

A STUDY OF THE SPONTANEOUS ACTIVITY OF THE GUINEA PIG¹

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INTRODUCTION

In the past decade various investigators have studied spontaneous activity in vertebrates in the hope of throwing some light on the fundamental problem of the relation between metabolism, activity, rest and fatigue in these animals. The following paper deals with a study of this problem in the case of the guinea pig.

It is generally believed among laboratory workers that guinea pigs are very quiet animals. They will sit quietly in a corner of the cage for many hours when anyone is near them. This inactivity is apparently due to an inhibition from fear. If guinea pigs are placed in a quiet environment under normal conditions of temperature, humidity, and illumination they are found to be almost continually active. This condition so far as is known is unique among mammals. In the following paper we describe how, by means of activity-recording cages, continuous records extending over several months have been obtained which show the activity of the guinea pig to be organized on an entirely different plan from that of other rodents such as rats and mice, and, indeed, of other mammals. Periodic alternations of complete rest and activity are conspicuously absent. Continuous and intermittent

¹ This paper was presented as partial fulfillment of the requirements for the degree of Doctor of Science in Hygiene, School of Hygiene and Public Health, Johns Hopkins University. The work was carried out in Dr. W. H. Howell's laboratory in the Department of Physiology under the direction of Dr. Reynold A. Spaeth. I am indebted to Dr. Howell for numerous helpful suggestions and to Dr. Spaeth for constant supervision and criticism. In the observation experiment I was assisted by Dr. and Mrs. R. A. Spaeth and Miss Jean C. Snyder to whom I gladly acknowledge my indebtedness.

activity periods are present in the records but there are no indications of protracted intervals of sleep, which are familiar phenomena with rats, mice and other mammals. There is likewise an absence of both diurnal and nocturnal rhythm.

Studies have been made of the influence of changed environmental conditions and the relation of forced activity to food and rest.

The activity of the guinea pig and the rat has also been compared under identical conditions. In its activity the guinea pig is physiologically most nearly comparable to the vertebrate heart. By combining a high rate of metabolism with a scattered distribution of short rest periods, long rest periods and possibly sleep also, become superfluous. We are not prepared to say that the guinea pig never sleeps. Our records show however that if the guinea pig does sleep it is either (1) for very short periods or (2) combined with an activity that approaches somnambulism.

Previous experimental studies of mammalian activity

Studies of spontaneous activity and rest have hitherto been largely limited to the invertebrates or lower vertebrates. Surprisingly little work has been done upon mammals.

Slonaker (1907) studied the spontaneous activity of white rats in revolving cages and found that the amount of activity varied with age. He found that the age of greatest activity as represented by the number of revolutions of revolving cages ranges from 87 to 120 days. The rat spends much more time in rest than in activity and is more active at night.

The most extensive studies have been made by Szymanski (1920). He found the white, gray and dancing mouse spent about half their time in activity and half in quiet, the time of activity ranging from 10 to 14 hours. The dancing mouse showed one long activity period of 10 hours and seven very short periods alternating with periods of quiet. The white mouse had sixteen short periods of activity alternating with periods of quiet and the gray mouse twenty-three activity periods of even shorter duration during the twenty-four hours.

The white rat showed 10 hours of activity broken into ten short periods. The rabbit showed 12 hours of activity divided into twenty-one short periods and twelve of quiet similarly divided. The cat had only 4.5 hours of activity divided into seven different periods and the dog 6.75 hours divided into thirteen periods. The young infant showed 10 hours of activity and 14 hours of quiet. In all of these animals, with the exception of the dancing mouse, there is little difference in the amount of activity during the twelve hours of the day as compared with the twelve hours of the night.

Richter (1921) found that the white rat showed four to ten activity periods during the twenty-four hours and was most active during the night. He also found that the amount of activity decreased with age.

No studies have so far been made of the amount of activity and quiet of the guinea pig. Allen (1904) states that the guinea pig seems to be more active in the dark, than in the light, but she made no experimental study. The general impression among animal experimenters seems to be that in the laboratory, guinea pigs are unusually quiet animals. It is interesting to note, however, that guinea pigs apparently never assume a characteristic sleeping pose like that of a dog or rat or mouse, and that thus far we have failed to find anyone who recalls having seen a guinea pig sleeping.

APPARATUS

The apparatus used to determine the amount of activity of the guinea pig was similar to the one used by Richter (1921) in his work on the activity of the rat (fig. 1). It consisted of an equilateral triangular cage 25 inches on each side. The bottom was made of plaster board reinforced on each side with narrow strips of wood. The sides were made of 14 mesh mosquito netting, 8 inches high. Each cage weighed about 2 pounds. This cage rested upon the points of three large screws 1 inch in length. The screws had their heads soldered to small metal discs about an inch in diameter (fig. 1, *D*). These discs rested

upon rubber membranes (*M*) which were stretched over the top of specially constructed brass cups (*C*). These cups were 1.25 inches deep and 2.12 inches in diameter and at the center of the bottom a metal nipple (*N*) 1.25 inches long was inserted. Holes were bored in the table on which the apparatus was assembled and the metal nipples projected through these holes. The cups then rested upon the table. The rubber tubing from the three metal cup nipples was brought together by means of a glass four-way connection. A long piece of tubing joined the four-way

