Table 2-1. Essential mineral elements and their approximate concentrations in animal bodies

Essential				*Probably essential*	
Macro-elements	*(%)*	*Micro-elements*	*(ppm)*	*Micro-elements*	*(ppm)*
Calcium	1.50	Iron	20-80	Fluorine	No data
Phosphorous	1.00	Zinc	10-50	Bromine	No data
Potassium	0.20	Copper	1-5	Barium	No data
Sodium	0.16	Manganese	0.2-0.5	Strontium	No data
Chlorine	0.11	Iodine	0.3-0.6		
Sulphur	0.15	Cobalt	0.02-0.1		
Magnesium	0.04	Molybdenum	1-4		
		Selenium	No data		

.1.1.1. Energy

Feed costs account for about 50 to 75% of the total cost of animals produced under intensive systems of production. Thus, factors, which affect the efficiency with which your animals convert feed to product, have a major effect on the economy of animal production. Under optimal conditions of environment and nutrition, the animal ingests just as much feed energy as needed for maintenance and production, and the protein taken in at the same time is also available for use. However, when an animal is kept under sub-optimal environmental conditions, its feed intake may not meet its energy and protein needs. When this happens, feed conversion efficiency, and thus overall efficiency of animal production, wanes.

Several energy use schemes for animals have been proposed and modified over time. However, the following conventional scheme of energy utilization as developed by committees of the National Research Council of the United States and the Agricultural Research Council of the United Kingdom may be useful in organizing your thoughts as to what happens to dietary energy.

➲ Gross Intake Energy (IE) = the total combustible energy in the feed an animal eats.

Feedstuffs vary in their gross energy content. Not all of it is useful to the animal, and that which is not useful represents wastage.

➲ Fecal Energy (FE) = the undigested feed plus metabolic and microbial products in feces. Ruminants lose up to 50% of the gross energy of roughage as fecal energy. Non-ruminants lose only around 20% of the gross energy of concentrate diets in the feces.

➲ Apparent Digestible energy (DE) equals Intake Energy (IE) minus Fecal Energy (FE).

DE = IE - FE

This may sound more complicated than it actually is, so let us look at it again. The amount of digestible energy (DE) can be computed by taking the total combustible intake energy available from feed the animal eats (IE) less the undigested or waste energy in feces (FE).

The apparent digestibility of dietary energy for a given animal depends largely on the diet's composition. In general, the higher the feed intake rate, the lower the apparent digestibility.

➲ Metabolizable energy (ME) is the apparent digestible energy (DE) minus the energy in gaseous digestion products (mostly methane) (GE) and in urine (unused nutrients and from tissue breakdown) (UE).

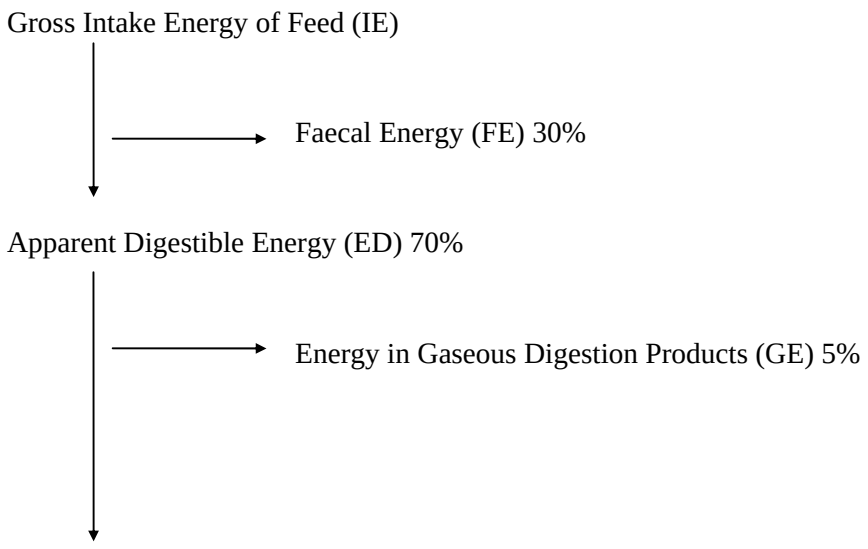
ME = DE - GE + UE

Gaseous products of digestion contain around 6% of intake energy in ruminants, and usually less than 1% in non-ruminants. Both kinds of animals lose less than 10% of the digestible energy in the urine.

