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The Effect of a Strictly Vegetable Diet on the  
Spontaneous Activity, the Rate of Growth,  
and the Longevity of the  
Albino Rat

BY

JAMES ROLLIN SLONAKER  
ASSISTANT PROFESSOR OF PHYSIOLOGY

WITH ONE PLATE AND FIFTEEN TEXT FIGURES

STANFORD UNIVERSITY, CALIFORNIA  
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# THE EFFECT OF A STRICTLY VEGETABLE DIET ON THE SPONTANEOUS ACTIVITY, THE RATE OF GROWTH, AND THE LONGEVITY OF THE ALBINO RAT.\*

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## INTRODUCTION.

The study of dietetics today occupies one of the most important places in the field of physiological investigation. Many popular articles have appeared in the past few years advocating this or that diet as best adapted to the needs of man. The argument is usually based on the personal opinion of the writer or the effects a certain diet may have had upon him. The personal idiosyncrasies which appear in these articles are too numerous to mention. Such writings are of no scientific value, and only show the trend of a certain class of people.

In contrast to these popular articles appear the writing of various scientific men giving the results of their investigations. These results are based on the comparative digestibility and absorption of the different foods and upon their ability to maintain nitrogenous equilibrium in the animal experimented upon.

The tendency of humanity is to go to the extremes, and nowhere is this more manifested than in dietetics. One class, vegetarians, maintains that man should abstain exclusively from animal foods, the other class claims that the human alimentary tract is more adapted to omnivorous food than to a strictly vegetable diet.

Vegetarianism as used by most people is a misnomer. The larger proportion of the so-called vegetarians partake freely of such animal foods as milk, eggs, butter, cheese and the like. A few, the fruitarians, live wholly on nuts and fresh fruits. Another small group live on nuts, fruits, legumes and vegetables, either in the raw or cooked state. The much larger number of vegetarians (?) live on a mixed diet which differs from the ordinary mixed diet in only one respect—the absence of meat.

Most investigators have studied the effects of a certain diet on the animal for a limited time, which in most cases is insufficient to warrant

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\*From the Physiological Laboratories of Stanford University.

such sweeping conclusions. Because an animal is able to maintain its weight and health for a limited time, is no argument that it could do so for its entire life. Neither has the effect on the offspring been ascertained. Such results can only be obtained by continuing the experiment during the lifetime of the animal and succeeding generations.

The present experiment was undertaken to determine as fully as possible the comparative effect of a strictly vegetable diet, and an omnivorous diet, upon the spontaneous energy of the animal as manifested by its voluntary activity, the effect on its growth, and on the length of its life. An experiment is now under way to study the effect on the progeny. No attempt has been made to study the income and outgo of nitrogen.

#### MATERIALS AND APPARATUS.

In order that such an experiment may be of value a number of similar animals must be used, and the environment of these must be the same in every respect, with the exception of diet.<sup>1</sup>

In this experiment sixteen rats were used. To secure these as nearly alike as possible, sisters were mated to the same male. After numerous trials, lasting more than a year, two sister rats of approximately the same size, which had been mated to the same male, gave birth to eight each, just a day apart. Previous observations<sup>2</sup> have shown that the young of a litter of three not only averaged heavier at birth than those of a litter of ten, but also gained more rapidly during the nursing period and had a better start at the weaning time than those of the larger litter. Also the age of the mother had an effect on the size of the litter and the average weight of the young. Very young mothers were less prolific than older females.

Minot<sup>3</sup> found in his observations on the guinea pig that the average young of a litter of one weighed 85.5 grams, and the average of a litter of eight 52.2 grams. Also that the males averaged heavier (71 grams) than the females (70.2 grams). A similar condition exists between the sexes of the albino rat. This difference in weight of the two sexes becomes much more marked as the animals grow older. One should therefore have rats of the same age, of as nearly as possible the same parentage, the same number in the litter, and the same number of each sex. Owing to the fact that it is difficult to determine the sex of the young rats with accuracy, the sexes were not distributed as I would have wished.

These sixteen young were arranged and designated as follows:

No. 1 and No. 2 from litter A, and No. 3 and No. 4 from litter B, were put into revolving cages to be used as omnivorous feeders in determining their activity; No. 5 and No. 6 from litter A, and No. 7 and No. 8 from litter B, were put in revolving cages to be used in ascertaining the amount of work the vegetarian feeders would perform; No. 9 and No. 10 from litter A, and No. 11 and No. 12 from litter B, were put in stationary cages for omnivorous controls; and No. 13 and No. 14 from litter A, and No. 15 and No. 16 from litter B, were placed in stationary cages for vegetarian controls. Thus each litter was equally and uniformly distributed. Unfortunately the sexes were not ideally grouped. The following table illustrates the manner in which the young were distributed.

Omnivorous Exercised Rats			Vegetarian Exercised Rats			Omnivorous Control Rats			Vegetarian Control Rats		
Litter	No.	Sex	Litter	No.	Sex	Litter	No.	Sex	Litter	No.	Sex
A	1	Male	A	5	Male	A	9	Male	A	13	Female
"	2	"	"	6	Female	"	10	"	"	14	Male
B	3	Female	B	7	"	B	11	Female	B	15	"
"	4	Male	"	8	"	"	12	Male	"	16	"

Each rat was thus confined in a cage by itself, which served as its home for its entire lifetime, and from which it was taken at intervals of about two weeks for a time sufficient to weigh the rat and clean its cage.

The apparatus for recording the activity has already been described,<sup>4</sup> but may be briefly given again. It consisted of a series of eight cylindrical cages which revolved on stationary axles to which were attached the nest boxes. The food and water boxes were attached to the ends of the nest boxes. The cage thus revolved about the stationary nest box whenever the rat ran. Automatic devices were attached to register the number of revolutions and to record them on paper kept moving by a continuous roll kymograph. The first device being read in the morning and in the evening gave the daily and nightly run of each rat through its lifetime. The second arrangement showed the distribution of the activity of each rat for each twenty-four hours during its whole life. These records were of great assistance in showing the peculiarities of activity which occurred at different ages.

This apparatus was therefore only adapted to recording the running activity of the animals. Previous observations<sup>2</sup> have shown that the running activity of the rat is proportional to the other activities.

Changes in the amount of the running activity are correct indicators of similar fluctuations in the other activities of the animal.

### FEEDING.

No attempt was made to give a definite amount of protein food in the diet nor to try to maintain nitrogenous equilibrium. The diet was varied as much as possible, and the amount of food given was more than was eaten before the feeding time on the following day. The feed and water boxes were then cleaned and a new supply given. Cracked corn was always given. The young were weaned at the age of 28 days and placed in their respective cages, as already described. A rich mixed diet, consisting largely of bread and milk with an occasional feed of baked beans and meat hash, was given all to prevent any disastrous effects resulting from the sudden change in environment and methods of feeding. This mixed diet was continued for twenty-eight days. At this age (fifty-six days) all appeared perfectly healthy and normal in every respect. They had each made a normal gain. The males averaged 70.1 grams and the females 59.3 grams.

The difference in the character of the food was introduced at this time, the one group being designated vegetarians, and the other, omnivorous feeders. These two groups were fed exactly the same food each day, with the exception of meat and other animal foods which were given about three times a week to the omnivorous feeders in addition to the vegetable food. The vegetable foods were as rich in protein as it was possible to obtain from this class of foods, and consisted of such articles as the following: fresh vegetables, such as lettuce, kale, cabbage, cauliflower, clover and celery; cooked vegetables, such as white, corn, brown and graham bread, biscuits, buckwheat cakes, doughnuts, crackers, cookies, oatmeal mush, fried cornmeal mush, dumplings, corn, rice, baked beans, potatoes, carrots and onions; nuts, fruits and grains, such as almonds, English walnuts, apples, cracked corn, wheat, and corn meal. Occasionally, when the vegetarians seemed to be losing ground too fast, a feed of cheese, milk, or some other animal food was given. This was done only a few times soon after the vegetarians were first put on their exclusive diet.

As can be readily seen, the above articles composing the vegetarian diet are either found on our tables or can readily be procured from shops. Some of them contained small portions of animal food, i.e., graham muffins usually contain an egg and milk, bread often contains milk, doughnuts and several other articles contain animal fat. As only



very small amounts of animal food were present as compared to a large quantity of vegetable food, I have called this a strictly vegetable diet, at the same time realizing it is not absolutely such a diet.

The amount of food given to each rat was not weighed, but measured as accurately as possible with a spoon, or by pieces of equal size.

The following few days' diet taken at random will serve to show the variety of food and its frequency.

April 23. Cooked corn, lettuce, cracked corn and water.

April 24. Water-soaked bread, almonds, lettuce, cracked corn and water.

April 25. Baked beans, lettuce, cracked corn and water.

Omnivorous had also meat.

April 26. Graham muffins, almonds, cracked corn and water.

April 27. Water-soaked bread, lettuce, cracked corn and water.

April 28. Water-soaked bread, almonds, cracked corn and water.

April 29. Cracked corn and water.

April 30. Mashed potatoes, lettuce, cracked corn and water.

Omnivorous had also meat.

April 31. Water-soaked bread, buckwheat cakes, cracked corn and water.

Another example at another season of the year is as follows:

Nov. 14. Bread, cracked corn and water.

Nov. 15. Potatoes, macaroni, cracked corn and water.

Omnivorous had also meat.

Nov. 16. Bread, oatmeal mush, cracked corn and water.

Omnivorous had also meat and bread hash.

Nov. 17. Water-soaked bread, cracked corn and water.

Nov. 18. Water-soaked bread, cracked corn and water.

Omnivorous had also meat and bread hash.

The amount of meat given to each of the omnivorous rats was usually small, consisting of but a few grams. It was given on an average two or three times each week.

We have thus sixteen rats as nearly alike in regard to age, parentage, size and tendencies as it is possible to obtain, subjected to the same environments, fed the same food with the exception that the eight omnivorous feeders had a few grams of animal food added to their diet about three times each week. It is obvious, therefore, that whatever differences may be found between these two groups of rats in regard to their activity, rate of growth, and longevity must be due wholly to the presence and absence of animal food in the two diets.

## ACTIVITY.

In studying the characteristics of the activity one needs to refer to the kymograph records. Figures 1 to 10 inclusive are reproductions of such records, and show the activity of each rat for twenty-four consecutive hours at different ages. By comparing these figures a great difference is noticed in the activity at different ages.

Figure 1 represents the activity of each rat at the age of thirty-two days, and just four days after they had been weaned and placed in the revolving cages. There is no regularity in the distribution of the activity and periods of rest. Neither is there any apparent tendency to be more active at one time in the twenty-four hours than at another. They were restless, playful and filled with a spirit of investigation. Since they were all fed at this time on the same diet, any differences in the character of the activity may be attributed to individual variation.

In Figure 2, which shows the distribution of the activity at the age of six months, two important things are noticed. First, the great bulk of the activity occurs during the evening and early night time; second, the omnivorous rats (O) are more active than the vegetarians (V). There is more or less random running for an hour or so before and after the feeding time (4 p.m.), but the most is done during the night.

