A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

By

KUNIO MORI

*Department of Anatomy, School of Medicine, Kyushu University**(Director, Prof. Mori)**Department of Histology, Kyushu Dental College**(Director, Prof. Saegusa)*

Growth phases of experimental animals have been so far variously studied by many investigators. Donaldson (1924) was the first investigator who made detailed measurements on various bodily parts and organs in the growing albino rats. Later Huxley ('32) and Teissier ('34) studied particularly the problem of the relative growth in animals and they are credited to have devised an equation $y = bx^\alpha$ in which the whole or a part of the growing animal was represented by x , another part or an organ by y and α represented the relative growth rate or the coefficient of relative growth. Recently reports on the relative growth have also been made in our country, of which Shimizu's was rather exhaustive. However, the report was based upon Shimizu's recalculation of the data coming from other investigators such as Negishi, Watanabe, Tappe and Donaldson, rather than upon the data obtained by himself from actual measurement of animals of his own breeding. The present report concerns with the study on the development of various parts of the body including the main internal organs which were collected from albino rats bred in the author's laboratory. The results of the measurement of these animals were used to calculate the relative growth rates of each bodily part and each organ against growth rate either of body length or of body weight.

MATERIAL AND METHOD

The embryos, sucklings and adults of the albino rat were used as the materials. The embryo to be studied for each stage of growth was collected in the following way: Male and female adult rats, one for each sex, were caged together for 12 hours, at the termination of which both were separated. The female was kept singly for another 12 hours, and embryos delivered from her meanwhile were designated as the first day embryos. Based on this dating embryos and sucklings were daily collected from 13th embryonic day on to the 20th day after birth, and from then further on to the 50th day sucklings were collected once in 5 days. Besides these, adults animals were collected freely.

The measurement was worked on the following items at each growth stage of the animal.

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

Embryo :

- 1) Head to tail length
- 2) Body weight

Suckling and Adult :

- 3) Head to tail length
- 4) Body length
- 5) Body weight
- 6) Length between lower lip and anus
- 7) External orbital breadth
- 8) Internal orbital breadth
- 9) Breadth of rima palpebrae
- 10) Mouth breadth
- 11) Maximum face breadth
- 12) Maximum head length
- 13) Maximum head breadth
- 14) Length of mandibular angle

- 15) Height of ramus mandibularis

- 16) Length of upper extremities

- a) Humerus
- b) Ulna
- c) Radius

- 17) Length of lower extremities

- a) Femur
- b) Tibia

- 18) Length of intestine

- 19) Heart weight

- 20) Lung weight

- 21) Stomach weight

- 22) Liver weight

- 23) Kidneys weight

- 24) Spleen weight

- 25) Thymus weight

Method

Calipers were used for the measurement of length, and beam-balance or, if necessary, an analytical balance was used for the measurement of weight. In the study of relative growth the equation $y=bx^{\alpha}$ was utilized following the previous investigators. In the post-natal animals the growth rates in body weight, in lengths of body and four extremities, in lengths of various parts of head and in lengths of extremity bones were studied against the body length, and the weights of various internal organs were studied of the growth rates against the body weight. In the embryo of the animal the growth rate of body weight against the head to tail length was studied. The data presented here express the mean values for the respective part or item in the respective growth stage of the animal. Here x represents body length or body weight, and y represents each part of the body or each internal organ. The relative growth rate α and log b were calculated by the method of least squares. The value thus obtained were further studied on the logarithmic graphs.

RESULTS

The results obtained for each item of measurement were shown by Tables and Figures together with brief accounts of the developmental phases involved.

1) Head to tail length of the embryo.

The length increases slowly from the 13th to the 19th embryonic day when it reaches 1.63cm. By the 20th embryonic day, however, an abrupt increase takes place attaining as much as 2.49cm, an increase shared also by body weight growth simultaneously. (Table 1, Fig 1)

Table 1

Days	13	14	15	16	17	18	19
M±m (cm)	0.86±0.02	1.07±0.01	1.30±0.02	1.45±0.04	1.50±0.01	1.54±0.01	1.63±0.03
σ	0.05	0.04	0.05	0.11	0.01	0.04	0.09

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(3) --201--

20	21
2.49 ± 0.02	2.54 ± 0.04
0.09	0.11

Fig. 1

Fig. 2

2) Body weight of the embryo.

It increases steadily from the 13th to the 21th day just before birth. But it increases abruptly in two days from the 19th to the 20th day and acquires as much as 2 times its previous weight. (Table 2, Fig. 2)

Table 2

Days	13	14	15	16	17	18	19
M±m (gr)	0.11 ± 0.03	0.26 ± 0.01	0.30 ± 0.01	0.41 ± 0.01	0.49 ± 0.01	0.56 ± 0.01	0.74 ± 0.03
σ	0.01	0.04	0.02	0.03	0.01	0.04	0.09

20	21
1.85 ± 0.05	1.98 ± 0.05
0.18	0.15

3) Head to tail length (post-natal).

The length of 5.85cm at the first day of birth increases with a constant rate attaining about 2 times increase by the 16th, about 3 times increase by the 35th and about 4 times increase by the 50th post-natal day. (Table 3, Fig. 3).

Table 3

Days	1	2	3	4	5	6	7
M±m (cm)	5.85 ± 0.04	6.73 ± 0.20	6.95 ± 0.05	7.05 ± 0.06	7.35 ± 0.10	7.78 ± 0.13	7.98 ± 0.11
σ	0.09	0.40	0.10	0.11	0.20	0.26	0.22

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

8	9	10	11	12	13	14	15
8.08 ± 0.15	9.03 ± 0.17	9.60 ± 0.18	9.65 ± 0.30	10.65 ± 0.34	10.78 ± 0.20	11.38 ± 0.24	11.78 ± 0.07
0.30	0.33	0.37	0.59	0.67	0.39	0.48	0.15

16	17	18	19	20	25	30	35
12.45 ± 0.08	12.88 ± 0.17	13.03 ± 0.29	13.15 ± 0.26	13.38 ± 0.15	16.63 ± 0.15	17.45 ± 0.15	18.75 ± 0.40
0.17	0.34	0.58	0.52	0.30	0.30	0.30	0.80

40	45	50	ad
21.25 ± 0.31	22.08 ± 0.40	23.03 ± 0.51	32.00 ± 1.27
0.61	0.80	1.02	4.02

※ ad (adult)

Fig. 3

4) Body length.

The body lengths for the first, 25th and 50th day after birth were respectively 4.48 cm, 9.65cm, and 13.05cm, the rate of growth throughout the entire period remaining nearly constant. (Table 4, Fig. 4)

Table 4

Days	1	2	3	4	5	6	7
$M \pm m$ (cm)	4.48 ± 0.04	4.80 ± 0.06	4.73 ± 0.13	5.13 ± 0.04	5.30 ± 0.11	5.33 ± 0.11	5.75 ± 0.10
σ	0.08	0.12	0.25	0.08	0.22	0.22	0.21

8	9	10	11	12	13	14	15
5.88 ± 0.07	6.00 ± 0.10	6.53 ± 0.02	6.55 ± 0.18	6.93 ± 0.16	7.18 ± 0.14	7.33 ± 0.13	7.55 ± 0.19
0.15	0.20	0.04	0.36	0.31	0.29	0.25	0.38

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(5) - 203 -

16	17	18	19	20	25	30	35
7.55 ± 0.04	7.80 ± 0.08	7.90 ± 0.08	8.43 ± 0.13	8.60 ± 0.28	9.65 ± 0.25	10.20 ± 0.07	10.30 ± 0.35
0.09	0.16	0.16	0.26	0.56	0.50	0.14	0.70
40	45	50	ad				
11.75 ± 0.09	12.03 ± 0.13	13.05 ± 0.29	19.00 ± 0.28				
0.18	0.26	0.57	0.89				

Fig. 4

5) Body weight.