Hence, the metabolizable energy value of a diet is roughly 82% of the apparent digestible energy content for ruminants and roughly 94% for non-ruminants.

The animal's conversion of its diet into useful energy is influenced by factors that affect the feed value of the various feeds, feed availability and voluntary intake by the animal.

The way in which intake of energy of feed is partitioned within the ruminant is schematically described in Figure 2-3.



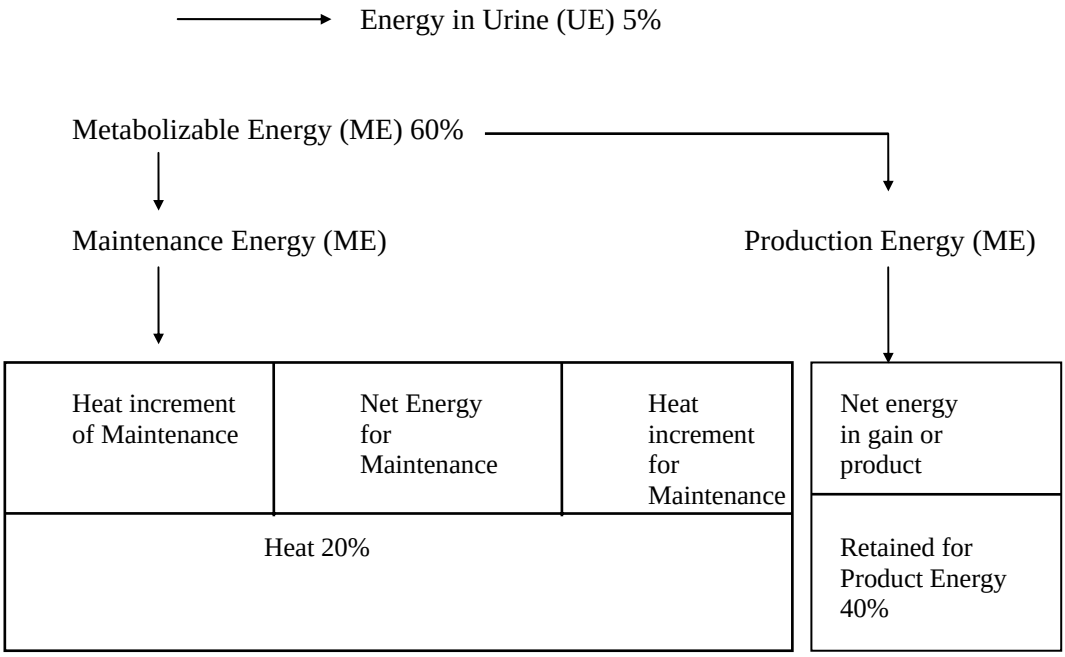


Figure 2-3. Conventional Scheme of the Ruminant Animal's Partition of Dietary Energy

Do's and Don'ts

Do not allow your feed troughs to be contaminated with metallic and wooden debris, as this could lead to hardware disease and the death of the animal. Always clean troughs before feeding.

Highlights

Ruminants digest fibre which humans cannot. This fibre (grass, crop residues, food processing waste), is the ruminant food which they eat to be able to grow and produce milk.

Conclusion

Ruminants require energy to maintain growth, produce meat and milk and reproduce young and to produce work (tractive power). In order to this, they need a balance of nutrients for feed conversion efficiency. In this unit we have discussed the utilisation of nutrients in the animal by studying its digestive system.

This is just the beginning of your understanding of the practical aspects of ruminant nutrition. Ruminant nutrition cannot be satisfactorily covered in one unit. Throughout your study in this manual of the various ruminants and of forages, you will master your knowledge of feeding management for optimum production. In your next unit you will study mammalian reproduction and the roles of males and females in ensuring the continuation of their species.