At the age of eleven months (Figure 3) the periods of activity and rest are more sharply defined. Also the difference in the amount of voluntary activity of the two classes is very obvious. The activity of the vegetarians is approaching closely in appearance that of old age.<sup>2</sup>

In Figure 4 the activity at the age of sixteen months is seen. Some days previous to this record the feeding time was changed to the morning to see what effect it would have on the distribution of the activity. The main bulk is seen to remain constant, but the usual random running which occurs at the feeding time has shifted to the morning. At this age two of the vegetarians have died and the other two compare very unfavorably with the work of the omnivorous.

Figure 5, which represents the activity at the age of twenty-one months, shows that when the feeding time is returned to the afternoon the periods of activity and rest are sharply defined. The omnivorous feeders are still quite active when compared to the remaining vegetarians.

At the age of twenty-five months all the vegetarians were dead (Figure 6). The records of the omnivorous rats show a marked tendency toward old age. Especially is this true in No. 1 and No. 4.



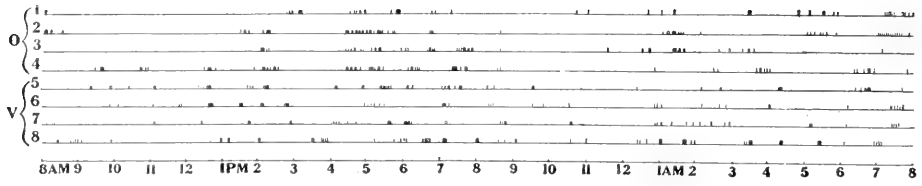


Fig. 1. Graphic records showing the distribution of the activity of each of the exercised rats as recorded on the kymograph paper. The rats were 32 days old and had been weaned and put in their cages but four days before. O and V refer to omnivorous and vegetarian rats respectively.

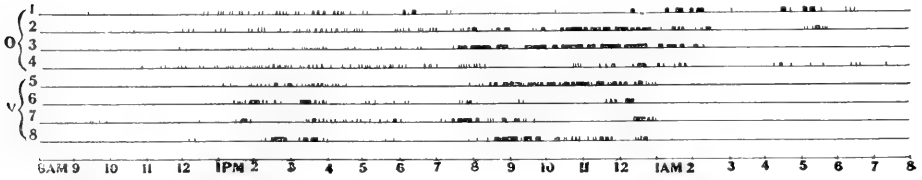


Fig. 2. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 6 months.

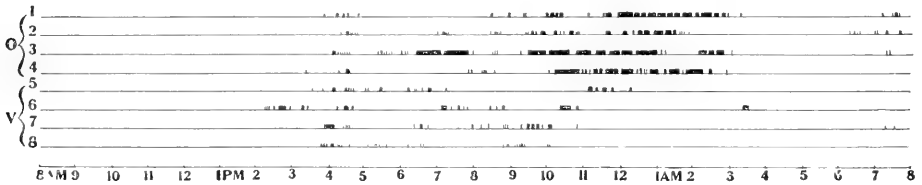


Fig. 3. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 11 months.

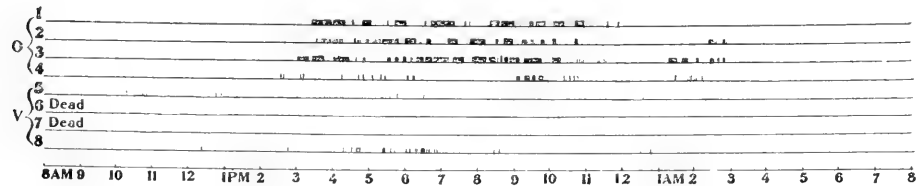


Fig. 4. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 16 months.

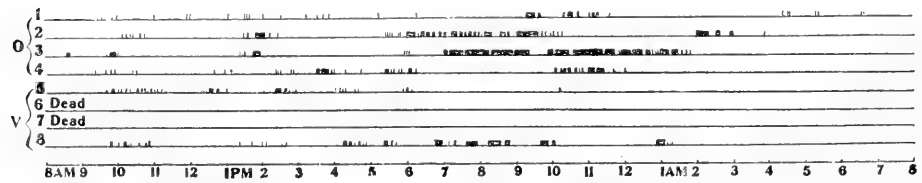


Fig. 5. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 21 months.

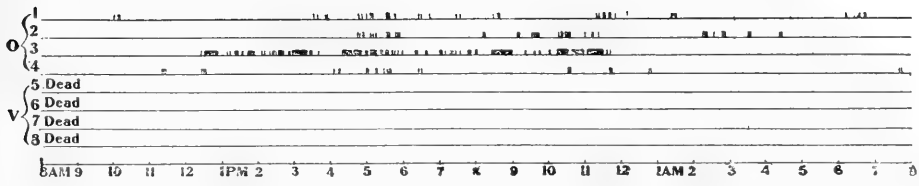


Fig. 6. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 25 months.

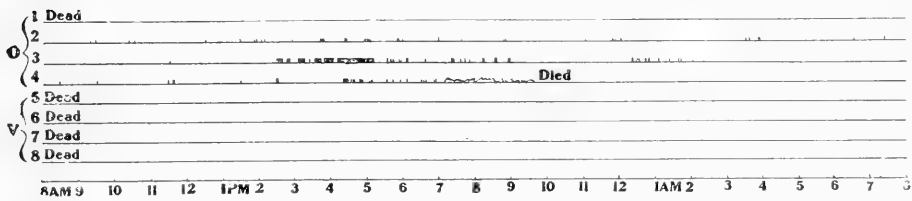


Fig. 7. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 26 months.

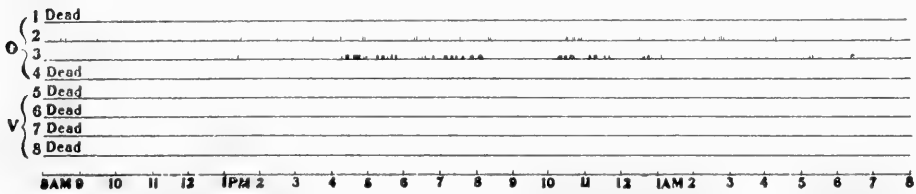


Fig. 8. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 28 months.

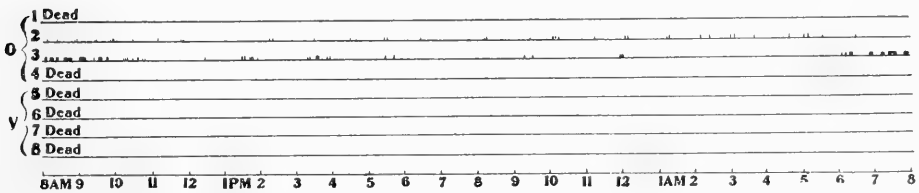


Fig. 9. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 31 months.

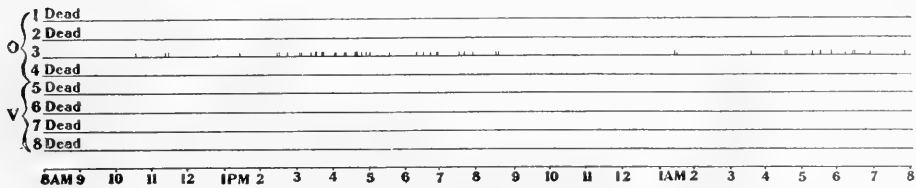


Fig. 10. Graphic records of activity of omnivorous (O) and vegetarian rats (V) at the age of 34 months.



The remaining figures (7, 8, 9 and 10) represent the records for the ages twenty-six, twenty-eight, thirty-one and thirty-four months respectively. No. 4 in Figure 7 shows the death struggle of this rat, which ended a little before 10 p.m.

In comparing these different records of activity, one notices that in the young rats the periods of activity and rest are of short duration and have no definite arrangement so far as the time of the day is concerned. As the rats grow older the activity becomes greater and occurs more and more during the night time, the periods of rest being confined to the daytime. This continues until the rats reach the prime of life. After some months of almost uniform activity there is a gradual reduction, and the distribution and amount of work done approaches that of youth. It also shows that the vegetarians are not as active, that they age more early, and that their duration of life is shorter than the omnivorous rats.

Since all the animals were fed on a mixed diet for twenty-eight days after commencing the experiment, any difference in activity during this period must be considered due to individual variation. This variation is sometimes very noticeable, as seen in Table I. This table represents the average number of revolutions of five consecutive days of each rat at the ages indicated. There is not a gradual and regular increase in the amount of running done by each, but fluctuations—now greater, now less. At first this was thought to be due to making the average from too small a number of days. Therefore another table (Table II) was made, by taking the average run of each sex of each group for a whole month. The figures in the column of the omnivorous males thus represent the average of thirty days' run of three individuals. But here again we see the lack of a uniform increase. In other words, the activity manifests itself rhythmically. No doubt if the number of individuals had been greater the results would have been more uniform. In a former paper I have discussed the causes of these fluctuations.<sup>2</sup>

Table II is put in the form of curves in Figure II. The rhythmical variations are very conspicuous. These fluctuations also correspond in many cases both in regard to time and appearance. For example, from the beginning to the third month there is a rapid rise in the curves, showing a great increase in the daily activity. This was, no doubt, due to the feed, for they were all fed on a strong mixed diet for almost a month, and on rich food for almost two months. The effect of this food carried them over apparently till the end of the third month, when they began to feel the effects of the lack of it. This was followed in a general reduction of amount of daily activity in all except the omnivorous

Age in Mos.	OMNIVOROUS RATS				VEGETARIAN RATS			
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
	Male	Male	Female	Male	Male	Female	Female	Female
1	348	1002	620	448	1182	752	318	970
2	1200	1124	2118	1336	1964	668	716	1952
3	790	886	1956	1832	1618	682	1396	2238
4	5028	5850	5782	9406	2150	542	2870	1468
5	1206	3930	7280	834	420	657	1206	3496
6	540	1644	8482	540	596	920	1170	1472
7	1307	3144	10185	3574	1084	1128	3244	1904
8	2024	3274	9518	4276	676	5652	2400	3884
9	6002	7574	8930	2836	836	656	8962	4106
10	2618	4398	8260	2882	858	578	876	2962
11	3620	2096	8640	2310	1006	340	670	882
12	2186	4258	8902	2616	1144	528	898	1004
13	4964	7066	11044	3084	602	46	316	708
14	3860	6374	10992	3004	168	....	524	634
15	1428	4768	8198	2556	90	....	918	96
16	1006	2642	13002	1364	342	....	68	96
17	2684	4776	5982	1998	84	....	....	72
18	744	2364	9732	1512	88	....	....	22
19	996	2476	8312	808	70	....	....	60
20	806	2056	9658	720	82	....	....	24
21	690	1520	2210	482	56	....	....	58
22	336	1810	5468	290	52	....	....	22
23	1696	1680	3188	456	40	....	....	88
24	380	1352	3100	220	....	....	....	....
25	94*	1466	4612	196	....	....	....	....
26	....	188	2538	48*	....	....	....	....
27	....	160	1968	....	....	....	....	....
28	....	180	5171	....	....	....	....	....
29	....	72	2424	....	....	....	....	....
30	....	56	2832	....	....	....	....	....
31	....	28*	1706	....	....	....	....	....
32	....	....	2312	....	....	....	....	....
33	....	....	488	....	....	....	....	....
34	....	....	435	....	....	....	....	....
	....	....	60*	....	....	....	....	....

