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THE REPRODUCTIVE ORGANS AND SEMEN OF THE BOAR

FRED F. MCKENZIE, J. C. MILLER, and L. C. BAUGUESS

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The Missouri Agricultural Experiment Station and the Bureau of Animal Industry, United States Department of Agriculture, Co-operating.

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ABSTRACT

Data on the anatomy and physiology of the reproductive organs from 13 yearling boars are presented. The histological structure of the various accessory sex glands is described. Semen from normal boars and from boars whose accessory sex glands had been removed surgically was studied physically and chemically. The effects of frequency of ejaculation on the quality and quantity of semen is reported.

The seminal vesicles are large pyramid shaped glands whose total weight ranged from 150 to 843 grams, contained from 40 to 500 grams of gray, opaque, medium viscous fluid with a pH of 6.7 and contribute 15 to 25 per cent of the semen volume. The Cowper's glands are firm, cylindrical bodies 12 to 15 cm. in length and 3 to 5 cm. in diameter. They are compound tubulo-alveolar glands, secrete a thick, white, waxy material having a pH of 7.2 and contribute 10 to 20 per cent of the semen volume. The body of the prostate gland weighs approximately 20 grams, is a firm multilobular, compound tubulo-alveolar gland, without apparent storage space and contained no liquid which could be expelled by pressure. The pelvic urethra is 20 to 25 cm. long and weighs 100 to 150 grams, about half of which is compound tubular gland tissue. The secretions of the prostate and urethral glands are clear, slightly viscous, have a pH of 8.0 and together contribute 55 to 70 per cent of the semen volume. The epididymal fluid is milky white, has a pH of 6.9, contains about 5,000,000 sperm per cu. mm. and contributes 2 to 5 per cent of the semen volume.

The seminal vesicles contribute most of the potassium, phosphorus, total nitrogen and all the glucose in the semen. Cowper's glands contribute most of the sodium, calcium, magnesium, and also considerable nitrogen. Epididymal fluid is rich in phosphorus and total nitrogen. Prostatic and urethral secretions are the source of most of the chlorides in semen. The composition of the prostate and urethral secretions is quite unlike that of blood serum and plasma.

The volume of semen normally varied from 125 to 500 cc. and the number of sperm ranged from 5 to 300 billion per ejaculate. Repeated ejaculations at intervals of 24 hours or less reduced semen volume below 200 cc., reduced the number of sperm to 2-20 billion per ejaculate, reduced duration of sperm motility and increased the number of abnormal sperm forms. Sperm with a cytoplasmic cap appeared after extreme sexual activity.

Removal of the accessory sex glands did not affect libido or reduce fertility in the boars. Castration had little immediate effect on libido. There was no regeneration of tissue following removal of the accessory glands.

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Introduction

The growing interest in artificial insemination in farm animals, together with the ever present problem of sterility has focused attention on factors affecting fertility in the male. Recent investigations have shown that sterility in one form or another is just as common in males as it is in females, and that the means of combating it are equally as complex. Definite information on the anatomical and physiological limitations of the reproductive organs of an animal is essential to an understanding of his breeding capacity.

Certain ideas have prevailed for generations regarding the function of the various male accessory sex glands, but exact information on the quantity and quality of their secretions and the roles they play in insemination and fertilization is limited. While the general structure of the male genitalia is common to all mammals, differences peculiar to the species exist. Such differences in form and function must be recognized in order to understand the physiology of reproduction in the species concerned.

Because of his large accessory glands, the great volume of his semen per ejaculate and the relative ease of collecting semen from him, the boar is well adapted to a study of this nature. The investigation herein reported deals with the anatomy and physiology of the reproductive tract of the boar. Physical and chemical analyses of seminal fluids are included.

REVIEW OF LITERATURE

Anatomy

The first detailed description of the genitalia of the boar was published by Sisson in 1910. This work has since been revised, the last revision appearing in 1921. In addition to the more common knowledge of anatomy, Sisson stated that the seminal vesicles in the adult boar are 12 to 15 cm. long, 5 to 8 cm. wide, 4 to 5 cm. thick, and weigh 6 to 8 ounces. The secretion was described as thick and turbid with an acid reaction. The bulbo-urethral glands (Cowper's)

are large and dense and reach a length of 12 cm. and a diameter o 2 to 3 cm. in a large boar. The prostate consists of two parts: th body which is 2.5 cm. wide and overlaps the neck of the bladder and the pars disseminata which surrounds the pelvic part of th urethra, throughout its length of some 15 to 20 cm. The prostati ducts are numerous and small. These accessory glands are ver small in animals which have been castrated early. Sisson also de scribed eight efferent ducts joining the rete testis to the head of th epididymis. He found no ampulla in the vas deferens, and de scribed separate openings in the pelvic urethra for the vasa and sem inal vesicle ducts, but stated that the ducts may unite.

Hunter (1792) described the seminal vesicles of the boar as fol lows: "In the boar these bags are extremely large and divided int cells of considerable size; or they may more properly be said to form ramifications closely connected with one another and having a large canal duct common to all". . . . "The ducts contain a whitish fluid very unlike what is found in the vasa deferentia of the same animal with which they have not the least communication."

Schmaltz (1911) described the seminal vesicles as two large struc tures lying caudally over the pelvic urethra united into one body by connective tissue. Each lobe has up to six ducts that unite into one excretory duct of 2 mm diameter which duct is lateral to the vas def erens. The same author described the Cowper's glands as of cu cumber shape surrounded by a red muscle, each lobe having its ex cretory duct situated some 2 cc anterior to the caudal end. Each lobe has often a diameter of 5 cm and is branched within the outer covering giving four sacs—two with large and two with small lumi na. The excretory duct enters the dorsal wall of the urethra.

Schmaltz described in some detail the microscopic anatomy of these organs. The prostate of the boar is described as containing fewer muscle fibers than that of the stallion or ruminants, since in the boar the prostate is surrounded by the muscles of the urethra. He further stated that all glands in the walls of the urethra have to be considered as parts of the prostate. He was inclined to think that the glandular lobes are not numerous though they do appear throughout the entire length of the penis. These glands open into the urethral lumen through its ventral longitudinal fold. The body of the prostate has no large excretory duct. Schmaltz further point ed out that the upper portion of the vas deferens is glandular inas much as in that portion lying over the bladder the epithelium begins to form folds that branch out.

Schmaltz has described the testes of the boar as having a tunica

albuginea 0.75-1.5 mm thick, containing large blood vessels. The mediastinum occupies the central part of the organ and has a diameter 3-7 mm. It is compact and contains considerable connective tissue with muscle fibers. There are 7-8 efferent ducts constituting the beginning of the caput and these are separated by a great deal of connective tissue. (Note the number of efferent ducts reported in the present investigation varies from 1-5. See page 27). Each efferent duct is 200-300 micra in diameter. This diameter decreases to 100 micra toward the ductus epididymis. The ductus epididymis itself is approximately 600 micra in diameter.

Bourdelle published in 1920 a well illustrated description of the reproductive tract of the boar. He described common ejaculatory ducts entering the urethra, carrying the materials from the epididymis and the seminal vesicles. He also described a mucous fold surrounding the lumen of the urethra pierced by a great number of glandular orifices. He did not mention the activity of the glands. The prostate was described as having a small volume, and the Cowper's glands were described as large and massive.

Baker (1927) studied the influence of age at castration on the size of various organs in pigs. He observed that the seminal vesicles and Cowper's glands were much larger in pigs castrated at 200 days than in those castrated at 100 days. There was little or no difference in the size of these glands in pigs castrated at 50 and 100 days. Uncastrated pigs, slaughtered at the same age as the castrated ones had much larger seminal vesicles and Cowper's glands. A summary of his results are listed in tabular form.

WEIGHT OF SEMINAL VESICLES AND COWPER'S GLANDS OF PIGS CASTRATED AT DIFFERENT AGES (BAKER'S DATA)

Age at Castration	Age when Slaughtered	Body Weight	Weight of Sem. ves.	Weight of Cowper's gl.
(days)	(days)	(kg)	(gm)	(gm)
50	302	97.2	1.44	2.53
100	301	85.5	1.46	2.95
200	301	85.0	9.00	12.60
not castr.	302	89.0	317.00	117.00

The author suggested that there is a change, beginning at about 100 days of age, rendering these glands progressively more and more sensitive to the male hormone. The size of thyroid, pineal and pituitary was not significantly affected by the age of castration.

Phillips and Andrews (1936) observed that the first marked development of the germinal epithelium occurred at about 84 days of age in the boar, and spermatozoa were first found at 147 days. These observations coincide with those of Baker as to the age when sexual maturity is approached, and indicate that with the onset of spermatogenesis, the testis hormone is released in sufficient quantity to

stimulate marked growth of the accessory glands, or that they are sensitized to the male hormone simultaneously with the initiation of spermatogenesis.

From an examination of pig fetuses, one normal boar, and castrates, Passantino (1934) reported the presence and glandular activity of seminal vesicles. In the boar each measured 14 x 6 x8 cm. and together weighed 250 grams. Castration reduced their size and weight, the degree of reduction being associated with age at castration.

Aside from the brief descriptions given by Sisson and Bourdelle, and the more detailed report of Schmaltz, the histology of the reproductive tract of the boar has not been studied. The histology of the reproductive organs in man and in certain laboratory animals has been rather completely described in the literature, and is too generally accessable to justify a review here.

Physiology

The function of the testis, epididymis, vas deferens, and penis are so well known that a review of that literature does not seem necessary except for brief discussions on cryptorchidism and castration. Information concerning the functional activity of the accessory sex glands is somewhat obscure and numerous species differences both in form and function have been described in the literature.

In a study of the modifying effect of cryptorchid testes on the homologous accessory sex glands in swine, Nordby and Gildow (1933) found the prostate 25 per cent, the seminal vesicles 26 per cent and the Cowper's glands 21 per cent larger in boars than in comparable cryptorchids. The testes were more than twice as large in the boars. The authors believe both basic and specialized sex cells of the seminiferous tubules play a part in controlling development of the accessory sex glands.

Castration of farm animals is practiced, not only to prevent mating of undesirable individuals, but also to prevent the development of secondary sex characters which are undesirable in the production of market meat animals. Although not so generally known, castration also arrests the normal development of the accessory sex organs. Investigations on laboratory animals have demonstrated the striking dependence of growth and secretory activity of the accessory sex glands on the presence of the testes. So sensitive are these glands in certain animals to secretions from the testes that they have come to be used as indicators for the assay of male hormones. A few examples will serve to illustrate the relation of the accessory sex glands to the testes.

Using rat prostate and seminal vesicle cytology as testis hormone indicators, Moore et al. (1930) were able to prevent castration changes and repair castration damage by testis extract injections.

Working with ferrets, Allison (1932) observed a marked increase in size and secretory activity of the testis, epididymis and vas deferens during the breeding season.

Winters (1933) observed that unilateral castration of albino rats did not affect the height or activity of the epithelial cells of the epididymis. Bilateral castration however, showed effects within five days, and secretory activity was completely stopped by 20 days after castration. The epididymides of bilaterally castrated immature rats remained immature while unilateral castrates developed mature epididymides.

Although there was extensive degeneration of seminiferous tubules following ligation of the vasa efferentia in the rat, White (1933) reported no histological changes in the accessory reproductive organs, indicating no decrease in testis hormone output following the operation.

In a study of the normal development of the prostate and seminal vesicles of the rat, with experimental post-natal modifications, Price (1936) found that castration at 2 to 6 days of age inhibited seminal vesicle growth partially, and differentiation completely. The prostate continued to grow and develop to about 30 days of age before regression began. Castration at 30 days or later brought about rapid prostate atrophy. Male hormone injections in young castrate rats produced precocious differentiation in prostate and seminal vesicles.

By daily subcutaneous injections of synthetically prepared androsterone (male hormone) Moore and Price (1937) were able to maintain secretory function and normal growth rate of prostate and seminal vesicles in castrate male rats. Castration damages were repaired in prepuberal and postpuberal castrates.

Although dependent on the testes for normal growth and functioning, the accessory sex glands lack the power of regeneration. By removing one of the glands, Shih (1934) demonstrated the absence of compensatory hypertrophy of the Cowper's glands in the albino rat.

According to Marshall (1922) the earlier views ascribed to the seminal vesicles the function of receptacles or storehouses for the spermatozoa before ejaculation, hence their name. Investigations, however, have failed to bear out this opinion for in most species spermatozoa are not found in the seminal vesicle fluid. The early

work of Hunter (1792), Lode (1895), Steinach (1910), Schmaltz (1911) and Marshall (1922) demonstrated the secretory function of the seminal vesicles as their chief purpose. Hunter maintained that the fluid in the seminal vesicles is not like semen, either in color or odor, and that "the bags called seminal vesicles are not seminal reservoirs but glands secreting a peculiar mucus," and "the use of vesiculae in the animal economy must, in common with many other parts, be dependent upon the testicles." Schmaltz said of them that their secretion is of acid reaction.

Early ideas differed on the function of the prostate. Some investigators believed prostatic fluid essential for cleansing the urethra of urine prior to ejaculation. Others believed its chief function was to activate the spermatozoa. Still others believed the prostatic fluid to contain a ferment which was responsible for the formation of the vaginal plug "bouchon vaginal," in rodents. Later investigations have done little to clarify these conflicting opinions except to disprove them in whole or in part. Beyond the fact that it contributes additional fluid to the semen, little is known regarding the function of the prostate.

Information on the function of the Cowper's glands is equally confusing. To the viscous secretion of these glands has been given the function of neutralizing the acidity of the urethra and vagina caused by urine, and of the formation of the vaginal plug.

Marshall suggested that the urethral glands, or glands of Littré (or Morgagni as they are called in man) probably serve the same purpose as Cowper's glands.

Semen Studies:—Lewis (1911) kept boar sperm motile 15-25 hours at 30° C. He found that they remained motile longer at lower temperatures and that sunlight was detrimental to sperm vitality. He suggested the probability of poor breeding qualities in semen with low sperm motility.

Rodolfo (1934 a) made a study of the semen of boars under different mating frequencies. He found no consistent difference in the spermatozoa of the first mating and subsequent matings. There was a great variation in volume and total number of spermatozoa per ejaculate but no correlation between them. The average number of sperm per ejaculate from a number of boars was 78.3 billion. The author believed the total number of sperm gave a rough measure of the fecundity of the boar, and that poor fecundity probably meant poor fertility. From these data, he suggested that a boar should not be used until he was 14 months old and then only slightly, and that intensive matings should be delayed until the boar was two

years old or more. He believed matings should not be allowed more frequently than once a day, with two days rest following two days matings.

In studying the mating behavior of the boar, Rodolfo (1934 b) observed that sexual attraction played an insignificant role, and that boars mounted dummy sows just as readily as they did real sows. He reported that the length of the entire female tract might reach 3.5 meters (including both uterine horns) and believed the large volume of semen ejaculated by the boar directly into the cervix was necessary for carrying the sperm the considerable distance they must travel. The thick, sticky white substance which came at the end of the ejaculate formed the vaginal plug, which the author believed was essential for retaining the volume and producing a pressure which washed the semen to the distal ends of the uterine horns.

From a study of boar sperm morphology, Rodolfo (1934 c) described three types of spermatozoa; type 1, which had no protoplasmic drop; type 2, where the drop was on the neck, and type 3, where the drop was toward the middle of the tail. He believed these types represented successive stages in their development. All of the sperm in the proximal end of the epididymis were of type 2 and were transformed into type 3 and finally into type 1 which was predominant in semen. Motility was greatest in type 1, less in type 3; and type 2 sperm which were found in the proximal end of the epididymis were all nonmotile. Intensive mating did not alter the relative numbers of the three types.

In efforts to obtain the bulk of the spermatozoa with the minimal contamination from the accessory secretions, Rodin (1934) collected the ejaculate of boars in glass vials, changed every 15 seconds. On data from 18 ejaculates he distinguished three phases. Phase one lasted 0.5 to 1.5 minutes, consisting of about 20 cc. of urine-contaminated liquid containing few sperm. The second phase lasted 1.5 minutes, consisted of over 100 cc. of semen and contained some 34 billion sperm. The highest sperm concentrations were found in the first fractions of this phase, and sperm in those fractions remained motile much longer than sperm in the low concentration fractions. The third phase lasted 2.5-5 minutes in which 164 cc. containing 2.2 billion sperm were ejaculated. The author stated that the seminal vesicles contained 140 cc., the Cowper's glands 55 cc. and the prostate 1 to 4 cc. of glandular secretion.

Rodin (1935) used the high sperm-containing fractions secured in the first part of the second phase plus a diluent for artificially in-

seminating sows, with satisfactory results. Later he used whole undiluted semen with the gelatinous or tapioca-like material strained out with equally good results. He recommended diluting boar semen four times and using doses of 100 to 150 cc.

After comparing the breeding records of boars with their sperm morphology, Phillips (1935) concluded that the sperm morphology of a boar could be taken as an indication of his fertility. Semen from fertile boars did not exceed 200 abnormal sperm forms per 1000. Abnormal forms ranging from 200 to 500 per 1000 occurred in semen from boars which produced small litters, dead and mummified fetuses, or from boars which failed to settle their sows.

Milowanow (1936) stated that in boars the presence of 30 per cent pathological sperm forms had to be regarded as normal because it did not cause a reduction in fertility.

McKenzie and Phillips (1934) studied the morphological appearance of ram sperm in relation to their fertility. Williams and Savage (1927) reported correlations between fertility of bulls and the morphology of their spermatozoa. Lagerlöf (1935) stated that the number of abnormal sperm should not exceed 180-200 per 1000 in semen of good breeding bulls. He believed the protoplasmic drop to be an indication of immaturity, and its location on the head, mid-piece or tail to be a measure of the degree of immaturity. He observed the drop on or near the head of sperm in the proximal end of the epididymis, on the mid-piece in the body of the epididymis and on the tail or absent on sperm in the distal end of the epididymis.

After conducting a rather thorough study on the relation of sperm morphology to human sterility Moench and Holt (1931) concluded that abnormal sperm heads should not exceed 19-20 per cent in normal semen, that impaired fertility occurred when the number reached 20 to 23 per cent, and that sterility was usually present when the number of sperm-head abnormalities exceeded 25 per cent.

Chemical Properties of Semen:—The growing interest in artificial insemination in this country and abroad and the ever present problem of sterility in farm animals have stimulated investigations in the chemistry of semen.

Nesmeianowa (1936) reported the results of a study of the mineral components of boar semen, seminal vesicle, and epididymal fluids, especially sodium, potassium, and calcium. Semen was collected in separate vials and divided into five fractions according to the sperm concentration. The first fraction averaged 33 cc. and consisted of clear liquid secretion and a small quantity of formative elements which were chiefly epithelial cells and fat droplets. The second or

intermediate fraction averaged 17.5 cc., contained glandular secretions, and some spermatozoa. The third fraction averaged 47.5 cc. and was the sperm-containing fraction. The fourth, or second intermediate fraction averaged 26.2 cc., contained secretion, and a great many sperm. The fifth fraction averaged 58.7 cc., contained a few sperm, and was cloudy and thick. Throughout the course of ejaculation a thick tapioca-like material (secretion of the Cowper's glands), which was separated from the semen and not included in the analyses, was expelled. Only the first, third and fifth fractions of semen were analyzed. Seminal vesicle fluid was obtained from slaughter house material. Two to ten cc. of fluid were obtained from both of the epididymides. Chemical determinations were run on centrifuged material.

Results of the analyses are shown in Table 1.

TABLE 1.—THE MINERAL COMPONENTS OF BOAR SEMEN. (NESMEIANOWA, 1936)

	Calcium	Sodium	Potassium	Na/K
	mgm. per cent			
Semen fraction 1	5.77	311.8	54.2	5.75
Semen fraction 3	8.88	284.5	99.8	2.85
Semen fraction 5	5.77	305.2	56.1	5.44
Epididymal fluid	9.17	97.0	245.8	0.39
Seminal ves. fluid	9.44	62.7	167.0	0.49
Blood serum	9.57	358.9	24.6	13.00

The average number of spermatozoa in the epididymal fluid was 4,396,000 per cu. mm. Sperm were not found in the secretion of the seminal vesicles. From a study of the chemical data it is evident that a considerable dilution of the epididymal and seminal vesicle fluids took place during ejaculation. The author concluded that the ejaculation of the boar was not produced chiefly through the secretion of the seminal vesicles. He ruled out the Cowper's glands because of the nonliquid nature of their secretion. He believed the prostatic secretion activated the sperm, but its function needed more study. Based on the results of his study, he concluded that the chief bulk of the ejaculate was formed by a diluting process of the semen through a fluid from the epididymis that is similar in its composition and proportion of electrolytes to blood. He believed the seminal vesicles participate in a small way in forming the ejaculate or else their secretion was modified greatly during ejaculation. The seminal vesicle fluid was found to be rich in protein, in fact, 2 to 5 times as high as the semen fractions. The epididymal fluid also contained more protein than semen. The efficacy of Nesmeianowa's chemical procedure may be questioned, certainly his report does not refer to any attempt on his part to check the accuracy of his analytical chemical methods.

Shergin (1935) found semen of most animals had a weak alkaline reaction. The pH values determined electrolytically with a quinhydrone electrode were: man, 7.79; drake, 7.25; bull, 6.74; ram, 7.08; rabbit, 7.20; stallion, 7.23; and boar, 7.57. Semen was usually more acid than blood of the same species. Semen became acid or nearly so when active glycolysis occurred. During storage, bull and ram semen shifted one pH unit to the acid side while boar semen shifted one pH unit to the alkaline side.

Schersten (1936) found citric acid in the semen of man, bull, boar, rabbit, and guinea pig to the extent of 180-410 mg. per cent. He did not establish its physiological significance in semen beyond the fact that it prolonged the survival time of sperm when added to physiological saline or Ringer's solution in concentrations not exceeding the physiological limits.

In studies on the physiology of spermatozoa, Bernstein (1933 a) observed that the presence of nutrient substances in semen did not increase the time of survival of spermatozoa. He believed spermatozoa to have a very high resistance to pure solvents containing a single neutral salt or sugar.

Bernstein and Slovachotov (1933) found that fresh ejaculates of man and bulls contained 40 to 50 mg. per cent of lactic acid. The content increased in stored semen. Sperm motility gradually decreased, but complete cessation occurred at different lactic acid levels.

Bernstein (1933 b) also studied glucose metabolism in semen. He found glucose present to the extent of 300 mg. per cent in bull semen, 116 mg. per cent in dog semen and 82 mg. percent in stallion semen. Glucose was present both in the sperm and in the seminal fluids. The concentration in stored semen remained constant in the sperm but fell in seminal fluids. There was a very slight fall in glucose in fluids freed of sperm by centrifuging. The author suggested that spermatozoa can metabolize glucose contained in the seminal fluids.

Goldblatt (1935) studied the constituents of human seminal plasma. He found urea present in concentrations twice that of blood, averaging 72 mg. per 100 cc. Seminal fluid also contained 2 to 3 times as much reducing substances as was found in blood. He believed sugar to be a nutrient for sperm and demonstrated a fall in glucose and a rise in lactic acid in stored semen when the sperm were kept alive. He found the seminal vesicles to be the source of sugar. Prostatic fluid had no reducing power.

Huggins and Johnson (1933) presented results of a study of hu-

man seminal fluids. They found no inorganic phosphorus or glucose in spermatocele fluid. Semen contained large amounts of glucose, calcium, acid-soluble phosphate, and relatively small amounts of chloride. Vasectomy had little effect on the composition of semen. Seminal vesicle fluid contained about the same amounts of glucose and phosphorus as semen and was believed to be the chief source of those substances in semen. Prostatic fluid contained very little reducing substances and about the same level of acid-soluble phosphate as is present in blood. The authors believed vasectomy might lead to inhibition of release of the prostatic secretion.

Iljasow (1933) studied the creatine, creatinine, and phosphate contents of seminal fluids. He found human semen highest in acid labile phosphates (29.9 mg. per cent), and less in the semen of the bull, dog and stallion. Creatine was present in semen at the level of 13.9 mg. per cent and creatinine at 3.22 mg. per cent. There appeared to be a relation between the duration of sperm motility and the decomposition of creatine-phosphoric acid.

From his study of glycolysis and motility of spermatozoa, Ivanov (1935) concluded that motility of spermatozoa did not depend on glycolysis.

Killian (1933) reported that fresh human semen, contained 4 to 6 times as much sugar as normal blood and 5 times as much lactic acid. During incubation at 38°C., there was a constant fall in sugar and a corresponding rise in lactic acid as long as the sperm remained motile. Semen normally contained 60 mg. urea per 100 cc. Changes in pH between 5.0 and 8.0 had no effect on motility, but maximum depression occurred beyond those limits. For best maintenance of motility, the author suggested a medium containing 0.5 M. glucose buffered by phosphates between pH 7.4 and 7.8.

McCarthy et al. (1928) presented chemical analyses on human prostato-vesicular secretions. The average composition of semen in mg. per 100 cc. was: total nitrogen, 365; urea N, 50; creatinine, 5.5; chlorides as NaCl, 231; calcium, 66; inorganic phosphorus, 95; and glucose, 136. The sugar content varied but exceeded greatly that in blood. The amount of lactic acid formed during glycolysis did not account for all the glucose lost.

In the light of the varied observations referred to above it is evident that additional investigations are necessary to establish the functional activity of the several accessory sex glands and the role they play in the physiology of spermatozoa. What is the nature of the secretions from the seminal vesicles, Cowper's glands, urethra, prostate, and epididymides, and what is the volume of their separate

contributions to the semen? In what order are they thrown into the semen during ejaculation? Are they essential for fertility in the boar, and if so what part do they play in activating or preserving the life of the sperm? What are the effects of frequency of service on the quality and quantity of semen from the boar? Experiments designed to answer some of these questions have been conducted and the observations are reported in this paper.

MATERIALS AND METHODS

Ten Chester White (purebred) and three Duroc Jersey (purebred) boars, ranging from 12 to 16 months of age were used in this investigation. The Chester White boars were bred by the Department of Animal Husbandry, College of Agriculture, University

Fig. 1.—The boars used in 1936.

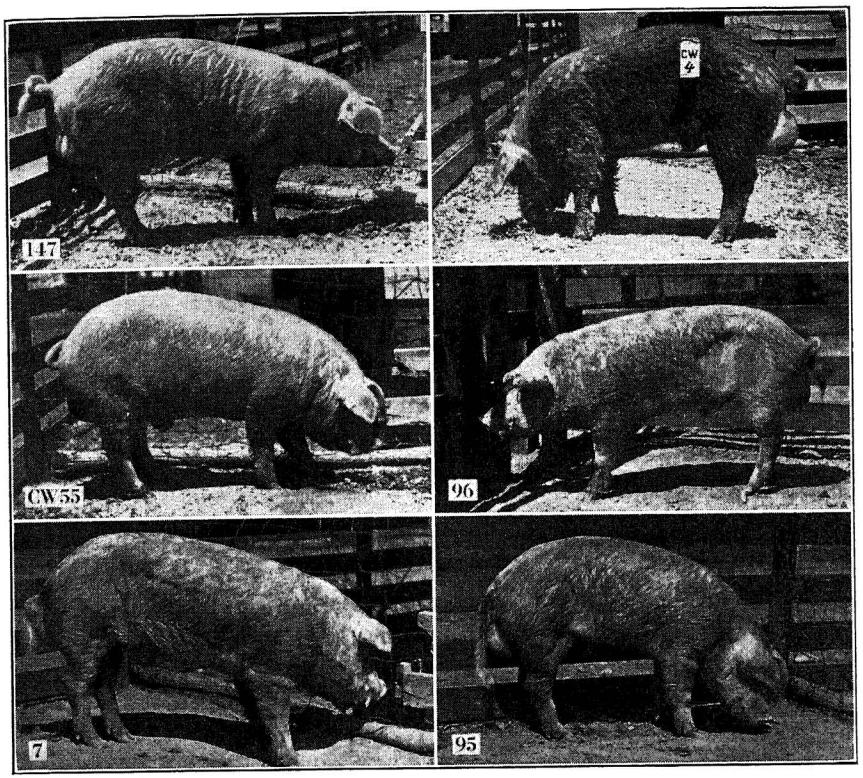

Fig. 2.—Boars used in 1937.

of Missouri. These animals were all related, either being litter mates or out of dams that were closely related and sired by boars which were litter mates. Thus, boars 6, 8, and 9 were litter mates; 4 and 7 were litter mates; 94, 95, and 96 were litter mates; and 55 and 147 were sired by the same boar.

The Duroc Jersey boars were bred by the Department of Animal Husbandry of Berea College, Kentucky, and purchased by the Missouri Agricultural Experiment Station, Department of Animal Husbandry for this work. Boars 3 and 33 were litter mates and boar 18 was by the same sire and out of a sow which was a litter mate to the dam of 3 and 33.

Some of the accessory reproductive glands were removed surgically from the three Duroc Jersey boars in December, 1935; and these boars, together with three normal Chester White boars, were used for a preliminary study during the summer of 1936 which was reported by McKenzie et al. that year.

Five Chester White boars were used for continuation of the work during the spring of 1937. Two additional Chester White boars (numbers 55 and 147) were introduced into the experiment in the summer of 1937 in order to serve as checks on some previous work. Thus a total of 13 boars have been used in this investigation. The six boars, (D. J. 3, 18, 33 and C. W. 6, 8, and 9) used for the preliminary study in the summer of 1936 were farrowed in March, 1935 and were approximately 16 months of age at the beginning of the work. The seven Chester White boars (4, 7, 94, 95, 96, 55, and 147) used in 1937 were all farrowed in February or March of 1936 and were 12 to 13 months of age when placed on experiment.

Except for the first two days of the work in 1937, all boars were kept in separate pens during the experiment in order to prevent pederasty. While on experiment they were fed yellow shelled corn and tankage (in the ratio of 10:1 at the rate of about two per cent of their live weight.) Legume hay was kept before them all the time. Except for the loss in weight following operations, all the boars remained in a vigorous state of health and made slight gains during the course of the experiment. (Table 2.)

TABLE 2.—WEIGHT RECORD OF BOARS (POUNDS)

Boars Used in 1936

Weighing dates	12-23-35	6-6-36	7-8-36	7-15-36
D.J. 3	225	338	346	350
D.J. 33	200	294	297	300
D.J. 18	220	305	312	315
C.W. 6			442	445
C.W. 8			430	433
C.W. 9			383	

Boars Used in 1937

Weighing dates	1-18	2-16	3-1	3-8	3-15	3-22	4-5	4-12	4-19	4-26	5-3	5-10	5-17	5-24	5-31	6-7	6-1
C.W. 4	341	344	358	354	352	380	360	370	370	370							
C.W. 7	291	288	308	300	304	320	300	315	322	320	330	327	348	352	332	350	
C.W. 94	332	338	354	360													
C.W. 95	280	268	276	284	280	290	265	290	298	278	280	284	296	320	324	326	
C.W. 96	230	230	245	236	234		265	280	275	265	268	274	286	282	266	256	
C.W. 55															400	362	
C.W. 147															366	350	36

Operative Technique

The animals were kept off feed for at least twelve hours. Nembutal (sodium-ethyl (1-methyl-butyl) barbiturate), injected intra-

peritoneally, was used for general anesthesia. Dosages of one grain per five pounds live weight dissolved in distilled water (1 gr. per cc.) proved satisfactory until one boar (C. W. 94) failed to tolerate that dosage and died. Thereafter, 80 per cent of the regular dosage was used to bring the animals down, and ether was used for deep anesthesia. The seminal vesicles were removed through a vertical flank incision. The Cowper's glands were removed through a horizontal incision ventral to the anus. The vasectomies were made through mid-ventral incisions directly between the hind legs, or at the base of the scrotum. Following the operation, the animals were allowed about two weeks for recovery before semen collections were resumed. In almost every case they seemed ready for service within a few days but it was deemed unwise to use them sooner than two weeks.

Gross Anatomy

When the animals were slaughtered, or at the time of removal of glands the parts of the reproductive tract were weighed, measured, and the volume determined by replacement. The contents were removed from glands, weighed, the volume determined, and the weight and volume of the empty glands obtained.

Histology

Blocks of the glands and various regions of the reproductive tract were fixed in Bouin's solution for histological study. Sections were cut at 8 micra. Mallory's stain with strong aniline acid fuchsin was used for all the tissue in the manner described by Warbritton and McKenzie (1937). Studies of the histology and gross anatomy of the genital organs are reported in the section on anatomy.

Semen Collection

Semen was collected by the method described by McKenzie (1931). This method involves the use of a piece of Gooch rubber tubing, 18 inches long by 1¼ inches in diameter. One end is stretched over a metal ring, and a wide glass tube is attached to the other end. When the boar mounts the sow, his penis is directed into the rubber tube. By applying moderate pressure with the hand to the spiral extremity of the boar's penis, ejaculation occurs in a normal manner. A stanchion specially designed for the purpose was used for holding the sow while collections were made. After the first two or three collections, it was not necessary to use a sow which was in heat. Almost all collections were made between 7 and 8 a. m. unless semen was collected twice daily, when the afternoon collections were made between 6 and 7 p. m. Feed was withheld

until after semen collections had been made to avoid any sluggishness due to feeding. After a brief training of two or three collections, all boars worked very satisfactorily.

The schedule of semen collections from three normal boars and from three operated boars in the summer of 1936 is given in Table 3. In addition to complete whole collections, semen was collected in glass vials (25 cc. size) at minute intervals for study. The quantity and quality of semen were studied, although complete chemical determinations were not made. Data on these semen collections are presented separately except where they are comparable to data obtained from semen collected in 1937.

