THE INFLUENCE OF EXCESSIVE SEXUAL ACTIVITY OF MALE RABBITS

I. ON THE PROPERTIES OF THE SEMINAL DISCHARGE

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INTRODUCTION

During the past two years the animal breeding laboratory of the department of Animal Husbandry of Iowa State College has carried on work aimed to throw some light on the effects of excessive sexual activity of the male (1st) on the properties of the seminal discharge and also (2d) on the nature of the resulting offspring. This paper is a report of the first-mentioned line of work. A report by one of us on the nature of the offspring appears in the same number of this Journal (Hays, F. A. The influence of excessive sexual activity of male rabbits: II. On the nature of their offspring.) The attributes of the semen and its spermatic content, as influenced by heavy sexual service, which are here reported on are as follows:

The amount of seminal discharge;
The number of sperm¹ per unit volume of semen;
The type of motion and the rate of motion of sperm in fresh semen;

Duration of motion of the sperm;
The certainty of pregnancy induced by the sperm, and
The size of litter from various services.

References to previous published observations will be made under the section on which they most directly bear.

GENERAL PLAN OF EXPERIMENT

Rabbits were selected as the experimental animal: They are large enough to furnish semen sufficient in quantity on which to work, and yet thrive well and reproduce rapidly in close confinement and at slight expense of maintenance. The great majority of the observations were made upon three males. In general the plan was to have the male accomplish, in as rapid succession as possible, a certain number of preliminary 'services' and then to mate him once to the breeding female from which the litter was desired. The 'end services' from which litters were secured for the progeny studies were the 5th, 10th, 15th and 20th, and about an equal number of 1st-service litters were obtained as controls. However, when semen studies were made it was aimed to recover specimens from the 1st and from every 5th service thereafter; thus, in a series of 20 services, five specimens of semen would ideally be recovered for study. This ideal set of specimens from a 20-service series was seldom obtained, however.

In order to provide females for the 'preliminary matings' special provisions were necessary. A single female rabbit will sometimes receive the male as many as fifteen times in the space of about two hours; but, on the other hand, a female may, though she shows every indication of 'heat,' refuse the male after three or four services, and it is not feasible to commence a

¹ Throughout this work the word sperm will be used instead of the technically more correct but cumbersome spermatozoa.

series of fifteen or twenty preliminary matings without having at least two females in heat in addition to the female which is to receive the 'end service.' Moreover, inasmuch as the semen specimens were recovered from females after a natural service by the male, it was necessary to have an unused female for every five services made, or at least for every specimen of semen which is to be recovered. In practice a long series of matings was never commenced unless at least three and preferably four or five females were in heat at the same time. The oestral period in rabbits recurs every two weeks if the female does not conceive, and the period of gestation is about thirty-one days. Females will always receive the male the day following parturition, but females in this condition may not be used for recovery of semen because of the presence of large amounts of blood and other fluids residual from the foetal nutrition. Thus, to carry on the work with normal females, an excessively large stock of animals would be necessary. To cut down the number of females necessary to provide the preliminary matings a considerable number were operated upon. The Fallopian tubes were sectioned and the free ends sutured. This operation absolutely prevented conception and for a year or so after the operation the sexual behavior of the female was for the most part otherwise unchanged, and heat recurred with fair regularity about every fifteen days throughout the year. Females treated thus proved to be admirably adapted for our use.

There were some exceptions to the rule in the behavior of the operated stock. A certain agouti female, for example, could be induced to accept the service of the male at almost any time if the male were aggressive. This female apparently went through the regular oestrous cycle, at which time she was much more ardent toward the male and would accept many more copulations than at other periods. A certain sooty female also showed a similar tendency. Attempts to secure copulation with other operated females when not in heat were unsuccessful. After about a year of incessant copulation many of these operated females began to show great pugnacity towards the males, and often, though obviously in heat, refused to accept them alto-

gether. When this behavior developed such females were discarded and replaced by newly operated stock. Post-mortem examinations of some of the discarded females showed no easily apparent changes in their reproductive organs to account for their changed behavior toward the males. Many of them had become very fat and rather sluggish. Altogether about twenty-five females were operated upon. About an equal number of females were used for 'end matings.'

RECOVERY OF SEMEN

There are several methods which have been used by investigators and others for securing specimens of mammalian semen. Ivanoff ('07) recommends highly the vaginal sponge, and advocates the same for use in the horse, the cow, and the sheep. An attempt was made to adapt this method to the rabbit by packing the vagina with absorbent cotton. The method was not successful. The size of the piece of sponge which can be placed deep in the vagina is too small to absorb and yield up sufficient semen on which to work, and if larger pieces are used they remain too near the exterior and prevent penetration by the male. The condom (breeding bag of stallion grooms) has been used much by horse breeders when practicing artificial insemination of females. Good membranes of this sort were prepared from the caeca of chickens, but it was found impossible to use them on the males; neither could they be held in position as a 'false lining' of the vagina at the time of coition. Detlefsen ('14) successfully secured for examination specimens of semen from many different males by making a slight incision in the epididymis and expressing a few drops of its contents. This method will not answer when, as in the present case, a large number of specimens must be taken from a single male. In the case of the rabbit, ejaculation cannot be induced by artificial stimulation.

The method finally adopted and used in all cases was the old and simple one—recovery by catheter. A small-diameter rubber catheter moistened in a saline solution was introduced for a distance of about 16 to 20 cm., thus penetrating as far as the os.

This operation may generally be accomplished, but often folds of the vaginal wall are encountered and much patience is necessary; in very few cases was failure to introduce the catheter deep into the vagina complete. In very rare cases the catheter penetrates the bladder, rather than passing over the papilla, in which event the female in hand is spoiled for recovery of semen that day, because even a small amount of urine remaining in the vagina is highly inimical to the sperm. With the inner end of the catheter placed near the os, a glass pipette is inserted into the outer end and the semen withdrawn by suction. The amount of material recovered is small; generally about one to three tenths cc., and consists of the secretions of the testes, epididymis, seminal vesicle, prostate and Cowper's glands from the male. These may also be mixed with uterine cervical and vaginal secretions, also lymph, epithelial cells, and leucocytes from the female.

During the earlier stages of the work, a female was simply bred once to a male for the recovery of semen without previously attempting to remove any uterine or vaginal secretions which might be present. As the work progressed, it was considered advisable to remove as much as possible of these secretions from the female, in the manner described above, before breeding her, and this step was worked into the routine of our practice. In the great majority of cases the amount of these secretions thus recovered before the breeding was negligible, but sometimes as much as 0.8 cc. was withdrawn. This material differs much in physical properties from semen. It is generally thicker, more viscous, yellowish in color, and does not mix freely with a saline fluid (Ringer's), but gives a mixture with two phases. It is heavily loaded with leucocytes and other cells. Specimens of semen which are mixed in appreciable amounts with this material are easily recognized, and were discarded for study of numbers of sperm per cubic millimeter.