TABLE I.—Average daily revolutions of the omnivorous and vegetarian rats at ages indicated.

female, which remained practically unchanged. Then, with the exception of the vegetarian female, there was another general increase up to the fifth month. Again, at the tenth month, all show an increase, excepting the vegetarian male, which shows a slight decrease.

\*The number of revolutions during the 24 hours previous to death.



## DIFFERENCES IN ACTIVITY

. 11

Age in Months	OMNIVOROUS		VEGETARIAN	
	Male (Avg. 3)	Female (Avg. 1)	Male (Avg. 1)	Female (Avg. 3)
1	73	102	68	53
2	689	724	1169	1040
3	2455	2,944	3542	2017
4	642	3,014	1853	1273
5	4375	6,835	5021	75
6	3286	8,843	845	146
7	3405	13,308	1242	1175
8	3673	10,808	1211	2188
9	3535	9,688	1057	2156
10	4717	11,643	828	2316
11	3119	10,136	998	905
12	2935	10,513	1010	738
13	3957	9,684	826	680
14	5081	11,613	458	482
15	2285	9,110	517	519
16	2247	8,692	140	267
17	2069	9,027	179	29
18	2262	7,579	99	26
19	2212	9,357	96	7
20	1599	9,247	54	21
21	980	6,940	55	16
22	1273	7,156	37	13
23	1062	5,730	81	16
24	727	3,664	....	....
25	746	3,529	....	....
26	266	3,909	....	....
27	105	3,774	....	....
28	149	3,609	....	....
29	15	3,339	....	....
30	25	2,808	....	....
31	10	1,911	....	....
32	4	3,134	....	....
33	....	2,033	....	....
34	....	320	....	....

TABLE II.—Average daily work as indicated by the number of revolutions computed by dividing the total run of the month previous by 30.

It is especially noticeable that the curves representing the two sexes of the omnivorous feeders correspond much more closely in their fluctuations than those of the vegetarian feeders. In fact after the third month similarity in the character and time of these fluctuations of the

omnivorous and vegetarian feeders grows rapidly less and less. The same may be said regarding the amount of daily activity of the two classes. The omnivorous female far surpasses all others. The omnivorous male comes next in order. Then follows the vegetarian female,

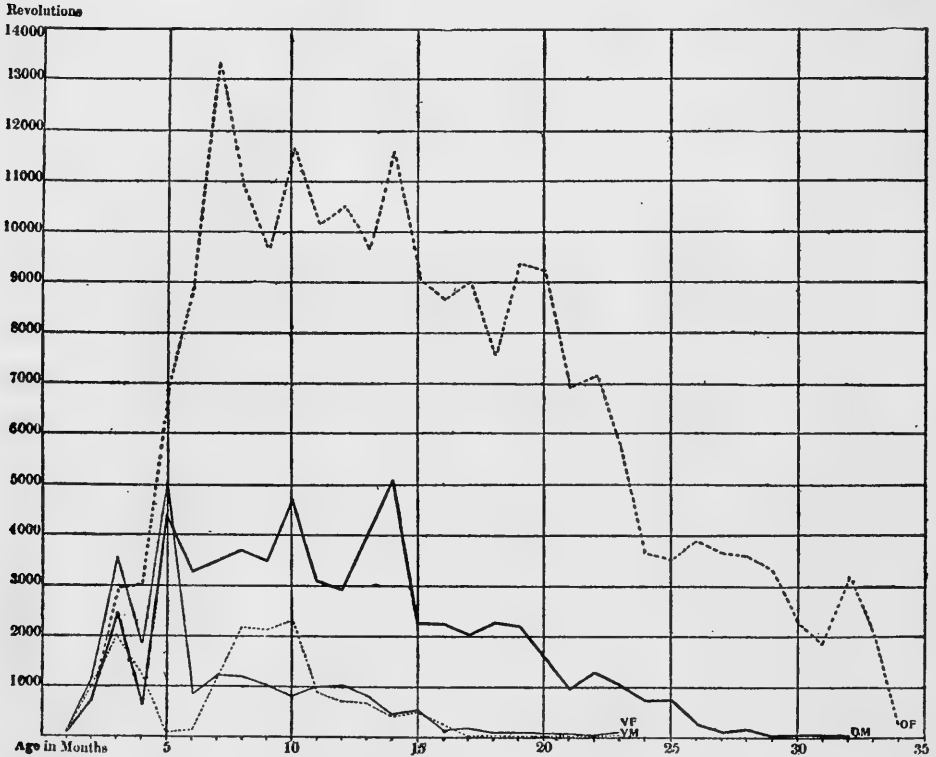


Fig. 11. Curves representing the average daily activity of each sex of the exercised rats at the ages indicated. The heavy solid line (OM) is the omnivorous males, the heavy dotted line (OF) is of the omnivorous females. The light solid line (VM) is the vegetarian males. The light dotted line (VF) is the vegetarian females.

closely followed by the vegetarian male. The females of each class thus surpass the males of the same group in average daily activity.

When we consider the time in life at which these rats do the greatest amount of daily running we see, on consulting the curves of Figure 11, that it occurs in both classes at an early age in life, usually between the seventh and twelfth month. In the omnivorous feeders it is a little later than in the vegetarians. In a former experiment<sup>2</sup> it was ascertained that the greatest average daily run of the normal male and female occurred when they had reached a trifle more than one-third of their

natural lifetime. In this experiment the vegetarians seem to have done their best day's work when about one-fourth of their life had passed. This was equivalent to about one-sixth of the lifetime of the normal omnivorous rat.

Let us now consider the total amount of work, as indicated by the

Age in Mos.	OMNIVOROUS EXERCISED RATS				VEGETARIAN EXERCISED RATS			
	Male	Male	Female	Male	Male	Female	Female	Female
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
1	1,200	3,050	1,300	2,060	2,040	1,180	760	2,810
2	18,850	26,140	23,010	23,390	37,120	26,620	22,550	49,120
3	79,750	91,130	111,320	118,150	143,380	59,680	76,840	149,330
4	148,460	189,620	201,730	248,780	198,980	82,070	133,430	238,940
5	248,990	322,420	406,780	409,250	249,600	98,350	180,070	285,940
6	329,900	438,020	672,070	508,500	276,960	111,670	238,550	364,240
7	403,070	523,320	1,041,330	656,470	314,520	132,580	290,780	406,700
8	487,130	650,490	1,388,260	777,640	350,550	158,890	374,400	483,720
9	576,360	786,660	1,678,890	870,400	382,320	187,910	450,980	575,160
10	722,880	982,210	2,028,190	952,860	407,150	210,720	555,180	659,590
11	817,000	1,082,000	2,332,260	1,039,650	437,090	224,790	581,180	694,980
12	883,120	1,215,190	2,647,640	1,104,240	467,380	238,750	604,830	723,820
13	961,360	1,378,680	2,938,160	1,218,620	492,170	244,370	634,340	749,280
14	1,068,300	1,548,570	3,286,540	1,399,100	505,820	....	651,680	772,930
15	1,165,990	1,666,150	3,559,830	1,389,440	511,340	....	686,590	784,740
16	1,206,980	1,760,900	3,820,590	1,455,930	515,530	....	704,900	787,450
17	1,271,700	1,849,340	4,091,400	1,488,930	520,910	....	....	790,040
18	1,309,080	1,975,140	4,318,780	1,529,400	523,000	....	....	792,390
19	1,339,080	2,072,520	4,599,500	1,571,080	525,890	....	....	793,620
20	1,382,130	2,146,720	4,867,910	1,588,710	527,520	....	....	794,930
21	1,400,500	2,203,380	5,076,100	1,601,920	529,160	....	....	796,360
22	1,429,570	2,277,120	5,290,770	1,613,700	530,560	....	....	797,570
23	1,457,500	2,334,160	5,462,560	1,624,420	533,000	....	....	799,040
24	1,469,340	2,380,260	5,573,480	1,631,780	....	....	....	....
25	1,486,250	2,423,250	5,679,360	1,639,060	....	....	....	....
26	....	2,447,180	5,796,630	1,642,100	....	....	....	....
27	....	2,456,190	5,909,860	1,642,580	....	....	....	....
28	....	2,460,110	6,018,140	....	....	....	....	....
29	....	2,462,520	6,118,320	....	....	....	....	....
30	....	2,463,950	6,202,570	....	....	....	....	....
31	....	2,464,770	6,259,910	....	....	....	....	....
32	....	2,465,130	6,353,920	....	....	....	....	....
33	....	....	6,414,900	....	....	....	....	....
34	....	....	6,427,500	....	....	....	....	....

TABLE III.—Comparative number of revolutions made by the omnivorous and vegetarian rats at the ages indicated. The number of revolutions represents the amount of voluntary running or work of each rat.

number of revolutions which each of the exercised rats voluntarily made during its lifetime.

Table III represents the total number of revolutions of each rat at the ages indicated. To give a better idea of the amount of work equivalent to these revolutions, the actual distance in miles has been computed and shown in Table IV. By consulting these tables it is

Age in Mo.	OMNIVOROUS EXERCISED RATS				VEGETARIAN EXERCISED RATS			
	Male No. 1	Male No. 2	Female No. 3	Male No. 4	Male No. 5	Female No. 6	Female No. 7	Female No. 8
1	1	2.6	1.8	1.7	1.7	1	.6	2.4
2	16	22	19	19.6	31.5	22.6	19.1	41.7
3	68	77	95	100	122	50.6	65	126.6
4	121	160	170	210	168	67.6	113	202.5
5	211	273	336	346	211	83.4	153	242
6	278	373	572	495	234	94.7	200	309
7	341	434	882	555	257	112.4	246.5	345
8	414	551	1181	658	297	134.7	317.3	410
9	487	663	1435	740	305	159	382	487.5
10	612	832	1710	810	345	187	470.5	559
11	691	915	1980	876	370	190.5	492.6	589
12	749	1023	2230	945	396	202.3	508.3	613
13	812	1155	2490	1036	417	207	537.7	635
14	900	1318	2780	1115	428.6	....	552	655
15	986	1390	3020	1168	433.4	....	581.9	665
16	1020	1490	3230	1220	436.5	....	592.3	667
17	1080	1560	3460	1270	440.6	....	....	669.6
18	1110	1665	3650	1298	444.7	....	....	671.5
19	1125	1747	3890	1325	445.7	....	....	672.6
20	1165	1850	4125	1347	447	....	....	673.7
21	1188	1862	4280	1358	448.5	....	....	675
22	1210	1920	4475	1362	449.7	....	....	676
23	1225	1980	4620	1380	450.9	....	....	677.1
24	1244	2025	4720	1385	....	....	....	....
25	1265	2050	4810	1389	....	....	....	....
26	....	2074	4900	1391	....	....	....	....
27	....	2090	5000	....	....	....	....	....
28	....	2093	5100	....	....	....	....	....
29	....	2095.6	5180	....	....	....	....	....
30	....	2097	5250	....	....	....	....	....
31	....	2097.7	5300	....	....	....	....	....
32	....	2098	5350	....	....	....	....	....
33	....	....	5430	....	....	....	....	....
34	....	....	5447	....	....	....	....	....

