SENESCENCE AND REJUVENATION. BY CHARLES SEDGWICK MINOT. (Plates II. III. IV.)

(From the Physiological Laboratory of the Harvard Medical School.)

FIRST PAPER:—On the Weight of Guinea Pigs.

INTRODUCTION.

THE proper object, the final purpose of Biology, is the discovery of the nature and laws of life. The existence or non-existence of a vital force is a problem concerning which a great many dogmatic decisions have been put forth. It is evident that all opinions as to the essential nature of vitality, however much they may differ otherwise, are pretty much alike in lacking intellectual value and scientific foundations. There is no reason however for giving up the endeavour to get nearer the final goal of biology, because attempts to reach it by the short cut of speculation have always failed ignominiously. I believe that the time has come when work may be profitably directed towards answering general questions, the answers to which appear necessary preliminaries to attacking the problems of life itself.

It is now several years since I first published the thesis that the best and most fruitful biological work is that which contributes to determining the essential and fundamental peculiarities of living organisms. The paper[1] referred to, which was printed in abstract only, included an enumeration, as complete and exact as I could make it, of the phenomena which any tenable hypothesis of vitality must explain. The effort was to generalize the statements to the utmost scientific limit. The result was a very vivid impression of the inadequacy of all hypotheses of vitality.

Had circumstances permitted I should have steadily devoted myself from that time to researches having for their object the gaining of

[1] C. S. Minot. "On the conditions to be filled by a theory of life." *Proc. Amer. Assoc. Adv. Sci.*, XXVIII., 1879.

further insight into what I considered the fundamental phenomena of life. It cannot be questioned that there are many investigations of the character referred to, which are both feasible and worth while. In looking over the possibilities the best point of attack appeared to me to be the changes which age effects in organisms. They have been very little studied hitherto either in any systematic way or from any general stand-point. It is assuredly one of the most general phenomena in the life-histories of living organisms that they become old. From the age zero at the moment of sexual impregnation animals and plants both pass through a series of changes, until, barring accidents, they reach their limit of life, by which we mean the maximum longevity attainable for each individual under the optimum of conditions. Organisms are created young and grow old, and the old produce new young successors. The passage from youth to old age is best termed SENESCENCE, the procreation of the young REJUVENATION. Senescence is a property of most, perhaps of all living matters, and so far as known has no parallel in non-living matter. We may venture to assume for the present that senescence is an essential and never absent feature of life, finding its most striking expression in the gradual loss of the functional powers of the organism, its end in death; but we know as yet neither the essential character nor the real cause of that loss. Here then is a large field for work, of which I resolved to take advantage as largely as my restricted opportunities and means permitted.

Age causes various progressive changes in the organism, but none which are more obvious, and more accessible to exact study than those constituting growth. The first experiments were upon growth as the most promising subject for beginning the investigation of senescence. The work has continued through more than five years and has yielded results which it is thought desirable to publish in full. Several fragments have already been printed[1]. The present series is intended to cover all that has been thus far done, and to be completed subsequently. The material will be arranged in four papers;—1. the present one, On the Weight of Guinea Pigs; 2. On the Growth of Man; 3. On the Growth of Animals; 4. General Considerations. Most of my own experiments are included in the first article of the series.

It is deemed advisable to make this introductory explanation in order that the reader may at once understand the writer's point of view,

[1] Minot. *Science*, IV., 398—400; *Proc. Soc. Arts. Mass. Instit. Technol. Meeting* 310; *Science*, VI., 4—6; *Proc. Amer. Assoc. Adv. Sci.*, 1884, 517.; Wood's *Reference Handbook Med. Sci. Art-Age*; *Proc. Amer. Soc. Adv. Sci.*, 1886, 311.

and the real purpose in mind, which has determined the form of presentation. I need hardly say that I have no expectation whatsoever of solving the manifold problems of senescence, but have tried to add to our positive information. I shall be more than repaid for the labour spent, if my example induces others to make experiments on organisms as individual wholes; it would lead biologists into virgin fields, which await only cultivation to yield the husbandman a rich harvest of ever increasing value.

For the purpose of studying growth as a function of age it was desirable to eliminate the influence of external conditions of a variable character, as far as possible; the readiest way to accomplish this was to choose a self-regulative organism; accordingly one of the higher vertebrates was considered preferable, because of all organisms they are the most independent of outside circumstances. It remained only to pick out a convenient species; various considerations led to the choice of the Guinea pigs, *Cavia cobaya*. This animal offers the following advantages: it bears confinement well, is robust and but little liable to disease, breeds readily, is easily managed and fed, and gentle when handled; its maintenance is much less costly than that of a larger animal, an important consideration as upwards of 100 were kept at a time for several years[1]. Another important advantage depends on the fact that every individual is marked with spots and blotches of brown and black differently from all others, so that they all can be readily told apart without any artificial marks, and hence it is easier to follow the growth of individuals. Occasionally there is one all white, but such white ones can be marked with spots of nitrate of silver on the hair. Guinea pigs are so unintelligent that I have been unable to feel any interest except scientific in them, which has perhaps also been advantageous.

The pigs were kept in summer in spacious pens in the country, in winter in large boxes in well lighted and ventilated rooms, kept warm by artificial heat. They were carefully tended most of the time by myself; the endeavour was to secure continuously the best hygienic conditions by unremitting attention; it was my habit to make two visits daily. They were fed with the best food obtainable, in summer grain (oats), hay and fresh grass, in winter grain, hay and carrots.

To measure the growth the weights were taken of the growing and adult individuals, the weight being the only available measure for the whole animal,—and the only one permitting comparisons between differ-

[1] During one winter upwards of 18 barrels of carrots, 3 tons of hay, 26 bushels of oats, and some other food were eaten by my Guinea Pigs.

ent species of organisms. The weighings were made in the morning before the animals were fed. But they were kept always supplied with dry oats; this practice is desirable because it helps essentially in preserving the animals in good condition. It does not entail a sufficient error in the weights to be objectionable, because it is more or less constant and is not very large, as the animals will not eat a great deal of grain when they have plenty of green food or carrots. No fresh food was left in the pens or boxes over night.

In all the weighings there is necessarily an error $\pm$. A positive error, because the digestive tract, particularly the wide cœcum, contains always considerable quantities of undigested matter; moreover the bladder may hold a greater or less quantity of urine. A negative error because every illness, even a very slight indisposition, and every injury, such as a bite, for instance, causes a greater or less loss of weight. The quantitative values of these errors is presumably not very great; they probably counterbalance one another to a certain extent in the averages, which may be accepted as approximately accurate.

The advantage of these experiments over statistics taken from man lies especially in the fact that the same individuals are followed through the whole period of growth. Otherwise we may reach erroneous conclusions; thus in girls there is a very great acceleration of growth during the two or three years preceding puberty, that is, the epoch of the first menstruation; the acceleration shews itself also in a curve constructed from averages taken from a large number of observations upon many girls, but the variation appears less than it is for the individual and gives therefore an erroneous impression of the actual degree of prepubertal acceleration. This falsification necessarily ensues from the individual variations in the age of the first menstruation,—for the accelerations in one girl may occur at an older age than in another and a younger age than in a third, hence when a long series of observations is averaged the result shews an acceleration much longer in duration but smaller in amount, than is characteristic for the individual. Thus Dr B. A. Gould found that the stature of American soldiers increased steadily up to 35 years to 1·7391 metres, which was the maximum average height for any age. This observation does not prove that the growth period for Americans extends to 35 years, for the result noted may be due to more vigorous men growing more and surviving (but not growing) more years than the smaller and weaker men. The average at 35 is greater than at 30 because,—if the suggested explanation is correct,—the shorter men have died off. This might be decided by statistical study of the relation of the ages at death from disease to stature. It would certainly be worth while to investigate the problem, with a view of ascertaining whether there is any correspondence between the length of life and the size of individuals. A positive answer to the enquiry is to be expected. To return:—we have seen that if we do not compare the same individuals with one another we cannot be sure of correctly measuring the phases of growth. As Guinea pigs nearly complete their growth in one year it was possible to make the requisite number of observations within a reasonable period, which is not the case with man.

The total number of Guinea pigs weighed was about 400, of these 262 were weighed only at birth, and the remainder were followed up to varying ages. The total number of measurements taken was 8040, 4200 of males, 3840 of females. The total weight of all the Guinea pigs I have put in the scale pan is 1,799,920 grammes—which may be mentioned for amusement's sake.

As soon as a litter was born and the amniotic fluid dried off from the fur of the young, each individual was weighed, the sex noted, and an exact description of all the markings, which do not alter after birth, written down. The litter was numbered, and the date of birth and the parentage or at least the maternal parentage recorded. I found it a great convenience to give mnemonic names to all the pigs, of which I followed the growth—so that the name would suggest the appearance of the individual pig. For the most part the names referred directly to the marking, for instance "Brown rump," "Saddle back," "Snout," etc., —but often the allusion was more remote, as for instance "Hypocrite," whose head, seen from one side appeared entirely black, from the other entirely white. The record having been started the next thing was to enter in a diary all the dates during the remainder of the year upon which the litter in question was to be weighed[1]. The plan adopted after a little experience was to weigh each individual every day up to 40 days, then every fifth day up to 215 days, and then after every thirtieth day, and to avoid accidental variations also five days before and five days after each thirtieth day; for instance, the months being assumed at 30 days, the animal would be weighed for the 8th month at 240, also at 235, and 245 days, and the next set for nine months, 265, 270 and 275 and so on to the end of the second year after birth, at which age the observations were stopped. Of no individual have I an absolutely com-

[1] The simple apparatus for calculating the required dates is described in the appendix at the close of this Article.

plete series of weights, but of a good many the series are nearly complete. A very few of my animals died from disease. The effects of disease upon growth will be considered in the course of this paper—the study of them leads to an important theoretical conclusion.

The extent of my observations has been diminished by three accidents, of which the last was a heavy calamity. The first accident was due to a servant, who left the cover of the pen open while he went to cut some grass; during his absence a dog got in and killed several Guinea pigs. The second mishap was similar,—a person who was using without my being aware of it the room, in which my animals were kept during the winter, left the door open one evening and again a dog got in and killed eleven animals. The third misfortune was far more serious and put an abrupt end to my experiments. For greater safety my animals were kept in a locked room the floor of which was divided into large and commodious pens, I deemed myself safe from dogs, but unfortunately the janitor of the building had a bull terrier bitch which he wished to isolate for two or three days from other dogs, and therefore chained her up in the "animal room." During the first night the terrier broke loose and the next morning we found 94 guinea pigs lying dead leaving me only four alive of all those I had kept and weighed for a long period, making as I went along a careful biological record of each individual. I was thus deprived suddenly of nearly five years' labour. It had been my intention to follow out the alterations of weight on to extreme old age, to investigate the relations of the age of the parents to the sex, weight and number of the young, the alterations in the chemical composition of the body with age, and also to complete a series of experiments on heredity as shewn by the markings of the fur. My plan also included the study of the growth of the fœtus, of the causes affecting the length of gestation, of the influence of lactation on the weight, etc. All these enquiries can be answered accurately only by uninterrupted observation of individuals during their whole life-time, so that to get the desired results it will be necessary to go back five years nearly. Perhaps I may hereafter regain the courage to renew the undertaking which ended with such cruel unexpectedness. But since the destruction of my material I have been involved in less welcome duties than those of experimental biology. The expense of maintaining a large stock of animals is very considerable, and this has also prevented me from prosecuting the work as rapidly and extensively as desirable. In this country there are almost no funds from which grants in aid of biological researches can be made, so that the biologist in the United States is obliged to forego many of the material advantages enjoyed by his European colleague. I hope the difficulties I have encountered will plead in my excuse for some of the imperfections which characterize my growth experiments.

The experiments were begun in the physiological laboratory of the Harvard Medical School. Twice has my friend Dr H. P. Bowditch contributed to the expense of these experiments very generously as far as the income of his laboratory permitted. And I have to thank him for much valuable advice concerning the prosecution of the work and for much encouragement. With rare liberality he also placed at my disposal his own statistical material concerning the growth of Boston School children, which has afforded some new conclusions, that will be presented in the second article of this series. To several near relatives I am indebted for valuable help, for which I cannot thank them duly.

RESULTS.

PART I. THE CONDITIONS AT BIRTH.

1. *The number of young.* The number of young in each litter varies from one to eight, litters of one, two, three and four occurring by far the most frequently. Records of 143 litters give the following figures.

TABLE I.

Number in a litter	1	2	3	4	5	6	7	8
No. of litters observed	23	58	37	18	2	2	2	1

The table shews that litters of two are the most frequent; in fact it may be surmised that two is the natural number, not only on account of their predominating occurrence but also because the number of devoloped mammae is two. It is generally believed that there is a certain correspondence between the number of the mother's tits and the number of young born at once, for it is the rule among mammals that the maximum number of young at a birth rarely exceeds that of the tits. Reasoning loosely, we may conclude that the frequency with which guinea pigs have large litters, results from domestication,—an explanation which on account of its utter vagueness is decidedly a poor one. However the table shews that over half the litters are of one or two. Noteworthy is the very small number of litters of five. I cannot help anticipating that a large series of observations will obliterate the jump from litters of four to those of five and six.

Although most litters are of one or two yet most Guinea pigs are born in larger litters, Table II. shews that out of 366 pigs 227 were born in litters of three or more. The average numbers to a litter is 2·5. This result affords a very striking illustration of how far from the truth we come if we try to determine the typical or central form of a set of variations of a living organism by the arithmetical mean or average instead of by the geometrical mean or the most frequent variation. Thus the typical number of young for a Guinea pig to bear is two and not 2·5.

What determines the number of young? To this question I can give no adequate answer. Certain conditions affecting the number of young can be established from the statistics now available. The principal fact to be here mentioned is that older mothers have as a rule larger litters than the young mothers. This is shewn by

TABLE II.

Age of the mother at the time of littering in relation to the number of young.

Number in a litter	1	2	3	4	5	6	7	8
Average age of mothers	200·9	286	289·7	464·9	164	?	260	433 days
Number of observations	18	51	27	15	1	0	1	1

The age for litters of 5, 7 and 8 being based each on a single observation have little value for comparison with the averages for litters of one to four. The latter shew that the larger the litter the older the mother. The difference between the age for litters of two and that for litters of three is very slight. Had I been able to continue the experiments I should have watched with interest the effect of advancing years on these same mothers as regards the size of the litters.

To further elucidate the relations Table III. has been drawn up, to shew the sizes of the first litters of all the mothers, of the second litters, etc. Thus the table shews that of the first litters born by 50 mothers, 16 were of one, 25 of two and 9 of three.

The inspection of the table shews at once that the number of observations is insufficient to prove more than that the number of young tends to increase with the number of previous pregnancies. It however by no means follows that there is any causal connection, for it is not only possible but probable that it is entirely an effect of age. In fact my records shew that if a female guinea pig bears, while very young

TABLE III.

No. of Litter.	Number in the litter.							
	1	2	3	4	5	6	7	8
First	16	25	9				1	
Second		9	13	6	1			
Third		6	6	3				
Fourth			2	2				

itself, it will throw a litter of one or two, but if it is older it will throw a litter of two or three more probably than of one. To settle the question it would be necessary to guard several females in virginity until they were say two or three years old, and then to let them begin to bear, in order to compare their litters with those of young primiparæ and of multiparæ of their own age. I had started to do this at the time my animals were destroyed.

It appears to me that a second and important factor is the individual tendency of the mother to produce litters of a certain size. There is no apparent reason to suppose that the father influences the size of the litter, for there is always an excess of spermatozoa. On the other hand the hypothesis is natural that the tendency to discharge a greater or less number of ova may vary with individual females. The largest number of litters I have reared from one mother is four. Even this small number shews traces of an organic habit—thus one mother in successive litters 3, 1, 4 and 4 young; another mother 5, 2, 7 and 6. Further observations are needed to fully elucidate this point.

The warm season is favourable to the production of larger litters. This is shewn by the following table.

TABLE IV.

Number and percentage of litters born in each month.

Size of Litter.	Dec.		Jan.		Feb.		March		April		May		June		July		August		Sept.		Oct.		Nov.		Totals
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
1	2	1·4	6	4·1	3	2·0	1	·7	3	2·0	4	2·7	1	·7	1	·7			2	1·4	1	·7			24
2	9	6·1	11	7·5	8	5·4	5	3·4	9	6·1	7	4·8	6	4·1	4	2·7	3	2·0	2	1·4	1	·7			65
3	6	4·1	4	2·7	1	·7	3	2·0	3	2·0	4	2·7	1	·7	3	2·0	3	2·0	3	2·0	1	·7	3	2·0	35
4	2	1·4					1	·7			3	2·0	1	·7	4	2·7			2	1·4	3	2·0	1	·7	17
5									1	·7											1	·7			2
6																							1	·7	1
7																	1	·7	1	·7					2
8															1	·7									1
	19		21		12		10		16		18		9		13		7		10		7		5		147

In considering this table it must be borne in mind that the period of gestation is from 9 to 10 weeks so that as the number of young is, of course, determined at the moment of conception, therefore the litters born in July depend as to size on May influences and those born in November on September influences. The last line of the table shews plainly the favourable influences of the warm season. The result becomes more striking by rearranging the data given in Table IV. as shewn in Table V.

TABLE V.

Percentage of Litters according to the season.

Born in	Litters of				
	one	two	three	four	five–eight
Winter	7·5	19·0	7·5	1·4	0·0
Spring	5·4	14·3	6·7	2·7	0·7
Summer	1·4	8·8	4·7	2·4	1·4
Autumn	3·1	1·1	4·7	4·1	2·1
Winter, Spring	12·9	33·3	14·2	4·1	0·7
Summer, Autumn	4·5	9·9	9·4	6·5	3·5

In fact, we see the larger the litter the more likely it is to be born in summer or autumn. We can only speculate as to the mode by which this seasonal influence acts—to the physiologist it need hardly be mentioned that it would be most unsafe to attribute it to advantages of nutrition, as an inexperienced biologist might consider natural. Against such a deduction two reasons come foremost :—1°, such facts as we have indicated that poor rather than good nutrition incites fecundity; 2°, it is more probable that complex nervous effects are the chief factors.