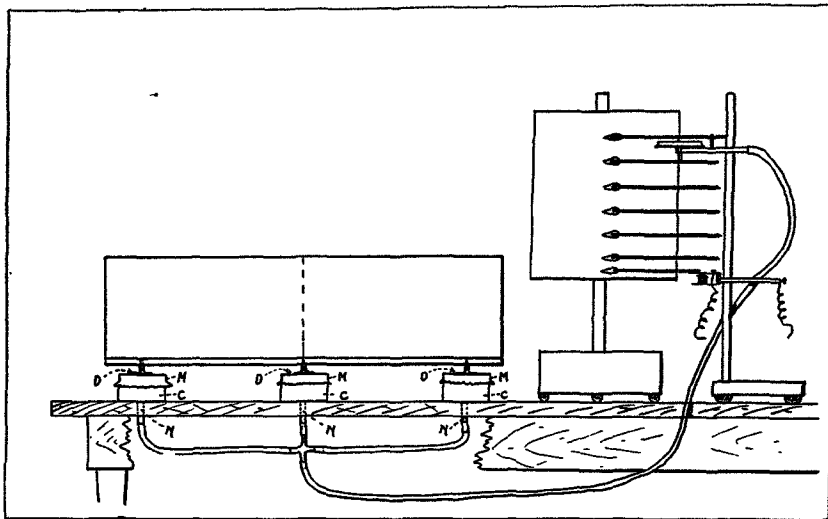


FIG. 1. DIAGRAM OF THE SCHEME OF THE APPARATUS USED IN THE ACTIVITY RECORDING EXPERIMENTS. SEE TEXT FOR DETAILS

connection to a Harvard tambour writing-lever. Any movement of the cage was transmitted by air pressure through the cups to the tambour and then to the kymograph via the writing lever. The cages were made as light as possible so as to rest easily upon the rubber membranes and to increase their sensitivity. Respiratory movements were not recorded but all such muscular movements as quiet eating, scratching, etc. were recorded. The records were taken on a long-paper kymograph.

All activity experiments were carried on in a brick vault 20.3 feet long and 7.51 feet wide which was 15 feet below the surface

of the ground. This vault in the former Physics Laboratory of Johns Hopkins University was especially constructed by Dr. Rowland for his dividing engine. It was designed to maintain a constant temperature and humidity and to be free from all vibrations. All these variables had to be kept constant in the present experiments and thus the vault offered ideal conditions. A further advantage was the absence of noise. The temperature in the dark was 19.5°C. and never varied more than one degree in either direction. When the room was lighted by two 75 watt nitrogen daylight bulbs the temperature rose about two degrees and then remained constant. The relative humidity in the dark was 42 per cent and in the light 44 per cent as measured by the sling psychrometer. No one was allowed to enter the room except the experimenter, and then only long enough to feed the animals and change the paper on the kymograph.

MATERIAL

All the guinea pigs used in these experiments were of healthy stock and varied in size from 200 grams to 300 grams. They were all of the common short-haired variety. In all experiments when a group of animals was used, half were males and half were females. The guinea pigs were kept in the vault for at least a week before they were used in any experiment so as to become accustomed to the new environment. To guard against the possibility of stimulating activity by the slight movement of the recording-cage floor the pigs were kept during this preliminary stage in a special cage set on springs. The movements of this cage closely simulated those of the recording-cage. The food consisted of oats and water which the animals had in their cages all of the time and three times a week they were given cabbage and carrots. The bedding consisted of 1 or 2 inches of cut hay. The guinea pigs that were being used during an experiment were kept in the vault all of the time even when no record was being taken of their activity. The vault apparently offered a splendid environment for the growth and development of the guinea pig. The growth curve of the animals used followed closely the growth

curve for guinea pigs as plotted by Minot (1891). It was found that if guinea pigs were taken upstairs into the animal room, after being in the vault for some time, they soon lost weight, became ill and frequently died.

The guinea pigs were handled constantly and became very tame. After a week or ten days they would not be frightened by the experimenter's entering the vault and instead of remaining quiet they would run about their cages squealing noisily. There were no deaths in the vault.

ACTIVITY OF THE GUINEA PIG

Activity in the dark

As it is generally believed that the guinea pig is most at home and most active in the dark, the first set of experiments, which endeavored to put the guinea pig in his most natural environment, was carried on in the dark.

Six healthy guinea pigs, three males and three females, whose weight ranged from 182 to 316 grams, were chosen for the experiment. They were taken into the vault and each was put into a separate recording-cage. They were given cut hay for bedding and oats and water. They were kept in their respective cages for three days before any records were taken of their activity so as to become accustomed to their new surroundings. The light was turned on for about fifteen minutes each morning during feed-time, but otherwise the room was in total darkness. There were no cracks where light could enter as the room opened by a tight fitting door into a larger room which was also dark. The doors both at the top and bottom of the steps which led into the vault were kept shut. There was therefore no possible way for any daylight to enter the rooms.

The experiment was started at nine o'clock in the morning and was continued for a week, every movement of the six guinea pigs being recorded throughout this period. A single kymograph sheet contained the activity of the six guinea pigs for twenty-four hours. The activity of each guinea pig was recorded, one directly under the other, with a time line at the bottom marking each

hour. Thus in a week seven separate records were obtained, each showing the activity of six guinea pigs for a period of twenty-four hours. Three separate weeks' records in the dark were made in all. One was made in the spring, one the following fall, and one a few weeks later in the fall.

In all the records there was the same general picture. The guinea pigs showed almost continuous activity (fig. 2). The activity was divided into two phases; (1) periods of "continuous" activity in which there were no rest or quiet periods and (2)

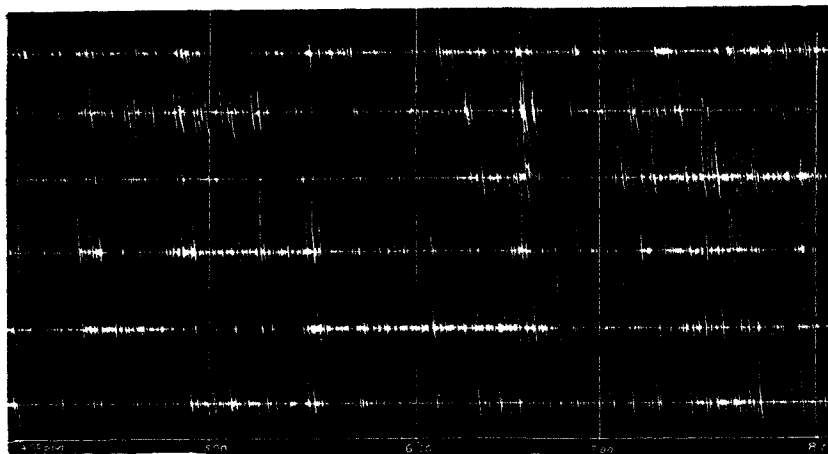


FIG. 2. THE ACTIVITY OF SIX GUINEA PIGS IN THE DARK

periods of "intermittent" activity in which there were a number of quiet periods varying in length from a fraction of a minute to ten minutes. There were no long rest periods whatsoever in any of the records. The periods of continuous activity varied in length from five minutes to several hours. These periods alternated with the periods of intermittent activity and were always considerably longer than the latter. There was a tendency for the six guinea pigs to be continuously active at the same time. This point will be discussed later in the paper. During continuous activity the movements were more violent than in the periods of intermittent activity.

