Introduction

Reproductive success is measured primarily by pigs produced per sow per year and is dependent upon both farrowing rate and litter size. In order to achieve optimal reproductive rates, both the anatomical and physiological workings of the reproductive system must function properly. A basic understanding of the anatomical and physiological function of the female pig reproductive system can aid producers in anticipating and troubleshooting reproductive problems, and in facilitating decisions which impact performance of the breeding herd. This article introduces the reader to the anatomy and physiology of female reproduction and how this acts to enhance or inhibit performance.

The Female Reproductive Tract

General Parts and Support

The female reproductive tract is composed of paired right and left ovaries, oviducts, and uterine horns (Figure 1). It contains only a single cervix, vagina and vulva (external genitalia). Collectively, these structures are supported by the broad ligament and hang loosely suspended below the rectum in the both pelvic canal and lower abdomen. The broad ligament is made of tough connective tissue, attaching near the point of the spine, and running continuously with the inner most layer of the abdominal cavity. Many of the blood vessels and nerves travel through this large piece tissue in order to supply the reproductive tract with blood, hormones and neural stimuli. In prepubertal gilts, the ligament is short, paper thin, and almost transparent. However, in late pregnancy it becomes very long as it stretches and thickens in order to support the increasing weight of the pregnant reproductive tract.

The Ovary

Follicle Development

The ovary of the pig is primarily important because it is the source for both reproductive hormones and eggs. The ovary is particularly responsive to important hormones that are released from other organs, especially those of the pituitary. The pituitary is located near the base of the brain and is the source of Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH). It is these two hormones which are responsible for initiating and stimulating the ovary to become active in order to begin reproduction. Note: PG600® is an approved drug for stimulating estrus in gilts and is very close in structure and function to FSH and LH.

FSH causes many small follicles (< 3 mm in diameter) to grow into medium sized follicles (3 - 6.5 mm). These follicles appear as small, blister-like structures on the surface of the ovary (Figure 1). Each follicle contains an egg and produces considerable amounts of steroid hormones, most notably, estrogen. The other pituitary hormone, LH, is important for the continued growth of the medium sized follicles into large follicles, which are responsible for releasing the egg at estrus. As the follicles grow, the egg inside the follicle also begins to mature as estrogen levels inside the follicle become very high. This elevated follicle estrogen ultimately leads to increased estrogen levels in the blood. When the blood concentrations of estrogen become high enough, the female shows signs of estrus and eventually stands for the back pressure test in the presence of a boar.

Ovulation

The occurrence of peak levels of estrogen in the blood, which originate from the large follicles on the ovary, is followed closely by a surge of LH into the blood at the time of estrus. Ovulation of the large follicles appears to occur at a specific time interval (~ 42 h) after this LH surge. The eggs from all of the large follicles from both ovaries ovulate in a
relatively short period of time (~ 3 h). However, even though there is minimal variation in the time to ovulate all follicles within a female, the time of ovulation after onset of estrus is highly variable between females. Some sows are observed to ovulate as early as 24 h to as late as 60 h after onset of estrus. This variation in time of ovulation is greater than or equal to 24 h. Therefore this variation is very significant since after ovulation, the egg only lives 8-12 h, and sperm are less able to fertilize an egg 24 h after insemination. The objective then, for obtaining optimal reproductive performance, is to inseminate females within 12 h before ovulation. It has been observed that females ovulate approximately two-thirds of the way through the length of estrus. However, since length of estrus, and time of ovulation after onset of estrus are variable, and knowing when the female is out of estrus is not of any practical value, the best way to compensate for variation in time of ovulation is to get the female bred for the potential of both and early and late ovulation, by using two inseminations 12 to 24 h apart. A note of caution: these numbers are only estimates, and sperm life may be even shorter as stored extended semen ages.

Ovulation Rate
Ovulation rate or the number of large follicles that grow and ovulate (release eggs) at estrus is important because this number becomes the first limiting factor to litter size in pigs. Interestingly, the pig develops hundreds of small follicles during an estrous cycle, but typically only ovulates between 10-20 of these follicles at estrus.