Worksheet –

Activity L

1. Draw and label the main parts of the ruminant digestive system. Look again at the diagram in your unit, but then try to do this assignment on your own, thinking about the functions of each unit as you work.
2. Draw a diagram of the conventional scheme of the animal's partitioning of dietary energy.
3. Please visit the units on nutrition in each of modules 3, 4, 5, 6 and 7 to see how the specifics on feeding are applied to each of the following ruminant species, sheep, goat, dairy cattle, beef cattle and buffaloes respectively.

Activity P

1. Visit an abbatoir to see what the digestive system of a ruminant animal looks like.

Activity E

1. In essay form, discuss the functions of the rumen, reticulum, omasum and obomasum in the post-weaned ruminant.
2. Name the main components of foods, plants and animals.

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Accompanying Readings

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Suggested Readings

None

Evaluation Materials

None

MODULE 2 — UNIT 2

.2. ANATOMY AND PHYSIOLOGY OF MAMMALIAN REPRODUCTION [Ruminant Reproduction]

Introduction

Reproduction, **the means of perpetuating and multiplying a species**, is a complex process and is dependent on a number of highly synchronized physical and biochemical events in both the male and the female. Your understanding of the factors affecting reproductive efficiency in ruminant production is of importance whether you want to improve a breed by maximizing genetic progress, increase your herd size, maximize a cow's lifetime milk production, or breed animals for beef.

Quick Start h

The learning objective of this unit is: for you to become familiar with the reproductive system of the ruminant: the male and female reproductive parts, endocrine gland and harmonal influences on sexual maturation, oestrus, ovulation, fertilization and pregnancy.

The Lesson

The female must be willing to accept the male in the act of mating (*copulation*) at or around the time an unfertilized *egg* is released. In addition the male must be willing and able to deliver *spermatozoa* to the proper site in the reproductive tract of the female at the proper time for *conception* to occur. Synchronization of release of the *ovum(the unfertilized egg)* from the ovary and the deposition of spermatozoa in the female reproductive tract is necessary <u>because</u> the sperm and the egg have limited lives.

The male is responsible for sperm production. In the female, reproduction relies on the maturation and release of the ovum (ovulation), oestrus, pregnancy, parturition and lactation. All these functions are dependent on various hormones.

NOTE:	Any abnormality in the anatomy or physiology will lead to reduced fertility or even sterility in both sexes.

.2.1. Male Reproductive Parts

The male's role in reproduction is much less complex than that of the female. After the mammalian male deposits viable spermatozoa into the reproductive tract of the female and the ovum is fertilized, his role in reproduction is completed. (Lucky guy!) Through his sperm, the male farm mammal contributes one-half of the inheritance to each of his progeny (offspring).

The **testicles** are the primary sex organ of the male. They produce spermatozoa and the male hormone, *testosterone*. Each male normally possesses two testicles carried in the scrotum. The scrotum also serves as the thermo regulating body, keeping the testicles of farm mammals 4 to 5° C below normal body temperature. Thus, in hot weather the testicles are lowered away from the body, and in cold weather are drawn towards the body.

Occasionally in the newborn male one testicle may fail to decend into the scrotum (*unilateral cryptorchid*). Sometimes both testicles are affected in this way (*bilateral cryptorchids*). Unilateral cryptorchids are usually fertile. The testicle in the body does not produce spermatozoa but produces testosterone. Bilateral cryptorchids are sterile but do possess normal sexual activity and the outward appearances of the male as they are still able to produce testosterone.