2. *The proportion of the sexes.* The number of pigs of each sex in 410 births recorded, was 187 females and 223 males;—or to every 100 females, 119·2 males. Statisticians have generally adopted this method of expressing the proportions of the sexes but it is, I think, not a good one because exact comparisons are impossible since the standard i.e., the number of females, is itself variable. It is better to express the results in percentages of the whole number of young, or in *pro milles.*

According to the above data, of 1000 Guinea pigs born, 456 + are females and 544 − males.

The number of my observations is so small that the probable error is considerable. To gather a notion of its value we may employ the following arbitrary calculations. Let us assume that the real proportion of the sexes is 500 to 500, which is certainly not very far from the truth. Then with one set of two observations, there would be four possibilities;—♀♀, ♂♂, ♀♂, ♂♀,—and the probable error would be 250 *per mille*. Now the error varies inversely as the square root of the number of observations, hence the error with 410 observations is given by the following equation:—

Let E be the probable error with a observations; when $a = 2$, $E = \pm 25\ ^{\circ}/_{0}$ and let $a = 410$.

therefore $$E \times \sqrt{410} = \sqrt{2}$$

whence $$E = \frac{25\ \sqrt{2}}{\sqrt{410}}$$

$$\log = 25 = 1{\cdot}39794$$
$$\tfrac{1}{2}\log - 2 = 0{\cdot}15051$$
$$\overline{1{\cdot}54845}$$
$$\tfrac{1}{2}\log \quad 410 = 1{\cdot}30640$$
$$\log E\ 1{\cdot}756 = 0{\cdot}24205$$

hence $$E = \pm\ 1{\cdot}756\ ^{\circ}/_{0} \text{ or } 17{\cdot}56 \text{ per mill.}$$

Now the observed number of females per mille is 456; using the probable error just found, the chances are even whether the number of females would be per mille $456 \pm E$, in round numbers between 438 and 474 females per 1000 or outside those limits.

The causes which determine sex I hope to discuss in a subsequent paper. My observations on Guinea pigs fail to shew any relation between the number of females and the age of the mothers. I have records of the ages of the mothers of 120 females and of 144 males—the average age of the former is 325 days, of the latter 310 days. It is possible that the slight difference really corresponds to a tendency to produce more females as the mother becomes older; I had originally intended to settle the point by continuing the record until the mothers were several years older. At present a definite conclusion as to the effect of the maternal age upon the sex of the offspring is unsafe.

To ascertain whether any correlation existed between the season and the sex of the young there has been prepared

TABLE VI.

Shewing the number and percentage of males and females born in each month of the year.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. of Males	23	13	11	16	28	11	19	13	25	16	9	24	208
% ,,	11·1	6·2	5·3	7·7	13·5	5·3	9·1	6·2	12·0	7·7	4·3	11·5	
No. of Females	17	9	13	19	25	9	23	9	16	7	10	22	179
% ,,	9·5	5·0	7·3	10·6	14·0	5·0	12·8	5·0	8·9	3·9	5·6	12·3	

From this table we learn that there were

Born in	winter	spring	summer	fall
of males	28·8	26·5	20·6	24·0 %
of females	26·8	31·9	22·8	18·0 %

In other words, during the spring and summer there is a relatively greater tendency to produce females. This does not prove that the season acts directly. It would be interesting to test the matter by more extended observations.

3. *Weight of Guinea pigs at Birth.* Measurements of 372 individuals gave the following results:—

200 males weighed 14162 grammes, Average 70·8
172 females ,, 12052 ,, ,, 70·1

As the individual variations depart from this average up to over ± 50 % it is evident that the difference in weight between males and females is so slight, only 0·7 grms. that it will occasion no sensible error, if we lump the two sexes together in order to study the influences, which affect the growth of the fœtus, and so cause variations in the weight at birth.

The variation is exceedingly great:—

The largest male weighed 128 grms. = 70·8 + 57·2 or + 80·8 %
,, smallest ,, ,, 35 ,, = 70·8 − 35·8 or − 50·6 %
The largest female weighed 111 grms. = 70·1 + 40·9 or + 58·3 %
,, smallest ,, ,, 35 ,, = 70·1 − 35·1 or − 50·1 %

It will be noticed that the variation above is greater than below the average—a fact, which I interpret, as will be explained, to be of fundamental importance. The weight of the largest male is altogether exceptional; the second largest being 113 grammes, which is 15 grms. less and only 59·6 % instead of 80·8 % above the average.

The total range of variation in the males is 131·4 % of the total average weight; in the females 108·4 %.

The following table gives 363 observed weights between these extremes as they are distributed around the average in groups of 5 grms. in range each. There is a slight error owing to the average being taken for convenience at the arbitrary value, 70·5 grms.

TABLE VII.

Distribution of weights at birth.

Wts. in grms.	Number in observations.		
	Male	Female	Totals
130·5—125·5	1	0	1
115·5—110·5	3	1	4
110·5—105·5	1	0	1
105·5—100·5	1	2	3
100·5— 95·5	8	0	8
95·5— 90·5	8	9	17
90·5— 85·5	13	7	20
85·5— 80·5	28	24	52
80·5— 75·5	16	15	31
75·5— 70·5	19	24	43
70·5— 65·5	16	19	35
65·5— 60·5	27	10	37
60·5— 55·5	19	16	35
55·5— 50·5	14	11	25
50·5— 45·5	10	23	33
45·5— 40·5	7	4	11
40·5— 35·5	5	3	8
35·5— 30·5	1	1	2
Totals	197	169	366

It will be noticed that although the extreme observations are fewer than the central ones, yet the distribution is far from regular and does not correspond to a binomial curve, as nearly as should be the case were the distribution due to chance, by which we understand an infinite number of causes. The degree of variation is enormous:—of 200 male Guinea pigs weighed, precisely 100 were above and 100 below the average. The weights of the heavier 100 averaged 84·5 grms.; and of the lighter 100, 57 grms. Hence the average variation was 19·50 % above and 19·49 below the mean for the whole 200. The corresponding figures for the other sex are 17·12 and 18·83; for the data nearly in full see Table VII. The weight at birth varies to an extraordinary degree and with unusual irregularity; it became therefore probable that Guinea pigs offer a favourable opportunity for ascertaining some of the causes of the natal variability. Such is the case in fact.

An inspection of the statistics shew at once that the most potent influence is the number of pigs in a litter, as is proven by the following table, which is based upon 351 observations.

TABLE VIII.

Guinea Pigs:—Average weights in grammes according to the number in litter.

No. in Litter	Males			Females			Total			
	Total no.	Total wts.	Average wts.	Total no.	Total wts.	Average wts.	Total no.	Total wts.	Average wts.	Diff.
1	9	777	86·3	11	924	84·0	20	1701	85·5	
2	57	4610	80·9	57	4334	76·0	114	8944	78·5	5·0
3	63	4269	67·8	48	3284	68·4	111	7553	68·0	10·5
4	43	2816	65·5	28	1733	61·9	71	4549	64·1	3·9
5	6	363	60·5	4	235	58·7	10	598	59·8	4·3
6	5	301	60·2	5	321	64·2	10	622	62·2	2·3
7	4	229	57·2	3	178	59·3	7	407	58·1	4·1
8	5	268	53·6	3	150	50·0	8	418	52·2	5·9
Totals	192	13633	71·0	159	11159	70·2	351	24792	70·6	

With this single exception of the litters of five and six and even these only with the females the larger the litter the smaller the pigs at birth. At first sight this seems easily explained as a mere ratio of food supply and demand; this would accord with certain views of Herbert Spencer but not with the facts of nature. To Mr Spencer's extraordinary conception of the relations of growth and reproduction we shall come in the fourth paper of this series. It will suffice now, to point out that there is a large excess of nutritive power in Guinea pigs, as in other mammals,—a fact which is made evident by the observation that a growing pig may itself bear young without impeding its own growth. Moreover the possible maximum product of young in weight is approached only by the largest litters, and if there is a sufficient food supply to produce a litter of seven weighing collectively,—as one of mine (A J.) did—407 grammes, we should certainly expect the supply to suffice for producing the heaviest individuals as well in a litter of two as in a litter of one, but such is not the case. There is then some other cause.

The cause we are seeking for, I think is probably the length of gestation, which certain observations of mine indicate to be shorter the larger the litter. The observations in point are discussed in the following paragraph. If the supposition is correct then the principal reason why the individuals of large litters weigh less at birth than the members of small litters, is that they are born sooner, or in other words have not been growing so long.

The length of the period of gestation is very variable in Guinea pigs. It is usually a little less than 10 weeks,—the average of 22 observations being 67·0 days. Of the twenty-two cases only twelve were determined by certain knowledge of the date of coitus as well as of that of delivery; the coitus in ten cases is fixed by probability only; in these ten instances, bucks were left continuously with the females, before, during, and after their littering; the females immediately became pregnant again and threw their young again just about the length of a natural period of gestation thereafter. Now as the does often readily admit the bucks immediately after having littered, I have considered it safe to regard the day of delivery in the ten cases cited as the day of commencement of the next gestation. The observations may be classed as follows:—

Gestation in days	64	65	66	67	68	69	70
Number of cases	2	3	2	7	4	2	2

Hence it appears that 67 days is the most frequent length. I regret very much that I was prevented from extending these observations as the curve of the variations cannot be indicated by so scanty statistics. In one case the number of young were not recorded; the remaining cases may be classed according to the number of young as follows:—

TABLE IX.

Relation of the number of young to the length of gestation.

No. of young	Gestation in days	Average.
1	66, 69, 70	68·7
2	64[1], 67, 68, 69, 70	67·6
3	64, 68, 68	66·7
4	67, 67, 67, 67, 67	67·0
5	65	66·0
6	67	
7	65, 68	
8	65	

The table shews plainly that the gestation is usually shorter the larger the litter, and were it not for one short gestation lowering the average in each of the first three groups the averages would offer still more striking contrasts. In the three short gestations alluded to we presumably have an abbreviation from some secondary cause of the period which would otherwise have continued longer. The observations given in Table IX. may be grouped in another way, namely according to the length of the gestation. This has been done in Table X. This table shews 1°, that the shorter the gestation the smaller the young: 2°, that there are other influences at work likewise causing variations:—this is indicated particularly by the five observations on litters of four. It is possible to ascertain some of the other influences, as will be explained shortly.

The extent of the influence of the length of gestation might be exactly ascertained by procuring premature delivery. The experiment was made a single time by putting a pregnant female together with a number of bucks. I obtained a litter of two (40th born Jan. 4, 1883) both females; they weighed respectively 68 and 63 grms., being as was expected from their having lost several days of intra-uterine growth very much undersized; the average weight for a litter of two as by Table VIII. is 76 grms. Incidentally it may be remarked that the mother at once began suckling her young, which is interesting, because it suggests that delivery in the "auslösende Reiz" of lactation, and thus implies the existence of a nervous mechanism, concerning which physiology is silent.

[1] One of the young died a few hours after birth.

TABLE X.

Relation of the length of gestation to the weight of the young.

In each square are given the average weights of the pigs born; the corresponding length of gestation is given at the left of the line, the number of young in the litter in question at the top of the column. For example: the gestation of one litter of two lasted sixty-four days and the average weight of the young was 60 grammes.

Gestation in days	Number of young in each litter.								
	1	2	3	4	5	6	7	8	Obs.
64		60·0	49·3						
65					62·2		58·0	52·2	
66	81·0								
67		84·0		64·0 70·0 80·7 82·0 99·0		61·0			
68		77·0	82·0 86·7						
69	93·0	119·9							
70	97·0	87·0							

Unfortunately we possess no sufficient observations concerning the growth of the fœtal Guinea pigs; as soon as they are made we shall be able to judge whether the growth during the last days *in utero* is so rapid that cutting off a few of them would make a large difference in the weight at birth. That it is so is probable, hence we may conclude that the principal reason why large litters are composed of smaller pigs than the small litters (Table VII.) is that they are born sooner. This conclusion has struck me especially because it is an illustration of the untrustworthiness of the method of addition and subtraction by which Spencer and other simplicists seek to elucidate biology. In the fourth article I hope to recur to the subject and justify the condemnation expressed above.

The weight at birth varies according to the season of the year. This is proven as follows:—The pigs born in the period from May 1st to Nov. 15th come from parents which had been supplied with green food, such as the parents did not have during the remainder of the year. Adopting these dates I have divided the young into two classes, designated respectively as summer born and winter born; 208 summer born averaged in weight 72·2 grms. = 70·5 + 1·7 grms., and 173 winter born averaged 62·5 grms. or 70·5 − 8·0 grms. The difference is 9·7 grms. or 13·9 % of the average weight 70·5. It will be remembered that the actual averages are, for all males 70·8, for all females 70·1. I see no reason to doubt that the difference found is due to the more favourable nutrition of the parents during the summer season.

The individuals of the same litter generally differ in weight. Let us take the recorded weights of 59 litters of two, leaving the sex, as hitherto, out of account since it is not an important determining factor of the natal weight.

TABLE XI.

Variation of weight of pigs born in litters of two.

Weight in grammes	Diff.	No. obs.
89–89, 84–84	0	2
90–89, 89–88, 83–82, 82–81, 78–77	1	5
99–97, 72–70, 61–59	2	3
82–79, 44–41	3	2
97–93, 85–81, 85–81, 74–70, 73-69	4	5
93–88, 91–86, 89–84, 84–79, 75–70, 74–69, 74–69, 68–63	5	8
73–67, 67–61, 67–61	6	3
82–75, 81–74, 67–60	7	3
93-85, 84–76, 83–75	8	3
102–93, 98–89, 91–82, 83–74, 70–61	9	5
85–75, 84–74	10	2
93–81, 47–35	12	2
100–87	13	1
81–67, 74–60	14	2
87–72	15	1
92–76, 91–75	16	2
128–111, 75–58, 64–47, 64–47	17	4
87–67	20	1
80–59, 74–53	21	1
99–75	22	2
81–57	24	1
113–76	35	1

Grouping the data of the above table we find that the two young differed in weight from 0— 3 grammes in 12 cases.

4— 7	„	„	19	„
8—11	„	„	10	„
12—15	„	„	6	„
16—19	„	„	6	„
20—23	„	„	4	„
23—27	„	„	1	„
35	„	„	1	„

In nearly half the cases,—28 out of 59,—the difference of weight is 6 grammes or less. Were the number of observations sufficiently numerous we should probably find five grammes to be the most frequent difference, and that the frequency of the differences would diminish rapidly towards the zero and more gradually towards the upper limit of difference. Thus a curve of the frequency of the differences would be steep on the side towards zero, and less steep on the other side—a fact, the importance of which will be shewn during the theoretical discussions to follow.

Looking again at Table XI. we may say that roughly speaking one-third of the litters shew a slight,—one-third a marked and one-third a great difference in weight between the two young. The original record shews that neither males nor females are more frequently undersized than the opposite sex. Probably these inequalities are due chiefly to inherent peculiarities of the individuals, and partly to varying conditions of nutrition in the uterus, such perhaps as a freer blood supply to one fœtus than to another. Possibly investigations of the embryonic growth may elucidate the factors determining its amount, but at present we can only guess at them. As regards litters of odd numbers of young it might be suggested as there are necessarily more young in one uterine horn than in the other,—that the majority that are together, would be less favourably nourished than the minority in the other horn. In favour of this suggestion speaks the observation that in litters of three for instance there are often two smaller pigs of about equal size and one larger one. For example:—

Litter	1,	First	pig	54	grms.	Second	56	Third	63
„	28	„	„	60	„	„	65	„	81
„	30	„	„	48	„	„	48	„	60
„	A	„	„	46	„	„	46	„	56
„	G	„	„	66	„	„	61	„	76

There are however very frequent exceptions; indeed the relations are actually reversed in three out of the first thirteen litters of three, there being two heavy and one light. Conclusive against the proposed explanation is the observation that the embryos taken from the uterus vary among themselves and that the under- or oversized one may be either alone or in the same horn as one of its mates. I dwell upon this point in order to make a renewed protest against the Spencerian view that growth is a simple debit and credit account between the organism and its food.

A conceivable explanation of some at least of the greater differences of weight in the members of one litter is the hypothesis of super-fœtation, with its corollary that some of the embryos are younger than others and therefore smaller. This hypothesis loses its plausibility through the observation that even when there has been only one coitus and the female kept isolated the young may be very unequal in weight. Thus in the 44th litter the gestation having lasted 70 days, there were two young of 93 and 81 grammes respectively—in the 45th litter gestation 68 days, two young 87 and 67 grammes.

It will be seen that I have not ascertained any of the factors causing purely individual variations in the weight at birth.

PART II. THE LOSS OF WEIGHT AFTER BIRTH.

Male Guinea pigs lose weight, as do new-born children, for a variable period of a few days, after birth. Table XII. gives the weights in grammes of males and females during the first five days, the data being copied from Tables XVI. and XVII.

TABLE XII.

Age in days	Males			Females		
	No. obs.	Average	Increase	No. obs.	Average	Increase
0	200	70·8		172	70·1	
1	47	68·9	−1·9	53	72·0	1·9
2	43	70·0	1·1	53	73·8	1·8
3	48	73·4	3·4	54	77·6	3·8
4	44	77·3	3·9	54	82·2	4·6
5	48	82·6	5·3	54	86·9	4·7

From this table we learn that there is a very marked difference between males and females for the former lose, the latter gain in weight the first day, so that though the females begin with less average weight than the males, yet by the end of the first day they are heavier. The advantage is long maintained. One might say therefore that the beginning of growth in one sex is the reverse of that in the other, being negative in the male and positive in the female. The statement, however, involves an obvious error, for the question of signs—plus or minus,—is not essential. It is essential to observe the relative growth immediately after birth, compared with that a few days later. Such comparison shews at once that in both sexes the growth is retarded by birth but much more in the male than in the female, so much, in fact, that there is an actual loss. Not always however does the male lose, on the contrary in a few instances the retardation is insufficient to produce a negative change; in certain rare cases there is a positive gain, though slight, as in the female. The following examples will serve to illustrate these assertions:—

TABLE XIII.