The weight 5.55g shown at the first day of birth amounts 2 times that in the embryo directly before birth.

However, after that the rate of increase returns normal so that it takes for the first day value nearly 9, 15 and 19 days to attain about 2-, 3-, 4- and 12 times increases respectively. (Table 5, Fig. 5)

Table 5

Days	1	2	3	4	5	6	7
M $\pm$ m (gr)	5.55 ± 0.04	5.94 ± 0.16	6.03 ± 0.23	7.05 ± 0.28	7.23 ± 0.13	8.57 ± 0.18	9.73 ± 0.25
σ	0.09	0.33	0.46	0.56	0.27	0.36	0.51
8	9	10	11	12	13	14	15
9.74 ± 0.56	10.84 ± 0.95	12.53 ± 0.64	14.28 ± 0.02	15.03 ± 1.31	15.38 ± 0.98	16.03 ± 0.85	16.45 ± 0.04
1.11	1.90	1.29	0.04	2.63	1.96	1.70	0.09
16	17	18	19	20	25	30	35
17.60 ± 0.04	18.50 ± 1.35	18.98 ± 0.03	23.60 ± 0.14	25.95 ± 2.07	32.20 ± 3.73	32.93 ± 0.73	39.78 ± 0.59
0.08	2.71	0.06	0.27	4.14	7.46	1.46	1.18
40	45	50	ad				
48.90 ± 1.01	57.23 ± 1.53	67.43 ± 3.08	197.40 ± 11.43				
2.01	3.07	6.16	36.12				

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

Fig. 5

6) Length between lower lip and anus.

The value 4.08cm at the first day of birth increases nearly 2 times (8.75cm) by the 25th day, nearly 3 times (13.58cm) by the 50th day showing that the rate of increase, alike that in the body length, maintains constancy throughout the period.

(Table 6, Fig. 6)

Table 6

Days	1	2	3	4	5	6	7
M $\pm$ m (cm)	4.08 $\pm$ 0.04	4.23 $\pm$ 0.07	4.35 $\pm$ 0.06	4.53 $\pm$ 0.04	4.65 $\pm$ 0.12	4.65 $\pm$ 0.19	5.28 $\pm$ 0.08
σ	0.08	0.15	0.11	0.08	0.23	0.38	0.16
8	9	10	11	12	13	14	15
5.23 $\pm$ 0.10	5.40 $\pm$ 0.06	5.80 $\pm$ 0	5.80 $\pm$ 0.15	6.00 $\pm$ 0.15	6.33 $\pm$ 0.28	6.43 $\pm$ 0.10	6.45 $\pm$ 0.10
0.19	0.12	0	0.31	0.31	0.55	0.19	0.21
16	17	18	19	20	25	30	35
6.83 $\pm$ 0.08	6.85 $\pm$ 0.14	7.00 $\pm$ 0.10	7.35 $\pm$ 0.12	7.50 $\pm$ 0.28	8.75 $\pm$ 0.26	8.98 $\pm$ 0.22	9.02 $\pm$ 0.02
0.16	0.29	0.20	0.23	0.56	0.51	0.43	0.04
40	45	50	ad				
10.75 $\pm$ 0.19	10.75 $\pm$ 0.11	13.58 $\pm$ 0.23	16.60 $\pm$ 0.19				
0.38	0.22	0.46	0.60				

Fig. 6

7) External orbital breadth.

The values at the 1st, 25th and 50th day after birth are respectively 1.80cm, 1.63cm

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(7) - 205 -

and 1.80cm, the rate of increase until 50th day being held nearly constant. The value in the adult is 1.97cm. (Table 7, Fig. 7)

Table 7

Days	1	2	3	4	5	6	7
M±m (cm)	1.08±0.04	1.08±0.02	1.15±0.03	1.18±0.02	1.03±0.02	1.18±0.02	1.28±0.02
σ	0.08	0.04	0.05	0.04	0.04	0.04	0.04
8	9	10	11	12	13	14	15
1.34±0.02	1.35±0.03	1.38±0.04	1.43±0.02	1.43±0.02	1.43±0.04	1.45±0.03	1.50±0.04
0.04	0.05	0.08	0.04	0.04	0.08	0.05	0.07
16	17	18	19	20	25	30	35
1.50±0.04	1.50±0	1.50±0	1.53±0.02	1.58±0.02	1.63±0.04	1.65±0.03	1.68±0.04
0.07	0	0	0.04	0.04	0.08	0.05	0.08
40	45	50	ad				
1.70±0	1.73±0.02	1.80±0	1.97±0.03				
0	0.04	0	0.09				

Fig. 7

8) Internal orbital breadth.

The values at the 1st, 25th and 50th day after birth are respectively 0.81cm, 1.10cm and 1.23cm, during which nearly the same rate of increase is maintained. As in the case of external orbital breadth even the value for the adult fails to attain twice that for the first day animal. (Table 8, Fig. 8)

Table 8

Days	1	2	3	4	5	6	7
M±m (cm)	0.81±0.01	0.84±0.02	0.85±0.01	0.86±0.01	0.86±0.01	0.89±0.01	0.92±0.01
σ	0.02	0.04	0.02	0.02	0.02	0.02	0.02

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

— 206 — (8)

Days	8	9	10	11	12	13	14
M±m (cm)	0.94±0.02	0.96±0.02	0.98±0.01	1.00±0.01	1.00±0.01	1.01±0.02	1.03±0.04
σ	0.04	0.04	0.02	0.03	0.03	0.04	0.08
15	16	17	18	19	20	25	30
1.06±0.02	1.07±0.03	1.08±0.01	1.08±0.03	1.08±0.01	1.10±0.02	1.10±0.02	1.13±0.02
0.04	0.06	0.02	0.05	0.02	0.03	0.04	0.04
35	40	45	50	ad			
1.13±0.03	1.14±0.02	1.19±0.01	1.23±0.02	1.41±0.07			
0.06	0.04	0.03	0.04	0.24			

Fig. 8

9) Breadth of rima palpebrae.

The value at the first day of birth is 0.30cm, thenceforth the growth until the 50th day being held constant.

The rate is relatively small, with the value 0.66cm at the 50th day, nearly twice that at the 1st day of birth. (Table 9, Fig. 9)

Table 9

Days	1	2	3	4	5	6	7
M±m (cm)	0.30±0.01	0.32±0.01	0.34±0.01	0.35±0.01	0.37±0.01	0.37±0.01	0.40±0.02
σ	0.02	0.02	0.03	0.03	0.02	0.02	0.05
8	9	10	11	12	13	14	15
0.43±0.02	0.44±0.02	0.49±0.01	0.49±0.01	0.50±0.01	0.50±0	0.50±0	0.50±0
0.04	0.04	0.02	0.02	0.02	0	0	0
16	17	18	19	20	25	30	35
0.50±0.02	0.52±0.01	0.52±0.01	0.52±0.01	0.56±0.02	0.58±0.01	0.58±0.01	0.59±0.01
0.04	0.02	0.02	0.02	0.04	0.03	0.03	0.02

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(9) — 207 —

40	45	50	ad
0.59 ± 0.05	0.60 ± 0.06	0.66 ± 0.01	0.80 ± 0.01
0.10	0.12	0.02	0.02

Fig. 9

10) Mouth breadth.