TABLE 3.—SEMEN COLLECTION RECORD 1936

NORMAL BOARS

Date	C.W. 6	C.W. 8	C.W. 9
6-18			F
6-20			F
7-3			F
7-11		W	F
7-13		F	Slaughtered
7-15		F	
7-17	W	Slaughtered	
7-20	F		
7-22	F		
8-5	Slaughtered		

OPERATED BOARS

Date	D.J. 3	D.J. 18	D.J. 33
12-23-35	Seminal Vesicles and Cowper's Glands removed.	Seminal Vesicles and ⅔ Prostate removed, and vasectomized.	Seminal Vesicles removed.
6-13-36	F		F
6-18	F	F	F
6-20	F	F	F
7-3		F	
7-11			F
7-13		W	F
7-15	W	F	Slaughtered
7-17	F	F	
7-20	F	Slaughtered	
7-22	Slaughtered		

W—represents whole collections.
F—represents fractionated collections.

In March, 1937, both whole and fractionated semen collections were made from five normal boars over a period of two to three weeks. The interval between collections was varied for different boars and on the same boar in order to study the effect of frequency of copulation on the quantity and quality of semen. Thus semen was collected from each boar at intervals of 12, 24, 48 and 72 hours over a period of several days. Later, semen was collected from two more normal boars. The schedule of semen collections from boars in 1937 appears in Table 4. Boar C.W. 95 was observed mounting the other boars and ejaculating the day prior to the beginning of the experiment, and for that reason semen was not collected from him until March 3. For several days prior to the beginning of the experiment C.W. 96 was observed engaging in pederasty, particularly at feeding time while the other boars were eating. To prevent this the boars were separated on March 3.

The semen was collected in sterile containers, and usually within an hour was brought into the laboratory where it was weighed, the volume measured, the gelatinous and liquid portions separated, and their respective weights and volumes determined. The pH of the fresh semen was determined by means of a quinhydrone electrode; the readings were made at 25°C., against a saturated calomel half-cell using no. 7654 Leeds and Northrup potentiometer. Small (2 cc.) vials were filled with the liquid portion of the semen, corked tightly to exclude the air and stored at 10°-12° C. for sperm motility studies. A layer of mineral oil was placed over the semen in some vials to study its effect on preserving sperm motility. At intervals of 24 hours, a drop of the semen was placed on a slide and examined for motility. This was continued as long as the sperm remained motile.

Duplicate sperm counts were made with a hemacytometer, and the degree of sperm motility recorded on all fresh samples. Slide smears were made and stained for sperm morphology studies. A classification of abnormalities similar to the one employed by McKenzie and Phillips (1934) was used in this study.

Semen was obtained from boars without seminal vesicles, from boars without Cowper's glands, from a boar without seminal vesicles and without two-thirds of his prostate and vasectomized, from boars without seminal vesicles and Cowper's glands, and from boars without seminal vesicles, Cowper's glands and vasectomized. Both whole and fractionated semen collections were made from operated boars, and the same procedure of study followed as described for normal semen.

TABLE 4.—OPERATION AND SEMEN COLLECTION RECORD 1937
NORMAL BOARS

Date	Time of day	C.W. 4	C.W. 7	C.W. 94	C.W. 95	C.W. 96	C.W. 55	C.W. 147
3-1-37	A.M.	W	W	W		W		
	P.M.							
3-2-37	A.M.			W		F		
	P.M.			No desire				
3-3-37*	A.M.	F			W	W		
	P.M.							
3-4-37	A.M.		F	F		W		
	P.M.			W				
3-5-37	A.M.	W		F		F		
	P.M.			W				
3-6-37	A.M.			F	F	W		
	P.M.			W				
3-7-37	A.M.	W	W	W		W		
	P.M.			No desire				
3-8-37	A.M.			No desire		F		
	P.M.			W				
3-9-37	A.M.	W	F	W	W	W		
	P.M.	W						
3-10-37	A.M.	W	W			W		
	P.M.	W				W		
3-11-37	A.M.	No desire	W	W	W	F		
	P.M.	W				W		
3-12-37	A.M.	W	F		W	W		
	P.M.	No desire				W		
3-13-37	A.M.	F	W	Died	W	W		
	P.M.	W				W		
3-14-37	A.M.	W	W		W	W		
3-16-37	A.M.		W		W			
3-17-37	A.M.	F	W		W			
3-18-37	A.M.	W	W		F	Cowper's Glands Removed		
3-19-37	A.M.	W	W		W			
3-20-37	A.M.	W	W		W			
3-21-37	A.M.	W						
3-22-37	A.M.	F	W		W			
3-23-37	A.M.	W	W		F			
3-24-37	A.M.	W	F		W			
3-25-37	A.M.	Sem. Vesicles and Cowper's Glands removed and vasectomized						
3-26-37			Sem. Vesicles and Cowper's Glands removed					
3-27-37					Sem. Ves. removed			
5-31-37							W	W
6-2-37							W	W
6-3-37							Sem. Ves. removed	Cowper's Glands removed

* Boars separated.
Note: W—indicates whole collection.
F—indicates fractionated collection.

TABLE 4 (CONTINUED).—OPERATION AND SEMEN COLLECTION RECORD 1937

Date	OPERATED BOARS C.W. 4	C.W. 7	C.W. 95	C.W. 96	C.W. 55	C.W. 147
4-12	W	W		W		
4-13	W	W	W	W		
4-14	W	F	W	F		
4-15	W	F	W	W		
4-16	F	W	W	W		
4-17	W	W	F	W		
4-18	W	W	F	W		
4-19	W	W	W	F		
4-20	W	W		Sem. Vesicles removed		
4-22			Cowper's Glands removed			
4-23		W				
4-24		W				
4-25		W				
4-26		W				
4-27	Vasa cannulized	W				
4-28		W				
4-29		W				
4-30		W		W		
5-1	Out of experiment	W		W		
5-2		W		W		
5-3		W		W		
5-4			W	W		
5-6			F			
5-8			W			
5-10			W			
5-13			Vasectomized			
5-17			W	W		
5-18		Vasectomized		W		
5-19		W	W	W		
5-20		W		W		
5-21		W	W			
5-22				Vasectomized W		
5-23		W		W		
5-24		W	F			
5-25		F		W		
5-31		W	W	W		
6-7		Castrated	Castrated	Castrated		
6-8					died	
6-14						W
6-16						W
6-17						W
6-18						W

Attempts to collect epididymal fluid by cannulizing the vasa deferentia either before or after vasectomy were unsuccessful.

Blood for chemical analyses was collected in sterile containers from the tails of the boars.

Chemical analyses were made on normal whole semen, on semen from boars without various accessory glands, on fractionated semen collections, on pure glandular secretions and on boar blood.

Presentation of Data

ANATOMY OF THE REPRODUCTIVE TRACT

The anatomical study is based on material obtained from the six boars slaughtered in 1936, boar C.W. 94 which died in 1937, and on the glands removed surgically from nine boars. The gross anatomy and histological data are presented together.

Testes

The testes of the boar are carried in a near vertical position. The head of the epididymis is on the ventral end, the body or mid-

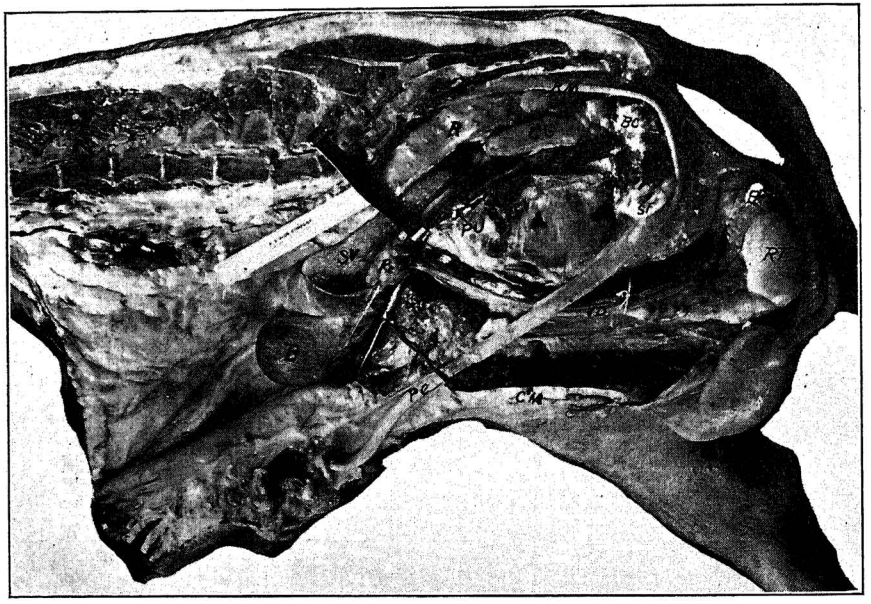

Fig. 3.—The genitalia of the boar in position. The left seminal vesicle has been removed to expose the prostate and pelvic urethra. B, bladder; BC, cavernosus muscle; R, rectum; CG, Cowper's gland; CM, cremaster muscle; Pe, penis; Pr, prostate gland; PU, pelvic urethra; RM, retractor muscle; SF, sigmoid flexure; SV, seminal vesicle; RT, right testis; TE, tail of epididymis; VD, vas deferens.

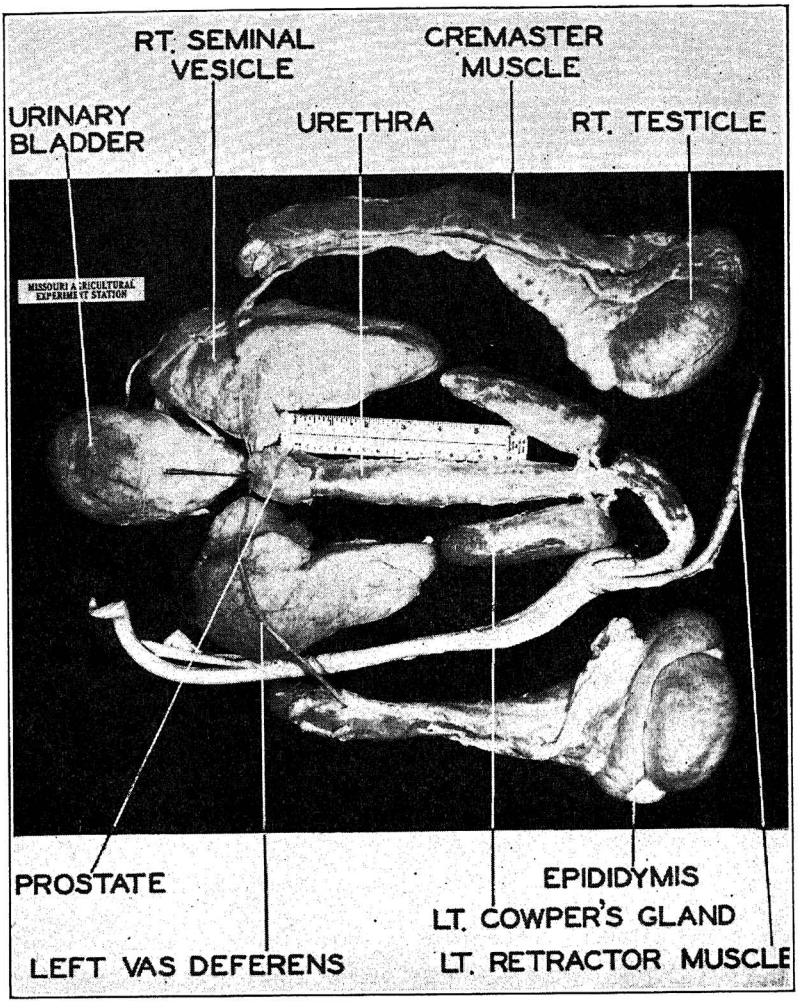

Fig. 4.—The genitalia of the boar. The probe is inserted into the urethral orifice of the left seminal vesicle duct.

region on the anterior surface, and the tail placed as a cap over the dorsal end of the testis (Figs. 3 and 4). After removal from the scrotum, the epididymis and attached tunica vaginalis were removed from the testis. The weight and volume of the trimmed testes appear in Table 5.

The testes of the boar are quite large, their total weight having a ratio to body weight of about 1:250. There appeared to be no direct relation between body weight and testis weight. The heaviest

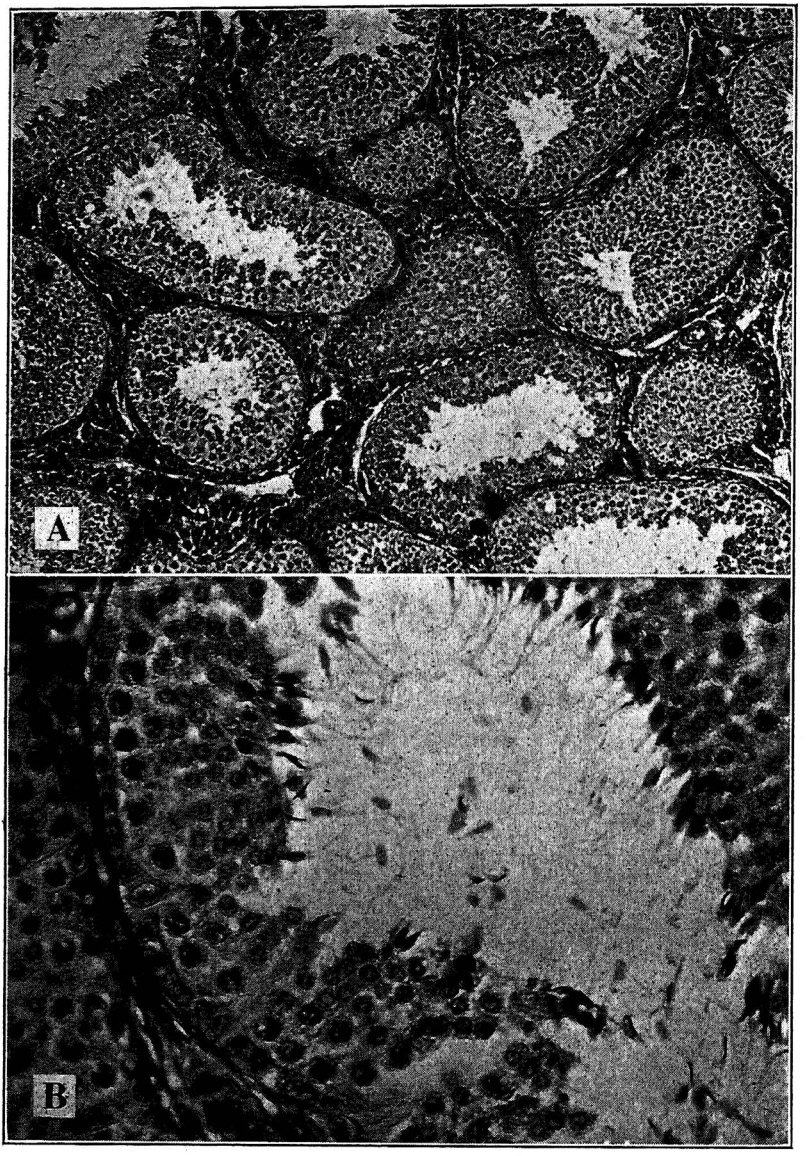

Fig. 5.—Section through testis showing seminiferous tubules. Ax90; Bx370.

boar (C.W. 8) did not have the largest testes, and the lightest boar, (D.J. 33) did not have the smallest testes. In seven of the nine animals whose testes were studied, the left testis was the larger. The density of the testes ranged from 1.052 to 1.077.

TABLE 5.—SIZE OF THE TESTES

Boar No.	Live Weight		Weight of Testes (gms.)			Volume of Testes (cc.)			Density of Testes	Ratio of Testes Wt. to Live Wt.
	kgs.	lbs.	L.	R.	Total	L.	R.	Total		
C.W. 9	175	385	306	294	600	282	275	557	1.077	1:292
D.J. 33	136	300	343	327	670	319	310	629	1.065	1:203
C.W. 8	198	435	355	345	700	334	325	659	1.062	1:283
D.J. 18	143	315	273	267	540	258	255	513	1.052	1:265
D.J. 3	159	350	397	406	804	365	395	760	1.058	1:198
C.W. 94	160	352	279	260	539	265	240	505	1.067	1:297
C.W. 95	148	326	346	279	625	327	265	592	1.056	1:237
C.W. 7	159	350	357	216	573	336	214	550	1.044	1:276
C.W. 147	159	350	281	281	562	272	271	543	1.033	1:283

The testis is covered by a thick, tough capsule (tunica albuginea). Between the tunica albuginea and the tunica vaginalis is a thin, watery liquid which bathes the testis and facilitates freedom of movement of the testis in the scrotal sac. The amount of this liquid varies greatly in different individuals.

The testis proper is a compound tubular gland, divided into many compartments (the lobuli testis) by thin partitions (the septula testis). These lobules in the boar testis converge with their apices toward the center, the mediastinum testis, unlike the testis of man where the mediastinum is located near the posterior edge (Maximow and Bloom, 1934). Each lobule contains one or more convoluted seminiferous tubules (Fig. 5), which terminate in the short, straight tubuli recti. The seminiferous tubules of the boar are similar to those of other mammals, but the interstitial tissue is somewhat more plentiful. The tubuli recti do not contain spermatogenic cells; the epithelium consists only of the cells of Sertoli. These tubules unite to form a network of irregular, epithelium-lined spaces, the rete testis (Fig. 6). The epithelium of the rete testis is cuboidal and may even be squamous in places. A "central flagellum" can be distinguished on the epithelial cells, but there seems to be no distinct basement membrane.

The number of efferent ducts arising from the rete testis varies in the boar. Most of the testes examined had only one large duct, emerging on the mid-ventral surface of the testis to join the head of the epididymis. From other testes as many as five efferent ducts were observed. On macroscopic examination in cross section the large ducts of the rete can be seen converging into fewer and larger ducts as the surface of the testis is approached. Just before reaching the surface, these ducts unite into one or more large vessels, the efferent ducts through which the spermatozoa pass to the epididymis (Fig. 7). These efferent ducts are lined with cuboidal

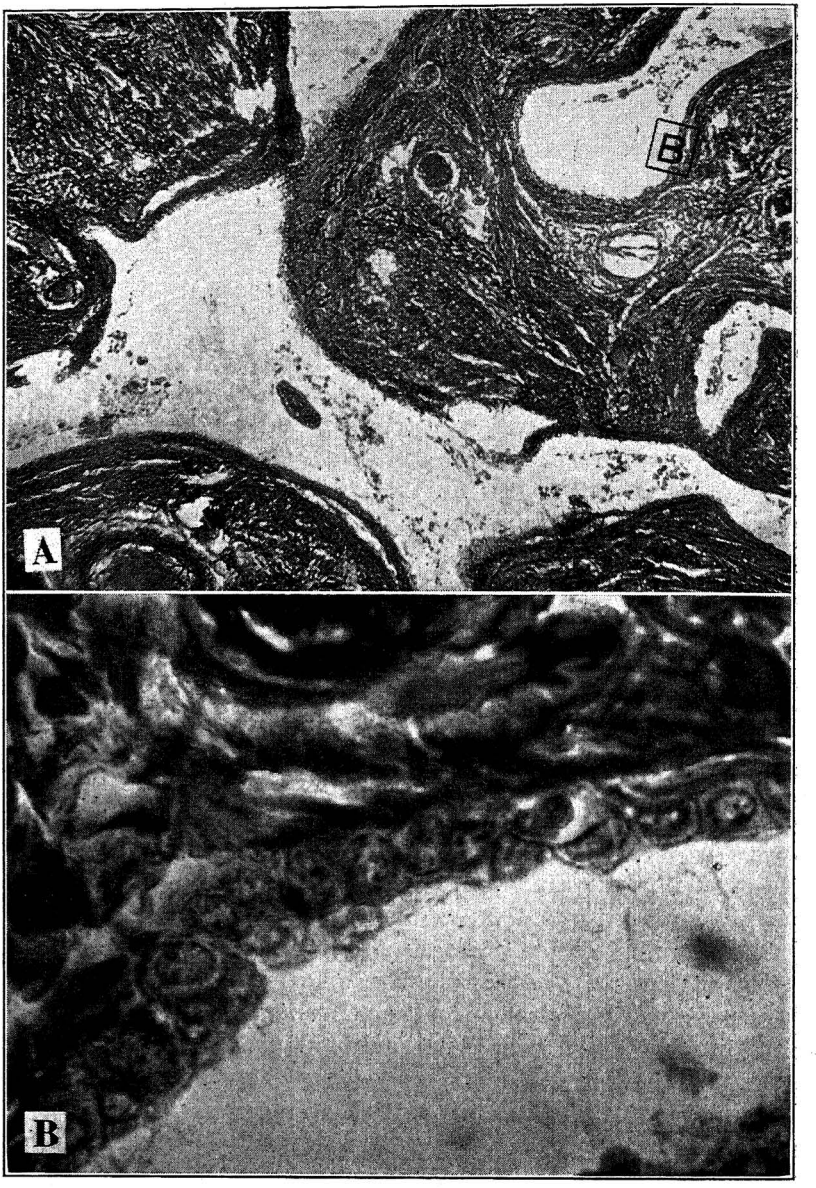

Fig. 6.—Section through the mediastinum testis. A—showing the rete tubules x 90. B—showing the epithelium of the rete tubule x 950.

and squamous epithelium. The islands appearing in the lumen of the duct are bordered with the same type of cuboidal epithelium as that which lines the duct itself (Fig. 7B). These islands there-

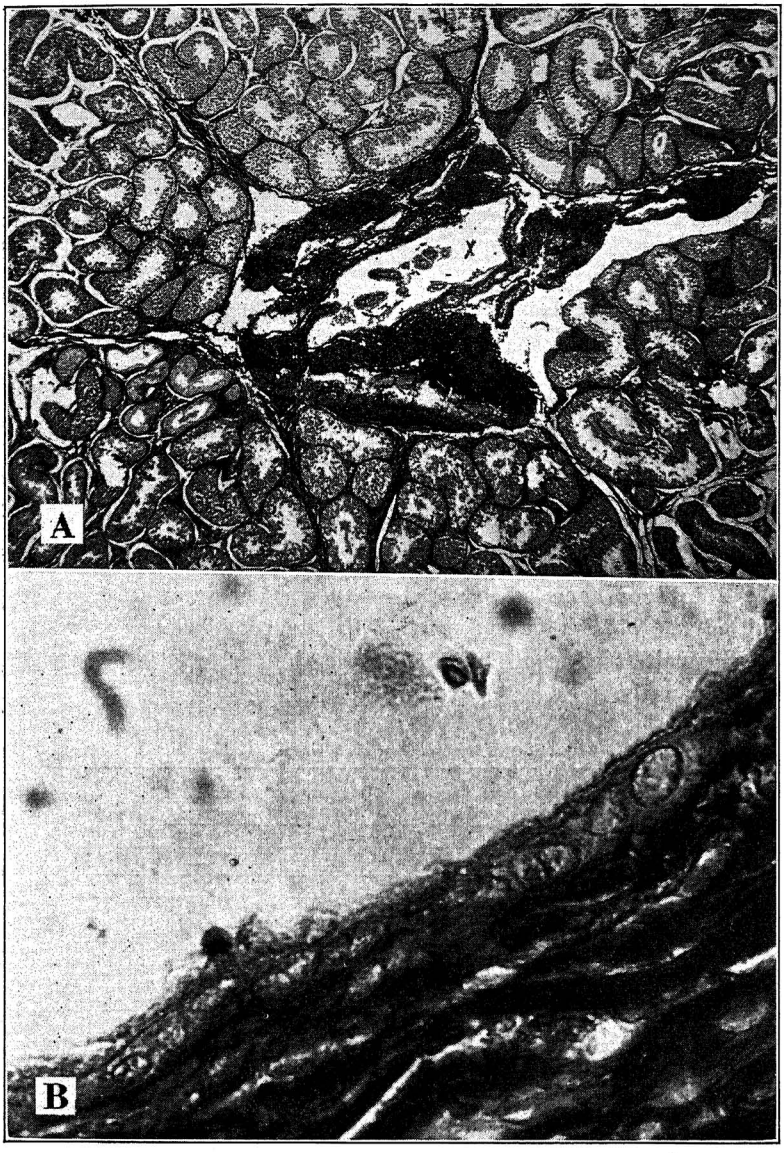

Fig. 7.—Sections through the efferent ducts of the testis. A—showing large duct (x) near surface of testis. Small ducts and blood vessels appear around the large duct. The islands in the center are points of anastomosis of small ducts x 24. B—epithelium of efferent ducts x 950.

fore would appear to be points of anastomosis of the rete tubules to form the efferent duct.

Cilia are absent on the free surface of the epithelial cells of the efferent ducts. Likewise there is no indication of secretory activity as described for the ductuli efferentes in man (Maximow and Bloom, 1934).

Epididymis

The epididymis of the boar is unusually large and spacious. The combined weights of the right and left epididymides except for those showing some pathological tissue, ranged from 168 to 219 grams (Table 6).

The left epididymis of D.J. 18 and the right epididymis of C.W. 95 and of C.W. 7 were enlarged and contained some pathological tissue. These boars had had their vasa cannulized; and, presumably due to infection, the epididymis was unusually large. Fifty cc. of fluid were obtained from the right, and 68 cc. from the left epididymis of boar 18, a total of 118 cc., whereas in normal non-vasectomized boars it was impossible to recover more than 10 cc. of epididymal fluid. Adhesions were present over the infected testis and epididymis, the tunica vaginalis adhering to the tunica albuginea. They were especially marked over the epididymis where pathological tissue was present. Cannulizing the vasa of these boars was doubtless responsible for the spread of infection into the epididymis. No infection was observed in the testis itself, even though pus was present in the epididymis.

The combined weights of the epididymides amounted to about one-third the combined weights of the testes, and had a ratio to the body weight of around 1:800. Like the testes, the left epididymis was usually heavier than the right.

TABLE 6.—SIZE OF THE EPIDIDYMIDES

Boar No.	Live Weight of animals		Weight of epididymides (gm.)			Volume of epididymides (cc.)			Ratio of epididymides weight to live weight of animals
	kgs.	lbs.	L.	R.	Total	L.	R.	Total	
C.W. 9	175	385	111	107	219	—	—	—	1:800
D.J. 33	136	300	85	83	168	81	80	161	1:810
C.W. 8	198	435	105	103	208	101	100	201	1:952
D.J. 18	143	315	205*	135	340	200*	130	330	1:421*
D.J. 3	159	350	100	101	201	95	95	190	1:791
C.W. 94	160	352	92	84	176	95	79	174	1:909
C.W. 95	148	326	186	225*	411	188	227*	415	1:360*
C.W. 7	159	350	137	408*	545	126	391*	517	1:292*
C.W. 147	159	350	92	97	189	90	95	185	1:841

* Some pathological tissue present.

The epididymis consists of many meters of a highly convoluted tube, forming a rather prominent head at its origin from the efferent ducts on the mid-ventral extremity of the testis. The mid-region or body of the epididymis is somewhat flattened and narrows down to about one centimeter in diameter as it traverses the anterior surface of the testis to the dorsal extremity where it is greatly enlarged to form a cap-like structure over the testis. This enlargement is known as the tail of the epididymis. The tube making

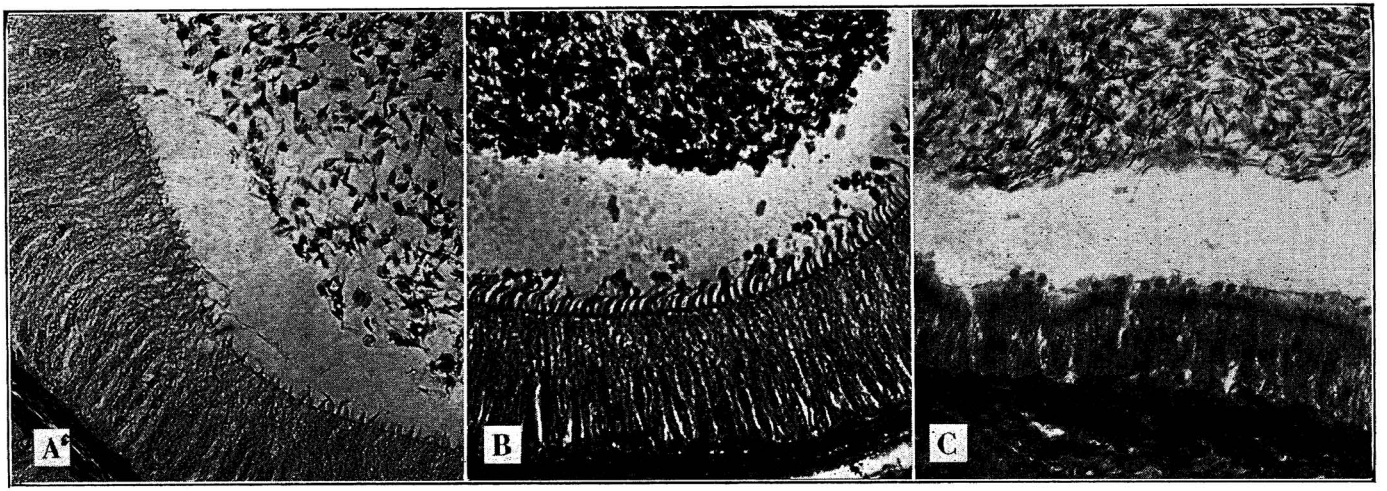

Fig. 8.—Sections through the epididymis. A—head region x 303; B—body region x 303; C—tail region x 303.

up the epididymis is quite small at its origin and remains so throughout the head and body, but is much larger in the tail, increasing in diameter as the point of transition into the vas deferens is approached.

In cross section, the ducts of the epididymis have a regular circular outline. The epithelium rests on a basement membrane, and is surrounded by circular, smooth muscle fibers (Fig. 8). The lumen of the ductus epididymidis is lined by a pseudostratified, columnar secretory epithelium. The brush-like projections on the free end of the cells are stereocilia, and presumably are non-motile. In the head region, the epithelium is tall; it is noticeably lower in the mid-region and still lower in the tail. However, the secretory activity, as judged by the presence of droplets on the stereocilia appears to be greatest in the tail region and least in the head of the epididymis. The body region shows a transitional stage between the head and tail.

The Ductus Deferens

From the point where the convoluted ductus epididymis straightens into the ductus deferens, to the urethral orifice is a distance of 25 to 30 cm. depending on the size of the animal. The outside diameter of the duct proper is normally 2 to 3 mm. with a lumen diameter of 0.5 mm. However, in animals which had been vasectomized for a period of time, the intact end adjoining the epididymis was considerably enlarged, having an outside diameter of 10 mm. with a lumen diameter of 6 mm. Normally the lumen is round, but on fixation the epithelium is thrown into folds due to contraction of the walls. The lumen is lined by pseudostratified columnar epithelium somewhat lower than that of the epididymis. Stereocilia containing secretion droplets line the free ends of the epithelium (Fig. 9). Stereocilia and secretion droplets on the epithelium are reduced or entirely absent in the urethral end of the vas deferens. They are prominent in the epididymal end, however.

Surrounding the epithelium is a heavy, smooth, muscular coat, consisting of a thin inner longitudinal layer, a very thick outer longitudinal layer and a medium thick but very dense intermediate circular layer. There are apparently many fibers running transversely in addition to the longitudinal and circular layers. Accompanying the true ductus deferens are loose longitudinal strands of smooth muscle, blood vessels and nerves, all of which make up the spermatic cord.

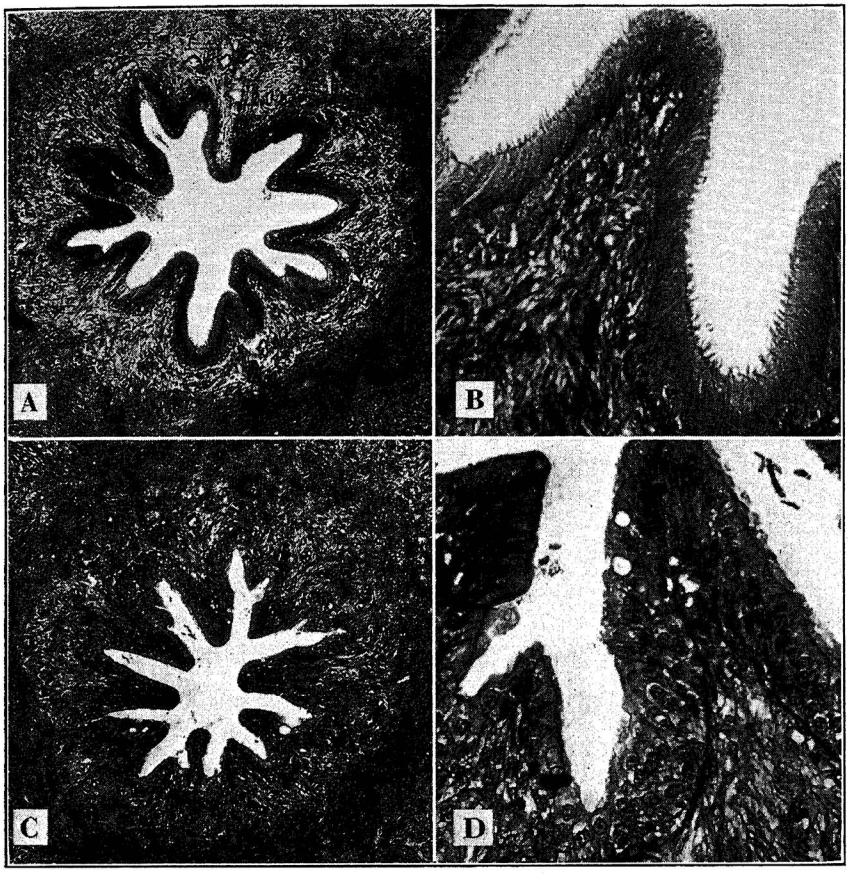

Fig. 9.—Cross sections of the vas deferens. A—epididymal end x 67; B—epididymal end x 275; C—urethral end x 67; D—urethral end x 275.