TABLE IV.—Comparative number of miles run by the omnivorous and vegetarian rats in the revolving cages at the ages indicated.

readily seen that the work done by all the rats corresponds rather closely during the first three or four months. This corresponds closely to the average daily work shown in Figure 11. As a matter of fact the vegetarians average a trifle more at the end of the third month than

Age in Mos.	Average number of revolutions				Average number of miles			
	Omnivorous		Vegetarian		Omnivorous		Vegetarian	
	Males Avg. of 3	Female Avg. of 1	Male Avg. of 1	Female Avg. of 3	Male Avg. of 3	Female Avg. of 1	Male Avg. of 1	Female Avg. of 3
1	2,103	1,300	2,040	1,583	1.8	1.8	1.7	1.3
2	22,793	23,010	37,120	32,783	19.2	19.	31.5	27.5
3	95,343	111,320	143,380	93,283	82.	95.	122.	80.7
4	195,620	201,730	198,980	131,480	164.	170.	168.	127.7
5	326,887	406,780	249,600	133,747	277.	336.	211.	159.5
6	425,473	672,070	276,960	238,133	349.	572.	234.	201.1
7	527,620	1,041,330	314,220	273,353	443.	882.	257.	234.6
8	638,420	1,388,260	350,550	339,003	541.	1181.	297.	287.7
9	744,473	1,678,890	382,320	403,683	630.	1435.	305.	342.8
10	885,983	2,028,190	407,150	473,163	751.	1710.	345.	405.5
11	979,550	2,332,260	437,090	500,317	827.	1980.	370.	424.3
12	1,067,517	2,647,640	467,380	522,467	906.	2230.	396.	441.
13	1,186,220	2,938,160	492,170	542,663	1001.	2490.	417.	470.
14	1,338,657	3,286,540	505,820	556,327	1111.	2780.	428.6	471.3
15	1,407,193	3,559,830	511,340	571,900	1181.	3020.	433.4	482.6
16	1,474,603	3,820,590	515,530	578,907	1243.	3230.	436.5	488.8
17	1,536,670	4,091,400	520,910	579,770	1303.	3460.	440.6	486.6
18	1,604,540	4,318,780	523,000	580,553	1338.	3650.	444.7	490.3
19	1,660,893	4,599,500	525,890	580,763	1399.	3890.	445.7	490.6
20	1,705,853	4,867,910	527,520	581,400	1454.	4125.	447.	491.
21	1,735,267	5,076,100	529,160	581,877	1469.	4280.	448.5	491.4
22	1,773,463	5,290,770	530,560	582,280	1497.	4475.	449.7	491.8
23	1,805,327	5,462,560	533,000	582,770	1528.	4620.	450.9	492.1
24	1,827,127	5,573,480	.....	.....	1551.	4720.	.....	.....
25	1,849,520	5,679,360	.....	.....	1568.	4810.	.....	.....
26	1,858,510	5,796,630	.....	.....	1577.	4900.	.....	.....
27	1,861,673	5,909,860	.....	.....	1582.	5000.	.....	.....
28	1,862,980	6,018,140	.....	.....	1583.	5100.	.....	.....
29	1,863,450	6,118,320	.....	.....	1587.2	5180.	.....	.....
30	1,864,220	6,202,570	.....	.....	1587.7	5250.	.....	.....
31	1,864,533	6,259,910	.....	.....	1587.9	5300.	.....	.....
32	1,864,653	6,352,920	.....	.....	1588.	5350.	.....	.....
33	.....	6,414,900	.....	.....	.....	5430.	.....	.....
34	.....	6,427,500	.....	.....	.....	5447.	.....	.....

TABLE V.—Showing the relative amount of work done by the two classes of animals in revolving cages as indicated by the average number of revolutions and the average distance run at the different ages.

the omnivorous. This is seen by consulting Table V, which represents the averages of each sex of these two groups.

From this I think one of two conclusions may be reached. Either the sudden reduction in the rich protein food of the omnivorous rats to almost a vegetarian diet (meat being given only two or three times a week) has had the effect of checking the activity of all alike, or a strictly vegetarian diet at this age is conducive to a slightly greater activity. If the latter is true it may be explained in this manner: The omnivorous rat had a satisfying diet; the vegetarians did not, and ran

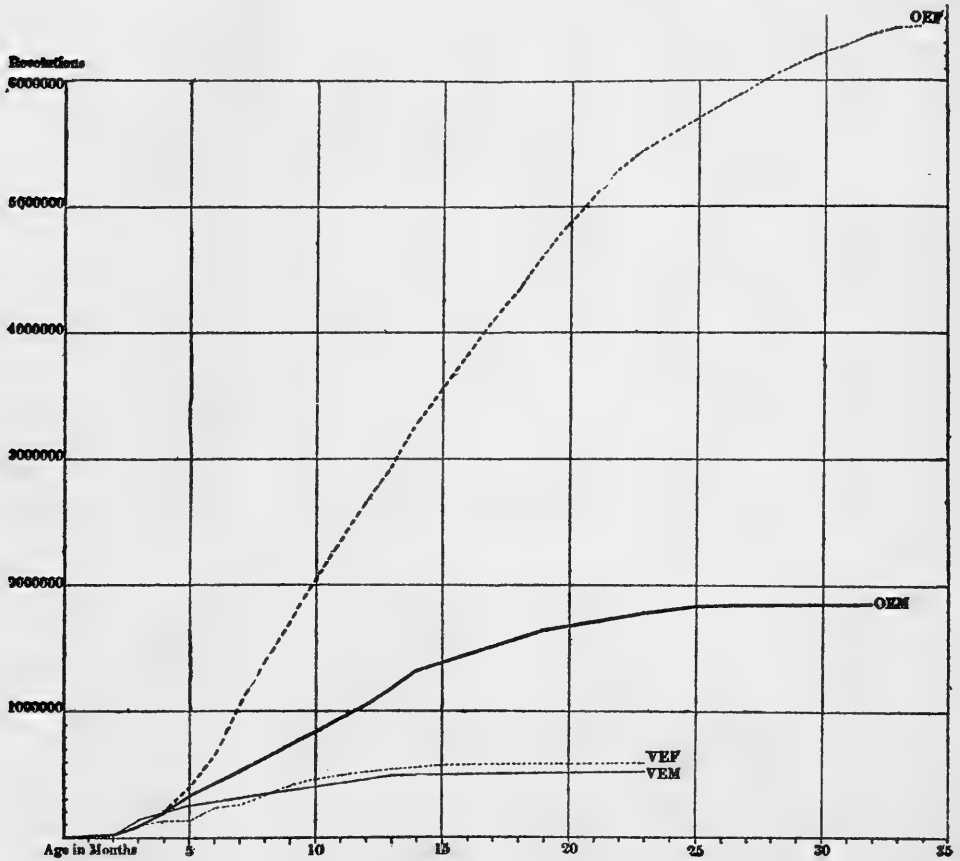


Fig. 12. Curves showing the average total work and the rate it was done of each sex of exercised omnivorous and vegetarian feeders. The heavy solid line (OEM) represents the work of the omnivorous males, the heavy dotted line (OEF) the omnivorous females; the light solid line (VEM) the vegetarian males, the light dotted line (VEF) the vegetarian females.

a great deal, apparently in search for what they desired. The behavior of the vegetarians strongly supports this supposition. When they were fed they ate ravenously, as if they had been starving. This was not so manifest in the omnivorous. It was true that both classes of exercised rats always appeared more hungry than the control rats of the same group.

After the third month the general average of the vegetarians falls below that of the omnivorous. This is shown in the curves of Figure 12. Here we see that the omnivorous female rapidly surpasses the omnivorous male in the amount of work done. The female vegetarian also excels the male of the same class in the distance run, but only to a small extent. The females are thus voluntarily more active than the males. We also note that the omnivorous male is much more active than either sex of the vegetarians. At the time of the death of the vegetarian rats (twenty-five months) the omnivorous female had voluntarily done almost nine and one-half times as much work as the female vegetarian, and the omnivorous male almost three and one-half times as much as the male vegetarian.

When the total amount of work voluntarily done by each class is considered, a still greater difference is observed. The omnivorous female ran a total distance of 5447 miles, while the vegetarian female ran only 492.1 miles, or a ratio of about 11 : 1. The omnivorous male ran 1588 miles, compared to 450.9 miles for the vegetarian male—a ratio of 3.5 : 1. The average run for both sexes was, for the omnivorous rats 3517.5 miles, and for the vegetarians 471.5 miles, or a ratio of almost 7.5 : 1.

We thus see that when the initiative and ability to do work are considered, the result is decidedly in favor of the rats that had received animal food in their diet, and overwhelmingly against the vegetarians.

The curves of Figure 12 show in a general way the rate at which the life's work was accomplished by each rat. But to show this more clearly Table VI has been constructed. The total average work for each sex in the two groups was arbitrarily divided into eight equal parts. Then the per cent of average lifetime required to do these fractional parts was computed; also the average age in months equivalent to this per cent is given. For example, when the omnivorous male had done one-eighth of its total life's work it had lived 16.1% of its average lifetime, and had reached the average age of 4.5 months. This table shows that the males of each group turn off their work at a relatively earlier age than the females on the same diet. As an illustration, when the omnivorous male had done one-half its life work it had lived 36.4%

of its life, while the omnivorous female had lived 41% of its life when it had accomplished a similar part of its total work. A similar relation is seen to exist between the two sexes of the vegetarians. We also see that the same fractional part of total work is accomplished at an

Fractional part of total amount of life's work			$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
Omnivorous Exercised Rats	Males (3) ..	Percentage of life required to do work..	16.1	21.4	32.1	36.4	46.4	53.8	67.9
		Age in months required to do work..	4.5	6.	9.	10.2	13.	15.	18.
	Female (1) ..	Percentage of life required to do work..	19.1	26.1	32.3	41.	48.8	53.8	72.6
		Age in months required to do work..	6.5	8.9	11.1	13.8	16.6	19.9	24.7
Vegetarian Exercised Rats	Male (1) ...	Percentage of life required to do work..	10.	12.3	17.6	24.1	32.8	41.6	51.7
		Age in months required to do work..	2.3	2.8	4.	5.5	7.5	9.5	11.8
	Females (3)	Percentage of life required to do work..	15.9	22.5	31.9	42.5	49.	53.3	66.1
		Age in months required to do work..	2.7	3.8	5.4	7.2	8.3	9.1	11.2

TABLE VI.—Comparison of omnivorous and vegetarian rats as to the rate of doing their life's work.

earlier age in the males than in the females of the same class, with the exception of the last two items in the vegetarian group: here the male is very slightly surpassed by the female. This shows that the male ages earlier than the female. That is, when the male has begun to be inactive the female of the same age is still quite active.