Parts of the male reproductive tract are shown in *Figure 2-4.*

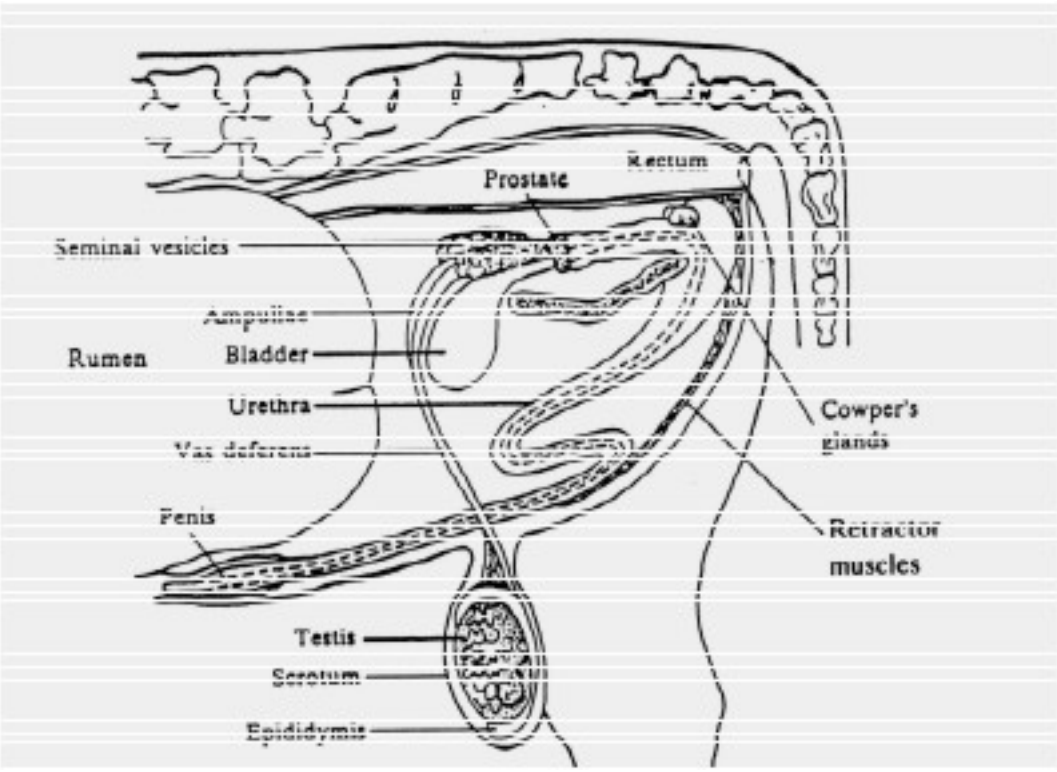

Figure 2-4. Reproductive Tract of the Bull

The ***epididymis*** is a long continuous tube measuring 400 - 500 feet in length in some instances. It consists of a head, body and tail. The head portion is connected to the

testes while the tail appears as an enlargement on the ventral[1] portion of the testes in the scrotum. The tail of the epididymis is a storage depot for spermaozoa. The spermatozoa mature physiologically as they progress through the epididymis. The tail of the epididymis widens into a larger duct (the *vas deferens*) which leads to the urethra.[2] The *vas deferens* widens and becomes enlarged in the ram and bull at the point where it joins the urethra. This enlargement, known as the *ampulla* may serve as a temporary storage deposit for spermatozoa in species, such as the bull and ram, in which ejaculation of semen is rapid.

The **urethra** begins at the opening of the bladder and is connected with the penis. It acts as a passageway for both urine and spermatozoa. In the sexually mature male, especially the bull, the posterior portion of the urethra is *S* - shaped and is known as the *sigmoid flexure*.[3] At the time the male mates with the female, the penis becomes erect and engorged with blood. The sigmoid flexure straightens, extending the penis so that semen can be deposited into the female's reproductive tract. The retractor muscle relaxes at this time, allowing the sigmoid flexure to straighten at the time of copulation. After copulation this muscle contracts, drawing the penis back into the sheath, where it is protected from injury.

The male reproductive tract consists of several glands, known as the accessory sex glands. These include the:

- Prostate Gland
- Vesicular Glands
- Cowper's Glands

NOTE:

The ***prostate gland*** is located near and around the opening of the bladder. Its secretions nourish and stimulate the activity of sperm.

The two ***vesicular glands*** enter the urethra near the *vas deferens* and near the neck of the bladder. The vesicular glands were called seminal vesicles for many years because it was thought that they were a storage depot for mature spermatozoa. This was later

[1] Situated near the abdomen or abdominal surface of the animal.

[2] The duct by which urine is discharged from the bladder of most mammals, and which, in males, carries the seminal discharge.

[3] A fold in the colon just above the rectum.

proved wrong. Functions of the vesicular glands are to neutralize urine residues, add volume to semen, and possibly to stimulate the activity of spermatozoa.

The two ***Cowper's glands*** are located posterior to the bladder, prostate, and vesicular glands. They resemble small walnuts in shape in the bull but are about 4 to 5 inches long in the sexually mature boar. Also known as the bullborethral glands, Cowper's glands secrete a fluid that becomes a gel in the semen of the boar when it contacts secretions of other accessory glands.