Male No.	Weighed at 0	1	2	3	4	5 days
	grms.	grms.	grms.	grms.	grms.	grms.
6	57·8	58·1	62·1	65·8	71·0	76·2
23	60	59	60	62	67	72
38	79	79	80	86	88	91
42	65	62	62	65	69	74
49	82	78	75	79	80	81

In not a single case male or female does the retardation fail to be well marked, that is to say the growth during the first two or three days is always much less rapid than from the fifth day on.

Hence we conclude that birth retards growth for from two to five days. In the third paper it will be shewn that the post-natal retardation occurs in all mammals so far studied although it has been curiously overlooked by certain writers. I consider the retardation to be normal and physiological.

PART III. GROWTH TO THE ADULT SIZE.

1. *Explanatory.* It will be advisable to describe the method of tabulation adopted, which has proved convenient. Others may wish to follow it perhaps in modified form. Large sheets 19 by 24 inches were ruled with cross lines, every fifth line being heavy and red, the others blue, and ruled also into pairs of vertical columns. The horizontal lines correspond each to a given age; each pair of vertical columns to an individual Guinea pig. Fifteen pigs can be entered on one sheet, and the averages for each age be recorded on the right hand side. Each sheet can be worked by itself and thus the tabulation and averaging be carried forward as the records accumulate. Finally the totals of all the sheets can be added together and the average of the whole series of observations quickly ascertained. On the sheets one readily follows the growth of a given individual or compares its weight with those of other individuals of the same age.

Table XIV. is a copy in condensed form of my Sheet 2 giving males Nos. 16—30, up to 210 days. It will serve to illustrate the character of the record; it should be said that it presents somewhat fewer gaps than most of the remaining sheets. For mere illustration the table would not be worth insertion; it will be found that it does also to demonstrate various points to be discussed later.

The males and the females have been tabulated separately. In the case of the latter there are two sets of observations, one on females throwing litters while young, and another on females not littering while young. In Table XV. these are all thrown together, with the result that the averages are too high, because many of them include the weight of the young carried by the mother. I have therefore constructed the corrected Table XVI. in which the weights falling within the periods of gestation are omitted.

The corresponding Table XVII. for the males of course requires no such correction.

TABLE XIV.

Age in days.	Number of pig. 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total weights.	Obs.	Average weights.
0						71	98	60	76	49	56	75	86	89	79	739	10	73·9
1						65	92	59	75	47	55	75	82	86	78	714	10	71·4
2						66	97	60	74	46	55	74	83	86	77	718	10	71·8
3						67	107	62	80	51	58	79	88	90	83	765	10	76·5
4						69	107	67	86	54	64					447	6	74·5
5						75	115	72	90	58	67	87	97	100	92	853	10	85·3
6						79	122					95	103	104	97	600	6	100·0
7						82	128	84	105	68	79	99	111	113	104	973	10	97·3
8						84		79	110	74	85	108	120	120	113	893	9	99·2
9	113	103	97	68	99	89	144	95	116	81	92	113	127	125	119	1581	15	105·4
10	115	104	100	72	103	96	148	99	119	83	96	116	128	131	124	1634	15	108·9
11	116	105	102	73	105	103	155	103	126	88	102					1178	11	107·2
12	125	117	112	79	113	111	158	112	131	95	109	124	140	142	134	1802	15	120·1
13	133	123	116	84	119	112	168	116	140	100	114	129	145	148	141	1888	15	125·9
14	129	119	112	81	116	119	177	120	144	105	118	131	152	149	144	1916	15	127·7
15	140	130	123	87	126	129	181	127	148	108	124	139	161	154	153	2030	15	135·3
16	142	134	127	89	128	137	188					147	169	162	160	1583	11	143·9
17	146	141	134	97	128		194	135	162	117	132	153	176	165	164	2044	14	146·0
18	150	151	139	95	134	152	195	144	167	120	133	164	185	170	174	2273	15	151·2
19	157	162	147	101	143	148	204	147	172	125	140	166	189	171	178	2350	15	156·7
20	160	165	147	102	142	163	211	157	183	135	151	173	198	183	187	2457	15	163·8
21	170	176	160	106	154	162	219	160	190	136	156	177	205	187	189	2547	15	169·8
22	177	183	159	112	157	167	229	166	197	146	161	181	212	194	193	2634	15	175·6
23	170	179	160	115	153	178	234	175	205	148	166	182	212	194	194	2665	15	177·7
24	176	184	164	115	160	185	243	176	207	151	169	193	224	206	212	2765	15	184·3
25	176	190	166	117	161	189	253	186	216	154	176	195	225	209	214	2829	15	188·6
26	180	185	167	125	160	191	256	188	221	162	176	212	239	225	220	2907	15	193·8
27	186	194	171	126	167	191	264	198	225	168	180	205	241	218	222	2956	15	197·1
28	190	200	175	131	174	200	268	192	224	166	182	221	260	237	238	3058	15	203·9
29	207	208	189	136	184	210	270	207	242	175	193	220	254	231	233	3159	15	210·6
30	210	213	195	143	190	212	268	214	248	181	195	222	255	235	235	3216	15	214·4
31	213	217	197	147	192	224	286	222	254	189	200	227	271	243	245	3327	15	221·8
32	214	218	198	146	194	226	290	218	258	190	201	240	277	258	258	3386	15	225·7
33	227	222	206	156	201	235	304	236	271	199	212	237	270	248	253	3477	15	231·8
34	230	230	213	164	210	238	304	231	265	198	210	246	287	263	270	3559	15	237·3
35	232	230	213	160	206	241	318	227	270	200	212	252	295	270	273	3599	15	239·9
36	244	240	223	173	220	247	315	237	278	208	221	256	298	272	276	3708	15	247·2
37	241	241	220	170	220	252	315	241	290	219	234	260	305	274	276	3758	15	250·5
38						258	325	235	280	215	225	254	294	266	270	2622	10	262·2
39	254	252	231	187	239	250	335	247	300	229	244	272	313	289	295	3937	15	262·5
40	265	263	243	191	244	267	329	242	309	234	243	274	313	286	291	3994	15	266·3
45	306	294	272	219	276	296	338	261	333	250	257	282	319	311	296	4310	15	287·3
50	325	320	291	239	292	309	345	288	364	275	279					3327	11	302·5
55	340	330	309	251	302	328	358	314	374	289	298	293	324	321	311	4742	15	316·1
60	391	363	331	286	339	333	359	335	401	307	313	297	374	331	337	5097	15	339·8
65	379	355	327	292	345	367	376	351	407	322	327	300	345	325	337	5155	15	343·7
70	401	367	336	297	350	379	370	364	412	339	343	364	428	389	399	5537	15	369·1
75	390	369	350	307	369	401	404	400	457	375	378	379	447	409	425	5860	15	390·7
80	430	396	374	329	390	418	441	414	479	357	398	395	462	435	444	6162	15	410·8
85		403	371	310	385	443	447	436	503	344	420	418	490	447	464	5881	14	420·1
90	475	429	408	363	405	455	463	465	534	345	440	412	492	454	463	6603	15	440·2
95	487	439	425	380	436	485	473	474	544	377	452	435	508	481	469	6835	15	457·7
100	499	447	432	380	442	509	486	497	562	398	465	459	535	518	483	7112	15	474·1
110	561	491	470	420	490	533	489	465	560	412	450	487	561	514	494	7397	15	493·1
120	598	545	498	448	507	556	505	512	606	471	502	515	579	562	532	7936	15	529·1
135	657	577	540	483	555	581	536	552	610	487	498	513	548	574	504	8215	15	547·7
150	683	602	572	495	578	581	535	600	645	533	533	565	614	605	569	8710	15	580·7
165	692	617	580	503	573	575	565	655	653	596	588	562	616	622	568	8965	15	597·7
180	714	647	602	523	601	610	560	642	689	608	603	604	661	674	608	9346	15	623·1
195	718	644	545	535	625	627	617	610	650	572	555	644	635	706	633	9316	15	621·1
210	706	642	550	515	600	632	662	703	753	660	637	690	684	764	677	9875	15	658·3

TABLE XV.

Guinea pigs—female. Averages of weight, etc. for successive ages, based on all the observations.

Age days	Totals Weights	Totals No. obs.	Average	Increase over last measurement	Average daily increase	Daily % increase
0	12052	172	70·1			
1	3818	53	72·0	1·9	1·9	2·7
2	3909	53	73·8	1·8	1·8	2·5
3	4193	54	77·6	3·8	3·8	5·1
4	4438	54	82·2	4·6	4·6	5·9
5	4692	54	86·9	4·7	4·7	5·7
6	4576	50	91·5	4·6	4·6	5·3
7	5173	54	95·8	4·3	4·3	4·7
8	5549	55	100·9	5·1	5·1	5·3
9	5898	56	105·3	4·4	4·4	4·4
10	6262	57	109·9	4·6	4·6	4·4
11	6108	53	115·2	5·3	5·3	4·8
12	6337	53	119·6	4·4	4·4	3·8
13	6370	50	127·4	7·8	7·8	6·5
14	7327	56	130·8	3·4	3·4	2·7
15	7171	52	137·9	7·1	7·1	5·4
16	7650	53	144·3	6·4	6·4	4·6
17	7731	52	148·7	4·4	4·4	3·0
18	8020	52	154·2	5·5	5·5	3·7
19	7737	48	161·2	7·0	7·0	4·5
20	8029	49	163·9	2·7	2·7	1·7
21	8767	52	168·6	4·7	4·7	2·9
22	9412	54	174·3	5·7	5·7	3·4
23	9208	51	180·5	6·2	6·2	3·6
24	9253	51	181·4	·9	·9	·5
25	9637	52	185·3	3·9	3·9	2·1
26	9650	51	189·2	3·9	3·9	2·1
27	9820	51	192·5	3·3	3·3	2·0
28	9718	49	198·3	5·8	5·8	3·0
29	10750	53	202·8	4·5	4·5	2·3
30	10701	51	209·8	7·0	7·0	3·5
31	10309	49	210·4	·6	·6	·3
32	9753	45	216·7	6·3	6·3	3·0
33	9146	42	217·8	1·1	1·1	·5
34	10428	47	221·9	4·1	4·1	1·9
35	10920	49	222·9	1·0	1·0	·5
36	9974	43	232·0	9·1	9·1	4·1
37	10869	47	231·3	− ·7	− ·7	− ·3
38	9703	41	236·7	5·4	5·4	2·3
39	12197	50	243·9	7·2	7·2	3·0
40	12831	51	251·6	7·7	7·7	3·1

TABLE XV. (*continued*).

Age days	Totals Weights	No. obs.	Average	Increase over last measurement	Average daily increase	Daily °/o increase
45	13609	51	266·8	15·2	3·0	1·2
50	13488	48	281·0	14·2	2·8	1·1
55	14946	50	298·9	17·9	3·6	1·3
60	15170	47	322·8	23·9	4·8	1·6
65	16236	49	331·3	8·5	1·7	·5
70	16286	47	346·5	15·2	3·0	·9
75	18299	49	373·4	26·9	5·4	1·6
80	19210	49	392·0	18·6	3·7	1·0
85	20660	49	421·6	29·6	5·9	1·5
90	19883	45	441·8	20·2	4·0	1·0
95	19961	46	433·9	− 7·9	− 1·6	− ·4
100	21542	46	468·3	34·4	6·9	1·6
105	11528	24	480·3	12·0	2·4	·5
110	18436	38	485·2	4·9	1·0	·2
115	10572	20	528·6	43·4	8·7	1·8
120	20370	40	509·2	− 19·4	− 3·9	− ·7
125	12628	24	526·2	17·0	3·4	·7
130	11720	22	532·7	6·5	1·3	·2
135	20512	40	512·8	− 19·9	− 4·0	·7
140	10290	20	514·5	1·7	·3	·06
145	10841	21	516·2	1·7	·3	·06
150	23131	42	550·7	34·5	6·9	1·3
155	15672	26	602·8	52·1	10·4	1·9
160	14153	23	615·3	12·5	2·5	·4
165	25492	43	592·8	− 22·5	− 4·5	− ·7
170	12524	22	569·3	− 23·5	− 4·7	− ·8
175	13800	24	575·0	5·7	1·1	·2
180	25008	42	595·4	20·4	4·1	·7
185	12566	21	598·4	3·0	·6	·1
190	13258	22	602·6	4·2	·8	·1
195	23769	39	609·5	6·9	1·4	·2
200	10095	17	593·8	− 15·7	− 3·1	− ·5
205	11504	20	575·2	− 18·6	− 3·7	− ·6
210	22087	36	613·5	38·3	7·7	1·3
215	11154	18	619·7	6·2	1·2	·2
months						
8 − 5	15201	24	633·3	13·6	·7	·1
8	23385	36	649·6	16·3	3·3	·5
8 + 5	11769	18	653·8	4·2	·8	·1
9 − 5	10943	17	643·1	− 10·1	− ·5	− ·07
9	16794	25	671·7	28·0	5·6	·9
9 + 5	8711	13	670·1	− 1·6	− ·3	− ·04

TABLE XV. (*continued*).

Age months	Totals		Average	Increase over last measurement.	Average daily increase	Daily % increase
	Weights	No. obs.				
10 – 5	12226	18	679·2	9·1	·5	·07
10	22342	31	720·7	41·5	8·3	1·2
10 + 5	14594	21	698·8	– 21·9	– 4·4	·6
11 – 5	17135	24	714·0	15·2	·8	·1
11	23517	32	734·9	20·9	4·2	·6
11 + 5	17663	24	736·0	1·1	·2	·03
12 – 5	17471	23	759·6	23·6	1·2	·2
12	22180	30	739·3	– 20·3	– 4·1	– ·5
12 + 5	14681	20	734·0	– 5·3	– 1·1	– ·1
13 – 5	10698	13	822·9	88·9	4·4	·6
13	17602	22	800·1	– 22·8	– 4·6	– ·6
13 + 5	13092	16	818·2	18·1	3·6	·5
14 – 5	9589	11	871·7	53·5	2·7	·3
14	16031	20	801·5	– 70·2	– 14·0	– 1·6
14 + 5	9056	10	905·6	104·1	20·8	2·6
15 – 5	10947	13	842·1	– 63·5	– 3·2	– ·3
15	16815	22	764·3	– 77·8	– 15·6	– 1·8
15 + 5	10780	13	829·2	64·9	13·0	1·7
16 – 5	7824	9	869·3	40·1	2·0	·2
16	13038	16	814·9	– 54·4	– 10·9	– 1·2
16 + 5	5430	6	905·0	90·1	18·0	2·2
17 – 5	11885	14	848·9	– 56·1	– 2·8	– ·3
17	14016	17	824·5	– 24·4	– 4·9	– ·6
17 + 5	8523	10	852·3	27·8	5·6	·7
18 – 5	6006	7	858·0	5·7	·3	·03
18	9661	12	805·1	– 52·9	– 10·6	– 1·2
18 + 5	3880	5	776·0	– 29·1	– 5·8	– ·7
19	7683	10	768·3	– 7·7	– ·3	– ·04
20	6682	9	742·4	– 25·9	– ·9	·1
21	6127	8	765·9	23·5	·8	·1
22	5506	7	786·6	20·7	·7	·1
23	4530	7	647·1	– 139·5	– 4·6	– ·5
24	3886	5	777·2	130·1	4·3	·6

TABLE XVI.

Guinea pigs, female. Averages of weight, etc. for successive ages, the observations on pregnant female not being included in the tabulation.