The values at the 1st, 10th, 20th, 30th, 40th and 50th are respectively 0.56cm, 0.69cm, 0.81cm, 0.85cm and 0.91cm, increasing with approximately the same constant rate. But the rate is small, the value for the adult not exceeding 1.5 times the value for 1st day animal. (Table 10, Fig.10)

Table 10

Days	1	2	3	4	5	6	7
M±m (cm)	0.56±0.02	0.58±0.02	0.58±0.01	0.60±0.002	0.61±0.01	0.62±0.01	0.65±0.02
σ	0.04	0.04	0.02	0.004	0.02	0.02	0.04
8	9	10	11	12	13	14	15
0.65±0.002	0.68±0.01	0.69±0.004	0.73±0.02	0.73±0.01	0.74±0.03	0.75±0.03	0.75±0.04
0.004	0.02	0.008	0.04	0.02	0.05	0.06	0.09
16	17	18	19	20	25	30	35
0.77±0.02	0.79±0.04	0.79±0.03	0.80±0.002	0.81±0.02	0.83±0.01	0.85±0.04	0.86±0.02
0.04	0.07	0.06	0.004	0.03	0.03	0.09	0.04
40	45	50	ad				
0.88±0.02	0.88±0.01	0.91±0.01	0.81±0.02				
0.05	0.02	0.02	0.05				

Fig. 10

11) Maximum face breadth.

The value 0.55cm at the first day of birth increases approximately twice by 11th day

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

with 1.11cm, but thenceforth the rate of increase becomes moderate and attains 1.49 at the 50th day (nearly 3 times), approximately 2.10cm (nearly 4 times) at the adult. (Table 11, Fig. 11)

Table 11

Days	1	2	3	4	5	6	7
M±m (cm)	0.55±0.03	0.61±0.01	0.65±0.004	0.69±0.01	0.83±0.06	0.87±0.01	0.92±0.01
σ	0.04	0.02	0.01	0.02	0.13	0.02	0.02
8	9	10	11	12	13	14	15
0.95±0.004	1.02±0.01	1.06±0.004	1.11±0.01	1.12±0.01	1.15±0.01	1.16±0.01	1.18±0.01
0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02
16	17	18	19	20	25	30	35
1.20±0.03	1.25±0.02	1.26±0.01	1.27±0.01	1.31±0.01	1.36±0.02	1.39±0.04	1.40±0.01
0.05	0.04	0.02	0.02	0.02	0.04	0.07	0.02
40	45	50	ad				
1.40±0.01	1.45±0.01	1.49±0.02	2.10±0.03				
0.02	0.02	0.05	0.12				

Fig. 11

12) Maximum head length.

The value at the 1st day of birth is 1.58cm. Thenceforth the rate of increase is moderate, showing 3.26cm (nearly 2 times) by the 45th day and 4.22cm (nearly 3 times) at the adult. (Table 12, Fig. 12)

Table 12

Days	1	2	3	4	5	6	7
M $\pm$ m (cm)	1.58 $\pm$ 0.02	1.60 $\pm$ 0	1.64 $\pm$ 0.01	1.70 $\pm$ 0	1.74 $\pm$ 0.01	1.82 $\pm$ 0.01	1.90 $\pm$ 0.04
σ	0.03	0	0.02	0	0.02	0.02	0.05

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(11) — 209 —

8	9	10	11	12	13	14	15
1.90±0.02	2.08±0.01	2.26±0.02	2.40±0.05	2.47±0.03	2.58±0.03	2.65±0.01	2.75±0.02
0.03	0.03	0.04	0.09	0.06	0.07	0.02	0.05
16	17	18	19	20	25	30	35
2.79±0.04	2.84±0.004	2.89±0.02	2.90±0.01	2.91±0.01	2.99±0.02	3.05±0.02	3.16±0.02
0.07	0.01	0.04	0.02	0.02	0.04	0.04	0.04
40	45	50	ad				
3.20±0.01	3.26±0.03	3.32±0.06	4.22±0.08				
0.02	0.06	0.11	0.17				

Fig. 12

13) Maximum head breadth.

The value at the 1st day of birth is 0.81cm and the value at the adult is 1.63cm (nearly 2 times), showing relatively small rate of growth in comparison to other parts and organs. (Table 13, Fig. 13)

Table 13

Days	1	2	3	4	5	6	7
M±m (cm)	0.81±0.01	0.82±0	0.85±0	0.88±0.02	0.97±0.01	1.07±0.02	1.08±0.02
σ	0.02	0	0	0.03	0.02	0.03	0.03
8	9	10	11	12	13	14	15
1.07±0.01	1.21±0.004	1.22±0.01	1.29±0.01	1.29±0.01	1.31±0.01	1.33±0.07	1.35±0.01
0.03	0.01	0.02	0.02	0.02	0.02	0.15	0.02
16	17	18	19	20	25	30	35
1.37±0.01	1.39±0.01	1.40±0.004	1.41±0.01	1.42±0.004	1.43±0.01	1.45±0.02	1.4. ±0.02
0.02	0.02	0.01	0.02	0.01	0.02	0.04	0.04
40	45	50	ad				
1.46±0.01	1.48±0.01	1.55±0.04	1.63±0.01				
0.03	0.03	0.08	0.02				

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

Fig. 13

14) Length of the mandibular angle.

The measurement was done at the 8th day of birth, when it showed 1.22cm in the left, 1.29cm in the right. The growth thenceforth proceeded slowly, showing in approximately 50 days 2.24cm in the left 2.21cm in the right, that is, only 2 times values.

This is comparatively small rate of growth. (Table 14, Fig. 14)

Fig. 14 (Right)

Table 14

— Right
— Left

Days	8	9	10	11	12	13	14
R M $\pm$ m(cm)	1.29 $\pm$ 0.01	1.30 $\pm$ 0.02	1.37 $\pm$ 0.04	1.38 $\pm$ 0.04	1.51 $\pm$ 0.02	1.52 $\pm$ 0.04	1.54 $\pm$ 0.03
σ	0.03	0.05	0.08	0.08	0.05	0.08	0.07
L M $\pm$ m(cm)	1.22 $\pm$ 0.02	1.31 $\pm$ 0.04	1.30 $\pm$ 0.01	1.35 $\pm$ 0.04	1.50 $\pm$ 0.03	1.51 $\pm$ 0.003	1.55 $\pm$ 0.05
σ	0.03	0.07	0.03	0.08	0.06	0.01	0.09
15	16	17	18	19	20	25	30
1.58 $\pm$ 0.02	1.60 $\pm$ 0.06	1.68 $\pm$ 0.04	1.69 $\pm$ 0.01	1.78 $\pm$ 0.02	1.79 $\pm$ 0.01	1.94 $\pm$ 0.01	2.10 $\pm$ 0.01
0.03	0.12	0.08	0.02	0.04	0.02	0.02	0.03
1.56 $\pm$ 0.02	1.65 $\pm$ 0.02	1.68 $\pm$ 0.05	1.69 $\pm$ 0.01	1.75 $\pm$ 0.02	1.76 $\pm$ 0.01	1.98 $\pm$ 0.01	2.07 $\pm$ 0.02
0.05	0.05	0.09	0.03	0.04	0.02	0.02	0.04

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(13) — 211 —

35	40	45	50	ad
2.10 ± 0.02	2.11 ± 0.01	2.14 ± 0.02	2.21 ± 0.06	2.80 ± 0.04
0.03	0.02	0.04	0.11	0.14
2.10 ± 0.01	2.20 ± 0.02	2.21 ± 0.10	2.24 ± 0.03	2.81 ± 0.04
0.02	0.04	0.19	0.06	0.14

15) Height of ramus of mandibularis.