Some abnormalities do occur with follicle development, which ultimately leads to abnormal ovulation rates. In gilts at pubertal estrus, ovulation sometimes does not occur or only a few follicles actually grow and ovulate. This is also observed in some sows after weaning at certain times of the year and under cases of excessive weight loss during lactation. Sometimes follicles develop to the large size but fail to ovulate, leading to the condition known as cystic ovary disease.

There have been reports where certain factors have been shown to specifically increase ovulation rate. In gilts, elevated feeding of dietary energy during the last 10 days before estrus and an increase in the number of lifetime estrous cycles appears to increase ovulation rate in females.

Post-Ovulation
Once the follicle ovulates and releases the egg, there is some bleeding from the rupture site but this quickly forms a small blood clot on the ovary where the follicle once was. Within a few hours after ovulation, the cells of the follicle begin to rapidly change and divide into a new type of cell, which over the next few days, will form into corpus luteum cells, which produce progesterone, the hormone needed for developing the uterus, inhibiting estrus, and maintaining pregnancy.

After ovulation of all the large follicles at estrus, the egg is moved into the tube called the oviduct. This movement occurs by the coordinated muscular contractions of a thin piece of tissue called the fimbria (Figure 1). The fimbria wraps around the entire ovary, and under the influence of estrogen, induces muscular contractions which propel all of the eggs into the funnel shaped opening of the oviduct.

The Oviduct
The oviduct is a short convoluted tube that connects the ovary to the uterus (Figure 1). This short tube is very important since it must propel the eggs in one direction and the sperm in the opposite direction. Fertilization takes place in the mid portion of the tube, called the ampulla. Most of the eggs reach the site of fertilization within 30 min to 1 h after ovulation. The eggs will remain viable and fertilizable in the tube for approximately 8-12 h after ovulation. Therefore it is important that insemination occur prior to ovulation so that sperm are waiting for the egg.

Insemination and Fertilization
Sperm are typically deposited into the reproductive tract near the junction of the cervix and uterus. Although much of the inseminate enters the uterus, there is a significant back-flow loss of semen volume which occurs over the next several hours after insemination. Under stimulation from uterine contractions induced by both oxytocin from the female and prostaglandins in the semen of the boar, sperm are moved to the site of fertilization. Of the billions of sperm that are inseminated, only a very small fraction of these (hundreds to thousands) actually arrive at the site of fertilization. Many sperm are prevented from entering the oviduct from the uterus by a small restrictive muscle that can open and close under the control of hormones. Therefore, only a small sperm reservoir is typically maintained in the oviduct. Some sperm cells reach the site of fertilization within minutes after insemination, however, these sperm cells are incapable of fertilizing eggs because a time dependent passage through the female uterus is required to prepare them to attach to the egg. Most of the fertilizing sperm will reach the egg in about 3-6 h after insemination, but numbers of sperm will continue to increase in the oviduct for up to about 12 h after insemination.
After fertilization, the early embryos enter the uterus. Pregnancy embryos secrete hormones and nutrients for the developing fetuses. The innermost glandular layer produces and secretes hormones. The other important layer is when contractions will occur depend upon which reproductive hormones and how and where they are present. Many of the reproductive hormones and how and where they are present. Many embryos actually enter the uterus. However, not all embryos are equal and some are defective and others are slower developing. It has been observed that many embryos are lost prior to day 10 of pregnancy and additional embryos are lost prior to day 20, for a total embryo loss of almost 40% prior today 20 of pregnancy. Obviously, this is one of the primary factors limiting litter size in swine.

Of the embryos that do survive past day 10 of pregnancy, they must signal the mother that they are present by secreting the hormone estrogen, which in turn will prevent the mother from releasing prostaglandin from the uterus, a hormone which will destroy the corpus luteum and cease progesterone production, resulting in termination of pregnancy. If there are no embryos present or too few embryos produce a signal, then prostaglandin is released and this has the effect of reducing blood supply to the corpus luteum. Once progesterone is suppressed, uterine contractions may begin and a new wave of follicles begins to develop, so that the female can begin to cycle again. If the embryos are successful at signaling the mother, progesterone will remain high and uterine contractions will be inhibited until birth. If females do not conceive, they should return to estrus at a regular interval (21 days). However, if their eggs are fertilized but pregnancy cannot be established, then the female will often return to estrus at irregular intervals after mating.

