ORGAN WEIGHTS OF NORMAL RABBITS.

By WADE H. BROWN, M.D., LOUISE PEARCE, M.D., AND CHESTER M. VAN ALLEN, M.D.

(From the Laboratories of The Rockefeller Institute for Medical Research.)

(Received for publication, May 11, 1925.)

The work carried out in these laboratories over a period of more than 10 years has emphasized the necessity for devoting more attention to the factor of the animal organism in the study of medical problems. In the fall of 1921, we began a systematic study of the animal organism in relation to disease which included parallel observations on normal rabbits and on rabbits inoculated with *Treponema pallidum* or with a malignant tumor. The study of normal rabbits was intended, in part, to serve as a control for the other experiments and, in part, to provide material for a comprehensive study of the mass relations of the various organs with especial reference to the subjects of variation, the effects of environmental influences, and the relation of these conditions to phenomena of animal resistance or the occurrence and general course of disease. These investigations are still in progress but they have reached a stage where it is possible to begin a correlation of results in a satisfactory manner.

This study of the normal animal was not planned primarily with a view to determining normal standards under what might be regarded as the most acceptable conditions but for the purpose of obtaining values applicable to the particular conditions that it was necessary for us to employ in the conduct of other experiments. Nevertheless it is believed that the results obtained are sufficiently accurate for all practical purposes and that they provide reliable information concerning conditions that obtain in normal stock rabbits.

Preliminary reports have been published covering several aspects of this work but no detailed reports have been made (1). These will appear as opportunity permits. The present paper will be limited to a report on the weights of organs without reference to the relation

of one organ to another or to any factor that may affect the weight of individual organs or their relations to one another. These subjects will be reserved for future consideration.

Methods and Material.

The results reported in this paper are based on a study of 350 *male* rabbits killed and examined between January 1, 1922, and July 1, 1924.

The rabbits comprising the series represent carefully selected stocks of well nourished animals, free from any external evidence of disease. They were obtained from numerous breeders or dealers who draw their stock chiefly from New York, New Jersey, Pennsylvania, Delaware, and Maryland. A few animals came from some of the New England states but the great majority of them came from eastern Pennsylvania and the immediate vicinity of New York City. The series includes all of the breeds of rabbits that are commonly used and in essentially the same proportions as such breeds have been used in our laboratory for other experiments. The exact age of the animals was unknown in most instances but the great majority of them were between 6 months and 2 years old.

The plan followed in carrying out the investigation was essentially the same as that used in the conduct of other experiments. Animals were selected from the general stock and placed in individual cages for observation. The period of observation varied (in individual instances) from a few days to as long as a year but in most instances was from 2 weeks to 2 months, the exact time being determined by experiments for which these animals served as controls. While under observation, the animals were kept in large, well lighted, and well ventilated rooms with a southern exposure. The rooms were heated and the temperature was maintained at a relatively constant level of 60–70°F. during the colder months of the year (October to May). The cages and bedding were kept scrupulously clean. The animals were fed in accordance with a regular system of feeding employed in these laboratories. Their diet at all seasons consisted of hay, oats, and cabbage or carrots of the best quality obtainable.

The records kept included the source of the animal, the date of receipt, an age grouping, a breed or type classification, a weight chart, and a record of the general physical condition of the animal during the period of observation. Animals that did not remain well and in good physical condition were excluded from this series but were used as a check against the others and to supply data on the health of animals kept under the conditions mentioned above. Groups of five to ten animals were killed at intervals of 2 to 3 weeks. As a rule, there were two groups for each month; the first group was killed near the middle of the month and the second at the end of the month, thus giving a total of a least ten rabbits and usually as many as fifteen or twenty for each month with the exception of July, 1922, and August, 1922 and 1923. It was impracticable to maintain routine observations during these months but some data are available for July, 1922.

The method of conducting the final examination was as follows: Animals received no food on the day they were killed; they were weighed, then anesthetized with ether and bled from the inferior vena cava while the heart was still beating. More recently, killing by air embolism has been substituted for the ether as a quicker and less disturbing procedure. Autopsy was performed immediately. The postmortem examination included two sets of observations: first, the noting of anatomical malformations or defects and of all gross evidences of disease, whether in the form of active or healed lesions, and second, the making of weight determinations on certain organs and tissues. These observations were later supplemented by microscopic examination of tissues from a number of organs.[1] No animal was excluded from the series on account of postmortem evidence of the presence of disease, but the results of the postmortem examination were used as the basis for classifying animals in a study of the relation of various pathological conditions to organ weight, the results of which will be reported in another paper.