The measurement was done at the 8th day of birth when it showed the value 0.43cm in both rami. The length increased approximately 2 times(0.88cm in both rami) in 50 days. (Table 15, Fig. 15)

Table 15

Days	8	9	10	11	12	13	14
R M±m(cm)	0.43 ± 0.01	0.46 ± 0.03	0.50 ± 0.03	0.53 ± 0.02	0.53 ± 0.02	0.56 ± 0.04	0.58 ± 0.01
σ	0.02	0.05	0.06	0.04	0.04	0.08	0.02
L M±m(cm)	0.43 ± 0.01	0.49 ± 0.02	0.50 ± 0	0.50 ± 0.02	0.53 ± 0.01	0.57 ± 0.02	0.59 ± 0.03
σ	0.02	0.04	0	0.05	0.02	0.03	0.06

15	16	17	18	19	20	25	30
0.60 ± 0.02	0.61 ± 0.004	0.62 ± 0.01	0.66 ± 0.01	0.68 ± 0.01	0.72 ± 0.06	0.80 ± 0.03	0.81 ± 0.01
0.04	0.01	0.02	0.02	0.03	0.12	0.07	0.02
0.59 ± 0.01	0.59 ± 0.03	0.63 ± 0.01	0.65 ± 0.02	0.66 ± 0.01	0.68 ± 0.01	0.76 ± 0.02	0.78 ± 0.03
0.03	0.06	0.02	0.03	0.02	0.02	0.04	0.06

35	40	45	50	ad
0.81 ± 0.004	0.81 ± 0.004	0.86 ± 0.02	0.88 ± 0.01	1.22 ± 0.01
0.01	0.01	0.03	0.02	0.02
0.81 ± 0.004	0.82 ± 0.01	0.86 ± 0.02	0.88 ± 0.01	1.22 ± 0.01
0.01	0.02	0.04	0.02	0.02

Fig. 15 (Right)

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

16) Length of upper extremities.

a) Humerus :

The values at the 1st day of birth are 0.39cm in the right, 0.40cm in the left, reaching at the 15th day 0.8cm in the right and 0.82cm in the left (2 times), at the 25th day 1.37cm in both sides (nearly 3 times), at the 50th day 1.59cm in both sides (nearly 4 times), and in the adult 2.39cm bilaterally (nearly 6 times). The rate of growth was relatively constant. (Table 16a, Fig. 16a)

Fig. 16a (Right)

Table 16a

Days	1	2	3	4	5	6	7
R M±m(cm)	0.39±0.03	0.45±0	0.50±0.004	0.54±0.01	0.56±0.004	0.61±0.004	0.63±0.02
σ	0.04	0	0.01	0.02	0.01	0.01	0.02
L M±m(cm)	0.40±0	0.45±0.02	0.54±0.02	0.58±0.02	0.58±0.004	0.61±0	0.64±0.04
σ	0	0.03	0.03	0.03	0.01	0	0.06
8	9	10	11	12	13	14	15
0.64±0.02	0.64±0.004	0.67±0.01	0.70±0.004	0.74±0.01	0.79±0.004	0.80±0.04	0.81±0.004
0.03	0.01	0.02	0.01	0.02	0.01	0.09	0.01
0.63±0.02	0.65±0.02	0.68±0.01	0.69±0.004	0.77±0.01	0.80±0.01	0.81±0.01	0.82±0.01
0.03	0.04	0.03	0.01	0.02	0.02	0.02	0.02
16	17	18	19	20	25	30	35
0.82±0.02	0.85±0.004	0.89±0.01	0.98±0.06	1.06±0.03	1.37±0.01	1.39±0.01	1.46±0.02
0.04	0.01	0.02	0.13	0.02	0.02	0.03	0.04
0.86±0.003	0.88±0.03	0.91±0.01	0.97±0.08	0.98±0.07	1.37±0.01	1.38±0.01	1.45±0.03
0.01	0.06	0.03	0.16	0.14	0.02	0.03	0.05

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

(15) —213—

40	45	50	ad
1.46 ± 0.02	1.52 ± 0.03	1.59 ± 0.01	2.39 ± 0.04
0.03	0.05	0.03	0.13
1.46 ± 0.02	1.48 ± 0.02	1.59 ± 0.01	2.39 ± 0.06
0.04	0.04	0.02	0.21

b) Ulna :

The value at the 1st day of birth is 0.46cm in the right, 0.45cm in the left, at the 12th day 0.94cm in both sides (nearly 2 times), at the 50th day 1.82cm in the right, 1.79cm in the left (nearly 4 times), in the adult 2.78cm in the right, 2.79cm in the left. (Table 16b, Fig. 16b)

Table 16 b

Days	1	2	3	4	5	6	7
R M $\pm$ m(cm)	0.46 ± 0.01	0.53 ± 0.02	0.61 ± 0.004	0.61 ± 0.01	0.57 ± 0	0.65 ± 0.03	0.69 ± 0.03
σ	0.02	0.03	0.01	0.01	0	0.04	0.04
L M $\pm$ m(cm)	0.45 ± 0	0.49 ± 0.01	0.63 ± 0.02	0.59 ± 0.01	0.57 ± 0.004	0.66 ± 0.03	0.67 ± 0.04
σ	0	0.01	0.03	0.01	0.01	0.04	0.06

8	9	10	11	12	13	14	15
0.69 ± 0.04	0.75 ± 0.03	0.79 ± 0.01	0.87 ± 0.01	0.94 ± 0.02	0.96 ± 0.04	1.03 ± 0.05	1.08 ± 0.01
0.08	0.06	0.02	0.02	0.03	0.07	0.10	0.02
0.69 ± 0.03	0.78 ± 0.03	0.78 ± 0.03	0.80 ± 0.002	0.94 ± 0.06	0.97 ± 0.01	0.99 ± 0.004	1.01 ± 0.02
0.06	0.05	0.07	0.004	0.12	0.02	0.01	0.04

16	17	18	19	20	25	30	35
1.12 ± 0.11	1.14 ± 0.02	1.16 ± 0.01	1.16 ± 0.02	1.29 ± 0.03	1.61 ± 0.01	1.63 ± 0.02	1.66 ± 0.03
0.22	0.04	0.03	0.04	0.07	0.02	0.03	0.06
1.04 ± 0.01	1.08 ± 0.04	1.08 ± 0.01	1.17 ± 0.03	1.17 ± 0.02	1.62 ± 0.03	1.62 ± 0.01	1.64 ± 0.02
0.03	0.08	0.02	0.05	0.03	0.06	0.02	0.04

40	45	50	ad
1.70 ± 0.02	1.74 ± 0.04	1.82 ± 0.04	2.78 ± 0.05
0.03	0.08	0.07	0.17
1.68 ± 0.02	1.77 ± 0.03	1.79 ± 0.02	2.79 ± 0.04
0.04	0.05	0.03	0.13

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

Fig. 16b (Right)

c) Radius :

The values at the 1st day of birth is 0.38cm bilaterally, at the 13th day 0.77cm bilaterally (nearly 2 times), at the 50th day 1.42cm in the right, 1.40cm in the left (nearly 4 times), showing the same rate of growth as the preceding humerus and ulna. In the adult the value is 2.20cm in the right, 2.23cm in the left. (Table 16c, Fig 16c)