Besides a careful study of the records, it was thought advisable to devise a method by which to obtain a numerical criterion of the actual amount of activity shown by each guinea pig. In this way the amount of activity of the six guinea pigs could be compared with each other on the same and on different days. The activity of one guinea pig could also be compared on the seven different days. We hoped to obtain a numerical figure which represented the approximate amount of activity of a guinea pig in the dark for twenty-four hours.

The method finally decided upon was to measure all activity periods which contained no quiet periods of 2.5 minutes ($\frac{1}{2}$ inch) or more in length. This was done by means of a small map measurer. The instrument was set at zero, placed at the beginning of an activity period, and run along until it came to a quiet period an eighth of an inch or more in length. The instrument was then carefully lifted from the paper and put down again on the other side of this quiet period and run along until another quiet period $\frac{1}{2}$ inch or more in length appeared in the record. The total amount of activity in feet and inches was then recorded. Only twenty-three hours were measured, the hour between nine and ten in the morning not being counted. During this hour each day the paper was changed on the kymograph and there was a loss of time varying from five minutes to half an hour. The guinea pigs were continuously active at this hour, partly because they were fed, but also because of the disturbances of the light and the presence of the experimenter. Conditions thus being not comparable with the other hours of the day, it was thought best to eliminate this hour.

The total length of paper which represented the twenty-three hours was measured from the time line, and the number of inches of paper which represented one hour was determined by dividing the total length by twenty-three. The total number of inches of activity was then divided by the length which represented one hour and the amount of activity in time was determined. The results were tabulated in chronological order and the averages obtained. By practice a fair amount of accuracy was obtained

in measuring the amount of activity and the error did not vary more than plus or minus three per cent of the distance measured.

This method demonstrated the extreme activity of guinea pigs in the dark. Out of the 23 hours, the smallest amount of activity for any one animal was 17.5 hours and the largest amount 23 hours. The averages for individual records of the six guinea pigs for seven days varied from 19.69 hours to 21.73 hours out of the 23, and the average total activity for all six guinea pigs in the dark was 20.8 hours out of the 23, or at the rate of 21.6 hours out of the 24. The absolute activity for 24 hours was actually greater than the calculated 21.6 hours, since during the anticipatory excitement of feeding the animals were in continuous motion. The small amount of rest was broken up into numerous short periods averaging 3 to 4 minutes in length. The longest rest period on any record was 10 minutes.

The quiet periods of less than $\frac{1}{8}$ inch were measured with the total amount of activity for two reasons. First, in measuring the length of the activity periods it was impossible to leave out the quiet periods of less than one-eighth of an inch without introducing a considerable error. The measuring instrument had to be lifted from the paper a great many more times and this factor increased the possibility of error in the total length. Secondly, the quiet periods of less than $\frac{1}{8}$ inch are approximately $\frac{1}{8}$ to $\frac{1}{16}$ of an inch in length which represents but 0.6 to 1.2 minutes in time. It was found by observation that slight movements such as quietly chewing were not recorded by the levers and these might account for some of the periods. The guinea pig is also extremely sensitive to sounds even those caused by the gnawing or scratching of other guinea pigs. Whatever the cause of these momentary quiet periods they are more or less constant in all of the records and as all the records are measured in the same way they can be compared with each other without introducing an error.

Activity in the light

The next set of experiments was carried out under exactly the same conditions as those in the previous experiment with two

exceptions. The room in this case was constantly lighted by two 75-watt nitrogen daylight bulbs which were suspended directly over the cages. These lights raised the temperature about 2°. This small increase in temperature probably failed to affect the activity records in any significant way (vide infra table 4 and fig. 6). The same set of guinea pigs was used as in the above experiment. They were left in their separate cages for three days, so as to become accustomed to the light before any records were taken.

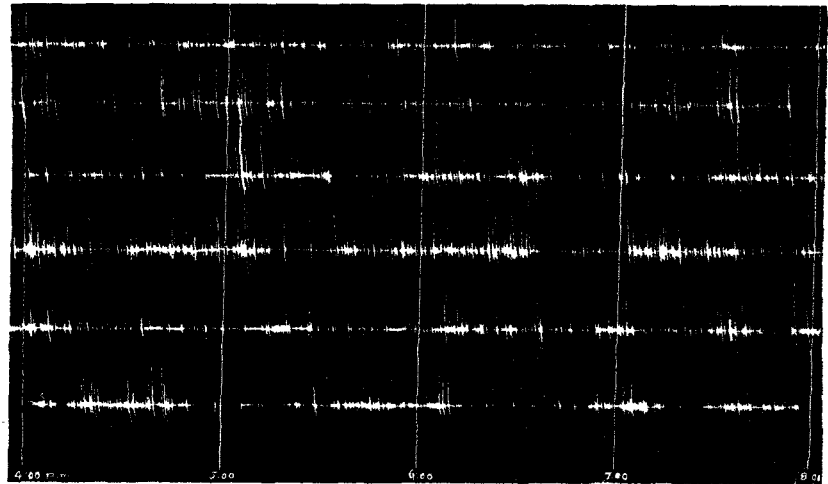


FIG. 3. THE ACTIVITY OF SIX GUINEA PIGS IN THE LIGHT

In this case the pigs are the same as those shown in figure 2

The experiment was started at nine o'clock in the morning and was continued for a week. Two sets of records in the light were taken about two months apart. In the first set, the paper was changed every twenty-four hours, and in the second the drum was run faster and the paper was changed every twelve hours. The records obtained were tacked on the wall beside the set taken in the dark and the two were compared. There was practically no difference in the two sets of records (fig. 3). There was the same general picture of extreme activity broken up into periods of "continuous" activity and periods of "intermittent" activity. These periods were essentially similar in

both dark and light records and the rest periods were not typically longer or any more frequent in the light than in the dark.

