00 P. M. to 3:00 A. M. but of a lesser order of magnitude than from 12:00 midnight to 6:00 A. M. in the former series (cf. Figs. 1 to 4).

3. *Comparison of the Twelve O'Clock and Nine O'Clock Bases.*—Growth within each six-hour period is necessarily represented as uniform owing to the requirements of the method; but it is obviously improbable in the highest degree that this is actually the case. The purpose of repeating the original observations made on a twelve o'clock basis by another set of observations based on nine o'clock was to ascertain whether by comparison it would be possible to determine at least the three-hour period with the lowest rate of growth. The remainder of the diurnal curves of growth (cf. Figs. 1 to 4) does not exhibit sufficient variation to encourage an attempt at closer determination of the time of maximum rate of growth.

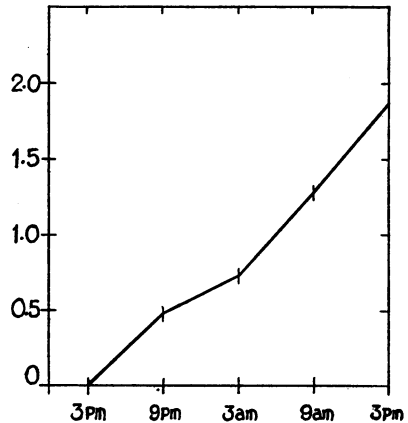


FIGURE 4  
Saddle feathers. From data of table 7. The grand average of six-hour increments of the three birds plotted. Based on 9:00 o'clock. Ordinates = millimeters of growth; abscissae = time of day.

In table 9 we have divided the growth of each six-hour period into equal halves, thus establishing arbitrary three-hour periods of growth both on the twelve o'clock and the nine o'clock bases; these figures are taken from the grand averages of the first set of measurements in each case, and the corresponding three-hour periods for the two bases are thus brought directly into comparison. It will be seen that except for the periods of depression of growth rates, 12:00 P. M. to 6:00 A. M. on the twelve o'clock basis, and 9:00 P. M. to 3:00 A. M. on the nine o'clock basis, the three-hour periods

agree fairly well in the two series. In spite of the great discrepancies between the twelve o'clock and the nine o'clock bases during the periods of depression, it is nevertheless shown by the table that the sum of the amount of growth on the two bases in the three-hour period from 12:00 P. M. to 3:00 A. M. is much less than in any other three-hour period, even comparing the two adjacent three-hour periods. We would therefore conclude that the period of least growth is from midnight to 3:00 A. M.

This reinforces the conclusion that the diurnal curve of growth is in reality a flowing, and not an angular, curve. We have attempted to apply this conception by the triangular signs in table 9. These are intended to indicate that on the twelve o'clock basis the growth from 6:00 P. M. to 9:00 P. M. is probably more than from 9:00 P. M. to midnight, and that the

TABLE 9

DATA REARRANGED ON THE BASIS OF THREE-HOUR INCREMENTS. ALL DATA BASED ON THE AVERAGE OF THE FIRST SET OF MEASUREMENTS OF ALL THE THREE BROWN LEGHORN CAPONS USED

	12 M.- 3 P. M.	3 P. M.- 6 P. M.	6 P. M.- 9 P. M.	9 P. M.- 12 P. M.	12 P. M.- 3 A. M.	3 A. M.- 6 A. M.	6 A. M.- 9 A. M.	9 A. M.- 12 M.	TOTAL INC.
<b>Breast</b>									
12 o'clock basis	0.40	0.40	0.33	0.33	0.12	0.12	0.47	0.47	2.64 mm.
			▷		◁				
9 o'clock basis	0.38	0.315	0.315	0.18	0.18	0.285	0.285	0.38	2.32 mm.
			◁		▷				
<b>Saddle</b>									
12 o'clock basis	0.28	0.28	0.32	0.32	0.06	0.06	0.38	0.38	2.08 mm.
			▷		◁				
9 o'clock basis	0.295	0.24	0.24	0.125	0.125	0.275	0.275	0.295	1.87 mm.
			▷		◁				

growth from midnight to 3:00 A. M. is probably less than from 3:00 A. M. to 6:00 A. M. Similarly, on the nine o'clock basis the growth from 9:00 P. M. to midnight is probably more than from midnight to 3:00 A. M., and the growth from 3:00 A. M. to 6:00 A. M. less than from 6:00 A. M. to 9:00 A. M. Any corrections made in this sense would tend to even out the discrepancies between the two bases.

In figures 5 and 6 we have applied the principle of these corrections to the curves of growth for the breast feathers on the twelve o'clock and nine o'clock bases respectively (Figs. 1 and 2). The corrections are indicated by the flowing dotted curves crossing the original curves. The exact form of the dotted curve represents merely our best judgment of the amount and distribution of the corrections, and to that extent is arbitrary, but it is

believed to give a more correct representation of the actual growth rate than either of the unmodified curves. The six-hour period of least growth is emphasized by the stippled triangle below it. The 3:00 A. M. ordinate divides it into unequal parts.