BEHAVIOR OF MALES

The act of coition is of very short duration in the rabbit—one or two seconds suffices. The male generally mounts the female at once; when she is in heat she will raise her hinder parts and elevate the vulva. By a single thrust of the male the act is completed, and the force of the thrust varies with different males.

The time interval between services is influenced by many factors; the following circumstances tend to prolong the service interval; a high temperature in the laboratory; indifference of the female; heavy service by the same male a few days previously; a large number of copulations on the given day; allowing the female and male to remain together in the same cage after coition; failure to furnish 'fresh' females after the male has served the same operated animal several times; failure on the part of the experimenter to crowd the male to his maximum. The time interval between services ranged from five minutes in the early part of a given series to as much as twenty minutes in the latter part of the series. The great majority of services were made at intervals of ten minutes.

Twenty services in the space of about three hours is not the utmost that a rabbit can do; in our own work they have occasionally made several more. However, this was chosen as a safe upper limit, for on many more occasions we have been unable to induce the male to perform as many as twenty services in an afternoon, there being in these cases a complete temporary loss of desire. Several days were required for males to fully recuperate from a long series of services. It was the aim to allow at least seven days' rest between heavy-service days. When such series of matings follow each other too closely the males were unable to copulate even though they made pronounced efforts.

VOLUME OF SEMEN RECOVERED

The greater mass of the seminal fluid is made up by secretions from the accessory glands. These are true secretory glands, and if their behavior is analogous to other glands of this class,

they will show reduced activity after continued stimulation. In fact, workers for the most part agree that reduced volumes of semen is one of the most regular concomitants of excessive sexual activity.

Lewis ('11, p. 30) recovered 65 cc. from a stallion on the first copulation of a test. This same stallion then made one copulation daily for nine days. On the ninth day only 5 cc. of semen were recovered. Again after the horse had rested nineteen days, 60 cc. of semen were recovered from a single copulation.

Iwanoff ('07, p. 494) found that the volume of semen ejected by stallions generally decreases with several copulations, but this decrease is variable. He reports one case of a stallion in which 33 cc. was discharged at the first copulation, 30 cc. on the second, and 28 cc. on the third copulation on the same day. The day following 20 cc. were discharged on the first copulation and 18 cc. on the third. On the third day there were 30 cc. on the first, 25 cc. on the second, but 40 cc. on the fourth copulation.

In a single observation reported by Lode ('91) in man, the volume of semen decreased from 3000 cu.mm. on the first ejaculation to 2000 cu.mm. on the second copulation of the day. On the whole, however, Lode's results are in remarkable contrast to those mentioned above. In the case of a dog the total volume recovered from the first ejaculation was 75. cu.mm. and on the fourth ejaculation of the day 1500 cu.mm. On a second observation, the volume of the first ejaculation was 800 cu.mm. and 1500 on the fourth (the length of the interval between these ejaculations is not stated). Lode makes much of this point; he quotes Ludwig ('91) as saying that "Man vermuthet, dass eine öftere Entleerung des Samen die Neubildung desselben beschleunige," and Nothnagel ('91), "Manches weist vielmehr darauf hin, dass nur nach vorherigen Entleerungen eine stärkere Production stattfindet."

The volume of semen discharged by the male rabbit is necessarily very small, since the animal is small and the time of ejaculation is extremely short. We have found it impossible, as has

TABLE 1
Volume of semen recovered from different services in cubic centimeters

DATE	INTERVAL SINCE LAST SERVICE	1ST	5TH	10TH	15TH	20TH
<i>Male 1</i>						
<i>1916</i>	<i>days</i>					
6-28	10	0.225		1.01		
6-30	2	0.295	0.460	0.645		
7- 6	6			0.12		
7-13	7	0.435	0.209	0.165		
8-23	13	0.560	0.105		0.05	
8-28	5		0.05			
11-14	7				0.34	
11-18	4			0.1		
12- 9	6				0.3	
12-22	3	0.071	0.210			
12-26	4	0.245			0.095	
<i>1917</i>						
1- 1	6	0.19				0.09
1- 4	3	0.600				
1-13	9				0.05	0.04
1-14	1	0.300				
6-13	73	0.714	0.107	0.10	0.08	0.05
6-18	5	0.34				
6-29	11	0.512		0.205		0.175
7- 9	10	0.575		0.072	0.085	0.13
7-16	7	0.515		0.170	0.145	0.07
<i>Male 3</i>						
<i>1916</i>						
7- 7	11	0.2	0.2			
7-11	4	0.230		0.15		
9-16	29	0.190	0.09	0.05	0.05	
9-22	6	0.500				
9-26	4	0.500				
10-22	16	0.400	0.30	0.30	0.3	
11- 6	15	0.300				
12-21	31	0.499	0.715	0.21		
12-30	9	0.074	0.4			
12-31	1	0.200			0.05	
1-24	24	0.200				0.13

TABLE 1—Continued

DATE	INTERVAL SINCE LAST SERVICE	1ST	5TH	10TH	15TH	20TH
<i>Male 4</i>						
<i>1916</i>	<i>days</i>					
6-27		0.460	0.214	0.015		
6-29	2	0.25				
7- 8	9	0.212				
11- 9	25	0.610	0.07			
12-28	11	0.1		0.1		
<i>1917</i>						
1-10	13					0.13
1-19	9					
6-14	17		0.09			
<i>Male 5</i>						
<i>1917</i>						
6-15		0.28	0.05	0.13	0.05	
6-28	13	0.12		0.163		0.082
7-13	15		0.14		0.145	0.08
Means		0.341	0.213	0.218	0.134	0.098
Standard deviation of means		± 0.03072	0.0436	0.0593	0.0287	0.0122
Standard deviation of difference of means		± 0.0533	0.0735	0.0658	0.0311	

already been pointed out, to recover the entire amount of the discharge, neither is it possible by the methods used to recover the semen free entirely from the secretions of the female genital tract. But there is no a priori reason to think that the amounts recovered are not proportional to amounts deposited. To measure such small amounts of a thick, viscous fluid, volumetric methods are not feasible, and the record of amounts was, in all but a few cases, obtained by weighing.