By actually measuring the activity periods, as in the previous experiment, the following figures were obtained: Out of the 23 hours the smallest amount of activity for any one guinea pig was 15.6 hours and the greatest 22.6 hours. The individual averages for the six guinea pigs for 7 days varied from 19.4 hours to 21.53 hours and the average activity for all six guinea pigs for a week in the light was 19.83 hours out of 23 or at the rate of 20.64 hours out of the 24. Thus in comparing the total activity of the six guinea pigs in the dark with the total activity in the light, there was 1 hour less activity in the light per day, or a decrease of 4.6 per cent.

Distribution of activity

The guinea pig divides his time into periods of "continuous" activity and periods of "intermittent" activity. It is difficult to count the exact number of periods of each, since the periods frequently run into each other. Roughly, they vary from fourteen to twenty-three of each. The continuous activity periods vary in length from five minutes to three or four hours and their length does not correlate in any way with the following period of intermittent activity.

The absence of any correlation between activity and time of day was demonstrated by plotting the continuous activity periods of the same guinea pigs on three different days. Periods were chosen of over ten minutes in length which were broken by no quiet periods. No tendency was found for the guinea pig to be active at the same time each twenty-four hours. The activity furthermore is quite evenly distributed over the twenty-four hours and there is no nocturnal or diurnal rhythm. The periods of "continuous" activity are greater in length than the periods of "intermittent" activity.

Comparison of the activity of single animals and groups

The question arose as to the possibility of the six guinea pigs stimulating each other and thus increasing their normal amount

of activity. In order to decide this question an experiment was carried out in which a guinea pig was placed alone in the vault and his activity recorded. This procedure was repeated using different guinea pigs and two days' records were taken of each animal. In two further experiments the activity of two guinea pigs and a group of six guinea pigs was studied. The same guinea pigs were used throughout the experiments. The work was carried out in the dark.

The records were measured and the average activity for the different groups was determined. The results were as follows:

	<i>hours</i>
Activity for one guinea pig alone.....	20.55
Activity for two guinea pigs, side by side but in separate cages..	21.55
Activity for six guinea pigs in a group of separate cages.....	20.38

From these results there is apparently no significant difference in the amount of activity of the guinea pig whether alone or in groups.

Influence of age upon activity

Slonaker (1907) and Richter (1920) both found in the study of the white rat that the amount of activity decreases with age. A set of experiments was therefore carried out to see if this was true in the case of the guinea pig.

Records were taken in the dark of the activity of four young guinea pigs one month old. Records were also taken of four adult guinea pigs between eight and nine months old. We had at hand records of six guinea pigs three months old and of the same guinea pigs six weeks later. The results obtained by measuring the amount of activity are as follows:

	<i>hours</i>
Average activity of guinea pigs one month old.....	21.19
Average activity of guinea pigs three months old.....	21.6
Average activity of guinea pigs four and a half months old.....	20.38
Average activity of guinea pigs eight months old.....	21.18

There is thus apparently little difference in the amount of activity of guinea pigs ranging in age from one to nine months. The records of the older guinea pigs have the same general ap-

pearance as those of the younger. The amplitude of the movements is higher with the older guinea pigs because of the increase in weight.

Relative activity of males and females

In the experiments on the activity of guinea pigs in the dark and in the light in each case three male and three female guinea pigs were used. A study was made of the activity of each group to see if the amount of activity varied with the sex. Richter (1921) found in the case of the white rat that in the revolving drum the females were more active than the males.

TABLE 1

The amount of activity of three male and three female guinea pigs in the dark for seven days

	MALE			FEMALE		
	Guinea pig A	Guinea pig D	Guinea pig F	Guinea pig B	Guinea pig C	Guinea pig E
Weights, grams	222	261	316	236	182	255
Date	Activity			Activity		
October 18.....	20.5	22.8	22.3	19.6	20.8	23.0
October 19.....	22.5	20.8	17.5	19.2	18.8	18.2
October 20.....	21.8	23.0	20.0	20.9	21.5	22.5
October 21.....	20.6	21.4	18.3	20.2	22.1	20.9
October 22.....	20.3	19.7	20.8	18.5	—	19.2
October 23.....	22.4	22.9	21.8	20.6	22.0	20.7
October 24.....	20.6	21.2	21.7	19.8	—	21.9
Averages.....	21.24	21.73	20.34	19.69	21.04	20.81
Average 23 hours.....	21.10			20.51		
Average 24 hours.....	22.01			21.40		

Table 1 shows that in the dark the average amount of activity during 24 hours for three female guinea pigs was 21.40 hours and of three male guinea pigs was 22.01 hours. The male guinea pigs show in this case an increase of activity over the females of 0.61 hours. In the light (table 2) the females showed 20.44 hours of activity and the males 21.18 hours, with an increase in the

case of the males of 0.74 hours. Thus both in the light and in the dark male guinea pigs show a slightly greater activity than the female guinea pigs, under the conditions of our experiments.

The influence of food upon activity

The guinea pig is an herbivorous animal and spends most of his time eating. An attempt was made in this set of experiments to determine the part that food plays in the activity of the guinea pig. If food is partially or completely removed will the guinea pig still continue to be as active as normally?

TABLE 2
The amount of activity of three male and three female guinea pigs in the light for seven days

	MALE			FEMALE		
	Guinea pig A	Guinea pig D	Guinea pig F	Guinea pig B	Guinea pig C	Guinea pig E
Weights, grams	251	299	330.5	271	207	286
Date	Activity			Activity		
October 26.....	21.9	20.0	18.9	18.9	19.2	16.9
October 27.....	20.3	22.6	20.9	19.9	19.0	22.0
October 28.....	20.7	19.9	21.6	19.9	19.1	20.0
October 29.....	21.9	21.9	21.2	22.2	21.2	21.7
October 30*.....	10.7	10.8	11.4	10.1	10.6	11.1
October 31.....	22.6	18.9	18.6	19.8	20.6	19.9
November 1.....	21.8	18.0	15.6	19.0	17.3	16.1
Averages.....	21.53	20.21	19.46	19.95	19.40	19.43
Average 23 hours...	20.40			19.59		
Average 24 hours...	21.18			20.44		

* On a run of 12 hours.

