

SPERM TRANSPORT IN THE FEMALE REPRODUCTIVE TRACT
OF LIVESTOCK AND POULTRY

by

IMTIAZ AHMED QURESHI

B. Sc. (A.H.), University of Panjab, Lahore, West Pakistan
M. Sc. (A.H.), West Pakistan Agricultural University,
Lyallpur, West Pakistan

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Major Professor

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INTRODUCTION

The process of fertilization is brought about by the fusion of two sexual cells, the sperm and the ovum. In many invertebrates and lower vertebrate form, this occurs outside the body of the female. The eggs are shed, usually into the water, and the male pours sperms directly on to them (Wood, 1966).

In mammals, on the other hand, fertilization occurs within the female body, usually in the narrow fallopian tubes which lead from the ovaries into the uterus. However, during mating the male deposits sperms in lower region of the female reproductive tract, either into the uterus, as for example in the pig, stallion and dog, or into the cranial end of the vagina and on to the cervix as occurs in the sheep, cow and man (White, 1966). In either case, the sperms have to move a considerable distance within the female body to reach the site of fertilization. The mechanisms by which this sperm transport process is brought about have attracted interest for many years.

Since their discovery in the 17th century, it has been known that mammalian sperms are actively motile. For two centuries, the almost universal opinion in the gynecological circles was that sperms deposited in the vagina made their way to the point of fertilization by means of their own automotive ability (Hartman, 1957). The vigorous motility of seminal spermatozoa has long been a source of fascination and naturally gave strong support to these early suppositions that migration in the female is due to the activity of the cells themselves. This is now known not to be generally true, and only in certain limited segments does active sperm motility seem of possible importance in transport from the vagina to the site of fertilization (Bishop, 1961). Suggestions have been made, in fact, that sperm motility

may be unnecessary even for egg penetration (Allen and Grigg, 1957), but such has never been demonstrated in studies of fertilization of either invertebrate or vertebrate gametes. The speed with which spermatozoa traverse and reach the upper portion of the female reproductive tract in farm animals, indicates that little time lapses between ejaculation and arrival of sperm at the site of fertilization. There is strong evidence to believe that in all farm animals and, in poultry, it takes only a few minutes for motile sperm to reach the ovarian portion of oviducts after natural mating or artificial insemination (Hancock, 1962; Saeki et al., 1963; Moeller and Van Demark, 1951; Starke, 1949; Burger, 1952; Mattner and Braden, 1963).

The distances through which spermatozoa are transported in vivo in a matter of minutes is much more than is indicated as possible from their own motility in vitro (Rothschild, 1953a; Moeller and Van Demark, 1955; Gray, 1958).

In addition, dead sperm, seminal components other than sperm and some inert substances--India ink, powdered charcoal--have been observed to be transported with almost the same efficiency as do motile sperms in the reproductive tract (Van Demark and Moeller, 1951; Mann et al., 1955; Mattner and Braden, 1963; Allen and Grigg, 1957; Rowson, 1955). It is, therefore, logical to suspect that cooperation by the musculature of the female genital tract is instrumental in this rapid transport of sperm.

Investigations have shown that in all farm animals, strong uterine contractions are induced through stimulation of genital system by natural mating or artificial breeding techniques (Van Demark and Hays, 1952; Mann et al., 1955; Debackere et al., 1961; Van Demark and Hays, 1951). This seems to be especially true in cows, where such contractions have been

observed to set in merely by the sight of the male (Van Demark and Hays, 1952). All these observations are interpreted to mean that stimulation of the genital system induces nervous impulses that reach the posterior lobe of the pituitary gland via the hypothalamus activating the release of oxytocin, which then causes the uterine and oviducal contractions that are responsible for the rapid movement of semen from the site of ejaculation to the oviduct.

The purpose of the report under review is to investigate the rate of sperm cell travel in the female reproductive tract of Livestock and Poultry with particular reference to the mechanisms involved in their transport.

REVIEW OF LITERATURE

Cow

Speed of Transport

The speed with which spermatozoa, traverse the reproductive tract of the female following natural and artificial insemination has been the subject of considerable research over a period of several years. Knowledge of this phenomenon became more important with the need for proper timing in the increasing practice of artificial insemination. The most striking evidence that sperm migration in the female tract cannot be attributed solely to sperm motility is afforded by the results of studies of the rate of transport and the time required to pass from the point of insemination to the site of fertilization or to intermediate levels of the reproductive system. The interval between coitus and the arrival of the first few sperm at the site of fertilization is difficult to establish with certainty, and authorities vary widely in their estimates.

Studies were made by Beshlebnov (1938) on the rate of movement of sperm and duration of its survival in the female genital tract of cows. Observations on 22 cows which were served or inseminated 10 hours after the beginning of heat and killed at frequent intervals from 40 minutes to 40 hours after insemination, demonstrated the cervix was filled with spermatozoa in half hour, and the first spermatozoa entered the uterus less than 40 minutes after service. Live spermatozoa were found in the ovarian part of the fallopian tubes 4 hours after service, and in one case after 105 minutes. It was thought the migration of the sperm was aided by uterine contractions. In nine cows serviced while not in estrus spermatozoa reached the

infundibula. With cows in heat, which were inseminated with dead (heated) spermatozoa into the cervix, spermatozoa were found far beyond the site of insemination, in the upper portions of the uterine horn and even in the tubes.

Brewster, May, and Cole (1940) reported the minimum time for artificially deposited spermatozoa to reach the upper 1/3 of the fallopian tube was 5.5 hours for mature cows and 4.25 hours for heifers. Experiments with dead sperms gave no indication that sperm travel was influenced by uterine contractions. These workers suggested 6-9 hours in mature cows and 4-7 hours in heifers for the time it would take sperm to reach the infundibulum after insemination.

Investigations were carried out by Van Demark and Moeller (1950) to determine the minimum time required for spermatozoa to reach the ovarian portion of the oviduct after deposition in the cervix of the cow by artificial insemination. Ten cows were slaughtered at various intervals after insemination, and the uterus and oviducts were clamped off at various locations. While carefully controlling the temperature of the tract, fluid samples were withdrawn from each isolated location by means of a syringe and needle and examined microscopically for the presence of spermatozoa. The interval between insemination and clamping off after slaughter was gradually diminished from 140 minutes down to 30 minutes. Spermatozoa of varying degree of activity were found in the ovarian portion of the oviducts at the shortest interval studied. To eliminate the possibility that spermatozoan transport in the first of this study was a result of the slaughtering procedure, the right horn and oviduct of each of a second series of cows were clamped off before slaughter through a surgical opening in the flank. Using

this technique, these investigators found spermatozoa in the ovarian portion of the oviduct when the interval between insemination and clamping off was 11 minutes.