We further see that the vegetarians do the bulk of their work at an earlier age than the omnivorous rats. That is, they become old, decrepit, lack energy and a desire to be active at an earlier age than is true in the case of the omnivorous rats. This is true both as to percentage of life lived and age in months. For example, when the omnivorous rats had done seven-eighths of their total work the males had lived 67.9% of their life and the females 72.6%, the two sexes averaging 70%. In the case of the vegetarians the males had lived 51.7% and the females 66.1%, or an average for the two sexes of 59%. We thus see that the vegetarians had still an average of 41% of their lives to live, during which time they did only one-eighth of their work. The omnivorous had an average of 30% to live to do the remaining one-eighth of their total work.



We have already shown that the ratio of total average work done by the omnivorous rats as compared to that of the vegetarians was about as 7.5 : 1. To make allowance for this, Table VII was constructed. This shows the percentage of lifetime of the omnivorous rats and their age in months which was required to do certain fractional parts of the total work of the vegetarians. That is, the two groups are considered in respect to their ability to perform the same amount of work. The data of the vegetarians is therefore the same in this table as in Table VI. From this we see that the average ages in months of the two classes correspond rather closely until three-eighths of their work was done. After this the ages rapidly differ. When the vegetarian male died it was 22.8 months old. The omnivorous male had accomplished the same amount of work when it was but 6.9 months old and had lived but 22.5% of its life. The female vegetarian died at the average age of 16.9 months. In contrast, the omnivorous female had done the same amount of work at the age of 5.6 months, which was equivalent to but 16.6% of its lifetime. Or the average total amount of work of both sexes of vegetarians was performed at the average age of 19.8 months,—that is, their average lifetime. Both sexes of the omnivorous feeders had done the same work at the average age of 6.2 months, which was but 20.9% of their lifetime.

Fractional part of total amount of life's work			1/8	1/4	3/8	1/2	5/8	3/4	7/8	8/8
Omnivorous Exercised Rats	Males (3) ..	Percentage of life required to do work..	9.8	13.8	14.6	15.7	18.3	20.5	22.5	25.2
		Age in months required to do work..	2.7	3.8	4.	4.3	5.	5.6	6.2	6.9
	Female (1) ..	Percentage of life required to do work..	8.2	10.5	10.9	12.7	13.6	14.7	15.7	16.6
		Age in months required to do work..	2.8	3.6	4.	4.3	4.6	5.	5.3	5.6
Vegetarian Exercised Rats	Male (1) ...	Percentage of life required to do work..	10.	12.3	17.6	24.1	32.8	41.6	51.7	100.
		Age in months required to do work..	2.3	2.8	4.	5.5	7.5	9.5	11.8	22.8
	Females (3)	Percentage of life required to do work..	15.9	22.5	31.9	42.5	49.	53.3	66.1	100.
		Age in months required to do work..	2.7	3.8	5.4	7.2	8.3	9.1	11.2	16.9

TABLE VII.—Showing percentage of whole lifetime of omnivorous rats required to accomplish the same work as that performed by the vegetarian rats during the whole of their lifetime.

We thus have the same amount of work done by the two classes. The vegetarians required 19.8 months, or the whole of their lifetime, while the omnivorous needed only 20.9% of their lifetime, and averaged 6.2 months of age. Thus the ratio of omnivorous to the vegetarians in regard to efficiency would be 100 : 20.9, or about 5 : 1. We must not lose sight of the fact that this difference in ability to do work is caused by the presence of animal food in one diet and the absence of it in the other, this being the only difference in the environment.

If a table were made comparing the amount of work done by each class at the same average age, the difference would be more marked than just shown. It is not considered necessary to construct such a table.

### GROWTH.

We have just considered what a marked effect on the efficiency of the rat these two diets had. Let us now consider the effect on growth.

The rats were weighed before feeding about once each two weeks. Weighings made approximately a month apart were selected in making Table VIII. This shows the individual weights of each of the sixteen rats at intervals of about a month during their entire lifetime. The young at the age of thirty days thus appear to be nearly uniform in size. The advantage is slightly in favor of the vegetarians, the males averaging 42 grams and the females 39 grams, while the omnivorous male averaged 41 grams and the female 38 grams. Twenty-eight days later, when the two groups were put on the omnivorous and vegetable diets, the sexes averaged approximately the same. Eleven days later a difference in the rate of growth is already noticed. This is more obvious in Table IX, which represents the averages of each sex in the different groups. As the rats became older this difference in weight was more and more noticeable, becoming greater as age advanced.

It was previously noted<sup>2</sup> that the control rats surpassed the exercised ones in weight. The same is observed here in both groups of rats. This is especially noticeable in the curves of Figure 13, which represent the data of Table IX. The heavy lines are the averages of the omnivorous rats, the light lines the vegetarians. The male in each case is decidedly heavier than the female of the same group. Also the control and exercised males excel both the control and exercised females of the omnivorous group. This relation does not exist in the vegetarian. The heaviest omnivorous female exceeds the heaviest vegetarian male by 9 grams and the heaviest vegetarian female by 36 grams. The maximum weight in each of these tables is shown in bold type.

		OMNIVOROUS EXERCISED RATS IN REVOLVING CAGES				VEGETARIAN EXERCISED RATS IN REVOLVING CAGES				OMNIVOROUS CONTROL RATS IN STATIONARY CAGES				VEGETARIAN CONTROL RATS IN STATIONARY CAGES			
Age		M	M	F	M	M	F	F	F	M	M	F	M	F	M	M	M
MO	DA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	30	42	43	37	39	36	42	40	36	34	45	39	45	37	47	42	42
2	11	79	89	76	68	72	67	76	64	84	100	84	92	78	96	89	86
3	5	107	123	107	99	92	81	90	81	146	157	124	141	102	121	111	111
4	5	132	143	123	128	101	86	98	89	183	200	140	178	109	137	124	132
5	3	145	165	136	145	112	94	107	95	214	225	154	205	125	151	136	143
6	3	170	170	141	169	124	102	113	102	241	249	165	242	134	160	152	158
7	4	179	195	152	185	131	100	116	103	265	262	178	265	137	164	160	166
8	13	201	219	158	205	143	110	129	115	282	283	161	292	145	184	180	173
9	13	206	218	161	222	136	108	128	116	288	289	180	298	155	185	196	187
10	11	215	245	163	221	142	108	127	115	291	301	184	308	156	181	204	186
11	9	217	248	161	226	143	109	123	116	296	304	200	315	157	182	205	187
12	13	226	247	159	230	125	100	118	120	308	322	199	309	155	163	199	182
13	2	232	265	170	238	124	97	126	126	310	331	135	319	164	..	209	190
14	3	234	259	168	246	141	..	107	119	291	295	*	296	151	..	196	172
15	1	231	254	164	240	138	..	100	119	291	295	..	294	155	..	188	154
16	17	242	272	168	252	140	..	..	125	286	300	..	298	156	..	185	130
17	1	249	268	176	257	138	..	..	132	289	298	..	304	156	..	177	107
18	4	252	270	165	258	145	..	..	122	302	310	..	313	161	..	168	..
18	22	245	269	159	261	134	..	..	115	297	293	..	310	152	..	162	..
20	24	240	244	153	249	133	..	..	111	290	282	..	291	159	..	117	..
21	15	245	262	161	250	134	..	..	109	290	284	..	290	160	..	..	..
22	12	244	270	163	254	119	..	..	103	295	280	..	294	159	..	..	..
23	7	235	261	159	242	96	..	..	84	288	270	..	292	147	..	..	..
24	10	235	269	163	248	..	..	..	..	292	283	..	294	148	..	..	..
25	6	214	271	155	233	..	..	..	..	290	283	..	284	133	..	..	..
26	18	..	259	148	215	..	..	..	..	278	272	..	297	102	..	..	..
27	18	..	252	154	..	..	..	..	..	287	275	..	294	..	..	..	..
28	7	..	256	139	..	..	..	..	..	284	278	..	294	..	..	..	..
29	7	..	251	147	..	..	..	..	..	293	270	..	302	..	..	..	..
30	15	..	263	157	..	..	..	..	..	288	268	..	300	..	..	..	..
31	7	..	264	163	..	..	..	..	..	288	263	..	304	..	..	..	..
32	5	..	206	151	..	..	..	..	..	279	269	..	302	..	..	..	..
32	20	..	..	145	..	..	..	..	..	271	258	..	285	..	..	..	..
33	9	..	..	159	..	..	..	..	..	264	252	..	280	..	..	..	..
33	26	..	..	128	..	..	..	..	..	259	251	..	277	..	..	..	..
34	26	..	..	..	..	..	..	..	..	264	249	..	280	..	..	..	..
35	9	..	..	..	..	..	..	..	..	247	225	..	268	..	..	..	..
36	2	..	..	..	..	..	..	..	..	..	242	..	277	..	..	..	..
37	10	..	..	..	..	..	..	..	..	..	229	..	269	..	..	..	..
37	25	..	..	..	..	..	..	..	..	..	227	..	259	..	..	..	..
38	18	..	..	..	..	..	..	..	..	..	226	..	238	..	..	..	..
39	6	..	..	..	..	..	..	..	..	..	225	..	230	..	..	..	..
40	6	..	..	..	..	..	..	..	..	..	220	..	225	..	..	..	..
40	24	..	..	..	..	..	..	..	..	..	210	..	203	..	..	..	..
41	11	..	..	..	..	..	..	..	..	..	203	..	..	..	..	..	..
44	16	..	..	..	..	..	..	..	..	..	185	..	..	..	..	..	..
45	12	..	..	..	..	..	..	..	..	..	170	..	..	..	..	..	..

TABLE VIII.—Showing rate of growth of the different groups of rats at the ages indicated. The bold figures indicate the maximum weights. Weights are in grams.

\* Was killed on account of sickness.