Food one hour a day. The same six guinea pigs were used as in the previous experiment and the work was carried out in the dark. All food and bedding was removed from three of the recording-cages and paper bedding was substituted for the hay. At nine o'clock in the morning the six guinea pigs were weighed and the experiment was started, three guinea pigs being without food and three controls with food. The next morning at nine

o'clock the six animals were again weighed and the three guinea pigs without food were given food for one hour. Water was left in the cages all of the time. At the end of the hour all the food was again removed from the same three cages. This was continued for seven days and records were taken of the amount of activity and rest. The guinea pigs were always weighed at nine o'clock in the morning just before they were fed. The three control animals were also weighed at this time.

As in the previous experiments, the activity for twenty-three hours only was measured. The time between 9 a.m. and 10 a.m., when the guinea pigs were fed and the recording paper was changed, was not counted. From the data obtained the average individual activity for the three guinea pigs fed for 1 hour a day for 7 days was 21.33 hours, 22.0 hours and 20.93 hours, making a total average of 21.42 hours of activity in the 23 hours for all three guinea pigs, or at the rate of 22.2 hours in the 24. The three control guinea pigs showed individual averages of 21.95 hours, 21.05 hours and 21.5 hours for 7 days, a total average of 21.5 hours of activity in 23 hours, or at the rate of 22.3 hours out of 24 hours. Thus the three guinea pigs without food showed no significant decrease in activity although the amount of food eaten each day was considerably less than that of the three control guinea pigs.

Since there was no decrease in activity, we expected to find a loss in weight each day and this was actually the case. One guinea pig showed a loss in weight of 41 grams the first day and only had 13 hours of activity. The cause of this great loss both in weight and activity was quite obscure. Guinea pig F did not show any loss in weight the first day and guinea pig D showed a loss of 10.5 grams. The controls showed gains of 6.5 grams, 5 grams and 5 grams the first day. The average loss in weight for the week for the three guinea pigs without food was 29.8 grams while the average gain for the control animals was 11 grams. It is fair to assume that if the three guinea pigs without food had been given their normal rations for the week they would not only have maintained their original weight but would probably have shown a proportional increase of weight of approxi-

mately 11.0 grams like the controls. Therefore the total average loss in weight for the three fasting guinea pigs may be considered as 40.8 grams or 13.6 grams per guinea pig. Thus the fasting guinea pigs maintained their normal activity, but at the expense of their body weight.

No food. As a check on the above experiment another one was carried out in which three guinea pigs were not given any food at all for three days. This time the food and cut hay bedding were removed from three of the cages and no paper bedding was substituted. Wire mosquito netting was put over the bottom of the cages so as to prevent the guinea pigs from nibbling the plaster board. Three healthy guinea pigs were chosen all weighing over 300 grams. Three similar pigs were chosen for controls.

The guinea pigs that were to be starved were weighed and the experiment was started. The following day at the same hour the three guinea pigs were again weighed and again on the second and third day. At the end of the first day the three guinea pigs without food seemed very restless and ran about their cages squealing. On the second day one seemed sick while the other two were quite lively. On the third day all three sat humped up with their eyes partly closed and seemed to move with difficulty. They were given food gradually and within a week they were weighed again and all but one had regained his original weight.

The records obtained were measured in the usual way. The first day the starved guinea pigs showed an average amount of activity of 15.6 hours while the controls had an average of 18.4 hours. On the second day, the starved guinea pigs showed an average activity of 18.7 hours as compared with 18.5 hours shown by the controls. On the third day, the three starved pigs showed 7.1 hours, 7.1 hours and 7.6 hours of activity respectively, making an average of 7.3 hours. The controls had 17.3 hours. Thus on the first and second day there was little falling off of activity as compared with the controls but on the third day the amount of activity decreased over 50 per cent.

In comparing the activity with the loss in weight, we find the loss the first day was the least, i.e., 6.0 grams, 6.5 grams, and 7.0 grams. The loss on the second day was much greater—24.0 grams, 33.5 grams, and 31.5 grams. This was also the day on which the average amount of activity was the greatest. On the third day the loss of weight was 21.5 grams, 19 grams, and 21.0 grams. As in the previous experiment the three guinea pigs continued their activity at the expense of their body weight up to a certain point.

It is interesting to note in this experiment that the control guinea pigs did not show as much activity as was found in previous experiments. As these guinea pigs were the same as were used in many of the other experiments this absence of activity may have been due to the influence of the starved guinea pigs. The control guinea pigs showed their smallest amount of activity on the third day when the activity of the starved animals had fallen off over 50 per cent. The reduced activity of the fasting guinea pigs may therefore have had an inhibiting effect upon the controls.

The influence of physical exhaustion upon activity

In this set of experiments we studied the relation between physical exhaustion produced by forced running in a motor-driven drum and subsequent activity. In some of the experiments a separate food cage was connected to the main cage by a small opening. The food cage was set upon separate tambours and all movements were recorded independently on the drum. The purpose of this set-up was to determine the amount of time the guinea pig spent in the food cage.

Six guinea pigs were used varying in weight from 245 to 314 grams. Similar guinea pigs were used as controls. A guinea pig was weighed and placed in the motor-driven drum and made to run until he was exhausted. An animal was considered exhausted when he lay on his back or side and let the cage slide under him and when he remained in the same position for some minutes after the drum was stopped. He was again weighed and immediately taken down into the vault and put into the

recording-cage for two hours. The records were spread out more than in the earlier experiments in order to emphasize individual movements. The six guinea pigs were exhausted in the same manner and records were taken of their behavior afterwards.