The results obtained are shown in table 1. The decrease in volume with advanced services shown by these figures is certainly not pronounced. The means from the different end services and standard deviations of these means are given. The standard deviations of the differences between the means (calculated

by the formula $\sigma x - y = \sqrt{\sigma x^2 + \sigma y^2}$ where x and y represent two different means) are also set down. If an observed difference between two means exceeds three times the standard deviation calculated thus, then the difference can hardly be ascribed to fluctuations of sampling (Yule, p. 346, also 140, Ed. 1916). The means, to be sure, show a continuous decline, but the differences between no two contiguous means, as tested by the above principle, are significant.

If we consider the differences in mean volumes between the 1st and the 15th service, however, we have a decrease for the 15th which is certainly significant. The standard deviation for the difference between the 1st and the 15th means is 0.0420, only about one-fifth the difference between the means. The corresponding figure for the 1st-20th is 0.0329 which is less than one-seventh of the difference between the means. In a very general way our data on volume of semen corroborate the work of others cited with the horse and with man, but it is not to be compared, in significance, with the results quoted on horse, man, and dog, in which cases, the entire discharge may be recovered and in which additions from the female tract may be avoided.

CHANGES IN GENERAL PROPERTIES

Certain changes in general properties of the semen occur when a number of coitus rapidly succeed each other. The semen becomes less viscous and tends to lose its characteristic milky appearance until at the 20th service the fluid recovered is frequently of a thin, watery nature. In other words, under continued stimulation the glands which produce the semen not only show reduced activity, but the quality of their product is changed as well. This change in consistency and composition of semen due to excessive sexual activity has been recorded by other workers. Lode ('91) found that in the case of the dog there was a decrease in specific gravity of semen from 1.014 at the first ejaculation to 1.010 on the third ejaculation in a day, and Lewis ('11, p. 37) reports a decrease in total solids after a stallion had served twice daily for a number of days.

NUMBER OF SPERM PER UNIT VOLUME

A few investigators have made counts of the number of sperm per unit volume of semen recovered after the male has engaged in little or much sexual activity. Conspicuous among these is Lode, who was the first to attempt a precise numerical determination of the sperm content of mammalian semen. He presents two observations on man; in the first case the number of spermatozoa per cubic millimeter decreased from 53,200 at the first copulation to 0 on the third copulation of that day. On a second observation, the number decreased from 56,800 on the first to 19,400 on the second copulation. With a dog, the number of sperm for the first ejaculation was 75,000 per cubic millimeter and fell to 3008 on the fourth ejaculation. With a second observation on the same dog, the numbers were 50,000 on the first ejaculation and 29,000 on the fourth. Still a third count at a later period showed 56,840 on the first and no sperm on the fourth ejaculation. Mantegazza states (Stigler, '14) that in semen of man obtained from the second ejaculation in one hour there were scarcely one-half as many sperm in the same volume as in semen from the first ejaculation.

Iwanoff ('07, p. 494) in writing of a stallion, says that the number of sperm cells decreased greatly during the third and fourth copulations in a day, but he does not give the numbers. Lewis ('11) reports the number of sperm cells per cubic millimeter in the semen from a draft stallion as 131,750 at the first service and 5840 on the ninth service made at the rate of one copulation daily for nine successive days. Another stallion showed 68,500 sperm cells per cu.mm. in semen from the third copulation made in two days and 23,000 per cu.mm. in the twentieth copulation made at the rate of two copulations daily.

The counts reported from our own work do not represent absolute number of sperm per cubic millimeter, but a close approximation to the same, based upon the assumption of 1.0 as the specific gravity of semen. As mentioned, volumetric methods with the very small quantities of this viscous fluid available are not suitable for quantitative work. In practice the whole

TABLE 2

Number of sperm per cubic millimeter in semen from different services

DATE	INTERVAL SINCE LAST SERVICE	1ST	5TH	10TH	15TH	20TH
<i>Male 1</i>						
<i>1915</i>	<i>days</i>					
11-13		244,000				
11-17	4	344,000				
<i>1916</i>						
6-22	4	270,000				
6-28	6	5,000				
6-30	2	220,000	78,000	25,000		
7- 6	37	93,700	27,000	13,000		
7-13	7	126,000	20,750	2,500		
8- 9				1,250		
8-23	14	59,700	37,000			
9-16	15	31,000	26,000	24,000	17,857	
10-13	11	7,140				
11-25	2	6,000				
12- 9	6				800	250
12-22	3	62,000	0			
12-26	4	72,000			440	
1- 1	6	194,000				12,000
1- 4	3	38,000				
1-13	9				1,120	
1-14	1	22,000				
<i>1917</i>						
6-13	43	120,000	6,000	41,000	9,000	5,000
6-18	5	57,000				
6-29	11	140,000		4,000		8,000
7- 9	10	230,000		6,000	400	700
7-16	5	109,000			720	200
<i>Male 3</i>						
<i>1915</i>						
12- 8		235,000				
<i>1916</i>						
7- 3	8	21,250		55,000		
7- 7	4	108,000		13,600		
7-11	4	279,000				
9-26	30	6,250				
10-22	16	7,290	43,740	26,250	10,410	
11- 6	15	66,700	16,300			
12-21	30	10,786	10,700	29,000		
12-30	9	44,000	72,000		300	
12-31	1	47,000				
<i>1917</i>						
1-24	24	26,000				

TABLE 2—Continued

DATE	INTERVAL SINCE LAST SERVICE	1ST	5TH	10TH	15TH	20TH
<i>Male 4</i>						
1916						
6-27	10	230,000	50,000			
6-29	2	3,000				
7- 8	9	191,400	117,500			
9-30	8	8,330				
10- 1	1					
11- 9	24	13,000	5,000	1,300		
1917						
1-10	20	216,000				
1-19	9					107
6-14	30		13,000			
<i>Male 5</i>						
6-15		115,000	35,000	3,000	500	
7-13	28		1,360			1,680
Means.....		104,578	34,886	14,692	4,155	3,492
Standard deviations of means.....		15,318	6,991	3,784	1,840	1,458
Standard deviations of difference of means.....		16,836	7,949	4,206	2,346	

mass of semen recovered was placed into a weighed dish. The weight of semen present was multiplied by 9 and this volume of diluent (Ringer's isotonic solution) was added. In this shape the specimen was used for study of live sperm. To 1 cc. of the fluid prepared was added 1.5 cc. of a 4 per cent Na_2CO_3 solution (the latter mixed with a small amount of saturated alcoholic methylene blue). This gave (on the assumption of 1.0 as specific gravity of semen) a dilution of 25 times which was found to be most satisfactory for 'normal' semen. The Na_2CO_3 broke up the agglutinated masses and the stain made counting easy when a drop of the fluid prepared thus was placed in the ruled counting chamber of a haemocytometer. We did not determine the actual specific gravity of rabbit semen. Lode made some determinations of this kind on dog and man; for the

former he gives the specific gravity 1.0116 (average of 7 specimens) for the latter 1.035 (average of 9 specimens). It is probable that the specific gravity of rabbit semen is slightly greater than 1.0, and that the figures as published here represent slightly less than the true number of sperm per cubic millimeter.