Using a modified procedure in order that effect of killing could be eliminated, and also to permit checking shorter intervals, the same workers (1951) attempted to study rate of sperm travel in cows. The time interval obtained between artificial insemination of motile spermatozoa into the cervix and clamping off the reproductive tract ranged from 140 down to 2.5 minutes. In every instance where motile spermatozoa were used they were found in the ovarian portion of the oviduct, and in all other isolated segments of the tract. Similar rapid transport of spermatozoa to the nonmotile spermatozoa inseminated into the cervix were transported to the ovarian portion of the oviduct in 4.3 minutes or less. Also, in cows 4-8 days post-estrus, spermatozoa reached the upper portions of the oviducts within approximately 5 minutes after artificial insemination.

Rao et al. (1960) reported the results of their studies with buffalo-cows as follows:

Estrus was induced in 12 non-pregnant adult buffalo-cows by expression of the corpora lutea at mid-cycle. One group was artificially inseminated and the other received natural service. The right side of the reproductive tract of all animals was clamped at 5 sites at varying intervals after service or insemination to prevent migration of spermatozoa. Clamping was carried out through a surgical incision in the right flank. The buffalos were then sacrificed and the different parts of the reproductive tract examined for the presence of spermatozoa. These workers reported the minimum time required for the ascent of spermatozoa to the anterior portion of

the fallopian tube following artificial insemination was 3 minutes 10 seconds and after natural service 3 minutes 20 seconds.

Howe and Black (1963) conducted studies with young calves in order to determine whether the mechanisms which affect spermatozoan transport in the adult animal were present in calves that were well below the breeding age, and also to determine if exogenous hormones modify these mechanisms. For the purpose of this experiment, 10 control and 10 hormone treated calves ranging in age from 29 to 80 days, were slaughtered at varying intervals after vaginal insemination. The authors observed motile bull spermatozoa in the oviducts of these young calves within 13 minutes after vaginal insemination. Since the shortest insemination interval in this study was 13 minutes, and since spermatozoa were found in the oviduct at this time, the exact time required for sperm transport in the calf was not determined. These workers stated there is no reason to doubt the time may be shorter than the 13 minutes observed. Data from this study indicates the female bovine reproductive tract is capable of transporting spermatozoa at a very early age. Further, the administration of pregnant mares serum (PMS) and human chorionic gonadotropin (HCG) with or without added progesterone and estrogen did not affect this transport.

Sevcov (1965) conducted experiments with cows and heifers. He reported that sperm transport in the female genitalia was more rapid in females inseminated 10-12 hours after the end of estrus than in those inseminated 9-12 hours after its onset. This was attributed to the uterine cervix being only slightly open after estrus and preventing as great a loss of semen. When females were slaughtered at various intervals between 5 and 25 hours following insemination, motile spermatozoa were found in the genitalia up

to 20 hours post insemination.

In view of these extremely short sperm-cell travel times, one might ask: Is sperm cell travel in the female tract effected solely by the motility of the sperm, or does it depend on some other factor, such as the rhythmic muscular contractions of the uterus?

In vitro Speeds of Bovine Spermatozoa

Before answering the above question, it would be appropriate to review some of the "in vitro" work which was done in an attempt to evaluate the speed with which bull sperms can travel a given distance and then comparing it with their "in vivo" rate of travel.

Adolphi (1905) reported the average movement of bull spermatozoa as 4.02 mm per minute. Rothschild (1953a) in a preliminary report indicated the mean speed of bull spermatozoa was 117 U per second.

Using a photographic method and employing the probability-after-effect principle, the same author (1953b) reported a rate of travel for bull spermatozoa as 111 U per second.

The mean velocity observed by Baker et al. (1957) in 15 samples of bovine semen was 4.23 mm. per minute.

Gray (1958) reported the average propulsive speed for 235 cells as 100 U per second.

Moeller and Van Demark (1955) with the aid of a micrometer eye piece and a stop watch made a quick measurement of the speeds of spermatozoan travel. They reported the mean speed of the 960 spermatozoa observed was 114 U per second, with the range from 10 to 352 U per second.

Brewster et al. (1940) found the length of the extended reproductive

tract of the cow to average 25.4 inches (64.95 cm.) for mature cows and 20.7 inches (52.7 cm.) for heifers. If the mean velocity of bull sperm is to be considered on the order of 100 U per second (Moeller and Van Demark, 1955; Gray, 1958), and if a straight path were followed, it would require about 1-1/2 hours for the sperm to cover the entire length of the tract, actually the time required after natural mating is less than 2.5 minutes (Van Demark and Moeller, 1951).

Factors Affecting Sperm Transport

According to Hartman (1932), Lott had suggested as early as 1872 that one or more of the following factors might operate to transport spermatozoa through the female reproductive tract: (a) the force of ejaculation; (b) the pistonlike action of the penis; (c) the suction action of the uterus; (d) the capillary action of the cervical luman; (e) the ciliary action of the oviducts; (f) the muscular activity of the female tract; (g) the pressure of the viscera; (h) the motility of the spermatozoa.

Since a good part of the distance between the cervix and upper portions of the oviducts is made up of the uterus, it was thought the uterus and its activities at mating must be involved in sperm transport and that these activities were probably under nervous or hormonal control (Van Demark and Moeller, 1951). The muscular contractibility of the genital tract has been implicated in the process of sperm migration since the earliest studies of mating behavior and insemination (see Austin and Bishop, 1957). The most spectacular development involving endocrine control of sperm transport during the past decade has been the demonstration that oxytocin, as an important mediator of uterine activity is essential for rapid migration of sperm from

the cervix to the site of fertilization (Van Demark and Moeller, 1951; Van Demark and Hays, 1952; Hays and Van Demark, 1953a).

Some evidence suggesting a relationship between stimulation of the reproductive organs and milk ejection is found in the work of Nuesch (1904). In a review of literature, he states that a publication in 1727 refers to a practice of the Hottentots of blowing air into the vagina to bring about milk ejection in the absence of the calf. Nuesch also states that Skyths of India milked mares in a similar manner. Generally, it is accepted that the principal cause of milk ejection in the intact animal is the action of oxytocin on the mammary gland (Ely and Peterson, 1941; Petersen, 1942; Debackere and Peeters, 1959).

Evidence for the release of oxytocin during both artificial insemination and natural mating was obtained by Hays and Van Demark (1951) and Hays and Van Demark (1953a). They observed that stimulation of the vulva and cervix by massage caused an increase in intramammary pressure in 88% of 99 trials on 16 cows for an average increase of 8.0 cm. of water. In 15 natural matings, 80% gave a positive response for an average increase of 4.5 cm. of water. Blood taken before massage of the vulva and cervix had no effect, but blood taken after stimulation caused contractions of excised perfused cow uteri in each of 3 trials similar to that caused by oxytocin. There were no significant differences in the responses on different days of the estrous cycle. These investigators suggested that stimulation of the cervix and vagina of the cow causes release of oxytocin which in turn causes increased uterine contractions. Results of the studies by Hansel and Wagner (1960) indicated that uterine stimulation does result in an increased output of oxytocin in the cow, and apparently this response may occur at times

other than estrous.