Seminal Vesicles

The seminal vesicles are large, pyramid-shaped glands with the apex pointing posteriorly, lying on either side of the pelvic urethra. They cover the neck of the bladder, the ureters, the prostate gland, and the vasa deferentia. The combined weight of the two glands varied from 151.0 to 843.5 gms. in the eight animals whose glands were studied, and the total weight of gland contents ranged from 39 to 507 gms. (Table 7). There seemed to be no relation between body weight and size of the seminal vesicles or amount of glandular secretion present. Neither was there any relation between the amount of secretion present and the time elapsed since last ejacula-

TABLE 7.—SIZE OF THE SEMINAL VESICLES

Boar No.	Date obtained	Live weight of animals kgs.	lbs.	Days since last ejaculation	Weight of glands plus contents (grams) L.	R.	Total	Weight of glands empty (grams) L.	R.	Total	Weight of gland contents (grams) L.	R.	Total	Ratio of gland weight (empty) to live weight of animals
C.W. 9	7-13-36	175	385	2	210.0	190.2	400.2	96.0	73.2	169.2	114.0	117.0	231.0	1:1034
C.W. 8	7-17-36	198	435	2	343.5	351.5	695.0	116.0	121.5	237.5	227.5	230.0	457.5	1:832
C.W. 94	3-13-37	160	352	2	81.0	70.0	151.0	56.0	56.0	112.0	25.0	14.0	39.0	1:1431
C.W. 4	3-25-37	164	360	1	151.0	120.0	271.0	97.0	84.0	181.0	54.0	36.0	90.0	1:905
C.W. 7	3-26-37	145	320	2	209.0	202.0	411.0	120.0	105.0	225.0	89.0	97.0	186.0	1:646
C.W. 95	3-27-37	134	295	3	450.0	393.5	843.5	176.0	160.5	336.5	274.0	233.0	507.0	1:400
C.W. 96	4-20-37	125	275	1	356.0	360.0	716.0	140.0	151.0	291.0	216.0	209.0	425.0	1:430
C.W. 55	6-2-37	181	398	1						186.0				1:1070

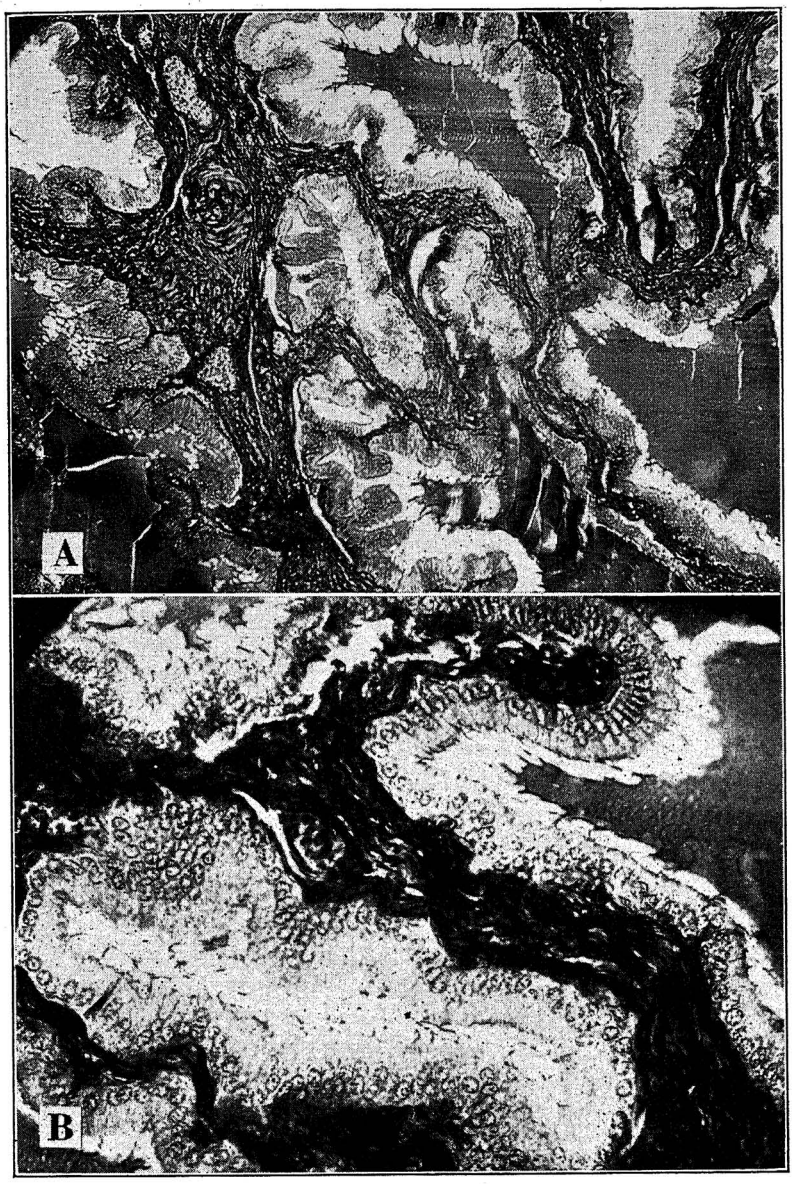

Fig. 10.—Sections through seminal vesicle. A x 90; B x 870.

tion. The ratio of empty weight of the glands to live weight of the boars ranged from 1:400 to 1:1431. These data indicate a wide individual difference in size and secretory activity of the seminal

vesicles. Subsequent data on semen studies support these observations.

The glands are tortuous, elongated, hollow bodies, with very irregular, branched lumina and numerous outpocketings. The wall consists of a thin external connective tissue sheet, of a thin middle layer of smooth muscle, and of a mucous membrane resting upon a thin submucous layer. The mucous membrane forms an elaborate system of thin, high primary folds which branch into secondary and tertiary folds. These project far into the lumen, anastomosing frequently with one another, thereby forming many irregularly shaped cavities of different sizes. These cavities are separated from one another by thin branching partitions, and all open into a larger cavity (Fig. 10).

The epithelium lies on a thin vascularized connective tissue supported by muscle strands. Although showing some variation, the epithelium is simple columnar in nature, with some areas pseudostratified. The nuclei are round or oval shaped and located at or near the base. Secretion granules are present above the nuclei, and on the free surface, drops or bleblike formations appear. These are cast into the lumen, forming the secretion product. The fluid has a gray, opaque color, a medium viscosity and a pH of approximately 6.7.

There is no central duct of the seminal vesicles. Instead, there are several large ducts branching and anastomosing irregularly, which finally converge into one excretory duct. The duct from each seminal vesicle enters the urethra as a slit-like opening, close to but ventro-lateral to the vasa openings.

Urethral Orifices of the Vasa Deferentia and Seminal Vesicle Ducts

The vasa deferentia and seminal vesicle ducts enter the urethra through four separate and distinct openings (Figs. 11 and 15). They are located on the dorsal surface of the anterior extremity of the pelvic urethra at its origin from the neck of the bladder. The vasa orifices are medial, and surrounded by thick muscular layers. The orifices of the ducts of the seminal vesicles are located ventro-laterally to the vasa orifices. They are surrounded by a thin muscle layer and are lined by a pseudostratified columnar epithelium similar to that in the body of the gland. Lying in the mid-ventral region is the rudimentary male uterus (uterus masculinus) which ends blindly. It is lined by a pseudostratified columnar epithelium somewhat similar to but not identical with that lining the orifices of the seminal vesicle ducts. Concretions are found in the duct. Prostatic tissue appears at the edge of the section (Fig. 11).

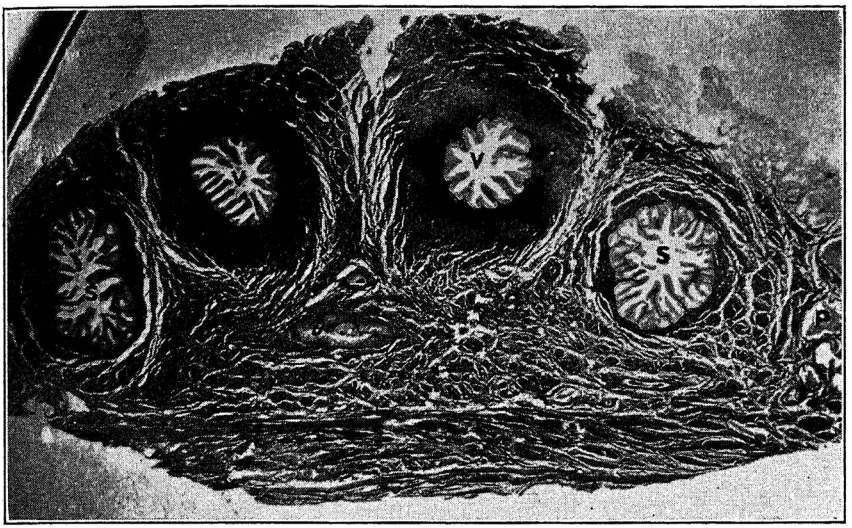

Fig. 11.—Section through the pelvic urethra showing orifices of the vasa deferentia and seminal vesicle ducts x 16. V, vasa orifices; S, seminal vesicle duct orifices; u, uterus masculinus; p, prostate tissue. See Fig. 15 for location of section.

Cowper's Glands

The Cowper's glands (bulbo urethral) are compound tubulo-alveolar in nature and in some respects resemble mucous glands. They lie parallel to the pelvic urethra one on either side, and are attached to it on the ventral side by a heavy muscular attachment extending the length of the glands (Fig. 4). The excretory duct is located at the posterior end of the gland and enters the pelvic urethra at its posterior extremity.

The glands are somewhat cylindrical in shape, measuring about 15 cm. in length by 3 to 5 cm. in diameter, depending on the size of the animal. There is more uniformity of size in Cowper's glands than in seminal vesicles in different individuals. The total empty weight of the two glands ranged from 146 to 209 gms., and the total weight of gland contents varied from 19.5 to 178 gms. for the 10 animals whose glands were studied (Table 8). The wide range in weight of gland contents was due in part to the fact that some of the glands were not completely emptied. Since the glandular material is a very thick, white, waxy substance when warm, and is even more viscous when cool, it is quite difficult to remove from the gland. Only after repeated washing with water or physiological saline solution was it possible to remove all the waxy material. If

TABLE 8.—SIZE OF THE COWPER'S GLANDS

Boar No.	Date obtained	Live weight of animals kgs.	Live weight of animals lbs.	Days since last ejaculation	Weight of glands plus contents (grams) L.	Weight of glands plus contents (grams) R.	Weight of glands plus contents (grams) Total	Weight of glands empty (grams) L.	Weight of glands empty (grams) R.	Weight of glands empty (grams) Total	Weight of gland contents (grams) L.	Weight of gland contents (grams) R.	Weight of gland contents (grams) Total	Ratio of weight of gland (empty) to live weight of animals
C.W. 9	7-13-36	175	385	2	134.0	124.0	258.0			203.0			37.0*	1:862
D.J. 33	7-15-36	136	300	2	110.5	114.0	224.5	102.0	103.0	205.0	8.5	11.0	19.5*	1:663
C.W. 8	7-17-36	198	435	2	147.0	147.0	294.0	108.5	105.5	214.0	38.5	41.5	80.0*	1:925
D.J. 18	7-20-36	143	315	3	86.0	92.5	178.5	71.0	75.0	146.0	15.0	17.5	32.5*	1:979
C.W. 94	3-13-37	160	352	2	101.0	84.0	185.0	85.0	72.0	157.0	16.0	12.0	28.0*	1:1019
C.W. 96	3-18-37	114	251	4	133.0	150.0	283.0	67.0	80.0	147.0	66.0	70.0	136.0	1:776
C.W. 4	3-25-37	164	360	1	156.0	191.5	347.5	80.0	89.5	169.5	76.0	102.0**	178.0	1:968
C.W. 7	3-26-37	146	320	2	155.0	156.0	311.0	71.0	78.0	149.0	84.0	78.0	162.0	1:980
C.W. 95	4-22-37	134	295	3	170.0	174.0	344.0	103.0	105.0	208.0	67.0	69.0	136.0	1:644
C.W. 147	6-2-37	166	365	1	157.5	163.5	321.0	103.0	106.0	209.0	54.5	57.5	112.0	1:794

* Contents cooled before being expelled.
** Washed out with saline solution.

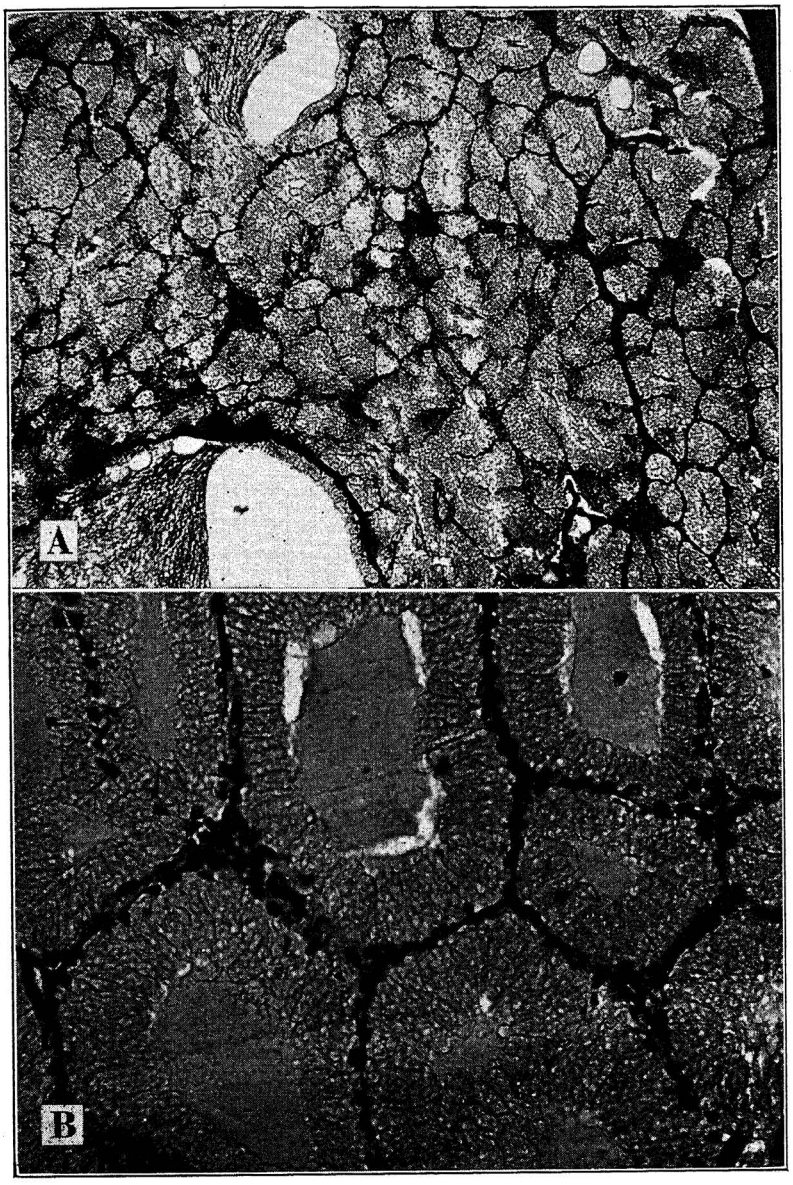

Fig. 12.—Section through lobule of Cowper's gland. A x 90; B x 370.

those glands which were allowed to cool, and those which were washed clean are omitted, the contents of the glands which were squeezed out while warm ranged from 112 to 162 gms. for the four pairs. The range on the five pairs allowed to cool was from 19.5 to 80 gms. of wax.

There seemed to be little or no relation between the amount of glandular secretion present and the time elapsed since the last ejaculation. The ratio of empty gland weight to the live weight of the animals ranged from 1:644 to 1:1019. The glands plus contents had densities ranging from 1.028 to 1.075. Due to the nature of the secretion, specific gravity was very difficult to determine but it approximated 1.04.

The gland is a firm, dense mass of lobules, whose terminal portions end blindly or anastomose with one another. Connective tissue partitions separate the lobules. These partitions contain networks of elastic fibers and strands of striated and smooth muscles. The secretory epithelium of the alveoli consists of a single layer of columnar or cuboidal cells with small nuclei at their base (Fig. 12). The epithelium rests on a thin basement membrane. Secretion granules are present and bleblike droplets appear on the free ends of the cells. The epithelium of the larger ducts is somewhat flattened but remains typically cuboidal. After fixation, the secretion appears as a dense mass of cuboidal droplets, staining pale blue with Mallory's stain. The duct formation inside the glands varies greatly. Some have only one large ventrally located duct extending the length of the gland. Others have two, lying parallel and joining at the posterior extremity to form the excretory duct, and still others were found with one large central duct and a smaller side duct joining it midway in the gland (Fig. 13).

There is a thick muscle-layer covering the ventral surface of the gland which secures it to the ventro-lateral surface of the pelvic urethra. Doubtless this heavy muscular arrangement plays some part in forcing the waxy secretion through the excretory duct into the urethra during ejaculation.

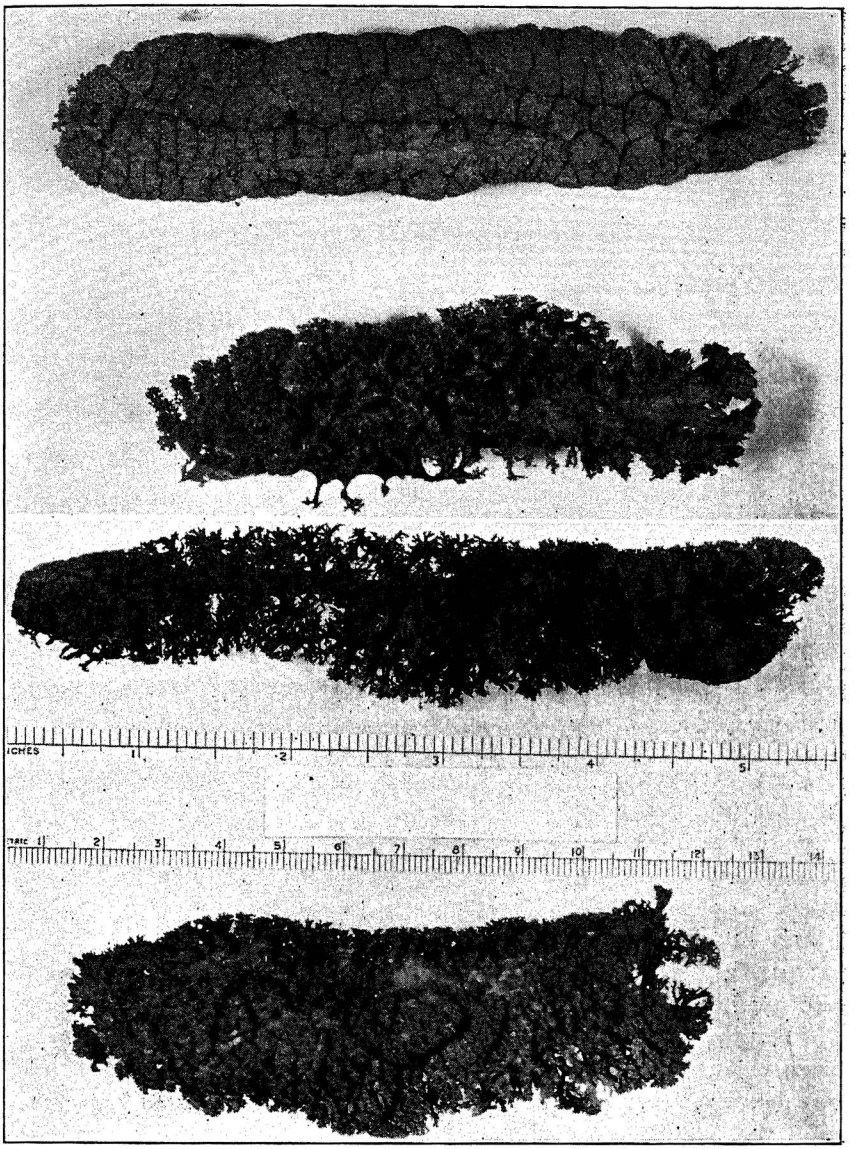

Fig. 13.—Models showing the glandular structure of the Cowper's glands. Made with vinyl resin (vinylite 0110 furnished by the Chemical and Carbide Corporation of New York) according to the method of Narat, Loef and Narat (1936).

The Prostate Gland

The prostate gland in the boar is a yellowish multilobular gland (Fig. 4). It is composed of two parts: the body or bulb, closely attached to the dorso-lateral surface of the pelvic urethra at its anterior extremity, and the pars disseminata which is attached to the body but embedded in the wall of the pelvic urethra beneath the body of the gland. The body of the gland weighs from 15 to 25 grams and measures about 5 cm. in length by 4 cm. across by 1.5 cm. thick (Table 9). The ratio of prostate body weight to live weight of the animal was about 1:8,000. Since the pars disseminata could not be removed surgically, the prostate was left intact in all animals, except D.J. 18, where about two-thirds of the body of the prostate was removed.

TABLE 9.—SIZE OF PROSTATE GLAND

(Exclusive of the portion embedded in the urethral wall.)

Boar Number	Live Weight (kgs.)	Live Weight (lbs.)	Weight of Prostate (gms)	Volume of Prostate (cc)	Ratio of Prostate to Live Weight	Dimensions (cm)
C.W. 9	175	385	25.0	25.0	1:7,000	
D.J. 33	136	300	17.5	17.0	1:7,771	5.5x4x1.5
C.W. 8	198	435	26.0	23.0	1:7,615	
D.J. 18	143	315	8.0*	10.0	1:17,875	2x3x1
D.J. 3	159	350	15.0	13.0	1:10,600	5x4x1.5
C.W. 94	160	352	18.0	19.0	1:8,889	

*About two-thirds removed by operation.

The glandular tissue is firm, without apparent storage space and contains no secretion which can be expelled by pressure. Incomplete sections which have not been made in a known direction present a bewildering mass of secretory tubules, follicles, connective tissue, smooth muscles, blood vessels, nerves and lymphatics. The gland is a composite of many small compound tubulo-alveolar glands, giving rise to numerous excretory ducts which open into the urethra independently on its dorsal wall.

The prostate is very irregular in form. Large branching cavities, narrow ducts and alveoli appear to be massed together in an irregular manner (Fig. 14). There is no distinct basement membrane and the glandular epithelium rests upon a layer of connective tissue. The epithelium varies from simple or pseudostratified columnar in the smaller alveoli to cuboidal or even squamous in the larger cavities. Numerous secretory granules can be seen in the cytoplasm, and cytoplasmic drops appear to be attached to the free end of the epithelial cells.

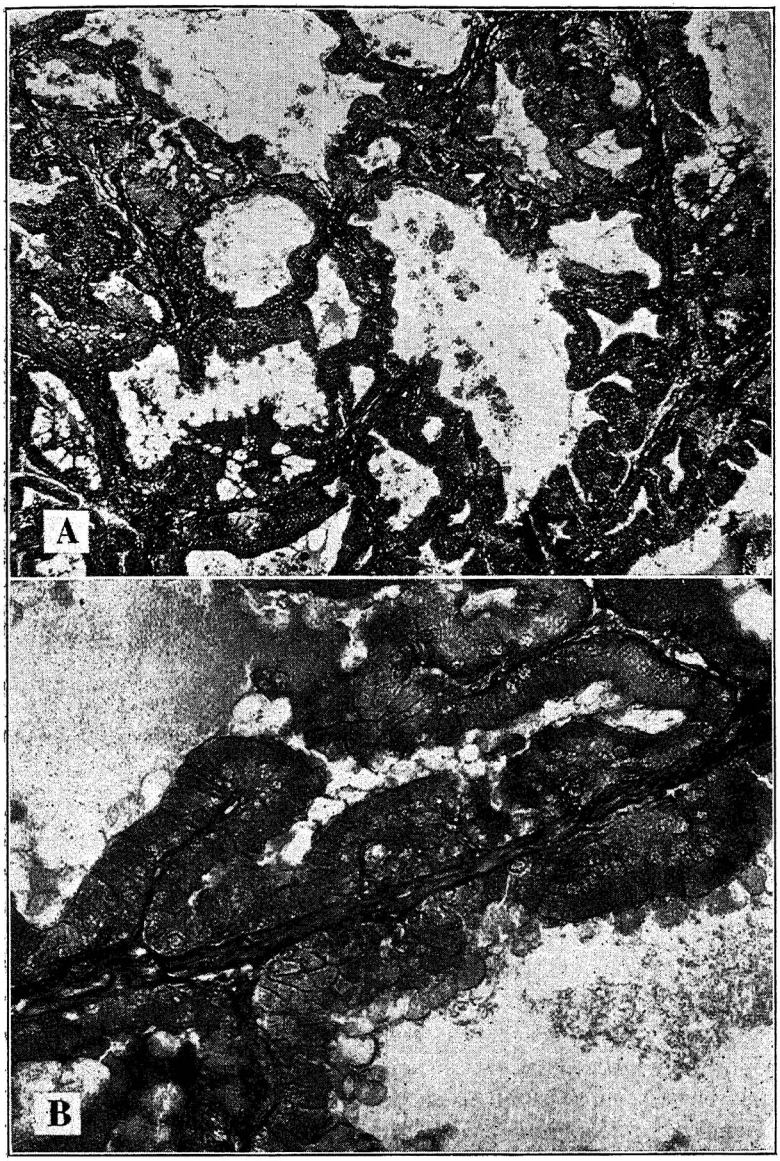

Fig. 14.—Section through lobule of prostate gland. A x 90; B x 370.

There is abundant interstitial tissue which appears to consist of dense connective tissue with collagenous fibers and elastic network, and many smooth muscles arranged in strands of varying thickness.

There is also a connective tissue capsule about the periphery of the gland.

The Pelvic Urethra

The pelvic urethra of the boar is 20 to 25 cm. long, extending from its origin at the neck of the bladder, to the entrance of the Cowper's ducts, the posterior extremity (Figs. 4 and 15). It is sur-

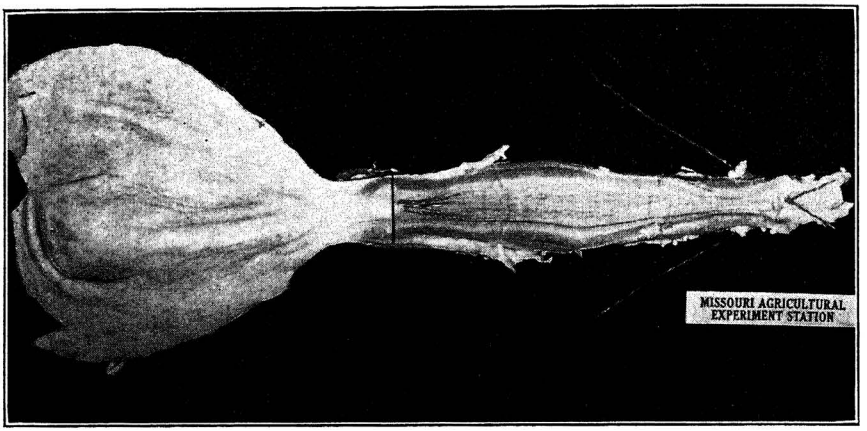

Fig. 15.—The pelvic urethra and bladder opened mid-ventrally. Note the thickness of the urethral wall. Probes at the left indicate the points of entrance of the vasa and seminal vesicle ducts, the center pair being the vasa orifices. Probes at the right show the orifices of the ducts of Cowper's glands. The line indicates the position of the section in Fig. 11.

rounded by a layer of glandular tissue, varying from 5 to 8 mm. in thickness. At the anterior end the pars disseminata of the prostate is conspicuous with its yellow color and characteristic prostatic histological structure. However, this characteristic tissue does not extend far beyond the limits of the body of the prostate. The remaining 15 to 20 cm. of the pelvic urethra is surrounded by a different type of glandular tissue. It lacks the yellow color of the prostate and, histologically, is compound tubular in nature instead of tubulo-alveolar, as is the prostate. Throughout this study, these glands have been referred to as the urethral glands. They possibly correspond to the glands of Littré described in man and other species.

The lumen of the urethra is lined by a pseudostratified low columnar or cuboidal epithelium, having large nuclei which nearly fill the cells (Figs. 16 and 17). It rests on a dense, thick submucosa. Immediately beneath the submucosa is an area of loose connective tissue in which numerous, large, blood vessels appear. They seem

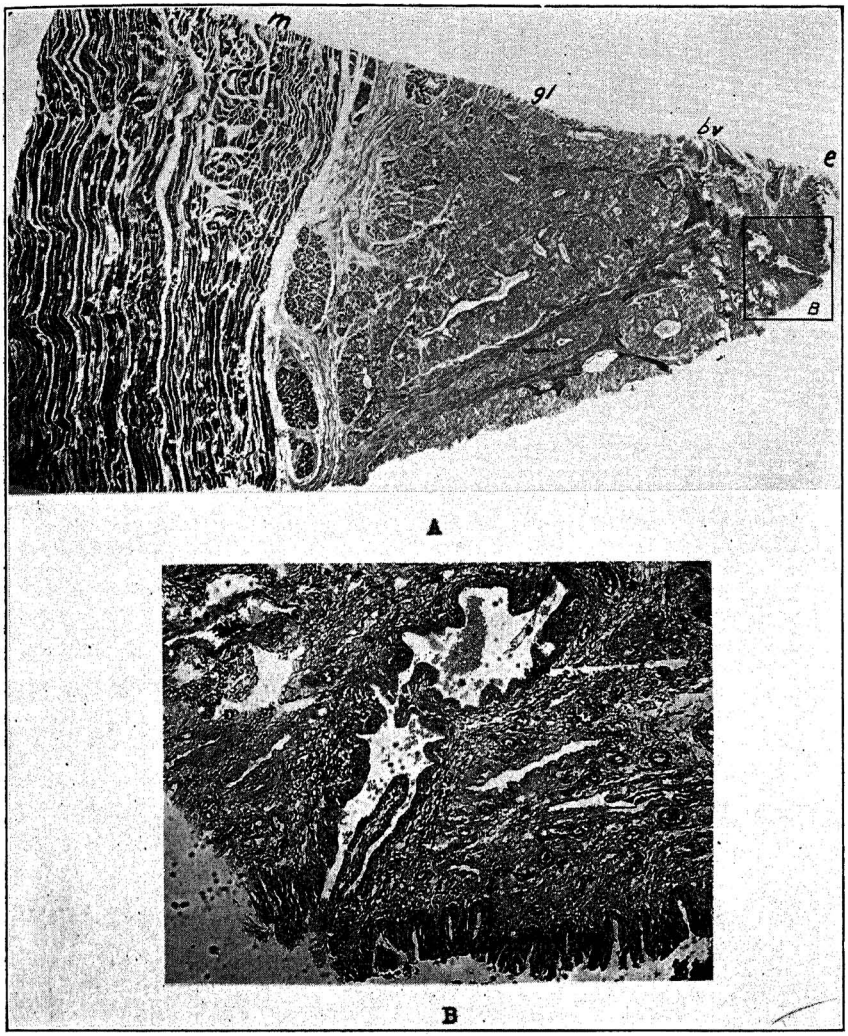

Fig. 16.—Section through ventral wall of pelvic urethra in region of prostate gland. A x 13; e, epithelium of urethra; bv, blood vessels; gl, glandular tissue; m, muscle layer. B showing duct emptying into urethra x 65.

to form a network around the urethra, running both longitudinally and circularly, and have the appearance of the vessels in the cavernous spaces of the penis. Doubtless these vessels play an important role during erection and ejaculation. Beneath this connective tissue is the thick (5 to 8 mm.) mass of compound tubular gland tissue. Vertical connective tissue septa with occasional smooth

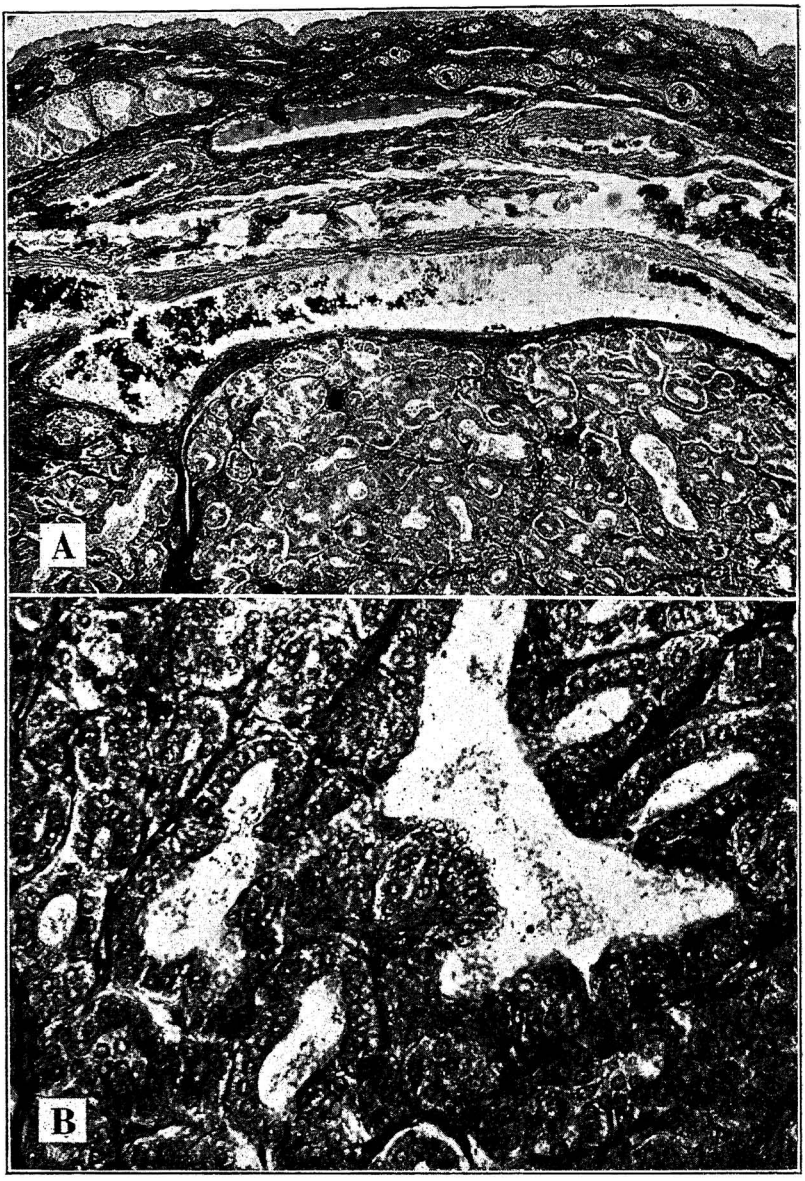

Fig. 17.—Section through the ventral wall of the pelvic urethra at the mid-Cowper's region. A showing the epithelium lining the urethra, the layer of blood vessels and the glandular tissue x 90. B showing epithelium of glandular tissue x 370.

muscle fibers penetrate the glandular tissue and divide it into wedge-shaped sections with the apex toward the lumen. Numerous ducts can be seen leading from the glandular tissue to the surface of the urethral lumen.