.2.2. Female Reproductive Parts

The female farm mammal plays a very important role in reproduction. Through her ovum she supplies one-half of the inheritance of each of her offspring, she nourishes the young within her body (in the uterus) until birth, and she nourishes (through her milk) and cares for the young after birth until weaning. The anatomy of the reproductive tracts of female farm mammals is roughly similar, but there are some differences in size and shape among species. The major differences are in the size and shape of the uterine horns. Parts of the female reproductive tract are shown in *Figure 2-5.*

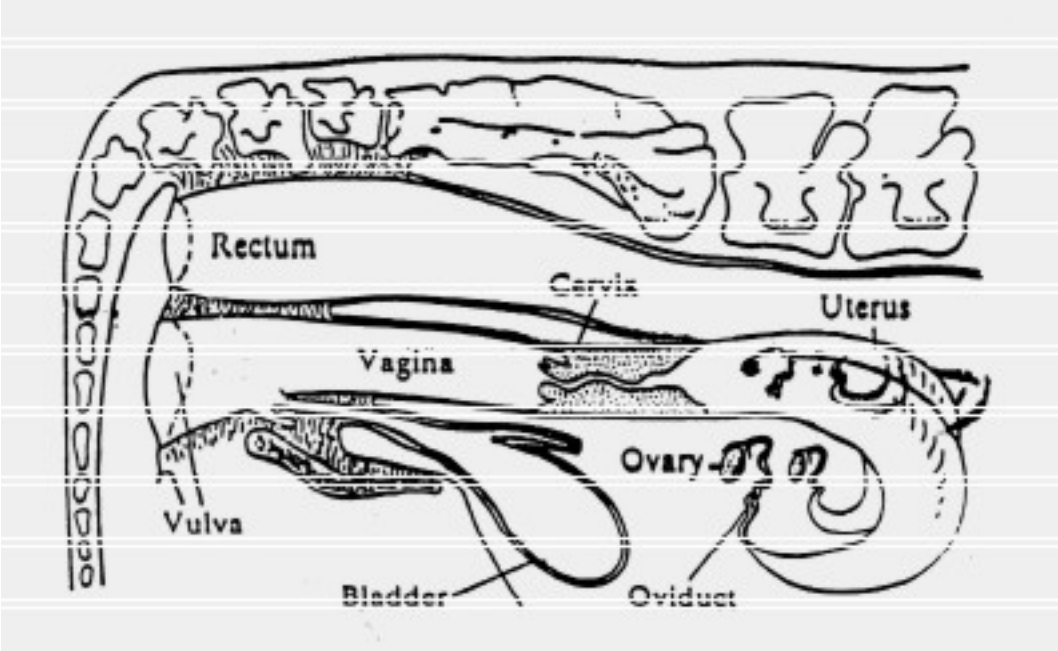

Figure 2-5. The Reproductive Tract of the Female Bovine

The ruminant female reproductive tract consists of the vulva, vestibule, clitoris vagina, cervix, uterus, uterine horns, oviducts, and ovaries.

The ***vulva*** is the exterior portion of the female reproductive tract. It serves as the entrance to the internal organs, and it also accommodates the passage of urine during urination.

The ***vestibule*** is the general passageway to the urinary and reproductive tracts. It extends inward from the vulva for about 4 inches (10 centimeters) to where the ureter opens into its ventral surface from the bladder.

The ***clitoris*** (which has the same embryonic origin as the penis) lies on the base of the vestibule.

The ***vagina*** is that portion of the reproductive tract between the vestibule and cervix. In the cow and ewe, semen is deposited by the male during copulation in the anterior portion of the vagina. In the mare and sow, at least a portion of the semen is deposited in the uterus.

The ***cervi****x* is the opening into the uterus through which sperm must pass to meet the egg in the process of fertilization. It is also the opening through which the young must pass from the uterus at birth. The cervices of the cow and ewe possess circular folds that make it difficult to pass a pipette[4] through them into the uterus. It is practically impossible to do this in the ewe, but it is possible in the cow.