Abrahams and Pickford (1954) presented evidence that, in response to emotional stimuli, there is a release of oxytocin and ADH hormones which increase the uterine contractions and causes water inhibitions simultaneously.

For several years it has been known that oxytocin stimulates the smooth musculature of the uterus. Since at the time of mating or artificial insemination there is a release of oxytocin, uterine activity would be expected to be concurrent (Salisbury and Van Demark, 1961).

Van Demark and Hays (1951) showed that various phases of the procedure during artificial insemination, resulted in uterine motility. Massage of the vulva and anal region, massage of the cervix, and passage of the inseminating tube into the cervix all caused increased uterine tone, and the last two especially caused tetanic uterine contractions of much greater magnitude than any of the contractions shown prior to the stimulation. They stated that similar responses were obtained in estrous and postestrous animals.

The uterine motility occurs in the cow during natural mating has been shown by the studies of Van Demark and Hays (1952). By placing in the uteri of the cows a water-filled balloon connected to a diaphragm and ink-writing lever, kymograph records were made showing uterine responses to mating. They reported that presence of the bull, nuzzling by the bull, noncopulatory mounting, and mounting followed by copulation and ejaculation all served as stimuli which resulted in increased uterine tone and uterine contractions within a few seconds. The latter stimulus produced the greatest response which was characterized by tetanic contractions. The uteri of both estrous and postestrous cows responded similarly to the various stimuli associated

with mating. They suggested that uterine activity evoked by mating plays a role in the rapid transport of spermatozoa in the cow. They also reported that varying degrees of response to mating shown by the bovine uteri suggests the release of varying amounts of oxytocin as a result of different stimuli of mating.

Sipilov (1966) reported the effects of neuro-sexual stimulation on uterine contractions and conception in cows. The uterine contractions in this experiment on 15 Kholmogor cows were registered before a vasectomized male was put with the females, during his approaches to them, during coitus, and immediately after 1-1/2 - 2 hours after coitus. He observed the frequency and intensity of contractions increased progressively until coitus and then gradually decreased. Contractions were still being registered 10-12 hours later. Of 161 cows in which estrus was detected and coitus occurred with vasectomized males, 65.8% conceived to a single insemination vs. 57% of 128 females in which estrus was detected by vasectomized males but no coitus occurred before the females were artificially inseminated twice at a 10- to 12-hour interval. On the basis of his findings, he concluded that artificial insemination does not stimulate all the sexual reflexes of the female.

The above responses--ejection of milk and increased uterine activity accompanying natural mating and manipulation of the genital organs of the cows--definitely indicated a release of oxytocin at the time of mating and of artificial insemination.

Further proof that oxytocin is involved was given by Hays and Van Demark (1953b). They conducted experiments in which uterine responses were recorded following intravenous injection of oxytocin into intact animals.

They reported that oxytocin increased the activity in each of 28 observations at all stages of the estrual cycle. The reactions started in 10 to 12 seconds after intravenous injection of oxytocin (15 U) and was usually characterized by a strong tetanic contractions. This was followed by a gradual reduction in tone and contraction of a large magnitude. Some workers observed the effect of epinephrine injection on uterine motility and reported that the effect was usually characterized by one sharp contraction followed by a period of reduced uterine activity. When epinephrine (2 ml. of 1:1000 adrenaline hydrochloride) was injected approximately 30 seconds prior to the injection of oxytocin, the effects of the oxytocin were either greatly diminished or completely obliterated.

Proof of the association between uterine activity, as produced by oxytocin, and spermatozoan transport was obtained in experiments conducted by Hays and Van Demark (1952) and Van Demark and Hays (1955), in which excised cow genital tracts were placed in a physiological bath at 39°C and perfused. The pattern of response of the excised uterus to injections of oxytocin and epinephrine was similar to that shown in the intact animal. Oxytocin produced tetanic contractions of the uterus, and epinephrine frequently caused one sharp contraction, followed by a prolonged period of inhibited activity and reduced tone. Epinephrine injected 30 seconds prior to the injection of oxytocin completely eliminated the effects of oxytocin. When semen was deposited midway in the cervix of an excised tract at the same time oxytocin was injected into the perfusate, spermatozoa were transported to the ovarian portions of the oviducts in less than 5 minutes in many of the tracts from estrous cows. When no oxytocin was given, little evidence of sperm transport was found even in tracts from estrous cows, and

no transport occurred in tracts from postestrous cows. Sperm transport failed in the perfused genital tract of the cow when epinephrine inhibited the action of oxytocin on the smooth musculature. The rapidity with which oxytocin and epinephrine act upon the uterus in vivo suggests that these hormones have a profound influence in producing a biochemical reaction.

In an attempt to obtain information on the metabolic role of these hormones in uterine muscle, studies were conducted by Inchiosa and Van Demark (1956) on the muscle lever and tissues homogenates and extracts. Aerobic and anaerobic studies by these workers of uterine motility and metabolism have suggested an influence of oxidation-reduction potential upon contractility and phosphorus metabolism. They observed that the relative effect of oxytocin in increasing uterine contractions was much greater under anaerobic conditions. They presented evidence as to the action of uterus being the result of stimulation of myosin and actomyosin adenosine triphosphate.

The work reported by Moghissi et al. (1964) concerned with certain biochemical processes which also appear to have a direct bearing on the over-all mechanism of sperm migration in the female reproductive tract. They reported that sperm penetrate clear, clean, watery midcycle mucous readily and rapidly and with increasing viscosity of the cervical mucus, the degree of sperm penetration was found to decrease. They also stated that acidic mucus immobilizes sperm, while alkaline mucus enhances sperm migration. They presented data implicating proteolysis of cervical mucus by seminal enzymes in sperm migration.

Gorohov and Trofimov (1965) conducted studies with cows and reported that release of oxytocin plays an important role in promoting uterine contractions and the transport of semen after service. They determined the

oxytocin content of the blood before, at the time of, and after artificial insemination by a pipette controlled rectally without use of a speculum or by the introduction of a catheter through the vagina using a speculum. They observed a greater release of oxytocin when the former method was used.

Studies in laboratory animals have suggested the "insuck" of semen into the uterus, and this would presumably depend upon a decreasing gradient of pressure in the cervix and uterus.

Higaki and Suga (1959) measured the absorption force of the uterus in the cow. Due to variation in pressure resulting from uterine motility, the absorption force during estrus was found to be greater (0.95 cm.) than it was in corpus luteum stage (0.25 cm.). No absorption force was detected in untreated or ovariectomized cows, but 48 hours after the infusion of 1000 I.U. estrogen and 10 mg. progesterone into the uterus, the force was similar to that found during estrus. The results of 83 inseminations indicated a positive relationship between the absorption force of the uterus and conception rate.