The epithelium of the ducts is cuboidal, and may even be low columnar in the tubules. It rests on a thin basement membrane. The nuclei are large and occupy a central position in the epithelial cells. Secretion granules can be identified.

Surrounding the glandular area is a thick muscular layer, about 10 mm. thick on the ventral and lateral surfaces but very thin or absent on the dorsal surface. Both smooth and striated muscle make up the muscular layer, the smooth muscle being confined largely to the area immediately adjacent to the glandular tissue. The muscles appear to be predominantly circular, although longitudinal and transverse fibers can be distinguished.

The total weight of the pelvic urethra, including the glandular and muscular tissue, ranged from 100 to 150 grams in the subjects studied. Although not actually separated by dissection, it was estimated that glandular and muscular tissue make up approximately equal portions of the pelvic urethra.

The Penis

The penis proper arises at the bulbo-cavernosus muscle (Figs. 3 and 4). In the sexually mature boar it measures from 50 to 75 cm. (20 to 30 inches) in length, and 1 to 1.5 cm. in diameter. The anterior part is somewhat flattened dorso-ventrally and the end is pointed and twisted to the left. The external urethral orifice is slit-like and is located on the ventro-lateral surface near the extremity. Two retractor muscles are attached to the ventral surface of the penis anterior to the region of the sigmoid flexure. In cross section, the penis presents a circular structure with a large, dorsal, corpus cavernosum penis, surrounded by a thick, fibrous membrane, the tunica albuginea (Fig. 18). Numerous cavernous spaces, separated by partitions passing in from the fibrous sheath (trabeculae) plus large blood vessels fill the corpus cavernosum penis. The small, ventrally located corpus spongiosum urethra contains the urethra throughout its length. The tunica albuginea surrounding the corpus spongiosum urethra is much thinner, and the cavernous spaces are quite limited in extent.

The penis urethra is lined by a pseudostratified cuboidal epithelium having large prominent nuclei, and resting on a dense submucosa. No indication of secretory tissue or activity was observed in the epitheluim of the penis urethra either anterior or posterior to the sigmoid flexure (Fig. 18B).

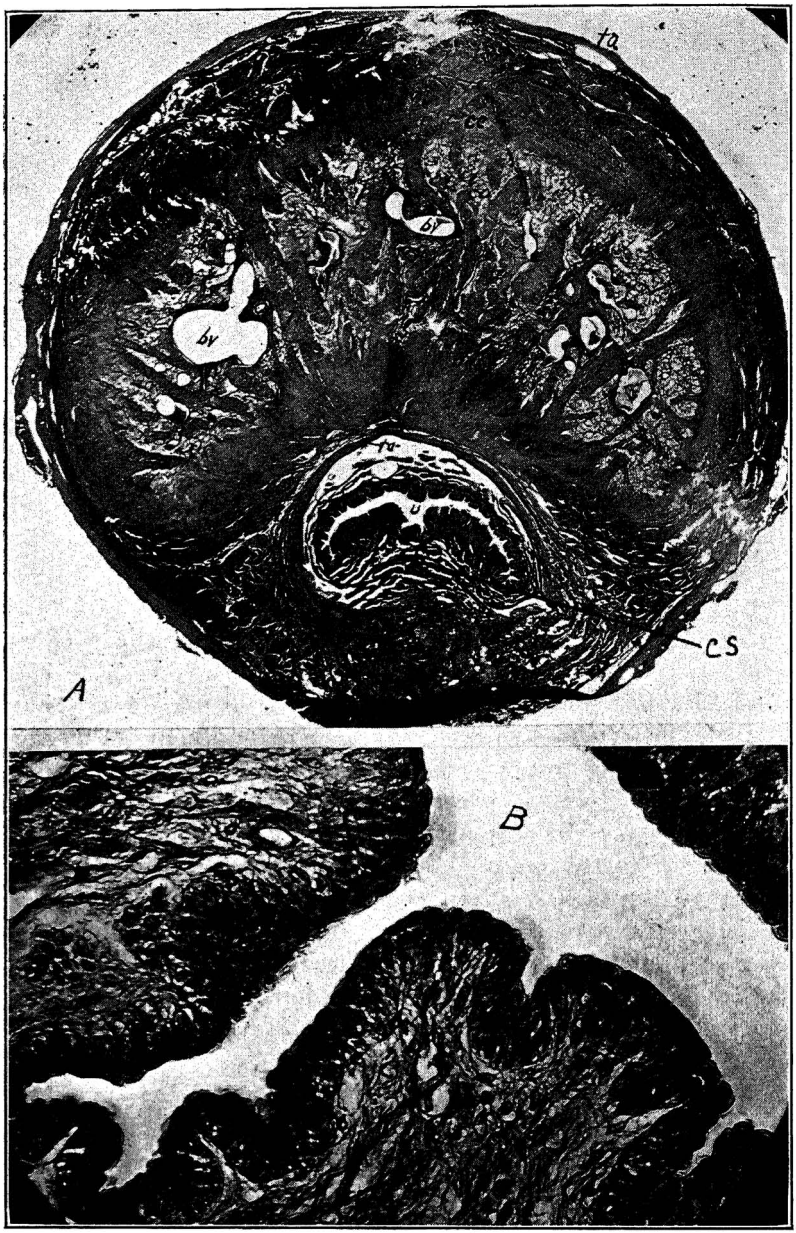

Fig. 18.—Cross section of penis, posterior to sigmoid flexure. A entire section x 8⅓; u, urethra; cc, corpus cavernosum; cs, corpus spongiosum. B epithelium of urethra x 309.

PHYSIOLOGY OF THE REPRODUCTIVE TRACT

Semen from Normal Boars

Whole and Fractionated Semen Collections:—Whole semen from normal boars is grayish to milky white in color, depending on the sperm concentration; the higher the sperm concentration the whiter the semen (Fig. 19). Fresh semen has no odor except when contaminated with urine or contents of the preputial pouch. The preputial pouch contains decomposing urine and cellular débris

Fig. 19.—Normal whole semen. A the entire ejaculate. B the same ejaculate with the liquid and gelatinous portions separated.

which have a disagreeable odor and constitute the characteristic sexual odor of the boar. Approximately 60 to 75 per cent of fresh whole semen is liquid, slightly viscous, and has a specific gravity

of 1.01 to 1.02. In addition to the liquid portion, normal whole semen contains lumps of gelatin-like material resembling tapioca. In freshly ejaculated semen this material appears as chains of platelets 3 to 5 mm. in diameter with their flat surfaces attached. On standing, these gelatinous bodies absorb liquid, become greatly enlarged, and settle to the bottom into a solid mass of jelly-like material. However, when placed in water they remain the same size. After cooling 24 hours or more they may take up the bulk of the liquid in the semen, and comprise 50 to 75 per cent of the total weight. This mass has an opaque gray color, with a specific gravity of 1.03 to 1.04. Sperm are present in the gelatinous material, apparently being trapped and held by it after ejaculation.

The initial collection following a period of sexual inactivity did not have necessarily the largest volume, but the sperm concentration per cu. mm. and the total number of sperm was in each instance greatest in the first collection. The concentration of sperm in 200 cc. of semen from C. W. 6 on 7-17-36 was 1,610,000 per cu. mm. with a total sperm number of 322 billion. C. W. 8 on 7-11-36 produced 372 cc. of semen containing 1,015,000 sperm per cu. mm. or a total of 377 billion. Subsequent collections from each of the boars showed a decreasing concentration with a corresponding reduction in total number of sperm. A summary of the fractionated semen collections from the normal boars used in 1936 is shown in Fig. 20. The weight, sperm concentration, total number of sperm per ejaculate, and duration of ejaculation are reasonably comparable for the three boars. Combining the summaries of the three boars into a final summary including eight collections gives an average weight of 284 grams per ejaculate, an average sperm concentration of 305,000 per cu. mm., and an average total number of more than 85 billion sperm per ejaculate. A summary of the fractionated semen collections from the normal boars used in 1937 appears in Fig. 21. Compared to the corresponding data on the boars used in 1936, the weight, sperm concentration and total number of sperm per ejaculate are materially lower. No doubt, this is due in part to the difference in the age of the boars, but principally to the greater number and frequency of ejaculations of the boars used in 1937.

The rate of ejaculation usually increased to the third minute, reached a peak in the third, fourth or fifth minute, and decreased thereafter for two or three minutes followed by a second rise near the end of the ejaculation. Thus there was a high initial peak and a second lower peak. Coincident with these peaks in rate of ejaculation were the peaks of sperm concentration, indicating two waves

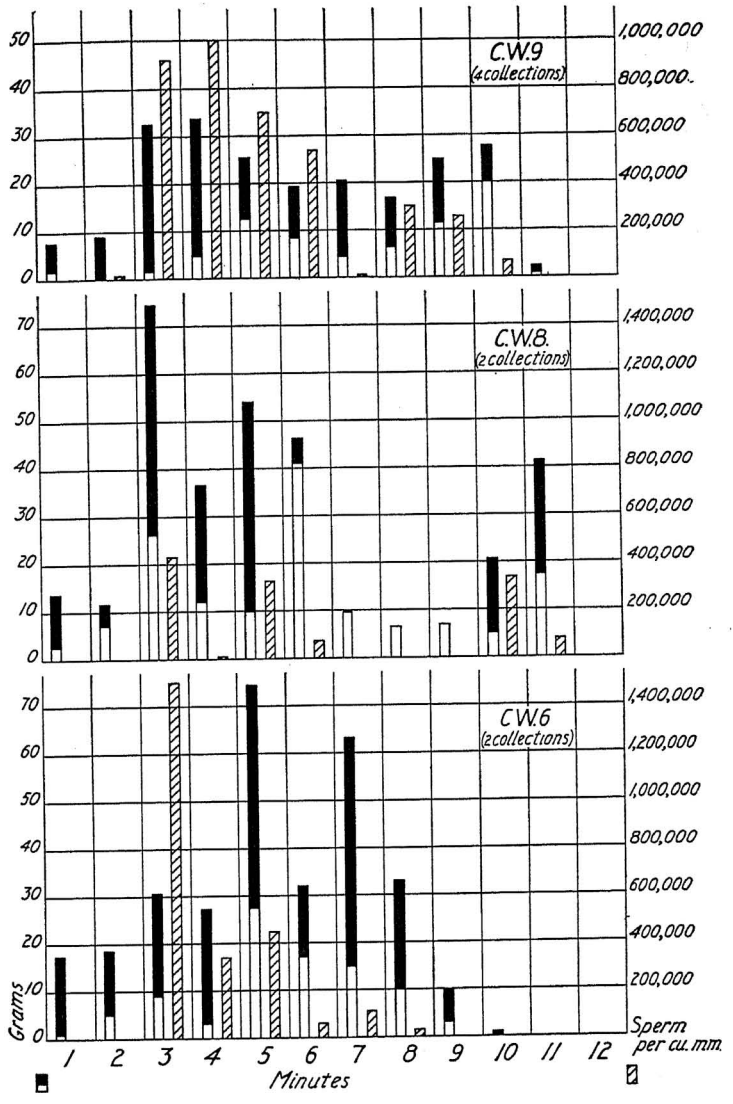

Fig. 20.—The rate of ejaculation and the sperm concentration each minute of normal boars used in 1936. The total height of the black and white bars represents grams of ejaculate. The white portion represents gelatinous portion of the semen. The shaded bars represent sperm per cu. mm.

or cycles of events in each ejaculation. The second wave was more pronounced in some boars than in others, and was entirely absent in some animals. There was a tendency for the second wave to disappear with more frequent ejaculations.

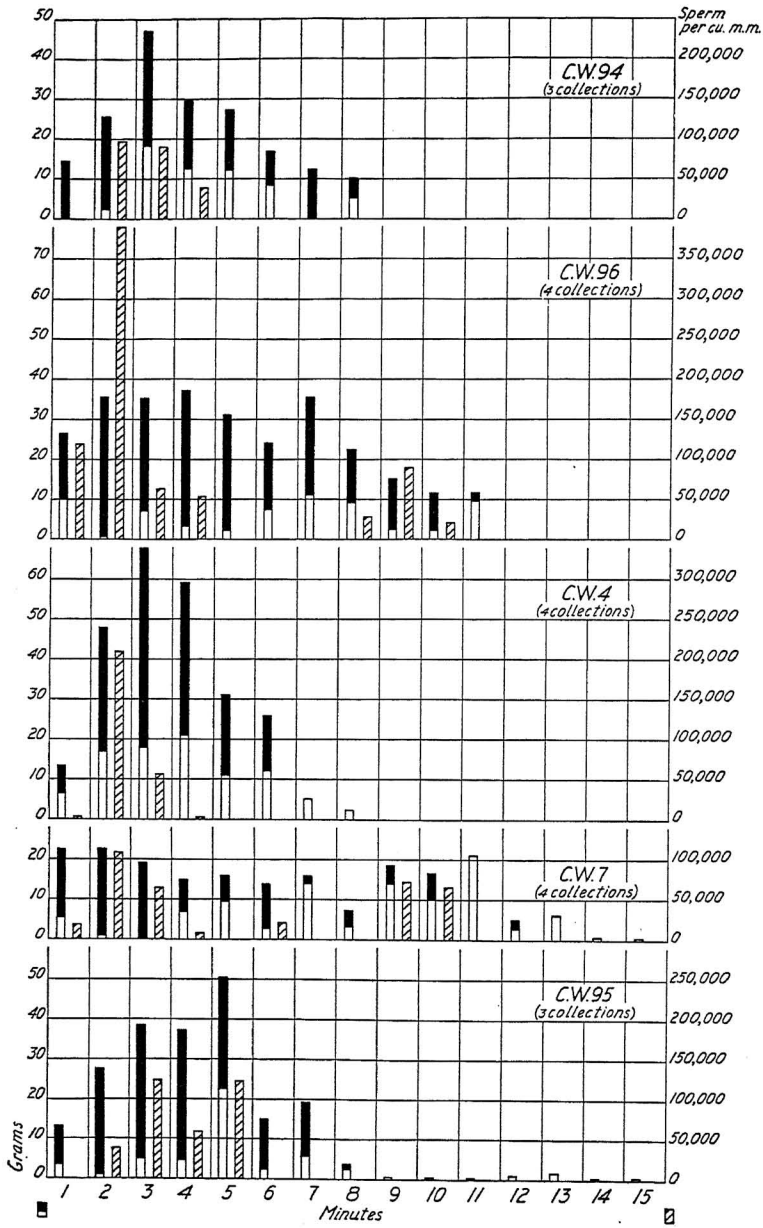

Fig. 21.—Rate of ejaculation and sperm concentration each minute of normal boars used in 1937. The total height of the black and white bars represents grams of ejaculate. The white portion represents the gelatinous portion. The shaded bars represent sperm per cu. mm.

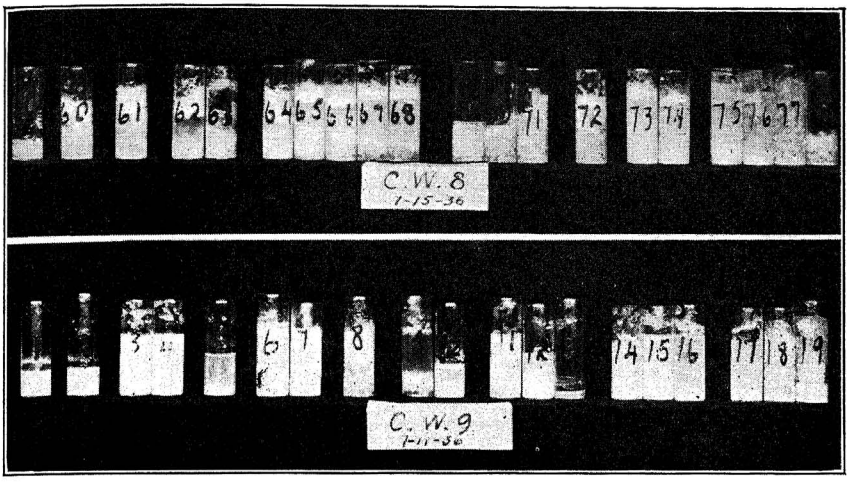

Fig. 22.—Fractionated semen collections from normal boars. The vials are grouped into minute fractions. Note the two waves of sperm-containing vials. Above: vials 64, 65, 66, 73, 74, and 75 are the high sperm-containing fractions. Below: vials 3, 4, 11, 14, and 15 are the high sperm-containing fractions.

Some gelatinous material was distributed throughout the period of ejaculation. However, it varied in appearance and in quantity with the stage of ejaculation. During the first minutes it was somewhat discolored, perhaps by urine, and lacked the characteristic tapioca lumps (Fig. 22). Instead, it was a more uniform mass, having the consistency of a thick lubricant. The greatest amounts of the typical tapioca material appeared with or immediately following the high sperm-containing fractions. Near the end of the sperm-containing fractions, the ejaculate was frequently all gelatinous material. In the interval between the high sperm peaks, or following it if only one peak occurred, a clear thin fluid appeared containing very few or no sperm and having a specific gravity of 1.01 or less.

The pH of normal whole semen ranged from 7.3 to 7.9. In the fractionated collections the initial or pre-sperm fractions usually had a high pH, due in part no doubt to contamination with urine, which in the boar had a pH ranging from 8.4 to 9.0. The high sperm-containing fractions had a lower pH and the intermediate and post-sperm fractions had a high pH although not as high as the pre-sperm fractions.

The duration of ejaculation varied greatly in different boars, ranging from 3 to 6 minutes in C.W. 55, to 11 to 25 minutes in C.W. 7, with averages of 4.5 and 16 minutes respectively (Table 10).

TABLE 10.—SUMMARY OF SEMEN COLLECTIONS FROM NORMAL BOARS 1937

Boar	Average live weight during the period kgs.	lbs.	Number of collections	Period of collection (days)	Duration of ejaculation (min)	Weight of ejaculate (gms)	Volume of ejaculate (cc)	Per cent liquid portion	Per cent gelatinous portion	Sperm per cu mm (1000)	Total number sperm (billion)
C.W. 4	168	369	21	24	4-9 6.3	146-423 262	142-415 257	55-81 68	19-45 32	25-180 73	5.9-50.4 19.6
C.W. 7	143	314	17	24	11-25 16	212-364 273	208-360 268	28-51 40	49-72 60	18-250 100	3.8-75.5 29.0
C.W. 94	162	357	12	11	4-8 6	127-319 211	125-310 206	45-78 67	22-55 32	20-480 101	4.1-76.8 19.1
C.W. 95	129	283	15	21	7-16 12	146-402 268	143-392 262	69-81 78	19-31 22	15-240 102	2.7-82.4 29.8
C.W. 96	109	239	18	14	7-19 11	143-510 319	140-500 313	63-83 76	17-37 24	20-230 83	5.2-72.4 26.0
C.W. 55	182	400	2	2	3-6 4.5	180-191 186	176-187 182			60-100 80	10.6-18.7 14.6
C.W. 147	166	366	2	2	5-8 6.5	165-267 216	163-262 212			75-165 110	19.6-26.9 23.3
Range	109-182 kgs. 239-400 lbs.		87*	2-24	3-25	127-510	125-500	28-83	17-72	15-480	2.7-82.4
Mean	151	333	12.5	14	10.0	267	262	66	34	93	24.3

*Total.

Note: The numbers appearing at the top give the range while the value below is the mean.

There was no apparent relation between frequency and duration of ejaculation.

With the exception of semen from C.W. 7, which averaged only 40 per cent liquid, the liquid-gelatinous ratio was fairly constant, averaging around 70 per cent liquid for the entire ejaculate.

The temperature in the barn where semen collections were made varied from-5° to 25° C (24° to 80°F). Temperature changes between these limits did not appear to affect the behavior of the boars nor the volume of their ejaculates.

Effect of Frequency of Ejaculation on the Quality and Quantity of Semen from Normal Boars.—The effect of frequency of ejaculation on volume of semen, on sperm concentration, number of sperm, duration of sperm motility, and sperm morphology was studied on semen from five boars. Because of individual variation, and different sequences of collection schedules, data on these boars are presented separately. Results of this study appear in Figs. 23, 24, and 25.

Volume of Ejaculate.—If allowance is made for individual differences, and for environmental factors which could not be controlled, the volume of semen per ejaculate remained near or above 200 cc. in all boars used at intervals of 48 hours or longer, over periods of 7 to 10 days. Except for C.W. 95, the volume of whose semen was materially reduced after several days, collections at 24-hour intervals did not reduce the volume below 200 cc., although there was a slight downward trend. However, collections made at 12-hour intervals resulted in a sharp drop the second day (C.W. 4, C.W. 96, and C.W. 94) with a loss of desire to mate in C.W. 4 and C.W. 94. The volume tended to be restored in the collections subsequent to the period of rest initiated by the lack of desire to mate. Although C.W. 96 was the smallest individual in the group, he was the most active sexually and produced the greatest volume of semen. Eighteen collections averaging 313 cc. were made in 14 days from this boar. Nine collections were made during the last five days of the period and although there was a marked reduction in volume, there was no apparent decrease in sex desire.

From data in Table 10 it is evident that the relationship between live weight and volume of semen per ejaculate is not direct. The smallest boar, C.W. 96, produced the greatest volume on the hardest collection schedule. The two largest boars, C.W. 4 and C.W. 94, produced the smallest average volumes in the group, on schedules with fewer collections per unit of time than that of C.W. 96. With the exception of C.W. 96 which lost 11 pounds, all boars gained weight during their respective periods of collection.

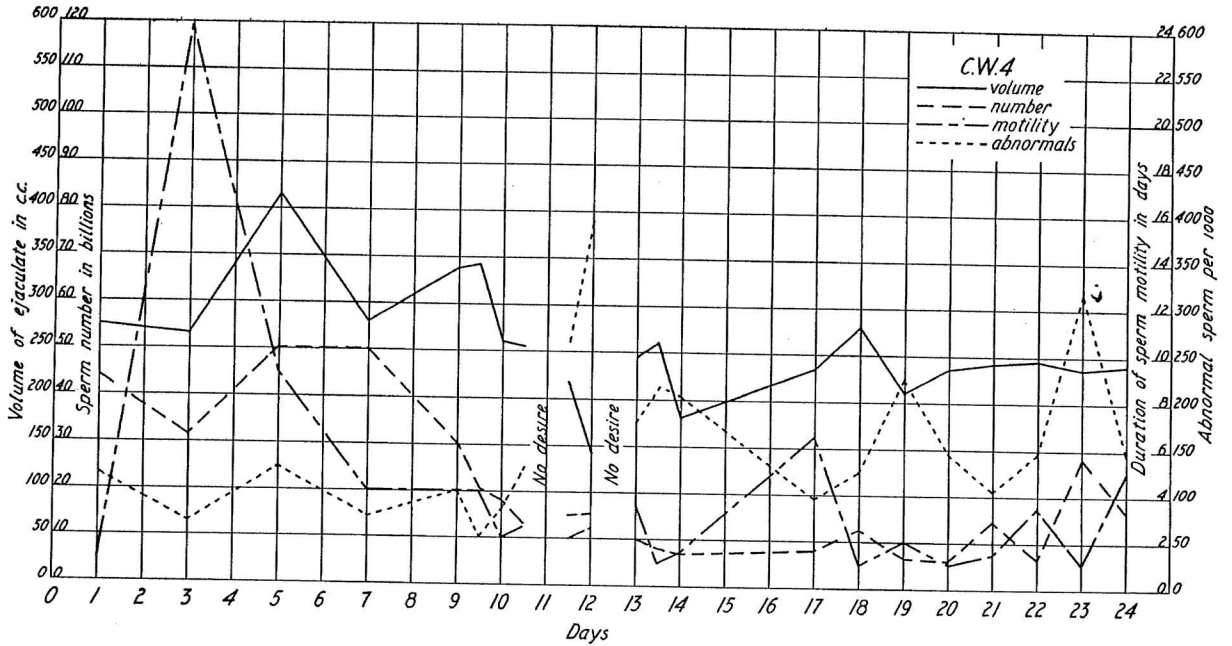

Fig. 23.—The effect of frequency of ejaculation on the volume of semen, sperm number, duration of sperm motility and sperm morphology.

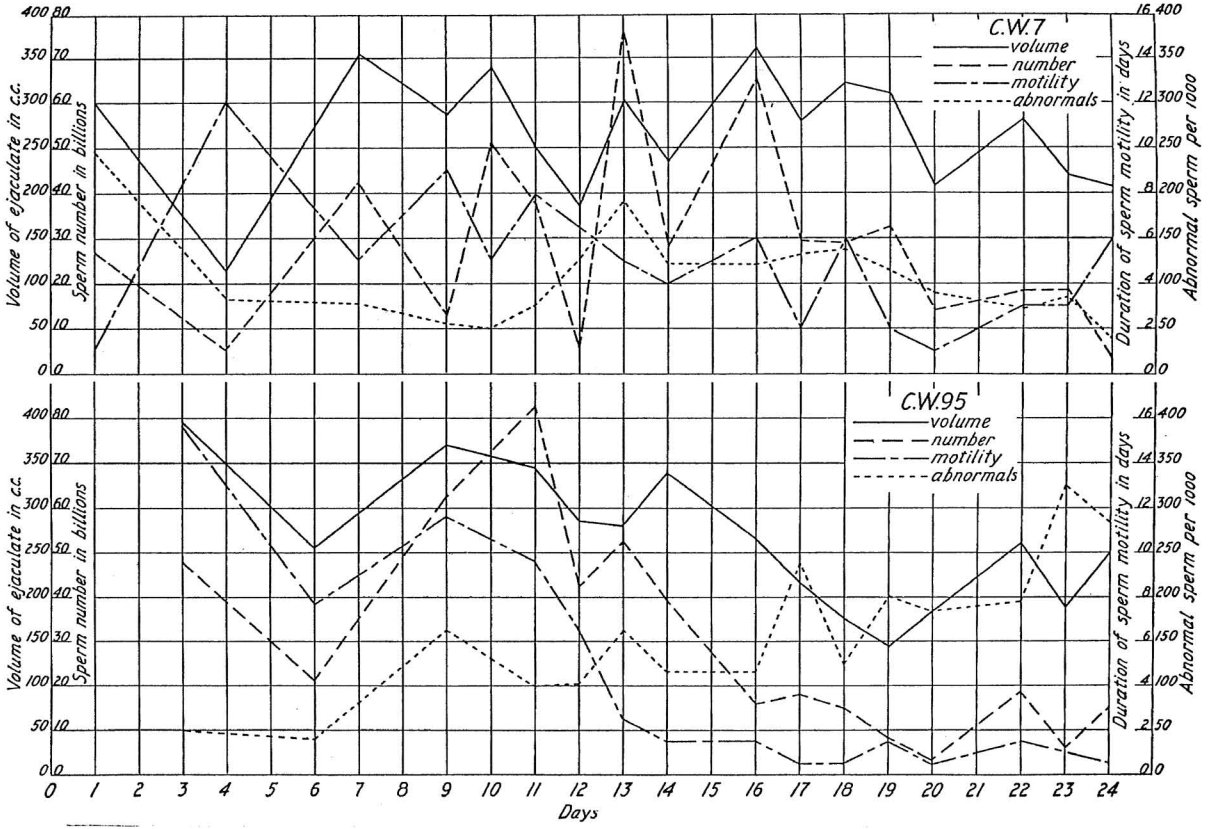

Fig. 24.—The effect of frequency of ejaculation on the volume of semen, sperm number, duration of sperm motility and sperm morphology.

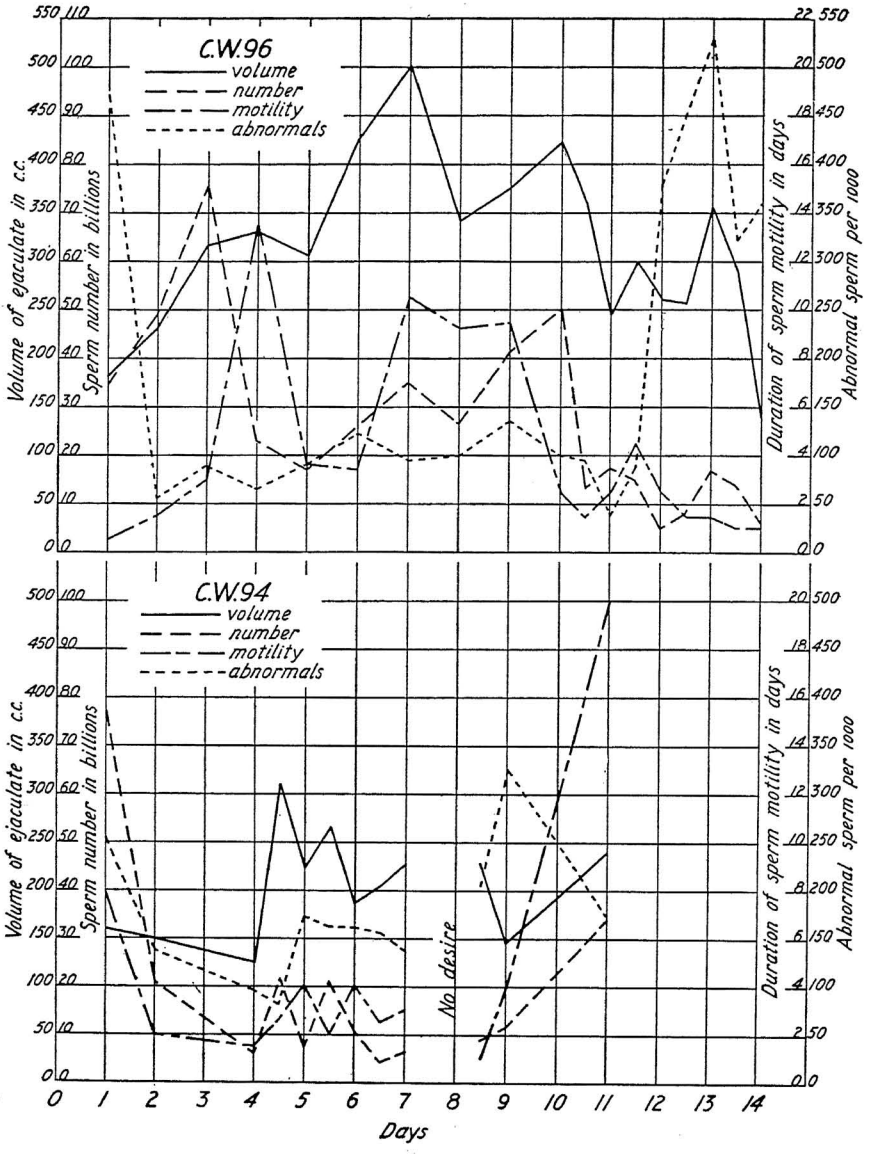

Fig. 25.—The effect of frequency of ejaculation on the volume of semen, sperm number, duration of sperm motility, and sperm morphology.

Sperm Concentration.—The average sperm concentration for all ejaculations was around 100,000 per cu. mm. for each of the five normal boars (Table 10). The two boars (C.W. 4 and C.W. 96) whose average sperm concentration fell below 100,000 were given harder usage than the other three boars. That may account for the lower figure. Although individual differences appeared in the way the boars rsponded to different frequencies of ejaculation, in general, the sperm concentration approached or exceeded 100,000 per cu. mm. except when the interval between ejaculations was less than 24 hours, and only after repeated ejaculations at 24 hour intervals. Ejaculations at 12-hour intervals reduced the sperm concentration to 50,000 or less by the third collection in each of the three boars used at that frequency.