Age days	Totals Weight	Totals No. obs.	Average	Increase over last measurement	Average daily increase	Daily % increase
0	12052	172	70·1			
1	3818	53	72·0	1·9	1·9	2·7
2	3909	53	73·8	1·8	1·8	2·5
3	4193	54	77·6	3·8	3·8	5·1
4	4438	54	82·2	4·6	4·6	5·9
5	4692	54	86·9	4·7	4·7	5·7
6	4576	50	91·5	4·6	4·6	5·3
7	5169	54	95·8	4·3	4·3	4·7
8	5549	55	100·9	5·1	5·1	5·3
9	5898	56	105·3	4·4	4·4	4·4
10	6262	57	109·9	4·6	4·6	4·4
11	6108	53	115·2	5·3	5·3	4·8
12	6337	53	119·6	4·4	4·4	3·8
13	6370	50	127·4	7·8	7·8	6·5
14	7327	56	130·8	3·4	3·4	2·7
15	7171	52	137·9	7·1	7·1	5·4
16	7650	53	144·3	6·4	6·4	4·6
17	7731	52	148·7	4·4	4·4	3·0
18	8020	52	154·2	5·5	5·5	3·7
19	7737	48	161·2	7·0	7·0	4·5
20	8029	49	163·9	2·7	2·7	1·7
21	8767	52	168·6	4·7	4·7	2·9
22	9412	54	174·3	5·7	5·7	3·4
23	9208	51	180·5	6·2	6·2	3·6
24	9253	51	181·4	·9	·9	·5
25	9637	52	185·3	3·9	3·9	2·1
26	9650	51	189·2	3·9	3·9	2·1
27	9820	51	192·5	3·3	3·3	2·0
28	9718	49	198·3	5·8	5·8	3·0
29	10750	53	202·8	4·5	4·5	2·3
30	10701	51	209·8	7·0	7·0	3·5
31	10309	49	210·4	·6	·6	·3
32	9753	45	216·7	6·3	6·3	3·0
33	9146	42	217·8	1·1	1·1	·5
34	10428	47	221·9	4·1	4·1	1·9
35	10920	49	222·9	1·0	1·0	·5
36	9974	43	232·0	9·1	9·1	4·1
37	10869	47	231·3	− ·7	− ·7	− ·3
38	9703	41	236·7	5·4	5·4	2·3
39	12197	50	243·9	7·2	7·2	3·0

TABLE XVI. (*continued*)

Age days	Totals Weight	No. obs.	Average	Increase over last measurement	Average daily increase	Daily % increase
40	12831	51	251·6	7·7	7·7	3·1
45	13609	51	266·8	15·2	3·0	1·2
50	13488	48	281·0	14·2	2·8	1·1
55	14946	50	298·9	17·9	3·6	1·3
60	14816	46	322·1	23·2	4·6	1·5
65	15848	48	330·1	8·0	1·6	·5
70	14487	43	336·9	6·8	1·3	·4
75	16231	45	360·7	23·8	4·8	1·4
80	15899	43	369·7	9·0	1·8	·5
85	16053	41	391·5	21·8	4·4	1·2
90	14964	37	404·4	12·9	2·6	·6
95	17837	42	424·7	20·3	4·1	1·0
100	16405	37	443·4	18·7	3·7	·9
105	7951	17	467·7	24·3	4·8	1·1
110	13283	29	458·0	− 9·7	− 1·9	− ·4
115	5888	12	490·7	32·7	6·5	1·4
120	15080	31	486·5	− 4·2	− ·8	− ·2
125	7841	16	490·1	3·6	·7	·1
130	9265	18	514·7	24·6	4·9	1·0
135	17448	35	498·5	− 16·2	− 3·2	− ·6
140	8483	17	499·0	·5	·1	·00
145	9048	18	502·7	3·7	·7	·1
150	17270	34	507·9	5·2	1·0	·2
155	10196	21	485·5	− 22·4	− 4·5	− ·2
160	9046	17	532·1	46·6	9·3	1·9
165	18075	33	547·7	− 15·6	− 3·1	− ·6
170	9068	17	533·4	− 14·3	− 2·9	− ·5
175	9750	18	541·7	8·3	1·6	·3
180	20499	36	569·4	27·7	5·5	1·0
185	8005	15	533·7	− 35·7	− 7·1	1·3
190	9957	18	553·2	19·5	3·9	·7
195	19255	33	583·5	30·3	6·1	1·1
200	8611	15	574·1	− 9·4	− 1·9	− ·3
205	10131	18	562·8	− 11·3	− 2·3	− ·4
210	20028	33	606·9	44·1	8·8	1·6
215	10352	17	608·9	2·0	·4	·05
months						
8 − 5	14214	23	618·0	9·1	·4	·07
8	22018	34	647·6	29·6	5·9	1·0
8 + 5	10721	17	630·6	− 17·0	− 3·4	·5
9 − 5	10464	16	654·0	23·4	1·2	·2
9	15486	23	673·3	19·3	3·9	·6

TABLE XVI. (*continued*)

Age months	Totals Weight	No. obs.	Average	Increase over last measurement	Average daily increase	Daily °/o increase
9 + 5	8711	13	670·1	− 3·2	− ·6	− ·1
10 − 5	12226	18	679·2	9·1	·5	·07
10	19953	28	712·6	33·4	6·7	1·0
10 + 5	13829	20	691·4	− 21·2	− 4·2	·6
11 − 5	16304	23	708·9	17·5	·9	·1
11	22659	31	730·9	22·0	4·4	·6
11 + 5	15890	22	722·3	− 8·6	− 1·7	− ·2
12 − 5	15781	21	751·5	29·2	1·5	·2
12	17954	25	718·2	− 33·3	− 6·7	− ·9
12 + 5	13124	18	729·1	10·9	2·2	·3
13 − 5	9820	12	818·3	89·2	4·5	·6
13	15016	19	790·3	− 28·0	− 5·6	− ·7
13 + 5	12217	15	814·5	24·2	4·8	·6
14 − 5	7474	9	830·4	15·9	·8	·1
14	11282	15	752·1	− 78·3	− 15·6	− 1·9
14 + 5	6767	8	845·9	93·8	18·8	2·5
15 − 5	9827	12	818·9	− 27·0	− 1·3	− ·1
15	16157	21	769·4	− 49·5	− 9·9	− 1·2
15 + 5	10780	13	829·2	59·8	12·0	1·6
16 − 5	7824	9	869·3	40·1	2·0	·2
16	12312	15	820·8	− 48·5	− 9·7	− 1·1
16 + 5	5430	6	905·0	84·2	16·8	2·1
17 − 5	11093	13	853·3	− 51·7	− 2·6	− ·3
17	13240	16	827·5	− 25·8	− 5·2	·6
17 + 5	7801	9	866·8	39·3	7·8	·9
18 − 5	5176	6	862·7	− 4·1	− ·2	− ·02
18	7023	9	780·3	− 82·4	− 16·5	− 1·9
18 + 5	3880	5	776·0	− 4·3	− ·9	− ·1
19	6661	9	740·1	− 35·9	− 1·4	− ·2
20	4127	6	687·7	− 52·4	− 1·7	− ·2
21	5129	7	732·7	45·0	1·5	·2
22	3581	5	716·2	− 16·5	− ·5	− ·07
23	4530	7	647·1	− 69·1	− 2·3	− ·3
24	2968	4	742·0	94·9	3·1	·5

TABLE XVII.

Guinea pigs, male. Averages of weight, etc., for successive ages based on all the observations.

Age days	Totals Weight	No. obs.	Average	Increase over last measurement	Average daily increase	Daily % increase
0	14162	200	70·8			
1	3236	47	68·9	– 1·9	– 1·9	– 2·7
2	3008	43	70·0	1·1	1·1	1·6
3	3524	48	73·4	3·4	3·4	4·9
4	3403	44	77·3	3·9	3·9	5·3
5	3964	48	82·6	5·3	5·3	6·9
6	3620	41	88·3	5·7	5·7	6·9
7	4201	46	91·3	3·0	3·0	3·4
8	4213	44	95·7	4·4	4·4	4·8
9	5241	52	100·8	5·1	5·1	5·3
10	5480	52	105·4	4·6	4·6	4·5
11	4842	45	107·6	2·2	2·2	2·1
12	5911	51	115·9	8·3	8·3	7·7
13	6065	50	121·3	5·4	5·4	4·7
14	6384	51	125·2	3·9	3·9	3·2
15	6480	49	132·2	7·0	7·0	5·6
16	6710	49	136·9	4·7	4·7	3·6
17	7382	52	142·0	5·1	5·1	3·7
18	7455	51	146·2	4·2	4·2	2·9
19	7550	49	154·1	7·9	7·9	5·4
20	7925	50	158·5	4·4	4·4	2·9
21	8442	52	162·3	3·8	3·8	2·4
22	8959	53	169·0	6·7	6·7	4·1
23	8846	51	173·5	4·5	4·5	2·7
24	8524	48	177·6	4·1	4·1	2·4
25	9049	50	181·0	3·4	3·4	1·9
26	8735	46	189·9	8·9	8·9	4·9
27	9450	49	192·9	3·0	3·0	1·6
28	8696	44	197·6	4·7	4·7	2·4
29	10172	50	203·4	5·8	5·8	2·9
30	9866	47	209·9	6·5	6·5	3·2
31	10187	48	212·2	2·3	2·3	1·1
32	9661	45	214·7	2·5	2·5	1·2
33	10343	47	220·1	5·4	5·4	2·5
34	9834	44	223·5	3·4	3·4	1·5
35	11075	49	226·0	2·5	2·5	1·1
36	9955	43	231·5	5·5	5·5	2·4
37	10353	44	235·3	3·8	3·8	1·6
38	9089	38	239·2	3·9	3·9	1·7
39	11540	47	245·5	6·3	6·3	2·6

TABLE XVII. (*continued*)

Age days	Totals Weight	No. obs.	Average	Increase over last measurement	Average daily increase	Daily % increase
40	12489	50	249·8	4·3	4·3	1·7
45	14306	52	275·1	25·3	5·1	2·0
50	13860	47	294·9	19·8	3·9	1·4
55	16097	52	309·6	14·7	2·9	1·0
60	16729	51	328·0	18·4	3·7	1·2
65	17875	52	343·7	15·7	3·1	·9
70	18514	51	363·0	19·3	3·9	1·1
75	19888	52	382·4	19·4	3·9	1·1
80	21105	52	405·9	23·5	4·7	1·2
85	20837	50	416·7	10·8	2·2	·5
90	22821	52	438·8	22·1	4·4	1·1
95	22365	50	447·3	8·5	1·7	·4
100	23038	43	466·0	18·7	3·7	·8
105	6420	12	535·0	69·0	13·8	3·0
110	22663	47	482·2	– 52·8	– 10·6	– 2·0
115	5625	11	511·4	29·2	5·8	1·2
120	26707	51	523·7	12·3	2·5	·5
125	6879	13	529·2	5·5	1·1	·2
130	6451	12	537·6	8·4	1·7	·3
135	23744	45	527·6	– 10·0	– 2·0	– ·4
140	5301	10	530·1	2·5	·5	·1
145	6496	12	541·3	11·2	2·2	·4
150	27405	48	570·9	29·6	5·9	1·1
155	6626	12	552·2	– 18·7	– 3·7	– ·6
160	6891	12	574·2	22·0	4·4	·8
165	29559	50	591·2	17·0	3·4	·6
170	7834	13	602·6	11·4	2·3	·4
175	7695	13	591·9	– 10·7	– 2·1	– ·3
180	30333	50	606·7	14·8	2·9	·5
185	7933	13	610·2	3·5	·7	·1
190	8044	13	618·8	8·6	1·7	·3
195	27065	43	629·4	10·6	2·1	·3
200	8783	14	627·4	– 2·0	– ·4	– ·06
205	7804	12	650·3	22·9	4·6	·7
210	23786	36	660·7	10·4	2·1	·3
215	8872	13	682·5	21·8	4·4	·7
months						
8 – 5	7128	11	648·0	– 34·5	– 1·7	– ·3
8	24509	36	680·8	32·8	6·6	1·0
8 + 5	5993	9	665·9	– 14·9	– 2·9	– ·4
9 – 5	8555	12	712·9	47·0	2·3	·3
9	23792	32	743·5	30·6	6·1	·9

TABLE XVII. (*continued*).

Age months	Totals		Average	Increase over last measurement.	Average daily increase	Daily % increase
	Weight	No. obs.				
9 + 5	6752	9	750·2	6·7	1·3	·2
10 − 5	8901	12	741·7	− 8·5	− ·4	− ·05
10	24160	31	779·4	37·7	7·5	1·0
10 + 5	9588	13	737·5	− 41·9	− 8·4	− 1·1
11 − 5	13622	18	756·8	19·3	1·0	·1
11	27807	36	744·4	− 12·4	− 2·5	− ·3
11 + 5	10951	14	782·2	37·8	7·6	1·0
12 − 5	11883	15	792·2	10·0	·5	·06
12	30598	39	784·6	− 7·6	− 1·5	− ·2
12 + 5	11505	14	821·8	37·2	7·4	·9
13 − 5	9020	12	751·7	− 70·1	3·5	− ·4
13	29089	39	745·9	− 5·8	− 1·2	− ·1
13 + 5	11712	15	780·8	34·9	7·0	·9
14 − 5	9273	12	772·7	− 8·1	− ·4	− ·05
14	32655	45	725·7	− 47·0	− 9·4	− 1·2
14 + 5	11648	15	776·5	50·8	10·2	1·4
15 − 5	9118	11	828·9	52·4	2·6	·3
15	31610	41	771·0	− 57·9	− 11·6	− 1·4
15 + 5	12938	16	808·6	37·6	7·5	1·0
16 − 5	9121	11	829·2	20·6	1·0	·1
16	28950	37	782·4	− 46·8	− 9·4	− 1·1
16 + 5	8674	10	867·4	85·0	17·0	2·2
17 − 5	17835	22	810·7	− 56·7	− 2·8	− ·3
17	31243	41	762·0	− 48·7	− 9·7	− 1·2
17 + 5	14994	19	789·2	27·2	5·4	·7
18 − 5	21717	28	775·6	− 13·6	− ·7	− ·08
18	28257	38	743·6	− 32·0	− 6·4	·8
18 + 5	18570	23	807·4	63·8	12·8	1·7
19	26428	35	755·1	− 52·3	− 2·1	− ·3
20	24899	32	778·1	23·0	·8	·1
21	26089	34	767·3	− 10·8	− ·3	− ·05
22	24854	32	776·7	9·4	·3	·04
23	26641	34	783·6	6·9	·2	·03
24	24418	31	787·7	4·1	·1	·02

TABLE XVIII. (See Plate III.)

To shew the average changes in weight of Guinea pigs for two years after birth as determined by condensing Tables XVI. and XVII.

Females: Averages: Daily % increase	Females: Averages: Average daily increase	Females: Averages: Increase over last measurement	Females: Averages: Average	Females: Totals: Observation	Females: Totals: Weight	Ages in days	Males: Totals: Weight	Males: Totals: Observations	Males: Averages: Average	Males: Averages: Increase over last measurement	Males: Averages: Average daily increase	Males: Averages: Daily % increase
f	*e*	*d*	*c*	*b*	*a*		*A*	*B*	*C*	*D*	*E*	*F*
			70·1	172	12052	0	14162	200	70·8			
2·1	1·5	4·4	74·5	160	11920	1—3	9768	138	70·8	0·0	0·0	0·0
5·5	4·1	12·2	86·7	158	13706	4—6	10987	133	82·6	11·8	3·9	5·6
5·4	4·7	14·0	100·7	165	16616	7—9	13655	142	96·2	13·6	4·5	5·5
4·7	4·7	14·1	114·8	163	18707	10—12	16233	148	109·7	13·5	4·5	4·7
5·0	5·8	17·3	132·1	158	20868	13—15	18929	150	126·2	16·5	5·5	5·0
4·3	5·7	17·0	149·1	157	23401	16—18	21547	152	141·7	15·5	5·2	4·1
3·5	5·2	15·6	164·7	149	24533	19—21	23917	151	158·4	16·7	5·6	3·9
1·7	4·7	14·0	178·7	156	27873	22—24	26329	152	173·2	14·8	4·9	3·1
1·9	3·4	10·3	189·0	154	29107	25—27	27234	145	187·8	14·6	4·9	2·8
2·6	4·9	14·7	203·7	153	31169	28—30	28734	141	203·8	16·0	5·3	2·8
1·8	3·7	11·1	214·8	136	29208	31—33	30191	140	215·6	11·8	3·9	1·9
1·6	3·5	10·5	225·3	139	31322	34—36	30864	136	226·9	11·3	3·8	1·7
1·8	4·1	12·2	237·5	138	32769	37—39	30982	129	240·2	13·3	4·4	1·9
1·1	2·5	28·0	266·1	150	39928	40—50	40655	149	272·9	32·7	3·0	1·2
1·3	3·3	50·6	316·7	144	45610	55—65	50701	155	327·1	54·2	3·6	1·3
·8	2·6	39·2	355·9	131	46617	70—80	59507	155	383·9	56·8	3·8	1·2
·9	3·4	51·2	407·1	120	48854	85—95	66023	152	434·4	50·5	3·4	·9
·8	3·1	46·4	453·5	83	37639	100—110	49121	102	481·6	47·2	3·1	·7
·5	2·3	34·8	488·3	59	28809	115—125	39211	75	522·8	41·2	2·7	·6
·2	·9	14·5	502·8	70	35196	130—140	35496	67	529·8	7·0	·5	·1
−·03	−·2	−2·6	500·2	73	36514	145—155	40527	72	562·9	33·1	2·2	·4
·5	2·7	39·9	540·1	67	36189	160—170	44284	75	590·5	27·6	1·8	·3
·2	1·0	14·3	554·1	69	38254	175—185	45961	76	604·7	14·2	·9	·2
·2	1·2	18·7	573·1	66	37823	190—200	43892	70	627·0	22·3	1·5	·2
·3	1·5	22·7	595·8	68	40511	205—215	40462	61	663·3	36·3	2·4	·4
						months						
·2	1·3	38·7	634·5	74	46953	8 − 5 to 8 + 5	37630	56	672·0	8·7	·3	·05
·2	1·1	32·1	666·6	52	34661	9 − 5 „ 9 + 5	39099	53	737·7	65·7	2·2	·3
·1	1·0	30·5	697·1	66	46008	10 − 5 „ 10 + 5	42649	56	761·6	23·9	·8	·1
·1	·8	24·6	721·7	76	54853	11 − 5 „ 11 + 5	52380	68	770·3	8·7	·3	·04
·05	·3	10·5	732·2	64	46859	12 − 5 „ 12 + 5	53986	68	793·9	23·6	·8	·1
·3	2·4	73·3	805·5	46	37053	13 − 5 „ 13 + 5	49821	66	754·9	−39·0	−1·3	−·2
−·03	−·3	−7·9	797·6	32	25523	14 − 5 „ 14 + 5	53576	72	744·1	−10·8	−·3	−·05
·00	·05	1·6	799·2	46	36764	15 − 5 „ 15 + 5	53666	68	789·2	45·1	1·5	·2
·2	1·8	53·0	852·2	30	25566	16 − 5 „ 16 + 5	46745	58	805·9	16·7	·5	·07
−·02	−·2	−6·6	845·6	38	32134	17 − 5 „ 17 + 5	64072	82	781·4	−24·5	−·8	−·1
−·2	−1·4	−41·7	803·9	20	16079	18 − 5 „ 18 + 5	68544	89	770·1	−11·3	−·4	−·05
−·1	−·9	−80·4	723·5	22	15917	19—21	77416	101	766·5	−3·6	−·04	·006
−·05	−·3	−31·1	692·4	16	11079	22—24	75913	97	782·6	16·1	·2	·02

2. *General course of Growth.* For convenience, for increased accuracy and for greater clearness, Tables XVI. and XVII. have been condensed and in their new form are reproduced in Table XVIII., together with certain results calculated from the data of observation. This table includes all my available measurements. It is fundamental to all the conclusions and deductions hereinafter to be discussed.