In order to evaluate the role of oxytocin in producing uterine contractions and helping in the rapid sperm transport, an experiment was designed by Rowson (1955), in which at varying intervals prior to slaughter, a quantity (usually 2 cc.) of the radio-opaque oil (neo-hydrinol) was deposited in the body of the uterus by means of an ordinary inseminating pipette and syringe, using the rectal technique. He observed that radio-opaque oil reached the tip of uterine horns in about 5 minutes, and entered the fallopian tubes in 30 minutes. It reached the fimbria about 75 minutes from the time of deposition. Intramuscular injection of oxytocin (30 units of pitocin) enhanced the transport of this inert material and it reached the

fallopian tubes within 2 to 3 minutes. He concluded that ascent of fluid in the reproductive tract was mechanical and oxytocin injection caused a more rapid ascent. He also studied that luteal phase uterus was relatively unresponsive to oxytocin whereas at estrous, the response was very great.

Ewe

Speed of Transport

Estimates of the time taken by sperm to travel the entire length of the female reproductive tract in ewes after deposition in the vagina, vary widely.

Quinlan and Mare (1931) reported the time to be about 6 hours for the passage of ram spermatozoa from the vagina to the ovarian end of the fallopian tubes.

Green and Winters (1935) studied the rate of sperm travel in ewes and concluded that time required for sperms to reach the infundibulum is approximately 5 hours after copulation, depending upon length of the female tract and activity of the sperms. They further reported that sperms reach the infundibulum of the ewe out of heat almost as quickly as when the ewe was in heat. Following 3 possible causes of variations in time necessary for sperm to reach their destination were summarized: (a) activity of the sperm; (b) condition of the female tract and (c) length of the female tract.

In 15 cases out of 17 observations made at 2 to 2.6 hours after insemination, sperms were found in the fallopian tubes by Warbritton et al. (1937).

Phillips and Andrews (1937) conducted experiments with sheep to compare speed at which ram spermatozoa travel in vivo with the rate they can travel in vitro. These studies indicated that ram sperm diluted in ringer's

solution had traversed the entire length of the genital tract in all the 7 ewes studied; the times ranging from 30 minutes to 7 hours and 7 minutes after insemination. On the assumption, that full 30 minutes were required for sperms to reach the upper end of the tract, the speed of travel was 12.4 mm. per minute.

Kelley (1939) indicated that in the ewe the spermatozoa travel upward at about 1.26 mm. per minute, reaching the middle third of the fallopian tubes 5 hours after coitus.

The material in the studies by Lopyrin and Loginova (1940) consisted of ewes mated at different stages of the estrus cycle, non-estrus ewes subjected to forced mating, and animals in which ovulation was induced in the interval between 2 normal estrus periods sperms were obtained from the female genital passages by laparotomy after intervals varying from 35 minutes to 52 hours post coitus. They reported that 35 minutes post coitus, all the spermatozoa were found in the most cranial part of the cervical canal. Starting from 2 hours 5 minutes post coitus, motile spermatozoa could be found in all parts of the uterine horns, including those adjoining the mouth of the fallopian tubes, though none were observed in the fallopian tubes until very much later, as a rule only from 8 hours 40 minutes post coitus. Observations by these workers on ewes mated at an early stage of estrus reveal the importance of the physiological state of the genital tracts; among 5 ewes mated 2-3 hours after the onset of estrus, only one showed isolated spermatozoa in the fallopian tubes 14 hours 55 minutes post coitus. Observations on non-estrus ewes demonstrated that conditions for movement and survival for spermatozoa become less favorable as the interval between estrus and mating increases. These investigators concluded that

forced mating of ewes which do not react to the teaser, cannot result in fertilization, not only owing to the absence of ovulation but also because the sperms cannot penetrate into the cranial portion of genital tract.

Ewes of Corriedale and Dorset breeds were used by Schott and Phillips (1941) to study rate of sperm travel in the genital tract. They reported that a time interval of 20 minutes was sufficient, in the majority of cases, for sperms to reach the upper part of the fallopian tubes following normal service by a ram. As to the rate of travel, they reported that sperms travel toward the ovaries at approximately 4 cm. per minute in the genital tract of the ewe. They further reported that sperms appear to travel independently of time of estrus and time of ovulation.

Starke (1949) reported presence of spermatozoa in the uppermost sections of both fallopian tubes of ewes 6 minutes after copulation; these spermatozoa having travelled 45 cm. at the rate of 7.5 cm. per minute. He also reported that ovarian activity and the duration of estrus did not affect the rate of sperm travel.

Dauzier and Wintenberger (1952) reported some of the data of their experiments with ewes on spermatozoal transport in the genital tract. Immediately after service, ewes of various breeds (Ile-de-France, Sologne, Berry and Merrino) were slaughtered and the genital tract removed. Spermatozoa were in the neck of the uterus 15 minutes after mating; they were in the uterine horns, and at the entrance, middle, and end of the fallopian tubes 2, 6, 8, and 14 hours, respectively, after mating. Although regression coefficients indicated that rate of spermatozoal transport was equal when mating occurred at the beginning or end of heat, spermatozoa reached the upper parts of the horns more quickly when mating occurred at the end of the

estrus. They further reported that only a small percentage of spermatozoa deposited in the vagina penetrated to the uterine horns, and very few spermatozoa penetrated the utero-tubal junction.

From autopsies carried out on 32 female goats from 2 to 40 hours after mating, it was shown by Ajello (1958) that spermatozoa did not reach the upper limits of the oviduct until at least 5 hours after mating.

Dauzier (1960) conducted experiments with sheep and concluded that in the ewe, spermatozoa takes 8 hours to travel from the vagina to the upper part of the fallopian tube.

Studies conducted by Edgar and Asdell (1960) indicated that ram spermatozoa take 3 hours after mating to reach the ovarian end of the fallopian tube. They observed that spermatozoa entered the tubes of ewes through a valve like utero-tubal junction which prevented the fluid from passing in the opposite direction.

Steklenev (1961) noted some spermatozoa in the oviduct of the ewe 5 hours after service but the majority did not reach it until 7-8 hours after service.

Mattner (1963a) noted presence of spermatozoa in the fallopian tubes at 15 minutes after coitus in 6 out of 7 ewes. He reported that, depending upon the previous management of the animal the conditions experienced at mating influence the speed with which spermatozoa are transported to the fallopian tubes in the ewe.

Spermatozoa transport in the genital tract of the ewe was further investigated by Mattner and Braden (1963). Tractable animals that were thoroughly conditioned to laboratory management and experimental procedures were used in these experiments. Results of these studies indicated that in

estrous ewes, spermatozoa were present in the fallopian tubes in 5 of 7 animals within 8 minutes after coitus, and inert particles (dead spermatozoa and carbon particles) passed to the fallopian tubes in 3 of 6 animals within 15 minutes after deposition in the anterior vagina. In untreated ovariectomized ewes killed 3-1/2 - 4 hours after coitus, spermatozoa were found in the cervix, uterus and fallopian tubes. The number of spermatozoa recovered from the fallopian tubes (though not from the cervix or the uterus) was lower than in similar ewes in which estrus had been induced by hormone treatment.