Total Number of Sperm per Ejaculate.—The total number of sperm in the entire ejaculate was usually lower for the fractionated collections than for the preceding or following whole collection. Since it was impossible to count the sperm in the gelatinous fractions, and since there were too few sperm to count in the clear, intermediate and post-sperm fractions, the total number of sperm in the ejaculate calculated by summing the number in each vial counted was probably below the actual number present. No doubt this accounts for some of the fluctuation in total number of sperm from day to day where fractionated collections were involved. The total number of sperm generally fluctuated in the same manner as the concentration per unit volume. The first ejaculate following a long period of rest was characterized by a high total sperm count. For the five boars under consideration the total number on the first collection ranged from 26.8 to 76.8 billion. The number remained relatively high on collection schedules of 48 and 72-hour intervals. However, when the interval was reduced to 24 hours, a downward trend was observed after three or four days. Collections at 12-hour intervals resulted in a great reduction of sperm after two or three collections. (Figs. 23 and 24)

A summary showing the number of sperm per ejaculate and the average daily output of sperm for each boar is presented in tabular form below.

Boar	Number of ejaculations	Number of days over which ejaculations were made	Average number sperm per ejaculate (billion)	Average number sperm ejaculated per day (billion)
C.W. 4	21	24	19.6	17.1
C.W. 7	17	24	29.0	20.0
C.W 94	12	11	19.1	20.8
C.W. 95	15	22	29.8	20.3
C.W. 96	18	14	26.0	33.4

These values indicate a fairly uniform rate of spermatogenesis in four of the boars, with C.W. 96 exceeding the others in level of spermatogenic activity.

Duration of Sperm Motility.—No attempt has been made to express the degree of sperm motility in Figures 23, 24, and 25. However, the degree of motility was recorded on fresh semen and again at 24-hour intervals as long as the sperm remained motile. Five degrees of motility were recognized. Semen containing many sperm showing vigorous, progressive motility was scored 5; semen containing few sperm showing vigorous motility was scored 4; semen containing many sperm showing moderate motility was scored 3; semen containing many sperm showing slight motility was scored 2; and semen containing few sperm showing slight motility was scored 1. Except for a few samples of semen from boars which had been used at frequent intervals over a period of several days, all fresh semen scored 5 on motility. After cooling at 10° to 12° C. for 24 hours, most samples scored no better than 3, when warmed to room temperature (20-22° C.), but many continued at about that level for several days. The values in figures 23-26 represent the actual time sperm were observed to be motile.

From Fig. 23 (C.W. 4) it will be noted that sperm collected the first day remained motile only one day, whereas sperm from the next collection (48 hours later) remained motile 24 days. The duration of motility remained 4 days or more until the period of collections at 12-hour intervals when it dropped to 2 days and then to 1. Three days' rest prolonged the motility to 6.5 days but with continued collections at 24-hour intervals the duration of motility remained low. The duration of sperm motility in the semen of C.W. 7 presents a similar picture. (Fig. 24). Sperm from the first collection remained motile only one day, whereas sperm from the second collection (72 hours later) remained motile 12 days. This boar was not used at 12-hour intervals, but continued collections at 24-hour intervals reduced the duration of motility to one or two days. It is not known why there should be a sharp rise in the duration of motility on the 24th day unless it was due to the fact that the semen was fractionated, and only the high sperm-containing fractions were used for motility studies. In almost every case, sperm from the highest sperm-containing fractions remained motile longest. Where samples from more than one fraction of a series were studied for duration of motility, the average of all fractions was used for the value of the collection. (Detailed data appear in tables 1, 2, 3, 4, and 5 in the Appendix).

In the case of C.W. 94, sperm collected the first day remained motile eight days (Fig. 25). The high sperm concentration (480,000 per cu. mm.) on that day probably accounts for a longer duration of motility. Collections at 12-hour intervals reduced the duration of motility to 2 days. It remained low on a 24-hour collection schedule, but when given a 48-hour interval the duration went to 20.5 days. It hardly seems plausible that 24 hours additional rest could be responsible for such an increase. The relatively high sperm concentration (140,000) on that date is equally hard to explain but doubtless is related to the longer duration of sperm motility.

Sperm collected in the first collection (March 3) from C.W. 95 remained motile 15.5 days. However, the initial collection from this boar does not represent the first semen following a prolonged period of rest. After remaining relatively high on a collection schedule of 72-hour intervals for several days, the duration of motility was reduced to less than one day on continued collections at 24-hour intervals. The duration of motility increased with each collection, and reached a peak the fourth day on a 24-hour schedule for C.W. 96 (Fig. 25) As previously mentioned, this boar was unusually active sexually for several days prior to the onset of collections. It is possible that he was partially exhausted at the beginning of the collections, and that separating him from the other boars and restricting him to one ejaculation per day might actually have been a rest for him. In any event his sperm showed a fairly high

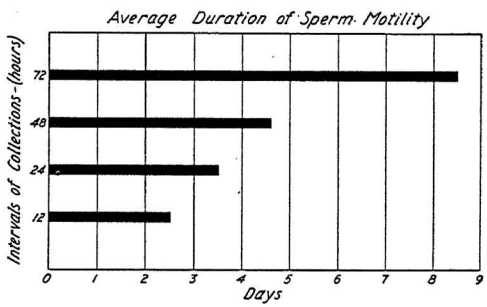

Fig. 26.—The effect of frequency of ejaculation on the duration of sperm motility. The values represent composites of semen samples from five normal boars. They include observations on 21, 40, 12, and 5 semen samples for the 12, 24, 48, and 72-hour intervals respectively.

duration of motility (3 to 13 days) over a 10-day period on a 24-hour collection schedule. On a 12-hour schedule, however, it was reduced to 1 to 2 days and remained there.

To summarize the motility studies on the five normal boars, the average duration of sperm motility of 21 samples collected at 12-hour intervals was 2.5 days, of 40 samples collected at 24-hour intervals, 3.5 days, of 12 samples collected at 48-hour intervals, 4.6 days and of 5 samples collected at 72-hour intervals, 8.5 days (Fig. 26).

In general, semen samples become acid on standing a few days at 10° to 12° C. Although not consistent, there was some indication that the longer the sperm remained motile, the more acid the semen. Bacteria became numerous in some samples, but there was nothing to indicate that they affected the duration of sperm motility.

Sperm Morphology.—Ten different types of abnormalities were recognized in the sperm. These types were: tailless sperm, coiled tail, tapering head, enlarged middle piece, middle piece bead, damaged head, double heads, giant head, small head, and undeveloped sperm. The number of each type per 1000 sperm was tabulated for each boar and appears in tables 8 to 12 in the Appendix. Coiled tails, middle piece beads and enlarged middle pieces were by far the most common types of abnormalities, appearing in that order (Fig. 27). Although there were wide variations between different boars, there was a correlation between frequency of ejaculation and the number of abnormal sperm per 1000 (Figs. 23, 24, and 25). Especially was this true when semen was collected at 12-hour intervals. In the case of C.W. 4, there were only 117 abnormals per 1000 in the initial collection. Subsequent collections at 48-hour intervals had little effect on the morphology, as the number of abnormals remained under 100 per 1000. Collections made at 12-hour intervals, however, produced a marked increase in the number of abnormal forms. A peak of 393 per 1000 sperm occurred on March 12. When placed back on the 24-hour schedule, the number of abnormals was somewhat reduced but remained relatively high. Aside from the increase in number of sperm with coiled tails, middle piece beads, and enlarged middle pieces, the most striking abnormality induced by frequent ejaculations was the enlarged cap about the head, appearing as a thin cytoplasmic membrane, completely and uniformly surrounding the head (Fig. 27 C and D). Since these forms appeared only after a period of frequent ejaculations they were interpreted as signs of immaturity, and those sperm were designated undeveloped.

The initial collection from C.W. 7 contained 246 abnormal forms per 1000. The number dropped to less than 60 in subsequent collections on a 48-hour schedule, and increased to more than 100 when

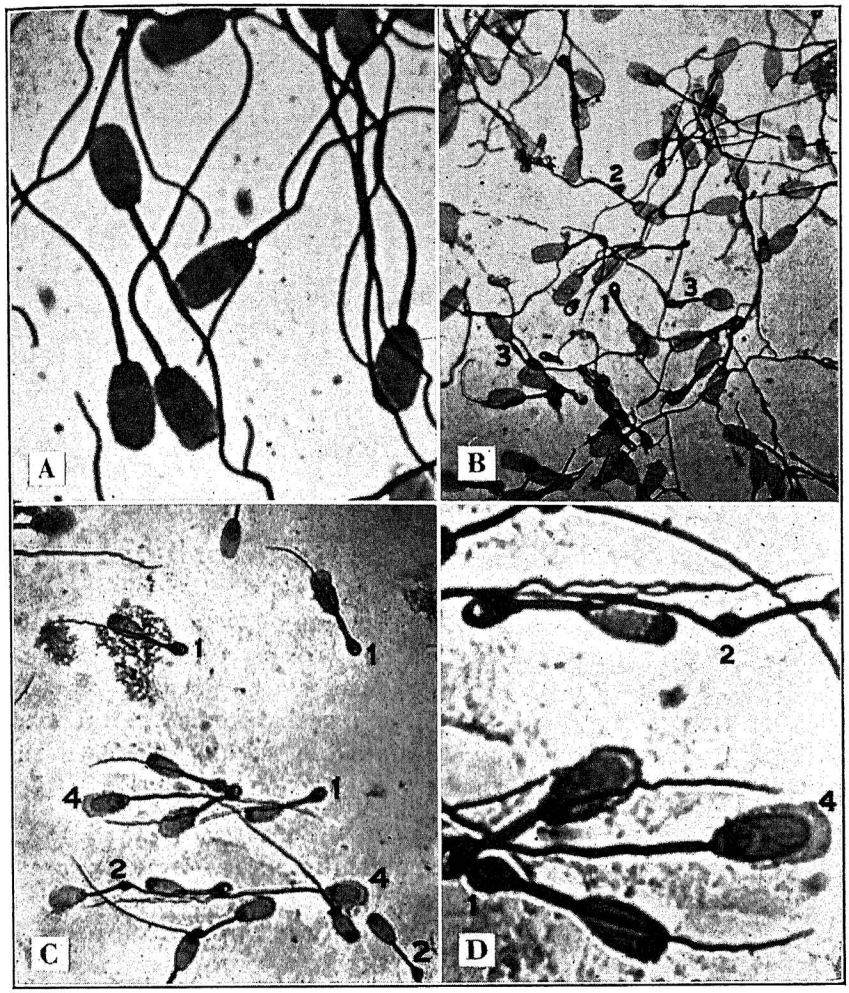

Fig. 27.—A, normal sperm x 1300. B, sperm showing various types of abnormalities x 520. C, sperm from boar following period of frequent ejaculations, note cytoplasmic cap, x 520. D, same as C x 1300. 1, coiled tail; 2, middle piece bead; 3, enlarged middle piece; 4, cytoplasmic cap.

the interval was reduced to 24 hours. A few undeveloped forms appeared throughout the period of collections at 24-hour intervals.

In the case of C.W. 94, the first collection contained 255 abnormal forms per 1000 sperm. This boar was used at 12-hour intervals, and except for a reduction in abnormal forms during the first few days, the number increased with frequency and number of collections. (Fig. 25)

The number of abnormal forms of sperm was low in the first semen collection from C.W. 95. Continued ejaculations at intervals of 24 hours increased the abnormal forms to more than 200 per 1000 sperm. The number of undeveloped sperm exceeded 200 per 1000 on March 23.

The initial collection from C.W. 96 contained 471 abnormal forms per 1000 sperm. It is difficult to explain the sharp drop to 54 abnormals the following day, but the count was based upon a high sperm-containing fraction (870,000 per cu. mm.). Isolation and subsequent ejaculations at only 24-hour intervals might actually have been a rest for C.W. 96, following frequent pederasty, but that hardly seems adequate to account for the drop from 471 to 54 abnormals in 24 hours. Although his semen showed a relatively low abnormality count throughout the 10-day period of collections at 24-hour intervals, he behaved like the other boars in showing a higher abnormality count when the interval of collections was shortened to 12 hours (Fig. 25).

From the figures it will be noted that in spite of individual variations, some of which cannot be explained satisfactorily, there is a consistent relationship existing between the abnormality count and the duration of sperm motility. This relationship is most striking during and following periods of frequent ejaculations.

Except for the immature forms, there was no consistent difference between the types of abnormalities found in the first ejaculates and those appearing in subsequent ones.

Semen from Operated Boars

Semen from Boars Without Seminal Vesicles.—Semen was collected and studied from two boars without seminal vesicles (D.J. 33 in 1936 and C.W. 95 in 1937). Semen from these boars was quite similar in appearance. It was characterized by a total absence of the gelatinous or tapioca-like material. When fresh it was a uniformly thick, syrupy fluid. On standing, the Cowper's gland contribution settled to the bottom into a gray waxy layer (Fig. 28).

Since no collections were made from D.J. 33 as a normal boar, comparisons with his normal semen cannot be made. However, when fractionated semen collections from him are compared with fractionated collections from normal boars, it appears that removal of the seminal vesicles had little or no effect on the relative rate or sequence of events in ejaculation, either as regards volume or sperm number. An average of five fractionated collections from this boar is represented in Fig. 29. Two waves of ejaculation were present,

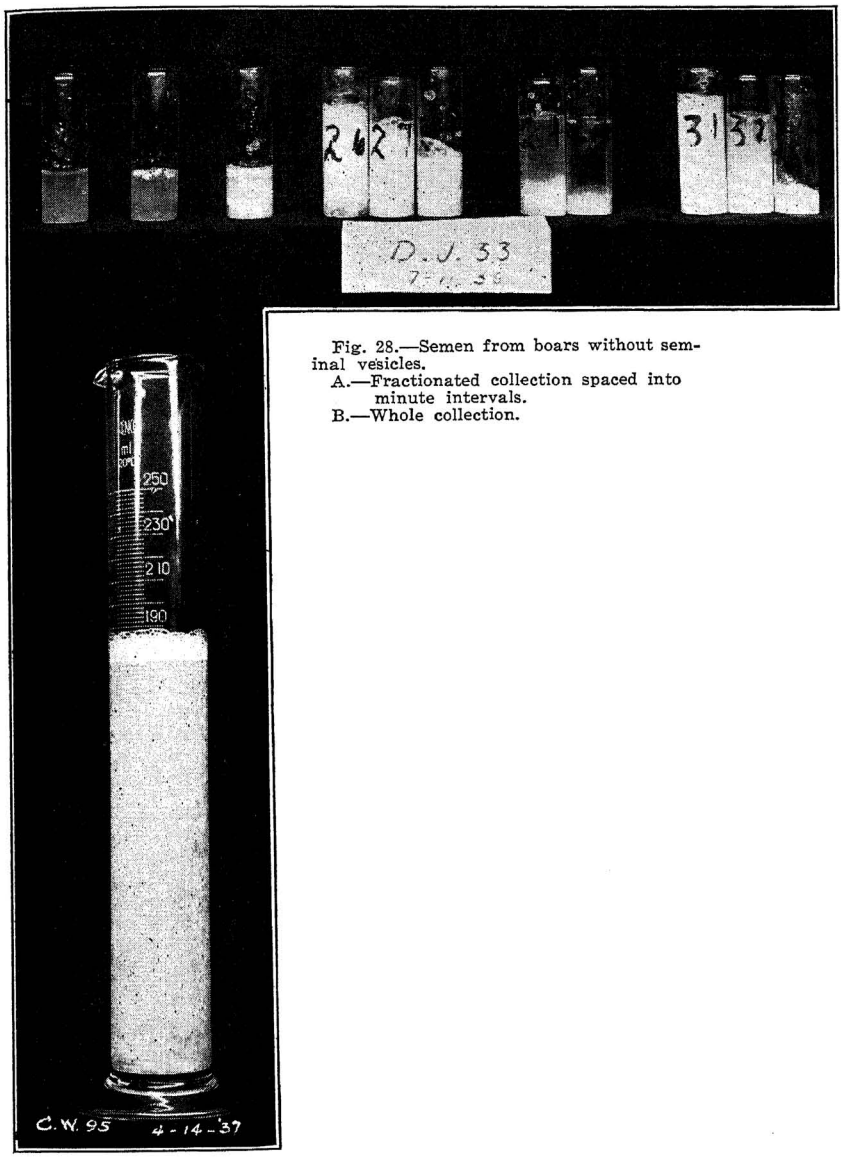

Fig. 28.—Semen from boars without seminal vesicles.
A.—Fractionated collection spaced into minute intervals.
B.—Whole collection.

although not quite so pronounced as in the normal boars. The average total weight of the ejaculates was 172 grams and the number of sperm per ejaculate exceeded 80 billion, which compares favorably with the number from normal boars.

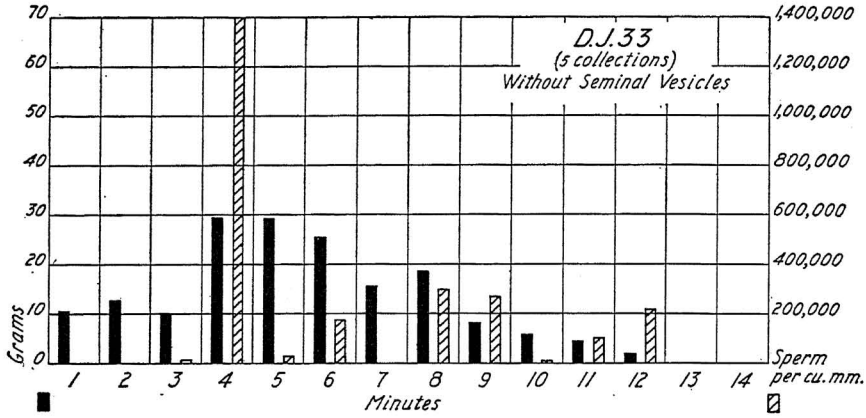

Fig. 29.—The rate of ejaculation and sperm concentration each minute, of boar without seminal vesicles.

Unfortunately there were too few sperm to count in the semen of C.W. 95 after removal of the seminal vesicles. Since sperm appeared in considerable numbers in his semen after removal of the Cowper's glands (second operation) it was concluded that there was some obstruction in the passages (probably caused by the first operation), which had not disappeared when the first collections were made. On the basis of volume of ejaculate, C.W. 95 produced in 7 ejaculations an average of 193 cc. which amounted to 74 per cent of the average volume he produced as a normal boar and 74 per cent of the average volume produced by all seven of the normal boars used in 1937 (Table 11). On this basis, 26 per cent of the volume of the semen was contributed by the seminal vesicles.

The pH of the first fractions was high (7.7), dropped off somewhat in the following fractions (to 7.4), and remained fairly constant during the remainder of the ejaculation.

The number of abnormal types per 1000 spermatozoa was comparatively low indicating that the absence of the seminal vesicle fluid had no deleterious effect on the sperm, so far as morphology was concerned. (Table 13 in appendix).

Semen from Boars without Cowper's Glands:—Semen collections were made from two boars (C.W. 96 and C.W. 147) whose Cowper's glands had been removed. Semen minus the contributions from the Cowper's glands was more liquid than normal semen, had uniform consistency, lacked the gelatinous lumps of normal semen and the waxy syrup of semen from boars whose seminal vesicles alone had

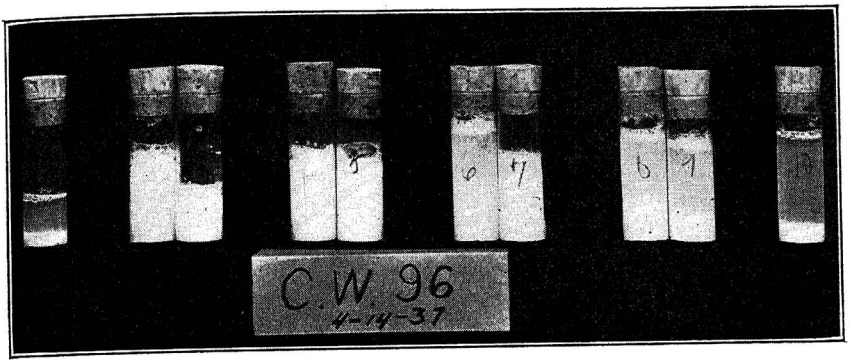

Fig. 30.—Fractionated semen collection from boar without Cowper's glands. The vials are grouped into minute collections. Vials 2, 3, 4, and 5 are the high sperm-containing fractions.

been removed (Fig. 30). Mixing and stirring fresh seminal vesicle fluid with fresh Cowper's gland wax, changed the waxy material into a gelatinous material similar to that found in normal semen but lacking the typical tapioca lumps.

Removal of the Cowper's glands exerted little or no influence on the duration, rate, or sequence of events during ejaculation. Fractionated collections were made from C.W. 96, a summary of which is presented in Fig. 31. The rate of ejaculation reached a peak the

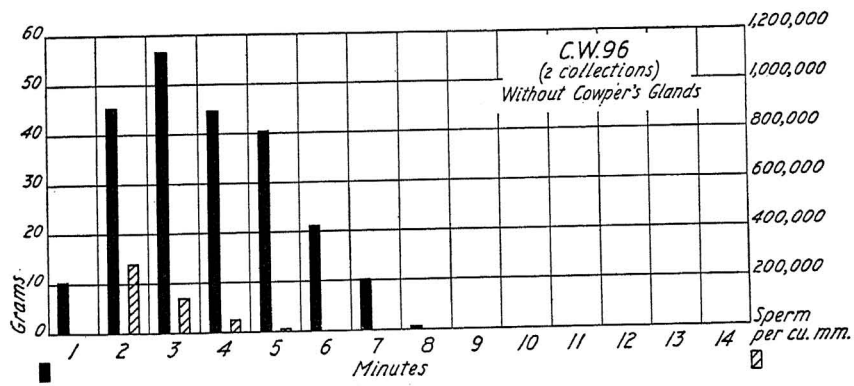

Fig. 31.—The rate of ejaculation and sperm concentration each minute, of boar without Cowper's glands.

third minute and declined gradually thereafter. Sperm numbers reached a peak the second minute. The second wave of ejaculation was absent from this boar. The pH of the pre-sperm fractions (first minute) was 7.4, but with the high sperm number in the second minute the pH was lowered to 7.0. Thereafter it increased as the sperm concentration decreased.

Observations on the 12 collections from the two boars showed an average volume of 212 cc., an average of 32 billion sperm per ejaculate, and an average ejaculation time of 6 minutes (Table 11). If these values are compared with those from normal boars they suggest that removal of the Cowper's glands reduced the volume of the ejaculate to 81 per cent and that 19 per cent of the ejaculate from normal boars originates in the Cowper's glands.

Since less frequent collections were made from the operated than from the normal boars, it is not surprising that the number of sperm per ejaculate exceeded the number for normal semen or that the sperm concentration was higher, since the volume of semen was reduced. However, the proportion of abnormal sperm in semen from a boar without Cowper's glands was actually lower than in the normal semen from the same boar (Table 14 in Appendix).

The duration of sperm motility after the removal of the Cowper's glands was studied for only one boar and under somewhat different conditions from those used for normal boars. The average duration of sperm motility for this boar was 7.8 days, based upon 8 collections at 24-hour intervals (Table 6 in Appendix). This value is more than twice the corresponding figure on normal boars. Covering the semen with a thin layer of mineral oil prolonged the period of sperm motility from 7.8 to 11.1 days.

Semen from Boars without Seminal Vesicles and Cowper's Glands.—Semen minus the contributions from the seminal vesicles and Cowper's glands was almost watery-thin and entirely free from gelatinous or syrupy material (Figs. 32 and 34). The color varied from gray to milky white depending on the sperm concentration. Semen collections were made from four boars whose seminal vesicles and Cowper's glands had been removed, (D.J. 3 in 1936, and C.W. 7, C.W. 95, and C.W. 96 in 1937). Six collections from D.J. 3 averaged 192 grams in weight, and 516,000 sperm per cu. mm. for a total of 108.4 billion sperm per ejaculate. A record of the five fractionated collections from D.J. 3 is represented in Fig. 33. Only one wave of ejaculation was present, with the maximum quantity of semen and sperm concentration coming in the second minute. However, the fractionated collections from C.W. 7 and C.W. 95 showed two distinct waves of ejaculations. The volume of the ejaculate was reduced, and the gelatinous material was absent, but the fractionated collections had much the same appearance as collections from normal boars.

The average volume of ejaculate in 32 collections from 3 operated boars (C.W. 7, C.W. 95, and C.W. 96) was 153 cc., or 58 per cent

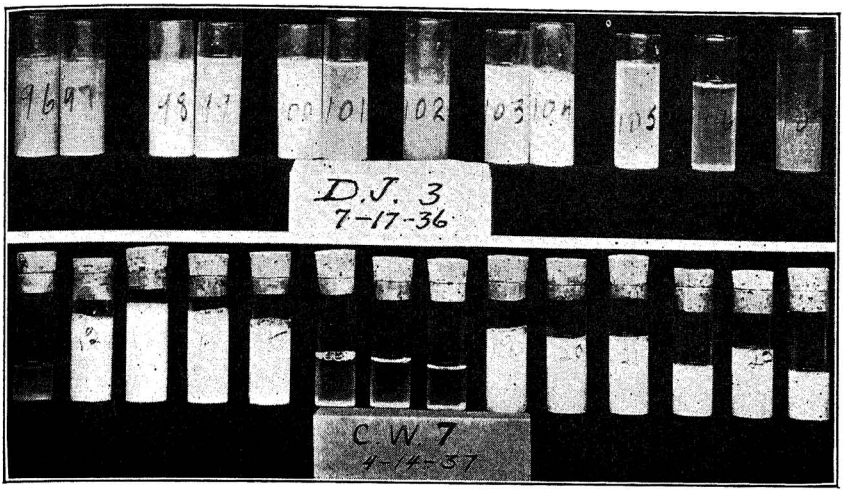

Fig. 32.—Fractionated semen collections from boars without seminal vesicles and Cowper's glands. Vials are grouped into minute fractions. Above: vials 98, 99, 100, and 104 are the high sperm-containing fractions. Below: vials 12, 13, 19, 20, and 21 are the high sperm-containing fractions.

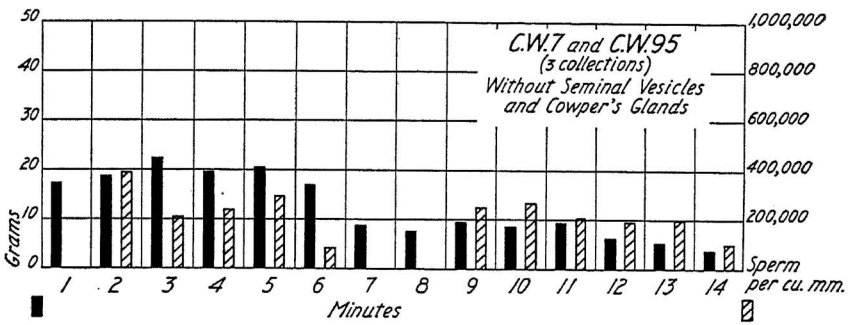

Fig. 33.—The rate of ejaculation and sperm concentration each minute, of boars without seminal vesicles and Cowper's glands.

of the volume from normal boars (Table 11). This leaves 42 per cent of the volume from normal boars to be contributed by the seminal vesicles and Cowper's glands. This is only three per cent less than the 45 per cent obtained by adding the separate values for the seminal vesicles and Cowper's glands shown in the same table. The low sperm number per ejaculate from these boars is due, principally, to inclusion of data from C.W. 95, whose sperm count was low. The average duration of sperm motility in 19 collections over 21 days from C.W. 7 was 5.6 days (Table 7 in Appendix). Covering his

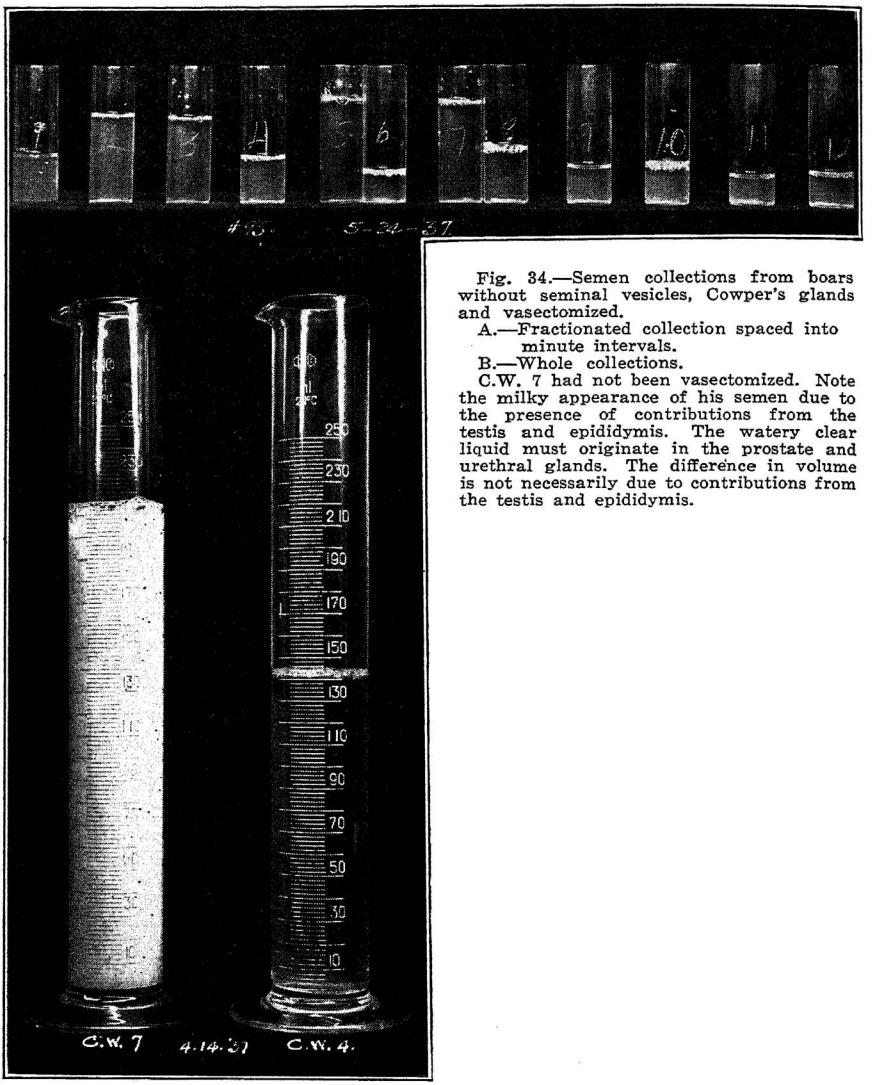

Fig. 34.—Semen collections from boars without seminal vesicles, Cowper's glands and vasectomized.
A.—Fractionated collection spaced into minute intervals.
B.—Whole collections.
C.W. 7 had not been vasectomized. Note the milky appearance of his semen due to the presence of contributions from the testis and epididymis. The watery clear liquid must originate in the prostate and urethral glands. The difference in volume is not necessarily due to contributions from the testis and epididymis.

semen with mineral oil extended the duration of motility one day. The number of abnormal spermatozoa per thousand was not materially different from the number in normal semen from the same boar (Tables 15 and 16 in Appendix).

Semen from Boar without Seminal Vesicles, Two-thirds of Prostate and Vasectomized.—The prostate gland was removed from only one boar (D.J. 18) and on autopsy it was revealed that about one-third of the body of the gland remained intact. Because of inability to remove the portion of the gland embedded in the urethral wall, further attempts at removal were not made. The vasa deferentia were accidentally ligated or severed during removal of the prostate gland so that D.J. 18 proved to be vasectomized as well as without seminal vesicles and two-thirds of his prostate. Libido of this boar seemed to be in no way affected by the operation. Except for the absence of sperm in his semen the only noticeable difference between this boar and the other Duroc Jersey boars was the reduced volume of ejaculate. The average volume of six ejaculates in 30 days from D.J. 18 was 100 cc., whereas on the same collection schedules, D.J. 3 averaged 190 cc. in six ejaculations and D.J. 33 averaged 172 cc. in five ejaculations.

Semen from Boars without Seminal Vesicles, Cowper's Glands and Vasectomized.—Severing the vasa deferentia removes from semen the contributions of the testes and epididymides. Removal of the seminal vesicles and Cowper's glands eliminates their secretions. In the absence of these contributions, semen is not only free of sperm but is clear, almost watery thin, and has a specific gravity of about 1.01 (Fig. 34). Four boars (C.W. 4, C.W. 7, C.W. 95 and C.W. 96) were vasectomized in addition to the removal of the seminal vesicles and Cowper's glands. The volume of semen was somewhat reduced, resulting in a decreased rate of ejaculation, and the absence of sperm gave the semen a uniformly clear appearance, but the relative rates of ejaculation per minute and the location of the weight peaks remained the same as in normal boars, or in boars with other types of operation. The duration of ejaculations ranged from 4.5 to 16 minutes, with an average of 8.0 minutes.

In the absence of the contributions from the testes and epididymides, the seminal vesicles, and the Cowper's glands, the semen, if any, must obviously originate in the prostatic and urethral glands. The average volume of the 25 collections from the 4 boars, was 147 cc., or 56 per cent of the normal ejaculate contributed by the prostatic and urethral glands (Table 11). This leaves a total of 44 per cent contributed by the remainder of the reproductive tract. Since 42 per cent was contributed by the seminal vesicles and Cowper's glands, the additional 2 per cent must have come from the testes and epididymides.