Table 2 presents the numerical data on sperm content obtained in this experiment. There are a great many gaps in the table and the observations seem badly scattered. This is the result, not of erratic methods, but of the vicissitudes and uncertainties of the work. Oftentimes the males would be used up to the 10th or 15th mating and then the female which had given signs of heat would refuse the service. This was the most usual cause of failure to carry the series through to the limit. Again the male (especially the case with No. 3) would fail to proceed with the series as planned. When there are intervening spaces, such, for example, as with female No. 1, January 1, where records are given only on the 1st and 20th services, the cause of failure to make the readings complete was generally due to one of four causes, a lack of sufficient number of females in heat, the recovery in the semen of urine, of blood, or of perceptible amounts of vaginal or uterine secretions which we had not succeeded in removing before service.

The figures obtained, moreover, show wide and apparently capricious variations. For example, in the case of male No. 1, consider the mating on June 29, 1917. After 11 days' rest the numbers on the 1st and 20th services are 140,000 and 8,000, respectively. On July 9th, after another rest interval of about equal length (10 days), the corresponding numbers are 230,000 and 700. In each case the number at the 20th is greatly reduced, but there is yet a strange lack of harmony in the relation of the numbers for the 1st and 20th services. This somewhat erratic nature of the data may perhaps in a measure be considered as due to the variations in mood and condition of the males, but doubtless in larger measure to the unavoidable imperfections in our methods of recovery of the semen and to the small amounts of the same. That is to say that quantities of female secretions so slight as to be by themselves non-recoverable by catheter, might, when recovered with such small quantities of semen, be

of significance in reducing the sperm counts made upon the same.

The averages of all the readings made from all the males at each service have been determined, and they show an unmistakable downward trend, except that, on account of two unusually large figures in the 20th, the decline from 15th to 20th is less marked than in the other cases. However, as measured by the criterion of three times their standard deviations (with this irregular data the use of the customary probable error is certainly not justified), the differences between contiguous means are without significance except in the case of that between the means for the 1st and 5th. The differences between the means of the 5th and 15th or 20th are also certainly significant, but not that between the 10th and 20th. On the whole the mathematical methods of examining the data indicate that heavy sexual use has no very grave effect upon the number of sperm per cubic millimeter. However, the marked lack of regularity in these data demands that caution be used in accepting the arithmetical constants derived from the data as reliable indices of significance of the means and the data as a whole. In such cases a study of the extended figures themselves may actually give a truer meaning of the facts than the usual statistical methods of analysis. There are 22 cases in table 2 where 2 or more counts were made within a single series of matings. In 16 of these there is a marked falling off in sperm content of the semen as the number of services increases; in three cases there is a tendency for an increase of like figures and in three cases there is neither a clear-cut upward or downward trend of the counts as service number increases. It seems to the writers that by reading across the horizontal rows, one after another, one is furnished with almost convincing proof that there is a well-marked reduction in number of sperm per cubic millimeter in the advanced services.

MOTILITY

Motility of sperm cells has attracted as much or perhaps greater interest than the matter of their number. Motion is effected largely by a rapid vibration of the tail piece, but in some cases it appears that a spiral rotation of the entire body may aid

progress. The sperm is oriented by currents which exist in the genital tract, as Kraft showed in 1890 (p. 216). He flooded a piece of uterine mucous membrane from a freshly killed cow with an isotonic salt solution and when rabbit sperm were placed thereon, they were observed to swim rapidly against the currents set up by the cilia of the membrane. Roth recorded a similar observation in 1893 (p. 352).

Pronounced motility may be in most cases accepted as evidence of the fertility of the male, but this is not always the case. For example, Detlefsen ('14, pp. 91-93) found in case of his hybrid guinea-pig males that though the presence of a high percentage of normal active spermatozoa in the fluid obtained from the epididymis was as a rule a very good indication of breeding power, nevertheless 10.2 per cent of such hybrid guinea-pig males were completely sterile though a copious supply of active sperm was present. And Reynolds ('16), after extensive studies on the question of sterility in the human subject, insists that the mere presence of active spermatozoa in the semen of a man is by no means certain evidence of his power to reproduce. He considers that investigations as to fertility, must take into account not only the existence of motility, but the duration of motion and still more the quality of motion present.

In regard to quality of motion, several writers have observed that various categories may be made out. As long ago as 1856, Kölliker in his description of the stimulus which certain substances produce in mammalian sperm, distinguished between an 'axedrehung' and a 'Schlange bewegung,' and Iwanoff ('07) emphasizes the importance of 'mouvements progressifs' in contrast to 'mouvements vibratoires.' But Reynolds' ('16) observations have been much more extensive and his interpretations more suggestive than those of other writers and his work deserves further mention. Reynolds' studies are based upon the examination of 45 specimens of semen from man collected sometimes free from the secretions of the female and sometimes mixed with these secretions. His studies have led him to the 'positive differentiation' of 5 types of motion, 3 of which he considers as

normal, and they appear to be consecutive phases. 1. 'Progressive Vibratile' motion consists of a rapid vibration of the after part of the flagellum propelling the sperm rapidly forward with the head moving practically in a straight line. The direction, in the absence of currents, is random. This type of motion would be well suited for a prolonged journey to the Fallopian tube. 2. 'Undulatory tactile' which normally follows type 1 is characterized by a slow lashing from side to side of the entire tail, causing the head and middle piece to sway back and forth through an arc of sometimes 90 degrees. Only slight linear advance is made in this phase and the path is exceedingly devious. Having arrived at the tube this kind of movement would provide that the sperm 'find' the egg. The sperm at this stage seem to be negatively thigmotactic, having the power to touch and back off from other bodies. 3. The third type succeeds the second and is distinguished by a 'bunting' action of the head and a rapid vibratile motion of the tail when in contact with another body. Reynolds considers that this type enables the spermatozoa to penetrate the egg membranes and to fertilize the ovum. The types of motion which are said to be abnormal will not be considered here.