The list of organs weighed has been changed several times since the investigations began so that there is considerable variation in the number of animals for which weights of different organs are available. The complete list of organs weighed is as follows: the heart, liver, kidneys, spleen, the gastrointestinal mass (including stomach, intestine, mesentery, omentum, and gastrointestinal contents), the brain, the testicles, the thymus, the thyroid (with internal parathyroids), external parathyroids (usually two in the neck region), suprarenals, hypophysis, the pineal gland with its stalk and the associated plexus of vessels, the popliteal, posterior axillary, and the deep cervical lymph nodes of both sides, and the main mesenteric mass of lymph nodes. The number of animals on which weights are available in each case is given in Table I.

The urine in the bladder was measured as a means of making corrections for body weight.

In making the weight determinations the work was so distributed that removal of the organs from the body, the preparation for weighing, and the weighing itself proceeded parallel and uniformly with little or no delay at any stage of the process. All organs were carefully prepared for weighing by trimming and removal of extraneous tissues. The cardiac vessels were cut on a level with the outlines of the auricles; the chambers were opened and all blood removed before weighing. The brain was cut anteriorly at the junction of the frontal and olfactory lobes and posteriorly at the lower margin of the fourth ventricle or on a level with the ventral margin of the foramen magnum so that the weights of the brain include the cerebrum, cerebellum, pons, and medulla but not the olfactory lobes. Weights of the testicle include the globus major but other parts of the epididymis were removed. No effort was made to separate the glandular tissue of the thymus from the fat contained within the capsule so that the weights for this organ represent the weight of the thymic mass rather than of the thymus itself. Weights of the

[1] This phase of the work is as yet incomplete.

hypophysis represent only the anterior, middle, and posterior lobes, but in the case of the pineal gland the entire stalk together with the associated plexus of vessels is included so that only a small part of the weights recorded represent glandular tissue. In order to avoid drying after removal from the body, the small organs were placed in Petri dishes and kept moist with physiological salt solution. Before weighing, the excess fluid was removed by absorption on filter paper.

The gastrointestinal mass and the liver were weighed on balances sensitive to 0.1 gm.; the heart, kidneys, brain, testicles, and mesenteric lymph nodes were weighed on balances sensitive to 0.01 gm.; while all other organs were weighed on balances sensitive to 0.001 gm.

The data recorded in this paper include the results of a primary analysis of actual weights and of weights per kilo of net body weight; *i.e.*, the gross weight minus the weight of the gastrointestinal mass as defined above and of urine.

The distribution curves given in Text-figs. 1 to 3 are based on the use of a group interval of approximately one-tenth of the average weight of the organ or the weight per kilo of body weight. The interval used in a given instance was determined by convenience but in plotting the distribution of actual weights and of weights per kilo of body weight for a given organ a constant ratio of 2:1 was maintained. The curves obtained by plotting the actual results were smoothed by the formula $\frac{a+2b+c}{4}$. The smoothed curve is graphed as the broken line in Text-figs. 1 to 3.

In some instances the curves are not extended to the upper limits of weight, as given in Table I, but the weights omitted are few and scattered. The limit to which a curve should be extended is indicated by a figure placed at the termination of the curve. Curves not marked in this way are complete.

The figures as given include all data irrespective of whether an organ was normal or pathological. It seemed best to present the material in this form before attempting to make corrections for disease or any other factor that might give rise to variations in weight. These subjects will be dealt with in subsequent papers.

RESULTS.

The results obtained from this series of weight determinations are presented in condensed form in Table I and Text-figs. 1 to 3.

DISCUSSION AND CONCLUSIONS.

In discussing the experiments reported, it should be pointed out at once that the results obtained in this instance are neither strictly comparable with those given in other reports dealing with organ weights of normal rabbits nor do they represent results that

might be expected from the examination of a group of animals where an effort is made to maintain uniformity of material and experimental conditions. One of the purposes of this investigation was to define the possible as well as the probable limits of variation in the weight of certain organs of rabbits comparable in all respects to those used in the conduct of other experiments. This has necessitated the use of animals of various ages and breeds and the extension of the observations over a long period of time. Finally, in analyzing the results, the problem has been approached first from the standpoint of the individual animal rather than the several groups which compose the series. All of these conditions tend to emphasize the element of variation which, at present, is the aspect of the subject in which we are most interested.