TABLE 11.—COMPARISON OF SEMEN VOLUME FROM NORMAL BOARS AND FROM OPERATED BOARS

Description of Boars	Number of Boars Included	Average Weight of Boars (lbs.)	Total number of semen collections included	Duration of ejaculation (min.)	Volume of ejaculate (cc)	Per cent of volume from normal boars	Apparent per cent contributed by part removed	Sperm per cu mm (1000)	Total number sperm (billion)
Normal	7	332	87	3-25 10.0	127-500 262	..	..	15-480 93	2.7-82.4 24.3
Without Seminal Vesicles	1	294	7	6-10 8.5	150-220 193	74	26	0+	0+
Without Cowper's Glands	2	313	12	3.5-11 6	97-330 212	81	19	52-530 168	9.7-56.9 32
Without Seminal Vesicles and Cowper's Glands	3	293	32	4-18 8.3	92-247 153	58	42	25-575 112	1.6-87.4 17.7
Without Seminal Vesicles and Cowper's Glands and Vasectomized	4	324	25	4.5-16 8	93.5-217 147	56	44	0	0

+ Too few sperm to count.
Note: The figures at the top give the range. The lower value is the mean.

Attempts at collecting epididymal fluid during ejaculation by means of cannulizing the vasa were unsuccessful, but epididymal fluid collected directly from the epididymides of 7 boars when slaughtered or castrated contained from 4,560,000 to 6,800,000 sperm per cu. mm., with an average of 5,800,000. Normal whole semen from the same boars averaged approximately 100,000 sperm per cu. mm. Thus two per cent of the semen volume contributed by the testes and epididymides would supply the sperm number.

The Effect of Removal of the Accessory Sex Glands and Subsequent Castration on Libido.

Removal of the seminal vesicles, Cowper's glands, two-thirds of the prostate and vasectomy did not reduce libido in any of the eight animals whose glands were removed. However, in some boars, after one or more operations, an apparent inability to maintain erection throughout ejaculation was observed. After the first few minutes the penis became limp, but ejaculation continued in a normal manner. In the case of boars whose vasa deferentia were cannulized, there was noticeable swelling of one or both testes within 7 to 14 days after cannulization. In some animals the testes became greatly enlarged, and the animals went off feed temporarily. On castration, the tunica albuginea was found adhered to the tunica vaginalis; and liquid normally present between those layers was totally absent. No actual increase in size of the testes proper occurred, but a great increase in thickness of scrotal tissue surrounding the testes with a corresponding increase in vascularization was observed. Pus was found in the tail of the epididymis in every animal which showed apparent swelling of the testis.

Castration had little immediate effect on libido in some animals. Ninety-two cc. of clear fluid were collected from C.W. 95, 16 days after castration, and 100 cc. of grayish liquid were collected from C.W. 147, four days after castration. C.W. 147 had his seminal vesicles intact, whereas C.W. 95 had neither seminal vesicles nor Cowper's glands. No sperm were present in the collection from either boar. Contributions from the seminal vesicles and the presence of many epithelial cells were probably responsible for the gray color of the semen from C.W. 147.

The Effect of Removal of the Accessory Sex Glands on Fertility. Two Duroc Jersey boars (3 and 33) and two Chester White boars (7 and 96) were mated to normal females in order to test their fertility. The results of these matings appear in Table 12. The two Duroc Jersey boars served their gilts in a perfectly natural manner; and save for the seemingly great loss of semen from the vagina during service, the matings appeared normal in every respect.

TABLE 12.—FERTILITY OF OPERATED BOARS

Boar	Glands Removed	Date of Removal of Glands	Breeding Record			
			Sows Bred	Date Bred	Nature of Service	Results
D.J. 33	Seminal Vesicles	12-23-35	Hampshire Gilt 54	2-3-36	Natural	Farrowed 11 pigs 5-27-36
D.J. 3	Seminal Vesicles & Cowper's Glands	12-23-35 12-23-35	Hampshire Gilt 56	2-14-36 2-15-36	Natural Natural	Farrowed 2 pigs 6-6-36
C.W. 7	Seminal Vesicles & Cowper's Glands	3-26-37	C.W. Sow 33	5-10-37	Natural	16 Embryos recovered 6-3-37
		3-26-37	C.W. Sow 81	5-14-37 a.m. 5-15-37 a.m.	Natural Artificial	12 Embryos recovered 6-3-37
C.W. 96	Seminal Vesicles & Cowper's Glands	4-20-37	C.W. Sow 51	5-14-37 p.m. 5-15-37 a.m.	Artificial Artificial	13 Embryos recovered 6-3-37
		3-18-37	C.W. Sow 84	5-14-37 a.m. 5-15-37 a.m.	Natural Artificial	14 Embryos recovered 6-3-37

The Chester White boars were unable to serve their sows with the same degree of success. C.W. 7 bred sow 33 naturally, but assistance was rendered in holding the penis in the vagina of sow 81 after the erection was lost. Sow 81 was artificially inseminated with 100 cc. of semen the second service. Because he was unable to make a satisfactory service, after the first attempt (5-14-37 a. m.) semen from C.W. 96 was artificially introduced into the cervix of sows 51 and 84. Semen was collected in sterile containers, taken up with a 50 cc. syringe and injected through a thick walled rubber tube (outside diameter 16 mm. inside diameter 6mm.) directly into

the cervix. The end of the tube inserted into the cervix was beveled and oiled to facilitate entrance. Approximately 100 cc. of semen was injected at each insemination. Except for sow 33 which would not permit the entrance of the boar's penis until the third day of heat, the sows were bred the second day of heat and rebred 24 hours later. The four Chester White sows had weaned litters of pigs just prior to being bred. They were sold for slaughter and the embryos recovered at time of slaughter.

Observations made when the boars were slaughtered revealed no regeneration of glandular tissue in any animal. Except for a third of the prostate left in the only attempt to remove it, there was in no case any remaining tissue of the glands removed.

Chemical Analyses

Representative samples of the freshly collected material were used for duplicate determinations of chlorides, glucose, urea, creatinine, solids, and total organic nitrogen. Chlorides were determined by the method of Van Slyke (1923). Glucose, urea, and creatinine were determined on aliquots of a protein-free, tungstic acid filtrate of the material. Glucose was determined according to the method of Folin-Wu (1929). Urea and creatinine were determined by methods given in Hawk and Bergeim (1931, pp. 419-420 and 421-422).

The effectiveness of the glucose and urea methods was established by the quantitative recoveries of known amounts of glucose and urea added to tungstic acid filtrates. It was not possible to establish the quantitative nature of the creatinine method; hence the creatinine values reported should be considered only as being very rough estimations.

The solid matter in a collection was determined by weighing the solids resulting from the drying of a known weight of the wet material at 100° C. in a hot air oven for 12 to 24 hours. The Kjeldahl method was used for the determination of total organic nitrogen.

The remainder of the collected material was placed in a chemically clean beaker, and freed of water by drying for 12 to 24 hours at 100° C. in a hot air oven. The organic matter in a known weight of the ground, well-mixed, solid material was destroyed according to the procedure of Gieseking, Snider, and Getz (1934) and the residual inorganic matter was dissolved in a small volume of 1:1 hydrochloric acid (C.P.) supplemented by a larger volume of distilled water. The resulting solution was transferred quantitatively to a suitable volumetric flask. The contents of the flask were then

TABLE 13.—RECOVERIES OF SODIUM, POTASSIUM, CALCIUM, MAGNESIUM, AND PHOSPHORUS WHEN ADDED TO THE SOLIDS FROM WHOLE NORMAL BOAR SEMEN

Dried material representing whole normal semen from boar.	Date Collected	SODIUM			POTASSIUM			CALCIUM			MAGNESIUM			PHOSPHORUS		
		mg. found in 2.50 gm. dried material + 39.4 mg. sodium.	mg. in 2.50 gm. dried material.	per cent of added sodium recovered.	mg. found in 2.50 gm. dried material + 14.2 mg. potassium.	mg. in 2.50 gm. dried material.	per cent of added potassium recovered.	mg. found in 2.50 gm. dried material. + 10.0 mg. calcium.	mg. in 2.50 gm. dried material.	per cent of added calcium recovered.	mg. found in 2.50 gm. dried material + 7.20 mg. magnesium.	mg. in 2.50 gm. dried material.	per cent of added magnesium recovered.	mg. found in 2.50 gm. dried material + 11.03 mg. phosphorus.	mg. in 2.50 gm. dried material.	per cent of added phosphorus recovered.
C.W. 96	3-3-37	426	385	104	85.7	71.5	100	12.70	2.59	101	12.96	5.88	98	14.52	3.63	101
C.W. 96	3-11-37	381	344	94	89.9	76.2	97	12.58	2.65	99	13.21	5.88	99	14.27	3.14	99
C.W. 4	3-9-37	497	455	107	87.0	73.0	99	13.14	3.05	101	13.00	5.94	98	15.18	4.05	100
C.W. 95	3-11-37	357	318	99	124.7	110.0	103	12.70	2.70	100	13.00	5.80	100	16.42	5.30	99
C.W. 95	3-16-37	393	354	99	98.8	84.6	100	12.93	2.78	102	12.98	5.86	101	15.74	4.86	99
C.W. 94	3-2-37	363	325	97	153.6	120.0	96	12.50	2.56	99	12.60	5.43	99	15.98	4.95	100
C.W. 7	3-10-37	437	400	94	106.1	92.6	95	12.94	2.79	102	13.15	5.78	98	15.21	4.14	100
C.W. 7	3-16-37	472	430	94	103.2	89.9	94	12.41	2.62	98	12.60	5.56	98	15.60	4.61	100

made up to volume by the addition of distilled water, and were well mixed. Aliquots of this solution were used for duplicate determinations of sodium, potassium, magnesium, calcium, and phosphorus. The methods used were: sodium—McCance-Shipp (1931), potassium—Shohl and Bennett (1928), magnesium—Denis (1922), calcium—Clark and Collip (1925), and phosphorus—Bell-Doisy (1920). The quantitative aspects of each of these analytical procedures are shown in Table 13. It will be observed that approximately 100 per cent of the element added was recovered in every case.

A complete summary of all determinations made in 1937 on the ten types of body fluids is presented in Table 14. Chemical analyses of all seminal fluids were not made in 1936 but the determinations that were made were quite comparable with those determinations made in 1937 and appear in Table 30 in the Appendix. The analyses of blood serum and plasma are listed chiefly to provide a basis from which to evaluate the composition of the various seminal fluids.

One of the significant points to be gained from an examination of these data is the fact that each of the various seminal fluids is distinctly specific in its composition. Of equal interest is the striking consistency of composition of each of these glandular products. Boar C.W. 95 produced very few sperm following removal of his seminal vesicles and there were also some inconsistencies in the chemical composition of his semen. Unfortunately the control animal (C.W. 55) died before collections were made for checking the data on C.W. 95. Except for this animal, no significant differences appeared in the composition of seminal fluids from different boars or from the same boars at different periods of sexual activity.

Since the semen from boars without seminal vesicles, Cowper's glands, and vasectomized, can obviously originate only in the prostatic and urethral glands, semen from those boars will be referred to as prostatic and urethral secretions.

The normal pH of the blood was around 7.5 to 7.6. Most of the seminal fluids were also alkaline. The seminal vesicle fluid, however, was acid with a pH of 6.7. Likewise epididymal fluid was acid, whereas secretions from the prostatic and urethral glands were more alkaline than blood. Similarly, the percentages of dry matter in seminal vesicle fluid and Cowper's gland material were almost the same, and nearly twice as high as in blood serum and plasma. Pure epididymal fluid was also high in dry matter; but since removal of the seminal vesicles and Cowper's glands reduced the

TABLE 14.—SUMMARY OF THE CHEMICAL DETERMINATIONS

(mgm. per 100 gm. wet weight)

Nature of Material	Number of Animals Involved	Number of Samples Analyzed (duplicated)	pH	Dry Matter, per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein equivalent
Blood serum	4	4	7.6-7.7 7.6+	8.1-8.2 8.14	186-227 203.0	22.7-25.2 23.5	9.7-11.5 10.3	2.0-4.5 2.9	6.7-8.7 7.9	495-600 551.0	80.7-91.0 85.4	12.2-14.2 13.5	2.4-2.4 2.4	957-1002 982.0	5984-6262 6135.0
Blood plasma	4	7	7.5-7.6 7.5+	8.4-9.2 8.7	.. ..	32.5-38.2 36.1	.. ..	.. ..	8.3-9.3 8.6	580-622 593.0	80.0-89.0 83.9	16.2-18.0 17.0	2.4-2.4 2.4	950-1143 1010.0	5941-7144 6315.0
Seminal Vesicle fluid	5	9	6.4-6.8 6.7+	15.8-18.4 16.3	300-606 398.6	1043-1471 1244.8	7.2-8.7 7.8	38.1-44.7 39.7	39.0-51.0 43.1	15.0-60.0 32.4	243.0-266.0 257.0	.. ..	4.9-5.6 5.3	1470-1512 1488.0	9187-9450 9302.0
Cowper's Gland Material	5	8	7.2-7.3 7.2+	14.5-18.3 15.8	857-1330 1094.6	422.0-557.0 493.1	27.1-38.0 30.1	128.0-166.0 140.6	8.9-11.8 9.8	377-435 408.6	.. ..	.. ..	.. ..	1238-1296 1275.0	7737-8100 7969.0
Epididymal fluid	3	3	6.7-6.9 6.9+	10.8-14.2 13.2	277-688 482.0	249.0-399.0 324.0	.. ..	.. ..	158.0-280.0 219.0	158-480 356.0	.. ..	.. ..	.. 1.4	.. 1606.0	.. 10038.0
Normal Whole Semen	7	19	7.3-7.8 7.5+	2.2-6.2 4.6	280-837 646.1	83.0-382.0 243.0	2.3-6.6 5.21	5.2-14.5 10.7	3.7-16.9 8.4	423-701 542.1	12.9-56.0 36.6	.. 0.0	0.1-0.3 0.3	334-765 613.0	2088-4785 3831.0
Semen from boar without seminal vesicles	1	3	7.6-7.8 7.7+	2.8-3.4 3.1	267-327 296.0	59.0-68.0 63.0	6.7-7.8 7.3	1.1-2.5 1.6	1.7-2.8 2.3	586-617 597.0	0.0 0.0	0.0 0.0	0.4-0.4 0.4	215-239 225.0	1344-1499 1408.0
Semen from boars without Cowper's Glands	2	8	7.2-7.4 7.3+	3.8-7.4 4.8	286-544 400.0	75.0-144.0 100.0	3.9-6.5 5.4	5.4-24.2 10.7	12.7-56.3 29.0	485-723 565.0	41.8-111.0 60.8	0.0 0.0	0.7-1.2 0.9	401-600 466.0	2500-2650 2914.0
Semen from boars without Seminal Vesicles and Cowper's Glands	3	11	7.4-7.8 7.6+	1.2-2.4 1.6	244-364 307	20.0-101.0 57.3	1.8-4.6 3.1	0.7-1.7 1.6	9.1-18.8 12.9	622-808 714.3	0.0 0.0	0.0 0.0	0.3-0.4 0.3	91-188 133.2	569-1175 832.5
Semen from boars without Seminal Vesicles, Cowper's Glands and vasectomized.	4	16	7.5-8.5 8.0+	0.9-2.3 1.2	24-77 41.5	15.0-68.0 28.6	1.1-3.5 1.8	0.5-0.5 0.5	0.1-0.1 0.1	624-818 753.3	0.0 0.0	0.0 0.0	0.2-0.4 0.3	55-109 73.7	344-681 461.0

+ Median.

Note: The numbers appearing at the top give the range, while the value below is the mean.

solid content of semen to 1.56 per cent, it is apparent that the bulk of the solids in normal semen come from the seminal vesicles and Cowper's glands (Table 14). The solid content of prostatic and urethral secretions was only 1.24 per cent.

Cowper's gland material was quite high in sodium, containing more than twice as much as seminal vesicle fluid and five times as much as blood serum. However, the seminal vesicles were the chief source of potassium, with a concentration more than twice as great as that of Cowper's gland material and 40 times that in blood serum. Epididymal fluid was also high in sodium and potassium, but due to its relatively small volume in the semen, probably contributed a minor part of those substances to the semen.

The calcium content was low in all the seminal fluids but relatively high in the Cowper's gland secretion. Magnesium was present in somewhat higher concentrations and also highest in the secretion from the Cowper's glands.

The epididymal fluid with its high sperm concentration was rich in phosphorus. Seminal vesicle fluid was next highest in phosphorus.

Secretions from the prostatic and urethral glands provide most of the chlorides of semen, and contain them in appreciably higher concentration than they appear in blood serum or plasma.

Glucose was present only in the seminal vesicle fluid or in semen from boars whose seminal vesicles were intact. The concentration in seminal vesicle fluid was about three times that in blood serum and plasma. Urea was not detectable by the method used in any of the seminal fluids, and creatinine was present in very small amounts. Total organic nitrogen was present in rather large amounts in all the seminal fluids except the prostatic and urethral secretions. Epididymal fluid contained the highest concentration of nitrogen, followed by seminal vesicle fluid and Cowper's gland material in that order.

The relative amounts of the various constituents in the ten different types of material are represented graphically in Figures 35, 36, and 37. These graphs are self-explanatory, but it might not be superfluous to call attention to the ratios of certain substances existing in some of the materials. The sodium-potassium ratio of Cowper's gland material was about six times greater than that of seminal vesicle fluid. The potassium-calcium ratio of seminal vesicle fluid was about ten times greater than that of Cowper's gland material. The magnesium-calcium ratios of the seminal vesicle fluid and Cowper's gland material were identical. The phosphorus-chlo-

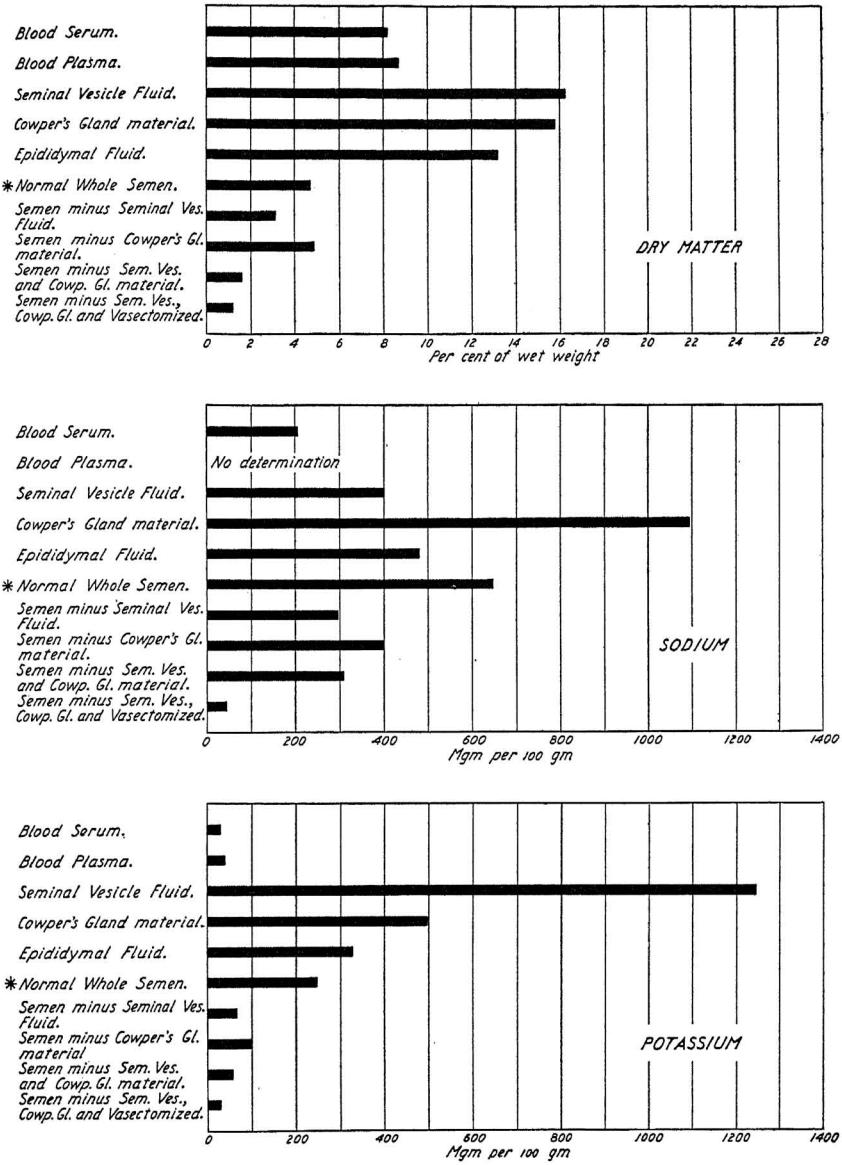

Fig. 35.—The percentage dry matter, and the amounts of sodium and potassium in blood and various seminal fluids of the boar.

rides ratio of the seminal vesicle fluid was from 4 to 15 times greater than that of the Cowper's gland material. The ratios of the various inorganic constituents, one with another, in the prostatic and

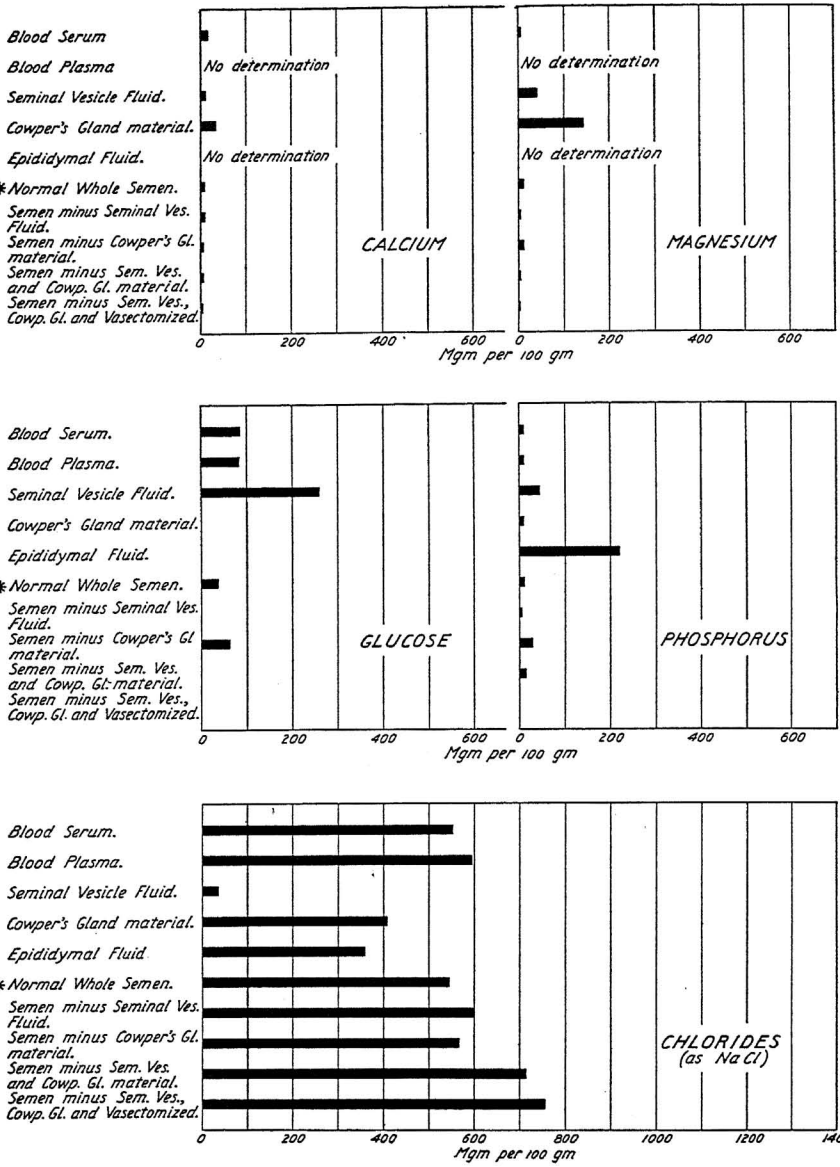

Fig. 36.—The amounts of calcium, magnesium, glucose, phosphorus and chlorides in blood and various seminal fluids of the boar.

urethral secretions are quite unlike the corresponding ratios in blood serum and plasma.

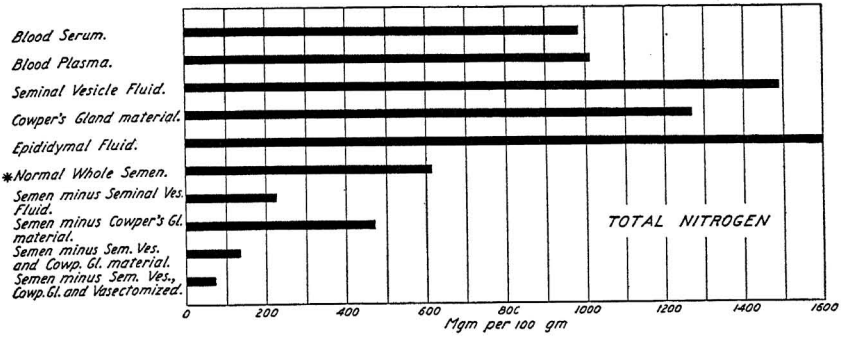

Fig. 37.—The amount of total nitrogen in blood and various seminal fluids of the boar.

The volume of sediment in whole semen after removal of the gelatinous portion, and in various seminal fluids was determined by centrifuging a volume of a sample in a graduated 15 cc. centrifuge tube for 10 minutes at 1500 r.p.m. There was no sediment measurable by this method in seminal vesicle fluid, Cowper's gland material, or in semen from vasectomized boars. Obviously the sediment in semen originated in the testis and epididymal contributions.

In order to learn more about the components of the gelatinous material in normal whole semen, chemical analyses were made of the liquid and the gelatinous portions of whole, normal semen (Table 15). Except for the gelatinous portion having a higher dry matter content, and somewhat more sodium and calcium, there was no significant difference in the composition of the two materials. If the seminal vesicle fluid and the Cowper's gland material are the only ingredients necessary for its formation, the gelatinous material should be similar in composition to those secretions. This is not the case, however, for examination of their compositions indicates that a considerable dilution has taken place in the formation of the gelatinous material.

Minute fractions of semen from normal and operated boars were analyzed in 1936 for dry matter, ash, chlorides, and total nitrogen. Although there were variations in the composition of the semen from minute to minute they were inconsistent and in many cases so slight as to be within the limits of experimental error. To study further the sequence of events during ejaculation, in 1937 fractionated collections of semen from normal boars were divided into presperm, sperm and post-sperm groups for analysis. In some collec-

TABLE 15.—SUMMARY OF THE CHEMICAL ANALYSES OF THE LIQUID AND GELATINOUS PORTIONS OF NORMAL WHOLE SEMEN

(mgm. per 100 gm. wet weight)

Number of Animals Concerned	Number of Collections	Material	Weight of Material in Ejaculate	Per cent of Ejaculate	Dry Matter per cent of wet weight	Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides
4	6	Liquid	102-326 246.5	62.9-79.4 73.0	3.01-5.47 4.09	458-743 555.0	158-447 275.3	4.23-7.6 5.4	8.8-15.6 10.9	7.1-17.4 10.3	471-597 533.8
4	6	Gelatinous	46-129 88.1	20-37.1 26.9	5.44-10.50 7.31	388-1080 870.3	194-464 262.6	7.1-14.8 9.6	9.8-20.4 16.7	10.2-18.4 14.8	447-590 534.0

Note: The figures at the top give the range. The lower value is the mean.

tions there were no sharp lines of demarcation separating the fractions into the three groups. In collections containing two cycles or waves of ejaculation it was difficult to know how to group the intermediate fractions of the ejaculate. Nevertheless groupings were made and chemical analyses run on each group. The summary of the chemical analyses of ten collections from five boars appears in Table 16. While there appears to be little doubt that the composition of semen fractions varied during the course of ejaculation, the methods of grouping and analyzing employed failed to reveal any significant differences.

TABLE 16.—SUMMARY OF CHEMICAL ANALYSES OF FRACTIONATED WHOLE SEMEN FROM NORMAL BOARS
(Mgm. per 100 gm. wet weight)

Constituent	Pre-sperm fraction	Sperm containing fraction	Post-sperm fraction
Weight (gms)	15.1-67.4 31	21.8-140 66	26.8-244 126
Dry Matter (% of wet weight)	4.90-6.14 5.06	4.16-6.17 5.22	4.14-6.43 4.95
Sodium	558-892 762	522-103 763	554-104 727
Potassium	128-285 177	123-376 243	167-314 237
Calcium	6.1-9.3 7.8	5.1-8.9 7.3	6.2-9.6 7.4
Magnesium	7.3-13.0 10.1	7.2-17.1 12.2	8.2-13.8 11.1
Phosphorus	4.6-13.0 9.8	5.8-14.4 9.9	6.2-12.7 9.8
Chlorides (as NaCl)	448-601 502	448-637 535	400-742 515

Note: The figures at the top give the range. The lower value is the mean.

DISCUSSION

The anatomy of the reproductive tract of the boar is similar in general structure to those of other mammals. However the rate of spermatogenesis, the extent of development of the accessory glands and the volume of semen per ejaculate greatly exceeds that of other farm animals. Species differences, peculiar to the boar exist in the number of efferent ducts connecting the testis with the epididymis where there may be one or more. There is no ampulla in the vas deferens and the vasa deferentia do not unite with the ducts from the seminal vesicles as is common in some other species, e. g. man. The urethral glands are apparently more extensive and more active than those of many other species. Probably because of these peculiarities, more time is required for ejaculation in the boar than in most other animals.

Observations made at the time semen was collected, together with data obtained from anatomical and semen studies, provide a basis for analyzing the physiology of ejaculation. In so doing the indi-

vidual differences in animals and in the way in which they respond to various stimuli must be recognized. For example, the duration of ejaculation in normal boars varied from an average of 4.5 minutes to 16 minutes. Likewise the volume of the ejaculate and the number of sperm per ejaculate varied considerably in different boars and in the same boar from day to day. Some of this variation might be accounted for by the receptivity of the sow being used. Although the boars performed in a normal way when the sow was not in heat but restrained in the usual manner they exhibited increased sexual excitement when she was in heat. The order in which the boars were used from day to day might also have been a factor. Even though no correlation was observed between the order of use and the performance of a boar, measured by quality and quantity of his semen, that factor is not altogether ruled out. Usually boars showed more sexual excitement when they were used after semen had been collected from one or more other boars than when they were used first on that particular occasion. This was probably due to the presence of the sow in the nearby pen. Just to what extent if any, this psychological effect might have had on stimulating the secretory activity of the accessory sex glands is not known.

When the nature of the pure glandular secretions of the male accessories is known, a study of the fractionated semen collections gives a reasonably accurate picture of the order in which the separate glandular systems make their contributions to the semen during the period of ejaculation. The thick jelly-like material found in the initial fractions is apparently a mixture of Cowper's gland material and fluid from the urethral or prostate glands. Its high pH, 7.5 to 8.0, eliminates the seminal vesicle fluid, and it does not have the consistency of the tapioca-like material which appears later. This initial material probably serves the double purpose of cleansing the urethra of urine and debris, and acting as a lubricant to facilitate entrance of the penis into the female tract. In normal coitus this material is usually discharged before the penis enters the vulva.

The high sperm containing fluid from the epididymis follows the initial discharge. It is diluted with secretions from the prostatic and urethral glands, plus some tapioca-like material. The rate of ejaculation is highest during this sperm-containing phase and the volume discharge is usually greatest. The excessive volume continues to come for a brief period during which the sperm concentration decreases rapidly. This considerable volume of liquid which appears during and immediately after the high sperm-con-

taining fractions comes from the prostatic and urethral glands. Evidence for this statement is based on its watery appearance, its high pH, and the fact that in operated animals which have only the prostate and urethral glands remaining the maximum rate of discharge occurs at this same relative period in the ejaculate. Apparently the chief function of this great volume of liquid is to wash the sperm well into the uterus. There appears to be little doubt that the boar normally deposits his semen directly into the cervix. The depth to which the penis enters, 30-45 cm. [and the length of the vaginal and cervical tract combined is no greater than this; see McKenzie (1926)] together with the fact that ejaculation proper does not begin until the penis is inserted to its greatest depth are evidence for this statement. It must be remembered too that the sow's cervix does not evaginate, but is continuous with the anterior vagina. Additional proof is furnished by the observation during semen collections that orgasm does not begin until after the penis has entered the rubber tube (artificial vagina) to a considerable depth and then only when sufficient pressure is applied by the hand to the spirally twisted end, presumably giving the same sensations as when the penis enters the cervix. (The variations in pressure afforded by the air bulb on the Swedish artificial vagina designed by Baeckström provide similar sensations and make possible continued ejaculation.)

Some gelatin or tapioca-like material is distributed throughout the ejaculate but the greatest amounts of it appear immediately following the high sperm-containing fractions and again near the end of the ejaculate. The absence of this material in semen from boars whose seminal vesicles *or* Cowper's glands have been removed indicates the necessity of both materials for its formation. However, that does not preclude the possibility that a third substance coming from the urethral or prostatic glands might also be necessary. As was previously stated, the addition of fresh seminal vesicle fluid to fresh Cowper's gland material produced a gelatinous formation similar to but not identical with that which appears in normal semen. The accumulation of the materials from the Cowper's glands and seminal vesicles in the post-sperm fraction, and the capacity of such substances for forming a rubbery, gelatinous mass indicates that they may serve to seal the cervix, thereby preventing the loss of semen until the sperm have had time to reach the fallopian tubes. That this vaginal or cervical plug is not absolutely essential to fertilization was shown when sows became pregnant and farrowed normal litters after being bred to

boars without seminal vesicles and Cowper's glands.