Mechanism of Sperm Transport

The in vitro speeds of ram spermatozoa ranges from 3 mm. per minute (Adolph, 1905) to 4.83 mm. per minute (Phillips and Andrews, 1937). Comparing these speeds of ram spermatozoa with the rate of their travel in the intact animal (7.5 cm. per minute as reported by Starke, 1949), one might say that sperms in the female genital tract travel at a much faster speed than could be attributed to their own power of locomotion. Many workers, therefore, have attempted to understand the mechanism involved in this rapid transport of sperm in the female genital tract.

Dauzier (1953) in a preliminary statement said that spermatozoal motility is responsible for sperm transport in the female genital tract. He later (1955a) conducted a series of experiments with ewes to study the factors responsible for spermatozoal transport. He concluded that uterine contractions are the essential factor in the uterine migration of spermatozoa. In another experiment (1955b), he studied the fate of ram sperm in the fallopian tube and stated that the essential factor in the spermatozoal

migration in the fallopian tube is spermatozoal motility. Again in 1960, he conducted some work on ewes and reported that spermatozoal motility is necessary for progress to the entrance of the fallopian tube, whereafter ciliary movement and muscle contraction of the female tract transport the spermatozoa.

Edgar and Asdell (1960) also pointed out that spermatozoa are carried passively up the female genital tract in the ewe. They were of the view that it is the strong contractions of the female genitalia which transport the semen rapidly from the point of deposition to the point of fertilization.

The indication of the release of oxytocin in ewes following vaginal manipulation came from Debackere and Peeters (1960). They stated that following the release, the uterine muscle responds to oxytocin by tetanic contractions.

As to the role of epinephrine, Alexander (1945) found that adrenaline inhibited uterine activity in both the pregnant and non-pregnant ewe.

Further proof of the release of oxytocin by stimulation of the genital organs in male and female sheep was provided by Debackere et al. (1961). They performed cross-circulation experiments using either 2 lactating ewes (six experiments) or one sexually mature ram and one lactating ewe (seven experiments). Under local anaesthesia an anastomosis was established by means of 2 plastic tubes between a jugular vein of one animal (A) and a jugular vein of the second animal (B) in each pair. The other jugular veins were clamped. Vaginal distension performed in ewe A by means of an inflated balloon often caused a sharp rise of pressure in the udder cisterns of ewe B after a minimum latency of 30 seconds. Massage of the seminal vesicles and

ampulae of the ram often caused a sharp pressure rise in the udder of the ewe after a minimum lag period of 30 seconds. On the basis of their findings, they concluded that manipulation of female reproductive organs in ewe causes the release of a hormone (oxytocin) into the blood immediately which in turn causes increased uterine activity.

Mattner (1963a) noted presence of spermatozoa in fallopian tubes of ewes at 15 minutes after coitus. He stated this rapid transport of spermatozoa in the ewe appears to be a result of strong uterine contractions, such as may take place immediately after coitus. The phase of rapid transport is probably of short duration as the increased uterine activity lasts for only a few minutes after mating. He further stated that slow transport appear to occur irrespective of the occurrence or failure of rapid transport and probably continues for as long as spermatozoa are present in the cervix. He also stated that although both spermatozoan motility and uterine contractions may contribute to the progression of sperm during the phase of rapid transport, their relative importance has yet to be determined. It has been postulated that in the vaginally inseminated animal the cervix and utero-tubal junction functions as barrier against the passage of large numbers of spermatozoa to the fallopian tubes (Austin and Braden, 1952).

Mattner (1963b) discussed the importance of the cervix and the utero-tubal junction in limiting the number of spermatozoa that pass in either direction in relation to the continuity of the transport from the cervix to the fallopian tubes in the vaginally inseminated ewe. Spermatozoa were recovered from the right uterine horn of each ewe 4 hours after either live or dead spermatozoa were deposited in the uterus near the left utero-tubal junction. The number of spermatozoa at this site, relative to total number

in uterus was also similar with either live or dead spermatozoa. On the basis of his observations, he pointed out that spontaneous contractions of the unstimulated uterus are able to transport spermatozoa in both cranial and caudal directions within the uterus independently of spermatozoan motility, but were of less importance than spermatozoan motility in the passage of spermatozoa from the uterus to the fallopian tubes. Mattner also noted the restrictive action of the cervix and of the utero-tubal junction being faced by spermatozoa in their ascent to the site of fertilization but these barriers along with spermatozoan motility, he thought, are responsible for maintenance of a gradient that would favor continual progression of spermatozoa toward the fallopian tubes.

Comments

It takes a few minutes for sperms to reach the site of fertilization after ewes are given natural service by the ram or artificially inseminated (Starke, 1949; Mattner and Braden, 1963). Evidence presented by Mattner and Braden (1963), that the inert particles (dead spermatozoa and carbon particles) when deposited in the anterior vagina of the ewes, passed to the fallopian tubes within 15 minutes or earlier, confirms findings of various observations made on cows (Van Demark and Moeller, 1951). In addition, as shown previously in the review of literature, there is a release of oxytocin in ewes following natural mating or artificial manipulation of reproductive organs. There seems little doubt, therefore, that in the ewe, rapid transport of spermatozoa from the point of deposition to the anterior part of the oviduct is accomplished primarily by contractions of the genital tract which, under the influence of oxytocin, are immediately set in during the

process of mating or artificial insemination. The phase of rapid transport, however, is probably of short duration as the increased uterine activity lasts for only a few minutes after mating (Mattner, 1963a). It may also be said that slow transport appears to occur irrespective of the occurrence or failure of rapid transport and probably continues for as long as spermatozoa are present in the cervix.

Sow

Rate of Sperm Transport

The subject of sperm transport has also been investigated in sows the past few years. Different workers have put forward their observations and opinions as to rate of sperm travel in the genital tract of the sow and mechanisms involved in its accomplishment.

Burger (1952) conducted experiments with commercial breeds of pigs. He reported that if during service, semen was deposited directly into the uterus, live sperms were recovered from the fallopian tubes 15 minutes after coitus. Du Mesnil et al. (1955a) studied the distribution and resorption of semen in the genital tract of the sow. In these preliminary studies, they stated that rate of spermatozoal transport up the uterine horns was slow and varied during estrus, being more rapid towards the time of ovulation.

In another experiment Du Mesnil et al. (1955b) studied the transport of boar spermatozoa in the genital tract of the sow during estrus. Twenty large white sows were mated during estrus and slaughtered at various intervals. They reported that when the females were mated in mid-estrus, the spermatozoa reached the foot of the ampulla in 2 hours and the top in 5 hours. They observed that sperm passage took longer at the beginning of the

estrus (8 hours) than at the end (2 hours).