With these facts in mind, the first point to be considered is the reliability of the data as an index of existing conditions. There are only a few instances in which this question need be discussed. The weights that are open to question are those of the thymus, the parathyroids, the pineal gland, and the superficial and mesenteric lymph nodes. It is obvious that the weights of these organs cannot be determined with the same degree of accuracy as the weights of the other organs.

The chief source of error in nearly all instances is in the presence of variable amounts of fat or areolar tissue which cannot be removed satisfactorily in the preparation of the organs for weighing. This applies especially to the thymus and the lymph nodes, but a similar condition exists in the case of the pineal gland. The parathyroids present difficulties of another kind. Only the external parathyroids are available for weight determinations. As a rule, there are two of these but occasionally only one can be found, or there may be three—rarely four. There are other masses of parathyroid tissue in the thyroid and the thymus and not infrequently the external parathyroids themselves contain small masses of thymic tissue. At all events, there is no way of determining whether the external parathyroids represent a relatively constant part of the parathyroid tissue and a sufficiently large part to serve as an index of the amount of such tissue present except by making a large series of weight determinations.

TABLE I.

Summary of Numerical Values Obtained from Determinations of Body and Organ Weights Made on 350 Male Rabbits of Various Ages and Breeds between January 1, 1922, and July 1, 1924.

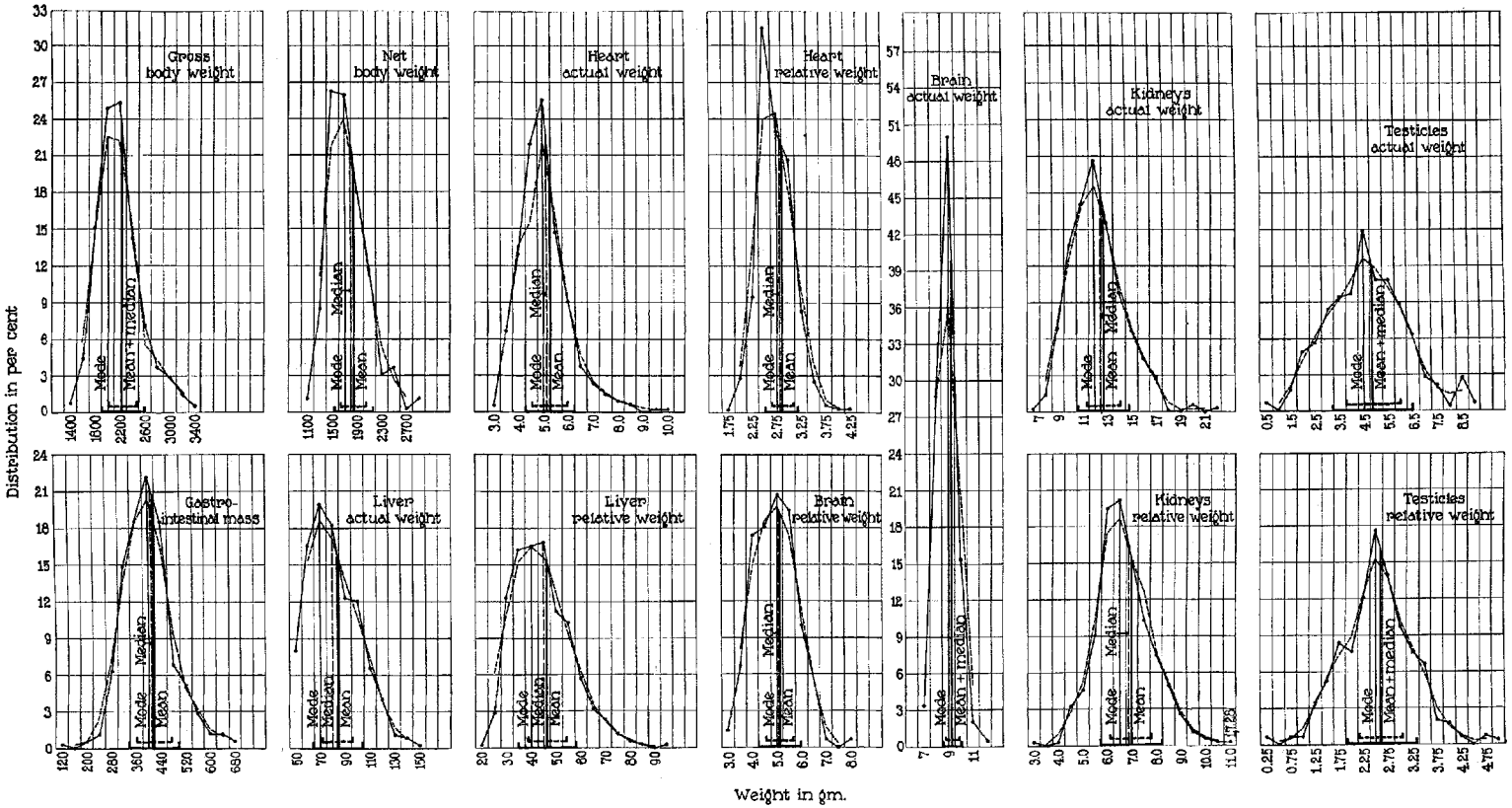
The upper row of figures in each couplet gives the values for actual weights while the lower figures are for weights per kilo of net body weight.