Data obtained from studies on semen volume, sperm concentration, and chemical analyses of seminal fluids afford a means of calculating the relative volumes contributed to the ejaculate by the separate glandular systems. Twenty-six per cent of the semen volume was contributed by the seminal vesicles and 19 per cent by the Cowper's glands (Table 11). Removal of both pairs of glands reduced semen volume 42 per cent, and vasectomy further reduced it 2 per cent. Thus 56 per cent (147 cc.) of the total semen volume consisted of prostatic and urethral secretions, 42 per cent (109 cc.) was contributed by the seminal vesicles and Cowper's glands, and 2 per cent (5.5 cc.) came from the testes and epididymides.

With an average of 5,800,000 sperm per cu. mm. in epididymal fluid, it would require 4.2 cc. of such fluid to supply the average number of sperm in one ejaculate from normal boars (Table 10). Since the average volume of semen in these same 87 collections was 262 cc., the epididymal fluid must have been diluted 62 times, or expressing it in another way, the testes and epididymides contributed 1.6 per cent of the total volume of semen.

Gunn (1936) working on the ram reported on the effect of unilateral vasectomy, or even bilateral vasectomy, on the amount of material ejaculated "to be almost negligible." He further states that the "secretion collected from fistulae of the vasa deferentia usually formed less than one-tenth of the total material emitted through fistulae and penis combined."

Since cellular material was thrown down by centrifuging only in semen from boars whose testes, epididymides, and vasa deferentia were intact, the sediment-supernatant ratio affords a third way to calculate the volume of the contribution from that source. The sediment in epididymal fluid averaged 0.51 cc. per cc. of material. The volume of sediment in the entire ejaculate divided by 0.51 gives the volume of the contributions from the testes and epididymides. The average of 27 collections of whole semen from five normal boars showed 6.3 per cent (with a range of 2 to 10 per cent) of the total volume of the ejaculate coming from the testes and epididymides. Similarly, the average of 10 collections from two boars without their seminal vesicles and Cowper's glands showed 9.3 per cent of the volume of the ejaculate coming from the testes and epididymides. This rise should be attributed to the decrease in semen volume.

Since the solid contents of the seminal vesicle fluid and the

Cowper's gland material were nearly identical (16.25 and 15.84 per cent respectively) it seemed safe to use an average of the two values to represent the solid content of the combined contributions from the two sets of glands (Table 14). Assuming that all the solids in normal whole semen come from the seminal vesicles and Cowper's glands, and knowing the total weight of the ejaculate, one can calculate the percentage of the ejaculate coming from those glands as well as the portion coming from other sources. On this basis, the average of 37 ejaculates from 10 different boars was 34.4 per cent coming from the seminal vesicles and Cowper's glands and 65.6 per cent from the prostatic and urethral glands, the testes and epididymides. Since the prostatic and urethral secretions contain 1.24 per cent dry matter and the epididymal fluid 13.2 per cent dry matter, it is obvious that the above values represent a super-maximal contribution for the seminal vesicles and Cowper's glands, and a sub-minimal contribution from the other sources.

The presence of glucose in the seminal vesicle fluid and in semen from boars whose seminal vesicles were intact, offers another approach to the contributions from the various glands. The average glucose content of nine samples of pure seminal vesicle fluid was 2.57 mg. per cc. Therefore, each unit of 2.57 mg. of glucose in an ejaculate represents one cc. of seminal vesicle fluid. The average of 17 collections from five normal boars calculated on this basis gave 14.7 per cent of the total volume contributed by the seminal vesicles and 85.3 per cent from other sources.

TABLE 17.—SOURCE OF SEMEN VOLUME

Calculation based on:	Amount contributed by				
	Seminal Vesicles	Cowper's glands	Seminal Vesicles plus Cowper's glands	Prostatic and urethral glands	Testes and epididymides
Reduction in volume following removal of glands (7 boars, 87 collections)	68 cc. 26%	50 cc. 19%	110 cc. 42%	147 cc. 56%	5.3 cc. 2.0%
Solid content of seminal vesicle and Cowper's glands secretions and of whole semen (10 boars, 37 collections)			34.4%	65.5% of whole semen	
Glucose content of seminal vesicle fluid, and of whole semen (5 boars, 17 collections)	14.7%	85.3%			
Sediment content of epididymal fluid and of whole semen (5 boars, 27 collections)	93.7%				6.3%
Sperm concentration of epididymal fluid and of whole semen (epididymides from 5 boars; 87 collections from 7 normal boars)	98.4%				1.6%

The percentage of semen volume contributed by the various glandular systems as determined by the different methods of calculation appear in Table No. 17.

Two things are especially significant in these data, namely, the relatively small volume contributed by the testes and epididymides, and the relatively large volume coming from the prostatic and urethral glands. This is contradictory to the findings of Nesmeianowa (1936) who concluded that the great dilution of boar semen was due to a secretion from the epididymis.

In spite of the extensive glandular structure of the urethral wall, it is difficult to account for the great volume of secretion coming from the prostate and urethral glands. The body of the prostate gland averaged less than 25 grams, and the total weight of the pelvic urethra averaged less than 150 grams, about half of which was glandular tissue. If we assume that the total weight of the glandular tissue in the prostate gland and the pelvic urethra is 100 grams (a very liberal figure) it follows that 100 grams of glandular tissue, without apparent storage space, produced one and one-half times its own weight of secretion in 8 minutes (Table 11). In spite of the apparent lack of storage space in these glands, it is possible that much of this volume might be held in the tubules and duct systems, even though it was impossible to expel more than a few drops by pressure when the animals were destroyed. Even if such an assumption is true, the prostatic and urethral glands remain the most active secretory systems in the entire reproductive tract. The peculiar arrangement of blood vessels, glandular and muscular tissues in the wall of the pelvic urethra doubtless plays a part in the rapid assimilation, and excretion of the urethral gland secretion during ejaculation (Figs. 16 and 17).

Nesmeianowa (1936) pointed out the similarity between the composition of semen and blood serum, especially with regard to the electrolytes, and suggested that this great dilution of semen was produced by material similar in composition to blood serum. Chemical determinations in this investigation failed to support that idea (Table 14). Blood serum contained 7 times as much dry matter, 5 times as much sodium, 6 times as much calcium, 6 times as much magnesium, and 79 times as much phosphorus as was found in prostatic and urethral secretions. The amount of chlorides in the prostatic and urethral fluids was materially higher than in blood serum.

It is difficult to account for the high chloride value in prostatic and urethral secretions in the presence of such low amounts of

sodium, potassium, calcium, and magnesium. The narrow range of values for the 16 determinations on collections from 4 boars should establish the validity of the determinations. Furthermore, there was a consistent reduction of sodium, potassium, calcium, and magnesium and an equally consistent increase in chlorides in semen as the various glandular systems were eliminated. The seminal vesicles were the source of most of the potassium, phosphorus, and total nitrogen, and the only source of glucose. Cowper's glands were the source of most of the sodium, calcium, magnesium and were also rich in nitrogen. Because of the relatively small volume from the testes and epididymides their total contribution of any constituent was probably small, but epididymal fluid was rich in phosphorus and total nitrogen.

The effects of frequency of ejaculation on the quantity and quality of semen provide a basis for measuring the capacity of individual animals as well as for comparing the different glandular systems in their ability to maintain a normal level of production.

Individual differences in the reproductive capacities of boars were numerous but many similarities have been observed. The first ejaculate following a period of sexual inactivity contained the greatest number of sperm, although the volume of the ejaculate was not necessarily the greatest. Repeated semen collections at short intervals reduced the volume of semen and the total number of sperm, but volume suffered less than sperm numbers. Chemical determinations failed to reveal any significant differences between the composition of the initial ejaculate and subsequent ones. Neither were there any consistent variations in the liquid-gelatinous material ratio of normal whole semen which could be attributed to frequency of ejaculations. These observations indicate no differences in the rate of exhaustion of the several glandular systems, measurable by the methods employed.

The findings of Gunn (1936) are interesting in this connection. He stimulated the ram electrically. If the stimulus was continuous the fluid ejaculate was collected almost indefinitely (12 ml. or over), and the material was very similar to the latter portion collected from a doubly vasectomized ram (clear watery fraction). Marshall (1922) states that stimulation of the hypogastric nerves stimulates secretion of the prostate gland, "the secretion continuing as long as the stimulation was kept up." Gunn (1936) agrees with Marshall and states that this watery material results "from the stimulation of the sympathetic secretory and motor fibers of the hypogastric nerves (from the lumbar outflow) supplying the accessory glands

(especially the prostate)." It would still seem possible that the excessive volume of watery material that must come from the urethra and prostate of the boar may owe its origin to either or both types of tissue, assuming that the nervous mechanism is somewhat similar in both species.

It is further noted from Gunn's (1936) observations that any considerable interruption (say ten minutes) in the series of stimuli applied was sufficient for spermatozoa to appear again in the ejaculate of the ram. This would be in line with the condition found in the boar, namely, a second spermatic wave which was observed to occur in fractionated ejaculates from six to eight minutes after the first sperm wave.

The rate of spermatogenesis, measured by the number of sperm ejaculated, was approximately the same, regardless of the frequency of ejaculation, in four of the five boars subjected to intensive semen collection schedules. The fifth boar was noticeably more active sexually and the rate of spermatogenesis was correspondingly greater. The data, too meager to be conclusive, indicate that sexual excitement and frequent ejaculation cannot increase the rate of spermatogenesis beyond that which normally occurs in the individual.

The time required for, and the sequence of events during, ejaculation were not affected by the frequency of ejaculations. However, frequency of ejaculations was an important factor in determining the morphology and duration of sperm motility. An inverse relationship existed between the number of abnormal sperm and the duration of motility. Intensive ejaculations did not alter the relative numbers of different types of abnormalities. This was also observed by Rodolfo (1934). During the periods of extreme sexual activity, however, sperm with the cytoplasmic cap appeared, the number varying with the individual and the degree of sexual activity (Fig. 27). These sperm were designated as undeveloped, but whether they actually represented a stage of immaturity or whether the condition was produced by a disturbed salt balance of the liquid medium due to excessive sexual activity is not known. Rodolfo believed the location of the protoplasmic drop was an index of the stage of maturity in boar sperm. Lagerlöf made the same observation on bull sperm. Neither investigator described anything resembling the cytoplasmic cap; but their observations were made on animals on relatively light mating schedules.

Unfortunately, the fertility of the boars was not tested during the periods when these presumably immature sperm appeared. Thus

the high abnormal sperm count and the short period of sperm motility observed during periods of excessive sexual activity cannot be evaluated in terms of fertility. Temporary sterility in overworked sires is probably the answer to the question of the fertility of such sperm.

Removal of the accessory sex glands from boars seemed in no way to affect libido. Whether the removal of one or more pairs of glands altered the activity of the remaining glands cannot be definitely answered. However, except for a reduction in semen volume and a slight reduction in the duration of ejaculation, there was nothing to indicate that the activity of the remaining glands had been altered. Absence of the secretions of the seminal vesicles and Cowper's glands had no harmful effects on sperm morphology or the duration of sperm motility; in fact, sperm in semen from boars without seminal vesicles and Cowper's glands remained motile longer than sperm in normal semen from the same boars. This was probably due to an increase in sperm density. Likewise, sperm in the high sperm-containing fractions from normal boars which were probably most nearly free from seminal vesicle and Cowper's gland contributions remained motile longest. Since the seminal vesicle fluid is the only known source of glucose in semen, it appears that glucose is not a factor in prolonging the life of the sperm, as judged by motility. Bernstein (1933a) also observed that the presence of nutrient substances in semen did not increase the time of survival of spermatozoa. From a later study of glucose metabolism in semen, (1933c) he suggested that spermatozoa could metabolize glucose contained in the seminal fluids. Goldblatt (1935) demonstrated a fall in glucose and a rise in lactic acid in stored human semen when the sperm were kept alive. Killian (1933) reported a similar observation on human semen. Ivanov (1935) concluded that motility of spermatozoa does not depend on glycolysis. It is apparent that more work needs to be done to clarify this point. What is the source of energy in glucose-free semen fractions? Might not glycogen still be? The respiratory quotient is 1, thus indicating a carbohydrate (private communication, A. Walton, 1937).

No attempt was made to determine the fertilizing ability of stored sperm either from normal or operated boars. That the presence of seminal vesicle and Cowper's gland secretions is not essential to fertility was amply demonstrated. The inability of two boars (C.W. 96 and C.W. 7) to maintain sufficient erection for satisfactory service might have been due to injury from operation

or from excessive sexual activity during the preceding weeks. However, this condition has been observed in normal unoperated boars, which when assisted were able to impregnate their sows in a satisfactory manner.

Since semen was collected from animals after castration (as long as 16 days from one animal) it is apparent that castration has little immediate effect on libido. This might be interpreted to indicate that the testes normally maintain a concentration of the male hormone in the blood in excess of that necessary for normal sexual activity, and that libido is retained so long as the concentration remains above the minimal amount required, even in the absence of the testes. Also, it must be kept in mind that these boars had learned to copulate at more or less regular intervals prior to the castration operation, and this fact may be important in explaining the performance here.

What happens to non-ejaculated sperm in the boar? This is a question that cannot be answered fully here. The high abnormal counts in semen from boars following a period of sexual inactivity has already been noted, and lends support to the contention that sperm disintegration occurs in the epididymis.

The large volume of semen, the extremely great number of sperm per ejaculate, the relatively long time required for ejaculation and the chemical composition of his semen give some indication of the heavy drain on the protein, mineral and energy supply of the boar during excessive sexual activity. Observations on the effects of frequent ejaculations on semen volume, sperm numbers, duration of sperm motility and sperm morphology indicate that yearling boars should not be used more often than once in 24 hours, and that best results might be expected at 48-hour intervals if the breeding season is to extend over a period of two weeks or more.

Summary and Conclusions

Data on the anatomy and physiology of the reproductive tracts from 13 yearling boars have been presented. The histological structure of the various accessory sex glands has been described. Semen from normal boars and from boars whose accessory sex glands had been removed surgically was studied.

ANATOMY

1. The combined weights of the testes ranged from 540 to 804 grams and had a ratio to the live weight of approximately 1:250. The number of efferent ducts joining the testis to the epididymis varied from one to five.

2. The combined weights of the epididymides ranged from 168 to 219 grams and had a ratio to the live weight of approximately 1:800. The height of the epithelium lining the ductus epididymis was greatest in the head region, lower in the body region and lowest in the tail region. Secretory activity of the epithelium as judged by the presence of secretion droplets was greatest in the tail region, less in the body and least in the head region.

3. The seminal vesicles are large pyramid shaped glands, whose total weight ranged from 150 to 850 grams, and contained from 40 to 507 grams of gray, opaque, medium viscous secretion with a pH of approximately 6.7. The glands are tortuous, hollow bodies, with irregular branched lumina and possess a simple columnar epithelium resting on thin, vascularized connective tissue.

4. The Cowper's glands are firm, cylindrical bodies, 12 to 15 cm. in length and 3 to 5 cm. in diameter. Their total weight ranged from 146 to 209 grams and the total weight of their contents ranged from 19.5 to 178 grams. They are compound tubulo-alveolar glands and secrete a thick, white, waxy material which has a pH of approximately 7.2. The secretory epithelium consists of a single layer of columnar or cuboidal cells with small nuclei at their base.

5. The prostate gland consists of a body, attached to the dorsolateral walls of the pelvic urethra at its origin from the neck of the bladder, and the pars disseminata embedded in the wall of the urethra beneath the body of the gland. The average weight of the body of the gland was 20 grams. It is a firm multilobular, compound tubulo-alveolar gland without apparent storage space and contained no secretion which could be expelled by pressure. The glandular epithelium varies from pseudostratified columnar to cuboidal and rests upon a layer of connective tissue. Pure prostatic

secretion was not obtained, but secretions of the prostate and urethral glands were studied together.

6. The pelvic urethra is 20 to 25 cm. long, and weighs from 100 to 150 grams. The outer muscular layer and the inner glandular layer make up approximately equal portions of the total weight. The glandular tissue is compound tubular in nature, possesses a cuboidal epithelium, exhibits evidence of being highly secretory and is quite unlike the prostate histologically.

7. The vasa deferentia and the ducts from the seminal vesicles enter the pelvic urethra through the dorsal wall at its anterior extremity by four separate and distinct openings. No exception to this arrangement was found.

8. The penis of the boar is 50 to 75 cm. long, consists of a large, dense, dorsal, corpus cavernosum penis, and a small, ventrally located corpus spongiosum urethra. No secretory tissue or activity was observed anywhere in the epithelium of the penis urethra.

PHYSIOLOGY

1. Normal whole semen is gray to milky white, depending on the sperm concentration, the higher the sperm concentration the whiter the semen. Twenty to 40 per cent of fresh semen consists of gelatin-like material resembling tapioca.

2. The volume, sperm concentration per cu. mm., and total number of sperm per ejaculate varied greatly in different boars and in the same boar from day to day.

3. There was no direct relation between live weight and semen volume, between total number of sperm and semen volume, or between duration of ejaculation and semen volume.

4. The volume of semen from normal boars ranged from 125 to 500 cc., the sperm concentration ranged from 25,000 to more than 1,000,000 per cu. mm., and the total number of sperm per ejaculate ranged from 2.7 to more than 300 billion.

5. Frequency of ejaculation is an important factor affecting volume of semen, sperm number, sperm morphology and duration of sperm motility.

6. When ejaculations were made at intervals of 48 hours or longer, the semen volume remained above 200 cc., the number of sperm per cu. mm. remained above 100,000 and the total number of sperm per ejaculate exceeded 20 billion. Furthermore, the number of abnormal sperm did not exceed 100 per 1000 and the sperm remained motile five or more days.

7. Repeated ejaculations at intervals of 24 hours or less reduced semen volume below 200 cc., sperm concentration to 15,000 to 50,000 per cu. mm., and total number of sperm to 2 to 5 billion. In addition, duration of sperm motility was reduced to 1 to 3 days and the number of abnormal forms increased to more than 200 per 1000 sperm. Two of the three boars used at 12-hour intervals temporarily lost their desire to mate after the third or fourth collection.

8. The most common abnormalities induced by frequent ejaculations were coiled tail, middle piece bead, and enlarged middle piece. Sperm with a cytoplasmic cap appeared in considerable numbers after extreme sexual activity and were interpreted as immature forms.

9. The number of abnormal sperm forms approached or exceeded 200 per 1000 in the first ejaculate from boars following a period of sexual inactivity.

10. Sperm were ejaculated at the rate of approximately 20 billion per day over a period of 11 to 24 days by four boars used at different intervals. A fifth boar which was noticeably more active sexually had a higher rate of spermatogenesis, and ejaculated sperm at the rate of 33 billion per day over a 14-day period. Frequency of ejaculation did not appear to affect the rate of spermatogenesis.

11. Semen from normal boars was collected in vials and divided consecutively into minute fractions. One or two waves or cycles of ejaculations were present.

12. An ejaculation can be divided into three or five phases, depending on whether there is one or two sperm waves in the ejaculate. The first or pre-sperm phase lasted 1 to 5 minutes, consisted of slightly urine colored semi-solid material, contained no sperm and comprised 5 to 20 per cent of the ejaculate. The second or sperm containing phase lasted 2 to 5 minutes, consisted of a milky white liquid and some gelatin or tapioca-like material, contained most of the sperm and comprised 30 to 50 per cent of the total volume of the ejaculate. The third or post-sperm phase lasted 3 to 8 minutes, consisted of a thin watery liquid with more or less gelatinous material, contained few sperm and comprised 40 to 60 per cent of the total volume. Where there were two waves of ejaculation the second and third phases were repeated but the sperm concentration and the volume were much lower than in the first wave.

13. Sperm in the high sperm-containing fractions retained their motility longest.

14. The pH of stored semen usually shifted to the acid side but there was a wide variation in the pH at which sperm became immotile.

15. Covering semen with a layer of mineral oil prolonged sperm motility 1 to 3 days.

EFFECTS OF REMOVAL OF ACCESSORY GLANDS AND CASTRATION

1. Removal of the seminal vesicles, Cowper's glands, two-thirds of the prostate and vasectomy had no effect on libido. Neither was there any indication that the removal of some of the accessory glands altered the activity of the remaining ones or the process of ejaculation.

2. There was some indication that the removal of the contributions of the seminal vesicles and Cowper's glands from semen reduced the number of abnormal sperm and increased the duration of sperm motility.

3. Removal of the seminal vesicles and Cowper's glands did not lower the fertility of the boars as judged by their ability to impregnant sows successfully.

4. On the basis of calculations made by a comparison of semen volumes from normal and operated boars and from chemical data, the seminal vesicles contribute 15 to 20 per cent of the semen volume, the Cowper's glands 10 to 25 per cent, the testes and epididymides 2 to 5 per cent and the prostatic and urethral glands 55 to 70 per cent.

5. The seminal vesicles contributed most of the potassium, phosphorus, total nitrogen, and all of the glucose in the semen. Cowper's glands contributed most of the sodium, calcium, magnesium, and also considerable nitrogen. The prostatic and urethral secretions were the source of most of the chlorides. The composition of prostatic and urethral secretions is quite unlike that of blood serum and plasma.

6. There was no regeneration of tissue in any instance following the removal of the accessory sex glands.

7. Castration had little immediate effect on libido, as judged by collections of 100 cc. and 92 cc. of semen from animals 4 and 16 days respectively after castration.

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Appendix

TABLE 1.—DURATION OF SPERM MOTILITY
C.W. 4 (Normal)

Date	Time of day	Nature of sample	Sperm per cu mm (1000)	Duration of Motility (days)	Initial pH	Final pH
3-1	A.M.	W	160	1	7.85	
3-3	A.M.	F	770	24	7.45	6.50
3-5	A.M.	W	120	9	7.35	6.60
3-7	A.M.	W	180	4	7.55	6.70
3-9	A.M.	W	90	4	7.45	6.70
	P.M.		60	4		
3-10	A.M.	W	70	2	7.30	
	P.M.		50	2.5	7.55	
3-11	P.M.	W	70	2		
3-12	A.M.	W	110	2.5		6.65
3-13	A.M.	F	280	6		6.40
			110	4		7.55
			10	2		
			10	2		
	P.M.	W	30	1		
3-14	A.M.	W	40	1.5		
3-17	A.M.	F	180	12.0	7.45	6.20
			10	1.0	7.45	7.40
3-18	A.M.	W	45	1.0	7.65	7.30
3-19	A.M.	W	30	2.0	7.65	6.90
3-20	A.M.	W	25	1.0	7.65	6.95
3-21	A.M.	W	60	1.5	7.35	6.95
3-22	A.M.	F	5	.5	7.35	6.80
			100	1.5	7.40	7.50
			110	3.0	7.40	7.50
			55	1.5		7.50
			5	.5		6.90
3-23	A.M.	W	120	1.0	7.90	7.55
3-24	A.M.	W	70	5.0	7.45	

TABLE 2.—DURATION OF SPERM MOTILITY
C.W. 7 (Normal)

Date	Time of day	Nature of sample	Sperm per cu mm (1000)	Duration of Motility (days)	Initial pH	Final pH
3-1	A.M.	W	90	1	7.70	
3-4	A.M.	F	190	12	7.50	
3-7	A.M.	W	120	5		
3-9	A.M.	F	170	9	7.45	6.80
3-10	A.M.	W	150	5	7.30	
3-11	A.M.	W	150	8	7.40	6.80
3-12	A.M.	F	250 80	10 3		5.95
3-13	A.M.	W	250	5		
3-14	A.M.	W	120	4		6.30
3-16	A.M.	W	180	6	7.30	6.10
3-17	A.M.	W	105	2	7.55	6.90
3-18	A.M.	W	90	6	7.60	6.15
3-19	A.M.	W	105	2	7.65	6.95
3-20	A.M.	W	70	1	7.60	6.80
3-22	A.M.	W	65	2.5	7.55	6.50
3-23	A.M.	W	85	2.5	7.80	6.50
3-24	A.M.	F	65 35 25	6.0 6.0 6.0	7.35	7.00 6.80 6.35

TABLE 3.—DURATION OF SPERM MOTILITY
C.W. 94 (Normal)

Date	Time of day	Nature of sample	Sperm per cu mm (1000)	Duration of Motility (days)	Initial pH	Final pH
3-1	A.M.	W	480	8.0	7.60	
3-2	A.M.	W	140	2.0	7.60	
3-4	A.M. P.M.	F W	150 70	1.5 2.5	7.35 7.40	
3-5	A.M.	F	50 100 240	2.5 2.5 7.0	7.35	
	P.M.	W	80	2.0	7.45	
3-6	A.M.	F	270 10	4.5 4.0		
	P.M.	W	20	2.5	7.55	
3-7	A.M.	W	30	3.0	7.55	6.75
3-8	P.M.	W	40	1.0	7.55	
3-9	A.M.	W	80	3.5	7.30	
3-11	A.M.	W	140	20.5	7.30	6.6

TABLE 4.—DURATION OF SPERM MOTILITY
C.W. 95 (Normal)

Date	Time of day	Nature of sample	Sperm per cu mm (1000)	Duration of Motility (days)	Initial pH	Final pH
3-3	A.M.	W	120	15.5	7.60	6.4
3-6	A.M.	F	280	7.5	7.45	
3-9	A.M.	W	170	11.5	7.55	6.35
3-11	A.M.	W	240	9.5	7.50	6.45
3-12	A.M.	W	150	6.5		6.20
3-13	A.M.	W	190	2.5		
3-14	A.M.	W	110	1.5		
3-16	A.M.	W	60	1.5	7.60	7.30
3-17	A.M.	W	85	0.5	7.35	7.25
3-18	A.M.	F	20 30 410 240	0.5 0.5 1.0 0.5	7.40 7.10 7.55	7.0 6.9 7.35 7.0
3-19	A.M.	W	60	1.5		6.0
3-20	A.M.	W	15	0.5	7.60	6.8
3-22	A.M.	W	70	1.5	7.45	6.5
3-23	A.M.	F	90 30 10 65 95 35	0.5 0.5 0.5 1.5 1.5 1.5	7.75 7.3 7.55 7.45 7.1 7.6	7.4 7.55 7.0 7.55 6.65 6.90
3-24	A.M.	W	60	0.5	7.45	7.6

TABLE 5.—DURATION OF SPERM MOTILITY
C.W. 96 (Normal)

Date	Time of day	Nature of sample	Sperm per cu mm (1000)	Duration of Motility (days)	Initial pH	Final pH
3-1	A.M.	W	190	0.5	7.80	
3-2	A.M.	F	870	1.5	7.40	
3-3	A.M.	W	230	3.0	7.55	
3-4	A.M.	W	70	13.5	7.45	6.70
3-5	A.M.	F	330 260 10 10 40 50	4.5 4.5 2.5 3.5 3.5 3.5		
3-6	A.M.	W	60	3.5	7.45	
3-7	A.M.	W	70	10.5		6.50
3-8	A.M.	F	950 100	16.5 2.0	7.3	6.20
3-9	A.M.	W	110	9.5	7.35	6.10
3-10	A.M. P.M.	W W	120 40	2.5 1.5	7.30 7.40	
3-11	A.M. P.M.	F W	280 50	2.5 4.5	7.40	6.6
3-12	A.M. P.M.	W W	20 30	2.5 1.5		6.8
3-13	A.M. P.M.	W W	50 50	1.5 1.0		6.75 6.40
3-14	A.M.	W	40	1.5		6.95

TABLE 6.—DURATION OF SPERM MOTILITY
C.W. 96 (Without Cowper's Glands)

Date	Nature of Sample	Sperm per cu mm (1000)	Duration of Motility (days)	Duration of Motility under oil (days)	Initial pH	Final pH	Final pH under oil
4-12	W	530	9.5	8.5	7.45	5.9	6.3
4-13	W	290	5.5	18.5	7.15	6.6	6.8
4-14	F1 F2	220 310	17.5 21.5	22.5 12.5	7.10 7.10	7.6 6.5	6.8 6.9
4-15	W	85	0.5	3.5	7.20	7.45	6.5
4-16	W	55	6.5	9.5	7.45	6.0	7.1
4-17	W	55	4.5	16.5	7.20	6.2	6.9
4-18	W	105	1.5	11.5	7.10	6.8	6.45
4-19	F1 F2	265 220	3.5 7.5	8.5	6.90 6.95	5.6 5.8	5.9
Total			78.0	111.5			
Average			7.8	11.1			

TABLE 7.—DURATION OF SPERM MOTILITY
C.W. 7 (Without Seminal Vesicles and Cowper's Glands)

Date	Nature of Sample	Sperm per cu mm (1000)	Duration of Motility (days)	Duration of Motility under oil (days)	Initial pH	Final pH	Final pH under oil
4-12	W	575	9.5	6.5	7.7	7.1	6.6
4-13	W	295	12.5	9.5	7.6	7.5	6.8
4-14	F	805	1.5	11.5	7.4	7.5	6.8
	F	210	8.5	8.5	7.85	7.0	6.9
4-15	F	575	11.5	12.5	7.25	7.3	6.5
	F	540	9.0		7.3	7.1	
4-16	W	65	5.5	10.5	7.65	7.3	6.95
4-17	W	100	7.5	7.5	7.65	7.1	6.85
4-18	W	130	4.5	4.5	7.35	7.2	6.9
4-19	W	115	4.5	9.5	7.3	6.8	7.0
4-20	W	45	1.5	2.5	7.55	6.7	6.95
4-23	W	65	6.5	4.5	7.6	7.1	7.05
4-24	W	95	4.5	3.5	7.45	6.8	7.1
4-25	W	110	3.5	3.5	7.50	7.2	7.3
4-26	W	185	4.5	8.5	7.3	7.2	7.6
4-27	W	100	3.5	9.5	7.55	6.9	6.8
4-28	W	90	5.5	4.5	7.45	7.1	7.1
4-29	W	100	3.5	3.5	7.45	7.35	7.3
5-1	W	65	3.5	3.5	7.65	7.2	8.0
5-2	W	75	1.5	2.5	7.6	7.6	7.2
5-3	W	100	4.5	5.5	7.4	7.15	7.10
Total			117.0	132.0			
Average			5.6 days	6.6 days			

TABLE 8.—NUMBERS OF ABNORMAL SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND

C.W. 4 (Normal)

Date	Time of Day	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Abnormals Per Thousand
3-1	A.M.	W	6	60	0	18	33	6	0	0	0	117
3-3	A.M.	F	12	3	9	21	24	9	0	0	1	81
		F	3	9	12	0	12	12	0	0	3	51
3-5	A.M.	W	12	84	0	21	9	0	0	0	0	126
3-7	A.M.	W	0	18	3	18	24	9	0	6	0	78
3-9	A.M.	W	6	69	3	0	21	0	0	0	0	99
	P.M.	W	12	12	3	3	9	9	0	0	0	48
3-10	A.M.	W	12	18	3	12	33	0	0	0	3	81
	P.M.	W	0	15	0	42	46	0	20	3	0	126
3-11	P.M.	W	0	90	3	99	36	0	30	0	3	261
3-12	A.M.	W	0	108	0	30	210	0	42	0	3	393
3-13	A.M.	F	9	18	0	75	21	0	48	0	0	171
	P.M.	W	6	69	0	54	63	0	18	0	3	213
3-14	A.M.	W	6	57	0	51	69	0	21	0	0	204
3-17	A.M.	F	6	15	0	42	15	3	15	0	0	96
		F	6	21	0	45	24	0	12	0	0	108
3-18	A.M.	W	3	42	0	33	15	0	33	0	0	126
3-19	A.M.	W	6	174	0	0	12	0	33	0	0	225
3-20	A.M.	W	0	36	0	21	63	0	24	3	0	147
3-21	A.M.	W	0	0	0	15	64	0	20	0	6	105
3-22	A.M.	F	12	27	6	24	42	0	36	0	0	147
3-23	A.M.	W	3	99	0	24	157	0	33	0	0	316
3-24	A.M.	W	72	3	0	27	36	0	9	0	0	147

Note: More than one F in the same collection denotes different fractions.

TABLE 9.—NUMBERS OF ABNORMAL SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND

C.W. 7 (Normal)

Date	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Small Heads	Abnormals Per Thousand
3-1	W	6	126	0	72	45	0	0	0	0	3	246
3-4	F	9	18	6	18	24	3	6	0	0	0	84
3-7	W	3	33	0	18	21	0	3	0	0	0	78
3-9	F	0	9	3	24	9	6	0	0	3	0	54
3-10	W	3	12	6	9	12	0	6	0	0	3	51
3-11	W	6	24	0	15	15	0	12	0	0	3	75
3-12	F	3	39	0	21	36	3	3	0	0	0	105
	F	3	42	3	57	36	0	0	0	0	0	141
3-13	W	42	114	3	12	12	3	6	0	0	0	192
3-14	W	3	45	6	12	33	0	24	0	0	0	123
3-16	W	6	63	3	27	15	0	6	0	0	0	120
3-17	W	3	66	3	12	33	3	9	0	0	0	132
3-18	W	9	90	0	15	15	0	6	0	3	0	138
3-19	W	9	72	0	15	12	3	6	0	0	0	114
3-20	W	0	27	0	27	24	0	9	3	0	0	90
3-22	W	6	30	0	15	9	0	3	0	0	3	72
3-23	W	6	18	15	12	12	0	6	0	6	0	85
3-24	F	12	6	6	3	0	3	6	0	3	0	39

Note: More than one F in the same collection denotes different fractions.