Age in Months	OMNIVOROUS EXERCISED RATS		VEGETARIAN EXERCISED RATS		OMNIVOROUS CONTROL RATS		VEGETARIAN CONTROL RATS	
	Male (Av. 3)	Female (Av. 1)	Male (Av. 1)	Female (Av. 3)	Male (Av. 3)	Female (Av. 1)	Male (Av. 3)	Female (Av. 1)
1.	41	37	36	39	41	39	44	37
2.4	79	76	72	69	92	84	90	78
3.2	110	107	92	84	148	124	114	102
4.2	134	123	101	91	187	140	131	109
5.1	152	136	112	99	215	154	143	125
6.1	170	141	124	106	244	165	157	134
7.1	186	152	131	106	264	178	163	137
8.4	208	158	143	117	286	161	179	145
9.4	215	161	136	118	292	180	189	155
10.4	227	163	142	117	300	184	190	156
11.3	230	161	143	117	305	200	191	157
12.1	234	159	125	113	313	199	181	155
13.1	245	170	124	116	320	135	187	164
14.1	246	168	141	108	294	*	177	151
15.	242	164	138	105	293	...	168	155
16.6	255	168	140	107	295	...	159	156
17.	258	176	138	110	297	...	149	156
18.1	260	165	145	106	308	...	146	161
18.7	258	159	134	104	300	...	144	152
20.8	244	153	133	103	288	...	129	159
21.5	252	161	134	102	288	...	...	160
22.4	256	163	119	100	290	...	...	159
23.2	246	159	96	94	283	...	...	147
24.3	251	163	...	...	290	...	...	148
25.2	239	155	...	...	286	...	...	133
26.6	228	148	...	...	282	...	...	102
27.6	227	154	...	...	285	...	...	...
28.2	228	139	...	...	285	...	...	...
29.2	227	147	...	...	288	...	...	...
30.5	230	157	...	...	285	...	...	...
31.2	231	163	...	...	285	...	...	...
32.2	212	151	...	...	283	...	...	...
32.7	...	145	...	...	271	...	...	...
33.3	...	159	...	...	265	...	...	...
33.9	...	128	...	...	262	...	...	...
34.9	...	...	...	...	264	...	...	...
35.3	...	...	...	...	247	...	...	...
36.1	...	...	...	...	255	...	...	...
37.3	...	...	...	...	248	...	...	...
37.8	...	...	...	...	244	...	...	...
38.6	...	...	...	...	237	...	...	...
39.2	...	...	...	...	234	...	...	...
40.2	...	...	...	...	231	...	...	...
40.8	...	...	...	...	220	...	...	...
41.4	...	...	...	...	218	...	...	...
44.5	...	...	...	...	212	...	...	...
45.4	...	...	...	...	207	...	...	...

TABLE IX.—Showing the average growth of the two sexes in the groups indicated. The maximum average weight is shown in bold type. The weights are in grams.

\*This rat was killed because of sickness.

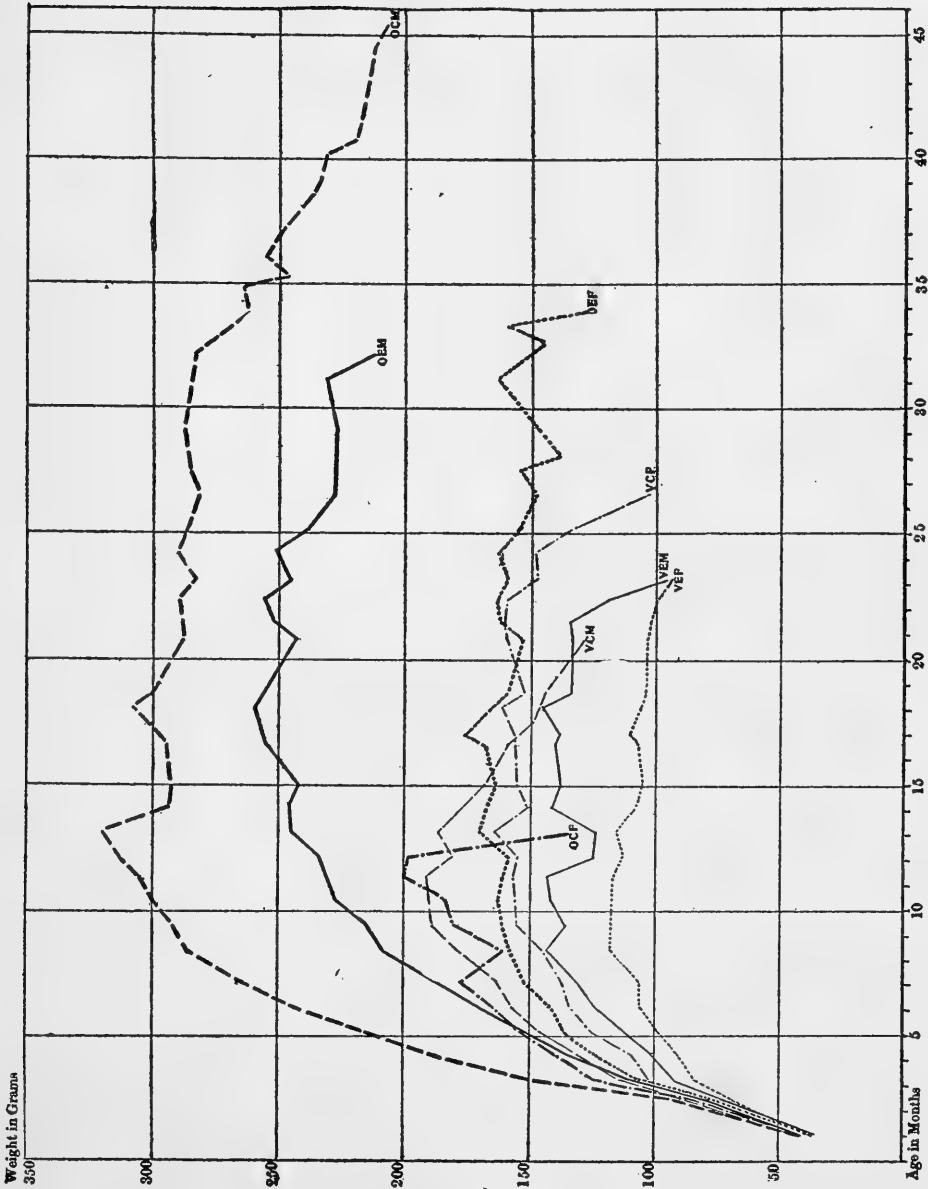


Fig. 13. Curves representing the average growth of each sex of the four groups of rats. The omnivorous feeders are all shown in heavy lines and the vegetarians in light lines. Lines of the same character refer to the same sex of similar groups. *OCM* and *VCM* refer to omnivorous and vegetarian control males; *OCF* and *VCF* represent omnivorous and vegetarian control females; *OEM* and *VEM*, omnivorous and vegetarian exercised males; *OEF* and *VEF*, omnivorous and vegetarian exercised females.

A glance at Tables VIII and IX shows that, with the exception of the exercised vegetarian female, the exercised rats reach their maximum weight at an older age than the control rats, regardless of the diet. In Table X these facts are in a more accessible form. It shows the individual weights and the age of each rat, and the average weights and ages of each sex in each group, at the beginning of the experiment, as the maximum weight, and at death. As already stated, the average weights of the young were about as uniform as could be gotten. When the maximum weights are considered a marked contrast is noted. In every case the average weight of each sex is decidedly in favor of the omnivorous rats.

Considering the exercised rats in regard to the maximum weights and weights at death, we find the following ratios:

	MAXIMUM WT.	AT DEATH
Omnivorous male to vegetarian male.....	1.8 : 1	2.2 : 1
Omnivorous females to vegetarian females	1.42 : 1	1.36 : 1

In regard to the control rats the following ratios were found:

	MAXIMUM WT.	AT DEATH
Omnivorous male to vegetarian male.....	1.64 : 1	1.9 : 1
Omnivorous female to vegetarian female..	1.22 : 1	.9 : 1

This last ratio is not reliable, as the control female had to be killed on account of sickness. There is no doubt had it been normal it would have reached a much heavier weight, since other omnivorous females did not reach their maximum weight until a much later age.

In regard to growth, we must conclude that the data is decidedly in favor of the omnivorous rats and against the vegetarians.

The appearance and attitude of the two groups is also in marked contrast. Figures 14, 15, 16 and 17 are photographs of eight of these rats, all being of the same age. Those on the left of each figure are omnivorous rats; those on the right are vegetarians. Figure 14 represents females. The other three figures are of males.

These photographs show the marked difference in appearance and attitude referred to above. The vegetarians were emaciated and skinny. Their back arched and more or less stiffened. The fur was harsh and ruffled, and the tail and nose inclined to be more or less covered with dry scale and sores. The attitude presented extreme lassitude and indifference. They remained in a crouched position most of the time, their legs appearing too weak to support their weight for only a short while. They lacked energy and would stay "put" when placed ready for photographing.

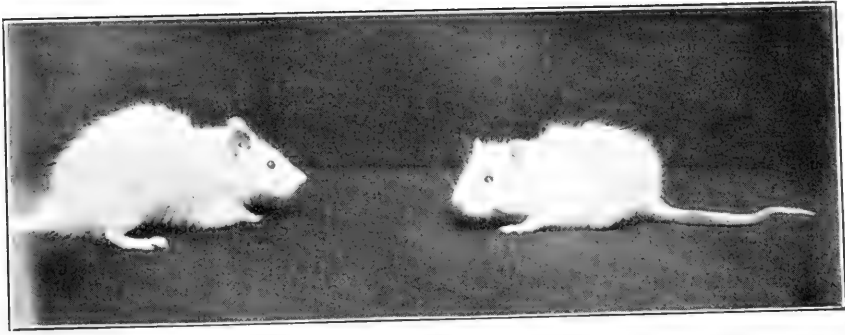


Fig. 14. Photographs of omnivorous female (left) and vegetarian female (right) at the age of 1 year 9 months 16 days. The omnivorous weighed 161 grams, the vegetarian 109 grams.

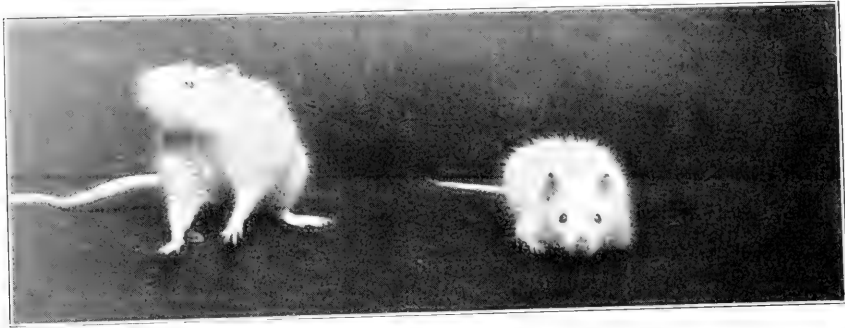


Fig. 15. Photographs of omnivorous male (left) and vegetarian male (right) at the age of 1 year 9 months 16 days. The omnivorous weighed 250 grams, the vegetarian 134 grams.