In all of the records the guinea pigs remained quiet for ten or fifteen minutes and then began eating. They ate continuously while they were in the cage. The records show a continuous line of small movements such as are registered by eating and there are few vigorous movements. Where the food cage is attached the records show that within a few minutes the guinea pig entered the food cage and remained there for what remained of the two hours, eating all of the time. The records of the con-

TABLE 3
Data concerning six guinea pigs fatigued to the point of extreme exhaustion

GUINEA PIG	WEIGHT	NUMBER OF REVOLUTIONS	DISTANCE	TIME	LOSS IN WEIGHT
	<i>grams</i>		<i>miles</i>	<i>hours</i>	
E	245	789	0.81	3	3
A	249	793	0.82	2.25	6
D	254	757	0.77	3.41	5
C	264	709	0.73	3.16	6
B	309	1636	1.67	4.75	6
F	314	1951	1.99	5.83	5

trol guinea pigs showed more vigorous movements and considerably less eating movements.

Upon observation the three guinea pigs sat humped up beside the dish of food, with their eyes partly closed but chewing vigorously. They did not move their position when the experimenter entered the vault or show any fear when touched. They did not respond to any stimulus except the one aroused by the desire for their food.

It seems therefore from these results that eating is more essential than sleeping in the recovery of guinea pigs from fatigue.

It is interesting to note that the heavier (older) the guinea pig the longer it took for him to become exhausted. Data concerning the weights of the pigs and the times and distances run are given in table 3.

The influence of temperature upon activity

During the first part of the experimental work we observed a constant tendency in our guinea pigs to stretch out on the bottom of the cage and remain inactive for long periods when the temperature was between 75° to 80°F. This was not an inhibition because of fear as the guinea pigs were all very tame. These long periods of inactivity were believed to be caused by the high temperature and the matter was further investigated by the following experiment.

Three young guinea pigs were put into separate recording-cages in a small room in the vault. The rubber tubing from the

TABLE 4
The influence of temperature upon the activity of the guinea pig

DATE	TEMPERATURE 12 NOON	GUINEA PIG A	GUINEA PIG B	GUINEA PIG C	AVERAGE ACTIVITY
April 4.....	65°	17.3	20.6	19.1	19.0
April 5.....	65°	21.7	20.4	21.8	21.3
April 6.....	65°	21.2	23.4	21.0	21.8
April 7.....	65°	21.2	22.8	20.0	21.3
April 8.....	79°	17.0	20.0	20.3	19.1
April 9.....	83°	15.8	17.3	16.3	16.4
April 10.....	85°	10.0	13.0	13.4	12.1
April 11.....	85°	12.7	13.3	11.6	12.5
April 12.....	79°	15.1	15.3	14.9	15.1
April 13.....	84°	12.0	11.3	7.7	10.3
April 14.....	86°	10.8	9.0	7.7	9.1
April 15.....	87°	10.4	12.1	10.7	11.1
April 16.....	87°	8.3	7.5	8.1	7.9

cages was passed through small holes in the door frame and connected with the recording device outside the door. The door was kept shut and was opened only a few minutes each day to give the guinea pigs fresh water and food. The room was heated by a Majestic electric heater. A Friez thermograph recorded the temperature.

Records were taken of the amount of activity of the guinea pigs at the normal dark temperature of the vault, 65°F., for four days. The electric heater was then turned on for four days and records were taken of the activity of the guinea pigs. The heater was turned off for twenty-four hours and then put on again for four days, and activity records were taken.

The records were measured in the usual way and the amount of activity for each day is recorded in table 3. The average amount of activity for the three guinea pigs at the normal temperature of the vault, 65°F., was 20.8 hours. As the temperature increased the amount of activity decreased (see fig. 4). At 79° there were 19.1 hours of activity and at 85° there were 12.1 and 12.5 hours of activity. When the electric heater was turned off for 24 hours the temperature fell to 79° and the amount of activity rose to 15.1 hours. The room was again heated and the temperature rose to 87° and the amount of activity decreased to 7.9 hours on the last day.

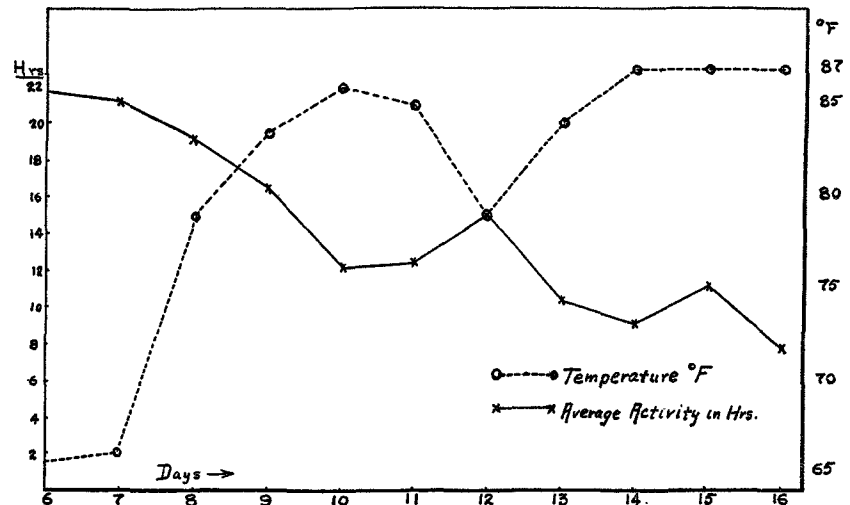


FIG. 4. THE RELATION BETWEEN ACTIVITY AND TEMPERATURE

The activity curve is an average activity of three pigs for twenty-four hours. The temperatures were read from the thermograph tracing at 4:00 p.m. on each day of the experiment. See table 4 and text for details.

The general appearance of the records is quite different for the days when the temperature was high as compared with the normal activity records. The "continuous" activity periods are very short and are broken by short quiet periods. The amplitude of the movements is considerably reduced. There are long periods of absolute quiet which are never found in a

normal activity record. We find from this experiment that there is a decided decrease in the activity of the guinea pig with an increase in temperature. The experiment therefore corroborates our casual observations of the reduced activity of guinea pigs at elevated laboratory temperatures.

The nature of the activity and rest of the guinea pig

From the records obtained of the activity of the guinea pig, it was found the activity was divided up into periods of continuous activity and intermittent activity. The latter contained numerous short quiet periods. The question therefore arose: Is the guinea pig practically continuously active with just snatches of rest or does he actually go to sleep and move in his sleep? The only way to settle the question was to watch the guinea pigs and find out by observation.