TABLE 10.—NUMBERS OF ABNORMAL SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND

C.W. 94 (Normal)

Date	Time of Day	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Small Heads	Abnormals Per Thousand
3-1	A.M.	W	3	216	6	15	9	3	0	3	0	0	255
3-2	A.M.	W	24	62	9	21	9	0	0	0	3	0	138
3-4	A.M.	F	3	30	0	57	9	3	6	0	3	0	111
		F	3	21	6	51	15	0	0	0	0	3	99
	P.M.	W	0	0	6	51	9	3	6	0	0	3	79
3-5	A.M.	F	15	90	6	30	15	0	0	3	0	0	159
		F	12	132	0	24	9	0	3	0	3	3	186
		F	3	120	0	24	27	0	0	0	0	0	174
	P.M.	W	6	118	3	6	27	3	0	0	3	0	163
3-6	A.M.	F	15	90	3	21	36	0	0	0	0	0	165
	P.M.	W	6	108	0	33	6	0	3	0	0	0	156
3-7	A.M.	W	12	90	3	15	15	0	3	0	0	0	138
3-8	A.M.	W	6	150	0	30	18	0	0	0	0	0	204
3-9	A.M.	W	63	213	6	15	18	0	0	0	0	0	325
3-11	A.M.	W	18	24	3	33	81	0	3	0	6	0	168

Note: More than one F in the same collection denotes different fractions.

TABLE 11.—NUMBERS OF SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND

C.W. 95 (Normal)

Date	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Small Heads	Abnormals Per Thousand
3-3	W	9	6	0	12	15	3	0	0	3	0	48
3-6	F	3	0	6	6	3	6	15	0	3	0	42
3-9	W	0	120	3	21	12	0	6	0	0	0	162
3-11	W	6	18	3	48	21	0	3	0	0	0	99
3-12	W	6	45	0	21	18	9	3	0	0	0	102
3-13	W	12	114	3	12	9	0	6	0	6	0	162
3-14	W	15	66	0	24	6	0	0	3	0	0	114
3-16	W	3	39	9	15	45	0	0	0	0	0	111
3-17	W	9	180	0	30	12	0	0	0	3	0	234
3-18	F	0	66	0	36	3	0	12	0	6	0	123
3-19	W	0	150	0	3	39	6	3	0	3	0	204
3-20	W	9	102	3	6	42	3	12	3	3	3	189
3-22	W	3	120	0	12	48	0	6	0	6	0	195
3-23	F	3	69	12	12	18	0	210	0	3	3	330
3-24	W	0	78	16	19	34	0	130	0	6	3	286

TABLE 12.—NUMBERS OF SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND

C.W. 96 (Normal)

Date	Time of Day	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Abnormals Per Thousand
3-1	A.M.	W	27	159	3	9	261	12	0	0	0	471
3-2	A.M.	F	15	3	0	0	36	0	0	0	0	54
3-3	A.M.	W	51	15	0	6	12	3	0	0	0	87
3-4	A.M.	W	6	9	6	18	21	0	0	0	6	66
3-5	A.M.	F	15	15	3	24	36	3	0	0	3	99
		F	0	21	0	27	30	3	0	0	3	84
		F	6	3	6	27	12	6	0	0	0	60
3-6	A.M.	W	6	60	3	30	24	0	0	0	0	123
3-7	A.M.	W	6	27	9	24	27	0	0	0	3	96
3-8	A.M.	F	3	18	3	30	42	0	0	0	3	99
3-9	A.M.	W	6	24	0	21	81	3	0	0	0	135
3-10	A.M.	W	0	15	0	12	75	0	0	0	0	102
	P.M.	W	9	18	3	6	57	3	0	0	0	96
3-11	A.M.	F	3	0	0	15	18	0	0	0	0	36
	P.M.	W	0	21	0	33	30	3	0	0	6	90
3-12	A.M.	W	30	108	9	12	210	12	0	0	0	381
	P.M.	W	6	21	3	48	357	12	0	3	3	453
3-13	A.M.	W	6	333	3	3	87	27	75	0	3	537
	P.M.	W	9	147	6	45	48	0	66	0	0	321
3-14	A.M.	W	12	135	0	42	123	3	42	0	3	360

Note: More than one F in the same collection denotes different fractions.

TABLE 13.—NUMBERS OF SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND

C.W. 95 (Without Seminal Vesicles)

Date	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Small Heads	Abnormals Per Thousand
4-13	W	6	33	3	24	63	0	0	3	0	0	142
5-4	W1	9	108	0	12	33	0	0	0	0	0	162
	2	9	90	3	31	39	0	0	0	0	0	162
5-6	F 1	18	54	9	15	21	0	3	0	0	3	123
	2	15	66	3	9	36	0	0	0	3	0	132
5-8	W1	3	51	0	24	75	0	9	0	0	0	163
	2	3	48	0	24	90	0	6	0	0	0	171

Note: The numbers in the slide column indicate duplicate slides.

TABLE 14.—NUMBERS OF SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND C.W. 96 (Without Cowper's Glands)

Date	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Small Heads	Abnormals Per Thousand
4-12	W	12	60	0	24	21	3	0	0	0	3	123
4-13	W	9	3	0	6	36	3	0	0	0	3	60
4-14	W	0	3	6	15	9	0	0	0	0	0	33
4-15	W	3	6	0	39	15	0	0	0	0	0	63
4-16	W	30	0	0	21	9	0	6	0	3	0	69
4-17	W	3	6	3	9	21	0	0	0	3	0	45
4-18	W	3	0	3	6	33	0	0	0	3	0	48
4-19	F	6	3	3	27	12	0	9	0	0	0	60
	F	9	12	6	15	0	3	0	0	0	12	57

TABLE 15.—NUMBERS OF SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND C.W. 96 (Without Seminal Vesicles and Cowper's Glands)

4-30	W1	9	9	0	12	27	0	3	0	0	3	63
	2	12	3	0	6	33	0	3	0	0	3	60
5-1	W1	3	12	3	12	6	0	0	0	0	0	36
	2	6	21	3	12	6	0	0	0	6	0	54
5-2	W1	30	12	0	0	3	0	21	0	3	0	69
	2	30	15	3	0	6	0	3	0	0	0	57
5-3	W1	18	3	3	3	9	3	0	0	0	0	39
	2	3	15	0	3	18	0	3	0	0	0	42
5-4	W1	6	3	0	6	105	0	6	0	0	0	126
	2	6	3	0	6	81	0	18	0	9	0	123

Note: The numbers in the slide column indicate duplicate slides.

TABLE 16.—NUMBERS OF SPERMATOZOA OF DIFFERENT TYPES PER THOUSAND C.W. 7 (Without Seminal Vesicles and Cowper's Glands)

Date	Slide	Tailless Sperm	Coiled Tails	Tapering Heads	Enlarged Middle Piece	Middle Piece Bead	Damaged Head	Undeveloped Sperm	Double Heads	Giant Heads	Small Heads	Abnormals Per Thousand
4-12	W	6	102	0	15	45	0	0	0	0	0	168
4-13	W	6	30	3	0	60	0	3	0	0	0	102
4-14	F	18	33	0	6	0	0	12	0	0	3	72
4-15	F	3	48	0	6	27	0	0	0	0	3	87
4-16	W	6	72	3	9	18	0	12	3	0	0	113
4-17	W	0	45	3	18	15	0	6	0	0	0	87
4-18	W	9	18	9	6	15	0	0	0	0	0	57
4-19	W	6	39	9	9	12	0	0	0	0	0	75
4-20	W	12	27	0	12	21	0	6	0	0	0	78
4-23	W	3	18	3	9	30	0	0	0	0	0	63
4-24	W	6	6	9	18	12	0	6	0	3	0	60
4-25	W	0	12	0	15	60	0	0	3	3	0	93
4-26	W1	6	117	3	15	15	0	9	0	0	9	174
	2	12	105	12	3	12	0	6	0	0	0	150
4-27	W1	3	15	3	3	6	0	6	3	0	0	39
	2	3	18	6	6	12	0	0	3	0	0	48
4-28	W1	21	9	0	24	27	0	0	0	0	0	81
	2	12	6	3	21	30	0	0	0	0	0	72
4-29	W1	6	30	3	9	9	3	3	0	0	0	63
	2	9	36	0	9	9	0	6	0	0	0	69
5-1	W1	3	96	3	9	3	6	3	0	0	0	120
	2	9	90	6	6	9	0	9	0	0	0	129
5-2	W1	6	21	0	9	30	3	6	0	0	3	78
	2	3	9	0	18	33	0	6	0	0	0	69
5-3	W1	3	3	3	21	42	0	3	0	0	6	81
	2	6	15	3	27	27	0	0	0	3	0	81

Note: The numbers in the slide column indicate duplicate slides.

TABLE 17.—SUMMARY OF SEMEN COLLECTIONS FROM BOAR WITHOUT SEMINAL VESICLES 1937

Boar	Average live weight during the period (lbs.)	Number of collections	Period of collections (days)	Duration of ejaculation (min)	Weight of ejaculate (gms)	Volume of ejaculate (cc)	Sperm per cu mm (1000)	Total number sperm (billion)
C.W. 95	294	7	6	6-10 8.5	152-223 195	150-220 193	0*	0*

* Too few sperm to count.
Note: The numbers appearing at the top give the range, while the value below is the mean.

TABLE 18.—SUMMARY OF SEMEN COLLECTIONS FROM BOARS WITHOUT COWPER'S GLANDS 1937

Boar	Average live weight during the period (lbs.)	Number of collections	Period of collections (days)	Duration of ejaculation (min)	Weight of ejaculate (gms)	Volume of ejaculate (cc)	Sperm per cu mm (1000)	Total number sperm (billion)
C.W. 96	277	8	8	3.5-11 7.25	100-339 236	97-330 230	52-530 135	9.7-53 28.3
C.W 147	350	4	5	4-7 4.5	148-298 197	146-294 194	110-390 200	18.5-56.9 35.0
Range Mean	277-350 313	12* 6	5-8 6.5	3.5-11 6	100-339 217	97-330 212	52-530 168	9.7-56.9 32

* Total.
Note: The numbers appearing at the top give the range, while the value below is the mean.

TABLE 19.—SUMMARY OF SEMEN COLLECTIONS FROM BOARS WITHOUT SEMINAL VESICLES AND COWPER'S GLANDS 1937

Boar	Average live weight during the period (lbs.)	Number of collections	Period of collections (days)	Duration of ejaculation (min)	Weight of ejaculate (gms)	Volume of ejaculate (cc)	Sperm per cu mm (1000)	Total number sperm (billion)
C.W. 95	282	4	6	4-10 6.5	98-166 135	97-166 135	25-100 40	1.6-13.7 5.49
C.W. 96	275	9	21	5-9 7.4	167-248 190	166-247 189	70-225 139	11.6-53.1 26.5
C.W. 7	322	19	22	7-18 10.8	92-232 136	92-230 135	45-575 156	6.3-87.4 21.0
Range Mean	275-322 293	32* 10.6	6-22 16	4-18 8.3	92-248 157	92-247 153	25-575 112	1.6-87.4 17.7

* Total.
Note: The numbers appearing at the top give the range, while the value below is the mean.

TABLE 20.—SUMMARY OF SEMEN COLLECTIONS FROM BOARS WITHOUT SEMINAL VESICLES, COWPER'S GLANDS, AND VASECTOMIZED 1937

Boar	Average live weight during the period (lbs.)	Number of collections	Period of collections (days)	Duration of ejaculation (min)	Weight of ejaculate (gms)	Volume of ejaculate (cc)	Sperm per cu mm (1000)	Total number sperm (billion)
C.W. 4	370	9	9	4.5-9 6.2	111.5-150.5 138	110-149 137	0	0
C.W. 95	310	5	15	6-10 8.3	127-191 151	126-190 150	0	0
C.W. 7	340	6	13	8-16 10.6	128-219 170	126-217 168	0	0
C.W.96	274	5	10	5-8 6.2	94.5-156 131	93.5-155 130	0	0
Range Mean	274-370 324	25* 6	9-15 12	4.5-16 8	94.5-219 148	93.5-217 147		

* Total.
Note: The numbers appearing at the top give the range, while the value below is the mean.

TABLE 21.—CHEMICAL ANALYSES OF BLOOD SERUM AND PLASMA

(mgm. per 100 gm. wet weight)

Boar	Material	Date Obtained	pH	Dry matter, per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 95	Plasma	3-24	..	9.20	..	37.7	..	..	9.3	580	81.0	16.9	2.4	987	6172
C.W. 95	Plasma	4-16	7.6	8.62	..	..	..	..	8.3	601	89.0	17.4	2.4	984	6147
C.W. 7	Plasma	3-24	..	8.38	..	32.5	..	..	8.4	622	86.0	16.4	2.4	1010	6312
C.W. 7	Plasma	4-16	7.62	8.92	..	..	..	..	8.7	596	80.0	16.2	2.4	1004	6278
C.W. 4	Plasma	3-24	..	8.47	..	38.2	..	..	8.5	580	81.0	18.0	2.4	994	6213
C.W. 4	Plasma	4-16	7.57	8.50	..	..	..	..	8.5	585	85.0	17.1	2.4	950	5941
C.W. 96	Plasma	4-16	7.52	8.48	..	..	..	..	8.5	592	85.6	17.0	2.4	1143	7144
Range			7.52-7.62	8.38-9.20	..	32.5-38.2	..	..	8.3-9.3	580-622	80.0-89.0	16.2-18.0	2.4	950-1143	5941-7144
Mean			7.57	8.65	..	36.1	..	..	8.6	593	83.9	17.0	2.4	1010	6315
C.W. 95	Serum	4-16	7.62	8.10	196	23.0	9.7	2.8	8.1	600	91.3	12.2	2.4	973	6081
C.W. 7	Serum	4-16	7.67	8.15	204	23.3	10.2	2.5	8.2	526	82.9	14.2	2.4	1002	6262
C.W. 4	Serum	4-16	7.67	8.20	186	25.2	11.5	2.0	6.7	495	87.0	14.0	2.4	957	5984
C.W. 96	Serum	4-16	7.67	8.12	227	22.7	9.7	4.5	8.7	584	80.7	13.6	2.4	994	6213
Range			7.62-7.67	8.10-8.20	186-227	22.7-25.2	9.7-11.5	2.0-4.5	6.7-8.7	495-600	80.7-91.0	12.2-14.2	2.4	957-1002	5984-6262
Mean			7.65+	8.14	203	23.5	10.3	2.9	7.9	551	85.4	13.5	2.4	982	6135

+ Median.

TABLE 22.—CHEMICAL ANALYSES OF SEMINAL VESICLE FLUID

(mgm. per 100 gm. wet weight)

Source of Material	Gland	pH	Dry matter, per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
				Sodium	Potassium	Calcium	Mag-nesium	Phos-phorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 95	Right	6.75	15.75	446	1268	7.40	38.3	44.0	41.0	266	0	5.6	1500	9375
C.W. 95	Left	6.50	15.80	452	1300	7.90	38.5	39.0	46.0	250	0	..	1512	9450
C.W. 96	Right	7.3++	15.95	300	1270	8.30	39.6	40.0	30.0	243	0	4.9	..	..
C.W. 96	Left	7.2++	15.99	443	1250	7.80	39.7	40.0	28.0	260	0	5.45	..	..
C.W. 8	Right	6.75	16.05	316	1043	7.60	39.0	45.0	24.0	..	0	..	1475	9218
C.W. 8	Left	6.75	16.05	360	1240	7.20	40.2	39.0	25.0	..	0	..	1470	9187
C.W. 9	Right	6.45	16.12	355	1161	7.60	39.2	46.0	23.0	..	0	..	1492	9325
C.W. 9	Left	6.45	16.14	310	1200	7.60	38.1	44.0	15.0	..	0	..	1483	9268
C.W. 7	Right +Left	6.80	18.38	606	1471	8.70	44.7	51.0	60.0	266	0	..	1486	9287
Range		6.45-6.80	15.75-18.38	300-606	1043-1471	7.2-8.7	38.1-44.7	39.0-51.0	15-60	243-266	0	4.9-5.6	1470-1512	9187-9450
Mean		6.75+	16.25	399	1245	7.79	39.7	43.1	32.4	257	0	5.31	1488	9302

+ Median.
++ Determined twenty-four hours after removal. Not included in range.

TABLE 23.—CHEMICAL ANALYSES OF COWPER'S GLAND MATERIAL
(mgm. per 100 gm. wet weight)

Source of Material	Gland	pH	Dry matter, per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
				Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides (as NaCl)	Glucose	Urea N.	Creatinine	Total Nitrogen	Protein Equivalent
C.W. 95	Right	7.2	15.10	857	443	28.4	133	9.2	420	..	..	..	..	..
C.W. 95	Left	7.3	15.06	1057	492	27.1	128	8.9	412	..	..	..	..	..
C.W. 8	Right	7.3	14.98	1048	492	27.6	133	9.2	380	..	..	..	1296	8100
C.W. 8	Left	7.3	14.52	1110	493	27.2	129	8.9	377	..	..	..	1290	8062
C.W. 96	Right +Left	7.3	16.00	1065	502	29.4	142	9.9	435	..	..	..	1267	7919
C.W. 94	Right +Left	7.3	16.00	1110	422	29.4	142	9.7	428	..	..	..	1238	7737
C.W. 147	Right	7.3	16.81	1180	544	34.0	152	10.9	..	..	..	..	1284	8025
C.W. 147	Left	7.2	18.25	1330	557	38.0	166	11.8	..	..	..	..	1276	7975
Range		7.2-7.3	14.52-18.25	857-1330	422-557	27.1-38.0	128-166	8.9-11.8	377-435	..	..	..	1238-1296	7737-8100
Mean		7.25+	15.84	1095	493	30.1	141	9.8	408.6	..	..	..	1275	7969

+ Median.

TABLE 24.—CHEMICAL ANALYSES OF EPIDIDYMAL FLUID
(mgm. per 100 gm. wet weight)

Boar	Date Obtained	Dry matter, per cent of wet weight	pH	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
				Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 4+	4-27	10.78	6.7	688	399	..	..	280	158	..	..	..	..	..
C.W. 7	6-6	11.65	7.0	277	249	..	..	158	480	0.0	0.0	1.44	1606	10038
C.W. 147	6-19	14.24	7.0	..	..	..	..	..	431	..	..	..	..	..
Range		10.78-14.24	6.7-7.0	277-688	249-399	..	..	158-280	158-480	..	..	..	..	..
Mean		13.22	6.9+	482	324	..	..	219	356	..	..	1.44	1606	10038

+ Fluid from left Vas Deferens.

TABLE 25.—CHEMICAL ANALYSES OF WHOLE SEMEN FROM NORMAL BOARS

(mgm. per 100 gm. wet weight)

Boar	Date of Collection	Total grams of Ejaculate	pH	Dry matter, per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent (N x 6.25)
C.W. 96	3-1	183	7.80	4.41	837	114	4.67	10.6	6.9	501	..	..	..	657	4100
C.W. 96	3-4	335	7.45	4.52	653	168	4.53	10.6	3.8	473	..	..	..	650	4060
C.W. 96	3-12	265	..	2.23	280	83	2.32	5.3	3.7	474	..	..	..	747	4665
C.W. 4	3-1	277	7.85	5.29	720	248	6.1	12.8	8.6	520	31.0	0.0	0.25	638	3990
C.W. 4	3-7	288	7.55	4.56	732	237	6.2	10.7	5.7	456	32.0	0.0	0.29	652	4070
C.W. 4	3-12	144	..	4.96	700	300	6.6	12.4	9.2	540	36.0	0.0	0.30	600	3753
C.W. 7	3-1	302	7.70	4.16	612	294	5.0	11.5	8.9	615	40.0	0.0	0.27	546	3409
C.W. 7	3-11	254	7.40	5.13	586	315	4.8	10.7	10.8	506	56.0	0.0	0.28	562	3510
C.W. 7	3-17	286	7.55	4.86	624	368	5.9	10.9	12.3	649	52.0	0.0	0.28	526	3285
C.W. 94	3-1	163	7.60	4.96	607	242	5.4	11.7	8.7	472	..	0.0	..	568	3558
C.W. 94	3-5	269	7.45	5.24	683	370	5.5	10.1	14.5	482	..	0.0	..	644	4020
C.W. 94	3-11	250	7.30	5.54	530	306	5.4	13.0	13.4	553	..	0.0	..	586	3660
C.W. 95	3-3	402	7.60	6.17	728	192	5.9	14.5	5.8	423	36.0	0.0	0.26	741	4635
C.W. 95	3-12	291	7.50	5.91	773	344	6.1	13.9	16.9	454	44.0	0.0	0.28	765	4785
C.W. 95	3-17	220	7.35	5.87	788	382	6.6	13.8	8.4	620	37.0	0.0	0.28	704	4400
C.W. 147	5-31	165	7.65	3.58	606	150	4.2	5.2	5.3	645	40.0	0.0	0.32	754	4712
C.W. 147	6-1	267	7.65	3.72	577	175	5.0	8.2	6.0	618	44.5	0.0	0.28	419	2619
C.W. 55	5-31	180	7.45	4.23	694	170	4.4	9.6	6.6	598	12.9	0.0	0.20	562	3512
C.W. 55	6-1	191	7.60	3.58	547	159	4.5	8.4	5.2	701	14.8	0.0	0.14	334	2088
Range		144-402	7.3-7.85	2.23-6.17	280-837	83-382	2.32-6.6	5.2-14.5	3.7-16.9	423-701	12.9-56.0	0.0	0.14-0.32	334-765	2088-4785
Mean		249	7.55+	4.68	646.13	243	5.21	10.73	8.42	542.10	36.6	0.0	0.26	613	3831

+ Median.

TABLE 26.—CHEMICAL ANALYSES OF SEMEN FROM BOAR WITHOUT SEMINAL VESICLES

(mgm. per 100 gm. wet weight)

Boar	Date of Collection	Grams of Ejaculate	Dry matter, per cent of wet weight	pH	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Mag-nesium	Phos-phorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 95	4-13	188	3.41	7.80	327	68	7.8	2.5	1.7	617	0.0	0.0	0.43	222	1387
C.W. 95	4-14	186	3.14	7.65	294	59	7.5	1.1	2.5	588	0.0	0.0	0.43	239	1494
C.W. 95	4-15	212	2.84	7.60	267	63	6.7	1.3	2.8	586	..	..	..	215	1344
Range		186-212	2.84-3.41	7.60-7.80	267-327	59-68	6.7-7.8	1.1-2.5	1.7-2.8	586-617	0.0	0.0	0.43-0.43	215-239	1344-1494
Mean		195	3.13	7.7+	296	63	7.3	1.6	2.3	597	0.0	0.0	0.43	225	1408

+ Median.

TABLE 27.—CHEMICAL ANALYSES OF SEMEN FROM BOARS WITHOUT COWPER'S GLANDS

(mgm. per 100 gm. wet weight)

Boar	Date of Collection	Grams of Ejaculate	Dry matter, per cent of wet weight	pH	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Mag-nesium	Phos-phorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 96	4-12	100	7.35	7.4	544	144	6.3	24.2	56.3	539	45.5	0.0	0.71	401	2506
C.W. 96	4-13	180	3.80	7.2	485	80	3.9	5.4	18.0	723	41.8	0.0	0.71	418	2616
C.W. 96	4-14	192	4.57	..	430	107	4.5	14.2	12.7	594	60.6	0.0	0.75	400	2500
C.W. 96	4-15	254	4.26	7.2	..	..	..	..	..	594	..	0.0	..	..	..
C.W. 147	6-14	148	5.10	7.2	336	109	5.1	9.0	44.0	530	50.0	0.0	1.07	580	3625
C.W. 147	6-16	298	5.26	7.3	286	108	6.5	9.9	15.0	485	111.0	0.0	1.20	600	3750
C.W. 147	6-17	185	4.04	7.2	338	76	5.8	5.9	12.0	532	60.0	0.0	1.17	444	2775
C.W. 147	6-18	157	3.96	7.3	380	75	5.7	6.3	37.0	526	56.9	0.0	0.94	420	2625
Range		100-298	3.8-7.35	7.2-7.4	286-544	75-144	3.9-6.5	5.4-24.2	12.0-56.3	485-723	41.8-111	0.0	0.71-1.2	401-600	2500-3750
Mean		189	4.79	7.3+	400	100	5.4	10.7	28.0	565	60.8	0.0	0.94	466	2914

+ Median.

TABLE 28.—CHEMICAL ANALYSES OF SEMEN FROM BOARS WITHOUT SEMINAL VESICLES AND COWPER'S GLANDS

(mgm. per 100 gm. wet weight)

Boar	Date of Collection	Grams of Ejaculate	pH	Dry matter, per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Mag-nesium	Phos-phorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 7	4-12	153	7.7	2.44	320	101	3.0	1.7	18.8	673	0.0	0.0	0.43	134	838
C.W. 7	4-13	132	7.6	1.87	244	78	2.3	1.3	16.7	709	0.0	0.0	0.35	151	940
C.W. 7	4-14	232	..	1.77	264	44	2.6	1.4	12.3	720	..	..	..	141	878
C.W. 7	4-15	151	..	1.73	258	43	2.5	1.4	12.2	715	..	..	..	159	999
C.W. 96	5-17	166	7.7	1.43	328	70	4.6	No detectable amount present.	0.32+	808	0.0	0.0	0.28	115	719
C.W. 96	5-18	167	7.4	1.30	312	70	3.9		0.38+	794	0.0	0.0	0.28	188	1175
C.W. 96	5-19	170	7.5	1.35	338	81	4.1		0.57+	635	0.0	0.0	0.29	102	638
C.W. 96	5-20	199	7.6	1.22	306	71	3.9		..	622	0.0	0.0	0.30	91	569
C.W. 95	5-4	138	7.8	1.50	364	28	..		10.7	725	..	..	..	118	737
C.W. 95	5-8	98	..	1.22	309	20	..		9.1	719	..	..	..	..	..
C.W. 95	5-10	166	7.5	1.38	336	25	1.8	0.69	10.6	738	..	..	..	..	..
Range		98-232	7.4-7.8	1.22-2.44	244-364	20-101	1.8-4.6	0.69-1.7	9.1-18.8	622-808	..	..	0.28-0.43	91-188	569-1175
Mean		161	7.6++	1.56	307	57	3.1	1.6	12.9	714	..	..	0.32	133	833

+ Not included in range and mean.
++ Median.

TABLE 29.—CHEMICAL ANALYSES OF SEMEN FROM BOARS WITHOUT SEMINAL VESICLES, COWPER'S GLANDS, AND VASECTOMIZED

(mgm. per 100 gm. wet weight)

Boar	Date of Collection	Grams of Ejaculate	pH	Dry matter per cent of wet weight	INORGANIC CONSTITUENTS						ORGANIC CONSTITUENTS				
					Sodium	Potassium	Calcium	Magnesium	Phosphorus	Chlorides (as NaCl)	Glucose	Urea N.	Apparent Creatinine	Total Nitrogen	Protein Equivalent
C.W. 4	4-12	139	8.00	1.30	40	32	1.2	0.50	0.14	624	0.0	0.0	0.43	216+	1350+
C.W. 4	4-13	151	7.80	1.17	33	29	1.1	0.46	0.12	723	..	..	..	245+	1531+
C.W. 4	4-14	141	7.55	1.06	31	15	1.3	0.49	0.11	722	0.0	0.0	0.43	249+	1556+
C.W. 4	4-15	148	7.55	1.00	29	29	1.2	0.46	0.10	721	..	..	..	..	..
C.W. 95	5-17	145	7.90	1.13	32	35	1.2	..	..	808	0.0	0.0	0.25	67	419
C.W. 95	5-19	190	7.90	1.09	31	19	1.5	No detectable amount present.		645	0.0	0.0	0.26	72	450
C.W. 95	5-21	145	7.90	1.03	43	23	1.9		No detectable amount present.	649	0.0	0.0	..	55	344
C.W. 7	5-19	143	7.65	1.32	43	29	2.7			802	0.0	0.0	0.24	73	456
C.W. 7	5-20	156	7.70	0.93	24	24	1.9			784	0.0	0.0	0.25	56	350
C.W. 7	5-21	159	7.80	1.09	42	30	1.9			790	0.0	0.0	..	64	400
C.W. 96	5-22	100	7.80	1.22	49	27	2.7			776	0.0	0.0	..	99	619
C.W. 96	5-23	94	8.15	2.13	60	43	2.1			780	0.0	0.0	..	83	519
C.W. 96	5-24	155	8.50	1.18	52	21	1.3			818	0.0	0.0	..	109	681
C.W. 96	5-25	153	7.90	0.98	33	16	1.8			786	..	..	..	86	538
C.W. 7	5-23	217	7.60	1.03	46	18	2.1			818	..	..	..	57	356
C.W. 95	5-24	145	..	2.28	77	68	3.5			807	..	..	..	64	400
Range		94-217	7.55-8.50	0.93-2.28	24-77	15-68	1.1-3.5	0.46-0.50	0.10-0.14	624-818	0.0	0.0	0.24-0.43	55-109	344-681
Mean		148.8	8.00++	1.24	41.5	28.6	1.8	0.47	0.11	753.3	0.0	0.0	0.31	73.7	461

+ Not included in range and mean.
++ Median.

TABLE 30.—SUMMARY OF CHEMICAL ANALYSES OF SEMEN AND GLANDULAR PRODUCTS, 1936

Nature of Material	Number of animals involved	Number of samples analyzed	Grams of ejaculate	pH	Dry matter, per cent of wet weight	Per cent of ash (basis of solids)	Sodium Chloride (mgm. per 100 gm.)	Total Nitrogen (mgm. per 100 gm.)
Seminal Vesicle fluid	3	8	..	6.45-6.85 6.7	16.0-18.7 16.7	1.70-3.72 3.0	12-44 25.5	1321-1544 1450
Cowper's Gland Material	6	16	..	7.25-7.30 7.3	14.5-17.1 15.5	3.0-7.5 4.5	356-406 380	970-1246 1183
Epididymal fluid	5	5	..	6.4-7.3 7.0	9.7-13.7 12.2	10.0-12.6 11.9	140-152 148	813-859 833
Whole semen from normal boars	3	7	200-397 312	..	4.99-9.0 6.9	5.8-9.3 7.6	394-698 478	507-826 643
Semen from boar without seminal vesicles	1	2	128-195 161	..	3.46-3.54 3.5	8.1-14.7 11.4	489-554 522	225-256 240
Semen from boar without seminal vesicles and Cowper's Glands	1	3	213-234 226	..	1.67-3.48 2.3	11.9-37.7 22.9	518-658 584	183-238 211
Semen from boar without seminal vesicles, ⅔ prostate and vasectomized	1	3	80-142 109	..	1.51-3.64 2.7	7.7-40.0 22.5	671-726 695	97-196 149

Note: The numbers at the top give the range. The lower value is the mean.

TABLE 31.—SUMMARY OF CHEMICAL ANALYSES ON FRACTIONATED SEMEN COLLECTIONS, 1936

Semen from Normal Boars (C.W. 6, 8 and 9) (5 collections)	MINUTE INTERVALS										
	1	2	3	4	5	6	7	8	9	10	11
pH	7.4	7.4	7.4	7.5	7.3	7.4	7.3	7.4	7.4	7.2	7.2
Per cent dry matter	4.8	7.5	5.8	6.7	7.2	7.1	7.1	7.6	6.6	9.2	9.6
Per cent ash (dry matter basis)	10.7	9.8	8.1	8.2	7.8	5.6	6.6	5.8	7.1	7.7	5.9
Sodium (NaCl) (mgm. per 100 gm.)	560	480	473	457	421	455	392	418	428	582	305
Nitrogen (mgm. per 100 gm.)	318	819	845	465	766	781	899	684	666	567	982
Semen from boar without seminal vesicles. (D.J. 33) (2 collections)											
pH	7.6	7.4	7.7	7.4	7.6	7.3					
Per cent dry matter	1.3	1.2	4.5	4.6	2.2	4.1					
Per cent ash (dry matter basis)	76.6	35.0	28.7	16.3	11.1	11.0					
Sodium (NaCl) (mgm. per 100 gm.)	867	593	593	383	497	473					
Nitrogen (mgm. per 100 gm.)	210	150	172	415	202	180					
Semen from boar without seminal vesicles and Cowper's Glands. (D.J. 3) (2 collections)											
pH	7.2	7.2	7.5	7.7	7.6	7.8	7.9	7.7			
Per cent dry matter	2.0	7.6	2.2	1.2	3.0	2.2	1.1	1.2			
Per cent ash (dry matter basis)	52.1	2.2	4.1	54.0	58.1	68.7	80.1	72.5			
Sodium (NaCl) (mgm. per 100 gm.)	610	683	637	648	637	730	759	712			
Nitrogen (mgm. per 100 gm.)	225	150	105	135	155	162	148	140			
Semen from boar without seminal vesicles, ⅔ prostate and vasectomized. (D.J. 18) (2 collections)											
pH	7.5	7.5	7.5	7.6	7.7	7.8	7.8				
Per cent dry matter	2.17	6.5	1.9	2.0	4.6	3.8	5.1				
Per cent ash (dry matter basis)	18.4	7.3	7.5	8.8	9.5	7.5	18.2				
Sodium (NaCl) (mgm. per 100 gm.)	405	623	721	718	677	666	643				
Nitrogen (mgm. per 100 gm.)	1023	267	530	160	100	130	234				