Mann et al. (1955) conducted studies with gilts and mares. At specified intervals after mating, the reproductive tract of the gilt was exposed, the uterine horns and fallopian tubes clamped into several segments and the contents of the isolated portions withdrawn for examination. They reported that in the gilt about 40 minutes after mating the uterine horns and fallopian tubes were found to be filled with semen containing spermatozoa.

Pitkjanen (1959) conducted studies on the transport of semen in the genital tract of the sow. In 16 young large white sows, a cannula was inserted by means of a fistula into the uterine horn near the fallopian tube. He observed that, after service by adult boars, semen reached the cannula in an average of 14.7 minutes after double mating, 17.1 minutes after single mating and 41.6 minutes after artificial insemination. When sows were mated naturally at the beginning of estrus, 24 and 48 hours later, the semen reached the cannula 14.9, 11.0 and 21.6 minutes, respectively. He made a very interesting observation that in the first second, semen reached the cannula in drops, then in the next 30 seconds, a steady flow of semen reached it. No spermatozoa remained in the cannula 1-3 hours later.

Observations were made by Hancock (1961) on ova recovered from mated, and from inseminated sows killed at various intervals up to 144 hours after the onset of heat. Spermatozoa were not found in the cumulus until 5-1/2 hours after mating.

Semen from 5 boars was used in a series of experiments conducted by Pitkjanen and Subin (1962) to inseminate young large white sows with a body weight of 100-110 kg., laparotomy was performed at various intervals. No spermatozoa were noted in the oviduct 1-1/2 hours after insemination but

there were considerable numbers in the lower part of the oviduct and some in the central part 2 hours after insemination. Six hours after insemination, 80% of the spermatozoa in the oviducts were motile.

Pitkjanen (1962) reported some data pertaining to the characteristics of the physiology of reproduction in sows. He reported that spermatozoa reached the uterus 10-15 minutes after mating and were in the oviduct in an hour. He further reported that after double mating, sperm transport through the uterus is more rapid and more sperm reach the oviduct; after artificial insemination fewer sperms reach the oviduct and they travel more slowly.

In an experiment with 70 sows Prokofjov (1965a) found that although the spermatozoa reached the upper part of the uterine horn in 40 minutes; the diluent and seminal fluid are absorbed by the lower part of the horn, the degree of absorption depending on the viscosity and type of diluent.

Factors Affecting Sperm Transport

There are many observations reported in the literature which reveal that different factors influence the efficiency with which spermatozoa are transported in the genital tract of the sow.

There are reports (Pitkjanen, 1958; 1962) which are suggestive of the fact that volume of semen deposited during natural mating or artificial insemination would affect the overall efficiency of sperm transport system. Thus, for example, double mating in sows was observed to have enhanced the rate of sperm transport. After service by boars semen reached the canula (fixed near the fallopian tube by means of a fistula) in an average of 14.7 minutes after double mating as compared to 17.1 minutes after single mating.

Experiments were performed by Baker (1965) in an attempt to understand

the regulation of the number of spermatozoa reaching the site of fertilization in gilts. These gilts were artificially inseminated and the oviducts were flushed in vivo to recover ova and spermatozoa at a precise time in relation to ovulation. Results of his studies indicated that a minimum volume of semen (20 ml.) and a minimum concentration of spermatozoa seem necessary for transport of spermatozoa to the oviducts. These studies further indicated that drugs like oxytocin or carbachol, if added to semen prior to insemination, increase fertility but only when a certain minimum volume of semen is inseminated.

Another factor which seems to be of considerable importance is the stage of estrus as it affects the sperm transport at the time of mating.

Results of studies conducted by Pitkjanen (1960) indicated that spermatozoa had not reached the oviduct one hour after mating, when coitus took place at the beginning of estrus as compared to when it took place at the end of estrus; all portions of the oviducts were filled with spermatozoa at the same time interval.

Dzink and Polge (1962) conducted experiments with swine and reported that spermatozoa are not transported in the oviducts when the level of endogenous estrogen is insufficient to cause heat. They observed that diethyl stilbestrol can induce sperm transport and permit normal fertilization. Despite all other factors mentioned above, uterine motility and its characteristic contractions at the time of mating or artificial insemination, remain to be of significantly great importance in the rapid sperm transport.

Chemical methods for the analysis of three characteristic constituents of seminal plasma, namely, fructose, citric acid and ergothioneine, were applied by Mann et al. (1955) in an attempt to evaluate in a quantitative

manner the participation of seminal plasma in the passage of sperms along the female reproductive tract of pig. In view of the fact this non-sperm portion of semen was passed from the vagina to the fallopian tubes within 40 minutes, they suggested such a transport should be accounted for by the cooperation of uterine musculature.

Results of the studies conducted by Docke and Worch (1964) with pigs, indicated that weaker uterine contractions occurred after artificial insemination than after natural mating; contractions were stronger when females were inseminated after massage of the genitalia, or when the boar was present.

The mechanism of semen transport in the genitalia of the sow was further investigated by Prokofjev (1965a). He reported that before and during ovulation antiperistaltic contractions predominated, and after ovulation peristaltic contractions were more frequent. It was therefore concluded that in the second part of the estrus, the probability of spermatozoa reaching the upper part of the uterine horns was reduced by more than half.

Sergeeva (1965) studied the pattern of uterine contractions in the sow. A small balloon was fixed at the vaginal end of the uterus and a second balloon 15-20 cm. further along the uterus; muscle contractions were observed through an incision in the uterine area and by the use of a roentgenoscope. He reported that at the beginning of the estrus, waves of uterine contractions travelled from the tubal end of the uterus to the cervix, and 18-32 hours later, they travelled in the opposite direction.

Experiments were carried out by Prokofjev (1965b) at the Pushkin Research Laboratory. He reported that both mechanical and psychic factors influence the contractility of the genital tract and appear to augment sperm

migration. During his experiments, he recovered no spermatozoa from the oviducts of the females which were excited during insemination; this was attributed to the release of adrenaline inhibiting uterine contractions.

To produce uterine contractions simulating those occurring with natural mating, Sergeev (1963) added oxytocin or neurotropic preparations to semen doses of 25-250 ml. Optimum results were obtained with pituitrin added to 50-200 ml. semen; the neurotropic preparations (carbocholine and Prozerine) did not induce a reaction as quickly as oxytocin.

In an attempt to increase the effectiveness of artificial insemination of pigs, Milovanov and Sergeev (1962) using 2 groups of sows, compared the effect of stimulating uterine contractions by adding 2.5-5.0 units of oxytocin per ml. distilled water to 25, 50 and 100 ml. boar semen diluted in glucose-citrate plus antibiotics with that of untreated, similarly diluted semen, by means of a fistula into the top of each uterine horn of each sow. They observed that in sows inseminated with semen containing oxytocin, the uterine contractions were of greater amplitude and frequency as compared with control sows. Also, the semen with oxytocin reached the fistula at the rate of 0.5 ml. per second v. 0.22 ml. per second for semen without oxytocin. In the 2 groups 77 and 42 percent, respectively, of semen inseminated was recovered through the fistula. Conceptions rate (95%) was greater with semen containing oxytocin than control group (70%).