The ***uterus*** of a female mammal normally possesses two ***uterine horns***, although one or both may be absent in abnormally developed individuals. The uterine horns of the sow are much longer than those of other female farm mammals. The sow's uterine horns may measure 5 to 7 feet in length. The sow possesses longer uterine horns because she normally gives birth to 10 or more young, whereas the cow and mare possess shorter uterine horns and usually give birth to only one young. The ewe often gives birth to one young, but it is not unusual for her to have twins, triplets, or ever quadruplets.

The anterior end of each utrine horn becomes much smaller and blends into a small tube, known as the ***oviduct***. The oviduct is lined with microscopic cilia (hairlike projections) that assist in the movement of the ovum toward the uterine horns. The oviducts are 4 to 5 inches (9 to 11 cm) long and end in a funnel-shaped membrane known as the ***infundibulum***. The infundibulum receives the ovum when it is released from the *ovary* at ovulation and guides it into the oviduct.

The normal female farm mammal possesses two *ovaries*, one ovary located close to each oviduct. The ovary possesses thousands of female sex cells in different stages of development. Female farm mammals, as well as the human female, possess all the potential ova they will ever have at the time they are born. However, only relatively few of these ova are ovulated.

Ovaries of mature female farm mammals possess follicles in different stages of development. During ***oestrus*** (heat or the period during which the female is receptive to the male) the ovary possesses mature follicles within which the *ovum* (single unfertilized egg) matures. When fully mature, the follicle ruptures and releases the ovum and this is called ***ovulation***.

.2.3. Physiology of Reproduction in Farm Mammals

Reproduction in farm mammals involves the different parts of the reproductive tract mentioned previously for the male and the female, as well as the endocrine glands and their secretions.

.2.3.1. Reproduction in Males

Gonadotropic hormones secreted by the anterior pituitary gland are involved in reproduction in the male. They are the same hormones from the anterior pituitary

[4] An instrument for passing fluids.

gland that affect reproduction in the female. ***Follicle-stimulating hormone*** (FSH) from the anterior pituitary gland stimulates sperm production by the seminiferous tubules. The ***luteinizing hormone*** (LH) stimulates the interstitial[5] cells to produce the male hormone, testosterone.

Testosterone causes the growth, development, and secretory activity of the accessory sex glands, which include the prostate, vesicular glands, and Cowper's glands. Testosterone also stimulates secretory activity of various other cells in the male reproductive tract, including those in the epididymis. The hormone also causes growth and development of the rest of the reproductive tract, including the penis, and it is necessary for maturation and survival of spermatozoa stored in the epididymis. The secondary sex characteristics, such as the male voice, the crest in the bull and boar, thick horns in the bull, as well as many other characteristics, are dependent on secretion of testosterone. This is very evident when males are castrated at a young age, because the secondary sex characteristics never fully develop in such individuals. Sex drive, or libido, in the male is also dependent to a great extent on testosterone production.

The amount of ***semen*** produced and the number of spermatozoa contained in each semen sample vary among species. Semen consists of ***spermatozoa*** mixed with secretions of various accessory sex glands and those of the epididymis. Semen contains some spermatozoa that are dead, some that are alive but nonmotile, others that are weakly motile, and some that show strong, forward progressive motility. The average volume of the normal ejaculate (semen) of the ram is about 1 cc, of the bull 5 cc, of the stallion 75 to 100 cc, and of the boar, 200 to 300 cc. The average number of spermatozoa per ejaculate varies from about 2.5 million in the ram to 20 million in the boar. Wow! *I guess you will develop more respect for boars.*

Spermatozoa may be stored and can retain their fertilizing capacity for several days in the epididymis within the body of males. However, in some species their fertile life is limited, when stored outside the body at temperatures slightly above freezing. Bull spermatozoa have been collected and stored outside the body with considerable success for use in *artificial insemination*.[6] Bull semen can also be frozen and stored indefinitely at very low temperatures. The fertile life of boar, stallion and ram spermatozoa stored at temperatures slightly above freezing is limited to 48 hours or less. The life of the spermatozoa of farm mammals in the female reproductive tract is limited to 24 to 96 hours.

.2.3.2. Reproduction in Females

The ovary of the sexually immature female farm mammal is inactive for a period of several months, but as she approaches puberty then suddenly…

- Follicles mature
- The female comes into oestrus (heat)
- The egg is ovulated, and
- The female reaches the age of sexual maturity (puberty).