III. DISCUSSION

1. *The Physiological Basis of the Diurnal Rhythm.*—(a) Diurnal fluctuations of basal metabolism. The determinations of Barott and others ('38)<sup>1</sup> of the diurnal fluctuations of the energy production and gaseous metabolism of male Rhode Island chickens aged from four to 130 days are by far the most thorough on record. On page 158 they give a curve of the diurnal rhythm of the energy metabolism, as measured by oxygen consumption, of fasting male Rhode Island Red chickens of between 15 and about 18 weeks of age. This is a very regular flowing curve covering three days. The high point of the curve occurs daily between 8:00 A. M. and 9:00 A. M. and the low point between 8:00 P. M. and 9:00 P. M. On the second day of the three-day record, the high oxygen consumption was about 0.85 cc. per hour per gram live weight, and the low about 0.72.

Bacq ('29) studied four cocks both under normal feeding and fasting régimes. His curve of diurnal fluctuations of basal metabolism (calories per kg. hr.) is quite similar to those of Barott though the observations are rather fragmentary; the low and high points are slightly later.

If we attempt a closer comparison to the oxygen consumption curve of Barott *et al.* we find that the lowest three-hour period of oxygen consumption, which offers the best basis for comparison of growth in the 24-hour cycle, is, according to their determinations, between 6:00 P. M. and 9:00 P. M. approximately, whereas the period of least growth according to our determinations is between midnight and 3:00 A. M., thus six hours later.

<sup>1</sup> Cf. also Benedict, Landauer and Fox ('32), and Scharnke ('32).

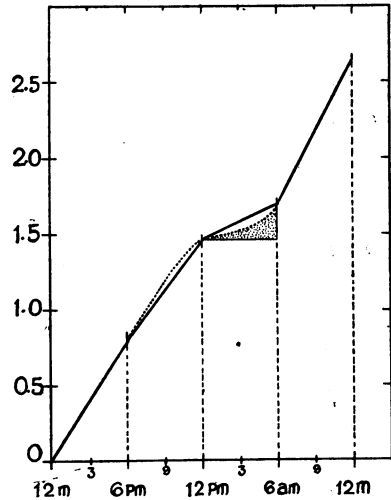


FIGURE 5

Breast feathers. The 12:00 o'clock basis (Fig. 1) modified by the dotted line based on comparison of the 9:00 o'clock basis (Fig. 3) as explained in table 9. The stippled area emphasizes the period of the least six-hour increment. Ordinates = millimeters of growth; abscissae = time of day.

If we assume that there is a causal relation between energy metabolism and growth in length of the feather, we have to find some explanation of the very considerable lag of effect.

Lillie and Juhn ('32) attempted to estimate the growth due to plasmatic growth, including cell-division, and to cell-differentiation, respectively, in the growth in length of the shaft (p. 143) and in the barbs (p. 150), and concluded that about 90% of growth in length is due to cell-differentiation and only about 10% to plasmatic growth. The amount of growth of the whole feather due to cell-differentiation, which consists, so far as magnitudes are concerned, in elongation and "ballooning" of cells, depends on the number of cells presented for differentiation as presumably the most important factor; and the number presented at any one time will depend on the rate of cell-division.

Even if the rate of cell-division should respond immediately to reduced  $O_2$  in the blood, time would be required for the new cells to move up into the zone of differentiation, and before reduction in the number of cells available for differentiation becomes a measurable factor in reduction of rate of growth. It is therefore not to be expected that the dampening effects of lower metabolism will receive simultaneous response in measurements of length increments at six-hour intervals. A certain amount of lag is to be expected on the hypothesis of a causal relation between the rates of energy metabolism and growth increments in such a system as the regenerating feather.

(b) Diurnal fluctuations of body temperature. Regular diurnal fluctuations of internal body temperature have often been recorded. Simpson and Galbraith ('05) record a maximum temperature of  $41.9^\circ C$ . for Dorking males at 3:00 P. M. and a minimum temperature of  $40.9^\circ$  at 3:00 A. M. The temperature drops suddenly from 6:00 P. M. to 9:00 P. M. and then holds near, or below,  $41^\circ$  to about 4:00 A. M. Riddle ('07) similarly recorded a marked drop in temperature in fowl, ducks and pigeons during the night. Hilden and Stenback ('16) record a series of observations on fowl and eight other species of birds confirming in general the determinations of Simpson and Galbraith, but adding the valuable determination that the regular day and night variations are readily reversed by keeping the birds in the dark during the day and furnishing illumination at night. A more systematic study of the diurnal temperature fluctuations in fowl under various conditions is, however, still much to be desired.

As regards other birds, Simpson and Galbraith ('05) record a much greater depression of body temperature during the night than in fowl in a considerable number of species, especially smaller birds; but they found that in the case of the owl, a bird of nocturnal habit, the situation was reversed. Wetmore ('21) made an immense number of careful determinations of body temperatures of birds taken in the field, and found, as regards



diurnal variations, marked depressions during the night, with the exception of birds of nocturnal habit in which the situation was reversed, confirming Simpson and Galbraith.