In our own work we have attempted to consider the type of motion present as well as the rate of motion, but we find it exceedingly difficult to make definite statements in regard to this matter. In a very general way our observations are in harmony with those of Reynolds, i.e., we find that the specimens of semen which show the largest amount of progressive vibratile movement as a rule show the longest duration of motion. But with the semen handled as herein described the essential cyclic nature of the different phases of motion as described by Reynolds is not clearly brought out; for example, even in the sperm of lowest 'vitality' as measured by duration of motion, 'stationary bunting' is the most usual type of motion. Further reference to type of motion will be made in the next section.

RATE OF MOTION

Very few direct observations on the rate of motion of spermatozoa have been made. Bischoff ('42) reports that Henle observed mammalian sperm to move forward in a straight line at the rate of about 0.056 mm. per second. Lott ('72) found that sperm taken from the epididymis of the dog move at the rate of 0.06 mm. per second against a current under a glass slide. Our own work, as will be shown later, indicates a velocity for normal rabbit sperm of about 0.05 mm. per second.

Many observations have been made, however, on the least time interval between the deposit of the semen and its arrival into the upper genital tract. Heape ('05) finds that as a rule sperm of rabbit are to be found at the top of the uterus two hours after copulation and within the folds of the infundibulum two hours later. Coste ('69, quoted by Hensen) states that in the rabbit, sperm are found at the ovaries two and three-quarter hours after copulation. The linear distance from cervix to fimbriae in the rabbit is about 280 mm. But if we wish to estimate the length of the path by which a sperm would cover this total distance by its own motile activity unaided by any other force, we should, on account of its devious lateral meanderings and the intricate folds of the surface over which it must travel, multiply the distance by at least 2. If we now allow three hours as the required time for this journey, the sperm would move at just about 0.05 mm. per second.

Data given by Payne ('14) for the chicken show unusually quick action. He killed virgin pullets at varying intervals after breeding and reports finding sperm at the extreme upper end of the shell gland, a distance of about 650 mm. from cloaca, in one and one-half hours after breeding. Again, if we multiply this distance by 2 and if the sperm travel this distance unaided by other forces, the rate would be 0.24 mm. per second. This is about four times as fast as any direct determinations which have been reported. Obviously, some other force, such as the aspirations of the os and peristalsis of the upper tract (Bischoff, '42, Lott, '72, Heape, '98), is operating, and the interval elapsing

between the deposit of the sperm and the time of its arrival in the upper tract cannot be used in reckoning the rate at which the sperm may move by virtue of its own motive power.

The point on which the present work particularly bears is the influence on the rate of motion, of unusual sexual exercise by the male. Iwanoff has reported data which bear on this point. He ('07, p. 494) mated a stallion which was known to produce sperm of great activity as follows: Beginning August 20, this stallion made two copulations, and August 23, four copulations at intervals of two hours. Sperm from the last three copulations showed very feeble motion (numerical data not given). Stigler ('14, p. 219) states that Mantegazza obtained semen from a man one-half hour after a previous copulation and that the sperm in the same 'mit viel geringer Energie bewegten.'

In making the counts given in this paper the semen was in all cases diluted with 9 volumes of Ringer's solution. In undiluted rabbit semen the sperm are so crowded that a straight-ahead course can be pursued for only a very short distance and the motion is greatly impeded. Moreover, the varying viscosities of natural semens, as Lepinase ('17) states, serve as an external factor to modify the rate of motion. A drop of this diluted semen was placed in the counting chamber of a haemocytometer. This instrument is very well suited for such readings because the graduations make the linear distance covered by the sperm easily determined and there is an abundance of free space in which the cells can move. The observations made on the 'rate of motion' of sperm were always made on individual sperm unencumbered by foreign bodies, showing the progressive vibratile type of motion. A stop-watch was used to determine the time required for a sperm cell to pass over from two to five or six 0.05 mm. spaces on the cytometer. This time interval was set down for a considerable number of sperm on the slide, an average of the results was taken as the correct measure of motility and recorded together with the temperature of the liquid in which the sperm were moving.

Temperature is of course a factor which has a most profound influence upon the rate of motion, and unfortunately this has

TABLE 3

Rate of progressive motion of spermatozoa from different services; millimeters covered per second, and temperature at each observation

DATE	TEMPERATURE	1ST	5TH	10TH	15TH	20TH
<i>Male 1</i>						
1916		mm. per sec.	mm. per sec.	mm. per sec.	mm. per sec.	mm. per sec.
8- 2		0.036	0.063			
8- 9		0.066	0.065	0.038		
8-23		0.052			no prog.	
9-16	14	0.015	0.017		0.031	
10- 2	24	0.038			0.022	
10-13	19	0.020				all dead
11-14	12	0.007				0.0008
11-23				0.0042		no prog.
12- 9					0.009	no prog.
12-26	20	0.038			no prog.	
11-30	18	0.030	0.012			
1917						
1- 1	22	0.030				0.034
1-13	22	0.038				0.027
6-13	27	0.055	0.025	0.031	0.026	0.016
6-18	27	0.030	0.028	all dead		
7- 9	25	0.083		0.042	no prog.	no prog.
7-16	25	0.060				
<i>Male 3</i>						
1916						
8- 1		0.048	0.040			
8-18		0.044	all dead			
1- 6	21	0.026		0.022		
10-22	22	0.021	0.024	0.010	0.066	
11- 6	22	0.029		0.023		
12-21	21		0.010			
12-30	19	0.021	0.021			
<i>Male 4</i>						
1916						
10- 1	no sperm		0.023	0.009		
10-15			0.004	0.016		
10-31	18	0.005		no prog.		
11- 9	16	0.009		0.012		
12-28	19	0.019		0.008		
1917						
6-18	21	0.017		0.022	0.013	
6-14	24		0.035			

TABLE 3—*Continued*

DATE	TEMPERATURE	1ST	5TH	10TH	15TH	20TH
<i>Male 5</i>						
6-15	23	0.030	0.020	0.034	0.010	
6-28	27	0.025		0.040		no prog.
Means		0.033	0.027	0.022	0.025	0.019
Standard deviations of means		0.0034	0.0049	0.0045	0.0068	0.0062
Standard deviations of differences		0.0058	0.0067	0.0081	0.0092	

been a factor which we were unable to control. The diluent, glassware, etc., remained at room temperature, which varied widely by days and by seasons, but almost in every case the readings on the various services of a given series were made at temperatures which did not vary more than one or two degrees. Under the circumstances the best that could be done was to record the temperatures at each reading, and these are set down in the table. Unless at least two readings at different services within a given series were obtained they were not set down in the table, consequently many readings on rate which were made are not there included.