Mare

Rate of Sperm Transport

Sperm cell travel in the mare has not been accurately determined. However, what little evidence is present in the literature, indicates that

little time lapses between ejaculation and passage of sperm cells into the fallopian tubes.

According to Hancock (1960), Parsutin in 1950 had reported that sperms reach the fallopian tube of the mare within 30 minutes after mating or artificial insemination.

Mann et al. (1955) recovered spermatozoa and non-sperm portion (fructose, citric acid) of the semen from the fallopian tubes of the mare 50 minutes after mating.

The stallion sperm in vitro can travel at the rate of approximately 100 U per second (Yamane and Ito, 1932). If the sperm cell has to travel in the intact animal, depending solely on its own motility, then it would take at least 2 hours for a sperm to traverse the entire length from the point of deposition, through the uterus into the fallopian tubes. But, as we have seen, the time spent by the sperm to reach the site of fertilization is far less than could be understood as possible from its own motility powers. Therefore, a passive mechanism should necessarily operate in order to accomplish this rapid transport.

Mechanism of Sperm Transport

As indicated above, sperm should depend on factors other than its motility for its rapid transport in the female genital tract of the mare. Evidence of the fate of spermatozoa, after their release in or near the cervix in the mare, is scanty.

Day (1942) pointed out that mares, served when the cervix is fully dilated have the semen ejaculated into the uterus.

Hammond (1938) stated that the period of estrus affects dilation of the

cervix, and, unless mares are served late in the estrus when the cervix is fully dilated, very few sperm gain entrance to the uterus.

The ejaculation of semen through the cervix uteri clearly presents many difficulties, and the possibility was considered of other forces playing a part, such as some forces of "negative uterine pressure". An experiment was designed by Millar (1952) to explore this hypothesis. He suggested that a negative uterine pressure of considerable strength occurs during coitus in the mare. He further suggested that this negative uterine force plays an important role in the uptake of semen after its vaginal deposition.

Mann et al. (1955) studied the mechanism of sperm transport in mares and reported that uterine activity in response to stimuli associated with the process of mating, gets enhanced and as a result sperms are transported up the genital tract with a great rapidity. In addition, these workers observed that seminal components other than sperms, were transported with the same rapidity as were sperms and concluded that such a transport must involve muscular mechanism.

Uterine contractions in mares were studied by Arhipov (1957) during the various phases of estrus cycle by bisecting the uterine horns and fixing the free ends to the skin wounds and made by unilateral or bilateral fistulae. He observed that the contractions continued throughout the cycle but their frequency and strength were greatest during ovulation; when inseminated spermatozoa are transported most rapidly to the site of fertilization.

Foultry

Rate of Sperm Transport

Because the fertilization of the avian egg takes place at the upper

part of the oviduct (Novik, 1957), it is necessary that spermatozoa traverse the entire length of the oviduct. The oviduct measures about 64.8 cm. long in the laying hen (Mimura, 1941). According to Romanoff and Romanoff (1949), it consists of several regions, which from cephalic to caudal end, on an average, are as follows: the infundibulum (7.0 cm.), the albumen-secreting portion (33.6 cm.); the isthmus (8.0 cm.); the uterus (8.3 cm.); and the vagina (7.9 cm.). The time for sperm migration in fowl appears to be of the same order of magnitude as that in most mammals.

Payne (1914) found that sperm in the chicken ascended to the lower portion of the infundibulum in one and one-half hours after coition.

Mimura (1941) studied the movement of sperm through the oviduct of the fowl and found that sperm inserted at the posterior end of the uterus reached the upper most part of the oviduct and the ovary in as short a time as 26 minutes. When a bird was inseminated whose oviduct contained an ovum in the albumen portion, or the more posterior parts of it, the sperms inserted were mostly retained in the inseminated part and showed little or no upward advance through the oviduct until the ovum was laid as a complete egg. When a bird was inseminated shortly after egg laying, at which time the oviduct was considered free of an ovum from the albumen secreting region posteriorly, rapid progress of sperms was deserved.

Moore and Byerly (1942) reported similar results. They observed that birds inseminated while a hard shell egg was in the uterus showed a significant tendency towards total infertility. Highest average fertility of inseminations resulted when inseminations were made immediately after an egg had been laid at which time the oviduct was free of albumen and hence highly receptive to motile sperms.

The distributions of living and dead sperm in the oviducts of hens at various time intervals after artificial insemination were determined by Allen and Grigg (1957) using sperm labeled with ^{32}P and assaying the radio activity of serial sections of the oviduct. He observed that following intravaginal insemination, spermatozoa reached the infundibula within one hour. The number of sperm reaching the site of fertilization at the upper end of the oviduct was dependent primarily on where in the lower genital tract the sperm were deposited. They reported that junction of the vagina and uterus or shell gland proved to be a barrier to sperm progress, as was shown by the greater efficiency of sperm utilization above the junction than below it. They further reported that dead sperm inseminated intravaginally did not pass into the uterus, but those inseminated into the uterus reached the infundibulum in as great numbers as a similar sample of live sperm.

The transport of spermatozoa in the oviducts of 88 hens was studied by Saeki et al. (1964) by means of smears, lavage, histological examinations and the use of a radioactive tracer. They reported that live spermatozoa reached the infundibulum 16 minutes following intravaginal insemination. Dead spermatozoa, charcoal powder and barium sulphate injected into the uterus reached the infundibulum almost as rapidly as live spermatozoa. They further reported the rate of transport was faster in laying than non-laying hens.

Mechanism of Sperm Transport

In view of very little time spent by fowl sperm to travel the full length of hen's oviduct following mating or artificial insemination, it is highly unlikely that motility of spermatozoa is solely responsible for their

speed. Several other mechanisms are apparently called into play to assist in transporting the sperm cells through the oviduct. If spermatozoa progress independently at any level in the female tract, it is probably when they pass the utero-vaginal junction (Allen and Grigg, 1957). Sperm transport above the uterus cannot be attributed to the automotive abilities of the sperm, as various workers (Allen and Grigg, 1957; Saeki et al., 1963) have shown that dead spermatozoa or powdered charcoal injected into the uterus reached the infundibulum almost as rapidly as live spermatozoa.

Payne as early as 1914 suggested the vibrating mass of cilia which cover the epithelial cells lining the oviduct, aid materially in the forward progress of the sperm cells.