Riley ('37) reports daily variation in the body temperature of the house sparrow ranging from an average of 110°F. during the day to 103–104°F. during the night. Spermatogenetic activity is limited to the period of reduced body temperature. Artificial inversion of light and dark periods with reference to normal day and night inverts also the normal day and night body temperatures and the time of spermatogenetic activity.

Huff ('39) has made a study of diurnal variation of temperature in canaries in connection with his study of malarial infections. He made several series of temperature readings every three hours in females by inserting hypodermic thermocouples deep into the pectoral muscles. The mean day temperature for all determinations was 42.3°C. ± 0.05, and the mean night temperature 41.0°C. ± 0.26. In certain apparently normal individuals the range might be as much as 6°C. over a 24-hour period. The curves show a sharp drop of temperature beginning about 4:00 P. M., reaching its lowest point about 3:00 A. M. to 4:00 A. M. and then sharply rising.

In attempting to compare the diurnal curve of growth with that of internal body temperature in fowl, we are limited by the lack of continuous records of the latter under controlled conditions.

Simpson and Galbraith ('05) record almost a plateau of low temperature from 9:00 P. M. to 3:00 A. M. from observations of a single male and female Dorking fowl. In canaries (Huff, '39) the high daytime body temperature begins to fall in the late afternoon and reaches its lowest point about 3:00 A. M. to 4:00 A. M. and then rises sharply. If it is permissible to combine observations on temperature in different species of birds for comparison with our growth rate on fowls we note that the rather sudden rise in body temperature about 3:00 A. M. to 4:00 A. M. agrees well with the sudden increase of rate

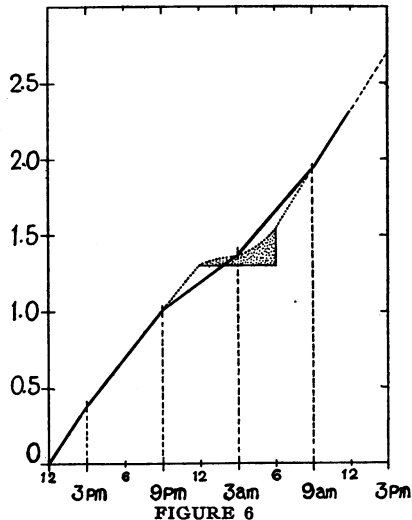


FIGURE 6  
Breast feathers. The 9:00 o'clock basis (Fig. 3) modified by the dotted line based on comparison of the 12:00 o'clock basis (Fig. 1) as explained in table 9. The stippled area emphasizes the period of the least six-hour increment. Ordinates = millimeters of growth; abscissae = time of day.

of growth of the feather at the same time, and the association of the regularly occurring night depression of body temperature and growth must be held to be significant. Precise comparisons would require simultaneous determinations of body temperature and rate of growth of feathers under carefully controlled conditions.

It would seem to be indicated that daily fatigue followed by rest involves a decrease of the rate of basal metabolism, which causes a drop in body temperature associated with a reduction in rate of growth of the regenerating feather. The fact that day-night body temperature relations are inverted in nocturnal birds would seem to indicate that light as such does not play a direct rôle in the presumed sequence of events.

2. *Morphological Consequences of the Diurnal Rhythm.*—The determination that the rate of growth undergoes a very sharp diminution each 24 hours between midnight and 3:00 A. M. checks well with C. O. Whitman's discovery of the fundamental bars of feathers, which have been especially studied by Riddle ('07, '08). Riddle believed, on the basis of good evidence, that each bar represents a single day of growth, and that the "defective lines, or points of apposition of the fundamental bars," are the loci of formation of the abnormal fault bars, characterized by absence or defect of barbules, which occasionally cross the vane of feathers at a constant angle. The fault bars were subsequently studied by Fraps and Juhn ('36) and interpreted as isochrones, i.e., as lines of simultaneous disturbance of development in the germ, in their entire extent, thus referable to a cause acting at one time.

H. and Josephine Michener ('38) have described bars that occur in flight feathers of house finches also which they studied during regeneration after plucking. They conclude that the bars across the feathers, resembling watermarks in paper, represent a single day's growth. They find that they are most distinct in winter-grown feathers and surmise that they are due to difference in metabolism at night and in the day.

It is indeed probable that the fundamental bars of feathers are related to diurnal physiological rhythms, but this remains at present hypothetical. The occurrence of such considerable depression of the growth rate of developing feathers during the night as we have determined for fowl offers a better mode of attack on this problem; for it has been established that thresholds of reaction in developing feathers vary according to rate of growth (Juhn and Gustavson, '32; Juhn, Faulkner and Gustavson, '31); moreover, Lillie and Juhn ('32, p. 170) have shown that component parts of the same feather, such as barbules and melanophores, have differential thresholds. On such a basis it should be possible to investigate more precisely than has hitherto been done the fundamental bars and other possible morphological consequences of diurnal rhythms in feathers.

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