Table 16c

Days	1	2	3	4	5	6	7
R M±m(cm)	0.38±0	0.42±0.01	0.54±0.01	0.47±0.004	0.48±0.004	0.51±0.01	0.56±0.03
σ	0	0.02	0.02	0.01	0.01	0.02	0.04
L M±m(cm)	0.38±0.01	0.42±0	0.44±0.01	0.48±0.004	0.48±0	0.52±0.01	0.56±0.03
σ	0.02	0	0.02	0.01	0	0.02	0.04
8	9	10	11	12	13	14	15
0.60±0	0.66±0.02	0.66±0.02	0.67±0.01	0.74±0.01	0.77±0.02	0.80±0	0.81±0.002
0	0.04	0.04	0.02	0.02	0.04	0	0.004
0.61±0.01	0.61±0.004	0.64±0.01	0.69±0.01	0.75±0.002	0.77±0.05	0.78±0.01	0.78±0.04
0.02	0.01	0.03	0.02	0.004	0.09	0.03	0.07
16	17	18	19	20	25	30	35
0.82±0.05	0.83±0.01	0.89±0.01	0.93±0.03	0.98±0.05	1.28±0.03	1.30±0.02	1.34±0.05
0.10	0.02	0.02	0.06	0.10	0.05	0.05	0.09
0.79±0.02	0.82±0.01	0.83±0.01	0.91±0.02	0.91±0	1.28±0.01	1.34±0.03	1.35±0.02
0.03	0.02	0.02	0.05	0	0.02	0.08	0.03

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(17) — 215 —

40	45	50	ad
1.35 ± 0.01	1.37 ± 0.01	1.42 ± 0.01	2.20 ± 0.04
0.02	0.02	0.02	0.13
1.37 ± 0.01	1.38 ± 0.01	1.40 ± 0.01	2.23 ± 0.04
0.02	0.02	0.02	0.13

Fig. 16 c (Right)

17) Length of lower extremities.

a) Femur :

The values at the 1st day of birth are 0.38cm in the right, 0.43cm in the left, at the 14th day 0.84cm in the right, 0.85cm in the left (nearly 2 times), at the 40th day 1.7-8cm, 1.65cm in the left (nearly 4 times) and at the adult 3.10cm in the right, 3.16cm in the left showing nearly 8 times growth. (Table 17a, Fig. 17a)

Fig. 17 a (Right)

Table 17 a

Days	1	2	3	4	5	6	7
R M $\pm$ m(cm)	0.38 ± 0	0.43 ± 0.02	0.45 ± 0	0.56 ± 0.03	0.56 ± 0.01	0.56 ± 0.01	0.60 ± 0.004
σ	0	0.03	0	0.04	0.02	0.02	0.01
I M $\pm$ m(cm)	0.43 ± 0.02	0.50 ± 0	0.55 ± 0.04	0.54 ± 0.01	0.55 ± 0.01	0.56 ± 0.01	0.60 ± 0
σ	0.03	0	0.06	0.02	0.02	0.02	0

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

—216— (18)

8	9	10	11	12	13	14	15
0.59±0.01	0.68±0.01	0.70±0.03	0.75±0.04	0.77±0.01	0.81±0.02	0.84±0.01	0.86±0.01
0.02	0.03	0.06	0.08	0.03	0.04	0.03	0.02
0.58±0.02	0.64±0.01	0.65±0.01	0.76±0.03	0.76±0.02	0.80±0.01	0.85±0.01	0.88±0.01
0.04	0.02	0.02	0.07	0.04	0.03	0.02	0.02
16	17	18	19	20	25	30	35
0.89±0.04	0.95±0.02	1.05±0.08	1.06±0.05	1.06±0.02	1.50±0.02	1.60±0.02	1.65±0.02
0.07	0.03	0.15	0.10	0.04	0.05	0.04	0.05
0.91±0.04	0.96±0.02	1.05±0.06	1.07±0.04	1.09±0.01	1.50±0.01	1.55±0.02	1.60±0.02
0.07	0.04	0.12	0.08	0.02	0.03	0.04	0.04
40	45	50	ad				
1.78±0.02	1.79±0.04	1.82±0.21	3.10±0.07				
0.04	0.08	0.42	0.23				
1.65±0.03	1.85±0.01	1.88±0.05	3.11±0.04				
0.05	0.03	0.10	0.13				

b) Tibia :

The values at the 1st day of birth are 0.50cm in the right, 0.43cm in the left, at the 20th day 1.73cm in the right, 1.36cm in the left, at the 40th day 2.07cm in the right and left, in the adult 3.40cm in the right, 3.42cm in the left. Compared to the value at the 1st day, the right values in every remaining stage of growth are slightly larger than the left values both eventually attaining nearly 8 times increase.

(Table 17b, Fig. 17b)

Table 17 b

Days	1	2	3	4	5	6	7
R M $\pm$ m(cm)	0.50 ± 0	0.56 ± 0.03	0.60 ± 0.04	0.66 ± 0.01	0.68 ± 0.004	0.67 ± 0.004	0.71 ± 0.004
σ	0	0.04	0.05	0.02	0.01	0.01	0.01
L M $\pm$ m(cm)	0.43 ± 0.02	0.53 ± 0.02	0.65 ± 0.004	0.65 ± 0.01	0.67 ± 0.01	0.69 ± 0.01	0.70 ± 0.01
σ	0.03	0.03	0.01	0.02	0.02	0.02	0.02
8	9	10	11	12	13	14	15
0.73 ± 0.01	0.82 ± 0.03	0.84 ± 0.02	0.89 ± 0.01	1.10 ± 0.06	1.08 ± 0.04	1.14 ± 0.02	1.12 ± 0.02
0.02	0.07	0.04	0.02	0.11	0.08	0.05	0.05
0.70 ± 0.01	0.73 ± 0.01	0.83 ± 0.04	0.87 ± 0.02	0.98 ± 0.02	1.10 ± 0.01	1.12 ± 0.01	1.14 ± 0.03
0.02	0.02	0.08	0.04	0.03	0.02	0.02	0.06

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(19) — 217 —

16	17	18	19	20	25	30	35
1.12 ± 0.02	1.20 ± 0.05	1.23 ± 0.02	1.28 ± 0.02	1.73 ± 0.17	1.94 ± 0.02	2.01 ± 0.004	2.04 ± 0.02
0.05	0.09	0.04	0.03	0.34	0.05	0.01	0.04
1.17 ± 0.10	1.19 ± 0.01	1.19 ± 0.06	1.21 ± 0.02	1.36 ± 0.03	1.93 ± 0.02	1.99 ± 0.01	2.04 ± 0.02
0.21	0.02	0.11	0.04	0.07	0.04	0.03	0.04
40	45	50	ad				
2.07 ± 0.04	2.14 ± 0.02	2.24 ± 0.02	3.40 ± 0.04				
0.07	0.04	0.05	0.13				
2.07 ± 0.03	2.18 ± 0.01	2.29 ± 0.03	3.42 ± 0.05				
0.06	0.03	0.06	0.16				

Fig. 17 b (Right)

18) Length of the intestine.