The data on rate of motion are given in table 3. Specimens which showed no sperm making progressive vibratile motion although other types of motion were present are recorded as 'no prog.' The means, their standard deviations and the standard deviations of the differences between contiguous means are set down. The slight downward trend of the mean rates as the service number advances, when studied in connection with standard deviations, is seen to be wholly without significance. In every case, except the 1st and 5th, the standard deviation of the difference between the means is actually greater than the differences themselves, whereas if these differences are to be significant the standard deviations should be not more than one-third the latter. These meager results suggest that a certain velocity is characteristic of progressive vibratile motion. If the energy of the sperm becomes spent so that this velocity cannot

be maintained, they rapidly cease this type of motion and become 'bunters' or 'spiral movers.'

But the fact that the velocity of any sperm which are showing progressive vibratile motion is as great in the latter services as in the earlier ones, considered by itself, does not give a true picture of conditions. For in semen from the earlier services the number of sperm which display this type of motion are more numerous. In specimens from the later services it was often necessary to search over numerous fields before a satisfactory number of progressive movers could be observed; in fact, as the table shows in actually one-half of the cases of 20th service, no sperm of this sort were discovered.

The statements quoted from Iwanoff and Stigler to the effect that in semen from heavily taxed males the motion is 'feeble' or shows 'little energy' do represent the general impression that would result from an examination of such material. But it seems this picture is not the result of a slowing down of the *forward* motion so much as the assumption of different types of motion, such as energetic 'bunting' motion, slow undulatory or rotary motion.

DURATION OF MOTION

The duration of motion of spermatozoa both in the female genital tract and outside the body under laboratory conditions has received greater attention from writers than any other phase of study about spermatozoa. Unless sperm show continued activity for several hours within the female genitalia, they never take part in fertilization. The published facts in regard to the length of time sperm may retain their fertilizing power within the body of the female and motility *in vitro* are numerous and not always in harmony with each other, and no attempt will be made to review them here. Semen held *in vitro* will withstand a wide range of temperatures. Mantegazza (Iwanoff, p. 493) asserts that mammalian sperm retain vitality between $-15^{\circ}\text{C}.$ and $47^{\circ}\text{C}.$, and Iwanoff himself carried semen of horse to a point where it solidified (ca. $-15^{\circ}\text{C}.$) without destroying motion when the temperature was raised, but the same author does admit

that a temperature of 100°C. is fatal to the sperm. The length of time that sperm will retain its motility is largely decided by the temperature at which it is held. Lewis found that sperm from the horse retained motility about twice as long as 1 °C. as at 30°C. Payne ('14) held sperm from cock birds at 34° F. and 106° F., and found that those at the former temperature displayed motility three times as long as the latter. Piersol ('93) kept human sperm at 3°C. and ca. 35°C. The former showed motion at the end of nine days, the latter had ceased moving long before. Therefore, in order properly to interpret observations on duration of motion, it is essential that temperature at which observations were made be reported.

In general it may be said that duration of motion is coincident with duration of life of the sperm, but this is not always true. At low temperatures, of course, contractile motion ceases, but returns upon warming. Stigler's ('14) results also show that high temperatures also cause cessation of motion, which may return on cooling. In one case (Versuch, '45) he repeatedly raised (45.5°C.) and lowered (room temperature) the temperature of a specimen of semen, thus causing repeated cessation and return of motion in the specimen. Hensen ('75) reports some very remarkable results which he obtained in inducing action in sperm which has ceased moving, by application of NaOH and KOH solutions. It is probable also that sperm which appear motionless under the microscope may be activated when placed within the female genital tract.

Observations on the effect of heavy sexual service of the male on the duration of motion of sperm produced by him are few. Lewis ('11, p. 30) allowed a heavy draft stallion to make nine consecutive services on as many days. This he considered heavy service for the stallion in question. The results of this series of services on the sperm content of the semen has been discussed. In the semen from the first service 20 per cent of the sperm were alive after 9.5 hours. In the case of 5th service all cells were dead at 9 hours. In case of 6th service 5 per cent were alive after 5 hours, but in the 9th service no cells were alive after 4.5 hours. (All observations at 21°C. to 23°C.) Lewis also offers

TABLE 4

Duration of motion of spermatozoa as affected by number of services. Percentage moving after various periods of time have elapsed. (All semen diluted with ten volumes of Ringer's solution)

DATE	AVERAGE TEMPERA- TURE	HOURS AFTER RECOVERY	PER CENT ACTIVE				
			1st	5th	10th	15th	20th
Male 1							
1916							
10- 2		16	81			0	
	24	24	34				
10-13	19	0					
		28	80				
		48	70				
			0				0
10-31		16	55	2			
		28	45				
		44	21				
	18	52	0				
11-14	19	28	30				0
12- 9	20	22				0	
12-22		20	0	0			
12-26		2	98			35	
		4	90		40	13	
		8	60		0	5	
		12	33			0	
		16	18				
		20	15				
		28	1				
	19	36	0.5				
		48	0				
1917							
1- 1		0	97				90
		4	95				50
		8	40				10
		16	35				0
		20	32				
		28	10				
	24	32	0				
1-13		0	65			95	50
		2					38
		4	58			44	
		8	41			33	0
		16	35			27	
		20				20	
	23	24	0			0	

TABLE 4—Continued

DATE	AVERAGE TEMPERA- TURE	HOURS AFTER RECOVERY	PER CENT ACTIVE				
			1st	5th	10th	15th	20th
Male 1							
1917							
6-13		0	90		90		50
		8	80	80	40	35	10
		16	2	0	0	0	2
6-18	25	20	2				
		0	45	60			
		4	45	35			
6-29	27	12	5	2			
		0	72		55		55
		4	60		40		
7- 9		8			35		50
		12	50		10		15
		20	1		0		0
7-16		0	80		60	20	85
		4	50			0	
		8	40		35		35
7-16		12	35		30		25
		20	20		0		30
		24	10				10
7-16	29	28	0				0
		0	90		75		75
		4	80		50		30
7-16		8	35		25		0
		12	35		25		
		24	10		0		
Male 3							
1916							
10- 6		16		0			
		20	50				
		24	37	90	83	20	
10-22		40	35	77	38	0	
		44		30	16		
		48	2				
11- 6	18	56	0	0			
		20	0		10		
	22	34			0		