Organ.	No. of animals.	Arithmetical mean.	Median.	Mode.	Minimum.	Maximum.	Standard deviation.	Probable error.	Coefficient of variation.
		gm.	*gm.*	*gm.*	*gm.*	*gm.*	± *gm.*	± *gm.*	*per cent*
Gross body weight	350	2,240.30	2,225	2,000	1,400	3,500	352.62	237.84	15.74
Gastrointestinal mass	350	416.35	410	400	115	710	80.85	54.53	19.42
Net body weight	350	1,848.50	1,800	1,700	1,150	3,010	323.27	218.04	17.49
Heart	348	5.26	5.12	5.00	3.20	10.18	0.96	0.65	18.23
		2.85	2.81	2.75	1.95	4.42	0.35	0.24	12.32
Liver	350	84.30	80.00	70.00	50.00	150.00	19.72	13.30	23.39
		46.46	44.90	40.00	23.20	97.40	11.84	7.99	25.48
Kidneys	348	12.70	12.50	12.00	7.15	22.73	2.07	1.40	16.30
		6.97	6.84	6.50	3.45	17.28	1.26	0.85	18.08
Spleen	347	0.99	0.90	0.70	0.08	3.20	0.436	0.294	44.04
		0.531	0.49	0.45	0.035	1.714	0.214	0.144	40.30
Thymus	349	2.21	2.13	1.75	0.45	5.90	0.848	0.572	38.37
		1.23	1.147	1.00	0.334	2.72	0.451	0.304	36.64
Testicles	290	4.86	4.85	4.50	0.81	9.12	1.63	1.10	33.54
		2.61	2.62	2.50	0.47	4.93	0.70	0.47	26.90