If pregnancy is established, the embryos will begin attachment to the lining of the uterus between d 14-17. They will loosely attach throughout the uterine surface and will continue to strengthen their attachment to allow more efficient transfer of nutrients. The uterus will accommodate many more embryos and fetuses than can actually be supported to term, until d 30. However, after this day, the fetuses that cannot be supported, due to a limit in uterine size, will be lost before day 50 of pregnancy.

The Uterus

The uterus is the largest single portion of the female reproductive tract and is capable of considerable change in size from the non-pregnant to the pregnant state. The uterus is composed of paired uterine horns with the cervix at one end and the oviducts at the other. The uterus has four layers, an innermost layer which is glandular, two additional inner layers which are muscular, and the fourth layer, which forms the outer surface. The large muscle layers are important for propelling sperm to the oviduct, moving and spacing embryos before attachment, and for delivery of piglets at farrowing. These layers are responsive to many of the reproductive hormones and how and when contractions will occur depend upon which hormones are present. The other important layer is the innermost glandular layer which produces and secretes hormones and nutrients for the developing embryos.

Pregnancy

After fertilization, the early embryos enter the uterus on day 4 and remain free-floating and mix with each other until approximately d 12-13. Fertilization of all eggs is usually very high (95%) and therefore many embryos actually enter the uterus. However, not all embryos are equal and some are defective and others are slower developing. It has been observed that many embryos are lost prior to day 10 of pregnancy and additional embryos are lost prior to day 20, for a total embryo loss of almost 40% prior today 20 of pregnancy. Obviously, this is one of the primary factors limiting litter size in swine.

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The Cervix

The cervix is approximately one inch in diameter and about 6-8 inches in length, and connects the vagina and the uterus. It is made of tough connective tissue and contains limited amounts of glandular and muscular tissue. It contains a series of five interdigitating pads (Figure 1) which provide pressure points for locking of the penis (or AI catheters). Its primary functions are to serve as a locking mechanism for the penis. The cervix is also a flexible structure and can open and close under the influence of hormones. The cervix is important for protecting the fetuses and will remain tightly closed except at estrus and at farrowing, when it will dilate to accommodate the boar’s penis and to allow passage of the piglets through the birth canal. The cervix is also the primary source of mucus. Under estrogen stimulation, such as that which occurs at estrus, the mucus becomes watery and can sometimes be seen seeping from the vulva. This mucus serves as a lubricant for the penis of the boar. Under progesterone stimulation during pregnancy, the cervical mucus will thicken and form a plug to prevent any contaminants from entering the sterile uterine environment. This cervical plug will dissolve just prior to farrowing.

The Vagina

The vagina is approximately 12-18 inches long and connects the cervix to the external genitalia of the
pig. There is limited muscular and glandular tissue in the vagina and it serves primarily as a copulatory organ for the boar and as a passageway from the uterus to the outside. The vagina does have some immunoprotectant function since antibodies such as IgA are present to prevent any uterine contamination. The pH of the vagina is also acidic and is unfavorable to sperm and microbe survival.

The bladder empties into the vagina on the floor of the vagina approximately two inches from the external opening. This is important because many types of spiral AI catheters can mistakenly be inserted into the urethral opening of the bladder. The vagina also houses the clitoris, an organ analogous to the male penis, which when stimulated may induce hormones responsible for initiating muscular contractions in the reproductive tract.

The Vulva

The external genitalia of the female pig is composed of some connective and fatty tissues. The vulva is endowed with blood vessels and in gilts the vulva is often observed to swell and change color near the time of estrus. This swelling and color change are not as evident in sows, and color changes are not observable in dark skinned pigs.

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For information on the web, see the University of Illinois swine reproductive website repronet at

or PORKNET at:
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