TABLE 4—Continued

DATE	AVERAGE TEMPERA- TURE	HOURS AFTER RECOVERY	PER CENT ACTIVE				
			1st	5th	10th	15th	20th
Male 3							
1916							
12-21		4	0		80		
		16			13		
	19	20			0		
12-30		4	10	35			
		16	0	25			
	22	24		0			
Male 4							
10- 1		20		72	0		
		24		13			
	22	28		1			
10-15		28	0	75	40		
	19	50		0	0		
11- 9		20	75		23		
		24	29				
		40			0		
	17	44	0				
12-28		4	35		50		
		10			18		
		16	5		15		
		20	0		14		
		28			2		
		36			0		
1-10		0	71		77	80	
		4	66		30		
		8			18	15	
		12	45		0	15	
		16	40			0	
		20	40				
		24	19				
		28	0				
6-14		0		55			
		4		30			
		12	24	0			
Male 5							
6-15		0	25	50	90	95	
		4	10	50	40	75	
		8	10	40	20	60	

TABLE 4—*Concluded*

DATE	AVERAGE TEMPERA- TURE	HOURS AFTER RECOVERY	PER CENT ACTIVE				
			1st	5th	10th	15th	20th
Male 5							
1916							
6-15		16	2	0	0	2	
		24	1			2	
	24	28	0			1	
6-28		0	85		30		30
		4	70		20		15
		8			10		0
		12	60				
	25	20	3		0		

data from another series of matings with a different stallion in support of the idea that the vitality of the sperm is reduced when the male is overtaxed but this case is not so demonstrative. Stigler ('14, p. 219) obtained semen from a man two hours after a previous copulation and found that sperm from the latter could successfully resist a high temperature for a longer time than the former. Held at 44.6°C. sperm from the first copulation ceased moving, but remained alive for 1 hour 45 minutes while sperm from the second copulation were killed altogether between 10 and 45 minutes. In our work with the rabbit the duration of motion determinations were made on the specimens prepared for a study of the rate of motion, i.e., the semen was diluted with 9 volumes of Ringer's solution. The conditions under which this work was done do not reduce, but, in fact, as will be shown, prolong the life of the sperm. The parcels of diluted semen were placed into small glass vials with cotton stoppers. These were all placed on the same shelf in the laboratory and were not exposed to direct sunlight, but were exposed to the varying temperatures of the room. On account of this temperature variation the results obtained on different days are sometimes not directly comparable, but the results from a series of specimens obtained within three or four hours of each other may be safely compared among themselves.

Table 4 gives the data on duration of motion, and at the end of each series of observations the 'average temperature' is recorded.

The aim was to make observations at four-hour intervals, but this was approximated in only a very general way; in some cases in the earlier part of the work but a single observation 20 hours or so after the semen was secured was recorded. We have discovered no convenient way in which this data may be condensed or summarized beyond the 'note-book' form in which it is given. An average of the first four-hour interval encountered as one passes downward in each 'service' column, at which no sperm are active, suggests itself as an expression of the average duration of motion at each service. But averages calculated in this way conceal the really significant more rapid dropping off in per cent of active sperm which is unmistakable in the semen from high-service groups. The table can best be studied by reading across the rows set opposite each four-hour interval and comparing the per cent of active sperm in semen from the different services at this number of hours after the several samples were taken. For example, in case of male No. 1 on January 1, 1917, the fresh semen (0 hours) from 1st service showed 97 per cent of the sperm active; from 20th only 90. In the next lower row we see that after standing on the table four hours the 1st service semen showed 95 per cent active, the 20th 50 per cent. At 16 hours after recovery there were 35 per cent active from 1st service, but all sperm were inactive in the specimen from the 20th service. But this more rapid decline in per cent active sperm in semen from more advanced service groups is again by no means universal with the data and in some cases the persistence of activity in semen from 15th or 20th service is fully the equal to that from the 1st (Male No. 1, July 9, for example).

A factor which gravely interferes with the precision of these results is that of bacterial growth and its products. No means to use sterile apparatus were at hand, and in spite of scrupulous cleanliness putrefaction of course eventually set in. In a few cases sperm will continue to move even though odors indicate that degenerative processes are well established, but almost always, motion has ceased before bacterial growth has proceeded thus far. Nevertheless sperm may be influenced by the incipient stages of putrefaction in the fluid and the onset of this process was not under our control.

TABLE 5
Duration of motion-'natural' semen compared with 'diluted'

DATE	HOURS AFTER RECOVERY	PER CENT ACTIVE					
		1st		5th		10th	
		Natural	Diluted	Natural	Diluted	Natural	Diluted
10-13	28	0	70				
	48		0				
11-14	28	15	30				
10-31	16	50	55				
	28	40	45				
	44	0	21				
	52		0				
10- 6	20	30	50				
10-22	24	0	37	22	90	20	83
	44			5	30	0	16
10- 1	20			0	72		
10-15	28	0	0				
11- 9	20	58	75				
	24	21	29				

However, we feel that a study of the data as above suggested will leave one with a decided opinion that there is a well-marked tendency for the sperm in semen from the higher-service groups to show less 'vitality' or 'potential energy,' as measured by the duration of motion which they will display.

Table 5 is inserted here to compare the duration of motion of sperm in semen as it was recovered from the female with sperm in semen diluted with ten volumes of an isotonic solution. The counts of 'per cent active' are much less accurate with undiluted semen than with diluted because of the crowding of the sperm. Moreover, they are so close together that the agitation set up by one active individual may cause several others to appear active, whereas they are not actually of themselves motile. But the point at which all sperm are inactive may of course be determined with as great accuracy in one case as in the other.

Though the table is not extensive, the deduction to be made from these figures is plain; namely, that sperm in diluted semen display a longer duration of motion than sperm in 'natural' semen. The probable cause of this phenomenon is that in the

TABLE 6

Matings and resulting pregnancies from the various end services

MALE NUMBER	1ST			5TH			10TH			15TH			20TH		
	Total matings	Pregnancies	Per cent pregnancies	Total matings	Pregnancies	Per cent pregnancies	Total matings	Pregnancies	Per cent pregnancies	Total matings	Pregnancies	Per cent pregnancies	Total matings	Pregnancies	Per cent pregnancies
1	17	11	64.70	9	7	77.77	12	6	50.00	12	6	50.00	26	10	38.46
3	14	12	85.71	15	9	60.00	11	6	54.54	5	2	40.00			
4	12	8	66.66	12	6	50.00	12	6	50.00	12	4	33.33	19	6	31.57
Total	43	31	72.09	36	22	61.11	35	18	51.42	29	12	41.37	45	16	35.55

natural semen the by-products of the metabolism of the sperm, and also of the developing bacteria more quickly reach a concentration that is deleterious or even fatal to the sperm. Whether the fertilizing power of the sperm is diminished by this dilution is a matter for further study. Certainly it is not completely destroyed, for Iwanoff reports inseminating rabbits with semen diluted with a weak Na_2CO_3 solution, with resulting pregnancy.