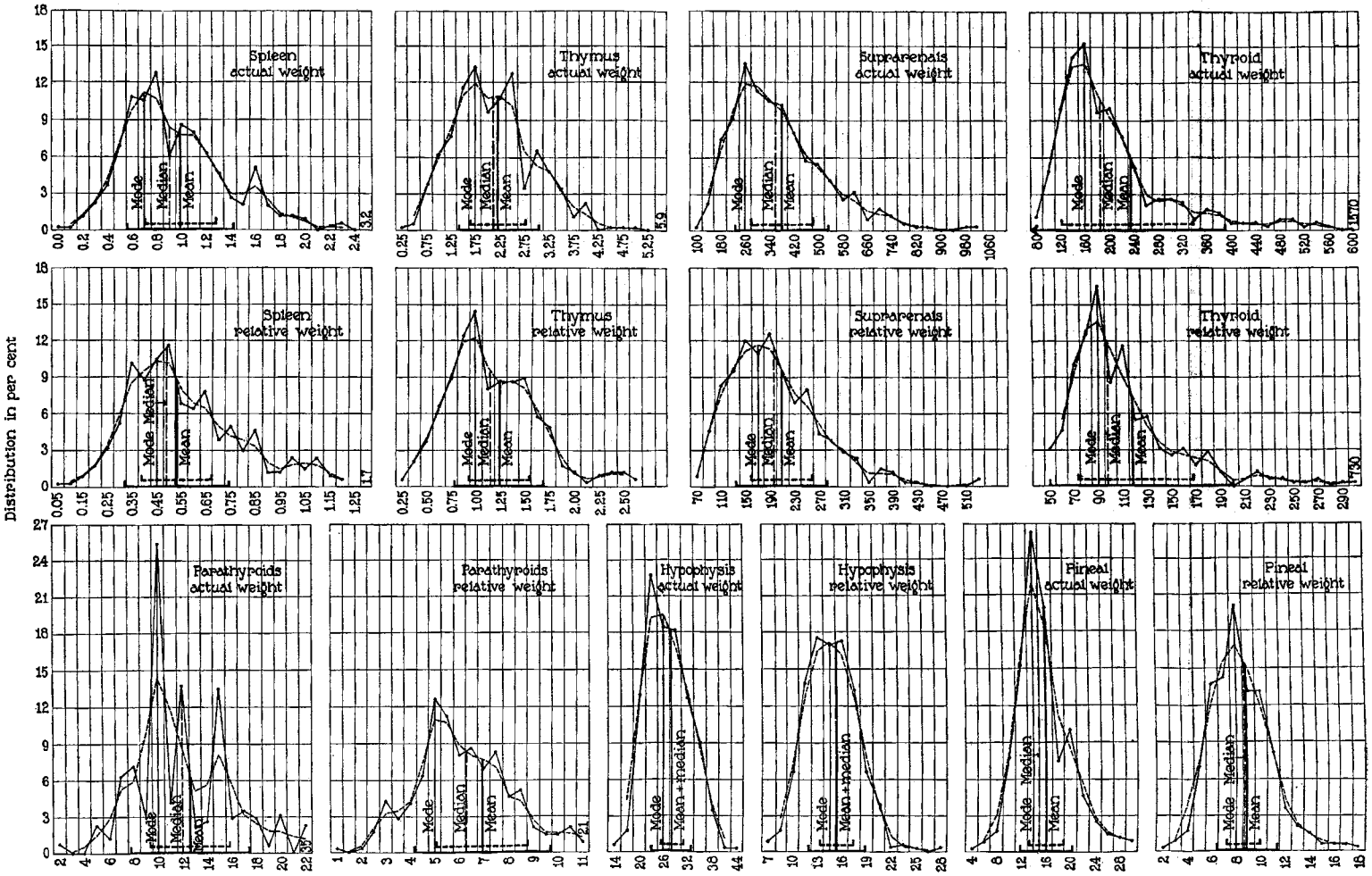
Brain	150	9.31	9.24	9.00	7.42	12.03	0.78	0.526	8.37
		5.113	5.06	5.00	3.33	8.16	0.87	0.58	16.92
		mg.	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	
Thyroid	349	230.48	185.00	160.00	85.00	1,570.00	162.09	109.33	70.33
		123.24	97.50	90.00	50.40	730.00	75.7	51.06	61.47
Parathyroids	349	12.56	12.00	10.00	2.00	35.00	4.86	3.28	38.69
		6.92	6.31	5.00	1.09	21.75	2.78	1.87	40.13
Hypophysis	348	28.00	28.00	26.00	15.00	44.00	5.17	3.49	18.46
		15.40	15.30	14.50	7.28	29.40	3.10	2.09	20.27
Suprarenals	349	380.12	358.00	260.00	115.00	1,050.00	155.01	104.55	40.78
		208.80	196.70	170.00	80.40	530.00	75.03	50.61	35.93
Pineal gland	348	16.09	15.00	14.00	5.00	30.00	4.29	2.89	26.66
		8.85	8.68	8.00	2.73	18.73	2.45	1.65	27.68
Popliteal lymph nodes	242	255.39	245.00	210.00	85.00	720.00	82.41	55.59	32.27
		135.73	136.10	150.00	52.50	382.00	48.73	32.87	35.90
Axillary " "	242	175.85	175.00	160.00	40.00	400.00	59.75	40.30	33.98
		97.22	91.00	80.00	18.65	242.00	37.79	25.49	38.87
Deep cervical lymph nodes	124	155.79	140.00	100.00	35.00	405.00	73.20	49.38	46.98
		82.07	72.40	60.00	20.52	211.00	37.12	25.04	45.23
		gm.	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	
Mesenteric " "	133	3.488	3.32	3.00	1.34	9.19	1.31	0.88	37.53
		1.828	1.763	1.70	0.72	3.71	0.642	0.43	35.12