For this experiment a hole 5 inches long and 2.5 inches wide was cut in the door which led into the room where the experiments were in progress. The guinea pigs were placed as near the door as possible and a foot from the floor. It was found that only four cages could be conveniently observed at the same time. Long narrow mirrors were placed beyond the two farthest cages to aid in seeing the faces of the guinea pigs when their backs were turned toward the observer. The room was lighted by two 75 watt, nitrogen, daylight bulbs hung low over the cages. The observer sat on a stool on the other side of the door with his eyes about 6 inches from the hole.

The experiment was started at 11:30 in the morning and continued until 11:30 the next morning. During the day the observer watched for periods of two to four hours but from nine o'clock in the evening until seven the next morning the shifts were never over two hours. This was to prevent loss of interest from fatigue on the part of the observer. The four guinea pigs were watched constantly and every movement and any signs of rest were carefully noted. Observations concerning the condition of each of the guinea pigs were written down every five minutes and in many cases more often.

The following facts seem worth recording. The guinea pigs divided their time into constant activity and intermittent activity. During the former they ran about their cages, with occasional leaps and jumps, called out to each other, tried to climb up the sides of their cages and gnawed at the wire netting or drinking cups. They would play with their food, dig in the food dish and scratch for choice bits in their bedding. They were wide awake and free from any fear. During these periods all the guinea pigs were more or less simultaneously active. Their activity would increase to a certain pitch and gradually they would quiet down again. These periods were longer than the less active periods and more frequent. They would vary greatly in the pitch to which the activity rose.

The intermittent periods were slightly different. They might be divided into fear, quiet eating, and actual rest. The guinea pigs in this experiment seemed to be conscious most of the time of the presence of the observer, but this factor did not disturb them to a great extent as they were all very tame. However, moving the stool or dropping a book would startle them and thereafter they would sit quietly watching the hole in the door as long as fifteen minutes at a time. These periods of fear were rather frequent due to the short shifts.

The guinea pig would often sit beside the food dish eating quietly and it was noticed that very slight movements such as chewing slowly did not record on the drum. The guinea pigs spent most of their time eating. The actual rest periods were few and of short duration. A guinea pig would relax and settle into a little heap in a corner of the cage and even put his head down but he would never stay quiet for more than a minute or two at a time. He would constantly move, yawn, stretch himself, and make movements with his jaws. He would remain in this quiet state for some time but he would continually be interrupted by something and then settle down again. In these rest periods, the guinea pig would frequently partly close his eyes but in only one instance did an observer state a guinea pig had his eyes completely closed.

The actual amount of activity was measured on the record and also for the three succeeding days. It was found that during the twenty-four hours of observation, there was a considerable falling off from the normal amount of activity as previously determined. As stated above the guinea pigs seemed conscious of the observer and there was probably an inhibition from fear. This inhibition persisted to a less extent the next day and disappeared the second day. The exact data are shown in table 5.

TABLE 5

The amount of activity in hours of the four guinea pigs in the observation experiment and the three succeeding days

DATE	GUINEA PIG 1	GUINEA PIG 2	GUINEA PIG 3	GUINEA PIG 4
November 19 observation experiment.....	14.5	15.4	13.8	15.9
November 20.....	15.6	16.8	16.0	18.1
November 21.....	19.8	22.7	18.9	19.2
November 22.....	17.0	20.7	18.0	19.8

Comparative activity of the guinea pig and the rat

Before completing the experiments on the normal behavior of the guinea pig it was thought advisable to make some comparative studies with another animal. The white rat was chosen for this purpose for two reasons. It belongs to the same order as the guinea pig and its size is convenient. A male white rat is not much smaller than a young guinea pig. Furthermore, Richter (loc. cit.) has made an extensive study of the behavior of the rat.

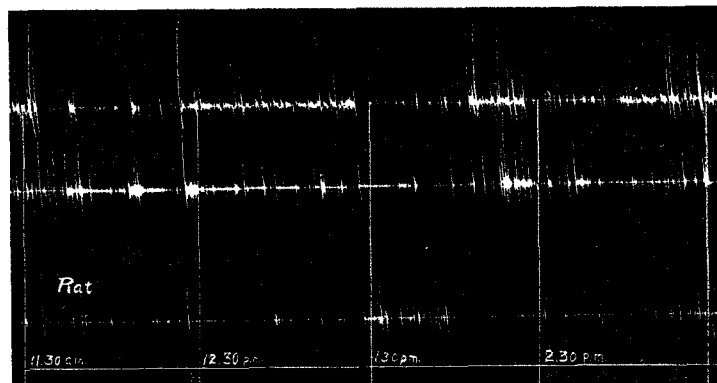
In these experiments a study was made of the activity of the guinea pig and rat when together in the vault and also when alone. The animals were all males and were about two and a half months old. Four animals were put into separate recording-cages in the vault with a rat alternating with a guinea pig. As the cages were arranged in the form of a square a rat had a guinea pig on each side of him and a rat opposite him. All four cages were covered with mosquito netting. The wire netting was necessary to prevent the rats' escaping from their cages. It was

put over the cages of the guinea pigs so as to make the conditions the same. The animals were given their customary diet. The guinea pigs had cut hay for bedding and oats and water. The rats were given paper bedding and oatmeal and milk. The experiments were carried on in the dark.