We began with an explanation of the arrangement of Table XVIII. The central column gives the range of ages from the records of which the data on the corresponding horizontal line have been calculated. The corresponding average age is given thrice in the first, middle, and last columns; this arrangement was adopted merely to facilitate reference to the table. The data for males are in columns on the right, each column being designated by a capital letter; the data for the females are on the left, each column being designated by a little letter. Thus the column *A* corresponds to column *a*, column *B* to column *b*, and so on. The columns for the two sexes are symmetrically arranged on either side of the central column, hence the order for the females is the inverse of that for the males.

1. The comparison of the preceding table with the two from which it is derived shews that the averages run much more regularly and that the grouping has essentially diminished the accidental irregularities in the results and that consequently the essential variations come out more clearly. Columns *C* and *c* give the average weights in grammes for the successive ages. They increase steadily up to twelve months but after that vary irregularly, and this is true of both sexes. At birth the male is slightly heavier than the female 70·8 as against 70·1; but the female immediately makes a marked gain owing to its having a less post-natal retardation than the male, and it is not until the 29th day that the male weighing 203·8, catches up with the female, weighing 203·7. After the first month to the end of the first year the males at every age are on the average heavier than the females. The averages during the second year are so irregular, being taken from a too limited number of observations, that direct comparisons between the two sexes cannot be made. We may however take the averages of all the observations from the thirteenth to the twenty-fourth month both inclusive and for each sex. The total of all the weights for the period is,—for females: 200115,—for males: 491753. The total number of observations is, for females: 250;—for males: 633. Hence the average weight during the second year is for

females 800·5 males 776·9

The females therefore are at birth slightly smaller than the males, during the first month decidedly larger, during the remainder of the first year considerably smaller, but when adult again decidedly heavier. The sexes do not vary alike and although one of them, the female, is during the majority of the period of growth considerably smaller than the other it yet surpasses its rival ultimately. These relations are rendered more evident by expressing the weights of the females in percentages of the weights of the males at the same age. This has been done for certain ages in Table XIX., which is based on Table XVIII.

TABLE XIX.

Shewing the relative weights of males and females.

Age	A. Males Weights	B. Females Weights	Wts. B. as % of correspond. Wts. A.
Days			
0	70·8	70·1	99 = 100 − 1
1– 3	70·8	74·5	105 = „ + 5
10– 12	109·7	114·8	104 = „ + 4
19– 21	158·4	164·7	103 = „ + 3
28– 30	203·8	203·7	99 = „ − 1
37– 39	240·2	237·5	98 = „ − 2
70– 80	383·9	355·9	92 = „ − 8
115–125	522·8	488·3	93 = „ − 7
160–170	590·5	540·1	91 = „ − 9
205–215	663·3	595·8	89 = „ − 11
Months			
9	737·7	666·6	90 = „ − 10
11	770·3	721·7	93 = „ − 7
13	754·9	805·5	105 = „ + 5
15	789·2	799·2	101 = „ + 1
17	781·4	845·6	108 = „ + 8
19– 21	766·5	723·5	94 = „ − 6
22– 24	782·6	692·4	88 = „ − 12

The course of growth for both sexes is most readily shewn graphically as is done by the two curves on Plate III. The curves are very similar. They begin with a very steep rise which gradually changes to a slight ascent. The latter part of each curve is quite irregular, the number of observations being insufficient to give a good series of averages such as I might have hoped for had the experiments not been interrupted. In spite of the irregularity the curves evidently tend to become asymptotic to the horizontal.

Considered as a whole the curve is remarkable for the absence of any marked variations other than accidental. In this respect it differs very markedly from the curve of human growth. In man the greatest fluctuation in growth is associated with puberty, there being, as discovered by H. P. Bowditch, a præ-pubertal acceleration and a post-pubertal retardation, both modifications being greatest in girls. I think that a similar fluctuation occurs in Guinea pigs though to a very much less degree. The determination of the age of puberty in guinea pigs, I have not yet been able to make accurately: it appears to be about four months, but is also evidently extremely variable. The determination rests firstly on the observation of the existence of the sexual impulse in males about the fourth or fifth month and secondly that young females left with older bucks not unusually become pregnant at from 100 to 150 days of age[1]. Now from Table XVIII. we may derive the following:—

TABLE XX.

The average daily increase in weight from

91–105	days is	3·1	grms.	in females,	3·1	grms.	in	males
106–120	„	2·3	„	„	2·7	„		„
121–135	„	0·9	„	„	0·5	„		„
136–150	„	0·2	„	„	2·2	„		„
151–165	„	2·7	„	„	1·8	„		„
166–180	„	1·0	„	„	0·9	„		„
181–195	„	1·2	„	„	1·5	„		„

From this table we learn that there is a diminution of growth in both sexes beginning about the end of the fourth month, which is greater in amount and longer in duration in the female than in the male. I venture to think that this retardation corresponds to the post-pubertal retardation of the human species. There appears to be also a prepubertal acceleration, not in the sense that there is an actual increase of rate of growth but that there is a maintenance of an earlier high rate, instead of an inflexible falling off in rate as there would be were there no fluctuation in the direction of an acceleration. These observations taken in conjunction with those of Bowditch and Pagliani

[1] It is to be distinctly understood that this determination of the age of puberty is far from certain. I have had females become pregnant before they were two months old.

on man raise the question whether in all mammals the double pubertal fluctuation of growth occurs.

2. The study of the individual variations yields two important conclusions: *First,* that any irregularity in the growth of an individual tends to be followed by an opposite compensating irregularity. *Second,* the variability diminishes with the age.

The irregularity of growth of an individual is very great.

Another branch of the investigation of the growth of guinea pigs, for which my experiments afford extensive materials is the study of individual variations. I have thought it best to postpone the discussion of this subject, as it demands special and systematic experiments to determine the causes and limits of the variation of growth [1]. There is however one phenomenon, which may be mentioned here, namely each individual appears to be striving to reach a particular size. The fact, which I have thus expressed, is that if an individual grows for a period excessively fast, there immediately follows a period of slower growth, and *vice versa,* those that remain behind for a time, if they remain in good health, make up the loss (at least in great part if not always completely) soon after. Indeed to permanently dwarf a guinea pig requires an astonishingly prolonged interference; thus a young pig may lose one third of its weight, from a severe intestinal catarrh and yet make it up subsequently. The number of similar observations is so great, that we might assert safely that a pretty severe and prolonged illness will not affect very much the ultimate size. It is probable that the same is true of man and that therefore the usual and even the severer illnesses of childhood and youth do not greatly affect the ultimate size of the adult. In fact Pagliani [2] has shewn that children brought up in poverty and undersized, will if placed under favourable conditions recover in the most surprising manner.

The actual variations occurring are well illustrated by Table XIV. By wây of further illustration, I give the growth of individuals in the following

[1] To illustrate the matter however I have given a few curves of the growth of individuals on Plate II.

[2] Pagliani. *Lo Sviluppo umano,* etc., Milano, 1879.

TABLE XXI. (See Plate IV.)

Growth of individual males.

No. of pig	34	36	38	40	50
Date of birth	19. xi. 81	16. xi. 81	17. xi. 81	27. xi. 81	6. xii. 82
Age in Days					
0	42	80	79	63	48
1	40	77	79	58	49
2	42	77	80	53	49
3	46	81	86	58	46
4	49	86	88	58	57
5	55	89	91	63	61
6	58	94	95		66
7	64	98	97	60	67
8	69	101	100	58	71
9	70	104	102	57	78
10	75	103	103	64	82
11	79	110	110	67	86
12	80	119	118	73	89
13	87	128	124	73	91
14	92	130	130	75	91
15	95	143	136	77	96
16	97	147	132	81	104
17	101	152	131	89	114
18	103	155	142	97	116
19	109	164	150	103	
20	112	174	156	106	116
21	117	174	156	113	116
22	121	181	166	105	125
23	125	189	161	104	131
24	126	191	177	104	134
25	127	197	190	111	137
26	140	207	192	115	139
27	141	204	200	123	139
28	139	214	194	122	141
29	140	207	197	126	140
30	144	210	197	122	149
31	142	209	202	124	154
32	151	211	204	133	157
33	151	213	212	130	163
34	152	220	210	128	160
35	160	219	224	136	172
36	158	230	217	136	165
37	157	227	239	137	168
38	156	241	227	157	177

TABLE XXI (*continued*).

No. of pig	34	36	38	40	50
Date of birth	9. xi. 81	16. xi. 81	17. xi. 81	27. xi. 81	6. xii. 82
Age in Days					
39	153	240	232	150	176
40	159	242	238	154	189
45	188	242	240	173	209
50	209	288	273	187	222
55	218	288	278	195	235
60	217	292	313	211	218
65	231	312	330	228	286
70	230	338	352	230	292
75	242	357	380	249	296
80	246	361	385	272	317
85	254	403	407	297	347
90	271	429	425	297	350
95	249	458	445	305	370
100	257	445		329	398
110	251	496	483	377	454
115					496
120	276	515	512	398	496
125					514
130					510
135	290	542	508	471	522
140					550
145					541
150	323	570	521	492	512
155					470
160					532
165	365	570	544		552
170					560
175					561
180	435	600	594		595
185					580
190					588
195					608
200					627
210					654
215					668
Months.					
8 – 5					635
8					652
8 + 5					687
10 – 5					640

TABLE XXI (*continued*).

No. of pig	34	36	38	40	50
Date of birth	19. xi. 81	16. xi. 81	17. xi. 81	27. xi. 81	6. xii. 82
Months					
10 + 5					705
11 − 5					695
11		575	630	613	
12 − 5					727
12		716	602	635	719
12 + 5					773
13 − 5					782
13	460	697	705	645	758
13 + 5					754
14 − 5					792
14	466	667	654	635	855
14 + 5					837
15		747	757	718	
15 + 5					901
16 − 5					912
16	568	758	775	723	926
16 + 5				730	925
17 − 5	571	810	722		968
17	540	842	745		976
17 + 5	487	838	763		
18 − 5	520	824	742	735	
18	449	800	750	700	967
18 + 5		805	762	702	988
19	469	801	833	698	
20	600	794	805	680	
21	575	809	772	687	
22	580		770	701	
23	553	810	760	715	
24	560	800	807	756	

From Table XXI. I have constructed the curves given in Plate II. Pig 34 is one which starts small and remains undersized. Pig 50 starts small and attains a large size. Pigs 38 and 40 start about the same and keep together throughout, and illustrate particularly how each rapid growth of an individual is followed by a slower growth and *vice versa.* Pig 36 is one which occupies an intermediate position and is remarkable for the regularity of its growth.

The relation of the variability to age may be conveniently studied by dividing the observations for each age into two groups one including all the observations above, the other all below the average weight for that age. The average of one group gives the average variation above, and that of the other the average variation below the total average for that age. By carrying out these calculations upon the data included in Table XVIII. there has been obtained the following.

TABLE XXII.

Average variation plus and minus.

Part I. Males.

Age	Average weight	No. obs. above average	Total weight	Average weight	% above total average		No. obs. below average	Total weight	Average weight	% above total average	
days											
0	70·8	100	8466	84·7	19·51		100	5696	57·	19·49	
1–3	70·8	72	6025	83·7	18·22		66	3743	56·7	19·92	
4–6	82·6	67	6652	99·3	20·22		66	4335	65·7	20·46	
7–9	96·2	72	8167	113·4	17·88	18·95	70	5478	78·3	18·61	18·99
10–12	109·7	71	9335	131·5	19·87		77	6898	89·6	18·32	
13–15	126·2	73	10928	149·6	18·54		77	8000	103·9	17·67	
16–18	141·7	74	12389	167·4	18·14		78	9158	117·4	17·15	
19–21	158·4	71	13212	186·1	17·49		80	10705	133·8	15·53	
22–24	173·2	76	15573	204·9	18·30	17·13	76	10756	141·5	18·30	16·87
25–27	187·8	75	16290	217·2	15·65		70	10944	156·3	16·77	
28–30	203·8	72	17001	236·1	16·09		69	11733	170·0	16·58	
31–33	215·6	71	17955	252·9	17·30		69	12236	177·3	17·76	
34–36	226·9	69	18103	262·4	15·65		67	12761	190·5	16·13	
37–39	240·2	68	18757	275·8	14·82	15·68	61	12225	200·4	16·57	16·31
40–50	272·9	76	23963	315·3	15·54		73	16692	228·7	16·20	
55–65	327·1	77	28983	376·5	15·07		78	21718	278·4	14·89	
70–80	383·9	83	36524	440·0	14·61		72	22983	319·2	16·85	
85–95	434·4	83	41004	494·0	13·72		69	25019	362·6	16·53	
100–110	481·6	57	30711	538·8	11·88	12·12	45	18410	409·1	15·05	13·31
115–125	522·8	33	19258	583·6	11·63		42	19953	475·3	9·08	
130–140	529·8	34	19590	576·2	8·76		33	15906	482·0	9·02	
145–155	562·9	39	23850	611·5	8·63		33	16677	505·4	10·21	
160–170	590·5	35	22390	639·7	8·33		40	21894	547·3	7·32	
175–185	604·7	34	22074	649·2	7·36	7·52	42	23887	568·7	5·95	7·48
190–200	627·0	37	24738	668·6	6·63		33	19154	580·4	7·43	
205–215	663·0	30	21238	707·4	6·65		31	19224	620·1	6·51	
months											
8 – 5 to 8 + 5	672·0	24	17573	732·2	8·22		32	20057	626·8	6·73	
9 – 5 „ 9 + 5	737·7	30	23674	789·1	6·51		23	15425	670·6	9·09	
10 – 5 „ 10 + 5	761·6	29	24321	838·7	10·12	10·66	27	18328	678·8	10·87	9·72
11 – 5 „ 11 + 5	770·3	30	26922	897·4	16·50		38	25458	669·9	13·03	
12 – 5 „ 12 + 5	793·9	29	25774	888·8	11·95		39	28218	723·4	8·88	
13 – 5 „ 13 + 6	754·9	37	30678	829·1	9·83		29	19143	660·1	12·56	
14 – 5 „ 14 + 5	744·1	38	31249	822·3	10·51		34	22327	656·7	11·75	
15 – 5 „ 15 + 5	789·2	32	27703	865·7	9·69	10·38	36	25963	721·1	8·63	11·41
16 – 5 „ 16 + 5	805·9	32	28327	885·2	9·84		26	18418	708·4	12·10	
17 – 5 „ 17 + 5	781·4	41	35889	875·3	12·02		41	28183	687·4	12·03	
18 – 5 „ 18 + 5	770·1	43	37001	860·5	11·74		46	31543	685·7	10·96	
19 „ 21	766·5	49	42012	857·4	11·86	12·10	52	35404	680·8	11·18	10·82
22 „ 24	782·6	44	38714	879·9	12·69		53	37199	701·9	10·31	

PART II. FEMALES.

Age	Average weight	No. obs. above average	Total weight	Average weight	% above total average		No. obs. below average	Total weight	Average weight	% above total average	
days											
0	70·1	90	7387	82·1	17·12		82	4667	56·9	18·83	
1–3	74·5	82	6967	85·0	14·09		78	4953	63·5	14·77	
4–6	86·7	78	7901	101·3	16·84		80	5805	72·6	16·26	
7–9	100·7	85	10172	119·7	18·86	17·07	80	6444	80·5	20·09	17·31
10–12	114·8	83	11224	135·2	17·77		80	7483	93·5	18·55	
13–15	132·1	77	11976	155·6	17·79		81	8892	109·8	16·87	
16–18	149·1	79	13732	173·8	16·57		78	9669	124·0	16·83	
19–21	164·7	74	14167	191·4	16·21		75	10366	138·2	16·09	
22–24	178·7	72	15084	209·5	17·24	15·69	84	12789	152·2	14·83	15·17
25–27	189·0	73	16069	220·1	16·46		78	12471	160·0	15·34	
28–30	203·7	77	17665	228·1	11·98		76	13504	177·7	12·76	
31–33	214·8	63	15931	252·9	17·74		73	13277	181·9	15·32	
34–36	225·3	69	17921	259·7	15·27		70	13401	191·4	15·05	
37–39	237·5	66	18043	273·4	15·12	15·97	72	14726	204·5	13·89	14·37
40–50	266·1	72	22114	307·1	15·41		78	17814	228·4	14·17	
55–65	316·7	65	23947	368·4	16·32		79	21663	274·2	13·42	
70–80	355·9	60	24927	415·4	16·72		71	21690	305·5	14·16	
85–95	407·1	54	25523	472·6	16·33		66	23331	353·6	13·14	
100–110	453·5	38	19989	526·0	13·78	15·44	45	17650	392·2	13·52	13·97
115–125	488·3	29	16397	565·4	15·79		30	12412	413·7	15·28	
130–140	502·8	34	19586	576·1	14·58		36	15610	433·6	13·76	
145–155	500·2	39	22648	580·7	16·09		34	13866	407·9	18·45	
160–170	540·1	35	21216	606·2	12·24		32	14973	467·9	13·37	
175–185	554·4	34	21324	627·2	13·13	13·19	35	16930	483·7	12·75	12·84
190–200	573·1	32	20431	638·5	11·41		34	17392	511·5	10·75	
205–215	595·8	39	25369	650·5	13·10		29	15142	522·1	8·90	
months											
8 − 5 to 8 + 5	634·5	36	25679	713·3	12·42		38	21274	559·8	11·62	
9 − 5 „ 9 + 5	666·6	19	14488	762·5	14·39		33	20173	611·3	8·30	
10 − 5 „ 10 + 5	697·1	35	27209	777·4	11·52	12·66	31	18799	606·4	13·01	11·64
11 − 5 „ 11 + 5	721·7	35	28735	821·0	13·76		41	26118	637·0	11·74	
12 − 5 „ 12 + 5	732·2	35	28500	814·3	11·21		29	18359	633·1	13·53	
13 − 5 „ 13 + 5	805·5	26	22543	867·0	7·63		20	14510	725·5	9·93	
14 − 5 „ 14 + 5	797·6	20	17241	862·0	8·09		12	8282	690·2	13·47	
15 − 5 „ 15 + 5	799·2	28	24614	879·1	10·00	10·44	18	12150	675·0	15·54	13·08
16 − 5 „ 16 + 5	852·2	15	14599	973·3	14·21		15	10967	731·1	14·21	
17 − 5 „ 17 + 5	845·6	19	18038	949·4	12·27		19	14096	741·9	12·26	
18 − 5 „ 18 + 5	803·9	10	9612	961·2	19·57		10	6467	646·7	19·55	
19 „ 21	723·5	8	6491	811·4	12·15	14·81	14	9426	673·3	6·94	12·12
22 „ 24	692·4	7	5463	780·4	12·71		9	5616	624·0	9·88	

From this table by condensation we obtained the following

TABLE XXIII.