At the beginning of our investigations, it was feared that the error attributable to the conditions mentioned above would be so large that it would completely overshadow any variations in the weights of glandular tissue and thus invalidate the results of weight determinations on this group of organs. Experience has shown, however, that this is not entirely true. This conclusion is indicated by a comparison of the results obtained for these organs with the results obtained for organs of a similar nature on which accurate weight determinations can be made. By reference to Table I, it will be seen that the values given for the parathyroid and the pineal gland are of the same general order as those given for the thyroid or the suprarenals and that the values for the thymus and lymph nodes are comparable to those for the spleen and the deep cervical lymph nodes. The dependence that may be placed upon weights of the thymus, the parathyroids, the pineal gland, and lymph nodes will become more apparent when we consider these organs from the standpoint of the various groups of animals composing the series. Meantime, it may be said that, while we regard the weights of these organs as possessing some significance, we recognize the existence of an unavoidable error, the usual effect of which is to increase weights and to minimize variations in the actual mass of glandular tissue. This error is most disturbing in the case of the pineal gland and the parathyroids due to their very small size.

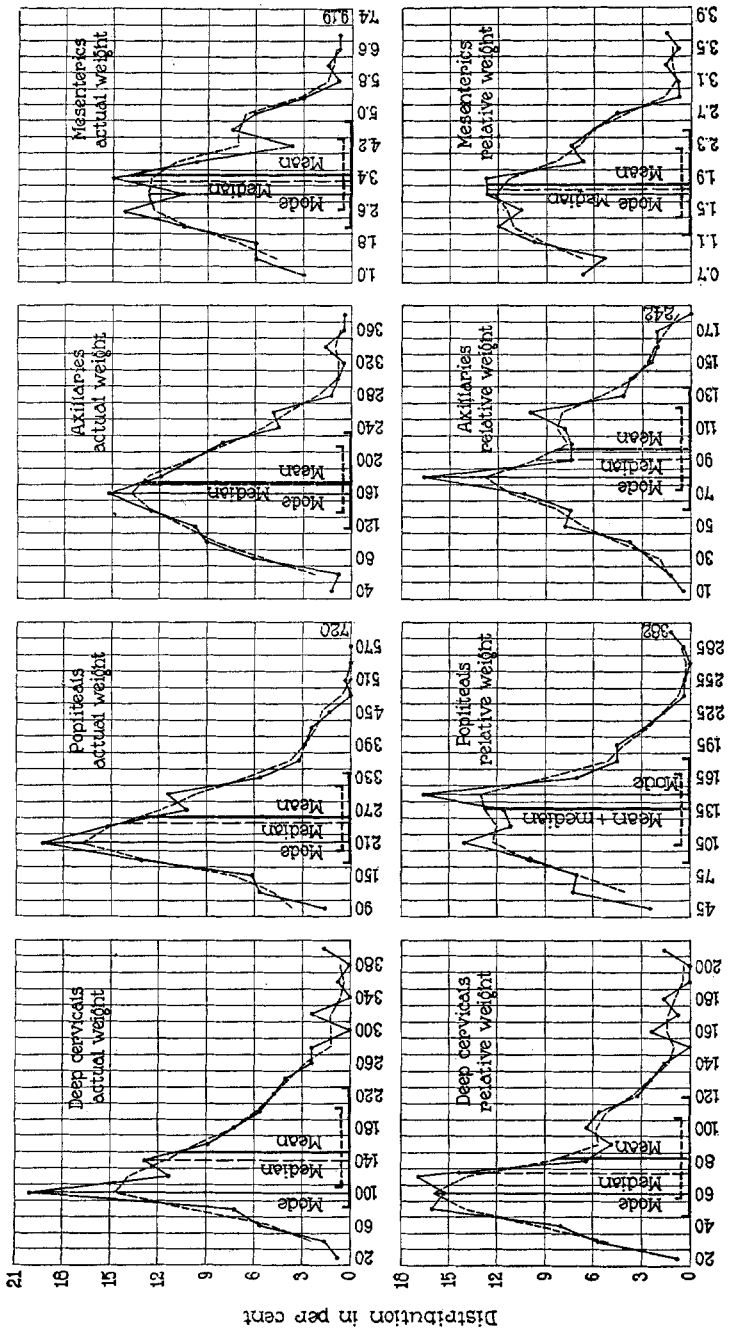
As regards the significance of the results in general, it is of interest to note that, in cases where comparisons can be made, values obtained for the rabbit appear to be of essentially the same order as those given for man. With the coefficient of variation as a basis for comparison, the values given by Pearl (2) for man and those obtained by us for the rabbit are as follows:



TEXT-FIG. 1. Curves of actual and relative weight distribution in per cent. The brackets at the bottom of the curves mark the limits of the standard deviation and the probable error.