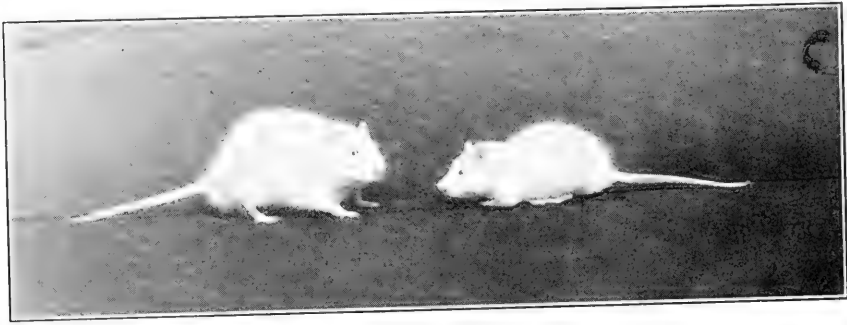


Fig. 16. Photographs of omnivorous male (left) and vegetarian male (right) at the age of 1 year 9 months 16 days.

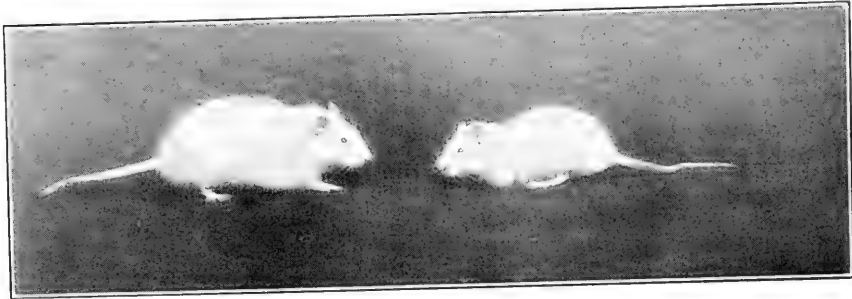


Fig. 17. Photographs of omnivorous male (left) and vegetarian male (right) at the age of 1 year 9 months 16 days.





The omnivorous were the reverse in all these respects. They were strong, well nourished and supple. Their fur was soft and well kept. Tail and nose were clean and smooth. They appeared full of vim and energy, it being difficult to keep them quiet long enough to photograph. The photographs, though showing a great difference, fail to show the marked contrast one would see in a few minutes' observation of the two groups. Such an observation would demonstrate the great difference in alertness and interest in surrounding objects, quickness and ease of movement in response to external stimuli, voluntary movement and vigor. The omnivorous appeared in the prime of life in all these respects, but in the case of the vegetarians these qualities were manifested as in extreme old age.

	Young						At Maximum Weight						At Death					
	No. Rat	Sex	Weight	Age in Days	Male Avg.	Female Avg.	Weight	Age in days	Male Av.		Fem. Av.		Age in days	Weight	Male Av.		Fem. Av.	
									Weight	Age in Days	Weight	Age in Days			Weight	Age in Days	Weight	Age in Days
Omnivorous Exercised Rats.....	1	M	42	30	..	..	252	544	...	...	...	214	746	...	...	...	...	
	2	M	43	30	41	..	272	497	262	534	...	206	925	212	819	...	...	
	3	F	37	29	..	37	176	509	...	...	176	509	128	1014	...	...	128	1014
	4	M	39	29	..	..	261	560	...	...	...	215	785	...	...	...	...	
Vegetarian Exercised Rats.....	5	M	36	30	36	..	145	544	145	544	...	96	685	96	685	...	...	
	6	F	42	30	..	..	110	253	...	...	...	97	381	...	...	...	...	
	7	F	40	29	..	39	129	251	...	...	124	338	100	463	...	...	94	508
	8	F	36	29	..	..	132	509	...	...	...	84	682	...	...	...	...	
Omnivorous Control Rats.....	9	M	34	30	..	..	310	392	...	...	...	247	1074	...	...	...	...	
	10	M	45	30	41	..	331	392	320	391	...	165	1361	241	1222	...	...	
	11	F	39	29	..	39	200	337	...	...	200	337	135	360†	...	...	135	360
	12	M	45	29	..	..	319	390	...	...	...	172	1232	...	...	...	...	
Vegetarian Control Rats.....	13	F	37	30	..	37	164	392	...	...	164	392	150	778	...	...	150	778
	14	M	47	30	..	..	185	283	...	...	...	163	373	...	...	...	...	
	15	M	42	29	44	..	209	390	195	342	...	117	578	129	484	...	...	
	16	M	42	29	..	..	191	353	...	...	...	107	500	...	...	...	...	

TABLE X.—Showing the difference between the omnivorous and vegetarian rats in regard to the age and weight at the beginning of the experiment, the prime of life, and the death of each individual.

\* This weight was taken 14 days before death and is therefore heavier than it should be.

† This rat was killed because of sickness.

## LENGTH OF LIFE.

The various tables and curves so far given show in a general way the comparative length of life of these two groups of animals. A more detailed comparison will be necessary.

In Table X the age of the death of each rat is given, also the average age of each sex comprising the various groups. When the same sex is compared it is noticed that the omnivorous feeders surpass the vegetarians in longevity by a good margin. The only exception was No. 11, which should not be used in these comparisons as it was killed on account of sickness. When the averages are compared the contrast

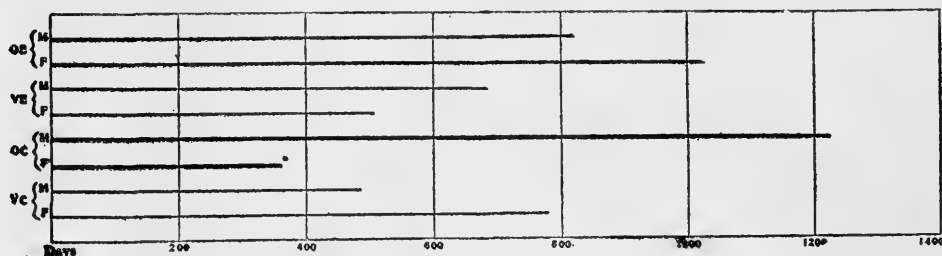


Fig. 18. Diagram representing the average age of each sex of the four groups. *OE* omnivorous exercised; *VE*, vegetarian exercised; *OC*, omnivorous controls; *VC*, vegetarian controls. *M* and *F* refer to male and female.

is still more pronounced. These averages are put in diagrammatic form in Figure 18. The horizontal lines represent the average age at death of each sex in the different divisions.

*OE*, *VE*, *OC* and *VC* refer to omnivorous exercised, vegetarian exercised, omnivorous control, and the vegetarian rats, respectively. The relatively short duration of life of the vegetarians is very conspicuous.

If the average lifetime of all the omnivorous males is compared with the average of all the vegetarian males, we find a ratio of 1020 days to 534 days; or 1.91 : 1. When the females are similarly com-

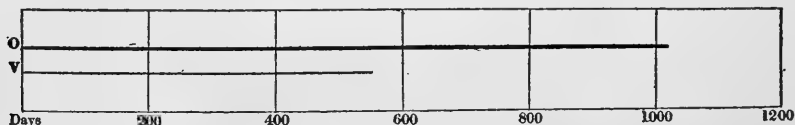


Fig. 19. Diagram showing the average lifetime of all the omnivorous rats (*O*) and all the vegetarians (*V*).

\*This rat was killed at this age because of illness.

pared the omnivorous averaged 1014 days, and the vegetarian 574 days, or a ratio of 1.77 : 1. If the average of all the omnivorous, including both sexes, is compared with the average of all vegetarian rats we have the relation of 1020 days to 555 days, or a ratio of 1.84 : 1.

Figure 19 shows in graphic form the total average lifetime of the omnivorous rats (O) and of the vegetarians (V). The first group lived almost twice as long as the last. This is a decided difference. When we recall that all these animals were of the same age and as nearly as possible the same parentage, were subjected to similar environment, and fed exactly the same food, with the exception that the omnivorous group received animal food in addition about three times a week, we must conclude that this great difference is due to the presence of this animal food and to nothing else.

#### GENERAL APPLICATIONS AND COMPARISONS.

Any attempt to make a practical application of these results to man, will no doubt be severely criticised by some on the ground that what is true of the albino rat would not hold true in man, owing to the wide difference in zoological position. Such a criticism would be based on the prevalent idea that man is a supreme being, occupying a place above animals, and with which he is not to be compared.

The rat is by nature an omnivorous animal. All evidence points to the fact that man is by nature an omnivorous animal. The character of the teeth and the digestive tract throughout are best adapted to a mixed diet. His nearest related kin in the animal kingdom—the anthropoid apes—are all omnivorous feeders. In his savage state he partakes of the food most accessible, which includes animal food whenever it is possible to secure it. There is probably no animal as capable of adapting itself to so great changes in environment and in diet as man. But though he is able to adapt himself to a restricted diet, is such a diet capable of developing and maintaining his maximum mental and physical energy for a long period of life? It is not a question of what food will keep the animal alive, but what diet will make it the most efficient machine. It is not so much a problem of determining what foods are necessary to maintain nitrogenous equilibrium in man, as it is of ascertaining what diet is necessary not only to prolong mental and physical efficiency during a long period of life, but to produce initiative in these respects.

The rats fed on the mixed diet had by far the greater initiative and

ability for muscular work. The mental ability was not tested, but one would judge from their appearance and alertness that they would far surpass the vegetarians in this respect.

A perusal of the literature of this subject convinces one of the fact that the results of the experiments on the rat can be applied to other animals, including man.

Jaffa,<sup>6</sup> in his investigations on a family of fruitarians, says that the youngest child which had lived from infancy on nuts and fruit "was certainly undeveloped. Her bones were very small, although she had no tendency toward rhachitis. She looked fully two years younger than she was." The diet was not satisfying and the craving for other foods was occasionally satisfied by eating them. All the family were below size.

Chittenden<sup>7</sup> fed dogs on vegetable foods and animal fat with disastrous result. In referring to this he says: "This is by no means an exceptional case, but we can cite many examples of like results where the animals when restricted to a purely vegetable diet, such as bread, pea-soup, bean-soup, etc., re-enforced by an animal fat, quickly passed from a condition of health into a state of utter wretchedness, with serious gastro-intestinal disturbance."

Caspari,<sup>8</sup> in studying the effect of a vegetarian diet on man, found that he could not maintain his body weight, but lost 13 K during the experiment. Milk and butter had to be added. In another person he found that he could maintain his weight on a vegetable diet. He was, however, very thin, and the amount of protein in the faeces was large. These experiments lasted for only a short time.

Langworthy,<sup>9</sup> in discussing food and diet in the United States, says: "In general, the food habits of the human race today are an expression of the thousands of years of experience in which man has sought to bring himself into harmony with his environment, and food habits have been determined, as regards materials selected, by available supplies, man being by nature omnivorous." Man likes variety. People of the United States are well nourished compared with other races. He further says: "The acknowledged energy and achievements of the American people, together with their general good health and physical well-being, certainly indicate that we have in the main used our food resources advantageously."