Average variation above and below for successive periods.

I. Males			II. Females		
Age	% above	% below	Age	% above	% below
Days			Days		
0	19·51	19·49	0	17·12	18·83
1–15	18·95	18·99	1–15	17·07	17·31
16–30	17·13	16·87	16–30	15·69	15·17
31–65	15·68	16·31	31–65	15·97	14·37
70–125	12·96	14·34	70–140	15·44	13·97
130–275	7·64	7·78	145–215	13·19	12·84
Months			Months		
10–13	12·10	11·33	8–12	12·66	11·64
14–17	10·51	11·50	13–17	10·44	13·08
18–24	12·10	10·82	18–24	14·81	12·12

It will be noticed that the periods taken for the two sexes are not quite identical. The condensed table shews very clearly that the range in variation diminishes with age, and further that there is a period from 130—275 days,—about three months and a half—during which the variation in the males is very much less than at any other time. The cause or significance of this period I have not ascertained. There is no corresponding phenomenon in the female. The actual diminution of variability with age is probably decidedly greater for both sexes than indicated by the tables because, as will be remembered, the number of observations for the older ages is too small to give regular averages,—compare the curves, Plate III.—and therefore it is probable that the average variations deduced from my record are excessive as compared with the true values. As subsequent articles will shew this diminution of variability with age is demonstrable in the growth of other mammals, hence it probably occurs in all. We are led by this to put the question, whether all variability of the higher animals does not lessen with the age of the individual. In view of the extreme variations of structure which occur in all vertebrate embryos, and which as all embryologists know familiarly are far greater and more frequent than the variations of the adult, we are justified in asserting that there is a diminution of variability with age. To this problem I hope to recur in a subsequent article as it is important for its bearings on natural selection.

Let us consider next the effect of gestation on growth. It has been asserted by Carpenter, Spencer and others that the functions of nutrition and reproduction are in principle opposed to one another, because reproduction makes such a demand upon the parent for material that the supply for nutrition and growth of the parent is lessened. The reproductive process causes, according to these authors the impairment of nutrition and growth. Unfortunately they have both overlooked that they have made a preliminary assumption without adequate justification,—namely, that before reproduction, the organism must be already growing nearly or quite up to the maximum of its assimilative power,—if this were not the case, then the surplus or reserve capacity for assimilation would be called in to meet the reproductive demand, and the parent organism would meanwhile keep on growing as before. Now Edelfsen and Hensen[1] have shewn experimentally that female guinea pigs grow about the same whether they have young or not during their own growing period. In other words these animals have precisely that surplus power of nutrition, which Carpenter tacitly assumed not to exist. My own observations fully confirm the conclusion of Edelfsen and Hensen. To utilize my own data I have proceeded in the following manner:—There are 66 litters, of whose mothers' weights at various times within 70 days before delivery I have records. These data have been tabulated so as to give the following

TABLE XXIV.

Average changes in weights of 66 mothers before delivery.

Days before delivery	Total Weight	No. of obs.	Average	Increase	Average daily increase	Daily °/₀ increase
70–66	16200	40	405·0			
65–61	25792	60	429·9	24·9	5·0	1·2
60–56	17168	40	429·2	– ·7	– ·1	– ·00
55–51	17270	38	454·5	25·3	5·1	1·2
50–46	18287	38	481·2	26·7	5·3	1·2
45–41	22925	42	545·8	64·6	12·9	2·7
40–36	18410	34	541·5	– 4·3	– ·9	– ·1
35–31	17554	31	566·3	24·8	4·9	0·9
30–25	22104	36	614·0	47·7	9·5	1·7
25–21	21227	33	643·2	29·2	5·8	0·9
20–15	21362	31	689·1	45·9	9·2	1·4
15–11	35241	46	766·1	77·0	15·4	2·2
10– 5	34976	42	832·8	66·7	13·3	1·7
5– 1	53137	63	843·4	10·6	2·1	0·3
3– 0	29999	35	857·1	13·7	4·6	0·5

[1] Hensen. *Arbeiten Keil. Physiol. Instit.*, 1868.

As the results of Table XXIV. are irregular I have sought to better them by a system of interpolations. The original records from which the table is calculated contain many observations giving the weights of the mother at intervals of five days or less. For all such intervals the weights have been calculated by dividing the difference between the two weights by the number of days, to ascertain the average daily increase, by which the weight for each day was then calculated. For example one mother weighed 487 grammes 40 days before delivery, and 522 grammes 35 days before delivery; she therefore gained on the average 7 grammes daily, and the weights to be interpolated for the four days are 494, 501, 508, 515. In this manner large additions could be made to the data for the averages, without risk of introducing any important error. The following Table XXV. gives the results of the corrected tabulation; comparison with Table XXIV. will shew the extent of the alterations resulting from the interpolations.

TABLE XXV.

Average changes in weights of mothers during gestation, based upon observed weights plus weights calculated and interpolated.

Days before delivery	Total weight	No. of obs.	Average	Increase	Average daily increase	Daily % increase
70–66	37891	89	425·7			
65–61	60302	147	410·2	– 15·5	– 3·1	– ·7
60–56	51459	131	392·8	– 17·4	– 3·5	– ·8
55–51	63506	143	444·1	51·3	10·3	2·6
50–45	68193	147	463·9	19·8	4·0	0·9
45–41	79725	155	514·4	50·5	10·1	2·2
40–36	73419	140	524·4	10·0	2·0	0·4
35–31	68324	127	538·0	13·6	2·7	0·5
30–26	76281	132	577·9	39·9	8·0	1·5
25–21	76654	124	618·2	40·3	8·1	1·4
20–16	86738	131	662·1	43·9	8·8	1·4
15–11	101412	143	709·2	47·1	9·4	1·4
10– 6	92000	123	748·0	38·8	7·8	1·1
5– 1	85969	108	796·0	48·0	9·6	1·3
3– 0	33207	40	830·2	34·2	11·4	1·4

It will be convenient to juxtapose the average daily percentage increments of the two Tables XXIV. and XXV. as is done in

TABLE XXVI.

Daily per cent. increase during gestation.

Table XXIV.	1·2	−0·00	1·2	1·2	2·7	−0·1	0·9	1·7
Table XXV.	−0·7	−0·8	2·6	0·9	2·2	0·4	0·5	1·5
	0·9	1·4	2·2	1·7	0·3	0·5		
	1·4	1·4	1·4	1·1	1·3	1·4		

The results from the corrected table are somewhat more regular than those from the observations merely. There is certainly a greater percentage increase of weight in the mother during the latter than during the first half of the period of gestation. According to the corrected table there is a loss of weight at the beginning of gestation, but as the averages are very irregular this may be an accidental result of the data being so few in number, but it is quite possible that such loss in weight is a normal consequence of the physiological disturbance ensuing upon conception.

Table XXIV. shews that about 67–68 days before delivery the average weight of the mothers was 405 grms. 67 to 68 days is the usual length of gestation. Now Table XV. shews that this weight corresponds to an age of 90 days, hence we may assume that the age of the 66 mothers of Table XXIV. was about 90 days. Table XV. also shews that 70 days later the weight is 532·1 grammes, instead of 830·2 the highest value of Table XXV. this value being the average weight just before gestation ends. Accordingly gestation adds 300 grammes or more to the weight of the mother. My weighings of the same 66 mothers within three days after delivery gives for 62 observations a total of 36456 grammes or an average weight of 588·0 grammes 0·3 days after delivery. Now the corresponding weight of females not pregnant is 532·1 as nearly as can be determined by my data, hence there is an excess of 55·9 grammes in favour of the gestating Guinea pigs. This is more noteworthy as immediately after delivery there is a loss of weight, so that the average of 588 is smaller than an average from a sufficient number of weighings at 0 days would be. So far then as we can judge at present gestation does not represent a tax upon the parent but a stimulus—it does not impede growth, but on the contrary favours it. The dogmatic assertions of Herbert Spencer concerning the opposition of growth and reproduction are open to justly severe criticism. On the other hand I think that Carpenter has contributed a very valuable generalization to biology in approximating the access of reproduction to the decline of nutrition, but I believe that he has interpreted the cause as effect, and that contrary to his view the diminished nutrition is the cause of the reproductive activity, is the exciting stimulus of the development of the sexual products; in fact the sexual elements are never developed until after the most active growth and nutrition are over, and in many protophytes, the reproduction bodies as in Vaucheria, are developed as soon as nutrition is impaired artificially.

How far an extra demand upon an organism may go, without seriously impeding its growth might be tested by raising warm-blooded animals at various temperatures. If young mammals really have a surplus power of assimilation then those that are raised at a lower temperature,—provided it be within the limits of health,—ought to be able to evolve enough extra warmth to maintain their body temperature and meanwhile grow to the same size as those raised at a higher temperature. Although such experiments appear to me of great practical as well as theoretical importance, I have been unable to attempt them on account of their great expensiveness.

The complexity of the relations of the total weight to physiological conditions is illustrated by the fact that though gestation does not hinder growth lactation causes a great loss of weight. I have utilized my records of the weights of the same 66 mothers tabulated in Tables XXIV. and XXV. and thus obtained the following

TABLE XXVII.

Average alterations of weight of 66 female Guinea pigs *past partum.*

Days after delivery	Total weight	No. of obs.	Average	Increase	Average daily increase	Daily % increase
0	14726	24	613·6			
1–5	31657	55	575·6	– 38·0	– 7·6	– 1·2
6–10	28367	51	556·2	– 19·4	– 3·9	– 0·7
11–15	20933	36	581·5	25·3	5·1	0·9
16–20	20595	36	572·1	– 9·4	– 1·9	– 0·3
21–25	15394	28	549·8	– 22·3	– 4·5	– 0·8
26–30	11603	20	580·1	30·3	6·1	1·1
31–35	11909	21	567·1	– 13·0	– 2·6	– 0·4

By the system of interpolations explained on p. 142 and used in the construction of Table XXV. I have obtained from the above table the following.

TABLE XXVIII.

Average changes in weights of mothers during lactation, based upon observed weights plus weights calculated and interpolated.

Days after delivery	Total weight	No. of obs.	Average	Increase	Average daily increase	Daily % increase
0	14726	24	613·6			
1–5	60974	110	554·3	− 59·3	− 11·9	− 1·9
6–10	57256	104	550·5	− 3·8	− 0·8	− 0·1
11–15	49134	87	564·8	14·3	2·9	0·5
16–20	55832	99	564·0	− 0·8	− 0·2	− 0·03
21–25	46864	85	551·3	− 12·7	− 2·5	− 0·4
26–30	39993	71	563·3	12·0	2·4	0·4
31–35	24543	43	570·8	7·5	1·5	0·3

These tables shew that there is a great and very rapid loss of weight immediately after delivery and continuing several days, and that subsequently there is a continued loss of weight going on at a somewhat slower rate for about three weeks, after which the recovery of weight begins. Unfortunately the available data are insufficient to give a regular series of averages. The change is often so conspicuous in an individual that the eye notes it in looking at the mother from day to day.

It is probable that during gestation there is an accumulation of material in the mother's body which afterwards is exhausted for the production of milk. In this manner we may account both for the overgain in weight before delivery, and the loss of weight after. The destruction of my animals prevented my accumulating the extended statistics I had planned, concerning the relation of gestation and lactation to the weight. The changes occurring indicate the existence of a complex nervous mechanism regulating the maternal nutrition.

It is interesting to determine the average rapidity of growth, by dividing the total weight of a full grown animal. This determination could in any case be only approximative since the time when an animal is full grown cannot be exactly fixed because the latter part of the curve of growth is asymptotic. In the case of my Guinea pigs there is the further difficulty that the number of observations for the older ages is too small to give the true average. Table XVII. shews that 632 observations of the weights of adult males from the age of 13 to 24 months give a total of 489753 grammes or an average of 774·9 grammes.

As there is only a slight change of weight during the second year, we may assume that there is no important error in fixing the weight of a male Guinea pig at the close of the first year at 775 grammes. To the 365 days we must add 67 days for the period of gestation, $755 \div 365 + 67 = 1{\cdot}82$. Now rabbits of the larger breeds reach about 2500 grammes in one year plus 30 days. Man acquires a weight of 63000 grammes in about 25 years plus 280 days' gestation. We may put these data in tabular form, thus:—

Guinea pigs	$775 \div 365 + 67 = 1{\cdot}82$	grms. *per diem*
Rabbits	$2500 \div 365 + 30 = 6{\cdot}30$	„ „ „
Man	$63000 \div 9139 + 289 = 6{\cdot}69$	„ „ „

That men are larger than rabbits because they grow longer is a common-place of observation, but the table shews the curious result that the average daily increments are nearly the same in man and rabbits. On the other hand rabbits attain a larger size than Guinea pigs not because they grow longer, but because they grow much faster. In other words we have obtained numerical values illustrating the two opposite methods of attaining large size. The further study of these two methods appears to me of great interest on account of the various problems involved, but such study can be carried out only by an investigator with considerable means at his command.

The average actual increments for the three species as reckoned above indicate the average rapidity but not the average rate of growth. The difference between rapidity and rate is discussed in the next section on senescence. To determine the rate we must divide the average weight by the average increment. As we have not sufficient data for calculating the average weight accurately for any of the three species, it will suffice for our present purpose to assume that average to be one half the adult weight. By this reckoning we obtain the following:

TABLE XXIX.

Average rates of growth		Average Increments	Increments % of average weights
Guinea pigs $\frac{1}{2}$ adult weight =	387	1·82	0·47
Rabbit „ „	1250	6·30	0·50
Man „ „	31500	6·69	0·02

From these per cents. we see that the *rate* of growth in guinea pigs and rabbits is not very different, as was to be expected in so nearly related animals; but it is sufficient to produce a great inequality in the final size, because the effect of the difference is accumulated, like compound interest on capital. The rate in man (0·02 %) is only $\frac{1}{25}$th of the rabbits' (0·5 %). This comparison renders it still more strikingly evident that the larger size of man depends on the greater duration of growth.

These percentages may be called the specific coefficients of growth. Together with the duration of growth they determine the ultimate size of the organism.

3. *The Law of Senescence.* Growing old is a very complex process of which no concise definition can be given by the morphologist or physiologist as yet. Of all the occurring changes none is more characteristic of age than the loss of the power of growth, and to ascertain how that loss occurs is an important preliminary to the further study of the effects of age. The loss of the power of growth is properly speaking a change in the rate of growth, we must therefore first fix exactly the meaning of *rate* in a strict technical sense. This is the more necessary as the current application of the term *rate* seems to me incorrect and misleading. In fact in the writings of Quetelet, Cowell, Roberts, Gould, Pagliani, Street, Boulton, Liharzik, Bowditch, and others the rate of growth is discussed, but I am compelled to consider that they have all misapplied the term. They compare the index of the rate, the actual absolute increments of equal successive periods, but since during each period the size of the body increases, then if the rate of growth were constant the proportionate increment would remain the same, but the absolute increments would become steadily larger. Reciprocally it is evident from this that if the absolute increments are constant the *rate* of growth diminishes, a point which so far as I am aware has been entirely overlooked hitherto. It may be added by the way, that the preceding considerations shew that very little value attaches to those frequently made comparisons between the weight of the child and its weight at birth, for they can and do give only false notions concerning the rate of growth.

Growth is a variable function of time. There are two convenient ways of presenting this variation, which I have adopted :—(1) we may take a constant interval of time (one day) and calculate the varying values of the change (percentage increments); (2) we may take equivalent changes and calculate the varying time. The latter method accords perhaps best with the actual phenomena, since as is shewn below, they are best expressed, aside from certain variations, thus:—The older the body the longer it requires to accomplish a given equivalent of growth.

(1). It is evident that the increase in weight depends upon two factors, first upon the amount of body substance or, in other words, of growing material present at a given time: second, upon the rapidity with which that amount increases itself. Hence for a given period the rate of growth may be expressed as the fraction of weight added during that period. Strictly speaking we ought to take the mean weight during the period, but that is hardly practicable, and for our purpose a less exact method will suffice, namely estimating the rate for each period, by converting the increase in weight during that period into a fraction of the weight at the beginning of that period. For convenience of comparison the fraction thus obtained may be reduced to the percentage increase during one day. The daily percentage increments have already been given in Table XVIII. columns *f*, *F*.

This method of analysing the statistics of growth does not appear to have been employed hitherto although it may be considered a ready way of determining approximately the rate of growth. The value here assigned to the percentage increments is due to their shewing approximately but directly the rate of growth. They demonstrate two fundamental facts:—*first* the rate of growth diminishes, almost uninterruptedly from the time onwards, when the animal recovers from the post-natal loss of weight; *second* the diminution is rapid at first but slower afterwards.

For convenience I copy in Table XXX. the percentages for the two sexes from Table XVIII.

During the first period from birth to two days the increase is zero per cent. in the males and only 2·1 per cent. in the females. These low values result of course from the post-natal retardation. By the fourth day the animals are well recovered so that for the second period (second to fifth day) the values are at the maximum for both sexes, being 5·6 and 5·5 for males and females respectively. From this age onward the percentage increment diminishes very rapidly at first, afterwards more slowly. Towards the end of the series the percentages become irregular and even negative, owing to the insufficiency of the observations in number. The series of increments is shewn in Pl. II. figs. 1 and 2 in a graphic form. The comparisons of the absolute and the percentage increments, Table XVIII. shews at once that the former are entirely misleading as a means of determining the *rate* of growth. The two series are not parallel and the error, which would ensue from taking the absolute increments as the measure of the *rate* increases, it will be seen, enormously with the age. The same holds true of human growth, as will be shewn in another article.