The value at the first day of birth is 13.9cm, at the 6th day 26.38cm (nearly 2 times), at the 9th 41.05cm (nearly 3 times), at the 14th 43.85cm (nearly 4 times), showing approximately constant rate of growth. At the 50th day it reaches 107.5cm length (nearly 8 times) which nearly equals to that seen in the adult of the animal. (Table 18, Fig. 18)

Table 18

Days	1	2	3	4	5	6	7
$M \pm m$ (cm)	13.93 ± 0.75	20.08 ± 0.21	23.63 ± 0.19	23.83 ± 1.16	24.85 ± 0.75	26.38 ± 0.24	29.18 ± 0.4
σ	1.49	0.42	0.38	2.31	1.51	0.49	0.8
8	9	10	11	12	13	14	15
33.25 ± 3.01	41.05 ± 0.95	41.65 ± 1.17	41.78 ± 0.79	42.3 ± 1.38	42.85 ± 0.34	43.85 ± 3.12	47.4 ± 0.45
6.18	1.90	2.34	1.57	2.76	0.68	6.38	0.91

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

16	17	18	19	20	25	30	35
48.53 ± 2.57	50.25 ± 3.43	50.55 ± 2.93	53.08 ± 0.52	58.03 ± 1.30	61.38 ± 1.0	64.23 ± 1.46	82.25 ± 1.44
5.14	6.86	5.86	1.04	2.61	1.98	2.93	2.87

40	45	50	ad
84.33 ± 1.74	100.13 ± 1.80	107.5 ± 2.36	107.1 ± 0.78
3.49	3.60	4.72	2.47

Fig. 18

19) Heart weight.

The values at the 1st, 18th, 50th days and at the adult are respectively 0.015g, 0.13g (nearly 10 times), 0.525g and 0.99g, showing approximately constant growth rate. (Table 19, Fig. 19)

Table 19

Days	1	2	3	4	5
M $\pm$ m (gr)	0.015 ± 0.001	0.049 ± 0.001	0.049 ± 0.002	0.067 ± 0.003	0.075 ± 0.001
σ	0.002	0.002	0.003	0.005	0.002

6	7	8	9	10	11
0.078 ± 0.008	0.083 ± 0.01	0.083 ± 0.001	0.098 ± 0.001	0.099 ± 0.001	0.10 ± 0.007
0.015	0.02	0.002	0.002	0.002	0.014

12	13	14	15	16	17
0.105 ± 0.001	0.105 ± 0.004	0.11 ± 0.005	0.11 ± 0.006	0.118 ± 0.01	0.123 ± 0.01
0.002	0.009	0.01	0.012	0.02	0.02

18	19	20	25	30	35
0.13 ± 0.02	0.183 ± 0.01	0.195 ± 0.01	0.295 ± 0.01	0.30 ± 0.03	0.32 ± 0.01
0.03	0.02	0.02	0.02	0.06	0.02

40	45	50	ad
0.463 ± 0.01	0.455 ± 0.02	0.525 ± 0.04	0.99 ± 0.03
0.02	0.03	0.08	0.09

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(21) — 219 —

Fig. 19

20) Lung weight.

The values at the 1st, 20th, 50th days and at the adult are respectively 0.13g, 0.36g (nearly 3 times), 0.79g (nearly 6 times) and 1.65g. (Table 20, Fig. 20)

Table 20

Days	1	2	3	4	5	6	7
M±m (gr)	0.13±0.01	0.15±0.002	0.17±0.01	0.19±0.01	0.24±0.03	0.24±0.01	0.25±0.02
σ	0.02	0.004	0.02	0.02	0.07	0.02	0.05
8	9	10	11	12	13	14	15
0.25±0.02	0.25±0.03	0.27±0.04	0.27±0.04	0.28±0.04	0.29±0.03	0.30±0.02	0.31±0.01
0.05	0.05	0.08	0.08	0.08	0.07	0.04	0.02
16	17	18	19	20	25	30	35
0.32±0.02	0.33±0.01	0.33±0.02	0.34±0.02	0.36±0.02	0.37±0.05	0.40±0.04	0.42±0.05
0.04	0.03	0.03	0.04	0.04	0.09	0.07	0.09
40	45	50	ad				
0.44±0.01	0.56±0.04	0.79±0.03	1.65±0.07				
0.02	0.07	0.07	0.23				

Fig. 20

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

21) Stomach weight.

The values at the 1st, 25th and 50th days of birth are respectively 0.03g, 0.37g (nearly 10 times) and 0.6g (nearly 20 times) with generally constant growth rate.

(Table 21, Fig. 21)

Table 21

Days	1	2	3	4	5	6	7
M±m (gr)	0.03±0.002	0.04±0.001	0.05±0.004	0.05±0.001	0.06±0.001	0.06±0.003	0.07±0.003
σ	0.004	0.002	0.01	0.002	0.002	0.01	0.01
8	9	10	11	12	13	14	15
0.07±0.03	0.08±0.01	0.08±0.01	0.10±0.003	0.10±0.002	0.10±0.01	0.11±0.02	0.12±0.01
0.06	0.02	0.02	0.01	0.004	0.02	0.05	0.02
16	17	18	19	20	25	30	35
0.12±0.01	0.13±0.02	0.15±0.02	0.15±0.02	0.24±0.02	0.37±0.01	0.44±0.03	0.45±0.04
0.02	0.03	0.04	0.04	0.04	0.02	0.07	0.09
40	45	50	ab				
0.46±0.01	0.53±0.06	0.60±0	1.46±0.08				
0.02	0.12	0	0.25				

Fig. 21

22) Liver weight.

The values at the 1st, 11th, 16th, 20th and 50th days are respectively 0.27g, 0.55g (2 times), 0.78g (3 times), 1.08g (4 times) and 4.73g (18 times) with generally constant growth rate. (Table 22, Fig. 22)

Table 22

Days	1	2	3	4	5	6	7
M±m (gr)	0.27±0.02	0.28±0.004	0.32±0.01	0.32±0.01	0.35±0.004	0.37±0.01	0.38±0.01
σ	0.04	0.01	0.02	0.02	0.01	0.02	0.02

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RALS

(23) — 221 —

8	9	10	11	12	13	14	15
0.40±0.03	0.44±0.02	0.48±0.03	0.55±0.03	0.58±0.06	0.58±0.05	0.60±0.01	0.67±0.02
0.06	0.04	0.05	0.06	0.12	0.09	0.03	0.03
16	17	18	19	20	25	30	35
0.78±0.02	0.80±0.06	0.83±0.06	1.02±0.01	1.08±0.03	1.53±0.11	1.95±0.20	2.14±0.19
0.04	0.13	0.11	0.03	0.06	0.22	0.40	0.39
40	45	50	ab				
3.30±0.25	3.95±0.14	4.73±0.18	10.40±0.49				
0.51	0.27	0.35	1.56				

Fig. 22

23) Kidney weight.

The value at the 1st day of birth is 0.019g which is increased 2 times (0.045g) at the 5th, nearly 4 times (0.08g) at the 9th, nearly 5 times at the 15th, nearly 10 times at the 20th and nearly 40 times at the 50th day and thenceforth the value shows approximately 0.84g, nearly equivalent to those of the adult. (Table 23, Fig. 23)

Table 23

Days	1	2	3	4	5	6	7
M±m (gr)	0.019±0.001	0.021±0.001	0.030±0.001	0.032±0.001	0.045±0.001	0.046±0.003	0.049±0.003
σ	0.002	0.002	0.002	0.002	0.002	0.01	0.01
8	9	10	11	12	13	14	15
0.050±0.004	0.080±0.004	0.080±0.014	0.088±0.01	10.09±0.01	0.093±0.004	0.094±0.01	0.10±0
0.01	0.01	0.03	0.02	0.02	0.01	0.02	0
16	17	18	19	20	25	30	35
0.108±0.01	0.12±0.02	0.145±0.01	0.17±0.02	0.175±0.02	0.2±0	0.208±0.004	0.255±0.02
0.02	0.03	0.02	0.04	0.04	0	0.01	0.04
40	45	50	ad				
0.36±0.02	0.523±0.06	0.80±0.43	0.84±0.03				
0.03	0.13	0.87	0.08				

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

—222— (24)

Fig. 23

24) Spleen weight.