In regard to the digestibility of animal and vegetable foods, we find investigators pretty closely agreeing in their results. Albu,<sup>10</sup> in metabolism experiments on a vegetarian, found that only 67% of the protein and 65% of the fat of this food was digested. Snyder,<sup>11</sup> in

discussing the comparative digestibility of animal and vegetable protein, says that 95% of the former and 85% of the latter are digested. Benedict,<sup>12</sup> in comparing the digestibility of animal proteins and fats, found that 97% of animal protein is digested and 84% of vegetable protein. In a mixed diet he found that 92% of the protein was digested. In regard to fats he found that 95% of animal fat was absorbed and a less amount of vegetable fat. Many other investigators have found that vegetable protein is not used by the body to the same extent as animal protein.<sup>13 14</sup>

In regard to the effect of diet upon activity, Thompson,<sup>15</sup> in his studies on dietetics, says: "Meat in general has a more stimulating effect upon the system and is more strengthening than vegetable food, and it gives rise to the sensations of energy and activity." A person<sup>16</sup> who changed from a mixed diet to a vegetable one, in describing the effect says: "I, too, felt chilled and sleepy by day and night, so tired that I could hardly walk." This describes the general appearance of the vegetarian rats very closely. Nitti,<sup>17</sup> in accounting for the greater efficiency of the Italians in the United States than in Italy, attributes it to the fact that their diet here is richer in protein; containing a greater proportion of meat.

In regard to the amount of protein required, most of the results again are in close accord.

Caspari<sup>18</sup> concludes that the minimum amount of protein required varies with different individuals, and may also vary in the same individual within wide limits. This is shown in the dietary study<sup>19</sup> of Sandow, the "Strong Man," who consumed 244 grams of protein each day. This is far above the average.

Chittenden (7) has demonstrated that man can maintain his nitrogenous equilibrium on a diet containing far less protein than the average diet. He has not, however, carried this far enough to determine what effect such a diet would have on the life of the individual or the race.

Shutt<sup>20</sup> found that in hogs fed on a low protein diet—corn only—the meat was inferior and soft. When additional protein was added in the form of milk, the meat was greatly improved. He also states that hogs fed on too high a protein diet had inferior meat. These results were confirmed by Skinner.<sup>21</sup> He adds that hogs fed on corn meal have "poor appetite, light bone, deficient development in valuable portions of the carcasses, and a general state of unthrift, as shown by the hair, skin, and hungry look of the animal." When one-sixth of the amount of normal ration rich in protein was added the hogs had normal growth and were in healthy condition.

Haecker<sup>22</sup> experimented on two groups of cows, the first group having a normal amount of protein and the second group a low amount. No difference was noticed at the end of the second year, except that the second group weighed less. Soon after this time the second group began to decline. They grew thin, hair became harsh, and their condition became generally poor, showing under-nutrition. The amount of protein had to be increased in order to preserve their lives. Here we see that this group did well for two years before any serious effects were manifested. A similar result was found in the rats experimented upon. The rats first showed a difference in weight. Later at the age of three or four months changes in the activity and general condition began to appear. One is not warranted, therefore, in drawing sweeping conclusions of the effects of certain diets on any animal from a few weeks' or months' experimentation.

McCay<sup>23</sup> studied the effect of the native diet, low in nitrogen and rich in non-nitrogenous foods, on the physical condition, the health and the efficiency of the Bengalis, compared to European diet and Europeans in the University of Bengal. From the data of body weight, height and chest measurement of 2,500 Bengali students he concludes that the Bengalis "do not reach the same standard of general physique as is attained by races of European origin; and yet from the evidence we can find no cause inherent in the Bengali as a race for this deficiency; on the contrary, we consider that there may be a very close relationship between the lower physical development of this people and the meager protein contents of the diet on which they subsist." In comparing growth of the Bengali and European students he says: "The two classes enter college about the same age, live in the same climate and under very similar conditions . . . but the results at the end of their college career are very different. The European boys develop into strong, healthy men quite up to the average of European standards, while the Bengali students almost remain stationary as regards development." He finds that the Europeans are much more capable of endurance.

Watson and Hunter<sup>5</sup> have shown that when young rats are fed on a diet of rice the growth is arrested and death results in two or three months. When fed on a porridge diet made by boiling together oatmeal, milk, water and salt the growth was arrested and death resulted within four months. They were evidently not able to assimilate this food even though it was reasonably rich in protein. When fed a strictly flesh diet the results were disastrous in most cases when the rats were very young. When rats two or three months old were put on an

exclusively ox-flesh diet the result was favorable, growth being promoted, the animals reaching a larger size than the normal control rats.

In regard to races of men it is interesting to note that those whose stature is large partake freely of meat, while those of small physique live largely on a vegetable diet.

Oshima<sup>25</sup> says in regard to the Japanese: "Among the ordinary families in the rural district the use of meat is (of necessity) restricted chiefly to festive occasions; and among the poorer peasantry even rice is used at such times." He further says that the poorer classes of cities and country, comprising about 75% of the total population, are vegetarians from force of financial circumstances rather than from principle. They eat animal food whenever they can get it. This usually consists of fish two or three times a month, and meat two or three times a year.

Boas<sup>26</sup> found that the North American Indians living on the mountains are smaller than those living on the plains. He attributes this to greater abundance of rich food on the plains.

Sill,<sup>27</sup> in his study of malnutrition of the school children in New York City, found that out of 210 cases, 83% practically depended on vegetable food, consisting largely of bread, tea and coffee.

Albertoni and Rossi<sup>28</sup> found that when meat was added to the diet of the peasants of the Abruzzi region, who had been almost exclusively vegetarians for generations, there was an increase in power of assimilation, in body weight, and in physical power.

Houssay,<sup>29</sup> in his experiments on chickens fed exclusively on animal and vegetable rations, found that the chickens fed on animal food grew much faster than those fed on vegetable rations. This corresponds closely to my experiments on the rats.

These results correspond closely with those of Bolté.<sup>30</sup> He fed chickens on a number of rations, and concludes: "In the absence of skim milk to mix with the grain, some other animal concentrate should be supplied. A ration containing 10% of animal meal gave a much greater gain than rations containing either no animal meal or 20% animal meal. The cost of feed per pound of gain was lessened one-third under the same condition.

In regard to therapeutics, diet has a great value.

Rubner,<sup>31</sup> in his studies on the diet of the poor who have lived largely or wholly on vegetables, concludes that this diet is the cause of lack of physical condition and ability for work; that it causes an increase in morbidity and mortality by lowering the ability to resist epidemic diseases.

In the treatment of tuberculosis it has been found<sup>32</sup> that food with a rich protein content is of great value.

McCay<sup>23</sup> finds that kidney disease is much more prevalent in native inhabitants of Bengal than in Europeans who live there. He attributes this to their diet, which is low in protein.

Thompson,<sup>15</sup> in regard to power of vegetarians to resist disease, says: "In regard to an exclusive or almost exclusive vegetable diet for man, the universal experience has been that while it may keep him in apparent health for some time, it eventually results in a loss of strength and general resisting power against disease, which becomes evident after some months, if not before . . . . Animal food in some form must be regarded as absolutely essential for all vigorous races."

It is claimed that vegetarians convalesce more slowly after a period of illness.<sup>33</sup> That animal food makes blood richer in red corpuscles and gives firmness to muscle without excess of fat.<sup>34</sup>

In 1883, when the diet consisted largely of rice, 33% of the Japanese marines had beri beri. In 1884 meat and bread were added to the rations, and now they hardly have three cases a year.<sup>7</sup>

When the effects of a restricted diet and of various diets upon the resistance of animals to certain poisons are considered, Hunt<sup>24</sup> has found that "diet has a marked effect upon the resistance of animals to certain poisons; the resistance of some animals may be increased forty-fold by changes in diet. (Certain diets, notably dextrose, oatmeal, liver and kidneys, greatly increase the resistance of mice to acetonitril; their effect is similar in this respect to the administration of thyroid. The experiments show that foods such as enter largely into the daily diet of man have most pronounced effects upon the resistance of animals to several poisons. They produce changes in metabolism which are not readily detectable by methods ordinarily used in metabolism studies. The ease and rapidity with which certain changes in function are caused by diet are in striking contrast with the essentially negative results obtained by the chemical analyses of animals fed upon different diets."

Hutchison<sup>33</sup> claims that intellectual capacity and bodily energy are dependent on a mixed diet, and that "it is not without reason that the more energetic races of the world have been meat eaters."

A study of the dietaries of the various races of the world confirms this. Wherever we find advancement in civilization, great achievements in the arts and sciences, maximum mental and physical ability, thrift and success, we find that animal food has formed a prominent portion of the diet.

The numerous observations and experiments on man and other animals in regard to the effects of an exclusive vegetable diet, as com-



pared to a mixed diet, upon the general condition of the animal, all agree. They show that the vegetable diet produces far inferior results in almost every respect. Man does more work on a mixed diet than he did on a vegetable diet or almost exclusive vegetable diet. Man attains a greater stature on a mixed diet rich in protein than on vegetable food. Man has made more advancement and achieved more intellectually and physically on a mixed diet than on a vegetable one. He is able to maintain his body weight and physical well-being best on a mixed diet.

The results of the experiments on the albino rats correspond so closely with those on man and other animals that one is almost justified in concluding that if man were subjected to the same conditions of food for his lifetime the results in regard to voluntary activity, growth and longevity would be the same.

### CONCLUSIONS.

When two groups of young rats of the same age and as nearly as possible the same parentage are subjected to the same environment and conditions, with the exception that one group has a vegetable diet and the other has the same vegetable diet plus animal food, the following results were obtained:

1. The omnivorous feeders are much more active and voluntarily do much more work during their lifetime than the vegetarians. The average ratio of efficiency is 7.5 : 1.
2. The females surpass the males of the same group in activity. This difference is greater in the omnivorous than in the vegetarian rats.
3. This difference did not become very noticeable until the experiment had proceeded two or three months; or until about one-fifth of the total life of the vegetarians had been lived. One cannot conclude, therefore, that a diet used for a few weeks is not injurious if no bad results occur during that time.
4. The total work accomplished by the vegetarians during their life was performed by the omnivorous rats when but 20.9% of their lives had been lived.
5. The vegetarian rats age much earlier in life, it requiring almost half their lifetime to perform the last one-eighth of their life's work, as compared to three-tenths for the omnivorous rats.
6. The growth of the vegetarians was greatly retarded. The ratio of maximum weights was as 1.62 : 1 in favor of the omnivorous feeders.

7. The effect on general conditions of the body was most overwhelmingly in favor of the omnivorous. The vegetarians were frail, weak, and showed extreme lassitude and indifference. The omnivorous were the reverse in all these respects.

8. The average life of the omnivorous was 1020 days, that of the vegetarian 555 days. This was a ratio of 1.84 : 1.

9. The control rats in stationary cages lived longer than the exercised rats of the same group.

10. All of the omnivorous rats surpassed the greatest age attained by the oldest vegetarian rats.

11. From numerous observations and experiments of other investigators on man we would infer that similar results would obtain if he were subjected to similar conditions throughout his lifetime.

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