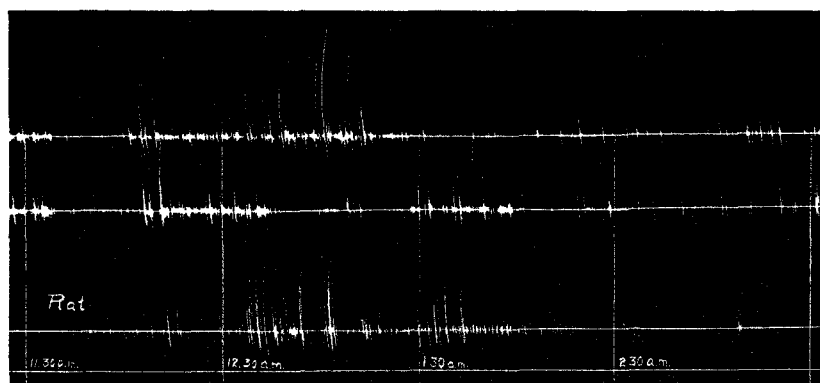
In the first experiment the four animals were taken into the vault and records were taken of their activity for periods of 24 hours. The records were then measured as in the previous experiments. This time the amount of rest was determined as well as the amount of activity. The two guinea pigs in 4 days showed an average activity of 22.28 hours while the rats showed 11.5 hours. Thus the guinea pig was almost twice as active as the rat. The guinea pig showed an average of 1.75 hours of rest and the rat an average of 12.5 hours. The guinea pig spent 93 per cent of the 24 hours in activity and 7 per cent in rest, while the rat spent 48 per cent of the time in activity and 52 per cent in rest.

There is a possibility in the above experiment that the rats and guinea pigs might have influenced each other to greater or less activity than normal. Therefore another experiment was carried out, in which the rats and guinea pigs were put in the vault alone and their activity recorded. The two guinea pigs were taken into the vault and their activity was recorded to 2 days, then they were removed and the two rats were taken down and their activity was recorded for 2 days. The guinea pigs showed an average activity of 21.25 hours and the rats an average activity of 9.87 hours. In the same period the guinea pigs showed 2.77 hours of rest the rats 14.1 hours. Thus the guinea pigs when alone spent 89 per cent of their total time in activity and 11 per cent in rest. The rats spent 41 per cent of their total time in activity and 59 per cent in rest. If we consider 9.87 hours, the amount of activity when the rat was alone as his normal activity, the relative increase in activity when the rat was with the guinea pig is 16.5 per cent while the guinea pig showed an increase of only 4.8 per cent. The extreme activity of the guinea pig may have disturbed the rat and prevented him from taking as much rest as would normally be the case.

In comparing the amount of activity during the day with the amount of activity during the night, the guinea pig and the rat are quite different. The day is taken from six in the morning to six at night and the night from six in the evening to six the



A



B

FIG. 5. THE RELATIVE DIURNAL (A) AND NOCTURNAL (B) ACTIVITY OF ONE RAT AND TWO GUINEA PIGS TAKEN ON THE SAME RECORD OF TWENTY-FOUR HOURS IN THE DARK

Note the reduced general activity of the rat during the day

next morning. The guinea pig shows 10.4 hours of activity at night and 10.8 hours during the day. The rat shows 6.27 hours

of activity at night and 3.6 hours during the day. There is, therefore, an increase of activity at night of about 80 per cent which agrees with the well known nocturnal habits of the wild rat. The absence of a distinctly nocturnal habit in the guinea pig is strikingly demonstrated by the above figures. The relative activity of two guinea pigs and one rat from noon till 2:00 p.m., and from midnight till 2:00 a.m. are shown in figure 5.

CONCLUSIONS

1. When guinea pigs are placed in an environment free from abnormal and disturbing stimuli and under constant conditions of temperature (65° plus or minus 1°F.) and humidity (42 per cent relative) they are found to be extraordinarily active. There are no alternations of protracted complete rest periods and activity. The time is divided into periods of "continuous" activity and "intermittent" activity. During the former they are continuously active and in the latter the periods are broken by small rest periods averaging three to four minutes in length. There is no nocturnal or diurnal rhythm. In the dark, at a temperature of 65°F. , they show an average activity of 21.6 hours out of 24.

2. With constant illumination and a temperature of 67°F. guinea pigs show an average activity of 20.64 hours out of the 24. The temperature rise of 2°F. is too small to account for the reduced activity. There is thus approximately 5 per cent less activity *in the light* than in the dark.

3. In comparing the activity of single animals and groups, it was found that the presence of other normal guinea pigs does not significantly affect the activity of a single pig.

4. There is apparently little difference in the amount of activity of guinea pigs ranging in age from one to nine months. The young guinea pigs showed an average activity of 21.19 hours, the three month old animals 21.6 hours, and the nine month old guinea pigs 21.18 hours.

5. In comparing the activity of the sexes, the male guinea pigs showed a slightly greater average activity than the females.

In the dark the difference is plus 2.8 per cent and in the light plus 3.4 per cent.

6. Guinea pigs fed for an hour a day showed a slightly higher average activity than when they had food in the cage all of the time. In the course of a week, however, they showed an average loss in weight per pig of 13.6 grams.

7. When three guinea pigs were given no food for three days, there was a falling off of activity from 15.6 hours to 7.3 hours. There was also a rapid decrease in weight.

8. When guinea pigs were fatigued to the point of extreme exhaustion in a revolving cage, upon being put back into their recording-cages, they immediately started to eat and continued to eat for at least two hours. It seems from these results that eating is more essential than sleeping in the recovery of the guinea pig from fatigue.

9. The amount of distribution of the activity of the guinea pig is influenced by the external temperature. At high temperatures (80-85°F.) the normal activity of the guinea pigs drops off over 50 per cent. At a high temperature they show short activity periods and long periods of quiet.

10. By observation it was found that during "intermittent" activity guinea pigs would settle into a relaxed condition but would never remain quiet for more than two or three minutes at a time. In these short rest periods the guinea pig would partly close his eyes and sometimes rest his head on the hay bedding. The guinea pig spends most of his time eating.

11. In comparing the guinea pig with the white rat, the guinea pig was found to spend 89 per cent of the twenty-four hours in activity and 11 per cent in rest. The rat was found to spend 41 per cent in activity and 59 per cent in rest. The activity of the guinea pig was evenly divided between the day and night. Our rats, however, were found to be 80 per cent more active at night than in the day.

12. It is certain that sleep does not play a rôle in the normal life of the guinea pig comparable to the sleeping of rats, mice and other mammals. We are not prepared to say that the guinea pig never sleeps, but, in an extensive inquiry among laboratory

workers, we have thus far failed to find anyone who recalls having seen a guinea pig sleeping.

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