---

[5] Situated within the tissues of an organ or part.

[6] Impregnation of the female with semen from the male withuot direct sexual contact; also called eutelegenesis.

The cause of the sudden onset of puberty in the female is not clear. Most females within a given species reach puberty near a certain general *age* and *weight*, however, breed, family and individual differences exist. The breed and family differences relative to puberty onset suggest a genetic control governing this trait.

.2.3.2.1. Endocrine Control of the Ovary

FSH[7] from the anterior pituitary gland, when released into the bloodstream, initiates development of ovarian follicles. LH[8] acts in synergism[9] with FSH to stimulate maturation of the follicles. As a follicle develops and matures, the egg also matures, and the cells lining the follicle multiply and secrete fluid until the follicle becomes a fluid filled cavity resembling a blister.

At this point, the cells lining the follicle begin to produce estrogens. ***Estrogens*** are any of several hormones found in ovarian fluids and exercise more or less specific and critical influence on the sexual cycle in mammals.

Estrogens have several important functions in the body. These include the:

- Induction of oestrus[10] (heat) in the female,
- Increase of mobility of the uterus, oviducts, and infundibulum during oestrus, which aids in bring the sperm and egg together in the process of fertilization,
- Dilation of the cervix,
- Synthesis and secretion of cervical mucus,
- Initiation of duct growth in the mammary gland, and
- Development of secondary sex characteristics.

In addition, estrogen acts in a unique manner in the hypothalamus[11] and the anterior pituitary gland to stimulate a massive release of LH. The LH surge stimulates follicle(s) to rupture and to release the egg (ovulation). The infundibulum[12] then picks up the egg and rapidly transports it down to the ampullary-isthmic junction for potential fertilization.

After ovulation, estrogen levels drop rapidly, and the cells in the ruptured follicle begin to grow and divide to form a new structure called the ***corpus luteum***. The corpus luteum begins to produce ***progesterone.***[13]

Progesterone has several functions:

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[7] Follicle-stimulating hormone.

[8] Luteinizing hormone.

[9] The mutually cooperating action of separate substances which together produce an effect greater than that of any component taken alone.

[10] On an interesting note, oestrus is also spelled estrus, which is from the Greek, meaning "frenzy, passion."

[11] The region below the thalamus, controlling visceral activities; internal organs, such as the stomach, lungs, heart, etc.

[12] A structure or conduit shaped like a funnel.

[13] A harmone active in preparing the uterus for reception of the fertilized ovum.

- It maintains pregnancy by blocking uterine contractions;
- It prevents ovulation, and
- It combines with estrogens to stimulate growth of the lobule-alveolar[14] system of the mammary glands.

If conception occurs, the corpus luteum will be maintained and will continue to produce progesterone, since progesterone appears to be required to maintain pregnancy. If conception does not occur, progesterone levels will drop and the corpus luteum will regress. A decline in progesterone follows an increase in Follicle Stimulating Hormone (FSH) which, together with Leuteinizing Hormone (LH), stimulates further development and maturation of follicles.

.2.3.2.2. Oestrus and the Oestrous Cycle

Oestrus is the time the female will receive the male in the act of mating. The oestrus cycle begins at puberty and is the interval between two oestrus periods (or heat) when the female is not pregnant. Oestrus and ovulation are synchronized in most species so that the introduction of spermatozoa into the reproductive tract of the female and the release of the ovum from the ovary occur at about the same time. This increases the probability of successful fertilization because the life of the ovum and sperm in the female reproductive tract is limited to only a few hours.

[14] Small-lobed, hollow-celled, honeycomb-like cell system.