The value 0.008g at the 1st day of birth is increased 10 times (0.08g) at the 15th day, 23 times (0.185g) at the 50th day and to 0.58g at the adult. (Table 24, Fig. 24)

Table 24

Days	1	2	3	4	5	6
$M \pm m$ (gr)	0.008 ± 0.006	0.013 ± 0.001	0.013 ± 0.0004	0.017 ± 0.0015	0.020 ± 0.0009	0.022 ± 0.0007
σ	0.0012	0.002	0.0007	0.0031	0.0019	0.0014
7	8	9	10	11	12	13
0.031 ± 0.007	0.033 ± 0.008	0.037 ± 0.004	0.043 ± 0.007	0.043 ± 0.006	0.068 ± 0.0004	0.07 ± 0.004
0.014	0.016	0.007	0.013	0.011	0.0008	0.007
14	15	16	17	18	19	20
0.075 ± 0.006	0.080 ± 0.004	0.084 ± 0.003	0.088 ± 0.004	0.088 ± 0.011	0.093 ± 0.004	0.095 ± 0.004
0.011	0.007	0.007	0.008	0.022	0.008	0.009
25	30	35	40	45	50	ad
0.11 ± 0.006	0.113 ± 0.011	0.115 ± 0.013	0.12 ± 0.024	0.12 ± 0.006	0.185 ± 0.008	0.58 ± 0.11
0.012	0.023	0.026	0.47	0.012	0.017	0.36

Fig. 24

25) Thymus weight.

The value 0.005g at the 1st day of birth is increased 10 times (0.053g) at the 16th day, 20 times (0.101g) at the 19th day, 40 times (0.235g) at the 50th day, showing constant growth rate. (Table 25, Fig. 25)

Table 25

Days	1	2	3	4	5	6
$M \pm m$ (gr)	0.005 ± 0.001	0.016 ± 0.002	0.015 ± 0.001	0.018 ± 0.001	0.019 ± 0.001	0.020 ± 0.001
σ	0.002	0.004	0.002	0.002	0.002	0.002

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(25) — 223 —

7	8	9	10	11	12	13
0.020 ± 0.001	0.020 ± 0.001	0.021 ± 0.001	0.021 ± 0.001	0.026 ± 0.002	0.033 ± 0.008	0.033 ± 0.005
0.002	0.002	0.002	0.002	0.004	0.016	0.010
14	15	16	17	18	19	20
0.042 ± 0.03	0.037 ± 0.005	0.053 ± 0.014	0.058 ± 0.011	0.098 ± 0.002	0.101 ± 0.002	0.103 ± 0.002
0.06	0.011	0.029	0.023	0.004	0.004	0.004
25	30	35	40	45	50	ad
0.120 ± 0.01	0.133 ± 0.018	0.135 ± 0.014	0.15 ± 0.021	0.183 ± 0.01	0.235 ± 0.02	0.60 ± 0.01
0.02	0.036	0.027	0.041	0.02	0.04	0.02

Fig. 25

THE RELATIVE GROWTH RATES

The data from every stage of the animal's growth as presented in the foregoing were utilized in studying the relative growth of the parts of the body as well as of its internal organs in the albino rats and the values represented by α and $\log b$ were calculated.

Body weight against head to tail length in the embryo.

- 1) The relation of the body weight to the head to tail length was studied by plotting the latter on the x-axis and the former on the y-axis of logarithmic graph as shown in Fig. 26.

The relation was generally linear. When the growth of the embryo until 19th fetal day was designated as the first stadium and that at the 20th to 21th day as the second stadium $\alpha_1=2.59$, $\log b_1=0.685$ and $\alpha_2=3.0$, $\log b_2=0.124$ were respectively computed.

However, when the relative growth of the body weight and the head to tail length were observed throughout the two stages, $\alpha=5.02$, $\log b=0.0681$ were obtained, revealing that the growth in body weight considerably exceeded that in head to tail length. (Table 26, Fig.26, Fig.40)

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

— 224 — (26)

Table 26

x	y	α	logb	x	y	α	logb
Head to tail length	Body weight (1st stage)	2.59	0.6851	Body length	Radius length (R)	1.26	0.0629
"	" (2nd stage)	3.0	0.124	"	Femur length (L)	1.41	0.0531
"	" (entire stages)	5.02	0.0681	"	" (R)	1.48	0.0457
Body length	Body weight	2.42	0.1376	"	Tibia length (L)	1.45	0.0592
"	Max. face breadth	0.82	0.2085	"	" (R)	1.58	0.0465
"	Max. head length	0.89	0.3042	Body weight	Heart weight	0.99	0.0078
"	Max. head breadth	0.52	0.4315	"	Lung weight	0.58	0.0593
"	Humerus length (L)	1.21	0.0749	"	Stomach weight	1.12	0.0056
"	" (R)	1.25	0.0683	"	Liver weight	1.12	0.0498
"	Ulna length (L)	1.27	0.0764	"	Kidney weight	1.15	0.0040
"	" (R)	1.28	0.0768	"	Spleen weight	1.06	0.0028
"	Radius length (L)	1.25	0.0495	"	Thymus weight	1.24	0.0013

Relative growth after birth

2) Relative growth of body weight.

The body lengths and the body weight were respectively plotted on the x-axis and y-axis as shown in Fig. 27. It was shown that both growths proceeded in parallel throughout the entire period with the same rate. The value $\alpha=2.42$, though decreased to approximately one half the value 5.02 shown at the animal's fetal stage, still marked a considerable growth rate of the body weight as compared to the length. (Table 26, Fig. 27, Fig. 40)

3) Relative growth of maximum face breadth.

As shown in Fig. 28 the maximum face breadth increased nearly in parallel with the body length, but the value $\alpha=0.82$ showed slight retardation in the growth as compared to the body length. (Table 26, Fig. 28)

4) Relative growth of maximum head length.

Both developed with nearly the same rate, but the value $\alpha=0.89$ showed a slight retardation in the growth of maximum head length as compared to the body length. (Table 26, Fig. 29)

5) Relative growth of maximum head breadth.

As shown in Fig. 30 the value $\alpha=0.52$ showed that the growth of maximum head breadth was inferior to that of body length as it was the same with the maximum

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(27) --225--

head length. (Table 26, Fig. 30)

6) Relative growth in the upper extremity.

The humerus, ulna and radius in both sides develop at approximately the same rate. The α value of humerus are 1.21 on the left, 1.25 on the right, of ulna 1.27 on the left, 1.28 on the right, of radius 1.25 on the left, 1.26 on the right, all showing very little difference between each side. As shown in Fig. 31 a, b, c, they slightly exceeded the growth rate of the body length. (Table 26, Fig. 31 a, b, c, Fig. 41)

7) Relative growth of lower extremity.

The constituent bones develop also at approximately the same rate. The α values of the femur are 1.41 in the left, 1.48 in the right, of the tibia 1.45 in the left, 1.58 in the right, showing little difference between each side. The growth rates of these bones are superior to that of body length. (Table 26, Fig. 32 a, b, Fig. 41)

8) Relative growth of heart weight.

The α value is 0.99 throughout the entire period, showing slight retardation in the heart weight increase against the body weight increase, but generally in parallel with the latter. (Table 26, Fig. 33, Fig. 42)

9) Relative growth of lung weight.

The value α is 0.58 showing marked retardation of growth as compared to the body weight. (Table 26, Fig. 34, Fig. 42)

10) Relative growth of stomach weight.

The growth rate of stomach slightly exceeds that of the body weight. The α value 1.12 persists throughout the entire period. (Table 26, Fig. 35, Fig. 42)

11) Relative growth of liver weight.