TEXT-FIG. 2. Curves of actual and relative weight distribution in per cent. The brackets at the bottom of the curves mark the limits of the standard deviation and the probable error.



TEXT-FIG. 3. Curves of actual and relative weight distribution in per cent. The brackets at the bottom of the curves mark the limits of the standard deviation and the probable error.

	Man.	Rabbit.	
Weight of body.			
Bavarians	21.32	15.74 (gross).	All breeds.
English	10.37	17.49 (net).	" "
Weight of heart.			
Healthy	17.71	18.23	Normal and pathological.
Gen. Hosp. Pop.	32.39		
Weight of liver.			
Healthy	14.80	23.39	" " "
Gen. Hosp. Pop.	21.12		
Weight of kidneys.			
Healthy	16.80	16.30	" " "
Gen. Hosp. Pop.	24.63		
Weight of spleen.			
Healthy	38.21	44.04	" " "
Gen. Hosp. Pop.	50.58		
Weight of brain.			
Various races (males)	7.592	8.37	All breeds.
	7.809		
	8.096		
	8.118		
	9.160		

In most instances the agreement between the two sets of figures is surprisingly close, while in no case is there a serious disagreement.

Referring briefly to some of the more important features of the results, the first thing to which attention should be directed is the variation in organ weights. An examination of the data contained in Table I and the distribution curves will show that the weights of nearly all organs are subject to wide and frequent variations whether we consider the actual weight or the weight per unit of body weight. The notable exceptions to this rule are to be found in the case of the brain, the heart, the kidneys, and the hypophysis, which show coefficients of variation less than or of the same general order of magnitude as those for the gross body weight, the net body weight, or the gastrointestinal mass. At the other extreme are found such organs as the thyroid, the deep cervical lymph nodes, the spleen, the suprarenals, and the parathyroids with coefficients of from two to four times the coefficients for body weight.

The exact order of variation depends somewhat upon whether one considers the actual weight of the organ or the weight per unit of body weight. This may be shown by arranging the organs in parallel columns according to the magnitude of the coefficient of variation.

Gross body weight	15.74
Net body weight	17.49
Gastrointestinal mass	19.42

Actual weight.		Weight per kilo.	
Brain	8.37	Heart	12.32
Kidneys	16.30	Brain	16.92
Heart	18.23	Kidneys	18.08
Hypophysis	18.46	Hypophysis	20.27
Liver	23.39	Liver	25.48
Pineal gland	26.66	Testicles	26.90
Popliteal lymph nodes	32.27	Pineal gland	27.68
Testicles	33.54	Mesenteric lymph nodes.	35.12
Axillary lymph nodes	33.98	Popliteal " "	35.90
Mesenteric " "	37.53	Suprarenals	35.93
Thymus	38.37	Thymus	36.64
Parathyroids	38.69	Axillary lymph nodes	38.87
Suprarenals	40.78	Parathyroids	40.13
Spleen	44.04	Spleen	40.30
Deep cervical lymph nodes	46.98	Deep cervical lymph nodes	45.23
Thyroid	70.33	Thyroid	61.47

This form of arrangement does not disturb the general order of variability but merely the relative position of different organs. That is, the same organs occupy the first five positions in both columns but their relative positions change. This situation obtains until we reach the three lowest positions; here the order is the same in both cases.

Essentially the same result is obtained if we employ any other method of comparison. It is possible to say, therefore, that among the organs studied the brain, the heart, the kidneys, the hypophysis, and the liver give the most constant values, while the weights of such organs as the thyroid and the spleen and the organs occupying a position between these two groups give values that are subject to much wider variation.

The comparison of coefficients of variation for actual and relative weights brings out another important point in mass relationships; namely, the degree of correlation that exists between the weight of an

organ and body weight. As yet, the correlation coefficients have not been calculated as the material on which this study is based did not seem to be sufficient to warrant the use of such an exact method, but a comparison of the figures given in Table I and of distribution curves would indicate that the degree to which the weight of an organ is dependent upon body weight is itself a matter of considerable variation.