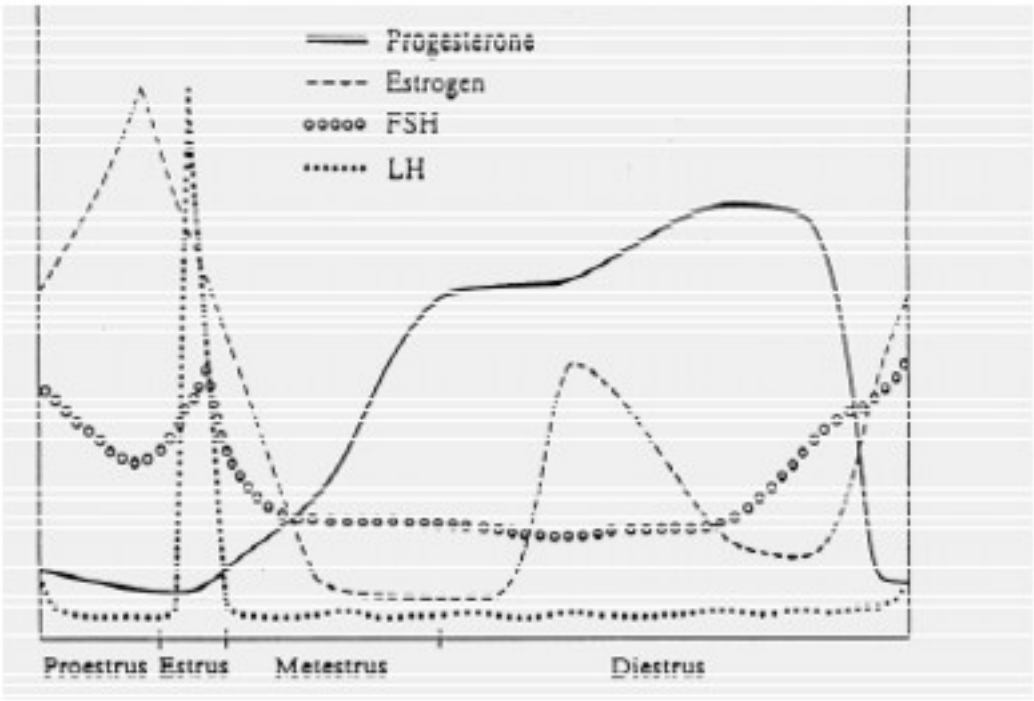

Figure 2-6. Relative Changes in Reproductive Hormones during the Oestrous Cycle of the Cow

Some female farm mammals show very obvious behavioural changes with oestrus. This is called the "Heat" period. The cow will often have a clear mucus on the vulva, she may become unusually nervous; have reduced appetite and milk production, bull, bellow, and walk about more than usual. She may also attempt to mount other cows; however, since this behaviour can also be seen in cows that are not in estrus, it is not a reliable indicator of estrus.

The most reliable sign of estrus is that the cow will stand to be mounted by other cows or by a bull. Mares commonly urinate frequently and exhibit rhythmic vulvar contractions called "winking." Sows will show an immobility response: standing still if pressure is applied to their backs.

Mares and sows demonstrate these forms of behaviour especially in the presence of stallions or boars. Oestrus is less obvious in ewes, but experienced producers can detect ewes in estrus.

The oestrous cycle in farm mammals has four different phases:

- Pro-oestrus
- Oestrus
- Metoestrus, and
- Dioestrus
- Anoestrus

Proestrus is that phase of the cycle which occurs just before oestrus. The reproductive system at that time is beginning preparations for release of the ovum from the ovary.

There is a thickening of the the vaginal wall, increased vascularity of the uterine mucosa lining, and maximum follicular growth.

Oestrus (Estrus) is the period of the estrus cycle when the female will accept the male in the act of mating and when the follicle matures and releases the ovum.

Metoestrus is the phase of the oestrous cycle immediately following estrus, when the uterus makes preparation for pregnancy and the corpus luteum[15] is formed and begins to secrete progesterone.

Dioestrus is usually the longest phase of the oestrus cycle, occurring between metoestrus and pro-oestrus. During the first part of dioestrus, the corpus luteum becomes fully developed. In the later part, there is regression[16] of the corpus luteum. The length of the cycle for the cow is given *Table 2-2.*

Anoestrus is the prolonged period of sexual rest during which ovarian function is in abeyance. Follicle development is almost absent and the uterus is small and anaemic and the cervix is constricted.

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[15] A mass of yellow tissue formed in the ovary by a ruptured Graafian follicle that has discharged its ovum: if the ovum is feritlised, this tissue secretes a necessary harmone.

[16] Reversion to an earlier or simpler form.