TABLE XXX.

Average daily per cent. increments.

Age	Males	Females	Age	Males	Females
Days			Months		
1–3	0·0	2·1	8	·05	·2
4–6	5·6	5·5	9	·3	·2
7–9	5·5	5·4	10	·1	·1
10–12	4·7	4·7	11	·04	·1
13–15	5·0	5·0	12	·1	·05
16–18	4·1	4·3	13	– ·2	·3
19–21	3·9	3·5	14	0·5	– ·03
22–24	3·1	1·7	15	·2	·00
25–27	2·8	1·9	16	·07	·2
28–30	2·8	2·6	17	– ·1	– ·02
31–33	1·9	1·8	18	– ·05	– ·2
34–36	1·7	1·6	19–21	·006	– ·1
37–39	1·9	1·8	22–24	·02	– ·05
40–50	1·2	1·1			
55–65	1·3	1·3			
70–80	1·2	·8			
85–95	·9	·9			
100–110	·7	·8			
115–125	·6	·5			
130–140	·1	·2			
145–155	·4	– ·03			
160–170	·3	·5			
175–185	·2	·2			
190–200	·2	·2			
205–215	·4	·3			

(2) Let us now take equivalent growths and calculate the varying times required to accomplish them. As the unit of this calculation I have chosen for convenience' sake 10 per cent. addition to the initial weight. Thus the average weight of males at birth is 70·8 grammes; add 10 per cent. and it makes 77·88—to this value 10 per cent. 77·88 + 7·788 = 85·66, and so on as by compound interest. Assuming now that between two successive observations the growth proceeds in a straight line,—and this assumption is very close to the actual truth,—it becomes a simple question of proportion to reckon the ages corresponding to the

series of weights by 10 per cent. additions. In this manner have been calculated the values given in the following

TABLE XXXI.

Age corresponding to ten per cent. periods.

Males				Females		
Weights increasing at the rate of 10 %	Age in days at which they fall	First Diff.		Weights increasing at the rate of 10 %	Age in days at which they fall	First Diff.
70·8	0·0			70·1	0·0	
77·88	4·1	4·1	1	77·11	2·9	2·9
85·66	5·6	1·5	2	84·82	4·6	1·7
94·22	7·7	2·1	3	93·30	6·4	1·8
103·64	9·6	1·9	4	102·63	8·4	2·0
114·00	11·8	2·2	5	112·89	10·6	2·2
125·40	14·0	2·2	6	124·17	12·6	2·0
137·94	16·2	2·2	7	136·58	14·8	2·2
151·73	18·7	2·5	8	150·23	17·3	2·5
166·90	21·7	3·0	9	160·25	20·3	3·0
183·59	25·3	3·6	10	181·77	24·1	3·8
201·94	28·7	3·4	11	199·94	28·3	4·2
222·13	33·6	4·9	12	219·93	33·5	5·2
244·34	38·8	5·2	13	241·92	38·7	5·2
268·77	43·7	4·9	14	266·11	44·8	6·1
295·64	50·2	6·5	15	292·72	53·2	8·4
325·20	59·2	9·0	16	321·99	59·9	6·7
357·72	68·6	9·4	17	354·18	73·6	13·7
393·49	77·3	8·7	18	389·59	84·5	10·9
432·83	88·6	11·3	19	428·54	96·0	11·5
476·11	100·7	12·1	20	471·39	112·0	16·0
523·72	120·0	19·3	21	518·52	155·8	43·8
576·09	160·6	40·6	22	570·37	192·8	37·0
633·69	201·3	40·7	23	627·40	236·6	43·8
697·05	258·2	56·9	24	690·14	296·6	60·0
766·75	298·3	40·1	25	759·15	374·8	78·2

If now we subtract the ages, each from the next following one, we obtain the first differences which are given in the third columns of the table, and which shew how long it takes to make each addition of ten per cent. (10 %). The first period required to make the first such addition is longer owing to the loss of weight after birth requiring to be made up; it is longer, 4·1 days, in the male than in the female, 2·9 days. The second period is much shorter, 1·5 for the male, 1·7 for the female. From the second period onwards the 10 per cent. intervals become longer uninterruptedly save for certain slight irregularities. Whether any of these irregularities are significant or whether they are all (like those near the end of the series) accidental I am unable to decide. The absolute value of the change of length from one period to the next alters slowly at first, afterwards rapidly.

I have used the data in XXXI. to construct the curve given as Pl. II. Fig. 3, in which the ordinates shew the weights calculated by ten per cent. additions and the abscissæ the ages at which those weights fall. The distances between the vertical lines give the comparative length of the successive periods. This curve may be called the *chart of senescence* because it shews the progressive loss of the power of growth with the advancing age. Table XXXI. permits another form of graphic representation, which is given in Pl. II. Figs. 4 and 5.

On these charts the periods are taken as units for the abscissæ, and every ten-per-cent. period is taken as equal to one unit. The ordinates give the length of each period in days, as recorded in the table. This curve may be termed in a certain *not* mathematical sense the obverse or complement of that of the daily per cent. additions drawn in Fig. 1.

I think it is now conclusively established that there is in guinea pigs a progressive loss in the power of growth, beginning almost immediately after birth. This has been overlooked by previous investigators[1], because they have not correctly determined the true *rate* of growth. Liharzik alone seems to have had some notion of this change, but he formulates his idea so vaguely and states his "law" in so complicated a manner, making both his absolute increments and the length of his periods variable, that I cannot be sure, but still think it probable, that he failed to really grasp the idea of progressive loss.

The loss of growth power as will be shewn in subsequent articles is equally demonstrable in the case of man, of other animals, and there can be little doubt that it is true at least of all mammals. This conclusion raises the question whether other animals do not obey the same law, and sets, too, the more general problem whether in all living beings there is not a certain impulse given at the time of impregnation, and whether this impulse does not gradually fade out so that from the very beginning of the new growth there occurs a diminution in the rate of growth. The problem seems to me to possess a very profound interest,

[1] With few unimportant exceptions previous investigators have been upon the growth of man.

because its solution, if I foresee correctly, would enable us to determine with precision and clearness a general characteristic of life.

The facts given in this paper together with others to be represented later fully confirm the views[1] which I advocated nearly ten years ago as to the course of growth and the nature of death, and I see no reason to give up those views, but on the contrary am compelled to regard Weissmann's notion of death as an entire misconception, nor can I agree to the theories of Bütschli or Götte. In the concluding article of this series I hope to return to this discussion and justify my attitude. To that article also is postponed the fuller presentation of the conclusion reached concerning the relation of organization to growth and death.

Throughout this article we have been discussing the weights of animals. The weight is the outcome of many factors, the sum from the addition of numerous quantities, which at different ages are united in different proportions. It is therefore self-evident that none of our weights are strictly comparable with one another. Their relation may perhaps be better understood by the aid of a conception which for want of a better name, I have termed "the theory of physiologically equivalent weights." If we change albuminous matter into fat, as may occur in the body, we shall obtain for a given weight of the former a fixed weight of the latter as an equivalent,—*but*,—this change induces secondarily other changes in the body, which will still further effect the weight of the body. The weight in the albuminous condition may therefore be in consequence of secondary changes, very different from the weight in the fatty condition. In an adult animal the weight often fluctuates, yet we cannot suppose that the animal actually grows and ungrows, but we must assume some such series of changes as we have just imagined in changing albumen to fat. In short, when the body has a composition, *A*, it has one weight, and when it has the composition *B*, it has another weight,—and these weights are "physiologically equivalent."

It cannot be doubted that a thorough investigation of the composition of the body at various periods of growth is indispensable for any satisfactory study of the effects of age. Here again is an important research, which must be left for the indefinite future.

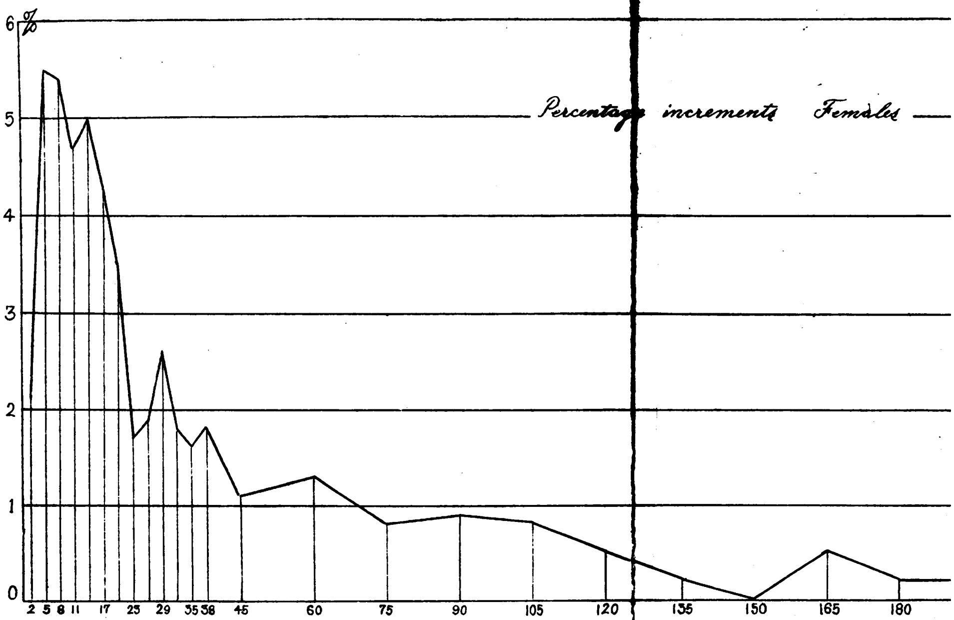
[1] *Proceed. Boston Soc. Nat. History*, xx. 1879, 191—192.

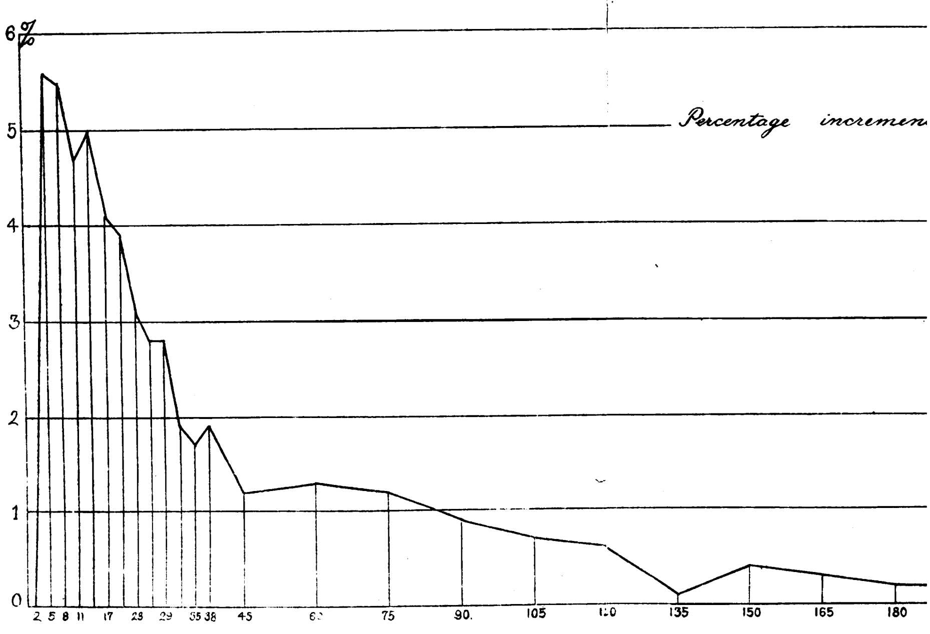
APPENDIX.

Two simple bits of apparatus, which I have found useful may be described.

The first is a feeding trough for oats and grain. It consists of a circular pan about 10 inches in diameter and 2½ inches deep, from the centre of which rises a cylinder of tin, 7 inches in diameter and 15 inches high; near the bottom of the cylinder are four holes 1¼ inches in diameter. The cylinder is filled with grain and supplies the trough as fast as the oats are eaten; as the animals cannot get in to the trough there is less chance, than there would otherwise be, of their soiling and scattering the supply of food.

The second apparatus is for calculating the dates at which a guinea pig is to be weighed, given the day of birth. It consists of a ring divided into 365 spaces, and enclosing a circular disc the edge of which is likewise divided into 365 spaces. The spaces on the ring are numbered according to the ages in days at which the weighings are to be made; the spaces on the disc are numbered to correspond with the days of the month. If now the ring is set with its zero opposite the day of birth all the ages for the weighings will stand opposite the proper dates on the disc, and one has only to read the dates off to escape all calculation. In leap years there is of course a correction to make for the 29th of February. By a simple device not calling for description either the ring or the disc may be revolved separately, or they may be revolved together.


6%
5
4
3
2
1
0
Percentage increments Females
2 5 8 11 17 23 29 35 38 45 60 75 90 105 120 135 150 165 180


6%
5
4
3
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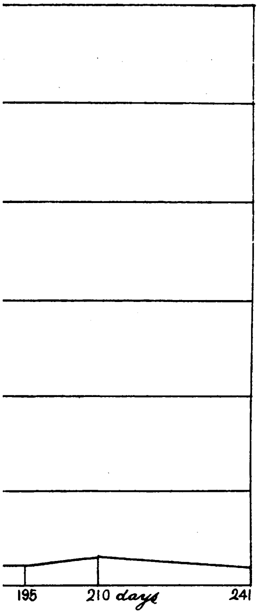
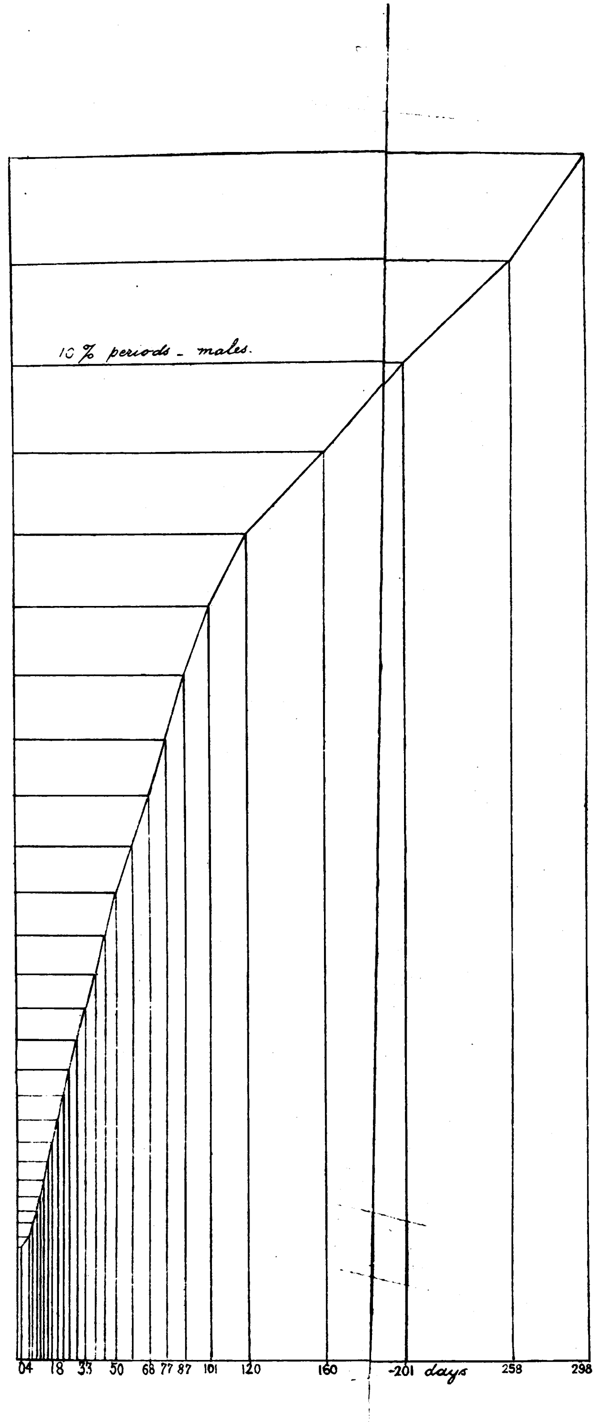
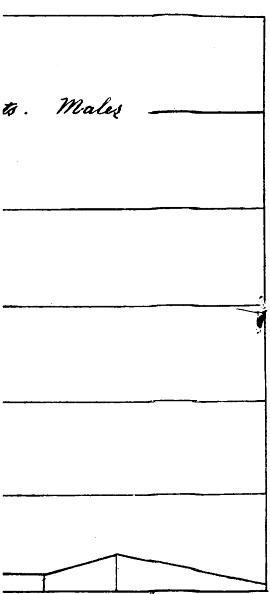
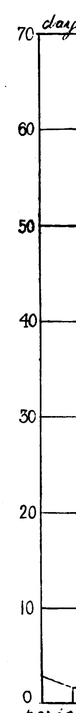
1
0
Percentage incremen
2 5 8 11 17 23 29 35 38 45 75 90 105 135 150 165 180