In the majority of cases, it would appear that the weights of organs are closely related to body weight, but there are a few instances in which the weight of the organ seems to be independent of body weight within certain limits. The most striking example of this is found in the case of the brain which shows a coefficient of variation for actual weight which is much smaller than that for the relative weight. There are other organs that may fall into the same class of relative independence such as the hypophysis and the kidneys. There are still other organs that show comparatively little difference between the constancy of the values obtained on the basis of actual and relative weights, but where the differences are so small and the coefficients large it is obvious that a larger amount of material will be required to determine the exact relationships. Meantime, it is worthy of note that organs occupying an intracranial position (the brain and the hypophysis) show an apparent tendency to conform to certain limits of weight independent of body weight. We do not mean to imply that the weights of these organs are fixed. On the contrary, it will be shown in a subsequent paper that, under certain circumstances, they vary as do the weights of other organs.

Another feature of the results to which reference may be made is the frequency with which organs of a given weight may be encountered and the probable direction of variation from the mean, mode, or median, as the case may be. These points are brought out in the distribution curves (Text-figs. 1 to 3) which have been grouped with a view to indicating the conditions that obtain in different classes of organs or tissues such as the parenchymatous organs, the organs of internal secretion, and the lymphoid tissues, the curves for which are given in the order mentioned.

It will be seen that a number of the distribution curves are of the same general form as those for body weight. The curves for the heart,

the liver, the kidneys, the brain, the hypophysis, the pineal gland, and the gastrointestinal mass are almost symmetrical; they show a relatively narrow range of weight distribution with a rapid rate of increase and decrease in the percentage of organs whose weight is close to the mean or mode and little or no tendency to the prolongation of the curves at either extreme. The curve for the testicles is also fairly symmetrical but shows a wider range of variation.

The distribution frequencies of other organs are much more irregular. The thyroid, the suprarenals, and some of the lymph nodes show a tendency to follow the same general form of weight distribution as the organs mentioned above but the range of weight is greater, the curves are irregular, and decidedly skewed, due chiefly to the occurrence of varying numbers of organs whose weights lie well above the mean. These conditions not only extend the zone of high frequency distribution but increase the probable error in estimations of the frequency of occurrence of organs of a given weight.

A third type of distribution is illustrated by such organs as the spleen and thymus. The feature of special interest in these curves is the presence of a wide zone of high frequency distribution within which there is comparatively little difference in the frequency with which organs of given weights may occur. Some of these curves are almost symmetrical while others are decidedly skewed.

The relative positions of the mean, the mode, and the median conform, in general, to theoretical expectations in nearly all cases. The only instance in which the mean and the median occupy a lower position than the mode is in the curve for the weight of the popliteal lymph nodes per kilo of body weight. This is probably an apparent rather than a real displacement which would not occur in the case of a fitted curve.

It seems unwise to carry the statistical analysis of the material further at the present time. The values as here given are affected by a number of variables whose influence must be considered before an attempt may be made to establish more exact values or to apply the results to any specific problem, except for purposes of orientation.

In the next paper, we will consider effects of pathological conditions of spontaneous origin which were not apparent clinically but were demonstrable by postmortem examination.

SUMMARY.

In November, 1921, a systematic study of normal rabbits was undertaken as a part of a more general investigation dealing with the subject of the animal organism in relation to disease. The present paper on organ weights is based on results obtained from a study of 350 male rabbits killed and examined between January 1, 1922, and July 1, 1924. Methods of conducting the experiments are described and the results are summarized in the form of a table and a series of text-figures.

The organs studied were the heart, liver, kidneys, spleen, thymus, testicles, brain, thyroid, parathyroids, suprarenals, hypophysis, pineal gland, and representative groups of lymph nodes.

The results recorded include maximum, minimum, and average weights, the median, the mode, the standard deviation, the probable error, the coefficient of variation, and the percentage distribution of organs of different weights.

No final conclusions are drawn but it is pointed out that the results obtained are comparable to those that have been reported from similar studies of organ weight in man. Attention is also directed to the tendency to the occurrence of wide variations in the weights of nearly all organs, and to an apparent difference in the degree of correlation that exists between organ weight and body weight in the case of certain organs. In this connection it is pointed out that within certain limits the weight of the brain, in particular, and of other organs to a lesser degree appears to be independent of body weight.

The results recorded in this paper are regarded as representing approximate values which are affected by numerous conditions for which correction should be made. These conditions will be considered in subsequent papers.

BIBLIOGRAPHY.

1. Brown, W. H., Pearce, L., and Van Allen, C. M., *Proc. Soc. Exp. Biol. and Med.*, 1923–24, xxi, 371, 373; *Tr. Assn. Am. Phys.*, 1924, xxxix, 466.
2. Pearl, R., *Biometrika*, 1905, iv, 13; Medical biometry and statistics, Philadelphia, 1923, 276.