CERTAINTY OF PREGNANCY

In the previous sections of this paper we have shown that excessive sexual service causes decrease in amount of ejaculated semen, decrease in number of sperm cells per cubic millimeter, decrease in the proportion of sperm that show progressive motion, and decrease in duration of motion. All these changes are such as to reduce the likelihood of such semen causing pregnancy of the female. In other words, we should expect the percentage of pregnancies induced by the copulations to become less as the number of preliminary services increases. This is in truth found to be the case as shown in table 6.

The decline proceeds with fair regularity whether we consider the males separately or together. This reduction in the per cent of effective matings when the male is sexually overworked is recognized by those engaged in animal breeding as one of the

TABLE 7
Size of litters at different services

MALE NUMBER	1ST		5TH		10TH		15TH		20TH	
	Num- ber litters	Aver- age size	Num- ber litters	Aver- age size	Num- ber litters	Aver- age size	Num- ber litters	Aver- age size	Num- ber litters	Aver- age size
1	6	6.66	6	6.00	7	7.71	7	5.85	11	4.27
3	11	6.50	8	5.75	7	7.57	2	10.5		
4	8	7.75	6	6.16	6	5.33	4	5.5	6	5.00
All males....	25	6.92	20	5.95	20	6.95	13	6.46	17	4.53

most noticeable and universal concomitants of heavy sexual service, but there is great divergency of opinion as to how frequent or how many copulations constitute 'heavy service' with various classes of domestic animals. Apparently in bringing about twenty services in three or four hours we have approached a point which for the rabbit seriously curtails his ability to produce offspring, and furthermore we have demonstrated in large part what is the direct basis for this curtailment.

SIZE OF LITTER

Having observed the described changes in the vital properties of the sperm in semen from advanced services, and also what is probably in large part a result of the same, namely, the reduced likelihood of pregnancy resulting from the more advanced services, it would seem a priori to follow that the number of young per litter would likewise undergo a reduction as the number of copulations increases. Table 7 presents the facts in regard to this matter.

Inspecting the columns up and down reveals no superiority of one male over another. Inspecting the horizontal rows reveals no marked effect of number of copulations on litter size; in fact, it may be questioned if it reveals any significant reduction. Certainly any falling off in litter size up to the 15th service is impossible to detect by inspection, but a very perceptible drop occurs between the 15th and 20th service.

TABLE 8
Relation between size of litter and number of previous services

SIZE OF LITTERS	NUMBER OF SERVICES					
	1st	5th	10th	15th	20th	Total
1		1	1	2	1	5
2	1	1		2	4	8
3		2	1		4	7
4					2	2
5	3	3	2	1	1	10
6	7	6	3			16
7	6	2	4	1	2	15
8	5	3	4	2	1	15
9	1		4	2		7
10	3	1		2	1	7
11		1	1		1	3
12				1		1
	26	20	20	13	17	96

Correlation coefficient = -0.2207 ± 0.06526 .

Table 8 shows the complete distribution of the litters on the basis of size arranged as a correlation table. The coefficient of correlation calculated from this table is -0.2297 ± 0.0653 , a figure which, though over three times its probable error, is yet of rather questionable significance. An inspection of the table, however, shows up a marked preponderance of small litters in the 20th service. If it is true that the critical number of services, so far as decreasing the number in the litter is concerned, is between the 15th and the 20th service, then of course the above method of determining the correlation between frequency of copulation and number in litter is not valid, for in this case the 20th, as one group, should be compared with all others as another group, and not be considered as one of five coordinate groups. In table 9 the first four columns of table 8 are combined and the percentage of the total litters in each group which are of a given size calculated.

The preponderance of small litters in the 20th-service group is thus revealed. If we condense the data still further into a four-fold classification, we find that in the 1 to 15 group 25.32 per cent

TABLE 9

Size of litter in 1st to 15th service group compared with 20th

SIZE OF LITTER	1-15		20	
	Number of litters of given size	Per cent of litters of given size	Number of litters of given size	Per cent of litters of given size
1	4	5.06	1	5.88
2	4	5.06	4	23.53
3	3	3.80	4	23.53
4	0	0	2	11.76
5	9	11.39	1	5.88
6	16	20.25	0	
7	13	16.45	2	11.76
8	14	17.72	1	5.88
9	7	8.86	0	0
10	6	7.59	1	5.88
11	2	2.52	1	5.88
12	1	1.28	0	0
Total.....	79		17	

of the litters were five or less in size, whereas in the 20th-service group 70.58 per cent of the litters were five or less in size. In spite of the fewness of the 20th-service litters, there seems to be a presumption in support of the idea, that by the time a male rabbit has performed twenty copulations within the space of three or four hours he is less able to beget large litters than when he has performed fewer than fifteen services within the same space of time.

When we consider in relation to each other the facts shown by tables 6 and 7 we are confronted by something of a puzzle. We have interpreted the facts shown in table 6, in part at least, as a direct consequence of the facts shown in the previous tables, i.e., that when the volume of semen, the number of sperm per cubic millimeter, the amount of progressive activity and the potential duration of motion of the sperm are all reduced, then the likelihood of spermatozoa reaching and penetrating the ova is reduced, and therefore the per cent of pregnancies is diminished. Table 6 shows a fairly regular and consistent decrease in certainty of pregnancy as sexual service increases. Now, as mentioned above, those circumstances which decrease the like-

lihood of pregnancies should a priori reduce in almost like degree the size of those litters which are produced. But table 7 does not by any means indicate such a regular and consistent decrease in size of litter. In fact, up to the 15th service there is no perceptible falling off in litter size whatever. It is possible of course to form hypotheses to account for this condition of affairs, but at this time we know of no sound basis on which this discrepancy between tables 6 and 7 may be satisfactorily dealt with.

There exists considerable discussion, but so far as the writers know, no carefully controlled experimentation to the effect that in multiparous animals the male is without influence on litter size; the millions of sperm supplied by any 'normal' male at a single ejaculation will, it is said, be more than ample to impregnate the ova liberated. Our own work indicates that for rabbits there is at least one condition, i.e., performing twenty services in a short time, under which 'normal' males may be unable to bring about complete development of the full quota of ova liberated by the female. It is not inconceivable that the reproductive system of supposedly and apparently 'normal' males may be chronically in a condition analogous to that brought about in this experiment by excessive sexual service.

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