Alike the preceding case the growth rate of liver exceeds slightly that of the body weight, the value α being 1.1. The growth rate of liver was nearly constant throughout the entire period. (Table 26, Fig. 36, Fig. 42)

12) Relative growth of kidney weight.

Alike the foregoing cases of stomach and liver, kidney weight increases at nearly the constant rate. The growth rate exceeds slightly that of body weight, the value being 1.115. (Table 26, Fig. 37, Fig. 42)

13) Relative growth of spleen weight.

The rate of increase is nearly constant throughout the entire period, exceeding slightly that of body weight with the value α 1.06. (Table 26, Fig. 38, Fig. 42)

14) Relative growth of thymus weight.

As shown in Fig. 39 the rate of increase is nearly constant throughout the entire period, exceeding slightly that of body weight with the value α 1.24. (Table 26, Fig. 39, Fig. 42)

SUMMARY

It would be evident from the preceding data that the rates of growth are not uniform with every part and organ of the animal's body. To summarize the whole data, however, it would be concluded that the rate of growth in the body weight during the fetal period and directly after birth is especially pronounced and that the increases in the weights of every internal organ was larger than those in the other parts of the body.

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

As shown in Table 26, the relative growth rates also differ between each part and organ of the body. The largest α value obtained is 5.02 in the body weight in animal's fetal period, followed by 2.42 in the body weight after birth of the animals. (Fig. 26) As for the growth rates of bones, the value α of the lower extremities is comparatively large showing the values 1.41 to 1.58, while that of the upper extremities slightly falls behind with the values 1.21 to 1.28. (Fig. 41) The bones in the head and face are poor in the growth rate in comparison to the growth rate of body length showing 0.52 to 0.89, values smaller than 1.0. Of the relative growth rates of the internal organs, the smallest is the value 0.58 for the lung, followed by 0.99 for the heart, both showing growth lesser than that of the body weight. On the contrary, the values 1.06 for the spleen, 1.12 for the stomach and the liver, 1.15 for the kidneys, 1.24 for the thymus, these values show that all these organs slightly exceed the body weight in the growth rates.

It has been known from reviewing the works of previous investigators that Shimizu had also studied the coefficients of relative growth in albino rats utilizing the combined data accumulated by Negishi and Watanabe concerning the tail, by Tappe concerning the body weight and by Donaldson concerning the various organs.

The α values 2.28 to 2.29 which Shimizu has given as the relative growth coefficient of the body weight against the head to tail-root length is fairly comparable with the author's value 2.42. Unfortunately no report being available as to relative growth of any part or organ of the rat embryo, the present author's value 5.02 was here given which showed a vigorous growth rate occurring in the fetal life of the animal.

Of the relative growth rates of various internal organs against the body weight, Shimizu, concerning the heart, has given the values from 0.77 to 1.03 regardless of sex difference of the animal, and Clark has given the value approximately of 0.8 in the mice, rabbits and dogs. These are closely comparable with the author's value 0.99. Of the lung Shimizu, in the albino rats, gave the values from 0.70 to 0.84, Brody, in the dog, 0.85 and the present author 0.58.

Of the stomach Shimizu gave values from 0.63 to 1.34 in the albino rats, Brody 0.72 of the stomach and the intestine in the dogs and the present author 1.12 in the albino rats showing a slight difference present between these data.

Of the liver Shimizu gave values from 0.75 to 1.81, Brody 0.7 in the dogs and the present author 1.12, an intermediate value of Shimizu's data.

Of kidneys Shimizu gave values from 0.81 to 1.75, while the present author gave 1.15.

Of spleen Shimizu's value were 0.93 to 1.56 and the present author's 1.06.

As shown above, the comparison of the author's data on the relative growth rates of internal organs against the body weight with those of the previous authors proves that there is general agreement between these except minor differences observed between two or three different organs.

According to Shimizu's opinion the α value of the internal organs did not change appreciably after the animal's body weight reached approximate value of 35g, and Donaldson added further that 35g of body weight was gained at the 34th to 35th day after birth of the animal and that this corresponded also to the 3rd molar eruption. The present author also confirmed that the animals weighed about 35g at the period from 30th to 35th

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(29) — 227 —

day after birth and that around at the same time the 3rd molar made their appearances. In this respect it would be worth mentioning here that Outhouse and Mendell observed that the time of 3rd molar eruption was least influenced either by good or poor growth of the animal, they appeared in the time when the growth activity of the animal had reached its prime and the rates of growth of every internal organs had become constant. He also observed that no marked developmental changes took place after the eruption of the 3rd molar. These observations were confirmed also in the present author's study.

CONCLUSIONS

The development of the embryos, sucklings and adults of the albino rats were studied at intervals either daily when it dealt with the embryos from the 13th to the day of birth and with the sucklings from the 1st day of birth to the 20th day, or once in five day when it dealt with the animals from 20th to 50th day and on to the adulthood.

- 1) The items of measurement : In the embryo head to tail length and body weight, in the post-natal animal head to tail length, body length, body weight, length between lower lip and anus, external orbital breadth, internal orbital breadth, breadth of rima palpebrae, mouth breadth, maximum face breadth, maximum head length, maximum head breadth, length of mandibular angle, height of rami mandibularis, lengths of upper and lower extremities bones, length of intestine, weights of heart, lung, stomach, liver, kidneys, spleen and thymus were respectively measured.

The results indicate that the increase in body weight is most marked in the embryonic period as well as in the period directly after birth of the animal, and that the increase is greater in the internal organs than in other parts of the body.

- 2) The greatest α value 5.02 is shown in body weight against head to length in the embryonic life of the animal, followed by the value 2.42 in body weight against body length. Besides these the growth in the upper and lower extremities exceeds that of body length both showing α values larger than 1.

In head and face, however, the growth was slightly inferior to that of body length showing α value smaller than 1.

Of the relative growth of the internal organs against the body weight, the α values of lung and heart are smaller than 1 showing slightly lesser growth than the body weight, while those of spleen, stomach, kidneys and thymus show superior growth rates than the body weight.

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References

- 1) Donaldson, H. H. : The rat, data and reference table. 1924
- 2) Huxley, J. S. : Problems of relative growth. 1932
- 3) Huxley, J. S. & Teissier, G. : Terminology of relative growth. Nature. Vol. CXXXVII 1936
- 4) Outhouse, J. Mendel, L. B. : The rate of growth. 1. Its influence on the skeletal development of the albino rat. J. Exp. Zool. Vol. 64 1933

A STUDY ON THE RELATIVE GROWTH IN
THE BODY OF ALBINO RATS

— 228 — (30)

- 5) **Shimizu Mitsuo** : On the relative growth of organs of albino rats. The Zoological Magazine Vol. 53 No. 1 1941
- 6) **Shimizu Mitsuo** : [On the relative growth of the body weight in albino rats.] Igaku to Seibutsugaku Vol. 1 No. 3 1942
- 7) **Shimizu Mitsuo** : [A personal opinion on the applicability of the relative growth study in studying general morphology.] Igaku to Seibutsugaku Vol. 5 No. 5 1944

Fig. 26

Fig. 28

Fig. 29

Fig. 27

Fig. 30

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(31) — 229 —

Fig. 31 (a)

Fig. 31 (c)

Fig. 31 (b)

Fig. 32 (a)

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

Fig. 32 (b)

Fig. 34

Fig. 35

Fig. 33

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

(33) — 231 —

Fig. 36

Fig. 38

Fig. 37

Fig. 39

A STUDY ON THE RELATIVE GROWTH IN THE BODY OF ALBINO RATS

— 232 — (34)

Fig. 40

Fig. 42

Fig. 41