Parker (1931) stressed the importance of adovarian ciliary currents in the oviducts of turtle, pigeon and chicken. He also demonstrated the presence of those cilia which have a sweeping action from the cloaca up towards the infundibulum in the genital tract of the female pigeon. The property of rheotaxis said to be shown by sperm cells *in vitro* has been thought to be one of the mechanisms which help spermatozoa to find their way up the genital tract. There is a considerable evidence to this effect that sperm orient against a current and when free-swimming make considerable progress upstream (Yamini and Ito, 1932; Brown, 1944; Sturgis, 1947; Tampion and Gibbons, 1962).

From the speed of transport of sperm and passage up the oviduct of sperm-freed fluid injected into the uterus, Allen and Grigg (1957) suggested the spasmodic contraction of muscle investing the wall of the upper vagina and lower uterus induces a response to tactile stimuli which is mainly responsible for sperm movement from the utero-vaginal junction to the

infundibulum. They also reported that motility of sperm is necessary only to traverse the vagina. At other stages of movement between the vagina and the egg, sperm play a passive role in their own transport.

In studies by Saeki et al. (1963) dead spermatozoa, charcoal powder and barium sulphate injected into the uterus reached the infundibulum almost as rapidly as live spermatozoa; muscular and ciliary action of the oviduct were considered to be mainly responsible for sperm transport.

Grigg (1964) reported the minimum number of sperm which have to be injected to ensure fertility will be proportional of efficiency of sperm transport which is strongly influenced by the site of insemination. He further stated that since sperm transport proximal to the uterus is a function of utero-oviduct activity, we might anticipate that efficiency of sperm transport will vary from female to female and possibly from strain to strain. The studies of Allen and Grigg (1957), however, are strongly suggestive of a difference in the mechanism of sperm transport, irrespective of breed or strain, on either side of utero-vaginal junction. The usual residence sites following copulation or intravaginal insemination in the hen, are the utero-vaginal glands (Bohr et al., 1964; Van Krey, 1965; Fujii and Tamura, 1964).

Verma and Chermis (1965) conducted studies with turkey hens and reported that sperm cells are stored only in the utero-vaginal junction and are gradually expelled until the tubules are evacuated. They further reported that evacuation of the sperm cells from the tubules is initiated in the same order as their entrance.

Bohr et al. (1962) suggested that in the hen utero-vaginal junction is the primary site of spermatozoa and that a few ascend to the site of

fertilization immediately prior to each ovulation.

Bohr et al. (1964) suggested that the spermatozoa are discharged from these storage sites by a mechanism close to the times of oviposition and/or ovulation, ascend the oviduct rapidly and are presumably responsible for the sequential fertilization. The observations of these investigators agreed with those of Mimura (1939) regarding the inhibiting effect that the presence of an egg in the oviduct has on sperm transport. They stated that ovum is merely a mechanical obstruction. The naked albumen surrounding an ovum anterior to the isthmus is an absolute obstruction; whereas, an egg covered with a membrane and shell is only a partial obstruction. Thus, each descending egg sweeps the oviduct clean of luminal spermatozoa (Bohr et al., 1964).

Van Krey (1965) also concluded that spermatozoa are released from utero-vaginal glands only in association with specific events of the egg-production cycle and that release is a response to a complex of stimuli, associated both with ovulation and ovi position.

SUMMARY

Numerous investigators have contributed to our knowledge concerning the fate of spermatozoa after deposition in the genital organs. For many years it was thought that spermatozoa deposited in the vagina, during mating or artificial insemination were dependent on their own motility for passage through the uterus and oviducts to the point of fertilization.

Carefully controlled studies have shown, however, that sperm transport to the oviducts takes place almost instantaneously after copulation in mammals. This has been demonstrated in rats, guinea pigs, cows, sheep, sows and mares. Observations on the fowl have been similar.

In addition to the transport of motile spermatozoa, dead sperm and in some cases inert substances such as India ink or powdered charcoal, are rapidly distributed in the female genital tract and reach the oviducts as rapidly as live sperm. These findings are suggestive of the fact that sperm motility in itself is not essential for sperm transport within the reproductive tract of the female. Experimental work leads to the conclusion that sperm are transported to the oviduct extremely rapidly by muscular contractions of the duct system. Because it is known that oxytocin, a posterior pituitary hormone, is released as a result of the stimulation of mating or artificial insemination techniques, it appears probable that sperm transport is accomplished by the action of oxytocin on the uterine muscle, which responds by a series of contractions greater than those normally seen in the sexually unexcited female.

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SPERM TRANSPORT IN THE FEMALE REPRODUCTIVE TRACT
OF LIVESTOCK AND POULTRY

by

IMTIAZ AHMED QURESHI

B. Sc. (A.H.), University of Panjab, Lahore, West Pakistan
M. Sc. (A.H.), West Pakistan Agricultural University,
Lyallpur, West Pakistan

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The entire process of sexual reproduction is centered around the act of fertilization. It consists essentially of the fusion of two cells, the male and female gametes to form one simple cell, the zygote. The site of fertilization in all farm and most other mammals is the lower portion of the ampulla of the fallopian tube. However, during natural mating the male deposits sperms in the lower region of the female reproductive tract either into the cervix and uterus, as for example in the stallion and pig, or into the cranial end of the vagina as occurs in sheep and cow. In either case, the sperm has to move a considerable distance within the female body to reach the site of fertilization.

Since spermatozoa possess motility, it has been widely assumed that sperms reach the fertilization site simply by swimming there under their own power of locomotion. However, work on the speed of sperm migration in different livestock, suggests this is far sooner than could be expected on the basis of the inherent motility and sense of direction of spermatozoa.

In all farm animals and poultry, assessments of the time required for spermatozoa to reach the upper end of the fallopian tubes have been very variable ranging from a few minutes to couple of hours. As the mean speed of spermatozoa travel in vitro is on the order of 100 U per second, it appears the genital tract itself must be primarily responsible for transportation.

In addition to rapid transport of spermatozoa, a number of investigators have demonstrated that non-motile and in some cases inert particles, such as India ink and powdered charcoal, are rapidly distributed in the female genital tract and pass rapidly from the cervix to the fallopian tubes. These findings suggest that sperm motility in itself is not

essential for sperm transport within the reproductive tract of the female. This does not mean, however, that motility is not essential for the sperm to meet the ovum.

Numerous investigations have served to clarify the role of genital tract of cow, ewe, sow and mare in the transport of spermatozoa. It has been clearly shown that oxytocin is released as a result of stimulation of mating and artificial breeding techniques. The hormone in turn stimulates the uterine muscle which responds by a series of contractions greater than those normally seen in the sexually unexcited females. These uterine contractions have a very essential role in sperm transport.

Another theory of sperm transport may be referred to as the "insuck" theory. This theory refers to the development of a negative pressure in the uterus, during coitus, which helps semen to be transported up the genital tract.

Transport within the fallopian tube is effected mainly by muscular contractions of the walls and possibly also by counter-currents produced in the fluid of the tubal compartments by the very numerous cilia that line the walls. This seems to be especially true in poultry.