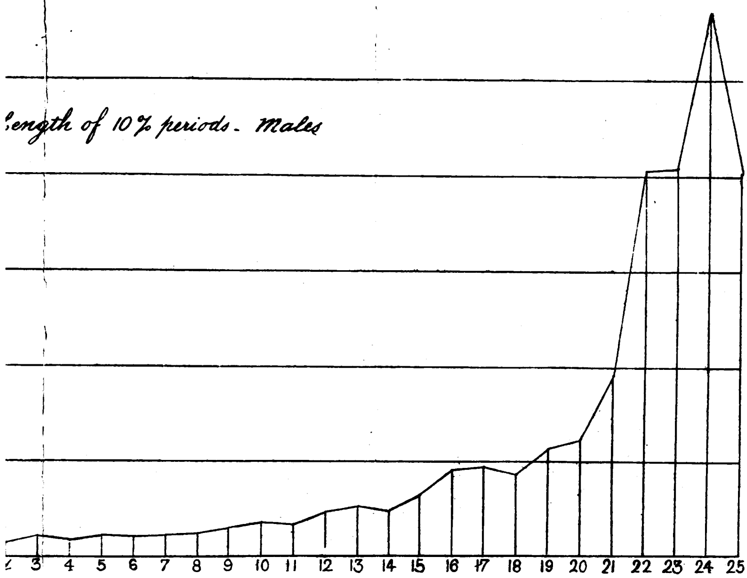

195
210 days
241

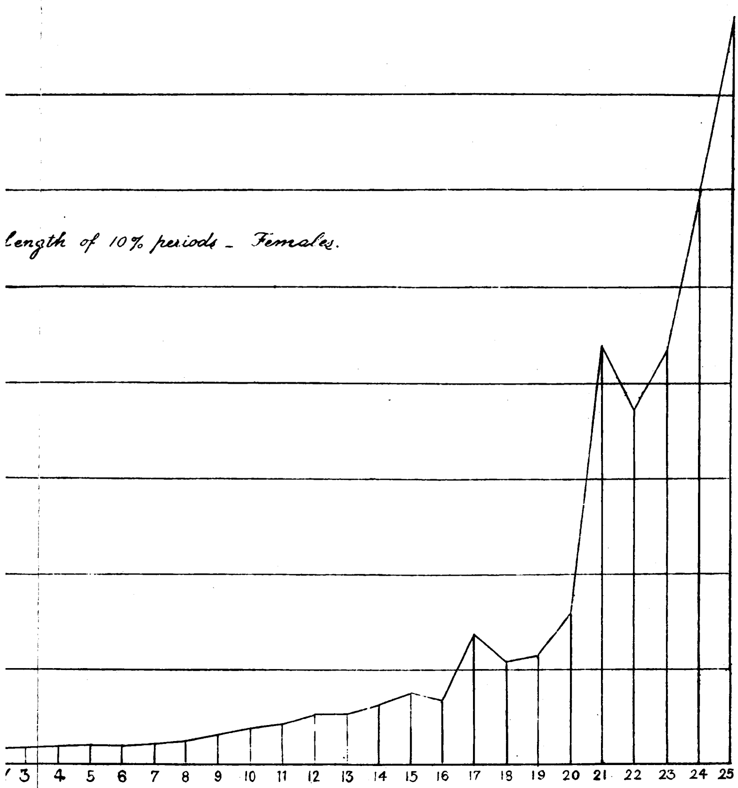

10 % periods _ males.
04
18
33
50
68
77
87
101
120
160
-201 days
258
298


days
50
40
30
20
10
0


Males
195
210 days
241


days
70
60
50
40
30
20
10
0



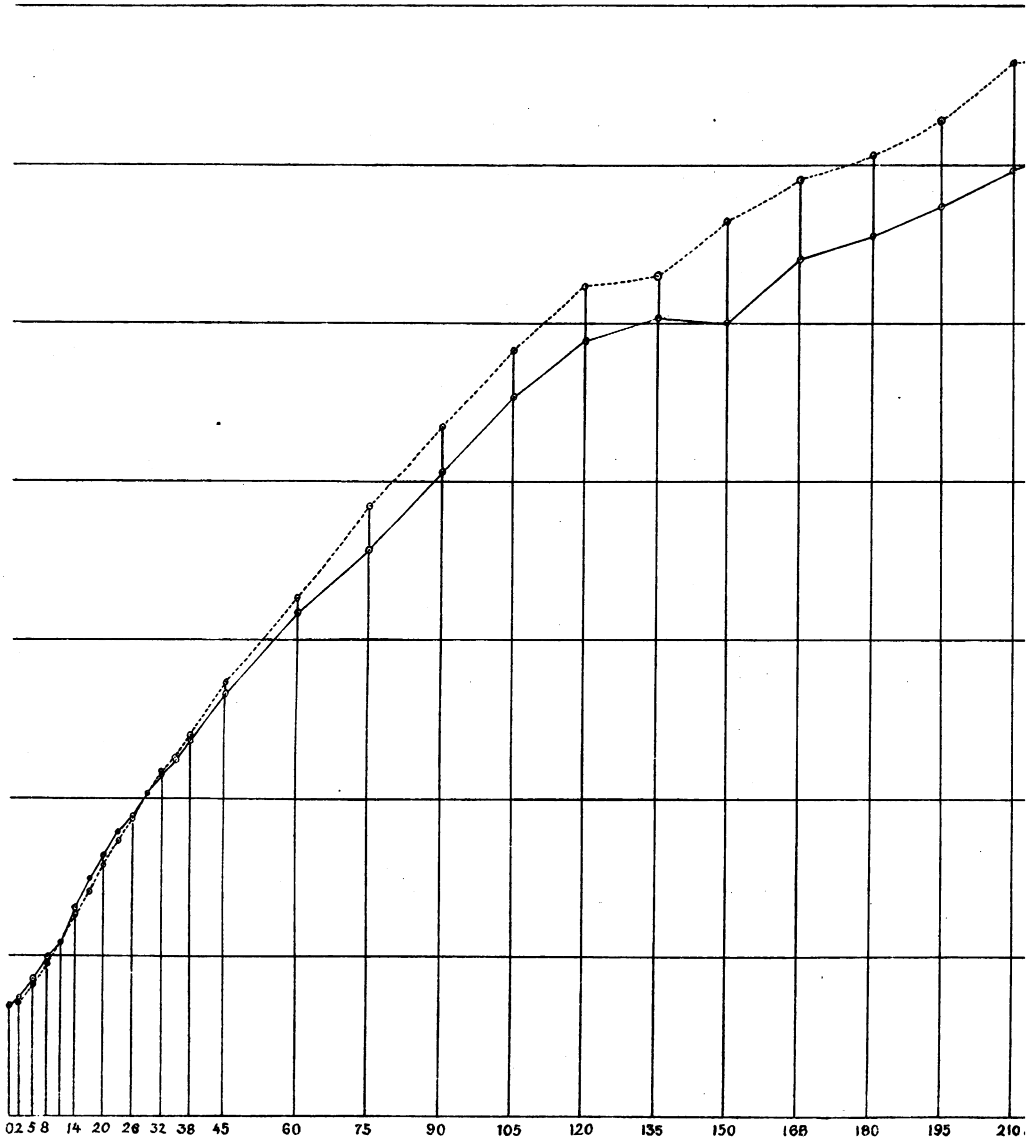


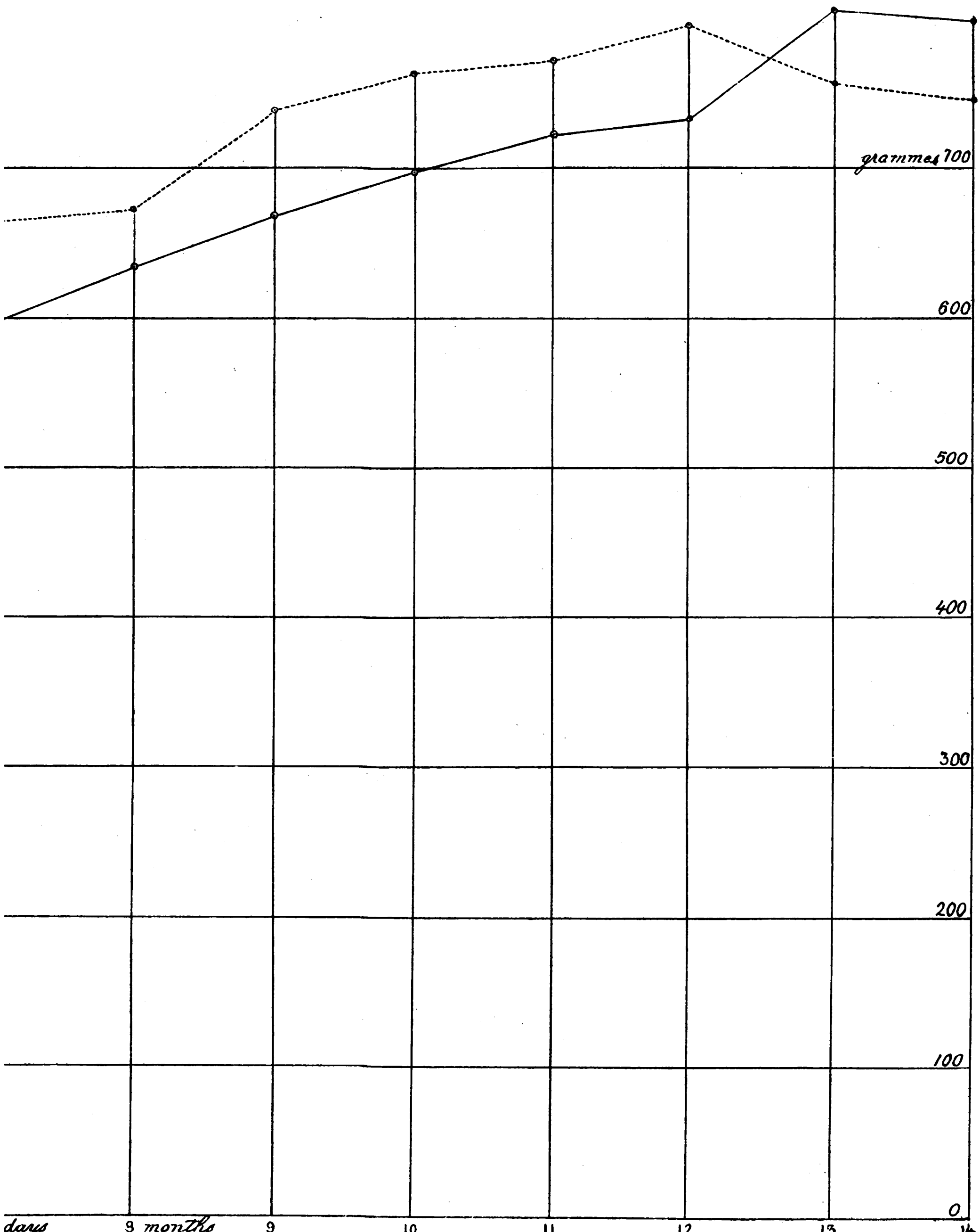
Cambridge Engraving Company.

Growth curves from Table XVIII

Males ....

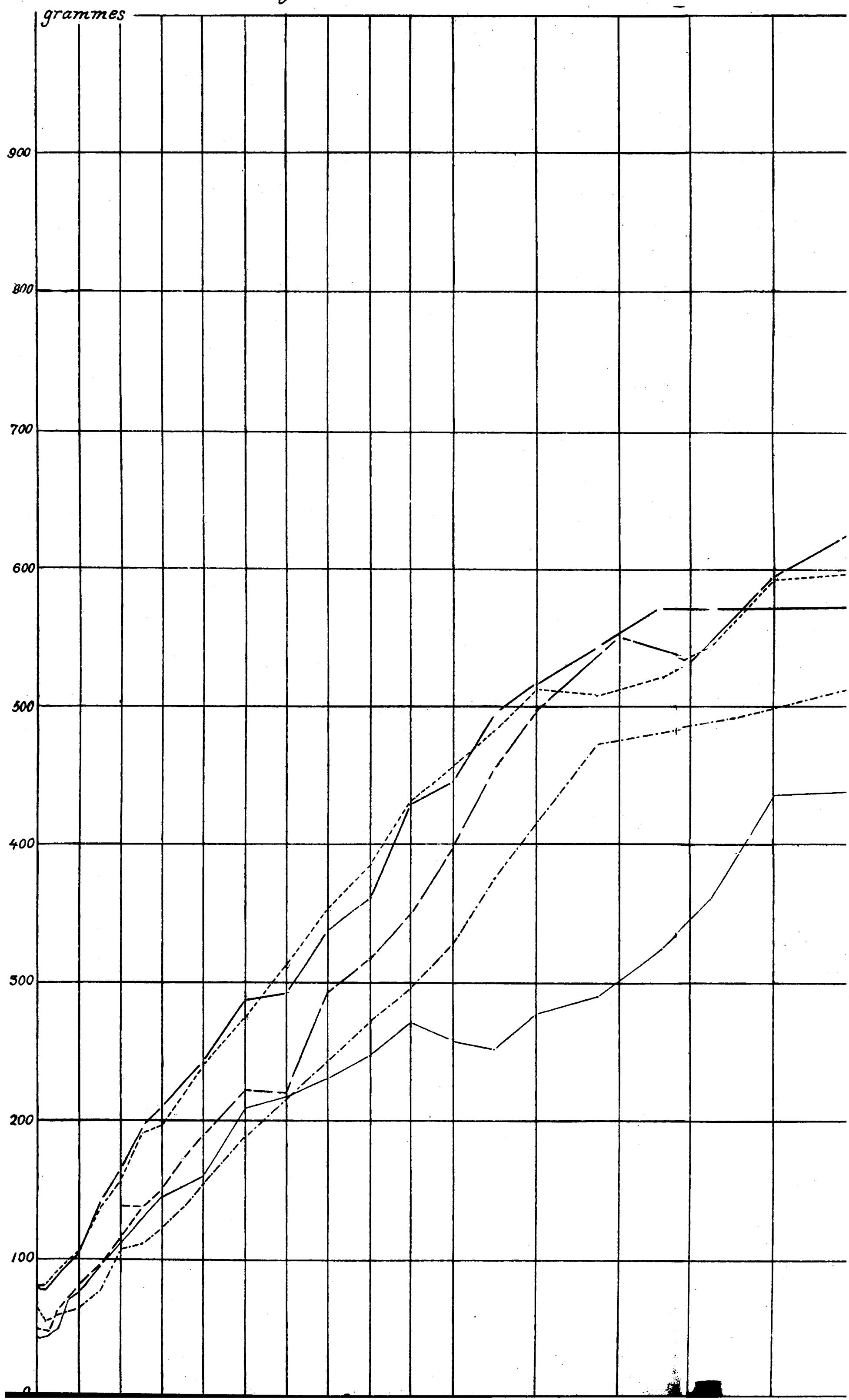
Females ____________

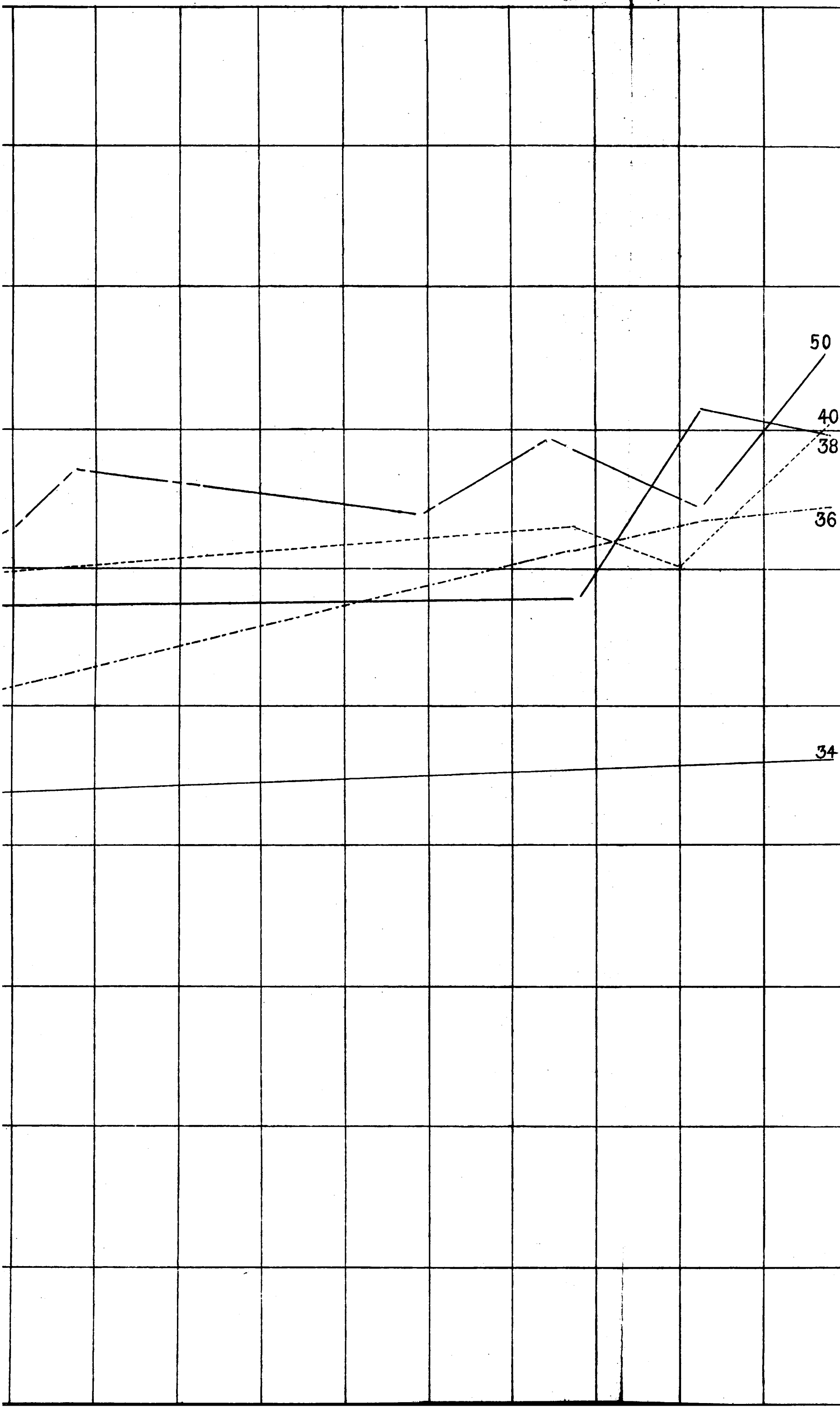




Cambridge Engraving Company.

Growth curves from Table XXI




50
40
38
36
34